Gorgon Gas Development:
Backfill Fields Offshore Project Proposal

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ES-1 Introduction

Overview

Chevron Australia Pty Ltd (CAPL) is the operator of the Gorgon Gas Development, one of Australia's largest natural gas projects located off the northwest coast of Western Australia. The first stage of the Gorgon Gas Development was the Gorgon Foundation Project (GFP), which included constructing the Gorgon Gas Treatment Plant (GTP) and domestic gas plant on Barrow Island and developing the Gorgon and Jansz–Io offshore fields.

CAPL is proposing to undertake the Gorgon Gas Development: Backfill Fields (the Development), which represents the next phase of the Gorgon Gas Development. A backfill field is a supply of natural gas that is required to maintain the throughput to an operating facility. The intent of the Development is to maintain gas supply to the existing gas plants on Barrow Island to sustain current production rates of liquefied natural gas (LNG), and domestic gas.

The proposed Development comprises the construction, installation and operation of drill centres, flowlines, and subsea tiebacks to access 7 backfill gas fields in the Greater Gorgon Area. The development of these fields was outlined in the original Gorgon Gas Development Environmental Impact Statement/Environmental Review and Management Process (EIS/ERMP) (Ref. 1), which stated that the other fields of the Greater Gorgon Area would be developed once production from the Gorgon and Jansz–Io fields began their natural decline. The WA *Barrow Island Act 2003* also refers to the Greater Gorgon Area, which includes the backfill fields.

All 7 fields are located in Commonwealth (Cth) waters off the north-west coast of Western Australia (WA); and comprise Chandon, Chrysaor, Dionysus, Eurytion, Geryon, Semele and West Tryal Rocks (WTR).

The Geryon and Eurytion (G&E) fields will be co-developed and fed into a single flowline. The Chrysaor and Dionysus (C&D) fields are anticipated to be co-developed in a similar manner. Consequently, while the OPP covers the 7 fields, activities, impacts, and risks associated with each set of co-developed fields are considered jointly.

The first stage of the Development is likely to be ready for installation in 2026.

Document Purpose

This Offshore Project Proposal (OPP) has been submitted to the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) in accordance with the requirements of the Commonwealth *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023* (OPGGS(E)R).

Location

The Development fields are located in Commonwealth waters offshore north-west WA. The fields and proposed flowlines lie to the north-west of Barrow Island, in the vicinity of the GFP fields. Water depths in the area range from ~150–1,400 m.

The closest infrastructure will be ~60 km from Barrow Island and ~130 km from Onslow. The outermost infrastructure will be ~190 km from Barrow Island and ~250 km from Onslow.

All planned petroleum activities within this OPP will occur in the operational area (OA), which lies in Commonwealth waters (Figure ES-1).

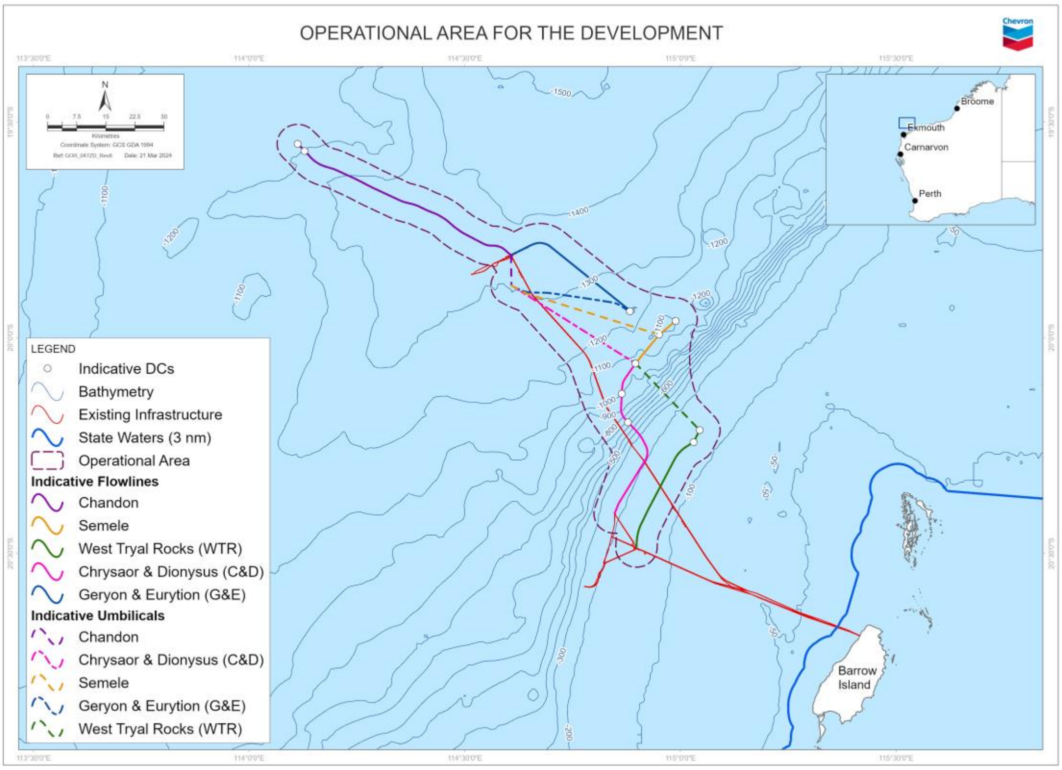

Figure ES-1: Operational area for the Development

Scope

The OPP addresses site surveys, drilling, installation and commissioning, operations, decommissioning phases; and support activities associated with the Development.

GFP developments currently in operation are not within the scope of the OPP. Activities associated with GFP developments that are currently being implemented or which are to be implemented at a later date, including Gorgon Stage 2 (GS2), and Jansz-Io Compression (J-IC) and other GFP power supply options, are excluded from the scope of the OPP.

Proponent details

CAPL is the proponent for the Development. The company has been operating in Australia since 1952 and is the operator for the Gorgon and Wheatstone Gas Developments in the north-west of WA.

CAPL is one of the major suppliers of domestic gas in the state.

ES-2 Requirements

The Development is located entirely in Commonwealth waters and therefore triggers two key Commonwealth acts: The *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Offshore Petroleum and Greenhouse Gas Storage Act 2006

The OPGGS Act provides the regulatory framework for all offshore petroleum exploration and production activities occurring in Commonwealth waters. The *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023* (OPGGS(E)R) were created under the Act and the OPP is required under these regulations. In addition to the OPP, the OPGGS(E)R require CAPL to have in place environment plans (EPs) for the petroleum activities within the scope of the Development.

Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act and the supporting *Environment Protection and Biodiversity Conservation Regulations 2000* (EPBC Regulations) provide for the protection and management of nationally and internationally important flora, fauna, ecological communities, and heritage places, including Matters of National Environmental Significance (MNES). If there is potential for any MNES to be impacted by offshore petroleum activities, an assessment of the impacts must be presented in the OPP.

Other environmental requirements that apply to the Development include relevant:

- Additional Commonwealth legislation
- Commonwealth and international policies and guidelines
- Western Australian legislation
- International agreements and conventions.

ES-3 Stakeholder consultation

CAPL is committed to building and maintaining relationships and conducting meaningful consultation with external stakeholders, including governments, Traditional Owners, and the communities where we operate. Early consultation with key stakeholders has been undertaken during the preparation of the OPP. This early consultation is the first phase in the stakeholder consultation that will occur throughout the lifecycle of environmental approvals for the Development. The full stakeholder consultation strategy consists of:

- Phase 1—Early consultation with key stakeholders (including relevant Traditional Owners) undertaken during the preparation of the OPP
- Phase 2—Public consultation under NOPSEMA’s public comment process

- Phase 3—Relevant Persons consultation during the preparation of EPs and on an ongoing basis after EP acceptance.

Results of Phase 1 consultation are summarised in Table 3-2.

ES-4 Description of the project

The Development will develop and operate 7 gas fields and associated flowlines and tie-ins. The fields will feed into the Gorgon GTP on Barrow Island.

The Chrysaor and Dionysus (C&D) fields are anticipated to be co-developed and will feed into a single in-field flowline. Similarly, the Geryon and Eurytion (G&E) fields will be co-developed and feed into a single flowline.

Chandon and G&E will be tied-in to the existing Jansz Feed Gas Pipeline. C&D, Semele (via C&D) and West Tryal Rocks (WTR) will be tied-in to the existing Gorgon Feed Gas Pipeline. Figure ES-2 shows the indicative drill centre locations, flowline routes and umbilical routes proposed for the Development and the existing pipelines.

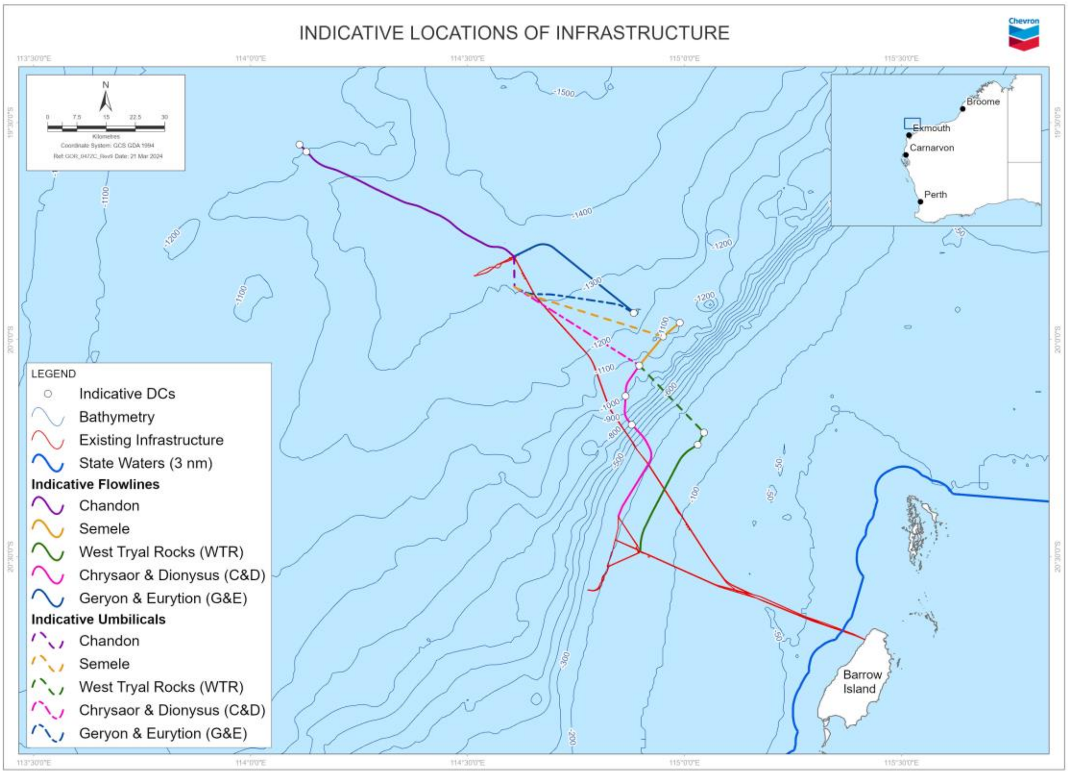

Figure ES-2: Indicative locations of infrastructure.

Timing

The durations of the Development phases and/or activities have been estimated for each field and are included in Section 4. Actual durations will vary depending on factors including final flowline routes, reservoir performance, weather events and vessel availability.

As the Development will be staged, some phases may occur concurrently for short intermittent durations, e.g., drilling may be occurring at one location while production operations have already begun at another. In addition, multiple activities may occur at the same time within a single field (e.g., drilling and pipelay). The sequence in which the fields will be developed has not yet been finalised.

The earliest the first stage of the Development is likely to be ready for installation is in 2026. The end of field life for the Development is notionally ~2070, with each field identified in the Development having its own end of life. The indicative range for the duration of operations is 10-30 years for each field. See section 4.1.4 for further detail.

Activities covered by this OPP can occur 24 hours a day, 7 days a week and at any time of the year.

Hydrocarbon system

The Development will comprise a new subsea hydrocarbon system which is summarised in Table ES-1.

Table ES-1: Key elements of the hydrocarbon system

System Element	Key Descriptions
Production wells	A maximum total of 40 wells will be located across 10 drill centres (DCs). Each well will be fitted with a subsea tree.
Subsea structures	Manifolds and pipeline termination structures (PTSs) and other tie-in structures (e.g., slug catchers, pressure protection skids) will be located at DCs and tie-in locations.
Flowlines, MEG pipelines, jumpers and spools PLETs and PLEMs	Five in-field production flowlines will have an estimated total length of 190 km. MEG pipelines, jumpers and spools will be installed. Pipeline end terminations (PLETs) or pipeline end manifolds (PLEMs) will be installed on the pipelines. In-line tees will be installed.
Umbilicals and power supply	Umbilicals, control distribution units (CDUs) and flying leads will be installed.

Development phases

The Development activities are grouped in phases in Table ES-2.

Table ES-2: Phases and activities of the Development

Phase	Key Activities
Surveys	Geophysical survey Geotechnical survey
Drilling	MODU positioning Drilling top- and bottom-holes Drilling fluids and cuttings handling Cementing operations Pressure-control equipment installation Well suspension Completions installation Production tree installation Well clean-up and testing Well evaluation
Installation and commissioning	Pre-lay works Excavation and trenching

Phase	Key Activities
	Installation of flowlines, MEG pipelines and PLETs/PLEMs Installation of subsea structures Post-lay works Hydrotest and pre-commissioning Commissioning (verification and pre-start-up testing) Start-up (introduction of hydrocarbons)
Operations	Operation of the hydrocarbon system Inspection Maintenance and repairs Major repairs Well intervention
Decommissioning	Flush and clean Flowline and MEG pipeline decommissioning Umbilical decommissioning Other subsea structures decommissioning Well plug and abandonment

ES-5 Alternatives analysis

A number of development concepts are feasible for developing the resources in the backfill fields of the Greater Gorgon Area. Development concepts can be implemented using a range of design and activity elements. All these alternatives have relative advantages and disadvantages. CAPL performed an alternatives analysis to consider the range of options and determine the preferred concept and design elements.

Analysis of the development concept, design and activity alternatives was based on the following focus areas: environment, technical feasibility, safety, commercial and social. Each focus area was further divided into categories and assessment criteria. A comparative assessment was carried out for the design concept, with the preferred option then carried through to a comparative assessment for the design and activity elements.

The development concept determined to be the most favourable was subsea tiebacks to existing pipelines. This concept scored significantly better than the other options on environmental criteria, and marginally better on all other focus areas. This option maximises the use of existing infrastructure and does not entail an additional shore crossing or pipeline installation.

Design and activity elements assessed included MODU type, hydrotest discharge and decommissioning activities. For MODU type, flowline retrieval and umbilical retrieval, it was determined that more than one option should be carried in the OPP. This allows for these elements to be finalised much closer to implementation to ensure the most favourable environmental option is selected.

ES-6 Description of the Environment

The OPP describes the environment that may be affected (EMBA) by the planned activities and unplanned events associated with the Development.

CAPL defined sub-areas of the EMBA based on oil spill modelling (Appendix C) to support the description of the environment and the impact and risk assessment. The Hydrocarbon Ecological EMBA has been determined based on the spatial extent of hydrocarbon exposure at thresholds relevant to ecological receptors.

The Hydrocarbon Social EMBA has been determined based on lower thresholds for surface and shoreline hydrocarbon exposure that are associated with visible oil but are below concentrations at which ecological impacts are expected.

The OA is the area in which all petroleum activities will be undertaken.

Ecosystems and their constituent parts including people and communities

The EMBA occurs in the North-west Marine Region (NWMR), which is characterised by shallow-water tropical marine ecosystems and high species richness (Ref. 103; Ref. 104). The seabed geomorphology identified in the benthic survey is characterised by bare sediments, bedforms, irregular seabed, mounds, depression/scours, rock veneer, rock reef and scarp. The OA occurs within the Northwest Province and Northwest Shelf (NWS) Province bioregions.

To support understanding of the existing environment within the OA and inform impact and risk assessment, CAPL commissioned a benthic survey by Advisian (Ref 105, Appendix A). The benthic survey targeted a range of sites, including proposed DCs and areas within key ecological features (KEFs). Overall, the distribution of benthic habitat within the OA comprises mostly a mixture of flat sediment terrain with bioturbation or bare sediment, and isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Ref. 109; Ref. 112). The mapped benthic habitats were representative of known regional and local habitats and no new benthic habitats or communities to the bioregion were observed.

A number of threatened or migratory species listed under the EPBC Act may be present within the Hydrocarbon Ecological EMBA, including:

- 33 marine mammals (29 within the OA)
- 24 marine reptiles (19 within the OA)
- 57 fishes, sharks, or rays (48 within the OA)
- 54 seabirds and shorebirds (14 within the OA).

Biologically important areas (BIAs) for humpback and pygmy blue whales, flatback turtles, whale sharks and wedge-tailed shearwaters overlap the OA.

Water clarity on the NWS is variable according to movement, depth, and sediment (Ref. 205). Water and sediment quality data collected for the benthic survey indicate the quality is consistent with ANZ Guidelines, except for copper and cobalt in water samples, and nickel in sediment at one location. Air quality in the EMBA is expected to be typical of the pristine air quality found in offshore areas.

The NWMR supports a range of economic, social, and cultural activities. Islands and waters within the Hydrocarbon Ecological EMBA are used for recreational activities. The land adjacent to the NWMR has been inhabited by Traditional Owners for at least 50,000 years and they continue to use the NWMR and adjacent coastal resources for their cultural identity, health, and economy.

Three KEFs have been identified as overlapping the OA:

- Ancient coastline at 125 m depth contour
- Continental slope demersal fish communities
- Exmouth plateau.

Natural and physical resources

Natural and physical resources include fishing stocks, petroleum reservoirs or values of the Commonwealth marine area.

Three Commonwealth-managed fisheries overlap the OA and Hydrocarbon Ecological EMBA, however, none had fishing effort recorded between 2010 and 2020 (Ref. 239). Seven State-managed commercial fisheries have management areas that intersect the Hydrocarbon Ecological EMBA and have fishing effort recorded between 2012 and 2021, only one of which overlaps the OA. Recreational and traditional fishing is not expected to occur in the OA, but shore-based fishing may occur within the Hydrocarbon Ecological EMBA.

The OA overlaps part of the NWS shipping fairway system.

No tourism or recreational activities are expected within the OA. However, the Hydrocarbon Ecological EMBA connects with some coastal areas where nature-based tourism may occur.

The OA is located in the Northern Carnarvon Basin, which is Australia's premier hydrocarbon-producing province. As a result, the basin contains an established network of oil, condensate, and gas production infrastructure. Several oil and gas facilities are located between ~5 km and ~130 km from the OA, and some production wells and pipeline are present within the OA.

Qualities and characteristics of locations, places, and areas

Several locations in the vicinity of the Development are protected via legislation as a result of their natural values.

There are no Australian Marine Parks (AMPs) within the OA, however Gascoyne, Montebello, Shark Bay, Ningaloo, and Argo-Rowley Terrace overlap the Hydrocarbon Ecological EMBA.

No State marine parks, management areas, reserves or terrestrial protected areas overlap the OA. Seven State marine parks, management areas or reserves and 19 State terrestrial protected areas overlap the Hydrocarbon Ecological EMBA.

Heritage value of places

The Ningaloo Coast is listed as a National Heritage place and World Heritage property. It overlaps with the Hydrocarbon Ecological EMBA.

Multiple shipwrecks have been identified within the EMBAs.

At the time of writing, CAPL understands through consultation with the relevant Traditional Owner groups that there are no known underwater cultural heritage sites within the EMBA.

ES-7 Environmental impact and risk assessment methodology

The OPGGS(E)R require that CAPL demonstrate the environmental risks and impacts arising from the Development are acceptable. CAPL evaluated the impacts and risks according to the following methodology.

The petroleum activity was identified and described (Section 4), values and sensitivities were identified (Section 6) and aspects of the activity that may interact with the environment were identified. The credible interactions between aspects, impacts and risks, and receptors were then mapped.

The impacts and risks were then evaluated by determining the source and consequence level for each impact and risk and identifying the likelihood of the consequence occurring for each risk. The overall risk level was determined using CAPL's Integrated Risk Prioritization Matrix (Table 7-4).

CAPL defined acceptable levels specific to receptors based on relevant contexts, including principles of ecologically sustainable development (ESD), internal and external context, and legislative requirements.

ES-8 Environmental risk assessment and management strategy

The environmental impact and risk assessment, consequence and/or residual risk, EPOs and adopted control measures are shown for each aspect in Table ES-3.

Table ES-3: Summary of the assessment of environmental impacts and risks from the Development

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	**C**	**Risks**	**C**	**L**	**RR**		
Seabed disturbance	Seabed disturbance may result in: • Localised and temporary reduction in water quality	6	A localised and temporary reduction in water quality may result in: • injury or mortality of marine fauna	5	4	Low (8)	**EPO01**: Reduce the risk of impacts to sensitive benthic receptors within the OA from the Development activities.	**CM01**: Prior to drilling or installation, surveys will be conducted to verify that no emergent seabed features / obstacles are present. Where these features are identified, infrastructure location may be amended if practicable. **CM02**: Mooring analysis for the MODU will be undertaken prior to anchoring activities commencing. **CM03**: Vessels will meet crew competency, navigation equipment, and radar requirements of the Chevron Marine Standard Non Tankers (Ref. 284). **CM04**: Seabed footprint to be reduced within the limits of technical requirements and practicability, as well as safety constraints in line with operational procedures. **CM05**: Implement CAPL's Asset Retirement philosophy, which aligns with legislative requirements.
	Seabed disturbance may result in: • Alteration of benthic habitats and associated communities	4	An alteration of benthic habitats and associated communities may result in: • injury or mortality of marine fauna	5	4	Low (8)		
			Seabed disturbance within a KEF may result in: • change to values and sensitivities of KEFs	4	4	Low (7)		
			Seabed disturbance may result in: • change to cultural heritage values	4	4	Low (7)	**EPO02:** No impacts to underwater cultural heritage from the Development activities. **EPO03:** No adverse change to First Nations cultural heritage values from the Development activities.	**CM06**: Prior to drilling or installation, studies, and surveys (as necessary) will be conducted to verify that no identifiable or reasonably detectable underwater cultural heritage (as defined in the *Underwater Cultural Heritage Act 2018* (Cth)) is present within areas of the seabed expected to be disturbed. Results will be incorporated into relevant subsequent EPs and, based on assessed risks, additional control measures may be adopted, or

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
								infrastructure locations may be amended if practicable. **CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development. **CM09**: A protocol to manage underwater cultural heritage will be developed, which will include a decision framework in the event of unexpected finds *in situ* during seabed-disturbing activities.
Air emissions	Air emissions may result in: • localised and temporary reduction in air quality.	6	-			N/A	**EPO04:** Planned air emissions from vessel operations during the Development activities will meet MARPOL requirements.	**CM10:** Fuel with a reduced sulfur content will be used when available. **CM11:** Comply with the requirements of Marine Order 97 (MARPOL 73/78 Annex VI) in relation to air pollution.
Greenhouse gas emissions	GHG emissions may result in: • contribution to the reduction of the global atmospheric carbon budget (by the amount of direct and indirect	6	GHG emissions may result in: • contribution to the anthropogenic influence on the global climate system			N/A	**EPO05:** Do not materially or substantially contribute to Australia not meeting its international GHG emissions commitments by managing direct or indirect GHG emissions associated with the Development in	**CM12:** CAPL will implement its emissions reduction review to identify emissions reduction opportunities (within its operational control) for the Gorgon Gas Development to be included in an enterprise-wide selection process. **CM13:** CAPL will support Chevron's corporate aspiration of managing global

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
	GHG emissions associated with activities under this OPP).						Australia[1] consistent with the emissions targets outlined in MS 1198 and the Safeguard Mechanism	upstream emissions by implementing management strategies, projects, or improvements for the Gorgon Gas Development selected during an enterprise-wide selection process. **CM14:** Comply with the requirements of Marine Order 97 (MARPOL 73/78 Annex VI) in relation to GHG emissions: • vessels will hold a valid International Air Pollution Prevention (IAPP) certificate and a current international energy efficiency (IEE) certificate • all vessels (as appropriate to vessel class) will have a Ship Energy Efficiency Management Plan (SEEMP) as per MARPOL 73/78 Annex VI. **CM15:** The tender evaluation for vessel and MODU contracts will include an evaluation of CO_2 emissions. **CM16:** CAPL is committed to continual improvement and adaptive management processes, and regularly monitors for revised or contemporary Australian regulatory and/or relevant international guidelines or standards in relation to GHG and carbon management.
							EPO06: Manage downstream indirect GHG	**CM17:** CAPL will undertake an annual adaptive management process to address the residual uncertainty

[1] Where 'direct and indirect GHG emissions associated with Gorgon Gas Development in Australia' refers to the direct emissions associated with activities within this OPP plus the indirect emissions from processing gas at the GTP on Barrow Island.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
							emissions[2] associated with the Development consistent with the objectives of the Paris Agreement.	associated with impacts and risks from the generation of GHG emissions, specifically including: • monitoring the historical and forecast global energy mix and associated emissions, including the role of Gorgon product types • review of the accuracy of estimated downstream indirect GHG emissions associated with the Gorgon Gas Development to validate the estimates used as the basis for the impact and risk assessment • review of the environmental impact and risk assessment for GHG emissions to ensure that GHG emissions are being reduced to ALARP and managed to an acceptable level in future EPs. **CM18:** CAPL will evaluate opportunities to partner with organizations that promote and address GHG emissions reduction and carbon offsets in the LNG value chain, and advocate for LNG and natural gas as fuels of choice. **CM19:** CAPL will report production and emissions data from the Gorgon Gas Development to Chevron Corporation annually for inclusion in the calculation of its portfolio carbon intensity metric.

[2] Where 'downstream indirect GHG emissions' refers to the emissions associated with transport, and third-party end-use of LNG, condensate and domestic gas products

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	**C**	**Risks**	**C**	**L**	**RR**		
Light emissions	Light emissions may result in: • localised and temporary change in ambient light.	6	A localised and temporary change in ambient light may result in: • change to behaviour in marine reptiles	6	5	Very low (10)	**EPO07:** No displacement of marine fauna, or disrupting biologically important behaviours of marine fauna, from BIAs, important habitats, or habitat critical to the survival of a species from light emissions associated with the Development activities.	**CM20:** MODUs and vessels will meet lighting requirements of the Chevron Marine Standard Non Tankers (Ref. 284) for sufficient lighting for navigational, safety and emergency requirements. **CM21:** MODUs and vessels working at night within a marine turtle BIA will be required to reduce external lighting to the minimum required for safe operations and navigation.
			A localised and temporary change in ambient light may: • change to behaviour in birds	6	5	Very low (10)		
			A localised and temporary change in ambient light may: • change to behaviour in fish	6	5	Very low (10)		
			A localised and temporary change in ambient light may result in: • change to cultural heritage values	6	5	Very low (10)	**EPO03:** No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.
Underwater sound	Sound emissions may result in: • localised and temporary change in ambient underwater sound	5	A localised and temporary change in ambient underwater sound may result in: • behavioural disturbance to benthic invertebrates	6	2	Low (7)	**EPO08:** No displacement or disruption of marine fauna, undertaking biologically important behaviours within BIAs or habitat critical to the survival of a species from underwater sound	**CM22:** In accordance with EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans, vessels and helicopters will implement caution and no approach zones, where practicable. **CM23:** In accordance with the EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration
			A localised and temporary change in ambient underwater sound may result in:	6	2	Low (7)		

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			• change to behaviour in fishes, including sharks and rays				generated by the Development activities. **EPO09:** No injury to marine fauna undertaking biologically important behaviours within BIAs or habitat critical to the survival of a species from underwater sound generated by the Development activities.	and whales: Industry Guidelines, VSP operations will implement precaution zones and management procedures, where practicable. **CM24:** Where required, appropriate acoustic mitigation and adaptive management measures will be developed in the EP phase in alignment with the Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16).
			A localised and temporary change in ambient underwater sound may result in: • change to behaviour in reptiles	6	2	Low (7)		
			A localised and temporary change in ambient underwater sound may result in: • change to behaviour in marine mammals	5	3	Low (7)		
			A localised and temporary change in ambient underwater sound may result in: • change to cultural heritage values	6	5	Very low (10)	**EPO03:** No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.
Planned discharges – MODU and vessels	Planned discharges from the MODU and vessels may result in: • localised and temporary reduction in water quality.	6	A localised and temporary reduction in water quality may result in: • changes to predator–prey dynamics.	6	6	Very low (10)	**EPO10:** Planned discharges from MODU and vessel operations within the OA during the Development activities will meet MARPOL requirements.	**CM25:** MODUs and vessels will comply with the requirements of Marine Order 96 (MARPOL 73/78 Annex IV) in relation to sewage discharge. **CM26:** MODUs and vessels will comply with the requirements of Marine Order 95 (MARPOL 73/78 Annex V) in relation to food waste discharge.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
								CM27: MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to oily bilge water discharges.
Planned discharges – subsea operations	Planned subsea operational discharges may result in: • localised and temporary reduction in water quality	6	A localised and temporary reduction in water quality may result in: • injury or mortality of marine fauna.	5	5	Very low (9)	**EPO11:** No impacts to benthic habitats or marine fauna outside the OA from planned subsea operations discharges during the Development activity.	**CM28:** Fluids planned for discharge are subject to the hazardous materials selection process as per the CAPL Hazardous Materials Management Procedure (Ref. 415). **CM29:** Chemicals planned for discharge will be selected and applied with the lowest practicable concentrations to provide technical effectiveness and reduce environmental impacts.
			A localised and temporary reduction in water quality may result in: • change to the functions, interests and activities of other marine users.	5	5	Very low (9)		
			Planned subsea operational discharges within a KEF may result in: • change to values and sensitivities of KEFs	5	5	Very low (9)		
			Planned subsea operational discharges within a KEF may result in: • change to cultural heritage values	5	5	Very low (9)	**EPO03:** No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	**C**	**Risks**	**C**	**L**	**RR**		
Planned discharges – drilling	Planned drilling discharges may result in: • localised and temporary reduction in water quality	6	A localised and temporary reduction in water quality may result in: • injury or mortality of marine fauna.	5	4	Low (7)	**EPO12:** No impacts to benthic habitats or marine fauna outside the OA from planned drilling discharges during the Development activity.	**CM01**: Prior to drilling or installation, surveys will be conducted to verify that no emergent seabed features / obstacles are present. Where these features are identified, infrastructure location may be amended if practicable. **CM28:** Fluids planned for discharge are subject to the hazardous materials selection process as per CAPL's Hazardous Materials Management Procedure (Ref. 415). **CM30:** Implement CAPL's Offshore Drilling Fluid Guidelines; of which key requirements include: • restrict heavy metal concentrations in barite • limit NADF concentrations on cuttings • limit NADF content in tank wash discharge • no overboard discharge of whole NADF. **CM31:** Drilling and cementing procedures will be developed prior to activities commencing, including controls on quantity of cement mixed.
	Planned drilling discharges may result in: • localised and temporary reduction in sediment quality.	6	A localised and temporary reduction in sediment quality may result in: • injury or mortality of marine fauna.	5	3	Low (7)		
	Planned discharges—drilling may result in: • alteration of benthic habitats and associated communities.	5	Planned drilling discharges within a KEF may result in: • change to values and sensitivities of KEFs	5	4	Low (8)		
			Planned drilling discharges within a KEF may result in: • change to values and sensitivities of KEFs	5	4	Low (8)		
Physical presence – other marine users	N/A	-	Unplanned interactions with commercial fisheries may result in: • change to the functions, interests and activities of other marine users.	6	3	Low (8)	**EPO13:** Reduce disruption to other marine users' activities within the OA to no greater tha1 necessary.	**CM05:** Implement CAPL's Asset Retirement philosophy, which aligns with legislative requirements. **CM32:** Before commencing offshore activities, relevant agencies will be notified of activities, vessel movements, and requested exclusion zones, to enable them to generate radio
			Unplanned interactions with petroleum activities and	6	3	Low (8)		

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			commercial shipping may result in: • change to the functions, interests and activities of other marine users.					navigation warnings and/or Notice to Mariners. **CM33:** Relevant parties will be advised of the commencement of key phases of activities and any exclusion zones and other relevant information as requested. **CM34:** MODUs and vessels will meet crew competency, navigation equipment, and radar requirements of the Chevron Marine Standard Non Tankers (Ref. 284). **CM35:** Consultation with relevant persons will be undertaken for all petroleum activities as part of EP development as per the OPGGS(E)R.
Physical presence – marine fauna	N/A	-	Unplanned interactions with birds may result in: • injury or mortality of marine fauna.	6	3	Low (8)	**EPO14:** No injury or mortality to marine fauna within the OA from the physical presence of the Development	**CM22:** In accordance with EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans, vessels and helicopters will implement caution and no-approach zones, where practicable. **CM36:** Minimise entrainment of fauna during water intake, by use of intake screens and controlling intake velocity.
			Unplanned interactions with fishes, including sharks and rays may result in: • injury or mortality of marine fauna.	6	3	Low (8)		
			Unplanned interactions with marine reptiles may result in: • injury or mortality of marine fauna.	6	3	Low (8)		
			Unplanned interactions with marine mammals may result in: • injury or mortality of marine fauna.	6	3	Low (8)		

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			Injury or mortality of marine fauna may result in: • change to cultural heritage values	6	3	Low (8)	**EPO03:** No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.
Introduction of invasive marine pests	N/A	-	Introduction of an IMP to a benthic habitats and associated communities or KEF may result in: • widespread, long-term displacement of, or competition with, endemic species.	3	6	Low (8)	**EPO15:** No introduction of invasive marine pests to the OA due to the Development activities.	**CM37:** MODUs and vessels will meet the relevant requirements of CAPL's Quarantine Procedure Marine Vessels (Ref. 74). **CM38:** Where required, MODUs and vessels will have a current antifouling system certification in accordance with Marine Order Part 98 (Anti-fouling systems) and Australian Biofouling Management Requirements (Ref. 58). **CM39:** Ballast water exchanges will be managed in accordance with the Australian Ballast Water Management Requirements (Ref. 58). **CM40:** Where required, MODUs and vessel pre-arrival information will be reported through the Maritime Arrivals Reporting System as per the *Biosecurity Act 2015* (Cth).
			Introduction of an IMP to a KEF may result in: • change to values and sensitivities.	3	6	Low (8)		
			Introduction of an IMP may result in: • change to cultural heritage values.	3	6	Low (8)	**EPO03:** No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
								CM08: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.
Unplanned release – solid objects	N/A	-	Unplanned release of solid objects in the marine environment may result in: • localised and temporary reduction in water quality	6	5	Very low (10)	**EPO16:** No uncontrolled release of solid objects to the environment during the Development activities. **EPO17:** No injury or mortality to marine fauna from an uncontrolled release of solid objects to the environment associated with the Development.	**CM41:** MODUs and vessels will comply with the requirements of Marine Order 95 (MARPOL 73/78 Annex V) in relation to managing waste (garbage) offshore. **CM42:** MODUs and vessels will have specific lifting plans in place for cranes before commencing lifting operations and transfers, to prevent dropped objects. **CM43:** Any dropped objects will be retrieved if practicable.
			Unplanned release of solid objects may interact with marine fauna to result in: • injury or mortality of marine fauna	6	5	Very low (10)		
			Unplanned release of solid objects may result in: • alteration of benthic habitats and associated communities.	5	5	Very Low (9)		
			Unplanned release of solid objects in a KEF may result in: • change to values and sensitivities	5	5	Very Low (9)		
			Unplanned release of solid objects in a KEF may result in: • change to cultural heritage values.	5	5	Very Low (9)	**EPO02:** No impacts to underwater cultural heritage from the Development activities.	**CM06**: Prior to drilling or installation, studies, and surveys (as necessary) will be conducted to verify that no identifiable or reasonably detectable underwater cultural heritage (as defined in the *Underwater Cultural Heritage Act*

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
							EPO03: No adverse change to First Nations cultural heritage values from the Development activities.	*2018* (Cth)) is present within areas of the seabed expected to be disturbed. Results will be incorporated into relevant subsequent EPs and, based on assessed risks, additional control measures may be adopted, or infrastructure locations may be amended if practicable. **CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development. **CM09**: A protocol to manage underwater cultural heritage will be developed, which will include a decision framework in the event of unexpected finds *in situ* during seabed-disturbing activities.
Unplanned release - minor LOC	N/A		Minor loss of containment may result in: • localised and temporary reduction in water quality.	5	5	9 (Very low)	**EPO18:** No unplanned release of hydrocarbons or chemicals to the marine environment during the Development activities.	**CM42:** The MODUs and vessels will have specific lifting plans in place for cranes before commencing lifting operations and transfers, to prevent dropped objects. **CM44:** MODUs and vessels will meet the requirements of the Chevron Marine Standard Non Tankers (Ref. 284), including pre-mobilisation inspections of

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			Minor loss of containment may result in: • injury or mortality of marine fauna.	5	5	9 (Very low)		equipment, couplings, and secondary containment. **CM45:** MODUs and vessels will have a bulk transfer procedure in place to prevent spills before commencing the activities. **CM46:** MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to having an approved Ship Oil Pollution Emergency Plan or equivalent in place.
Unplanned release – Vessel collision (MDO)	N/A	-	Unplanned release of MDO due to a vessel collision event may result in: • change in water quality.	4	5	Low (8)	**EPO19**: No unplanned release of hydrocarbons to the environment from vessel collision during Development activities.	**CM32:** Before commencing offshore activities, relevant agencies will be notified of activities, vessel movements, and requested exclusion zones, to enable them to generate radio navigation warnings and/or Notice to Mariners. **CM44:** MODUs and vessels will meet the requirements of the Chevron Marine Standard Non Tankers, including pre-mobilisation inspections of equipment, couplings, and secondary containment. **CM46:** MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to having an approved Ship Oil Pollution Emergency Plan or equivalent in place. **CM47:** In the event of a spill occurring, the accepted Oil Pollution Emergency
			Unplanned release of MDO due to a vessel collision event may result in: • change in sediment quality.	4	5	Low (8)		
			Unplanned release of MDO due to a vessel collision event may result in: • alteration of coastal habitats and associated communities.	4	5	Low (8)		
			Unplanned release of MDO due to a vessel collision event may result in: • injury or mortality of marine fauna	4	5	Low (8)		

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			Unplanned release of MDO due to a vessel collision event may result in: • change to the functions, interests and activities of other marine users	4	5	Low (8)		Plan (OPEP) in subsequent EPs for the Development will be implemented. **CM48:** In the event of a spill occurring, the accepted Operational and Scientific Monitoring Plan (OSMP) in subsequent EPs for the Development will be implemented.
			Unplanned release of MDO due to a vessel collision event may result in: • change to values and sensitivities of Australian Marine Parks	4	5	Low (8)		
			Unplanned release of MDO due to a vessel collision event may result in: • change to values and sensitivities of KEFs	4	5	Low (8)		
			Unplanned release of MDO due to a vessel collision event may result in: • change to values and sensitivities of the Ningaloo Coast	4	5	Low (8)		
			Unplanned release of MDO due to a vessel collision event may result in: • change to cultural heritage values	4	5	Low (8)	**EPO03:** No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
Unplanned release – Hydrocarbon system (condensate)	N/A	-	Unplanned release of condensate from the hydrocarbon system may result in: • change in water quality	4	5	Low (8)	**EPO20:** No unplanned release of condensate to the environment from the hydrocarbon system during Development activities.	**CM32:** Before commencing offshore activities, relevant agencies will be notified of activities, vessel movements, and requested exclusion zones, to enable them to generate radio navigation warnings and/or Notice to Mariners. **CM44:** MODUs and vessels will meet the requirements of the Chevron Marine Standard Non Tankers, including pre-mobilisation inspections of equipment, couplings, and secondary containment. **CM46:** MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to having an approved Ship Oil Pollution Emergency Plan or equivalent in place. **CM47:** In the event of a spill occurring, the accepted OPEP in subsequent EPs for the Development will be implemented. **CM48:** In the event of a spill occurring, the accepted OSMP in subsequent EPs for the Development will be implemented. **CM49:** NOPSEMA-accepted Well Operations Management Plan (WOMP) in place for all wells, in accordance with the OPGGS Act requirements. **CM50**: NOPSEMA-accepted Safety Case in place for all relevant facilities, in accordance with the OPGGS Act requirements.
			Unplanned release of condensate from the hydrocarbon system may result in: • change in sediment quality	4	5	Low (8)		
			Unplanned release of condensate from the hydrocarbon system may result in: • alteration of coastal habitats and associated communities	4	5	Low (8)		
			Unplanned release of condensate from the hydrocarbon system may result in: • injury or mortality of marine fauna	4	5	Low (8)		
			Unplanned release of condensate from the hydrocarbon system may result in: • change to values and sensitivities of KEFs	5	5	Very Low (9)		
			Unplanned release of condensate from the hydrocarbon system may result in:	4	5	Low (8)		

Aspect	Impact and/or risk level summary						EPOs	Adopted control measures
	Impacts	C	Risks	C	L	RR		
			• change to the functions, interests and activities of other marine users					
			Unplanned release of condensate from the hydrocarbon system may result in: • change to values and sensitivities of Australian Marine Parks	4	5	Low (8)		
			Unplanned release of condensate from the hydrocarbon system may result in: • change to values and sensitivities of the Ningaloo Coast	4	5	Low (8)		
			Unplanned release of condensate from the hydrocarbon system may result in: • change to cultural heritage values	4	5	Low (8)	**EPO03:** No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.

ES-9 Cumulative impact assessment

In addition to assessing the impacts and risks of the individual aspects, CAPL also assessed the cumulative impacts. The cumulative impact assessment (CIA) considered the potential additive effects on environmental values and sensitivities from activities within the Development and from other activities within the region, and the long-term cumulative effects from activities occurring over many years. The CIA considered potential changes to consequence levels, EPOs, and control measures as a result of cumulative effects.

As a result of the CIA for marine mammals, an additional control measure was determined (Section 9.2.11):

- **CM51**: CAPL will re-evaluate the cumulative impact assessment based on studies conducted for J-IC to manage scientific uncertainty against all potential cumulative impacts.

For all other values and sensitivities assessed, no changes to consequence, EPOs or control measures were indicated and the impacts were deemed acceptable.

ES-10 Implementation strategy

CAPL will carry out the Development in accordance with this OPP and all subsequent EPs. The implementation strategy will help achieve the EPOs, as per the requirements of Regulation 5A of the OPGGS(E)R.

CAPL's operations are managed in accordance with Chevron Corporation's Operational Excellence Management System (OEMS). The OEMS underpins the implementation strategy, aligns with ISO 1400:2015 and meets the requirements of the OPGGS(E)R.

Environmental monitoring and reporting will be undertaken to provide continuous review of procedures and activities, and to demonstrate regulatory compliance. Reporting will be carried out in compliance with the OPGGS(E)R.

The implementation strategy will be presented in more detail in subsequent EPs.

1 Introduction

1.1 Overview

Chevron Australia Pty Ltd (CAPL) is the operator of the Gorgon Gas Development, one of Australia's largest natural gas projects located off the northwest coast of Western Australia. The first stage of the Gorgon Gas Development was the Gorgon Foundation Project (GFP), which included constructing the Gorgon Gas Treatment Plant (GTP) and domestic gas plant on Barrow Island and developing the Gorgon and Jansz–Io offshore fields.

CAPL is proposing to undertake the Gorgon Gas Development: Backfill Fields Development (the Development), which represents the next phase of the Gorgon Gas Development. A backfill field is a supply of natural gas that is required to maintain the throughput to an operating facility. The intent of the Development is to maintain gas supply to the existing gas plants on Barrow Island to sustain current production rates of liquefied natural gas (LNG) and domestic gas.

The proposed Development comprises the construction, installation and operation of drill centres, flowlines, and subsea tiebacks to access 7 backfill gas fields in the Greater Gorgon Area. The development of these fields was outlined in the original Gorgon Gas Development Environmental Impact Statement/Environmental Review and Management Process (EIS/ERMP) (Ref. 1), which stated that the other fields of the Greater Gorgon Area would be developed once production from the Gorgon and Jansz–Io fields began their natural decline. The WA *Barrow Island Act 2003* also refers to the Greater Gorgon Area, which includes the backfill fields.

All 7 fields are located in Commonwealth (Cth) waters off the north-west coast of Western Australia (WA); and comprise Chandon, Chrysaor, Dionysus, Eurytion, Geryon, Semele and West Tryal Rocks (WTR). The Geryon and Eurytion (G&E) fields will be co-developed and fed into a single flowline. The Chrysaor and Dionysus (C&D) fields are anticipated to be co-developed in a similar manner. Consequently, while the OPP covers the 7 fields, activities, impacts, and risks associated with each set of co-developed fields are considered jointly.

1.2 Document Purpose

This Offshore Project Proposal (OPP) has been prepared by CAPL as Operator of WA-5-R, WA-14-R, WA-15-R, WA-20-R, WA-21-R, WA-22-R, WA-53-R, WA-75-R and WA-76-R in accordance with the requirements of the Commonwealth *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023* (OPGGS(E)R).

The OPP covers all phases of the Development project life from surveys, drilling, and installation, to operations and decommissioning.

The OPGGS(E)R require proponents of offshore projects to submit an OPP to the National Offshore Petroleum Safety and Environment Management Authority (NOPSEMA). NOPSEMA must accept an OPP before the proponent can submit more detailed environment plans (EPs) for project activities. The OPP process involves the proponent's evaluation and NOPSEMA's assessment of the potential environmental impacts and risks of petroleum activities conducted over the life of the Development. The process includes a public comment period and requires a proponent to ensure environmental impacts and risks will be managed to acceptable levels.

1.3 Location

The Development fields are located in Commonwealth waters offshore north-west WA. The fields lie to the north-west of Barrow Island, in the vicinity of the GFP fields. Water depths in the area range from ~150–1,400 m. Drilling will occur within petroleum titles WA-5-R, WA-14-R, WA-15-R, WA-22_R and WA-53-R. The location is shown in Figure 1-1.

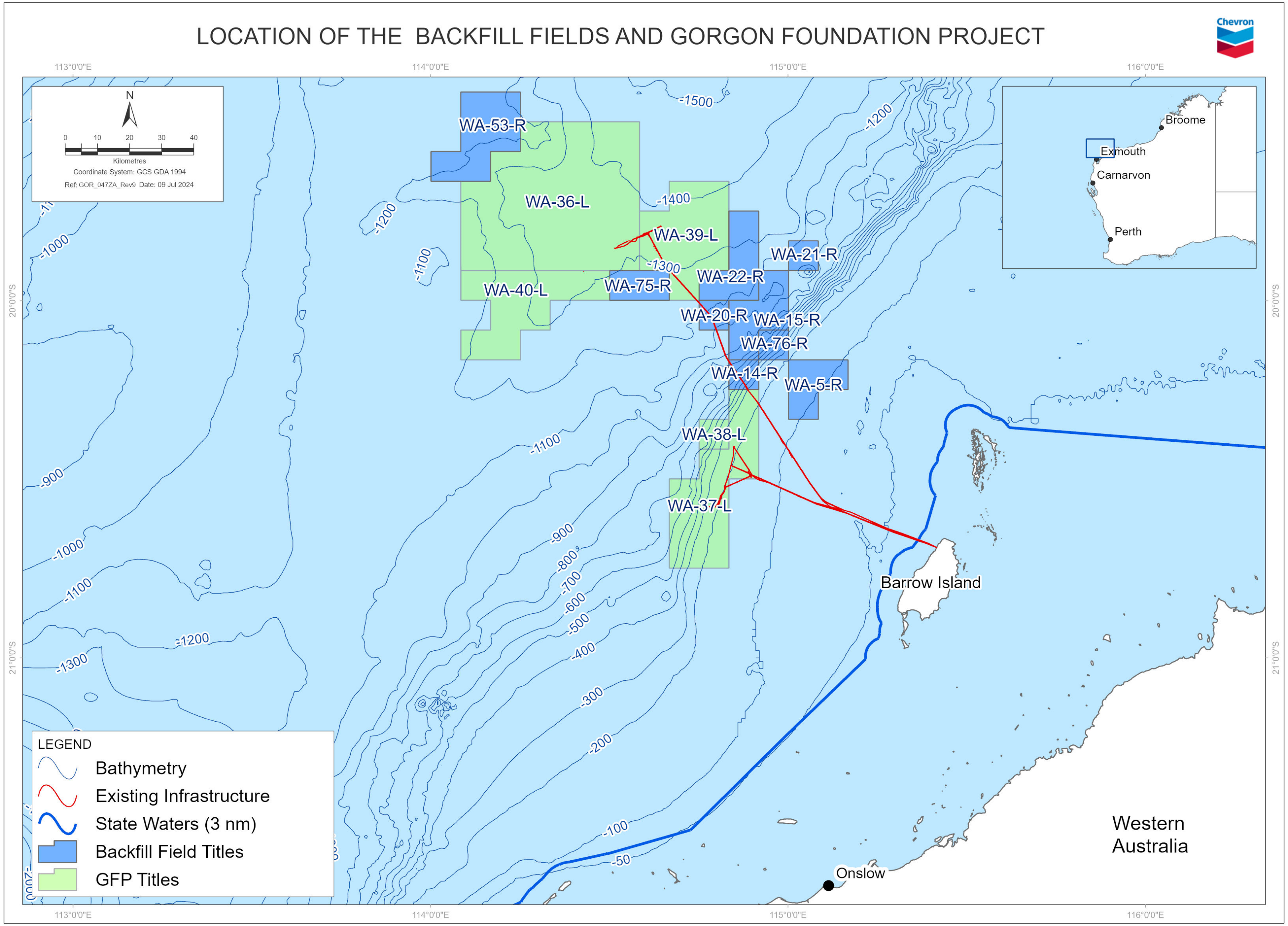

Figure 1-1: Location of the Backfill Fields and Gorgon Foundation Project

The closest infrastructure will be ~60 km from Barrow Island and ~130 km from Onslow. The outermost infrastructure will be ~190 km from Barrow Island and ~250 km from Onslow. Section 4 has detailed information about the location and layout of subsea infrastructure.

No petroleum activities in State waters or onshore are proposed under this OPP.

1.4 Scope

1.4.1 In scope

This OPP addresses these primary activities associated with the Development:

- surveys—geophysical surveys and seabed geotechnical surveys, including pre-installation and as-built surveys, occurring throughout the Development
- drilling —covers well construction, including mobile offshore drilling unit (MODU) positioning, spread mooring, drilling of production wells, blowout preventer (BOP) installation, cementing and completions in each field
- installation and commissioning—includes seabed preparation, pipelay (flowline and pipeline), subsea equipment installation, verification and testing of infrastructure, pre-commissioning, including hydrotesting and commissioning, and the introduction of hydrocarbons to the system
- operations—the gathering and transport of hydrocarbons and other fluids from the subsea wells to the existing GFP pipelines, including inspection, maintenance and repair (IMR) and well intervention
- decommissioning— long-term planning for decommissioning of infrastructure no longer in use, including removing subsea infrastructure, and plug and abandonment (P&A) of wells
- support activities—includes MODU topside activities and vessel, helicopter and remotely operated vehicle (ROV) operations.

Section 4 describes these activities in more detail.

1.4.2 Out of scope

The primary approval for the GFP was granted under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This approval was for constructing, installing and operating facilities associated with producing and transporting gas (including offshore production wells and feed gas pipeline infrastructure) from the Gorgon and Jansz–Io gas fields to the Gorgon GTP. The Gorgon Gas Development Area is defined under the WA *Barrow Island Act 2003*.

The GFP is defined as the combination of these developments, currently in operation or yet to be implemented, in accordance with subsequent approval documents:

- GFP developments in operation:
  - the foundation ‘Gorgon Gas Development’, the development proposed in the EIS/ERMP (Ref. 1) and subsequently approved under EPBC Reference: 2003/1294 and Ministerial Statement No. 748 (MS 748)
  - the ‘Revised and Expanded Gorgon Gas Development’, the development proposed in the Public Environmental Review (PER) (Ref. 2) and

subsequently approved under EPBC Reference: 2008/4178 and MS 800 and MS 865

- the ‘Jansz–Io Development Project and Jansz Feed Gas Pipeline’, the development assessed via EPBC Referral assessment processes and Environmental Impact Statement/Assessment on Referral Information (Ref. 3; Ref. 4) and subsequently approved under EPBC Reference: 2005/2184 and MS 769
- the ‘Gorgon Gas Development Additional Construction Laydown and Operations Support Area’ (Additional Support Area), use of additional uncleared land for the Gorgon Gas Development as approved under MS 965 and regulated through variations to EPBC References: 2003/1294 and 2008/4178.

GFP developments approved but have not been implemented at this point in time:

- the ‘Fourth Train Expansion Proposal’ (Fourth Train Proposal), development proposed in the Public Environmental Review/Environmental Impact Statement (PER/EIS) (Ref. 5), and subsequently approved under MS 1002 and regulated through a variation to EPBC Reference: 2011/5942.
- as amended by section 46 of the Environmental Protection Act 1986 (WA), and subsequently approved under MS 1136 and 1198.

Activities covered under GFP approvals, which are excluded from the scope of the OPP, include:

- drilling, commissioning, well maintenance, operations and support activities associated with the GFP and Gorgon Stage 2 (GS2), which are covered under EPs accepted by NOPSEMA and the WA Department of Mines, Industry Regulations and Safety (DMIRS) (Ref. 6; Ref. 7; Ref. 8; Ref. 9; Ref. 10)
- installing and operating infrastructure associated with the Jansz–Io Compression (J-IC) Project, including the field control station (FCS), as well as other GFP power supply options
- vessels (including emergency response vessels) transiting to or from the operational area (OA) (Section 4.1.3 defines the OA). These vessels are deemed to be operating under the Commonwealth *Navigation Act 2012* and are not performing a petroleum activity.

1.5 Proponent details

Chevron Australia Pty Ltd (CAPL) is the proponent for this OPP and the Development; Table 1-1 lists CAPL's contact details.

Table 1-1: Proponent's contact details

Proponent	Chevron Australia Pty Ltd
Business address	1 The Esplanade, Perth WA 6000
Telephone number	+61 8 9216 4000
Email address	feedback@chevron.com
Website	https://australia.chevron.com

1.6 Structure of OPP

This OPP aligns with NOPSEMA's current OPP content requirements (Ref. 11) and OPP assessment policy (Ref. 12); Table 1-2 summarises its structure.

Table 1-2: OPP structure

Section		Content
1	Introduction	Provides an overview of the project, location and proponent details.
2	Requirements	Describes the legislation, other regulatory requirements, relevant standards and guidelines that apply.
3	Stakeholder consultation	Summarises CAPL's stakeholder consultation methods, which includes the process of identifying stakeholders, consultation history and future consultation requirements.
4	Description of the project	Describes all activities including installation, commissioning, drilling, hydrocarbon offloading and decommissioning.
5	Alternatives analysis	Analyses alternative operations and procedures, and decision-making processes.
6	Description of the environment	Describes the existing environment, highlighting significant physical, ecological, and socio-economic values.
7	Environmental impact and risk assessment methodology	Describes how environmental impacts and risks were identified and evaluated.
8	Environmental risk assessment and management strategy	Details the results and justification of environmental impacts and risk assessments.
9	Cumulative impact assessment	Assesses the cumulative impacts for the project.
10	Implementation strategy	Details how environmental performance outcomes stated in this OPP will be implemented.
11	Acronyms and abbreviations	
12	References	

2 Requirements

The Development is located entirely in Commonwealth waters and therefore triggers these key Commonwealth acts: *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

2.1 Commonwealth legislation

2.1.1 Offshore Petroleum and Greenhouse Gas Storage Act 2006

The OPGGS Act provides the regulatory framework for all offshore petroleum exploration and production activities occurring in Commonwealth waters. The purpose of the Act is to ensure that these activities are undertaken in a way that:

- is consistent with the principles of ecologically sustainable development (ESD) as defined in section 3A of the EPBC Act
- reduces environmental impacts and risks of the activity to As Low As Reasonably Practicable (ALARP)
- ensures that environmental impacts and risks of the activity are of an acceptable level.

The OPGGS Act addresses all issues related to offshore petroleum exploration and development operations, including licensing, health, safety, environment, and royalties. Regulations created under the Act include:

- *Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009*
- *Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011*
- *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (OPGGS(E)R)*.

Section 6 of the OPGGS(E)R specifies that before commencing an offshore project, a proponent must submit an OPP to the regulator.

Table 2-1 specifies the OPGGS(E)R requirements in relation to the content of this OPP.

Table 2-1: Concordance table for the OPP requirements of the OPGGS(E)R

Section	Description	Document section
7 (2)(a)	The proposal must: i. include the proponent's name and contact details;	Section 1.5
7 (2)(b)	include a summary of the project, including the following: i. a description of each activity that is part of the project; ii. the location or locations of each activity; iii. a proposed timetable for carrying out the project; iv. a description of the facilities that are proposed to be used to undertake each activity; v. a description of the actions proposed to be taken, following completion of the project, in relation to those facilities;	Section 4
7 (2)(c)	describe the existing environment that may be affected by the project;	Section 6

Section	Description	Document section
7 (2)(d)	include details of the particular relevant values and sensitivities (if any) of that environment;	Section 6
7 (2)(e)	set out the environmental performance outcomes for the project;	Section 8
7 (2)(f)	describe any feasible alternative to the project, or an activity that is part of the project, including: i. a comparison of the environmental impacts and risks arising from the project or activity and the alternative; ii. an explanation, in adequate detail, of why the alternative was not preferred.	Section 5
7 (3)	Without limiting paragraph (5)(d), particular relevant values and sensitivities may include any of the following: (a) the world heritage values of a declared World Heritage property within the meaning of the EPBC Act; (b) the national heritage values of a National Heritage place within the meaning of that Act; (c) the ecological character of a declared Ramsar wetland within the meaning of that Act; (d) the presence of a listed threatened species or listed threatened ecological community within the meaning of that Act; (e) the presence of a listed migratory species within the meaning of that Act; (f) any values and sensitivities that exist in, or in relation to, part or all of: i. a Commonwealth marine area within the meaning of that Act; or ii. Commonwealth land within the meaning of that Act.	Section 6
7 (4)	The proposal must: (a) describe the requirements, including legislative requirements, that apply to the project and are relevant to the environmental management of the project; and (b) describe how those requirements will be met.	Section 2
7 (5)	The proposal must include: (a) details of the environmental impacts and risks for the project; and (b) an evaluation of all the impacts and risks, appropriate to the nature and scale of each impact or risk.	Section 8

2.1.1.1 Environment plans

The OPGGS(E)R require a titleholder to have an accepted environment plan (EP) in place for any petroleum activity or greenhouse gas (GHG) activity. The EP must be appropriate for the nature and scale of the activity, and must describe the activity, the existing environment, the impact and risk assessment and proposed control measures.

An EP must include an implementation strategy, with an accompanying Oil Pollution Emergency Plan (OPEP) and Operational and Scientific Monitoring Plan (OSMP).

EPs for activities associated with the Development will be submitted after the OPP has been accepted by NOPSEMA.

Activities will not start until NOSPEMA has accepted the relevant EP.

2.1.2 Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act and the supporting *Environment Protection and Biodiversity Conservation Regulations 2000* (EPBC Regulations) provide for the protection and management of nationally and internationally important flora, fauna, ecological communities, and heritage places. The aims of the EPBC Act are to:

- protect Matters of National Environmental Significance (MNES)
- provide for Commonwealth environmental assessment and approval processes
- provide for an integrated system for biodiversity conservation and management of protected areas.

If there is the potential for an MNES to be impacted by offshore petroleum activities, an assessment of impacts must be presented in the OPP. The MNES identified as relevant to the Development are:

- listed threatened species and ecological communities
- listed migratory species (protected under international agreements)
- Commonwealth marine environment
- World Heritage properties
- National Heritage places.

NOPSEMA oversees the assessment process as the delegated authority for petroleum activities under the EPBC Act.

2.1.2.1 Listed threatened species management plans, recovery plans and conservation advice

Under the EPBC Act, listed threatened species are managed through management plans, recovery plans or conservation advice. These plans provide information on relevant impacts and threats and set requirements for management and protection.

The requirements of species recovery plans and conservation advice were used to guide development of the appropriate management of the proposed activities for this OPP.

Table 2-2 summarises the management plans, recovery plans and conservation advice relevant to the Development. These documents were considered when assessing impacts and risks, assessing acceptability, and developing environmental performance outcomes (EPOs). The objectives and actions from these documents, relevant to the Development, are listed in Table 2-2 and cross referenced to the applicable sections within the OPP where details of how the requirements are met are located.

Table 2-2: Relevant management plans, recovery plans and conservation advice

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
Vertebrates					
All vertebrate fauna	Threat Abatement Plan for the Impacts of Marine Debris on the Vertebrate Wildlife of Australia's Coasts and Oceans (Ref. 13)	There are 4 relevant objectives: Objective 1: Contribute to the long-term prevention of marine debris. Objective 2: Understand the scale of impacts from marine plastic and microplastic on key species, ecological communities, and locations. Objective 3: Remove existing marine debris. Objective 4: Monitor the quantities, origins and hazardous chemical contaminants of marine debris and assess the effectiveness of management arrangements for reducing marine debris.	Marine debris	No explicit relevant management actions for non-fisheries related industries (note that management actions in the plan relate largely to management of fishing waste (e.g., "ghost' gear), and State and Commonwealth management through regulation).	8.12.3
Marine mammals					
Marine mammals	National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Ref. 14)	Objectives are to acquire data, determine risks of vessel strike, and identify mitigation measures, with the target audience being government agencies	Vessel collision	Ensure all vessel strike incidents are reported in the National Vessel Strike Database (Ref. 15). Identify and adopt best-practice mitigation measures and emerging technologies, and encourage the development of new mitigation measures	0
Blue whale (includes pygmy blue whale and Antarctic blue whale)	Conservation Management Plan for the Blue Whale 2015-2025 (Ref. 16)	The long-term recovery objective is to minimise anthropogenic threats to allow for their conservation status to improve so that they can be removed from the EPBC Act threatened species list.	Noise interference	Assess the effect of anthropogenic noise on blue whale behaviour. Anthropogenic noise in BIAs will be managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging area.	8.5.4

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
			Vessel disturbance	Ensure all vessel strike incidents are reported in the National Ship Strike Database (Ref. 15) Ensure the risk of vessel strikes on blue whales is considered when assessing actions that increase vessel traffic in areas where blue whales occur and, if required, implement appropriate mitigation measures.	0
			Marine debris	No explicit relevant management actions: marine debris identified as a threat.	8.12.3
			Habitat modification	No explicit relevant management actions.	8.6.3, 8.7.3, 8.8.3, 8.13.3, 8.14.4, 8.15.4
Fin whale	Conservation advice *Balaenoptera physalus* Fin Whale (Ref. 17)	No explicit relevant objectives	Anthropogenic noise	No explicit relevant management actions.	8.5.4
			Habitat degradation	No explicit relevant management actions.	8.6.3, 8.7.3, 8.8.3
			Pollution (persistent toxic pollutants)	No explicit relevant management actions.	8.13.3, 8.14.4, 8.15.4
			Vessel strike	Ensure all vessel strike incidents are reported in the National Ship Strike Database (Ref. 15)	0
Sei whale	Conservation advice *Balaenoptera borealis* Sei Whale (Ref. 18)	No explicit relevant objectives	Anthropogenic noise	No explicit relevant management actions.	8.5.4

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
			Habitat degradation	No explicit relevant management actions.	8.6.3, 8.7.3, 8.8.3
			Pollution (persistent toxic pollutants)	No explicit relevant management actions.	8.13.3, 8.14.4, 8.15.4
			Vessel strike	Ensure all vessel strike incidents are reported in the National Ship Strike Database (Ref. 15)	0
Southern Right Whale	Conservation Management Plan for the Southern Right Whale (Ref. 19)	Long-term recovery objective: The population has increased in size to a level that the conservation status has improved, and the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria. Interim recovery objective 5: Anthropogenic threats are demonstrably minimised.	Noise interference	Assess and address anthropogenic noise: shipping, industrial and seismic noise.	8.5.4
			Habitat modification	Addressing infrastructure and coastal development impacts.	8.13.3, 8.14.4, 8.15.4
	Draft National Recovery Plan for the Southern Right Whale (Ref. 20)	Long-term recovery objective: The population has increased in size to a level that the conservation status has improved, and the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria. Interim recovery objective 2: Anthropogenic threats are managed consistent with ecologically sustainable development principles and do not impede recovery of southern right whales	Pollution	Baseline surveys and monitoring undertaken during activity implementation are conducted in accordance with best practice standards and guidelines to ensure standardised datasets are obtained and suitable to inform environmental management decision making that can reduce the risk of threats to southern right whales.	8.13.3, 8.14.4, 8.15.4
			Anthropogenic underwater noise	Marine infrastructure development projects need to consider habitat requirements of southern right whales and BIAs at early stages of planning. Actions within and adjacent to southern right whale BIAs and HCTS	8.5.4

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
				should demonstrate that it does not prevent any southern right whale from utilising the area or cause injury (TTS and PTS) and/or disturbance.	
Reptiles					
Flatback turtle, green turtle, hawksbill turtle, leatherback turtle, loggerhead turtle	Recovery Plan for Marine Turtles in Australia (Ref. 21)	Long-term recovery objective: • minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 3: • anthropogenic threats are demonstrably minimised	Marine debris	Reduce the impacts from marine debris: Support the implementation of the EPBC Act Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (Ref. 13).	8.12.3
			Chemical and terrestrial discharge	Minimise chemical and terrestrial discharge: Ensure spill risk strategies and response programs adequately include management for marine turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs.	8.13.3, 8.14.4, 8.15.4
			Light pollution	Minimise light pollution: Artificial light within or adjacent to habitat critical to the survival of marine turtles will be managed such that marine turtles are not displaced from these habitats. Develop and implement best-practice light management guidelines for existing and future developments adjacent to marine turtle nesting beaches.	8.4.3

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
				Identify the cumulative impact on turtles from multiple sources of onshore and offshore light pollution.	
			Noise interference	No explicit relevant management actions.	8.5.4
			Habitat modification	Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to their survival. Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue	8.6.3, 8.7.3, 8.8.3
			Vessel disturbance	No explicit relevant management actions.	0
Leatherback turtle	Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle) (Ref. 22)	No explicit relevant objectives	Marine debris	No explicit relevant management actions: marine debris identified as a threat.	8.12.3
			Vessel strike	No explicit relevant management actions: vessel strike identified as a threat.	0
Leaf-scaled Sea Snake	Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 23)	No explicit relevant objectives	Habitat degradation/ modification	Ensure there is no anthropogenic disturbance in areas where the Leaf-scaled sea snake occurs, excluding necessary actions to manage the conservation of the species.	8.6.3, 8.7.3, 8.8.3, 8.13.3, 8.14.4, 8.15.4
Short-nosed Sea Snake	Approved Conservation Advice on *Aipysurus apraefrontalis* (Short-nosed Sea Snake) (Ref. 24)	No explicit relevant objectives	Habitat degradation/ modification	Ensure there is no anthropogenic disturbance in areas where the Short-nosed sea snake occurs, excluding necessary actions to manage the conservation of the species.	8.6.3, 8.7.3, 8.8.3, 8.13.3, 8.14.4, 8.15.4
Fishes					

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
All sawfish and river sharks	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25)	The primary objective of this recovery plan is to assist the recovery of sawfish and river sharks with a view to: • improving the population status leading to the removal of the sawfish and river shark species from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder recovery in the near future or impact the conservation status of the species in the future. The specific relevant objectives of the recovery plan are: • Objective 5: Reduce and, where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species • Objective 6: Reduce and, where possible, eliminate any adverse impacts of marine debris on sawfish and river hark species noting the linkages with the Threat Abatement Plan for the Impacts of Marine Debris on the Vertebrate Wildlife of Australia's Coasts and Oceans (Ref. 13).	Habitat degradation and modification	Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks. Implement measures to reduce adverse impacts of habitat degradation and/or modification.	8.1.3, 8.6.3, 8.7.3, 8.8.3, 8.13.3, 8.14.4, 8.15.4
			Marine debris	No explicit relevant management actions: marine debris identified as a threat.	8.12.3
Dwarf sawfish	Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish) (Ref. 26)	No explicit relevant objectives	Habitat degradation/ modification	No explicit relevant management actions: habitat loss, disturbance and modification identified as a threat.	8.1.3, 8.6.3, 8.7.3, 8.8.3, 8.13.3, 8.14.4, 8.15.4
Largetooth sawfish	Approved Conservation Advice for *Pristis pristis* (largetooth sawfish) (Ref. 27)	No explicit relevant objectives	Habitat degradation/ modification	Implement measures to reduce adverse impacts of habitat degradation and/or modification	8.1.3, 8.6.3, 8.7.3, 8.8.3, 8.13.3, 8.14.4, 8.15.4

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
			Marine debris	No explicit relevant management actions: marine debris identified as a threat.	8.12.3
Green sawfish	Approved Conservation Advice for Green Sawfish (Ref. 28)	No explicit relevant objectives	N/A	N/A	N/A
Grey nurse shark	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29)	The overarching objective of this recovery plan is to assist the recovery of the grey nurse shark in the wild with a view to: • improving the population status • ensuring that anthropogenic activities do not hinder the recovery of the grey nurse shark. The specific relevant objective of the recovery plan is: Continue to identify and protect habitat critical to the survival of the Grey Nurse Shark and reduce the impact of threatening processes within these areas.	Habitat modification	Review the level and spatial extent of protection measures at key aggregation sites to ensure appropriate levels of protection, and a consistent approach to the designation and implementation of protective measures, are applied. Use Biologically Important Areas (BIA) to help inform the development of appropriate conservation measures, including through the application of advice in the marine bioregional plans on the types of actions which are likely to have a significant impact on the species and updating such conservation measures as new information becomes available.	8.1.3, 8.6.3, 8.7.3, 8.8.3
			Pollution	No explicit relevant management actions: pollution identified as a threat.	8.13.3, 8.14.4, 8.15.4
Whale shark	Conservation Advice *Rhincodon typus* (whale shark) (Ref. 30)	No explicit relevant objectives	Habitat modification	No explicit relevant management actions: habitat modification identified as a threat.	8.1.3, 8.4.3, 8.5.4, 8.6.3, 8.7.3, 8.8.3, 8.13.3, 8.14.4, 8.15.4

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
			Marine debris	No explicit relevant management actions: marine debris identified as a threat.	8.12.3
			Vessel strike	Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations.	0
White shark	Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 31)	The overarching objective is to assist the recovery of the white shark in the wild throughout its range with a view to: • improving the population status leading to future removal of the white shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder recovery in the near future or impact the conservation status of the species in the future. The relevant specific objective of the recovery plan is: Objective 7: Continue to identify and protect habitat critical to the survival of the white shark and minimise the impact of threatening processes within these areas	Habitat modification	No explicit relevant management actions	8.6.3, 8.7.3, 8.8.3, 8.13.3, 8.14.4, 8.15.4
Blind cave eel	Conservation Advice for *Ophisternon candidum* (Blind Cave Eel) (Ref. 32)	No explicit relevant objectives	N/A	N/A	N/A
Cape range cave gudgeon, blind gudgeon	Conservation Advice for *Milyeringa veritas* (Blind Gudgeon) (Ref. 33)	No explicit relevant objectives	Diffuse pollution	No explicit relevant management actions	8.6.3, 8.7.3, 8.8.3
Seabirds and shorebirds					

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
All seabirds and shorebirds	National Light Pollution Guidelines for Wildlife (Ref. 34)	The aim of the Guidelines is that artificial light will be managed so wildlife is: • not disrupted within, nor displaced from, important habitat • able to undertake critical behaviours such as foraging, reproduction and dispersal.	Light Pollution	The Guidelines recommend: • best-practice lighting design to reduce light pollution and minimise the effect on wildlife • undertaking an environmental impact assessment for effects of artificial light on listed species for which artificial light has been demonstrated to affect behaviour, survivorship, or reproduction.	8.4.3
Seabirds	Wildlife Conservation Plan for Seabirds (Ref. 35)	Seabirds and their habitats are identified, protected and managed in Australia	Pollution	Enhance contingency plans to prevent and/or respond to environmental emergencies that have an impact on seabirds and their habitats.	8.4.3, 8.12.3, 8.14.4, 8.15.4
			Resource extraction	Ensure all areas of important habitat for seabirds are considered appropriately and consistently in the development assessment process.	0
Migratory shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 36)	Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	Artificial light	Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes.	8.4.3
			Habitat modification	No explicit relevant management actions	8.11.3, 8.14.4, 8.15.4
Threatened Albatross and Petrel species	National Recovery Plan for Albatrosses and Petrels (Ref. 37)	Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced.	Marine pollution, contamination, and debris	Risk based response strategies for marine pollution incidents are developed. Where appropriate monitoring of breeding colonies includes an assessment of marine debris, plastics and marine pollution impacts	8.12.3, 8.14.4, 8.15.4

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
				including the incidence of oiled birds at nest	
			Interactions with offshore installations and ships, including artificial light	No explicit relevant management actions	8.4.3, 0
Abbott's booby	Conservation Advice for the Abbott's Booby (*Papasula abbotti*) (Ref. 38)	No explicit relevant objectives	Marine debris	No explicit relevant management actions: marine debris recognised as a threat.	8.12.3
Asian dowitcher	Conservation Advice for *Limnodromus semipalmatus* (Asian dowitcher) (Ref. 39)	No explicit relevant objectives	Acute pollution	No explicit relevant management actions: oil pollution recognised as a threat.	8.14.4, 8.15.4
Australian fairy tern	Conservation Advice for Sternula nereis nereis (Fairy Tern) (Ref. 40)	No explicit relevant objectives	Oil spills	Ensure appropriate oil spill contingency plans are in place for the subspecies' breeding sites that are vulnerable to oil spills.	8.14.4, 8.15.4
	National Recovery Plan for (*Sternula nereis nereis*) (Australian Fairy Tern) (Ref. 41)	No explicit relevant objectives	Pollution	No explicit management actions: pollution recognised as a threat.	8.14.4, 8.15.4
Australian painted snipe	Conservation Advice for *Rostratula australis* (Australian Painted Snipe) (Ref. 42)	No explicit relevant objectives	N/A	N/A	N/A
Christmas Island white-tailed tropicbird, golden bosunbird	Conservation Advice *Phaethon lepturus fulvus* white-tailed tropicbird (Christmas Island) (Ref. 43)	No explicit relevant objectives	N/A	N/A	N/A

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
Common greenshank, greenshank	Conservation Advice for *Tringa nebularia* (Common Greenshank) (Ref. 44)	Minimise further loss of habitat critical to the survival of common greenshank throughout Australia.	Acute Pollution	No explicit relevant management actions: oil pollution recognised as a threat.	8.14.4, 8.15.4
Curlew sandpiper	Conservation Advice for *Calidris ferruginea* (Curlew Sandpiper) (Ref. 45)	No explicit relevant objectives	Habitat loss and degradation from pollution	No explicit relevant management actions: oil pollution recognised as a threat.	8.14.4, 8.15.4
Eastern curlew	Conservation Advice for *Numenius madagascariensis* (Far Eastern Curlew) (Ref. 46)	Minimise further loss of habitat critical to the survival of far eastern curlew throughout Australia.	Acute Pollution	No explicit relevant management actions: oil pollution recognised as a threat.	8.14.4, 8.15.4
Greater sand plover	Conservation Advice for *Charadrius leschenaultia* (Greater Sand Plover) (Ref. 47)	Minimise further loss of habitat critical to the survival of greater sand plover throughout Australia.	Acute Pollution	No explicit relevant management actions: oil pollution recognised as a threat.	8.14.4, 8.15.4
Grey falcon	Conservation Advice (*Falco hypoleucos*) Grey Falcon (Ref. 48)	No explicit relevant objectives	N/A	N/A	N/A
Night parrot	Conservation Advice *Pezoporus occidentalis* (night parrot) (Ref. 49)	No explicit relevant objectives	N/A	N/A	N/A
Northern Siberian bar-tailed godwit, Russkoye bartailed godwit	Conservation Advice for *Limosa lapponica menzbieri* (Yakutian bar-tailed Godwit) (Ref. 50)	Minimise further loss of habitat critical to the survival of Yakutian bar-tailed godwit throughout Australia	Acute Pollution	No explicit relevant management actions: oil pollution recognised as a threat.	8.14.4, 8.15.4
Red goshawk	Conservation Advice for *Erythrotriorchis radiatus* (red goshawk) (Ref. 51)	No explicit relevant objectives	N/A	N/A	N/A

Species	Management plan / Recovery plan / Conservation advice	Relevant objectives	Relevant key threats identified	Relevant conservation actions	OPP section
Red knot	Conservation Advice for *Calidris canutus* (Red Knot) (Ref. 52)	Minimise further loss of habitat critical to the survival of red knot throughout Australia	Acute pollution	No explicit relevant management actions: oil pollution recognised as a threat.	8.14.4, 8.15.4
Red-tailed Tropicbird	Conservation Advice for *Phaethon rubricauda westralis* (Indian Ocean red-tailed tropicbird) (Ref. 53)	No explicit relevant objectives	N/A	N/A	N/A
Sharp-tailed sandpiper	Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper) (Ref. 54)	Minimise further loss of habitat critical to the survival of the sharp-tailed sandpiper throughout Australia.	Acute Pollution	No explicit relevant management actions: oil pollution recognised as a threat.	8.14.4, 8.15.4
Shy albatross	Conservation Advice *Thalassarche cauta* (Shy Albatross) (Ref. 55)	Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced.	Marine Pollution	Where feasible, population monitoring programmes also monitor, in a standardised manner, the incidence of oiled birds at the nest, marine debris egestion / entanglement at the nests, and eggshell thinning.	8.14.4, 8.15.4
Soft-plumaged petrel	Conservation Advice for *Pterodroma mollis* (Soft-plumaged Petrel) (Ref. 56)	No explicit relevant objectives	N/A	N/A	N/A
White-winged fairy wren (Barrow Island), Barrow Island Black-and-white Fairy-wren	Approved Conservation Advice for *Malurus leucopterus edouardi* (White-winged Fairy-wren (Barrow Island) (Ref. 57)	No explicit relevant objectives	N/A	N/A	N/A

2.1.2.2 Australian Marine Parks

Under the EPBC Act, Australian Marine Parks (AMPs) are recognised for the purpose of conserving marine habitats and the species that live and rely on these habitats. Details of AMPs relevant to the Development are included in Section 6.

2.1.3 Additional relevant Commonwealth legislation

Table 2-3 summarises other Commonwealth legislation (additional to the OPGGS Act and EPBC Act) that is relevant to the environmental management of the Development.

Note: This is not a comprehensive list of legislation relevant to the Development, but a list of legislation relevant to impact assessment and proposed control measures.

Table 2-3: Relevant Commonwealth legislation

Legislation	Scope	Application to activities under the OPGGS(E)R
Australian Maritime Safety Authority Act 1990	This Act aims to: • promote maritime safety • protect the marine environment from: – pollution from ships – other environmental damage caused by shipping • provide for a national search and rescue service. The authority responsible for applying the Act is the Australian Maritime Safety Authority (AMSA).	This Act applies to offshore petroleum activities that have the potential to affect maritime safety and/or result in environmental damage, including pollution associated with operating vessels and oil spills from vessels during petroleum activities.
Biosecurity Act 2015 Biosecurity Regulations 2016	This Act defines ‘quarantine’ and is administered by Department of Agriculture, Fisheries and Forestry (DAFF). The Act aims to monitor, control, and respond to pests and diseases within Australia and its waters. The Maritime Arrivals Reporting System facilitates the collection of documentation required under the Act.	This Act regulates the condition of vessels and drilling rigs entering Australian waters with regard to ballast water and hull fouling. Obligations under the Act are set out in Australian Ballast Water Management Requirements (Ref. 58) and Australian Biofouling Management Requirements (Ref. 59). This Act also manages biosecurity risks in relation to goods that are brought into Australian territory from outside Australian territory.
Climate Change Act 2022	This Act sets out Australia’s GHG emissions reduction targets in a manner consistent with the Paris Agreement and Australia’s Nationally Determined Contribution (NDC) under the Paris Agreement. Australia’s GHG emissions reduction targets are as follows: • Reduce net GHG emissions to 43% below 2005 levels by 2030 which is implemented as a point target as well as an emissions budget covering the period 2021-2030.	The emissions targets established by this Act are inclusive of offshore petroleum activities.

Legislation	Scope	Application to activities under the OPGGS(E)R
	• Reduce Australia's net GHG emissions to zero by 2050.	
Environment Protection (Sea Dumping) Act 1981	This Act aims to minimise pollution threats by prohibiting ocean disposal of waste considered too harmful to be released in the marine environment and regulating permitted waste disposal to ensure environmental impacts are minimised. This Act also fulfils Australia's international obligations under the London Protocol to prevent marine pollution.	This Act regulates the disposal of hazardous waste from installations and operational vessels associated with the Development. Sea dumping activities will be undertaken in accordance with the Act and under permit as required.
Environment Protection and Biodiversity Conservation Regulations 2000: 8.1	These regulations provide guidance for operating aircraft and vessels in the vicinity of cetaceans.	All aircraft and vessels are required to operate at prescribed distances from cetaceans, as detailed in the Australian National Guidelines for Whale and Dolphin Watching (Ref. 60)
National Greenhouse and Energy Reporting Act 2007 (NGER Act) *National Greenhouse and Energy Reporting (Measurement) Determination 2008* *National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 (Safeguard Rule)* *Carbon Credits (Carbon Farming Initiative) Rule 2015* *Australian National Registry of Emissions Units Regulations 2011*	This Act provides for a single national framework for reporting and disseminating company information about GHG emissions, energy production and energy consumption. The Commonwealth Government's Safeguard Mechanism places a legislated obligation on Australia's GHG emitters with facilities that emit over 100,000 t CO_2-e per year to keep net emissions below their emissions limit (or baseline). The Australian Government's Safeguard Mechanism (Crediting) Amendment Bill 2023 (Safeguard Mechanism reforms) has been passed by Parliament and is in effect. The emissions reductions established under the Safeguard Mechanism are designed to deliver emissions reductions consistent with Australia's Nationally Determined Contribution under the Paris Agreement (Ref. 61).	Activities associated with the Development will result in the generation of atmospheric emissions and GHGs. Requirements of the Act must be adhered to, including energy and greenhouse gas reporting. Offshore petroleum activities that trigger the 100,000 tonnes per annum CO_2-e Safeguard Mechanism threshold will need to comply with the net emissions targets or baselines, and new gas fields, as defined under the Safeguard Rule will be assigned an emissions intensity of zero.
Navigation Act 2012	This Act regulates international ship and seafarer safety and also applies to protection of the marine environment from shipping and the actions of seafarers within Australian waters. In addition, the Navigation Act also gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). The Act regulates: • vessel crew • vessel survey and certification • occupational health and safety	All ships associated with petroleum activities within Australian waters must comply with the requirements under the Navigation Act. Marine orders that relate to petroleum activities include: • Marine Order 21: Safety and emergency arrangements • Marine Order 27: Safety of navigation and radio equipment • Marine Order 28: Operations standards and procedures • Marine Order 30: Prevention of collisions

Legislation	Scope	Application to activities under the OPGGS(E)R
	• passengers • personnel qualifications and welfare • vessel construction standards • handling of cargoes • marine pollution prevention • monitoring and enforcement activities.	• Marine Order 47: Offshore industry units • Marine Order 60: Floating offshore facilities • Marine Order 71: Masters and deck officers.
Offshore Petroleum and Greenhouse Gas Storage (Regulatory Levies) Act 2003 *Offshore Petroleum and Greenhouse Gas Storage (Regulatory Levies) Regulations 2004*	This Act imposes levies relating to the regulation of offshore petroleum activities and GHG storage activities.	This Act will apply to CAPL as a licence holder and operator.
Ozone Protection and Synthetic Greenhouse Gas Management Act 1989	This Act aims to control and reduce the manufacturing, import and export of synthetic GHGs and substances that deplete the ozone layer.	This Act will apply to CAPL if the company manufactures, imports, or exports these kinds of substances.
Protection of the Sea (Harmful Antifouling Systems) Act 2006	This Act aims to protect the marine environment from the effects of harmful antifouling systems. Under the Act, the negligent application of a harmful antifouling compound to a ship by a person or persons is an offence. The Act also requires that all Australian ships that meet specific criteria must hold 'antifouling certificates'.	Ships involved with offshore petroleum activities within Australian waters must comply with the requirements under this Act.
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	This Act aims to protect the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution. It also invokes certain requirements of the MARPOL Convention including those relating to discharge of noxious liquid substances, sewage, garbage, and air pollution. This Act requires ships >400 gross tonnes to have in place pollution emergency plans, and also provides for emergency discharges from ships. Includes the requirement for an approved Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (or equivalent, according to class) that describes emergency response activities.	Ships involved with petroleum activities within Australian waters are required to comply with the requirements under this Act. Numerous marine orders are enacted under this Act that relate to offshore petroleum activities, including: • Marine Order Part 91: Marine Pollution Prevention – Oil • Marine Order Part 93: Marine Pollution Prevention – Noxious Liquid Substances • Marine Order Part 94: Marine Pollution Prevention – Harmful Substances in Packaged Forms • Marine Order Part 95: Marine Pollution Prevention – Garbage • Marine Order Part 96: Marine Pollution Prevention – Sewage • Marine Order Part 97: Marine Pollution Prevention – Air Pollution • Marine Order Part 98: Marine Pollution Prevention – Anti-fouling Systems.

Legislation	Scope	Application to activities under the OPGGS(E)R
Underwater Cultural Heritage Act 2018 (UCH Act)	This Act protects the heritage values of shipwrecks, sunken aircraft, and relics (>75 years old) in Australian Commonwealth waters from the low water mark to the outer edge of the continental shelf (excluding the State's internal waterways). The Act allows for protection through the designation of protection zones. Activities and conduct prohibited within each zone will be specified.	This Act requires that protected cultural heritage sites are identified and any impacts and risks to these sites are assessed.

2.2 Relevant policies and guidelines

Table 2-4 summarises Commonwealth and international policies and guidelines that are relevant to the Development.

Table 2-4: Relevant Commonwealth and international policies and guidelines

Policy/guideline	Purpose	Relevance to the Development
Acoustic impact evaluation and management (Ref. 62)	Advice to titleholders to assist with preparing EPs for marine seismic survey activities, and in particular the components of an EP that relate to detailing, evaluating, and managing impacts from acoustic emissions.	Advice regarding noise modelling and impact assessment.
American Petroleum Institute (API) Compendium of GHG Emissions Methodologies (Ref. 63)	Provide methods, criteria, and measurement standards for calculating GHG emissions and energy data under the *National Greenhouse and Energy Reporting Act 2007* (NGER Act).	Used to calculate GHG emissions for the Development.
Antifouling and In-water Cleaning Guidelines (Ref. 64)	Provides best-practice approaches to applying, maintaining, removing, and disposing of antifouling coatings and managing biofouling and invasive aquatic species on vessels and movable structures in Australia and New Zealand.	Guidance for evaluation of contamination and biosecurity risk of in-water cleaning; and for in-water cleaning, including suitable coatings, coating service life, methods to ensure minimal release of biological material into the water, and appropriate disposal of collected cleaning debris.
API Recommended Practice 14G: Recommended Practice for Fire Prevention and Control on Open Type Offshore Production Platforms	Presents recommendations for minimising the likelihood of having an accidental fire, and for designing, inspecting, and maintaining fire control systems on fixed open-type offshore production platforms.	Describes safe handling and storage of materials such as dirty rags, garbage, waste oil, and chemicals.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018 (Ref. 65)	Aims to achieve the sustainable use of water resources by protecting and enhancing their quality while maintaining economic and social development.	Provides guideline values for assessing ambient water quality and monitoring.
Australian Ballast Water Management Requirements 2017 (Ref. 58)	Provides guidance on how vessel operators should manage ballast water when operating within Australian waters in order to comply with the *Biosecurity Act 2015*. These requirements also align with the International Convention for the Control and Management of Ships'	All vessels and installations are required to manage their ballast water and sediments in accordance with the Convention and *Biosecurity Act 2015*.

Policy/guideline	Purpose	Relevance to the Development
	Ballast Water and Sediments 2004 (the Ballast Water Management Convention).	
Australian Biofouling Management Requirements (Ref. 59)	Sets out vessel operator obligations for the management of biofouling when operating vessels under biosecurity control within Australian territorial seas.	Biofouling management for vessels, including pre-arrival reporting, and having biofouling management plans.
Australian Offshore Petroleum Development Policy	Encourages ongoing investment in, and development of, Australia's offshore petroleum (oil and gas) resources.	CAPL has an obligation to explore and develop petroleum reserves within its held titles.
Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector (United Nations Economic Commission for Europe 2019)	Provides guidance for developing and implementing effective practices for monitoring, reporting and verifying methane emissions from the oil and gas sector. It also provides guidance on remediation practices.	Used as guidance for energy efficiency and fugitive emissions management in the Gorgon Greenhouse Gas Management Plan (GHGMP) (Ref. 66).
EPBC Act Policy Statement 2.1 Interaction between offshore seismic exploration and whales	Provides practical standards to minimise the risk of acoustic injury to whales in the vicinity of seismic survey operations and provides a framework that minimises the risk of biological consequences from acoustic disturbance from seismic survey sources to whales in biologically important habitat areas or during critical behaviours.	Provides a framework for minimising acoustic and seismic disturbances to whales.
EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing, and mitigating impacts on EPBC Act listed migratory shorebird species	The purpose of this policy statement is to assist proponents in avoiding, assessing, and mitigating significant impacts on migratory shorebirds listed under the EPBC Act. This policy statement is a key action under the Wildlife Conservation Plan for Migratory Shorebirds (Ref. 67)	Provides guidance for identifying important habitat and significant impacts to migratory shorebirds or their habitat.
Guidelines for working in the near and offshore environment to protect Underwater Cultural Heritage DRAFT (Ref. 68)	Provides guidance on identifying, assessing, and protecting underwater cultural heritage. Includes guidance on how proponents can comply with the *Underwater Cultural Heritage Act 2018*.	Used as guidance in stakeholder consultation and the description of the existing environment.
Identifying and Evaluating Opportunities for Greenhouse Gas Mitigation & Operational Efficiency Improvement at Oil & Gas Facilities (Ref. 69)	Provides guidance on a pragmatic, integrated approach to identifying, evaluating, and advancing cost-effective, high-impact opportunities to manage GHG emissions and energy use at oil and natural gas facilities.	Used as guidance for energy efficiency and fugitive emissions management in the GHGMP (Ref. 66).
International Maritime Organization (IMO) Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (Biofouling Guidelines) (Ref. 70)	Guidelines for controlling and managing ships' biofouling to minimise the transfer of invasive aquatic species.	Specific requirements are that vessels have a biofouling management plan and biofouling record book.
ISO 50001 Energy Management Systems (Ref. 71)	ISO 50001 provides a framework of requirements for organisations to: • develop a policy for more efficient use of energy	Used as the basis for the GHG management system for the GHGMP (Ref. 66).

Policy/guideline	Purpose	Relevance to the Development
	• fix targets and objectives to meet the policy • use data to better understand and make decisions about energy use • measure the results • review how well the policy works • continually improve energy management.	
Marine Bioregional Plans	Designed to improve decisions made under the EPBC Act, particularly in relation to protecting marine biodiversity and the sustainable use of oceans and their resources by marine-based industries.	The plans provide information on the Australian Government's marine environment protection and biodiversity conservation responsibilities, objectives, and priorities in the 4 marine regions.
Matters of National Environmental Significance – Significant Impact Guidelines 1.1 (Ref. 72)	Provides overarching guidance on determining whether an action is likely to have a significant impact on a matter protected under national environment law—the EPBC Act.	Impacts and risks of the petroleum activity can be demonstrated to be at an acceptable level if they do not result in a 'significant impact' as described in these guidelines.
National biofouling management guidelines for the petroleum production and exploration industry (Ref. 73)	A voluntary biofouling management guidance document that has been developed to assist industry manage biofouling risk.	Guidance for evaluating the biofouling risk of types of structures and facilities; and on biofouling management and decommissioning. Used as guidance for CAPL's Quarantine Procedure Marine Vessels (Ref. 74).
National Light Pollution Guidelines for Wildlife, including Marine Turtles, Seabirds and Migratory Shorebirds (Ref. 75)	Aims to raise awareness of the potential impacts of artificial light on wildlife and provide a framework for assessing and managing these impacts around susceptible listed wildlife.	Includes requirements for impact assessment, best-practice lighting design and an artificial light management plan.
National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Ref. 14)	Provides guidance on understanding and reducing the risk of vessel collisions and the impacts they may have on marine megafauna.	Guidance to determine risks of vessel strike and identify mitigation measures.
NGER (Measurement) Determination 2008 (as amended)	Provide methods, criteria, and measurement standards for calculating GHG emissions and energy data under the NGER Act.	Used to calculate GHG emissions for the Development.
Offshore Petroleum Decommissioning Guideline (Ref. 76)	Clarifies the application, operation, and interaction between components of the Commonwealth regime for decommissioning offshore petroleum infrastructure in Commonwealth waters under the OPGGS Act, associated regulations and, where applicable, other Commonwealth laws.	Completely removing infrastructure and plugging and abandoning wells is the default decommissioning requirement. Options other than complete removal may be considered; however, the alternative decommissioning approach must deliver equal or better environmental, safety and well integrity outcomes compared to complete removal.
Offshore project proposal content requirements Guidance Note (Ref. 11)	Reflects NOPSEMA's interpretation of the content requirements of the OPGGS€R to support proponents in the preparation of OPPs.	This OPP has been developed to meet the requirements described.

Policy/guideline	Purpose	Relevance to the Development
Petroleum activities and Australian Marine Parks Guidance Note (Ref. 77)	Supports understanding of titleholder obligations regarding AMPs and consultation with the Director of National Parks (DNP).	Used to inform consultation with the DNP.
Planning for proactive decommissioning Information Paper (Ref. 78)	Encourages titleholders to commence planning for commissioning at the earliest stage of project development.	Provides information on the level of detail required in an OPP.
Reducing marine pest biosecurity risks through good practice biofouling management Information Paper (Ref. 79)	Clarifies biosecurity requirements relevant to offshore activities. Supports the industry's contribution to marine pest risk management consistent with Australia's MarinePestPlan 2018–2023 (Ref. 80).	Provides guidance that is consistent with the expectations of all jurisdictions responsible for regulating biofouling management within the Australian marine environment. Used as guidance for CAPL's Quarantine Procedure Marine Vessels (Ref. 74)
Section 572 Maintenance and removal of property Policy (Ref. 81)	Sets out NOPSEMA's compliance and enforcement of section 572 of the OPGGS Act, which requires titleholders to: • maintain all structures, equipment, and property in a title area in good condition and repair • remove all structures, equipment, and property when it is neither used nor to be used in connection with operations authorised by the title.	Guidance for decommissioning property at end of Development life.

2.3 Western Australian legislation

Table 2-5 summarises Western Australian legislation that is relevant to the environmental management of the Development. Although the Development occurs in Commonwealth waters, some State legislation is relevant to the primary approvals of the Gorgon Gas Development or to risk assessment of defined EMBAs.

Table 2-5: Relevant State legislation

Legislation	Scope/Purpose	Application to the Development
Biodiversity Conservation Act 2016	This Act provides a legislative framework for listing native species and ecological communities identified as under threat of extinction or collapse. The Act is administered by the Department of Biodiversity, Conservation and Attractions (DBCA).	Species protected under the Act are present within the EMBAs.
Aboriginal Heritage Act 1972 (AHA) *Aboriginal Cultural Heritage Act 2021*(ACHA)	*Aboriginal Heritage Legislation Amendment and Repeal Bill 2023* The ACHA came into force on 1 July 2023. On 17 October 2023, WA Parliament passed the *Aboriginal Heritage Legislation and Repeal Bill 2023* which will repeal the ACHA and amend the AHA.	Sites protected under the Act overlap with the EMBAs.
Barrow Island Act 2003	This Act regulates CO_2 storage on Barrow Island.	The Gorgon Gas Development Area is defined under the Act.

Conservation and Land Management Act 1984 (CALM Act)	This Act regulates the use, protection and management of certain public lands and waters and the flora and fauns within them.	State protected areas proclaimed under the CALM Act overlap with the EMBAs. The Act allows hunting of marine fauna by Traditional Owners.
Environmental Protection Act 1986 (EP Act)	This Act aims to reduce pollution and environmental damage in WA.	The Act is relevant to the primary approvals for the Gorgon Gas Development and the environmental management programme for the 2-train Gorgon Gas Development.
Fish Resources Management Act 1994	This Act regulates fishing ad aquaculture in WA.	State-managed fisheries which are regulated under the Act overlap with the OA. The Act allows for customary fishing by Traditional Owners.

2.4 International agreements and conventions

The principal international agreement governing petroleum operations in Commonwealth waters is the United Nations Convention on the Law of the Sea, 1982. Australia is also a signatory to several international conventions of potential relevance to the Development, as listed in Table 2-6.

Table 2-6: Relevant international agreements and conventions

Agreement/convention	Purpose	Potential relevance to the Development
Agreement on the Conservation of Albatrosses and Petrels	Multilateral agreement that coordinates international activities to conserve albatross and petrel species and mitigate threats to these populations.	Advice on the conservation responsibilities regarding albatross and petrel species.
China Australian Migratory Birds Agreement (CAMBA)	Bilateral agreement between China and Australia to protect and conserve migratory birds that use the East Asian – Australasian Flyway and their important habitats.	Advice on the conservation responsibilities regarding bird species that may use the OA as a migratory flyway between China and Australia. The EPBC Act gives effect to CAMBA by listing migratory birds recognised by the agreement as migratory under the EPBC Act.
Convention Concerning the Protection of the World Cultural and Natural Heritage 1972	Designed to acknowledge and protect areas of cultural and natural heritage across the world.	Guidance around recognising protected areas and areas of cultural and natural heritage and mitigating any potential affects that the Development may have on them.
Convention of the Conservation of Antarctic Marine Living Resources 1979	Developed based on an increasing need to protect the Antarctic ecosystem and its marine species. Responsible for setting conservation measures that determine the use of marine resources in the Antarctic	Provides advice on conservation responsibilities regarding Antarctic species that may migrate to the OA
Convention on Biological Diversity 1993	Provides legal representation for the conservation of biodiversity, the sustainable use of its resources and the equal sharing of any advantages that result from the use of genetic resources.	Advice regarding conservation responsibilities that are relevant to the impact and risk assessment of the Development.

Agreement/convention	Purpose	Potential relevance to the Development
Convention on the International Maritime Organisation 1948	Designed to promote efficient and sustainable shipping through international cooperation that focuses on safe, secure, environmentally sound practices.	Advice on how to travel overseas efficiently and sustainably in relation to navigation, maritime safety and marine pollution.
Convention on the International Regulations for Preventing Collisions at Sea 1972 (COLREGS)	Designed to create consistent guidelines for vessels operating in the sea and the responsibilities of their staff, including the risk of collision, a safe speed of travel and traffic separation schemes in areas of high traffic.	Provides instruction on the rules of operating vessels at sea in order to ensure safe travel. The *Navigation Act 2012* and subsidiary Marine Orders give effect to the regulations.
Extractive Industries Transparency Initiative 2003	Designed to set a standard for quality governance and accountable management of oil, gas, and mineral resources.	Provides instruction on established principles for resource-extracting activities.
Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services 2012	Provides policymakers with access to scientific assessments on information surrounding Earth's biodiversity, ecosystems, and their benefits to humanity.	Advice regarding the biodiversity and ecosystem communities relevant to the OA.
International Convention for the Prevention of Pollution from Ships, London, 1973/1978 (commonly known as MARPOL 73/78)	Provides advice on preventing and minimising accidental pollution and pollution that results from routine operations.	Guidance on preventing all potential and planned marine pollution associated with the Development. The *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and subsidiary Marine Orders give effect to MARPOL 73/78.
International Convention on Civil Liability for Oil Pollution Damage,1969 and 1992 (CLC 69; CLC 92)	In the case of oil pollution damage resulting from maritime casualties involving oil-carrying ships, ensures adequate compensation is made for those affected.	Provides insight into the ship's liability in the case of a maritime casualty.
International Convention on Harmful Anti Fouling Systems 2001 (AFS Convention)	Designed to protect the marine environment by prohibiting or restricting the use of harmful antifouling systems on ships.	Guidance for evaluating a vessel's condition and the process of applying, maintaining, removing, and disposing of antifouling coatings as required. The *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* and subsidiary Marine Orders give effect to the Convention.
International Convention on the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention)	An environmental treaty that uses international coordination in the advocacy of conservation and sustainable use of migratory species, their habitats and migration routes.	Guidance on the conservation responsibilities regarding migratory species. The EPBC Act gives effect to the Bonn Convention through listing species as migratory under Part 3 of the Act.
International Convention on the Control and Management of Ship's Ballast Water and Sediment (Ballast Water Management Convention)	Adopted with aims to prevent the international spread of non-native marine species by creating standards and procedures for the regulation and control of ships' ballast water and sediments.	Guidance for managing ballast water to reduce the risk of transferring of invasive marine species. The *Biosecurity Act 2015* gives effect to the Convention.
International Convention on the Control of	Regulates the transboundary movements of hazardous waste to	Provides instruction on appropriate handling, export and disposal of

Agreement/convention	Purpose	Potential relevance to the Development
Transboundary Movements of Hazardous Wastes and their Disposal 1989 (Basel Convention)	ensure that they are managed and disposed of in an environmentally safe manner. There is expectation that parties will also minimise the waste created and transported.	hazardous waste. The *Hazardous Waste (Regulation of Exports and Imports) Act 1989* gives effect to the convention.
International Union for Conservation of Nature (IUCN) 1948 (non-binding)	Created in hopes of finding logical solutions to the world's most critical environment and development challenges. Provides knowledge and tools that allow communities, economies, and nature to work together.	Advice regarding conservation responsibilities and protected area categories relevant to the OA and environment that may be affected (EMBA).
Japan Australia Migratory Birds Agreement (JAMBA)	Bilateral agreement between Japan and Australia to protect and conserve migratory birds that use the East Asian – Australasian Flyway and their important habitats.	Guidance on the conservation responsibilities regarding bird species that may use the OA as a migratory flyway between Japan and Australia. The EPBC Act gives effect to JAMBA by listing migratory birds recognised by the agreement as migratory under the EPBC Act.
Kyoto Protocol 1997	Designed to have industrialised countries commit to implementing policies and measures that reduce and limit their GHG emissions.	Advice on the impacts and risks associated with GHGs and is used in evaluating GHG emissions.
Law of the Sea Forum: The 1994 Agreement on Implementation of the Seabed Provisions of the Convention on the Law of the Sea 1994	The International Seabed Authority was established under the 1982 United Nations Convention on the Law of the Sea and the 1994 Agreement relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea (1994 Agreement). It organises and controls all mineral- and resource-related activities in the deep seabed.	Provides instruction on mandates established for activities related to the deep seabed.
London Protocol and Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1996	Adopted to protect the marine environment from human activities and promote the effective control of all marine pollution.	Guidance on preventing marine pollution and disposing of waste from installations and operational vessels associated with the Development. The *Environment Protection (Sea Dumping) Act 1981* gives effect to the London Convention.
The Minamata Convention on Mercury	The convention calls on signatories to protect human and environmental health from anthropogenic releases of mercury. The Convention came into force on 16 August 2017 and was ratified in Australia on 7 December 2021.	Australia is a signatory to the Convention. The Convention covers control and reduction of mercury in a range of processes and industries and is relevant to end of field life aspects such as waste and contaminated sites.
Montreal Protocol on Substances that Deplete the Ozone Layer 1987	Designed to protect the ozone layer by phasing out the production and consumption of ozone depleting substances (ODS).	Guidance on the impacts and risks associated with ODSs and evaluating GHG emissions. The *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* gives effect to the protocol.
Paris Agreement 2016 under the United Nations	Objective is to limit the global temperature rise to 2 C while pursuing	Advice for evaluating risks and impacts associated with the activity in regard to climate change. The Australian

Agreement/convention	Purpose	Potential relevance to the Development
Framework Convention on Climate Change	efforts to limit it to 1.5 C in comparison to pre-industrial levels. Provide financial assistance to developing countries that will help them mitigate and adapt to the impacts of climate change.	Government is committed to developing legislation to implement the commitments made in the Paris Agreement.
The Republic of Korea Migratory Birds Agreement (ROKAMBA)	Bilateral agreement between the Republic of Korea and Australia to protect and conserve migratory birds that use the East Asian – Australasian Flyway and their important habitats.	Advice on the conservation responsibilities regarding bird species that may use the OA as a migratory flyway between the Republic of Korea and Australia. The EPBC Act gives effect to ROKAMBA by listing migratory birds recognised by the agreement as migratory under the EPBC Act.
Rotterdam Convention a multilateral treaty to promote shared responsibilities in relation to importation of hazardous chemicals	Adopted to promote informed decisions and shared responsibility with regard to trade in hazardous chemicals. Enables cooperation and information exchange between nations to protect human health and the environment.	Provides instruction on the responsible handling and transport of specific hazardous chemicals.
Stockholm Convention on Persistent Organic Pollutants 2001	Created to protect the environment and human health from the adverse effects of persistent organic pollutants. Requires parties to adopt control measures that aim to reduce and potentially eliminate their use.	Provides instruction on the responsible management of specific hazardous chemicals and methods to decrease or eliminate handling.
United Nations 2030 Agenda for Sustainable Development (2030 Agenda)	Created 17 sustainable development goals that protect the planet and improve quality of life globally.	Informs acceptability evaluation for potential impacts that extend outside Australia's jurisdiction.
United Nations Framework Convention on Climate Change 1992	Objective is to stabilise global GHG concentrations at a level that allows ecosystems to adapt naturally to a changing climate.	Advice on the impacts and risks associated with GHGs and evaluating GHG emissions.

3 Stakeholder consultation

CAPL is committed to building and maintaining relationships and conducting meaningful consultation with key stakeholders, including governments, traditional owners, and the communities where we operate. Stakeholder consultation is an integral aspect of the environmental impact assessment and CAPL's process in the development of this OPP.

As the proponent of the Development, CAPL will undertake a phased approach to stakeholder consultation throughout the lifecycle of environmental approvals:

- Phase 1—Early consultation with key stakeholders (including relevant Traditional Owners) undertaken during the preparation of the OPP
- Phase 2—Public consultation under NOPSEMA's public comment process
- Phase 3—Relevant Persons consultation during the preparation of EPs and on an ongoing basis after EP acceptance.

3.1 Phase 1—Early consultation with key stakeholders undertaken during the preparation of the OPP

3.1.1 Overview

This section provides a description of the methods used, and outcomes of CAPL's early consultation with key stakeholders during the preparation of this OPP.

While the OPGGS(E)R do not require proponents to undertake consultation before submitting an OPP, CAPL considers it best practice to conduct early consultation with key stakeholders to allow them the opportunity to provide feedback on the Development.

The main objectives of this phase of CAPL's consultation are to:

- provide stakeholders with information about the Development
- provide stakeholders with a point of contact for the Development
- allow stakeholders the opportunity to comment on the Development and raise any concerns they may have about potential impacts and risks to their interests, functions and activities
- inform stakeholders of the project timeframes and the mechanisms by which they can receive further updates or provide additional comment
- identify the social and cultural features of communities within the ecosystem
- inform the control measures to eliminate, reduce and mitigate impacts and risks to those socio-cultural values and sensitivities in response to stakeholder concerns.

Early consultation with stakeholders commenced in February 2023 with a regulator engagement workshop. Broader consultation with stakeholders commenced in June 2023 and built on the ongoing consultation and engagement that CAPL has in place for the region.

3.1.2 Key Stakeholder Identification

The consultation identification process was undertaken in accordance with CAPL's *Stakeholder Engagement and Issues Management Process: ABU Standardised OE Process* (Ref. 82) to ensure potentially interested and affected stakeholders were identified and afforded the opportunity to provide feedback, identify concerns or seek further information on the Development. The key stakeholder list was developed through the:

- review of CAPL's current stakeholder list from prior and ongoing consultation in the region
- review of legislation applicable to petroleum and marine activities to ensure administrative agencies are consulted
- review of fishery catch data from Department of Primary Industries and Regional Development (DPIRD) and Australian Fisheries Management Authority (AFMA) for fisheries that may potentially be impacted from the Development
- use of prior feedback from existing stakeholders
- identification of representative groups (including relevant Traditional Owners and Native Title holders) and bodies who were considered to have a function, interest, or activity within the geographical boundary of the Ecological and Socio-cultural Environment that May Be Affected (EMBA) (defined as outlined in Section 6.1) or which may otherwise be impacted by the identified Environmental and socio-economic aspects, risks and impacts (as shown in Section 8)
- use of support from Prescribed Body Corporates to identify and facilitate introductions to other stakeholders who may be interested or relevant for the purposes of consultation
- use of Western Australian Fishing Industry Council's (WAFIC) consultation service for Oil and Gas consultation for state commercial fishers in the Operational Area (OA) of the Development.

The list of key stakeholders identified from these sources is shown in Table 3-1. CAPL will continue to revise and update this key stakeholder list throughout the life of the Development.

Table 3-1: Key stakeholders for preliminary consultation during the preparation of the OPP

Key stakeholders	
Commonwealth Government	
Australian Communications and Media Authority	Department of Climate Change, Energy, the Environment and Water (DCCEEW) (formerly DAWE)
Australian Fisheries Management Authority (AFMA)	Department of Defence
Australian Institute of Marine Science (AIMS)	Department of Foreign Affairs and Trade (DFAT)
Australian Maritime Safety Authority (AMSA)	Department of Industry, Science and Resources (DISR)
Australian Marine Oil Spill Response Centre	Director of National Parks (DNP)
Australian Hydrographic Office (AHO)	National Offshore Petroleum Titles Administrator (NOPTA)
Clean Energy Regulator	Parks Australia
Department of Agriculture, Fisheries and Forestry (DAFF) (formerly DAWE)	

Key stakeholders	
State Government	
Department of Biodiversity, Conservation and Attractions (DBCA)	Exmouth Gulf Task Force
Department of Jobs, Tourism, Science and Innovation	Gascoyne Development Commission
Department of Mines, Industry Regulation and Safety (DMIRS)	Minister for Environment
Department of Parks and Wildlife	Ningaloo Coast World Heritage Advisory Committee
Department of Primary Industries and Regional Development (DPIRD)	Pilbara Development Commission
Department of Transport (DoT) • Maritime Environmental Emergency Response (MEER) – Marine Pollution (formerly OSRC Unit) • Navigational Safety	Pilbara Ports Authority
Department of Water and Environmental Regulation (DWER)	Shark Bay World Heritage Committee
Environment Protection Authority (EPA)	Western Australia Museum
Commonwealth and State Commercial Fisheries	
Abalone Council Australia	Pearl Producers Association
Aquaculture Council of Western Australia	Recfishwest
Australian Council of Prawn Fisheries	Shark Bay Prawn Trawler Operators Association
Commonwealth Fisheries Association	Western Australian Fishing Industry Council (WAFIC)
Maxima Pearling Company	Western Rock Lobster Council
Northern Prawn Fishery	
Industry	
BP	PGS Australia Pty Ltd
Carnarvon Energy	Santos
Eni Australia	SapuraOMV Upstream
Exxon Mobil	TGS NOPEC Geophysical Company Pty Ltd
Jadestone Energy	Vermilion Oil & Gas
Kufpec	Vocus Communications
Pathfinder Energy	Woodside
Traditional Owners, Local Community and eNGOs	
Mardathoonera Cultural Heritage Pty Ltd	Murujuga Aboriginal Corporation
Australian Conservation Foundation	Nganhurra Thanardi Garrbu Aboriginal Corporation
Australian Marine Conservation Society	Ngarluma Aboriginal Corporation
Baiyungu Aboriginal Corporation	Ngarluma Yindjibarndi Foundation Ltd
Buurabalayji Thalanyji Aboriginal Corporation	Oil Spill Response Limited
Cape Conservation Group	Onslow Chamber of Commerce and Industry
Care for Hedland Environmental Association	Protect Ningaloo

Key stakeholders	
Carnarvon Chamber of Commerce	Robe River Kurama Aboriginal Corporation
Centre for Whale Research Western Australia	Shire of Ashburton (Pilbara)
City of Karratha (Pilbara)	Shire of Carnarvon (Gascoyne)
Conservation Council of Western Australia	Shire of Exmouth (Gascoyne)
Coral Bay Progress Association	Shire of Shark Bay
Coral Futures Corporation	Town of Port Hedland (Pilbara)
Exmouth Chamber of Commerce and Industry	WA Coastal and Marine Community Network
Greenpeace	WA Marine Science Institute
Kariyarra Aboriginal Corporation	Whale and Dolphin Conservation Society
Karratha & Districts Chamber of Commerce and Industry	Wilderness Island
Mackerel Islands & Onslow Beach Resort	Wirrawandi Aboriginal Corporation
Malgana Aboriginal Corporation	Yinggarda Aboriginal Corporation

3.1.3 Phase 1 Consultation Activities

The following was undertaken as part of the Phase 1 early consultation activities:

- Contact details for each of the identified stakeholders were confirmed via email and prior engagements.
- Information was provided in writing (via email) including details of the Development, planned activities, location and water depth, schedule and duration, the approval process, the Environment that May Be Affected and a summary of the impacts and risks and key proposed control measures.
- A dedicated page on CAPL's website, australia.chevron.com, was published, including details of the Development, planned activities, location and water depth, schedule and duration, the approval process, the Environment that May Be Affected, multiple points of contact to provide feedback or request additional information, and a summary of the impacts and risks and key proposed control measures.
- Multiple avenues for feedback were provided, including via the website, a tollfree number, and direct reply to a CAPL email address. The avenues to submit feedback were outlined within the email correspondence to identified stakeholders and on the dedicated page on CAPL's website.
- Additional customised consultation interactions were facilitated on a case by case basis, including:
  - a briefing and engagement session designed and held for state and federal regulators
  - engagement via face-to-face meetings, phone calls and emails with Traditional Owner groups as part of ongoing consultation for broader CAPL projects.

A summary of early consultation interactions undertaken with Key Stakeholders in the preparation of the OPP is provided in Table 3-2. Where previous consultation has raised matters that CAPL considers may be relevant to the OPP, these have been included in the table.

Table 3-2: Summary of key stakeholder interactions from early consultation

Stakeholder	Early consultation period	Summary	Section of OPP
Department of Climate Change, Energy, the Environment and Water (DCCEEW) (Cth) Department of Foreign Affairs and Trade (DFAT) (Cth) Department of Mines Industry Regulation and Safety (DMIRS) (WA) Department of Jobs, Technology, Science and Innovation (WA) Parks Australia (Cth)	Feb 2023 Regulator engagement workshop	CAPL introduced the Gorgon Gas Development: Backfill Fields OPP and provided information on key components of the Development. The following stakeholders were invited to the workshop but were not in attendance: AFMA, AIMS, AMSA, DNP, DAFF (Cth), Department of Defence (Cth), DoT (WA), DWER (WA), Department of Jobs, Tourism, Science and Innovation (WA), DBCA (WA), Department of Parks and Wildlife (WA), DPIRD: Fisheries (WA), EPA (WA), Pilbara Ports Authority.	No change required to OPP.
Abalone Council Australia	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Abalone Council Australia to consult on the Development.	No change required to OPP.
Mardathoonera cultural Heritage Pty Ltd (MCH)	August 2023 – November 2023	CAPL engaged with MCH as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a factsheet of the Gorgon Gas Development: Backfill Fields OPP and invited MCH to consult on the Development. MCH raised the significance and importance of Barrow Island, and that they held concerns regarding impacts to stories of cultural significance. MCH raised concerns regarding compliance with the Paris Agreement and energy transition. MCH and CAPL agreed to work together to design how they consult on current and future activities. Consultation with this stakeholder is ongoing.	No change required to OPP (The Paris Agreement and energy transition are discussed in Section 8.3). Further consultation is ongoing.
Aquaculture Council of WA	June 2023	CAPL engaged Aquaculture Council of WA as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Aquaculture Council of WA to consult on the Development. Aquaculture Council of WA acknowledged receipt of email and advised that they had not received any feedback from potentially affected parties.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
Australian Communications and Media Authority (ACMA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited ACMA to consult on the Development. No feedback has been provided by ACMA regarding the proposed Development during early consultation.	No change required to OPP.
Australian Conservation Foundation (ACF)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited ACF to consult on the Development. No feedback has been provided by ACF regarding the proposed Development during early consultation.	No change required to OPP.
Australian Council of Prawn Fisheries (ACPF) Ltd.	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited ACPF to consult on the Development. No feedback has been provided by ACPF regarding the proposed Development during early consultation.	No change required to OPP.
Australian Fisheries Management Authority (AFMA)	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AFMA to consult on the Development. AFMA stated they had no specific concerns, but recommended CAPL engage with relevant fisheries operators. CAPL confirmed that relevant fisheries operators were being engaged.	CAPL engaged with the Abalone Council Australia, Australian Council of Prawn Fisheries, Maxima Pearling Company, Northern Prawn Fishery, Pearl Producers Association, Shark Bay Prawn Trawler Operators Association and Western Rock Lobster Council during early consultation (refer to entries in this table).
Australian Hydrographic Office (AHO)	June 2023	CAPL engaged AHO as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AHO to consult on the Development. No feedback has been provided by AHO regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
Australian Institute of Marine Science (AIMS)	June 2023	CAPL engaged AIMS as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AIMS to consult on the Development. No feedback has been provided by AIMS regarding the proposed Development during early consultation.	No change required to OPP.
Australian Marine Conservation Society (AMCS)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AMCS to consult on the Development. No feedback has been provided by AMCS regarding the proposed Development during early consultation.	No change required to OPP.
Australian Marine Oil Spill Response Centre (AMOSC)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AMOSC to consult on the Development. No feedback has been provided by AMOSC regarding the proposed Development during early consultation.	No change required to OPP.
Australian Maritime Safety Authority (AMSA)	June 2023	CAPL engaged AMSA as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited AMSA to consult on the Development. No feedback has been provided by AMSA regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following matters: • Requirement to mitigate risk of collision within charted shipping fairways • Requirement to provide notification to JRRC and AHO prior to activity commencement • Requirement to ensure lighting requirements comply with relevant regulations.	All notification and lighting requirements are commonplace and industry standard and have been applied. Sections 8.4.4 and 8.9.4 list the relevant control measures, including: CM20, CM21, CM33 CM34 and CM35. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Baiyungu Aboriginal Corporation (BAC)	June 2023 – August 2023	CAPL engaged BAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited BAC to consult on the Development.	CAPL engaged with DBCA and NTGAC during early consultation (refer to entries in this table).

Stakeholder	Early consultation period	Summary	Section of OPP
		BAC advised CAPL to engage with DBCA and NTGAC. BAC advised CAPL that they support CAPL's approach of continuing to engage with NTGAC and BAC, and the formalising of an engagement plan with NTGAC. The development of this plan is ongoing. There were no matters raised by BAC regarding the proposed Development during early consultation. Previous engagements with this stakeholder for other activities within the region identified the following values and sensitivities: • Protecting land and Sea Country is a significant focus of the BAC. • The Baiyungu coastal area, Sea Country, and adjacent islands are highly valuable to the Baiyungu people. Engagement with this stakeholder is ongoing.	The OPP was revised to include Table 6-14, which includes specific responses from Traditional Owner consultation regarding cultural values and features.
BP	June 2023	CAPL engaged BP as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited BP to consult on the Development. No feedback has been provided by BP regarding the proposed Development during early consultation.	No change required to OPP.
Buurabalayji Thalanyji Aboriginal Corporation (BTAC)	June 2023 – September 2023	CAPL engaged BTAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited BTAC to consult on the Development. There were no matters raised by BTAC regarding the proposed Development during early consultation. During previous and ongoing engagements, CAPL and BTAC collaborated to draft an engagement plan to facilitate meaningful engagement. BTAC and CAPL discussed ongoing consultation, relationship building and support opportunities. The development of this plan is ongoing. CAPL and BTAC will continue to engage as part of ongoing consultation. Previous engagements with this stakeholder for other activities within the region identified that the Thalanyji people have a deep connection to Sea Country north of Onslow, extending out into the islands off the coast of the Pilbara including the Montebello Islands, Barrow Island, and Mackerel Islands.	The OPP was revised to include Table 6-14, which includes specific responses from Traditional Owner consultation regarding cultural values and features.
Cape Conservation Group (CCG)	June 2023	CAPL engaged CCG as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CCG to consult on the Development.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
		No feedback has been provided by CCG regarding the proposed Development during early consultation.	
Care For Hedland Environmental Association (CFH)	June 2023 – July 2023	CAPL engaged CFH as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CFH to consult on the Development. CFH indicated that they did not have any specific concerns regarding the activities but advised that the flatback turtles that nest in Port Hedland have been genetically linked to Barrow Island and the North-west Shelf (NWS) flatback turtle population. CAPL provided CFH with information on the activity and controls to be implemented to reduce impacts and risks. CAPL also provided information on the Chevron Community Spirit Fund and turtle monitoring programs. CAPL advised if CFH has any further questions about CAPL activities they should make contact.	Threatened and/or migratory marine turtles with the potential to be present within the EMBA are discussed in Section 6.2.3.2 and are considered in risk assessment (Section 8)
Carnarvon Chamber of Commerce Inc. (CCCI)	June 2023	CAPL engaged CCCI as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CCCI to consult on the Development. No feedback has been provided by CCCI regarding the proposed Development during early consultation.	No change required to OPP.
Carnarvon Energy	June 2023	CAPL engaged Carnarvon Energy as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Carnarvon Energy to consult on the Development. No feedback has been provided by Carnarvon Energy regarding the proposed Development during early consultation.	No change required to OPP.
Centre for Whale Research Western Australia (CWR)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CWR to consult on the Development. No feedback has been provided by CWR regarding the proposed Development during early consultation.	No change required to OPP.
City of Karratha (Pilbara)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited the City of Karratha to consult on the Development. No feedback has been provided by the City of Karratha regarding the proposed Development during early consultation.	No change required to OPP.
Clean Energy Regulator (CER) (Cth)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CER to consult on the Development.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
		No feedback has been provided by CER regarding the proposed Development during early consultation.	
Commonwealth Fisheries Association (CFA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CFA to consult on the Development. No feedback has been provided by CFA regarding the proposed Development during early consultation.	No change required to OPP.
Conservation Council of WA (CCWA)	July 2023 – September 2023	CAPL engaged CCWA as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CCWA to consult on the Development. CCWA responded requesting further engagement. CAPL met with CCWA virtually. At the meeting CAPL and CCWA agreed that it was important to focus on opportunities for positive engagement and collaboration around data and research gaps. CCWA advised that they will respond with any further questions. CAPL continues to engage with CCWA regarding the Development.	No change required to OPP.
Coral Bay Progress Association (CBPA)	September 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited CBPA to consult on the Development. No feedback has been provided by CBPA regarding the proposed Development during early consultation.	No change required to OPP.
Coral Futures Corporation	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Coral Futures Corporation to consult on the Development. No feedback has been provided by Coral Futures Corporation regarding the proposed Development during early consultation. Previous engagements with this stakeholder for other activities within the region identified their desire to be notified in the event of an emergency as well as receive ongoing engagement.	No change required to OPP. Topics raised during previous engagement which are relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Department of Agriculture, Fisheries and Forestry - Fishing impacts (DAFF) (Cth)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DAFF to consult on the Development. No feedback has been provided by DAFF regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
Department of Biodiversity, Conservation and Attractions (DBCA) (WA)	June 2023 – July 2023	CAPL engaged DBCA as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DBCA to consult on the Development. DBCA provided a written response that identified: • ecologically important areas within the vicinity of proposed operations, including the Barrow Island Marine Park and the Barrow Island Nature Reserve • the requirement to establish appropriate baseline survey data on the current state of areas supporting important ecological values and any current contamination if present within the area of potential impact of hydrocarbon releases • requirements for emergency management including, recommendations for information acquisition to support a before - after, control impact (BACI) framework, notification requirement and clean up expectations in the event of an oil spill • the following guidance documents for CAPL to refer to: ▪ National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds ▪ Offshore Petroleum Industry Guidance Note of September 2018 titled Marine Oil Pollution: Response and Consultation Arrangements ▪ DoT web content regarding marine pollution requirements for consultation. CAPL responded to DBCA indicating that the values of ecologically important areas had been considered in the development of the OPP. CAPL also confirmed that spill response and monitoring requirements would be assessed and addressed in subsequent activity specific EPs.	Ecologically important areas which overlap with the EMBA, and available baseline data are discussed in the Description of the environment (Section 6). The National Light Pollution Guidelines (Ref. 75) are considered in Section 8.4 and CM21. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Department of Climate Change, Energy, the Environment and Water (DCCEEW) (Cth)	June 2023	CAPL engaged DCCEEW as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DCCEEW to consult on the Development. No feedback has been provided by DCCEEW regarding the proposed Development during early consultation. During previous engagements for other activities within the region this stakeholder provided feedback on underwater cultural heritage (UCH) including: • engaging a suitably qualified and experienced maritime or underwater archaeologist for advice on how to mitigate risks associated with protected UCH • recommending undertaking a desktop UCH Assessment to identify known and potential UCH	The OPP was revised to include Section 6.5.2 which details UCH within the EMBA. CAPL has been and continues to engage with Traditional Owners to identify UCH. Topics relevant to the EP phase will be addressed as part of

Stakeholder	Early consultation period	Summary	Section of OPP
		• identifying mitigation measures to adequately reduce the risk of and avoid impacts • advising that the UCH Act provides that the discovery of specified UCH must be notified • considering potential impacts to First Nations UCH and recommending engagement with First Nations Peoples.	Phase 3 of stakeholder consultation.
Department of Climate Change, Energy, the Environment and Water - Director of National Parks (DNP) (Cth)	June 2023	CAPL engaged DNP as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DNP to consult on the Development. No feedback has been provided by DNP regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following matters: • Regulation of petroleum activities within marine management and park areas • Presence of the Montebello Marine Park Multiple Use Zone (IUCN VI) which is managed under the North-west Marine Parks Network Management Plan 2018.	The requirements of the North-west Marine Parks Network Management Plan (Ref. 83) are considered in risk assessment (Section 8).
Department of Defence (DoD) (Cth)	June 2023 – September 2023	CAPL engaged DoD as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DoD to consult on the project. No feedback has been provided by DoD regarding the proposed Development during early consultation.	No change required to OPP.
Department of Foreign Affairs and Trade (DFAT) (Cth)	June 2023	CAPL engaged DFAT as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DFAT to consult on the project. No feedback has been provided by DFAT regarding the proposed Development during early consultation.	No change required to OPP.
Department of Industry, Science and Resources (DISR) (Cth)	June 2023	CAPL engaged DISR as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DISR to consult on the project. No feedback has been provided by DISR regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
Department of Jobs, Tourism, Science and Innovation (JTSI) (WA)	June 2023	CAPL engaged JTSI as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited JTSI to consult on the project. No feedback has been provided by JTSI regarding the proposed Development during early consultation.	No change required to OPP.
Department of Mines, Industry Regulation and Safety (DMIRS) (WA)	June 2023	CAPL engaged DMIRS as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DMIRS to consult on the project. No feedback has been provided by DMIRS regarding the proposed Development during early consultation.	No change required to OPP.
Department of Primary Industries and Regional Development (DPIRD) (WA): Fisheries	June 2023 – July 2023	CAPL engaged DPIRD as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DPIRD to consult on the project. During OPP consultation DPIRD identified the potential impacts on the commercial fishing sector. DPIRD recommended CAPL liaise with WAFIC. CAPL confirmed that WAFIC had been engaged and all matters raised were addressed.	No change required to OPP. CAPL engaged with WAFIC during early consultation (refer to entry in this table).
Department of Transport (DoT) (WA) - Maritime Environmental Emergency Response (MEER) - Marine Pollution (formerly OSRC Unit)	June 2023	CAPL engaged DoT MEER as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DoT marine pollution to consult on the project. No feedback has been provided by DoT MEER regarding the proposed Development during early consultation. During previous engagements on other activities within the region DoT MEER requested that CAPL implement the requirements of the Transport Offshore Petroleum Industry Guidance Note – Marine Oil Pollution: Response and Consultation Arrangements (July 2020).	No change required to OPP. Topics raised during previous engagement which are relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Department of Transport (DoT) (WA) - Navigational Safety	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DoT Navigational Safety to consult on the project. DoT Navigational Safety recommended CAPL engage with the Pilbara Ports Authority. CAPL confirmed that the Pilbara Ports Authority were being engaged. There were no other matters raised by DoT Navigational Safety regarding the proposed Development during early consultation.	No change required to OPP. CAPL engaged with the Pilbara Ports Authority during early consultation (refer to entry in this table).

Stakeholder	Early consultation period	Summary	Section of OPP
Department of Water & Environmental Regulation (DWER) (WA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited DWER to consult on the project. No feedback has been provided by DWER regarding the proposed Development during early consultation.	No change required to OPP.
Eni Australia	July 2023 – August 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Eni Australia to consult on the Development. Eni Australia responded stating they had no concerns with the Development at this stage.	No change required to OPP.
Exmouth Chamber of Commerce and Industry (ECCI)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited ECCI to consult on the Development. No feedback has been provided by ECCI regarding the proposed Development during early consultation.	No change required to OPP.
Exmouth Gulf Task Force - DWER	June 2023 – September 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Exmouth Gulf Task Force to consult on the Development. No feedback has been provided by Exmouth Gulf Task Force regarding the proposed Development during early consultation.	No change required to OPP.
Exxon Mobil	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Exxon Mobil to consult on the Development. No feedback has been provided by Exxon Mobil regarding the proposed Development during early consultation.	No change required to OPP.
Gascoyne Development Commission (GDC)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited GDC to consult on the Development. GDC thanked CAPL for the update of the upcoming OPP. There were no matters raised by GDC regarding the proposed Development during early consultation.	No change required to OPP.
Greenpeace	July 2023 – October 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Greenpeace to consult on the Development. No feedback has been provided by Greenpeace regarding the proposed Development during early consultation.	No change required to OPP.
Jadestone Energy	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Jadestone Energy to consult on the Development. No feedback has been provided by Jadestone Energy regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
Kariyarra Aboriginal Corporation (KAC)	June 2023 – August 2023	CAPL engaged KAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited KAC to consult on the Development. KAC confirmed receipt of the written notice and advised CAPL of the importance of protection of marine fauna in the instance of an emergency event. CAPL met with KAC to further discuss the OPP and other CAPL activities within the region. KAC raised that they were interested in flatback turtles and the impact of rubbish in the sea, particularly bait and ice bags.	The OPP was revised to include Table 6-14, which includes specific responses from Traditional Owner consultation regarding cultural values and features. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Karratha & Districts Chamber of Commerce and Industry (KDCCI)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited KDCCI to consult on the Development. No feedback has been provided by KDCCI regarding the proposed Development during early consultation.	No change required to OPP.
Kufpec	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Kufpec to consult on the Development. No feedback has been provided by Kufpec regarding the proposed Development during early consultation.	No change required to OPP.
Mackerel Islands & Onslow Beach Resort	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Mackerel Islands & Onslow Beach Resort to consult on the Development. No feedback has been provided by Mackerel Islands & Onslow Beach Resort regarding the proposed Development during early consultation.	No change required to OPP.
Malgana Aboriginal Corporation	June 2023 – September 2023	CAPL engaged Malgana Aboriginal Corporation as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Malgana Aboriginal Corporation to consult on the Development. There were no matters raised by Malgana Aboriginal Corporation regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following:	Seagrass known to be present within the EMBA is considered in risk assessment (Section 8). The OPP was revised to include Table 6-14, which includes specific

Stakeholder	Early consultation period	Summary	Section of OPP
		• concerns about the significance and environmental protection of Shark Bay seagrass • request to initiate a structured communication agreement. CAPL and Malgana Aboriginal Corporation collaborated to draft an engagement plan to facilitate meaningful engagement. The development of this plan is ongoing. CAPL and Malgana Aboriginal Corporation will continue to engage as part of ongoing consultation.	responses from Traditional Owner consultation regarding cultural values and features.
Maxima Pearling Company	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Maxima Pearling Company to consult on the Development. No feedback has been provided by Maxima Pearling Company regarding the proposed Development during early consultation.	No change required to OPP.
Minister for Environment (WA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited the Minister for Environment to consult on the Development. No feedback has been provided by the Minister for Environment regarding the proposed Development during early consultation.	No change required to OPP.
Murujuga Aboriginal Corporation	June 2023 – August 2023	CAPL engaged Murujuga Aboriginal Corporation as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Murujuga Aboriginal Corporation to consult on the Development. There were no matters raised by Murujuga Aboriginal Corporation regarding the proposed Development during early consultation. During previous engagement with this stakeholder for other activities within the region, Murujuga Aboriginal Corporation noted the cultural significance of Sea Country and the need to ensure it is protected.	The OPP was revised to include Table 6-14, which includes specific responses from Traditional Owner consultation regarding cultural values and features.
National Offshore Petroleum Titles Administrator (NOPTA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited NOPTA to consult on the Development. No feedback has been provided by NOPTA regarding the proposed Development during early consultation.	No change required to OPP.
Nganhurra Thanardi Garrbu Aboriginal Corporation (NTGAC)	June 2023 – September 2023	CAPL engaged NTGAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited NTGAC to consult on the Development. There were no matters raised by NTGAC regarding the proposed Development during early consultation.	The OPP was revised to include Table 6-14, which includes specific responses from Traditional Owner consultation regarding

Stakeholder	Early consultation period	Summary	Section of OPP
		Previous engagement with this stakeholder for other activities within the region has not identified specific areas of significance, however NTGAC noted the cultural significance of Sea Country and the need to ensure it is protected. During previous and ongoing engagements, CAPL and NTGAC collaborated to draft an engagement plan to facilitate meaningful engagement. The development of this plan is ongoing. CAPL and NTGAC will continue to engage as part of ongoing consultation.	cultural values and features.
Ngarluma Aboriginal Corporation Registered Native Title Body Corporate (RNTBC)	June 2023 – September 2023	CAPL engaged Ngarluma Aboriginal Corporation RNTBC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Ngarluma Aboriginal Corporation RNTBC to consult on the Development. During consultation, Ngarluma Aboriginal Corporation RNTBC noted that offshore islands are culturally significant. During previous engagements, CAPL and Ngarluma Aboriginal Corporation RNTBC collaborated to draft an engagement plan to facilitate meaningful engagement. The development of this plan is ongoing. CAPL and Ngarluma Aboriginal Corporation RNTBC will continue to engage as part of ongoing consultation.	The OPP was revised to include Table 6-14, which includes specific responses from Traditional Owner consultation regarding cultural values and features.
Ngarluma Yindjibarndi Foundation Ltd (NYFL)	June 2023 – September 2023	CAPL engaged NYFL as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited NYFL to consult on the Development. There were no matters raised by NYFL regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following values and sensitivities: • The people from the land speak for and care about the marine animals, even if they are far out to sea. • Marine fauna, specifically whales, dugongs, and turtles are species of importance. • Many traditional narratives have origins and connection to the seascape and impacts to the seascape can have cultural repercussions. • Important intangible values are present, such as Barrimirndi (the serpent), which is an important part of dreaming for Ngarluma and Yindyibarndi people. • The cultural landscape is interconnected, whereby Traditional Owners from the western Pilbara are held to account by other Nyambali (cultural bosses) when proponents impact land and sea.	The OPP was revised to include Table 6-14, which includes specific responses from Traditional Owner consultation regarding cultural values and features.

Stakeholder	Early consultation period	Summary	Section of OPP
		• There are cultural responsibilities that transcend Native Title and other boundaries. During previous and ongoing engagements, CAPL and NYFL collaborated to draft an engagement plan to facilitate meaningful engagement. The development of this plan is ongoing. CAPL and NYFL will continue to engage as part of ongoing consultation.	
Ningaloo Coast World Heritage Advisory Committee (NCWHAC)	June 2023	CAPL engaged NCWHAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited NCWHAC to consult on the Development. No feedback has been provided by NCWHAC regarding the proposed Development during early consultation.	No change required to OPP.
Northern Prawn Fishery (NPF)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited NPF to consult on the Development. No feedback has been provided by NPF regarding the proposed Development during early consultation.	No change required to OPP.
Oil Spill Response Limited (OSRL)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited OSRL to consult on the project. No feedback has been provided by OSRL regarding the proposed Development during early consultation.	No change required to OPP.
Onslow Chamber of Commerce and Industry (OCCI)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited OCCI to consult on the Development. OCCI indicated to CAPL that they would share the factsheet provided to their committee and wider community. There were no matters raised by OCCI regarding the proposed Development during early consultation.	No change required to OPP.
Pathfinder Energy	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Pathfinder Energy to consult on the Development. No feedback has been provided by Pathfinder Energy regarding the proposed Development during early consultation.	No change required to OPP.
Pearl Producers Association (PPA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited PPA to consult on the Development. No feedback has been provided by PPA regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
PGS Australia Pty Ltd	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited PGS Australia Pty Ltd to consult on the Development. No feedback has been provided by PGS Australia Pty Ltd regarding the proposed Development during early consultation.	No change required to OPP.
Pilbara Development Commission	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Pilbara Development Commission to consult on the project. No feedback has been provided by Pilbara Development Commission regarding the proposed Development during early consultation.	No change required to OPP.
Pilbara Ports Authority	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Pilbara Ports Authority to consult on the Development. No feedback has been provided by Pilbara Ports Authority regarding the proposed Development during early consultation.	No change required to OPP.
Protect Ningaloo	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Protect Ningaloo to consult on the Development. No feedback has been provided by Protect Ningaloo regarding the proposed Development during early consultation.	No change required to OPP.
Recfishwest (WA)	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Recfishwest to consult on the Development. Recfishwest stated they had no concerns regarding the OPP and would appreciate it if CAPL kept Recfishwest up to date on the OPP moving forward. Previous engagement with this stakeholder for other activities within the region identified the following matters: • disturbance of recreation and charter fishing • presence of valued fish species in the region (including emperor, tropical snapper, mackerel, billfish).	No change required to OPP. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Robe River Kuruma Aboriginal Corporation (RRKAC)	June 2023 – September 2023	CAPL engaged RRKAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited RRKAC to consult on the Development. RRKAC requested they be included in future correspondence. There were no other matters raised by RRKAC regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following values and sensitivities:	The OPP was revised to include Table 6-14, which includes specific responses from Traditional Owner consultation regarding

Stakeholder	Early consultation period	Summary	Section of OPP
		• the area within their Kuruma Marthudunera native title claim, Jajiwurra (Robe River) and the waters extending seaward from the river mouth. • ecological integrity of Jajiwurra. Consultation with this stakeholder is ongoing.	cultural values and features.
Santos	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Santos to consult on the Development. No feedback has been provided by Santos regarding the proposed Development during early consultation.	No change required to OPP.
SapuraOMV Upstream	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: and Backfill Fields OPP via email and invited SapuraOMV Upstream to consult on the Development. No feedback has been provided by SapuraOMV Upstream regarding the proposed Development during early consultation.	No change required to OPP.
Shark Bay Prawn Trawler Operators Association (SBPTOA)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited SBPTOA to consult on the Development. No feedback has been provided by SBPTOA regarding the proposed Development during early consultation.	No change required to OPP.
Shark Bay World Heritage Committee	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited the Shark Bay World Heritage Committee to consult on the Development. No feedback has been provided by the Shark Bay World Heritage Committee regarding the proposed Development during early consultation.	No change required to OPP.
Shire of Ashburton (Pilbara)	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Shire of Ashburton (Pilbara) to consult on the Development. The Shire provided CAPL with a written response on the following: • the expectation that CAPL will identify, manage, and mitigate all possible impacts and risks in line with the relevant regulatory frameworks and world leading standards (regarding ocean waters and islands). • consultation of the Aboriginal Cultural Heritage Inquiry System (ACHIS) to ensure sites of Aboriginal Cultural Heritage significance are not impacted without consent. • emergency management matters including CAPL undertaking their own emergency management planning as well as briefing and communicating with appropriate	The results of the ACHIS consultation are noted in Section 6.5. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.

Stakeholder	Early consultation period	Summary	Section of OPP
		emergency management agencies at either/or National, State, District and Local levels. • engagement with the community. The Shire also requested that CAPL provide the Shire with further updates on this proposal as it progresses. CAPL responded to the Shire confirming: • risks and impacts from the proposed activities would be managed and mitigated in line with relevant regulatory frameworks and standards. • ACHIS had been consulted in the development of the OPP. • emergency management matters would be addressed during the EP phase of the activities. • relevant stakeholders within the community had been consulted during the development of the OPP.	
Shire of Carnarvon (Gascoyne)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Shire of Carnarvon (Gascoyne) to consult on the Development. No feedback has been provided by the Shire of Carnarvon (Gascoyne) regarding the proposed Development during early consultation.	No change required to OPP.
Shire of Exmouth (Gascoyne)	June 2023	CAPL engaged Shire of Exmouth (Gascoyne) as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Shire of Exmouth (Gascoyne) to consult on the Development. There were no matters raised by Shire of Exmouth (Gascoyne) regarding the proposed Development during early consultation.	No change required to OPP.
Shire of Shark Bay	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Shire of Shark Bay to consult on the Development. No feedback has been provided by Shire of Shark Bay regarding the proposed Development during early consultation.	No change required to OPP.
TGS NOPEC Geophysical Company Pty Ltd	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited TGS NOPEC Geophysical Company Pty Ltd to consult on the Development. No feedback has been provided by TGS NOPEC Geophysical Company Pty Ltd regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
Town of Port Hedland (Pilbara)	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Town of Port Hedland (Pilbara) to consult on the Development. Town of Port Hedland (Pilbara) acknowledged receipt of the information. There were no matters raised by Town of Port Hedland (Pilbara) regarding the proposed Development during early consultation.	No change required to OPP.
Vermilion Oil & Gas	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Vermilion Oil & Gas to consult on the Development. Vermilion responded questioning how they were considered a relevant stakeholder and if CAPL activities would have any impact on the Wandoo operations. CAPL advised that there were no planned associated risks or impacts to the Wandoo operations.	No change required to OPP.
Vocus Communications	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Vocus Communications to consult on the Development. No feedback has been provided by Vocus Communications regarding the proposed Development during early consultation.	No change required to OPP.
WA Coastal and Marine Community Network	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited the WA Coastal and Marine Community Network to consult on the Development. No feedback has been provided by the WA Coastal and Marine Community Network regarding the proposed Development during early consultation.	No change required to OPP.
WA Marine Science Institute	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited the WA Marine Science Institute to consult on the Development. No feedback has been provided by the WA Marine Science Institute regarding the proposed Development during early consultation.	No change required to OPP.
Western Australian Fishing Industry Council (WAFIC)	June 2023 – September 2023	CAPL engaged with WAFIC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited WAFIC to consult on the Development. There were no matters raised by WAFIC regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified the following matters for consideration: • engagement with local fishers	The potential presence of Bluefin Tuna breeding in the EMBA is addressed in Section 6.2.3 and assessed with fish in Section 8. Topics relevant to the EP phase will be addressed as part of

Stakeholder	Early consultation period	Summary	Section of OPP
		• concerns regarding decommissioning and seismic activities • presence of Bluefin Tuna Spawning area within the region as a potential receptor. During previous and ongoing engagements, CAPL and WAFIC collaborated to draft an engagement plan to facilitate meaningful engagement. The development of this plan is ongoing.	Phase 3 of stakeholder consultation.
Western Australian Museum (WAM)	June 2023 – July 2023	CAPL provided a formal written notice of the Gorgon Gas Development: and Backfill Fields OPP via email and invited WAM to consult on the Development. WAM provided a written response that: • directed CAPL to engage with DCCEEW, who would engage the WAM as its Delegate, if deemed necessary. • recommended referring to and addressing the requirements of the Underwater Cultural Heritage (UCH) Guidance for Offshore Developments and Guidelines for Working in the Near and Offshore Environment to Protect Underwater Cultural Heritage. • advised that a suitably qualified and experienced maritime archaeologist should be engaged to undertake a UCH Desktop Assessment to identify Aboriginal and non-Aboriginal UCH within the project area. • recommended CAPL consult with Traditional Owners, where appropriate. CAPL confirmed that DCCEEW were being engaged. CAPL acknowledged WAM's guidance in relation underwater cultural heritage (UCH) and confirmed that CAPL have and continue to consult with relevant Traditional Owners and that CAPL will comply with the applicable UCH guidance where appropriate.	The OPP was revised to include Section 6.5.2 which details UCH within the EMBA. CAPL engaged with DCCEEW during early consultation (refer to entry in this table). CAPL has been and continues to engage with Traditional Owners.
Western Rock Lobster Council (WRLC)	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: and Backfill Fields OPP via email and invited WRLC to consult on the Development. No feedback has been provided by WRLC regarding the proposed Development during early consultation.	No change required to OPP.
Whale and Dolphin Conservation Society	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: and Backfill Fields OPP via email and invited the Whale and Dolphin Conservation Society to consult on the Development. No feedback has been provided by Whale and Dolphin Conservation Society regarding the proposed Development during early consultation.	No change required to OPP.

Stakeholder	Early consultation period	Summary	Section of OPP
Wilderness Island	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: and Backfill Fields OPP via email and invited Wilderness Island to consult on the Development. No feedback has been provided by Wilderness Island regarding the proposed Development during early consultation.	No change required to OPP.
Wirrawandi Aboriginal Corporation RNTBC (WAC)	June 2023 - August 2023	CAPL engaged WAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited WAC to consult on the Development. During consultation with WAC, explanatory questions regarding the following matters were raised: • turtle species on Barrow Island. • environmental impacts of emergency response processes. • drilling processes and risks. • gas leaks from transporting gas. • CO_2 injection. • mercury content of gas extracted. • flaring at gas plants. CAPL provided a response to these queries during the meeting and encouraged WAC to make contact should they have any further questions. Previous engagement with this stakeholder for other activities within the region identified the following values and sensitivities: • The coastal area, Sea Country and adjacent islands are highly valuable to the Yaburara and Mardudhunera people. • connection to Barrow Island.	The OPP was revised to include Table 6-14, which includes specific responses from Traditional Owner consultation regarding cultural values and features. Turtle species with the potential to be present within the EMBA are addressed in the Description of the environment (Section 6)and are considered in risk assessment (Section 8). Drilling processes are addressed in the Description of the project (Section 4) and considered in risk assessment (Section 8). Potential gas leaks are addressed in the risk assessment (Section 8.15). CO_2 injection is addressed in the GHG emissions risk

Stakeholder	Early consultation period	Summary	Section of OPP
			assessment (Section 8.3). Flaring during the Development is addressed in the Description of the project (Section 4) and risk assessment (Section 8). Flaring at gas plants is not within the scope of the OPP. Topics relevant to the EP phase will be addressed as part of Phase 3 of stakeholder consultation.
Woodside	June 2023	CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited Woodside to consult on the Development. No feedback has been provided by Woodside regarding the proposed Development during early consultation.	No change required to OPP.
Yinggarda Aboriginal Corporation (YAC)	June 2023 - August 2023	CAPL engaged YAC as part of their ongoing relationship and to conduct engagement for the OPP. CAPL provided a formal written notice of the Gorgon Gas Development: Backfill Fields OPP via email and invited YAC to consult on the Development. There were no matters raised by YAC regarding the proposed Development during early consultation. Previous engagement with this stakeholder for other activities within the region identified a need for informed engagement, interest in developing an engagement framework with CAPL, and interest in receiving further information regarding partnership opportunities. The development of this engagement framework is ongoing. CAPL and YAC will continue to engage as part of ongoing consultation.	No change required to OPP.

3.2 Phase 2—Public consultation under NOPSEMA's public comment process

A public comment period is part of NOPSEMA's OPP assessment process, which includes the publication of the OPP on NOPSEMA's website. This formal consultation period allows stakeholders an opportunity to provide comment on the Development. The public comment consultation will allow consultation to be undertaken with stakeholders that were not initially identified by CAPL during the preliminary consultation. The public comment period of an OPP is undertaken for a period between 4 and 12 weeks, at NOPSEMA's discretion.

To notify stakeholders of the public comment period and to encourage feedback, CAPL will:

- place advertisements in Australian national, and Western Australian state and regional newspapers
- publish a dedicated page on CAPL's website including details of the Development, the Environment that May Be Affected, information regarding the approvals and a point of contact to provide feedback or request additional information.

CAPL is committed to considering all information received during the public comment period and addressing all relevant comments.

3.3 Phase 3—Relevant Persons consultation during the preparation of EPs and on an ongoing basis after EP acceptance

Following acceptance of the OPP, all the petroleum activities within the scope of the OPP must have a NOPSEMA accepted EP in place before CAPL can commence the proposed activities.

Relevant Persons consultation, as required under regulation 11A of the OPGGS(E)R, will be completed during the preparation of the EPs to inform decision-making and planning for the petroleum activities. This consultation will be described in the EPs for the petroleum activities associated with this Development.

Ongoing consultation, as required under regulation 14(9) of the OPGGS(E)R, will be undertaken after acceptance of the EPs and will be outlined within the EPs for the petroleum activities associated with this Development.

4 Description of the project

4.1 Overview

The Development will develop and operate 7 gas fields and associated flowlines and tie-ins, which will feed into the Gorgon GTP on Barrow Island.

This section summarises the Development as required under Regulation 5A (5)(b) of the OPGGS(E)R. The description of the Development activities is presented in the following subsections:

- the hydrocarbon system—includes all the infrastructure used for the gathering and transporting hydrocarbons to the existing GFP pipelines, and other supporting infrastructure (Section 4.2)
- surveys—geophysical surveys and seabed geotechnical surveys, including pre-installation and as-built surveys, occurring throughout the Development (Section 4.3.1)
- drilling—covers well construction and includes MODU positioning, spread mooring, drilling of production wells, BOP installation, cementing and completions in each field (Section 4.3.2)
- installation and commissioning—includes seabed preparation, pipelay (flowline and pipeline), subsea equipment installation, verification and testing of infrastructure, pre-commissioning, including hydrotesting and commissioning, and the introduction of hydrocarbons to the system (Section 4.3.3)
- operations—the gathering and transport of hydrocarbons and other fluids from the subsea wells to the existing GFP pipelines, including IMR and well intervention (Section 4.3.4)
- decommissioning— long-term planning for decommissioning of infrastructure no longer in use, including removing subsea infrastructure, and P&A of wells (Section 4.3.5)
- support activities—includes MODU topside activities and vessel, helicopter, and remotely operated vehicle (ROV) operations (Section 4.3.6).

The activities, locations and infrastructure described in this section are presented based on current technologies. CAPL will continue to seek and assess emerging technologies that may provide future opportunities to reduce risk and impact. Any new technology selected for the Development will be assessed and presented in subsequent applicable EPs.

4.1.1 Gorgon Foundation Project context

The GFP included the construction of a GTP and domestic gas plant on Barrow Island, which is located off the Pilbara coast (WA), 85 km north-north-east of Onslow. The Gorgon Gas Development was approved under the EPBC Act for constructing and operating facilities associated with producing and transporting gas (including offshore production wells and feed gas pipeline infrastructure) from the Gorgon and Jansz–Io gas fields to the GTP. The Gorgon Gas Development Area is defined under the *Barrow Island Act 2003* (WA).

Construction of GFP infrastructure began in December 2009, drilling activities in 2011 and liquefied natural gas production commenced in 2016. Subsea gathering systems and pipelines deliver feed gas from the Gorgon and Jansz–Io gas fields to the west coast of Barrow Island. The underground feed gas pipeline system then traverses Barrow Island to the GTP on the east coast. The GTP includes natural gas production lines (also known as trains) that produce LNG as well as condensate and domestic gas. Carbon dioxide (CO_2), which occurs naturally in the feed gas, is separated during the production process, and a proportion is injected into deep rock formations below Barrow Island. The LNG and condensate are loaded onto ships from a jetty and transported to international markets. Gas for domestic use is delivered by pipeline from Barrow Island to the domestic gas collection and distribution network on the WA mainland.

CAPL has undertaken further developments to maintain supply to the GTP with the GS2 Project, which involves the installation of additional wells in the Gorgon and Jansz-Io fields and accompanying offshore production pipelines and subsea structures.

4.1.2 Location

The Development includes 7 gas fields, all located in Commonwealth waters off the north-west coast of WA, and north-west of Barrow Island. The 7 fields are Chandon, Chrysaor, Dionysus, Eurytion, Geryon, Semele and West Tryal Rocks (WTR).

The area includes a steep scarp which represents the transition from the shallow waters of the continental shelf at ~150 m depth to water settings of ~1,400 m in the deeper water ~100 km out from the scarp. The closest infrastructure will be ~60 km from Barrow Island and ~130 km from Onslow. The outermost infrastructure will be ~190 km from Barrow Island and ~250 km from Onslow.

Existing GFP infrastructure comprises feed gas pipelines from the Jansz–Io gas field and the Gorgon gas field. These pipeline routes converge before the pipelines connect to the GTP on Barrow Island. The new flowlines will be tied-in to the Jansz or Gorgon Feed Gas Pipelines.

Figure 4-1 shows the location of the fields.

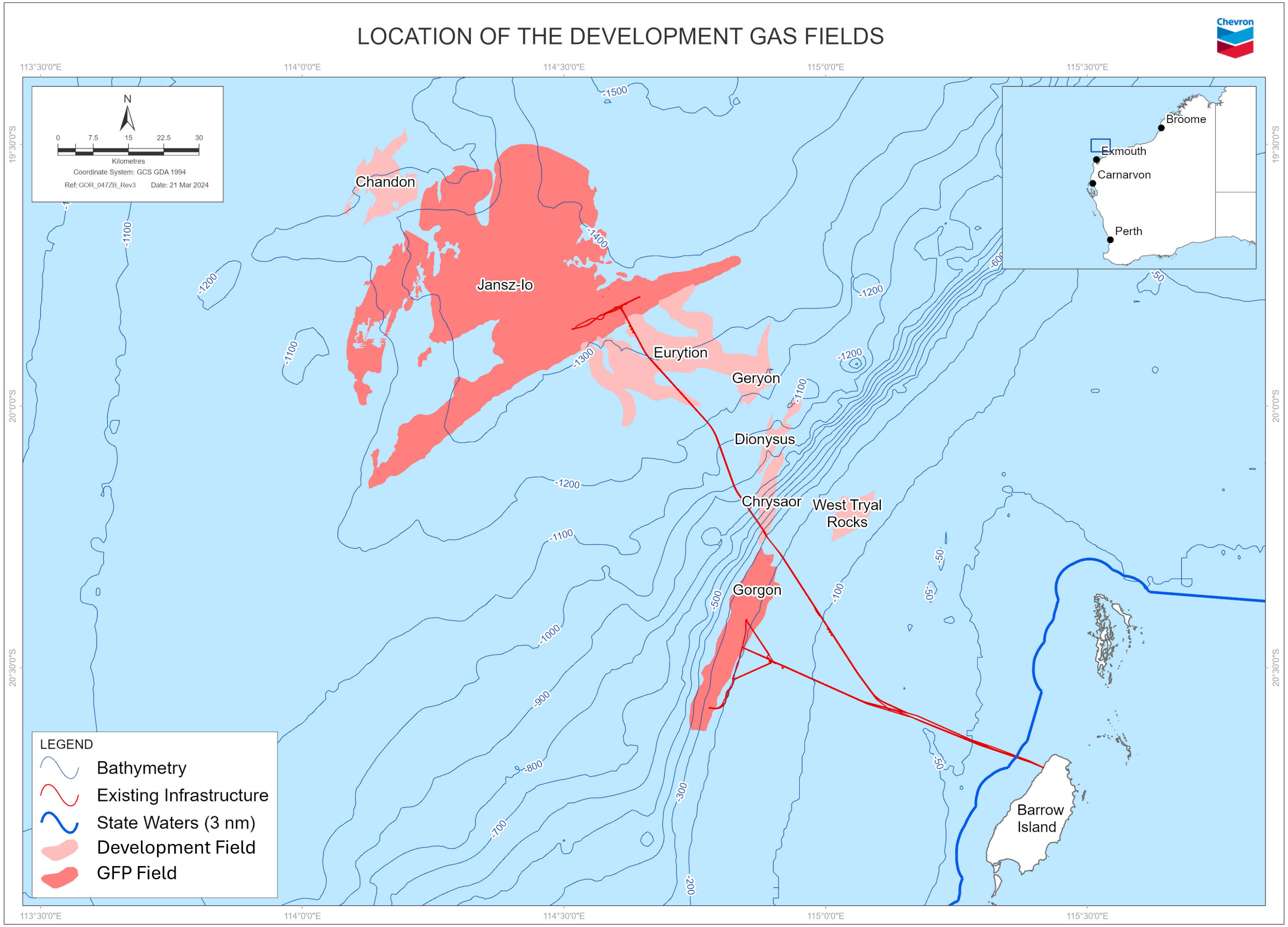

Figure 4-1: Location of Development gas fields

4.1.3 Operational area

The operational area (OA) is a defined area within which all petroleum activities associated with the Development occur, and which allows impact assessment of those activities. For this OPP, the OA includes the extent of all planned activities described in this OPP, with a 5 km radius around the expected position of subsea infrastructure (Figure 4-2).

As the final routes for the flowlines, MEG pipelines and umbilicals have not yet been confirmed; and multiple flowline, pipeline and umbilical routes or potential locations are under consideration, a 5 km buffer has been included around the outermost route or location, to give a conservative area to use for impact assessment. These indicative routes have been chosen to connect the fields to the Feed Gas Pipeline tie-in point (i.e. Gorgon or Jansz), while taking into account geographical features such as the scarp. In addition, to allow more flexibility, the OA boundary has been enlarged in some sections, such as around the existing Jansz Feed Gas Pipeline. Final flowline, pipeline and umbilical routes and location of structures will be confirmed later, following sea floor surveys and coring, and detailed engineering design, and will be specified in the EP phase.

The Development includes well construction from 10 drill centres (DCs).Table 4-1 lists the approximate water depth and indicative coordinates of each proposed DC. Indicative well locations have been chosen to minimise the number of wells and DCs required for optimal access to the reservoir. More accurate locations of the infrastructure will be included in the relevant EPs once final locations are selected.

Table 4-1: Water depth and indicative coordinates of DCs at each field

Fields	DC	Approx. water depth (m)	Indicative coordinates of DCs[3]	
			Latitude	Longitude
Chandon	Chandon DC-1	1,200	−19.566894752	114.128503654
	Chandon DC-2	1,200	−19.550449305	114.112716243
C&D	C&D DC-1	1,150	−20.059302764	114.895980290
	C&D DC-2	1,000	−20.129470731	114.864375418
	C&D DC-3	800	−20.195676362	114.878809246
G&E	G&E DC-1	1,200	−19.937438510	114.882671257
Semele	Semele DC-1	1,200	−19.960763696	114.989444688
	Semele DC-2	1,200	−19.992837921	114.950818998
WTR	WTR DC-1	150	−20.241792298	115.030611257
	WTR DC-2	150	−20.214084371	115.044652696

[3] GDA 94

While the final routes may move from the indicative locations presented in Figure 4-3, all final infrastructure will be located within the OA described in Section 4.1.3 (Figure 4-2).

The OA covers the operation and movement of vessels and helicopters that will be undertaking activities described in this OPP. The general transit of vessels, the MODU and helicopters to and from the OA is not considered a petroleum activity and therefore is excluded from the scope of this OPP. These activities will be undertaken in accordance with other relevant maritime and aviation legislation, including the *Navigation Act 2012* (Cth) and *Civil Aviation Act 1988* (Cth).

The operation of onshore facilities required to support the Development is outside the scope of the OPP.

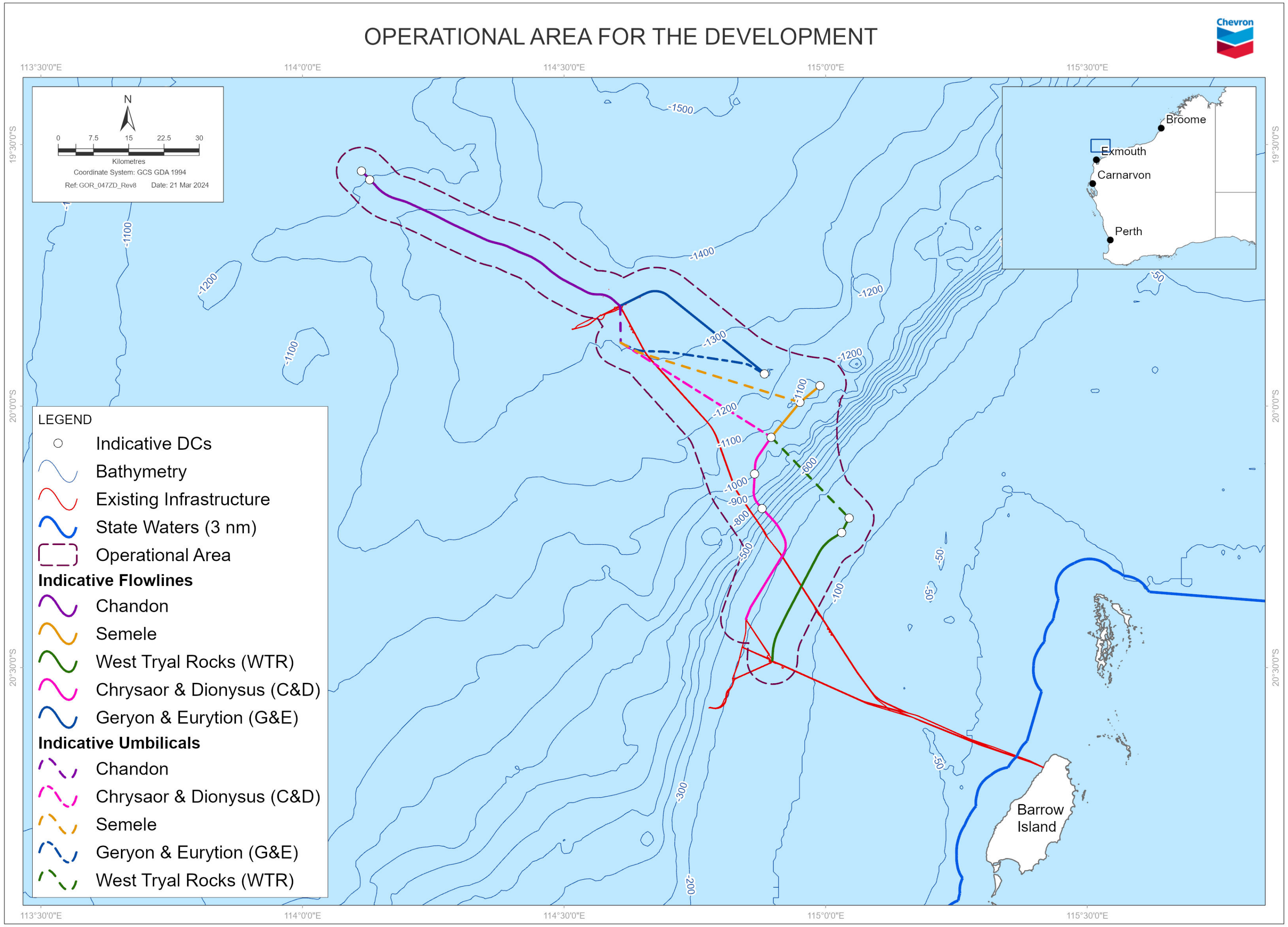

Figure 4-2: Operational area for the Development

4.1.3.1 Disturbance area

As the Development is in the early planning phase, the exact footprint of the infrastructure to be installed is still to be finalised. The exact details of each stage will be included in the respective EPs. To allow for environmental impact assessment in the OPP, a conservative disturbance area has been adopted. This seabed disturbance is classified as either long-term disturbance or short-term disturbance.

Long-term disturbance is a result of infrastructure that may remain on the seabed from installation through to decommissioning. The long-term infrastructure disturbance area comprises the direct footprint of the infrastructure as well as a buffer area either side of the flowlines, pipelines and umbilicals, and an area around the DCs and tie-ins (Section 8.1.1.7). For ease of reference and conservatism, the direct footprint of the infrastructure as well as the buffer area will be referred to as the long-term disturbance area throughout this document. CAPL has allowed for a further 50% as contingency for the long-term infrastructure disturbance area to allow for any changes to infrastructure footprints or placement within the OA boundary. All infrastructure described in Section 4.2 will be located within the long-term disturbance area.

Short-term disturbance is caused when infrastructure or equipment has contact with the seabed during a particular phase but is removed at or before the end of that phase. Anchoring of vessels or the MODU is an example. A further 50% contingency has been provided for the short-term disturbance area to allow for any changes to short-term infrastructure footprints or placement within the OA boundary.

Further detail on long-term and short-term disturbance is described in Section 8.1.1.7.

4.1.4 Timing

The Development will be staged, that is, the fields will be developed over multiple campaigns with the G&E co-development earmarked as the first stage of the Development. Subject to relevant approvals and other constraints, the earliest that G&E is likely to be ready for activities to commence in the OA is 2026, with subsequent ready for start-up in 2028. The end of field life for the Development is notionally ~2070, with each field identified in the Development having its own end of life. The indicative range for the duration of operations is 10-30 years for each field, which captures the potential for future technology and variance in field performance. Decommissioning and any post-decommissioning monitoring will occur as applicable following each field's end of life. The indicative timeframes and schedule of key Development activities are presented in Table 4-2.

Table 4-2: Indicative timeframes and schedule of key Development activities

Development Activity	Approximate Timing	Approximate Duration
G&E Drilling	Q3 2026	24 months
G&E Installation and commissioning	Q3 2027	12 months

G&E Operations[4]	2028	20-25 years
Subsequent field development	The subsequent fields will likely be developed post start up of G&E with timing of the respective fields based on the production outcomes of the fields sequenced before it i.e. as each field declines a new field(s) will be developed into the Gorgon and Jansz trunklines. The order that the fields will be developed has not yet been finalised. The activity durations for the individual fields will be similar to the durations presented for G&E except for installation activities at C&D which may take longer (15 months) due the presence of the scarp. Additionally, WTR may have an operational life up to 30 years.	

While the Development will typically be staged so that not all fields will be developed in a single campaign, some phases may occur concurrently within and across fields. There is potential for multiple Development activities to occur at the same time within a single field, for example drilling, installation and support activities could occur concurrently for short intermittent durations. There is also potential for concurrent activities to occur intermittently across fields for example drilling may be occurring at one field, while installation operations are occurring at a different field, or drilling and installation may occur in one field while commissioning occurs in another. As the Development is in the early planning phase the exact sequence of the activities is still to be finalised and the details of each sequence and the related cumulative impacts and risks will be included and assessed in the respective EPs. Where relevant, Sections 8 and 9 of this OPP consider potential concurrent and cumulative impacts and risks.

IMR activities on operational infrastructure may occur at any time, including during installation, commissioning, start-up, and operations.

Activities covered by this OPP can occur 24 hours a day, 7 days a week and at any time of the year.

4.1.5 Options to be selected after OPP Phase

Because OPPs are written prior to detailed engineering design, some activity and design options will not be finalised until later in the project design phase, which will likely occur after the OPP phase.

The Development has a long project life, and the OPP framework under the OPGGS(E)R does not have a change mechanism. Any changes would require a new or revised OPP to be submitted. As a result, the alternatives analysis process undertaken for design and activity options (Section 5.3) has identified some instances where multiple options need to be outlined in the OPP. This enables CAPL to consider methodologies and technologies that are not currently feasible or available, but which may be an option during the Development life. It also allows the flexibility to select the option with the best environmental outcome at the time.

Table 4-3 summarises the key options that will be selected prior to the EP phase, which are included in Section 4.3. The different options may have different

[4] *Operation duration is from the RFSU (Ready for Start up) for each development. A time range is provided to capture the potential for future technology and variance in field performance.*

impacts and risks; therefore Table 4-3 identifies which option presents the scenario with the greater environmental impact for specific key aspects. These options will be used for the impact assessment in Section 8 to ensure the option that presents the greatest potential environmental impact is assessed.

Table 4-3: Design and activity options included in the OPP

Activity / Design option	Option overview	Key aspects for impact assessment	Implications / discussion
MODU type	Moored MODU	Seabed disturbance	Moored and DP MODUs have similar total scores in the comparative environmental assessment, but the scores vary on some specific criteria. Moored MODUs impact the seabed due to anchoring and have greater potential to interact with marine fauna compared to a MODU on DP. Jack-up MODUs impact the seabed, but to a lesser extent than Moored MODUs. DP MODUs cause more underwater sound and atmospheric emissions compared to moored MODUs.
	Dynamically Positioned (DP) MODU	Underwater sound Atmospheric emissions	
	Jack-up MODU	Seabed disturbance	
Flowline retrieval	Cut and lift	Seabed disturbance Planned emissions and discharges Physical presence	The cut and lift option is much slower than reverse lay. Therefore, impacts and risks associated with vessel activities are greater for cut and lift due to the longer duration of the decommissioning vessel spread in the field. For this reason, the duration of flowline retrieval used for impact assessment in Section 8 was based on the cut and lift option. Cut and lift also requires disturbance of the seabed around each cut site to allow access for the cutting tools. Reverse lay for this size of pipe and water depth is not currently feasible at time of writing. However, it may become a more feasible option in future, which is why both options are selected.
	Reverse S-lay / J-lay	Introduction of IMPs	
Umbilical retrieval	Recover and cut on deck / reverse reel	Planned emissions and discharges Physical presence	Recover and cut on deck / reverse reel is slower than reverse carousel. Therefore, impacts and risks associated with vessel activities are greater for recover and cut / reverse reel due to the longer duration of the decommissioning vessel spread in the field. For this reason, the duration of umbilical retrieval used for impact assessment in Section 8 was based on the recover and cut on deck / reverse reel option. In consideration of potential future challenges associated with suitable vessel availability, both options have been included in this OPP.
	Reverse carousel	N/A. There is no material difference in key aspects.	

4.2 Description of hydrocarbon system

4.2.1 Overview

The planned hydrocarbon system supplements the existing GFP development to tie-in the additional fields and includes this subsea infrastructure:

- production wells
- production trees, manifolds, pipeline termination structures and other tie-in structures (e.g. slug catchers, pressure protection skids)
- flowlines to tie new production wells to the Gorgon or Jansz Feed Gas Pipelines
- associated MEG pipelines, spools, jumpers, manifolds, structures and in-line tees
- PLETs and PLEMs
- umbilicals, flying leads and controls distribution units (CDUs).

The key infrastructure components proposed for the Development are described in Sections 4.2.2 to 4.2.6. Any dimensions provided are based on early engineering estimates and may change; however, the intent of the long-term disturbance area (Section 8.1.1.7) is to allow for the footprint of all infrastructure described in Section 4.2.

In this OPP the term ‘flowline’ refers to new infield flowlines to be installed as part of the Development; ‘production pipeline’ refers to existing infrastructure. This helps differentiate existing infrastructure from that associated with the Development. Further terminology definitions are given in the following subsections and in the acronym/definitions table (Table 11-1).

The backfill fields within the scope of the Development will likely be tied-in to the GFP as follows:

- The Chandon field, which is the furthest from Barrow Island (~190 km), will be tied-in to the Jansz pipeline
- The C&D fields are anticipated to be co-developed and will feed into a single flowline. C&D will tie-in to the Gorgon pipeline. The C&D flowline will traverse the scarp on its route to the Gorgon pipeline
- The G&E fields will be co-developed and will feed into a single flowline. G&E will be tied-in to the Jansz pipeline
- The Semele field will be tied-in to the proposed C&D flowline
- The WTR field will be tied-in to the Gorgon pipeline.

Umbilicals will be required to provide power and controls to the new infrastructure. Umbilicals will be laid in the same corridor as the flowlines or follow a separate route to the flowlines. All umbilical routes will be within the OA. Umbilicals likely to be installed are described in Section 4.2.5.

The final routes for the flowlines, MEG pipelines or umbilicals have not yet been identified, and multiple route options are being considered. The figures in this OPP present a single indicative route for each proposed flowline, MEG pipeline or umbilical.

These indicative routes are considered the outermost routes or represent the worst-case environmental impact (i.e. longest route) for the Development. These indicative 'worst-case' routes were used for the impact assessment. All final flowline, MEG pipeline and umbilical routes will occur within the OA described in Section 4.1.3.

Figure 4-3 shows the indicative flowline and umbilical routes for the Development and the existing infrastructure.

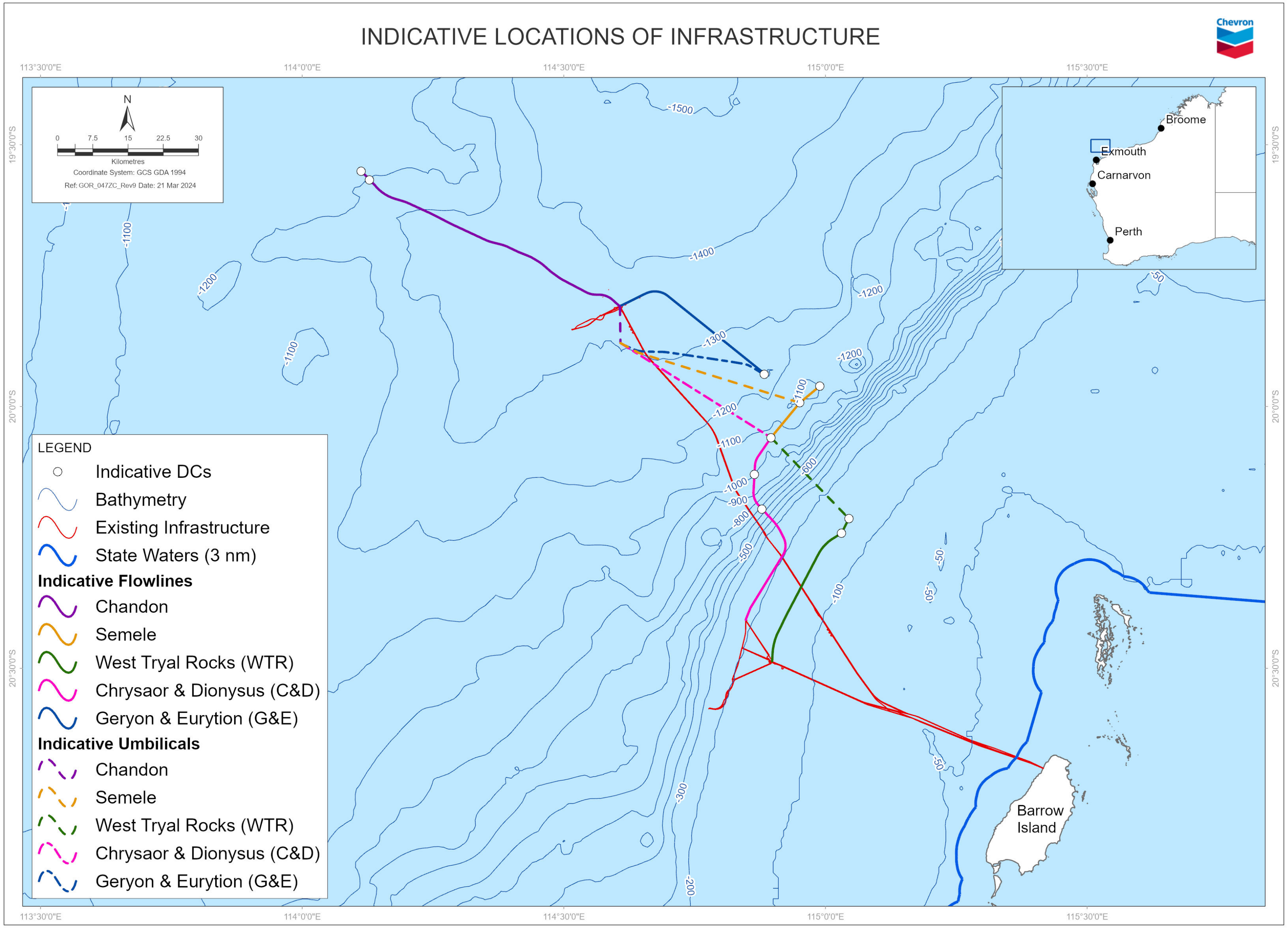

Figure 4-3: Indicative locations of infrastructure

Although the layout of subsea infrastructure at each DC will be different and specific infrastructure locations are yet to be finalised, a diagram showing an indicative DC layout has been prepared (Figure 4-4). This diagram illustrates the infrastructure described in this section; it is for illustrative purposes only as the DCs may vary slightly.

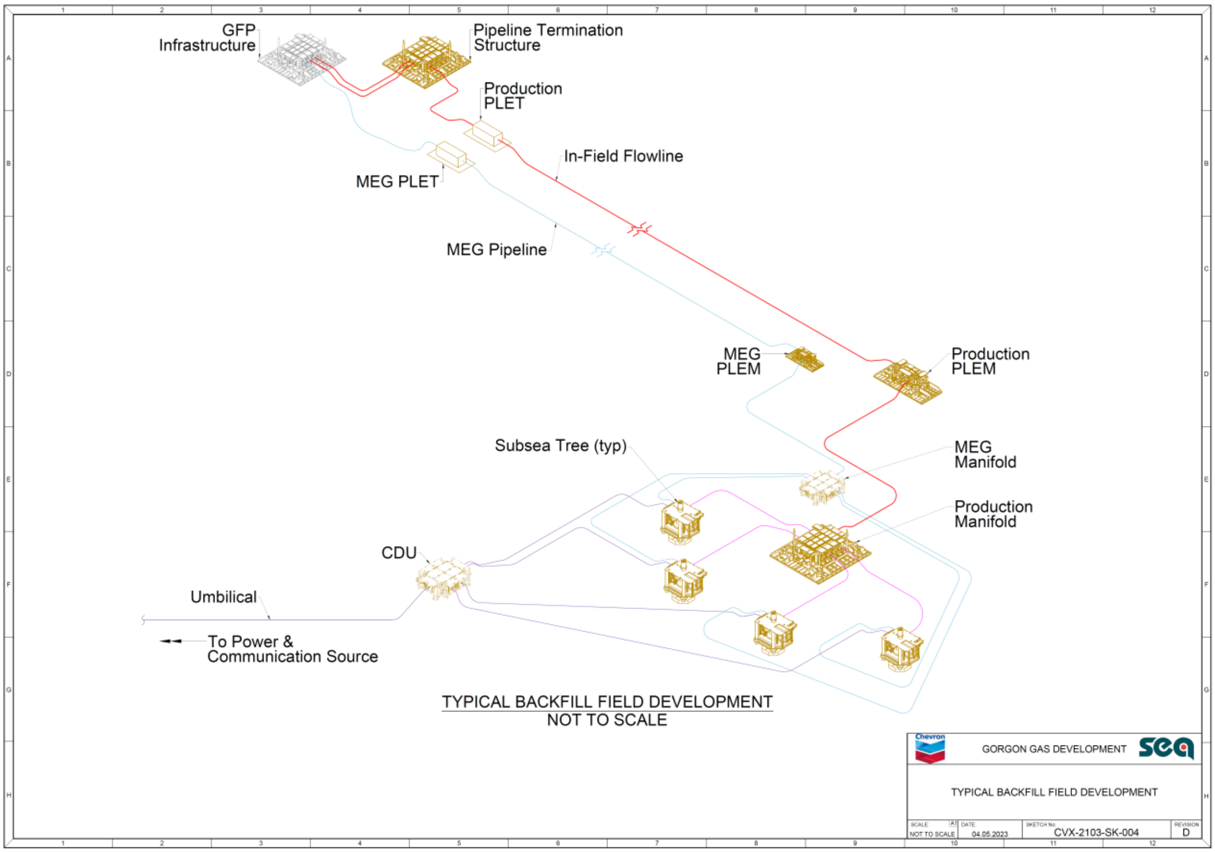

Figure 4-4: Indicative drill centre layout

4.2.1.1 Reservoir characteristics

Table 4-4 details the hydrocarbon compositions for the 7 fields.

Table 4-4: Primary inert and hydrocarbon composition (mol%) for each field

Component	Reservoir						
	Chandon	Chrysaor	Dionysus	Eurytion	Geryon	Semele[5]*	WTR
Carbon dioxide	0.3	10.8	9.4	0.6	1.2	6	11.3
Nitrogen	3.4	4.4	3.4	2.3	2.1	4	14.4
Methane	85.2	78.9	81.9	89.6	88.8	84	65.3
Ethane	5.1	4.0	3.9	4.5	4.5	4	3.9
Propane	2.6	1.3	1.2	1.6	1.6	1.2	1.4

[5] *The Semele field is a prospect at this time and as a result, no composition data is available. The field is contained within retention lease permits WA-14-R and WA-15-R, which also cover the Chrysaor and Dionysus fields. Semele values are interpretations from analogues, not data, and therefore may change.*

4.2.2 Production wells

A number of production wells will be drilled for each field, with a maximum 40 wells (total) for the Development. These wells will be distributed between the 10 DCs (Table 4-1).

Each production well is fitted with a wellhead and a production tree, which is the primary infrastructure for distributing hydrocarbons from the wells. Production trees include an arrangement of valves, controls, and instrumentation to monitor, direct and control hydrocarbon flow and facilitate injection of MEG and other chemicals.

Table 4-5 provides the key characteristics of the wells.

Table 4-5: Key characteristics of the wells

Characteristic	Field				
	Chandon	C&D	G&E	Semele	WTR
Maximum number of wells	8	8	8	8	8
Approximate water depth	1,200 m	800–1,150 m	1,200 m	1,200 m	150 m
Approximate total footprint	336 m^2	336 m^2	336 m^2	336 m^2	336 m^2

4.2.3 Subsea structures

Subsea structures, such as foundation (support) structures, manifolds and pipeline termination structures will be installed at DCs.

The production wells are connected to subsea production manifolds at each DC. These manifolds enable production fluids from each well to be commingled before entering the infield production flowlines. The infield production flowlines run from the production manifolds to the GFP tie-in points for each field. At each tie-in point, a variety of manifolds may be required to facilitate the flow of hydrocarbons at different stages of the Development.

Valve isolation is provided on the subsea production manifolds using valves that may be operated by an ROV if required.

Manifolds may also be required for MEG transfer at the DCs and tie-in locations.

Seabed support for subsea structures is achieved using foundation structures such as mudmats, which are used to prevent structures from sinking into soft sediment on the seabed. The largest predicted footprint for a single manifold ~900 m^2. The design of the manifolds is currently preliminary, with the final design footprint to be provided in subsequent EPs.

Pipeline termination structures may also be installed, with up to 2 required per flowline, one at each end. The predicted footprint is expected to be ~900 m^2.

Other structures (e.g. slug catcher, overpressure protection system) may also be installed. The overpressure protection system may be required to further safeguard the transfer of the Development hydrocarbons via the subsea compression station associated with J-IC. The predicted footprint is estimated to be ~2,100 m^2 for each unit. These structures are likely to be required at one of the Jansz tie-in locations only, with an expected one of each required.

4.2.4 Flowlines, MEG pipelines, jumpers, and spools, PLETs and PLEMs

Each production tree is connected to a subsea production manifold via jumpers. Jumpers, and spools, are also used to connect manifolds to flowlines/pipelines and flowlines/pipelines to GFP tie-in points. Jumpers and spools will have a nominal diameter of ~24″.

Subsea DC infrastructure connects to respective GFP tie-in points by infield flowlines and MEG pipelines.

The flowlines, which transport production fluids, will have a nominal diameter of 24″ and are typically constructed from corrosion-resistant alloys and carbon steel.

Table 4-6 lists the estimated lengths of the longest flowline routes and the approximate range of water depths that each flowline will pass through.

MEG pipelines provide MEG and other production chemicals to the field. These chemicals are then returned via the flowlines and GFP production pipelines to the GTP on Barrow Island, where MEG is regenerated for re-use. MEG pipelines will likely be 8″ in diameter and of a similar length to the flowlines for each field (Table 4-6).

A Pipeline End Termination (PLET) or Pipeline End Manifold (PLEM) structure may be installed (typically on foundations) at each end of the flowlines and MEG pipelines. There may be four installed for each field.

The Semele and C&D flowlines and MEG pipelines will most likely incorporate in-line tees laid on an integral foundation (Section 4.3.3.1).

Table 4-6: Expected lengths of flowlines

Flowline	Estimated flowline length (km)	Approx. range of water depths (m)
Chandon	60	1,200–1,400
C&D	45	200–1,150
G&E	35	1,200–1,400
Semele	15	900–1,200
WTR	35	150
Total expected length:	**~190**	**-**

Note: Well/subsea engineering use imperial measurements and thus some measurements in this and subsequent sections are provided in inches.

4.2.5 Umbilicals and power supply

The intent is to supply power and controls from GFP infrastructure. At the time of submitting this document the options are to utilise the FCS or other alternative GFP infrastructure which are out of scope of this OPP (Section 1.4.2).

New electrohydraulic umbilicals will be installed to power each of the fields. The umbilicals will provide hydraulic power, electric power, chemicals, and fibre-optic communications. The umbilical system is a medium-voltage (~3kV[6]) system.

[6] *The umbilicals are not expected to generate an electromagnetic field (EMF) at a significant spatial scale. Previous modelling of the EMF from a high voltage (132 kV) cable found that the EMF (B field) decreased to background levels within 20 m of the cable (Ref. 84). This is a much higher voltage cable and would therefore generate a higher intensity EMF, compared to the medium voltage (3 kV) umbilicals. As they are low voltage systems, they are not considered a source of risk to electromagnetically sensitive marine fauna.*

In some cases, umbilicals will run along the same routes as the flowlines. The following proposed umbilicals are likely to follow a separate route to the flowlines:

- from the power supply to G&E, C&D and Semele
- from the power supply to one of the Jansz–Io tie-in locations (to power Chandon)
- from C&D to WTR.

Figure 4-3 shows possible umbilical routes running from the FCS to the fields. These depicted routes represent the longest possible routes of umbilicals that run in a separate corridor to the flowlines. Table 4-7 lists their lengths. Umbilical routes that correspond with flowline routes are not shown. The final routes are yet to be identified but if a different route is selected, it will be shorter and still within the OA.

A control distribution unit (CDU) may be installed at each DC. The CDU is where the umbilical from the power supply splits to distribute supply hydraulics, chemicals, power and communications to each well at the DC and to connect additional DCs.

Flying leads, which are commonly used to connect subsea equipment to a CDU, will also be required. The Development may use electrical (EFL), steel tube (STFL) and/or hydraulic flying leads (HFL).

Table 4-7: Key characteristics of umbilicals that are separate to flowlines

Power supply element	Characteristic	Field				
		Chandon	C&D	G&E	Semele	WTR
Umbilical	Diameter	Likely ~5″, up to ~18″ diameter[7]				
	Length	8 km	36 km	30 km	38 km	23 km
	Approximate footprint	1,040 m^2	4,680 m^2	3,900 m^2	4,940 m^2	2,990 m^2

4.2.5.1 Temporary contingency power supply

If the planned umbilical power supply is unavailable, temporary contingency options will be used to ensure power is available. If contingency power is required, one of the 2 options detailed below will be used at any one time at a field.

When the umbilical power supply is restored, the temporary power supply equipment will either be retrieved to surface and transported onshore for preservation and storage, or it may remain deployed on the seabed so it is available for use until planned power and controls are restored. While deployed, the equipment will be maintained and inspected as part of the ongoing maintenance program described in Section 4.3.4.3.

Subsea battery system

A subsea lithium-ion battery contingency option may be required to provide power until a longer term power supply is available. This subsea battery system (SBS) connects to the CDU at the DC, and consists of:

- battery storage skids, containing lithium-ion battery storage modules

[7] *Diameter of ~18" is at the small sections where buoyancy cans are located.*

- a power skid
- open communication hub, used to enable control of the SBS from the GTP

EFLs connecting the SBS to the CDU.

The SBS will be located beside the relevant DC on foundations such as mudmats. The footprint on the seabed is estimated to be ~500 m^2 and will be within the long-term disturbance area (Section 8.1.1.7). The battery system is a low-voltage (~600 V[8]) system.

Vessel support would be required to charge the battery every ~2–4 weeks and would take ~1 week.

Downline power system

A second contingency option is providing power via a downline system from a vessel. The downline system consists of:

- a downline umbilical
- a downline termination unit (DTU) and junction box (installed on a mudmat)
- an infield umbilical (~700 m in length) laid on the seabed connecting this equipment to a CDU
- grout bags, which may be used to stabilise the umbilical.

To ensure safe lifting near live infrastructure, the DTU needs to be located ~700 m from the CDU. While this is a contingency option, to allow for conservatism, an additional (~13,600 m^2) at each field has been included in the long-term disturbance area used for impact assessment (Section 8.1.1.7).

The vessel would use DP and would need to stay on location while providing power to the field. If this contingency option is required, there is likely to be only one downline vessel in a field at any given time (for further details refer to Section 4.3.4.3). The downline system is a low-voltage (~600 V[8]) system.

All installed power supply infrastructure will be located within the long-term disturbance area (Section 8.1.1.7).

4.2.6 GFP tie-in points

The existing GFP infrastructure includes midline pipeline termination structures (MPTS), manifolds and DCs at both the Gorgon and Jansz–Io fields. The 2 feed gas pipelines run from this infrastructure to the GTP on Barrow Island (Figure 4-1).

The flowlines and MEG pipelines from G&E and Chandon are planned to be tied-in to Jansz–Io infrastructure. From the tie-in points, hydrocarbons from these fields are planned to be transported to the GTP on Barrow Island via the Jansz

[8] *The SBS or downline contingencies are not expected to generate an EMF at a significant spatial scale. Previous modelling of the EMF from a high voltage (132 kV) cable found that the EMF (B field) decreased to background levels within 20 m of the cable (Ref. 84). This is a much higher voltage cable and would therefore generate a higher intensity EMF, compared to the low voltage (~600 V) temporary power supply systems. As they are low voltage systems, they are not considered a source of risk to electromagnetically sensitive marine fauna.*

Feed Gas Pipeline. This pipeline runs for ~134 km between the Jansz–Io MPTS to the shore crossing at North Whites Beach on Barrow Island.

The flowlines and MEG pipelines from C&D and WTR (and from Semele via C&D infrastructure) will be tied-in to Gorgon infrastructure. Hydrocarbons from these fields will be transported from the tie-in points to the GTP on Barrow Island via the Gorgon Feed Gas Pipeline. This pipeline runs for ~65 km between the Gorgon MPTS to the shore crossing at North Whites Beach on Barrow Island.

The specific locations of the tie-in points have not yet been finalised. Any tie-in points shown in figures in this OPP are indicative only and do not indicate final locations or numbers. Conservative estimates of the required infrastructure at tie-in points are provided in Sections 4.2.3, 4.2.4 and 4.2.5.

The total footprint of infrastructure installed at the tie-in points will be within the long-term disturbance area (Section 8.1.1.7); which is used for the purpose of impact assessment.

4.3 Description of activities

The following subsections outline activities associated with each phase of the Development; these grouped phases are used for the impact assessment:

- survey
- drilling
- installation and commissioning
- operations
- decommissioning
- support activities (all phases).

Survey activities (Section 4.3.1) are likely to be carried out at the beginning of the Development but will also be required at various other times.

Support activities (Section 4.3.6) may occur throughout all phases of the Development and cover common activities on vessels and facilities that are not process related. These activities include sewage and greywater discharge, refuelling and bulk transfer.

For each field, the typical progression of phases is drilling, installation and commissioning, then operations. Due to the large scale of the Development, activities from multiple phases may be happening concurrently at different fields. There is also potential for multiple Development activities to occur at the same time within a single field (e.g., drilling and pipelay).

The sequence of field development will be finalised closer to the start of the Development and will be included in future EPs.

Activities described in this section are presented based on current technologies. CAPL will continue to seek and assess emerging technologies that may provide future opportunities to reduce risk and impact. Any new technology selected for the Development will be assessed and presented in subsequent applicable EPs.

4.3.1 Surveys

Surveys, each of which may take 3–4 weeks, may be undertaken at various times during the life of the Development.

Pre-pipelay surveys will inform the final route selection.

4.3.1.1 Geophysical survey

Geophysical surveys of the activity locations may be required at various times including during engineering, before drilling, before pipelay, after pipelay and before decommissioning. The pre-lay survey will confirm the bathymetric profile along the flowline and umbilical route and identify any seabed features or obstructions that may impact activities.

Inspection programs will use various survey techniques including:

- side-scan sonar (SSS)
- sub-bottom profiler
- multibeam echo sounder (MBES)
- magnetometer
- general video inspection.

Surveys are undertaken from a vessel and are supported by ROVs or autonomous underwater vehicles (AUVs). As technology develops, future options for inspections will be evaluated.

4.3.1.2 Geotechnical survey

Geotechnical surveys of the activity locations may be required at various times, during the life of the Development. Drilling cores may be taken for in situ testing and sample collection.

Surveys are undertaken from a vessel and are supported by ROVs/AUVs. The indicative footprint associated with geotechnical equipment is ~2 m^2 per deployment. Multiple deployments may be required at each location, giving a conservative footprint of ~20 m^2 per survey location. If drilling cores are taken, the footprint for the borehole sampling unit is expected to be ~14 m^2 at each location.

4.3.2 Drilling

Drilling will be carried out using a MODU.

Multiple wells will be drilled in each field, with each well taking ~3 months to drill, depending on well depth (Table 4-8).

Drilling activities are expected to take up to 24 months per field (assuming the maximum number of wells are drilled).

The MODU will position at each DC and drill multiple wells. Drilling may be undertaken across multiple campaigns, so the MODU may return to a particular DC for further drilling activities.

Table 4-8: Estimated duration for the drilling phase

Characteristic	Field				
	Chandon	C&D	G&E	Semele	WTR
Maximum number of wells	8	8	8	8	8
Number of DCs	2	3	1	2	2
Estimated total duration	24 months	24 months	24 months	24 months	24 months

The well design details are subject to change. As per the *Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011*, detailed well designs will be submitted to NOPSEMA via a Well Operations Management Plan (WOMP). Drilling will not begin until after the WOMP has been accepted by NOPSEMA.

4.3.2.1 MODU positioning

The type of MODU has not yet been finalised and depending on the water depth, may be a semisubmersible, drill ship or jack-up (also referred to as a self-elevating MODU). The MODU will moor or be positioned at each DC to drill wells in that area.

The MODU will either be moored using anchors connected to mooring chains or kept on location with DP using thrusters; or, in the case of a jack-up, be positioned on the seabed with legs. A jack-up MODU is only feasible at WTR due to the shallower water.

The MODU used may be supported by anchor-handling tugs as it moves between drilling locations (Section 4.3.6).

If a mooring system is used, up to 16 drag embedment anchors will be required; these will be placed on the seabed then set and pre-tensioned by support vessels before the MODU arrives. At each location, the area of benthic habitat disturbed by anchoring is estimated to be up to 28,480 m^2.

If the MODU is moored, the anchors may be outside the long-term disturbance area (Section 8.1.1.7).

If a jack-up MODU is used, 3 legs with spud cans will sit on the seabed. The legs are first soft-pinned, preloaded, then the rig is elevated to working height. At each location, the area of benthic habitat disturbed by the legs is estimated to be ~950 m^2.

Transponders may be used to accurately position the MODU over the proposed well locations. Transponders are attached to clump weights, lowered onto the seabed and then retrieved after positioning is finished.

4.3.2.2 Drilling top- and bottom-holes

Drilling will begin with the top-hole section and proceed in this sequence:

- Commence drilling of initial riserless hole section, run a conductor casing and cement it back to the seabed. Use sea water with high-viscosity gel sweeps and discharge cuttings at the seabed.

- Drill a further, deeper riserless section, run a casing string and cement it to the mudline. Use sea water with high-viscosity gel sweeps and discharge cuttings at the seabed.
- Following installation of the BOP and riser, drill next section to the required depth and cement a casing string into position. Use water-based fluids (WBF) or nonaqueous drilling fluids (NADF) and discharge cuttings at the sea surface.
- Drill the final section/s and cement a production casing string into place. At total depth, set the production liner into position. Use NADF and discharge cuttings at the sea surface.

The required depth of each step depends on the formation and reservoir details specific to the field and drilling location.

4.3.2.3 Drilling fluids and cuttings handling

The initial stages of drilling will use sea water with high-viscosity gel sweeps, with cuttings circulated to the seabed. High-viscosity sweeps comprise ~90% sea water, with the remaining 10% made up of drilling fluid additives that are either completely inert in the marine environment, naturally occurring benign materials, or readily biodegradable organic polymers with a very fast rate of biodegradation in the marine environment.

Drilling additives typically used include sodium chloride, potassium chloride, bentonite (clay), cellulose polymers, guar gum, barite, and calcium carbonate.

Throughout the drilling program various fluids will be run through the closed circulation system including, but not limited to:

- NADF—such as: a hydrocarbon, ether, ester, or acetal, organophilic clays, barite, lime, aqueous chlorine, rheology modifiers, fluid loss control agents and emulsifiers
- WBF—such as: water or saltwater, bentonite clay, barite and gellants (e.g. guar gum or xanthan gum)
- sea water
- suspension/completion brine.

Specific drilling fluid details will depend on conditions encountered on site.

Once the top-hole section is complete, installing the riser and BOP provides a conduit back to the MODU, forming a closed circulating system allowing solids control equipment to remove cuttings from drilling fluids before being recycled and circulated back to the MODU. Solids control equipment may include:

- vibrating screens (shale shakers)
- centrifuge
- cuttings dryer.

Cuttings are expected to range from very fine to very coarse (<1 cm diameter) after separation from the drilling fluid, and will likely comprise predominantly claystone, marl, and calcilutite from the upper sections of the wellbore, and sandstone and siltstone from the lower sections.

Tanks used to store NADF will be emptied and cleaned after drilling is completed. NADF tank washing residue (<1% residual hydrocarbon) may be discharged to the marine environment.

Volumes of drilling fluids and cuttings that are released to the environment will depend on the field and well site. Details of estimated volumes are provided in Table 8-44 in the Planned discharges—Drilling impact assessment (Section 8.8).

4.3.2.4 Cementing operations

During drilling, cement is used to seal the space between the casing and the formation, and for permanently positioning the casing into place. Once a job is completed, the cement unit is cleaned, and the residual cement discharged overboard.

In the rare event that the cement products become contaminated, the entire volume (~78 m^3) may need to be discharged to sea.

Details of all estimated cement discharge volumes are provided in Table 8-44 in the Planned discharges—Drilling impact assessment (Section 8.8).

4.3.2.5 Pressure-control equipment installation

The BOP is installed after the top-hole sections of the well have been completed.

Because BOPs are critically important to the integrity and safety of the MODU and the well, they are inspected, tested, and refurbished at regular intervals. The timing is determined by a combination of manufacturer recommendations, risk assessment, local practice, well type and legal requirements.

BOPs release small volumes of water-based hydraulic control fluid to the marine environment during function and pressure tests; ~2.5 m^3 for a full function test, and potentially a small amount of MEG with hydrotesting dye.

Regular ongoing function and pressure tests will occur during the drilling phase.

4.3.2.6 Well suspension

Well suspension (including de-suspension) may be required after drilling and during operations (Section 4.3.4.5).

During well suspension activities, small volumes of reservoir methane gas may need to be handled back to the rig. These volumes would be too small for flaring and would be cold vented to the atmosphere.

Following suspension, a wellhead cap may be installed to provide mechanical protection to the wellhead and protect it from marine growth. To inhibit marine growth or corrosion, ~210 L of a dilute biocide and corrosion inhibitor is injected into or placed within the wellhead cap.

4.3.2.7 Completions installation

Well completion steps include casing, cementing, perforating, installing screens, gravel packing and installing a production tree.

Completions generally follow this sequence:

- install lower completion, which may be a liner or screen assembly (no discharge to the environment)
- run wellbore clean-up (casing scrapers, circulate well to clean fluid)

- run the production tubing, including the wellhead (at surface).

The tubing will include safety and production devices; specifically, a downhole subsurface safety valve placed ~500 m below the seabed.

Bottom-hole completions options are to:

- install standalone sand screens
- install sand screens with gravel pack
- install slotted liners
- case-and-perforate style completions.

Completion brines will be released during this activity. The worst-case volume is ~500 m^3 at the end of each well campaign.

4.3.2.8 Production tree installation

Finally, a subsea production tree will be installed just above the seabed, supported on the main conductor from a MODU or support vessel. Installation would involve:

- Remove wellhead cap (if in place). Biocide and corrosion inhibitor may be released. The cap is then cleaned using mechanical means or seawater jetting, or a few litres of acid if there are calcareous deposits.
- install isolation plug
- remove BOP
- install production tree on the conductor. May release a few litres of hydraulic control fluid and dilute biocide and corrosion inhibitor.
- rig up slickline pressure-control equipment and recover isolation plug
- rig down slickline pressure-control equipment.

After installation, testing is carried out to confirm the pressure integrity of the production tree and to confirm that it is secured in place. Valve functionality testing will discharge small volumes of control fluid to sea.

4.3.2.9 Well clean-up and testing

Wellbore and casing clean-up is required at various stages of the drilling activity to ensure the contents of the well are free of contaminants before the next stage of drilling. Cleaning agents and other chemicals may be used to remove residual fluids (including drilling and completion fluids such as NADF) from the wellbore.

During the clean-up process, fluids are circulated back to the MODU, and may be analysed before they are discharged overboard. Any displaced fluid that has the potential to contain contaminants or oil is analysed for residual hydrocarbons before discharge.

Wells may be subject to a flowback at the end of the completions phase.

Flaring may be undertaken during flowback. If required, it will have a duration of ~1 day per well. Unforeseen circumstances such as weather events, may cause the flaring to be done again. As flaring is not planned to be undertaken at all wells, the duration estimate is ~1 day per well for impact assessment. Flaring will only occur from one well at a time.

4.3.2.10 Well evaluation

The wells may be evaluated using ‘logging while drilling’ techniques and mud logging. Wireline logging and formation testing/sampling may be done based on the results of the primary evaluation tools.

Wireline evaluation may be undertaken to determine rock and fluid properties of the targets. A suite of standard wireline logs may be run, including gamma ray, neutron-density, resistivity, sonic, acquisition of pressures and fluid samples, vertical seismic profiling (VSP), and side-wall coring.

While some well evaluation tools contain radioactive sources no radioactive material will be released to the environment. Generally, radiation fields are not detectable outside the tool if it is not energised; therefore, radiation does not present an environmental risk.

VSP uses a small airgun array as an acoustic source to generate a high-resolution seismic image of the geology in the well’s immediate vicinity and it may take up to 24 hours to complete, depending on the wellbore’s depth and the number of stations profiled.

4.3.3 Installation and commissioning

The installation and commissioning phase includes installing flowlines and other infrastructure, stabilisation works, and testing. Commissioning activities ensure that all components of the system are installed, tested, and function as per the project design documentation and specifications. Once commissioning is complete, start-up activities will introduce hydrocarbons to the system. Installation, commissioning, and start-up activities involve:

- pre-lay works and associated surveys
- excavation and trenching
- pipelay
- installation of structures, spools, jumpers, and umbilicals
- post-lay works and associated surveys
- hydrotest and pre-commissioning
- commissioning
- start-up.

The duration of installation and commissioning activities will vary for each field due to the differences in flowline and pipeline lengths, location, and infrastructure. The durations of the main activities have been estimated for the impact assessment, but do not include potential delays such as weather events and vessel mechanical downtime.

All seabed disturbance from installation and commissioning is located within the long and short-term disturbance area (Section 8.1.1.7).

4.3.3.1 Pre-lay works

Pre-lay works will vary depending on the flowline option or infrastructure installation being undertaken. Pre-lay activities are done to ensure infrastructure is installed on a solid, supported foundation. If seabed surveys show a clear pipelay route, minimal seabed preparation will be required before laying the flowlines, MEG pipelines and umbilicals.

Suction piling or gravity foundations may be used. Mattresses and foundations are commonly used in pre-lay works.

The total number of stabilisation elements will not be known until the pre-lay survey is performed. All stabilisation elements will be installed within the long-term disturbance area (Section 8.1.1.7).

Table 4-9 details the materials commonly used in pre-lay works.

Table 4-9: Key characteristics of pre-lay materials

Stabilisation materials	Description
Mattresses / grout bags	Usually made of concrete. Mattresses may be installed in groups and may be stacked on top of each other.
Foundations	Can be made of steel or concrete. Includes mudmats. Placed underneath structures such as manifolds.
Adjustable pipe support	A-frame structures on a mudmat foundation that supports and aligns loads in adjacent infrastructure.
Global buckling mitigation structures	Can be made of steel or concrete. Used to support the pipeline / flowline above the seabed.

In addition, an initiation anchor (deadman anchor) or suction pile will be deployed to fix the end of the flowline in place at the beginning of pipelay. A suction pile is installed by lowering a bucket to the seabed and pumping the entrapped water out of it to form suction. One initiation anchor or suction pile and its wire are required for each flowline. The anchor or pile is installed up to 3,000 m behind the flowline or MEG pipeline and the initiation wire is laid out on the seabed to the end of the flowline or MEG pipeline. These anchors and wires are recovered from the seabed at the end of the pipelay process.

If third-party infrastructure is present within 3,000 m of the start of the flowline, the initiation anchor will be positioned to avoid the infrastructure.

Pipeline crossings

The Development will require at least 2 pipeline crossings:

- The C&D flowline will cross the Jansz Feed Gas Pipeline and umbilicals.
- The WTR flowline will cross the Jansz Feed Gas Pipeline and umbilicals.

Three of the proposed umbilicals may also cross the Jansz Feed Gas Pipeline.

If new flowlines, MEG pipelines or umbilicals need to cross existing pipelines, pipeline supports would usually be laid on either side of the pipeline. Crossings may influence flowline or MEG pipeline routes as they may need to cross at close to 90 degrees as practicable.

Mattresses, ramping, plinths, or rock berms may be used at crossings. The footprint of these supports will be larger where new flowlines or MEG pipeline cross existing pipelines than where new umbilicals cross pipelines. If a flowline or MEG pipeline crosses an existing pipeline, the supports may extend for 500 m along the flowline or MEG pipeline but will be within the 30 m long-term disturbance area (Section 8.1.1.7).

If any third-party pipeline crossings are required, the details will be negotiated with the third-party.

4.3.3.2 Excavation and trenching

The C&D flowline and MEG pipeline route will cross the scarp to tie-in to the Gorgon Feed Gas Pipeline.

Excavation may be required at the top of the scarp to create a suitable seabed profile for the flowline and MEG pipeline, thus preventing the flowline/pipeline from exceeding their strength and fatigue limits. Excavation of the scarp was required during the GFP for the Jansz pipeline; the methodology used in this Development would be similar.

Based on the excavation undertaken for the existing Jansz pipeline, the trench required is estimated to be ~12 m wide, 50 m long and 8 m deep. More accurate estimates will not be available until the final route is selected, engineered and pre-lay surveys are performed. The final trench dimensions will be included in subsequent EP/s.

An umbilical may also run over the scarp—the trenching required will be smaller in scale than for the flowline.

Excavation and trenching using either high-pressure jetting/mass flow excavation or mechanical excavation are not planned along other parts of the flowlines but may be required. Excavation alongside infrastructure may be required to gain access for inspection or minor repairs at any time during the Development.

Drilling or blasting will not be used as an excavation method.

Spoil generated will be left in situ and will be within the long-term disturbance area.

Rock stabilisation or rock dumping may be required as a contingency. A barge would transport rock, then a vessel with specific capability would transfer the rock to the seabed (see Section 4.3.3.5).

4.3.3.3 Installation of flowlines, MEG pipelines and PLETs/PLEMs

Flowlines and MEG pipelines will primarily be installed using an S-lay or J-lay technique. Some smaller diameter flowlines and MEG pipelines may be installed using the reeling technique, where feasible.

S-lay installation methods involve welding the pipe joints on the vessel and then lowering pipe off the vessel over a support structure that extends behind the vessel.

J-lay installation methods involve lowering the pipe off the vessel in an almost vertical position. The pipe joints are welded inside the lay tower on the vessel before being lowered through the water column to the seabed.

Where the reeling technique is used, the flowline or MEG pipeline is welded together at an onshore spool base, reeled onto an installation carousel, transported to the OA via installation vessel and installed.

PLET or PLEM structures may be installed at each end of the flowlines or MEG pipelines to a spool. The structure is welded to the ends of the flowline or MEG pipeline on board the installation vessel and then is lowered to the seabed.

The largest flowline used for the Development will be a 24″ diameter production flowline. As detailed in Section 8.1.1.7, assessment of seabed disturbance uses the long-term disturbance area which is 30 m wide to encompass infrastructure and materials around the lines, as well as the trench.

The speed of pipelay varies depending on water depth, pipeline/flowline type and installation technique. The estimated duration of flowline installation is 3-6 months per field, including excavation.

4.3.3.4 Installation of subsea structures

The subsea structures associated with the Development include manifolds, pipeline termination structures, tie-in structures, slug catchers, over-pressure protection structures, jumpers, spools, in-line tees, umbilicals and CDUs.

Some of these—manifolds, pipeline termination structures, tie-in structures, in-line tees and CDUs—may be installed on foundations (e.g. steel mudmats or concrete mattresses) (Section 4.3.3.1) or directly onto the seabed.

Before installing any structure, jumper or spool, a seabed survey will be conducted to ensure there are no obstacles that may hinder installation activities. If debris or an obstruction is encountered, it will be cleared, if possible. If a significant obstruction is encountered, the alignment will be rerouted (but will remain within the OA).

Equipment may also need to be stored on the seabed as a contingency, in response to events such as cyclone demobilisation.

The estimated duration of subsea structure installation is 4 months per field.

Jumpers and spools

Before connection of jumpers and spools, any marine growth and calcareous build-up present on existing subsea structures that will be tied-in to will be removed via mechanical cleaning, acid wash or similar. Only small volumes of chemicals will be used for acid washing, and these chemicals will be applied directly to infrastructure. The volume will depend on the type of infrastructure and would be ~100 L to 1,000 L per application.

Jumpers and spools will be lowered by crane to the PLETs/PLEMs, manifolds, pipeline termination structures, tie-in structures, slug catchers, over-pressure protection structures, in-line tees and production trees. During tie-in of jumpers and spools, a small amount of preservation fluid will be released. Preservation fluid generally comprises treated water, MEG, and conditioning chemicals. The volume per tie-in is expected to be ~15 m^3 but is likely to be much lower.

Tie-in of jumpers and spools will be supported by ROVs or AUVs.

In-line tee

The in-line tees are likely to be welded into the flowline or MEG pipeline on board the pipelay vessel (PLV) and laid along with the flowline or MEG pipeline.

Umbilicals

The umbilicals will be installed by a lay system or carousel, assisted by cranes. Umbilicals will be reeled off the vessel and connected to the CDU. During connection to the CDU there is potential for a small volume of hydraulic control fluid to be released. A larger volume may be released if the initial connection is unsuccessful.

The other end of the umbilicals will be connected to the FCS or the alternative power supply.

Following the connection, umbilicals will be leak tested using hydraulic control fluid. On completion of the leak test, it is estimated that a small volume of this control fluid will be released into the environment. The largest single release of hydraulic control fluid during connection to the CDU and leak testing is estimated to be 2.5 m^3.

Flying leads

Flying leads will be installed via reels (for STFLs) and deployment frames (for EFLs and HFLs) from the installation vessel. Flying leads will be connected to the various structures by ROV.

Flying leads may need to be stabilised after installation (Section 4.3.3.5).

Other subsea structures

Manifolds, pipeline termination structures, tie-in structures, slug catchers, over-pressure protection structures and CDUs will be lifted off the installation vessel by an onboard crane and then deployed to depth. Structure positioning may be controlled using pre-installed baseline seabed arrays.

4.3.3.5 Post-lay works

Post-lay works (e.g. span rectification, stabilisation of flowlines and umbilicals) may be required, depending on the results of any post-lay surveys. A range of stabilisation methods may be used such as concrete mattresses and grout bags. Stabilisation may occur during installation, operations, or decommissioning.

Concrete mattresses and grout bags (Table 4-9) typically have a footprint of up to 27 m^2.

Rock dumping is not planned but may be required, so it is included in this OPP as a contingency. Rock dump material may be sourced from outside Australia. A barge would transport rock, then a vessel with specific capability would transfer it to the seabed.

The total number and location of these stabilisation materials will not be known until the post-lay survey is performed. All post-lay materials will be installed within the long-term disturbance area (Section 8.1.1.7).

4.3.3.6 Hydrotest and pre-commissioning

Following installation, the flowlines and MEG pipelines will undergo flood, clean, gauge and testing (FCGT), leak testing and pre-commissioning (conditioning). The estimated duration of hydrotest and pre-commissioning is 2 months per field. Planned discharges will generally be released at controlled discharge rates.

The pig launchers and receivers used will be temporary. They will be deployed, attached to a suitable connection point, and then removed when the process is complete.

FCGT

During FCGT activities, flooding, and gauge pigs pre-installed in the laydown/initiation head on one end of the flowline or MEG pipeline are sent through, driven by the FCGT media. FCGT media will be discharged to the environment after pigging; this typically contains MEG, treated water and conditioning chemicals.

During FCGT activities, treated water will be used to flood the flowline and MEG pipelines may be flooded with treated water or MEG/ treated water blend.

Treated water may contain a range of chemical additives such as biocide, oxygen scavenger, corrosion inhibitor, clear dye, and buffering solutions.

Leak testing

To conduct leak/barrier testing, the system is pressurised using a blend of MEG and/or treated water. After testing, depressurisation may discharge small volumes of test fluid to the environment.

During valve actuation, a small amount of hydraulic control fluid will be released to the marine environment from the valves and chokes on the production trees, manifolds, and other infrastructure.

Pre-commissioning

After leak testing and prior to when commissioning starts, the flowline or MEG pipeline will be dewatered and conditioned with a MEG/treated water blend preservation media, compressed air and/or nitrogen.

If MEG/treated water blend preservation media is used, several releases of the preservation media will occur while deploying the subsea pig launcher receiver (SSPLR)—from the SSPLR at the tie-in points, during pigging and when removing the SSPLR. The flowline will be left filled with a MEG/treated water blend ready for commissioning.

If compressed air or nitrogen is used for dewatering, the flowline will be conditioned, dried, and then packed with nitrogen to inert and preserve it, until commissioning and operations begin. Nitrogen and/or air will be vented in the OA as part of this process, primarily at the sea surface through a downline running between the flowline and a vessel.

Treated water and MEG/treated water blend may also be released during dewatering and conditioning at the SSPLR at the seabed. MEG pipelines may be dewatered with MEG/treated water blend.

Hydrotesting and pre-commissioning volumes

Table 4-10 lists the estimated volumes of the largest single discharges as a result of hydrotesting and pre-commissioning activities. The volumes in this table are based on the longest flowline in the Development (Chandon at ~60 km), and therefore are the largest discharge volumes expected for each material. These values are included to allow for impact assessment using the volume likely to have the most significant impact.

Table 4-10: Estimated discharge volumes from hydrotesting and pre-commissioning for a single field

Discharge type	Volume (per event)	Discharge location
Treated water	35,000 m^3	DC or GFP tie-in point At seabed
MEG	1,750 m^3	DC or GFP tie-in point At seabed

Discharge type	Volume (per event)	Discharge location
Hydraulic control fluid	2.5 m^3	DC or GFP tie-in point At seabed
Nitrogen gas / Compressed air	5,250,000 m^3	DC or GFP tie-in point At sea surface

4.3.3.7 Commissioning (verification and pre-start-up testing)

Verification and pre-start-up testing activities may include testing subsea valves, testing the emergency shutdown of infrastructure, and leak testing jumpers. These tests are likely to result in small discharges of hydraulic control fluids and MEG / treated water blend from valves.

These activities will be supported by a vessel (see Section 4.3.6.2 for vessel operations) and ROVs equipped with video cameras.

During commissioning of the production flowlines, dry hydrocarbon gas (methane sourced from the GTP) will be used to pressurise the flowline in readiness for the start-up phase. There may be a requirement to purge some or all of the pre-commissioning nitrogen gas at the end of the flowline at the seabed. This would result in a controlled release of a maximum of ~25,000 m^3 nitrogen gas, followed by a maximum of ~25,000 m^3 methane (based on the longest flowline in the Development).

The displacement and flushing of nitrogen from the flowline and pressurisation of the flowline with methane is required to prepare the flowline for further commissioning work. Pressurisation will be required to de-isolate the flowline from the existing production system at operating pressure in readiness for the start-up phase of the system.

4.3.3.8 Start-up (introduction of hydrocarbons)

Start-up activities commence with the controlled introduction of reservoir hydrocarbons into the infield production flowlines and production pipeline. The subsea infrastructure (including the MEG pipelines and the umbilicals) are then further function tested.

During the introduction of reservoir hydrocarbons, residual drilling fluids (within the wells) and other residual fluids (which may include MEG/water preservation media and nitrogen), within the flowlines will be displaced via production fluids from the production trees back to the GTP.

The estimated duration of commissioning (Section 4.3.3.7) and start-up is 3 months.

4.3.4 Operations

The principal activity during operations will be the flow and transportation of hydrocarbons and other produced fluids from the wells to the GFP tie-in points, and then to the GTP for processing.

Section 572(2) of the OPGGS Act requires a titleholder to maintain in good condition and repair all structures, equipment, and other property that is within the title area and is used in connection with the operations authorised by the title. Subsea infrastructure IMR activities are undertaken to ensure that the integrity of the hydrocarbon system is maintained.

IMR activities may occur at any time during operations, as well as during the commissioning and start-up phase.

Activities associated with operations include:

- operation of the hydrocarbon system
- inspection
- maintenance and repair
- major repairs
- well intervention.

At the operations phase, the Development activities will generally be consolidated with, and carried out as part of, the ongoing GFP operations.

The duration of operations will be 10–30 years, depending on the field. Section 4.1.4 has further details on timing and duration of operations.

4.3.4.1 Operation of the hydrocarbon system

During the operations phase, the hydrocarbon system will be a permanent fixture on the seabed of the OA. This system includes flowlines, manifolds, and other structures, and is described in detail in Section 4.2.

This subsea infrastructure is predominantly a closed system; however, there are discharge points (valves) located at the subsea electrohydraulic control systems and at production trees and manifolds (as described in Section 4.2). Operation of this system will result in discharges of hydraulic control fluid to the marine environment from the valves, with each valve actuation estimated to result in a loss of, on average, a few litres to the marine environment.

If field shut-in is required, system verification and pre-start-up testing will be required before start-up (see Section 4.3.3.7).

4.3.4.2 Inspection

Inspections provide assurance that infrastructure integrity is being maintained and equipment is being operated according to design. Inspections also proactively identify maintenance or repair activities that may be required. Inspections are generally conducted using a vessel and AUV or ROV.

Inspections will be undertaken with a frequency determined based on risk. Inspections are typically conducted more often during early operations, with the frequency likely to decrease during steady-state operations, depending on previous inspection results. Events such as cyclones or seismic activity that could affect the subsea infrastructure may also trigger inspections.

Inspection will be undertaken by a vessel and ROV or AUV and techniques may include but are not limited to:

- visual inspections
- marine acoustic surveys
- non-destructive testing
- cathodic protection measurements
- fatigue monitoring/inspection

- pigging

Some inspections may require the use of specialised monitoring equipment, SSS and MBES which are typically done from a vessel using towed acoustic instruments, ROVs, or AUVs (see Section 4.3.1)

Section 4.3.6 includes details of vessels, AUVs and ROVs.

4.3.4.3 Maintenance and repairs

Maintenance and repair activities, including equipment change-out, will be conducted during the operational life of the Development to:

- prevent deterioration and failure of infrastructure
- maintain reliability and performance of infrastructure
- ensure infrastructure is adequately maintained to enable the potential for future removal.

The exact frequency of maintenance and repair activities depends on the results of inspections. If minor maintenance or repair is required, vessels may remain on site for an estimated ~6 months. If major maintenance or repair is required, vessels may be on site for an estimated ~12 months.

Maintenance and minor repairs (and any associated testing) may include, but are not limited to:

- module/component/infrastructure change-out
- rectification and stabilisation activities
- cathodic protection system maintenance
- hydrate remediation
- sediment removal/ excavation to gain access to, or enable minor repairs of, infrastructure
- removing marine growth and calcareous deposits
- maintenance and repair activities typically require support vessels (see Section 4.3.6.2).

4.3.4.4 Major repairs

In the unlikely event that major repairs are required during the life of the Development, CAPL will use Emergency Pipeline Repair System (EPRS) equipment. The EPRS delivers a set of repair procedures and common repair equipment for repairing or replacing a range of infrastructure (including flowlines) and includes methods for repairing support infrastructure such as umbilicals and non-production pipelines.

The target repair duration is between ~6 and 12 months—from mobilisation of equipment and vessels, undertaking in situ repair, to recommissioning. Several vessels are likely needed to conduct and support the repair works or provide temporary power and controls to maintain system operability and reliability.

Repairing a flowline is the most complex major repair activity. To support this, the EPRS includes equipment that enables a section of the production flowline to be cut out and replaced. This equipment is deployed off the back deck of a support vessel and supported with ROVs. The EPRS equipment includes:

- hydraulic-actuated pipeline lifting and repair equipment deployment frames
- pipe preparation tools, including but not limited to, coating removal, weld seam removal, end preparation, and water blasting equipment
- pipeline-specific repair clamps and flange adapters.

Major repair activities on a flowline can be divided into temporary decommissioning, repair, and recommissioning phases, with the use of contingency power if required.

Pipeline temporary decommissioning

If a major defect or full-bore rupture occurs, the field would be shut-in, and the flowline allowed to naturally depressurise to subsea ambient pressure with sea water. The flowline would then be flooded with treated water (water inhibited with chemical additives including biocide and oxygen scavenger) that will propel a pig towards the defect.

This may result in discharges of treated water, sea water, residual gas condensate and MEG at the location of the defect. Discharges of treated water from this activity would be smaller than the 2 full flowline inventories assessed for pipeline recommissioning (~35,000 m^3 based on the longest flowline). Treated water may have some hydrocarbon content.

Pipeline repair

Pipeline repair includes these stages:

- undertaking a pre-deployment survey—the survey type depends on location and the event causing the defect but may include techniques described in Section 4.3.1. The flowline may require unburial or rock removal before repair, resulting in seabed disturbance.
- removing the damaged section.
- deploying the EPRS.
- installing the replacement section—after the flowline is installed, the entire flowline is then typically leak tested; this may involve the techniques described in Section 4.3.3.6.
- stabilising the pipeline (if required)—stabilisation needs will depend on the specific location and stabilisation types may include those described in Section 4.3.3.5.

Pipeline recommissioning

Following the successful leak test, the flowline must be recommissioned via a dewatering and conditioning pig train. The re-commissioning activity is similar to pre-commissioning and commissioning (Section 4.3.3.6).

The flowline contents will be discharged subsea at the appropriate GFP tie-in points.

4.3.4.5 Well intervention

Well intervention generally occurs within the wellbore and may include the following activities, as well as any other drilling activities described in Section 4.3.2:

- well logging activities (slickline, wireline, coil tubing)

- well testing and flowback
- well workovers
- replace/repair of well equipment (including casing, tubing, completions)
- drill a side-track wellbore
- suspend the well (Section 4.3.2.6).

CAPL estimates that intervention on a single well may be required once a year; however, intervention activities may be more or less frequent depending on well performance.

During intervention activities, local control of the production trees may be required, which would release small volumes of hydraulic control fluids to the environment. Intervention activities also include removing marine fouling by mechanical or acid soaking, resulting in the release of marine-fouling debris and small amounts of acid to the environment. When retrieving intervention tooling, small volumes of wellbore fluids may be displaced back into the well using nitrogen gas. The nitrogen will then be vented to the environment.

If discharges are required during intervention, they will be the same types as during drilling, but the volumes will be lower than those estimated for drilling.

Flaring may be required as part of well intervention. If required, it will be infrequent, and the duration is likely to be ~1 day per well. In the event of unforeseen circumstances, flaring may need to be done again. As flaring is not planned to be undertaken at all wells, the duration estimate is ~1 day per well for impact assessment.

Venting may also be required during well suspension activities. Small volumes of methane may need to be handled back to the rig but would be too small for flaring and therefore would be cold vented to the atmosphere.

4.3.5 Decommissioning

4.3.5.1 Regulatory obligation and decommissioning planning

CAPL recognises its obligations under the OPGGS Act related to the decommissioning of offshore infrastructure. In accordance with the OPGGS Act the following decommissioning requirements apply to the Development:

- Full removal (referred to as the ‘base case’) or otherwise satisfactorily dealing with structure, equipment, and property.
- Alternative arrangements from the requirement to remove property are subject to agreement and approval via acceptance of an EP by NOPSEMA.
- Design for all fields will be undertaken to meet the requirement for full removal of structures, equipment and property.
- All structures, equipment and property in the title area will be maintained in a state to ensure full removal can be achieved, unless a deviation from full removal has previously been accepted by NOPSEMA via acceptance of an EP.
- Decommissioning will occur as either a standalone campaign or as part of a wider decommissioning campaign. Progressive decommissioning including progressive well plug and abandonment and progressive removal

of structures, equipment and property or seeking acceptance for alternative arrangements will be undertaken in accordance with timeframes outlined in regulatory policy and guidelines. Any deviation to timeframes beyond those within regulatory guidance will be agreed with the regulator via the EP assessment process.

- Where required, environmental survey, site rehabilitation and monitoring will be undertaken.

These requirements are detailed within CAPL's Asset Retirement philosophy that aligns with key regulatory requirements and expectations for decommissioning offshore infrastructure.

4.3.5.2 Decommissioning overview

Activities associated with decommissioning will be conducted to ensure the requirements of the OPGGS Act s.572 are undertaken to the satisfaction of NOPSEMA. These activities are likely to include, but are not limited to:

- studies and survey activities
- suspending wells—if applicable
- well P&A
- flushing and cleaning flowlines
- removing flowlines
- removing other subsea structures and infrastructure
- post well abandonment and decommissioning monitoring (where required).

The list above does not indicate a particular sequence (e.g. flushing and cleaning may begin before well P&A can be carried out).

The following subsections describe the decommissioning activities at a high level based on current technologies and methodologies. Over the Development's operational life, CAPL will continually investigate and evaluate technology advances and opportunities for different approaches. Where new methodologies or technology are proposed to be used for decommissioning that have not been specifically considered in this OPP, they will be evaluated and approved under the EP process before deployment.

4.3.5.3 Studies, surveys, and monitoring

Details of surveys to be undertaken during the operational life of the asset will be provided in the respective EPs for each phase of the Development, when design has been finalised.

Studies and surveys that may be needed include:

- environmental surveys and studies to inform understanding of environmental conditions within the title areas including benthic, physicochemical and/ or biological surveys, if required
- review of IMR surveys during operations to confirm infrastructure integrity
- surveys of infrastructure to confirm burial status, condition of infrastructure including structural integrity for removal
- as-left survey following decommissioning activities

- monitoring surveys, as determined on a case by case basis, in consideration of the impacts and risks, and as agreed within a decommissioning EP accepted by the NOPSEMA.

An overview of some these surveys is provided in Sections 4.3.1, 4.3.3 and 4.3.4.2.

4.3.5.4 Flush and clean

When the Development fields are ready for decommissioning, the flowline contents will be flushed to remove hydrocarbons, and flowlines will be decontaminated if necessary.

Options for decontaminating the flowlines will be considered in more detail closer to end of field life and be informed by results of contaminant surveys.

Materials used for flushing and decontamination may include surfactants, hydrochloric acid, and MEG. Mercury and hydrocarbons may be present in the flushing materials after decontamination and will be managed accordingly.

Fluids from flushing and cleaning activities will be assessed and either captured for onshore disposal or discharged with necessary approvals in place.

4.3.5.5 Flowline and MEG pipeline decommissioning

Each flowline and MEG pipeline may be filled with sea water following flushing and cleaning; this would subsequently be released to the marine environment during decommissioning. The sea water may contain residual hydrocarbon, mercury, NORMs, surfactants, hydrochloric acid, or MEG. The volume of sea water that is likely to be released is determined by the flowline and MEG pipeline inventory (a maximum of 17,500 m^3 based on the longest flowline).

Implementing the base case removal requirement would involve some preparatory works such as jetting, mass flow excavation (MFE) or mechanical grab to remove sediment that has built up over the project’s life and allow access for cutting tools.

The flowlines and MEG pipelines may be removed in various ways. Current methodologies include:

- cut and lift
- reverse S-lay
- reverse J-lay.

4.3.5.6 Umbilical decommissioning

To facilitate removal, some preparatory works may be required, as described in Section 4.3.5.5.

The umbilicals may be removed in various ways. Current methodologies include:

- reverse reel
- recovery to carousel
- recover and cut on vessel deck.

4.3.5.7 Other subsea structures decommissioning

Manifolds and other structures (e.g. PLETs, production trees) will be flushed and cleaned as far as practicable during flowline flushing. Fluids from flushing and cleaning activities will be assessed and either captured for onshore disposal or discharged with necessary approvals in place.

Activities to facilitate removal of the remaining subsea structures and infrastructure may involve:

- disconnecting spools, jumpers, manifolds, and any other medium-to-large structures and preparing them for recovery
- removing overburden or sediment to get access for cutting, water jetting, MFE or mechanical excavation.

4.3.5.8 Well plug and abandonment

Well plug and abandonment (P&A) procedures involve isolating the reservoir and verifying this isolation, all with the intent of preventing the release of wellbore fluids into the marine environment. During abandonment, along with a range of associated activities, cement and mechanical plugs or another suitable barrier may be set within the wellbore to form a permanent reservoir barrier, and the severing and removal of the conductor, surface casing and wellhead at mudline or below.

Once production has ceased, wells will be shut in and monitored as part of IMR activities until well P&A is undertaken.

At this stage, it is assumed that well suspension and well P&A activities will be performed with either a MODU similar to that used for drilling, using drag embedment anchors for mooring or DP (Section 4.3.2.1). Well suspension is discussed in Section 4.3.2.6.

4.3.6 Support activities

Support activities associated with the Development will encompass MODUs, vessels, helicopters and ROVs. These support operations cover common activities occurring across all the activity phases (e.g. surveys, drilling, operations) which are not process related – such as sewage discharge, navigational lighting, and refuelling.

The support requirements will vary depending on phase (Table 4-11).

Table 4-11: Support activities for each development phase

Support activity		Development phase				
		Survey	Drilling	Installation	Operations	Decomm'g
MODU			✓		✓ If required	✓
Vessels	Survey vessels	✓	✓	✓	✓	✓
	Operational support vessels		✓	✓	✓	✓
	PLV and cable lay vessels			✓		✓
	Construction vessels			✓	✓	✓

Support activity		Development phase				
		Survey	Drilling	Installation	Operations	Decomm'g
	Supply vessels		✓	✓	✓	✓
Helicopter			✓	✓	✓	✓
ROV/AUV		✓	✓	✓	✓	✓

4.3.6.1 MODU operations

The MODU used will be semisubmersibles, drilling ships, intervention vessels or potentially a jack-up for shallow water well activities.

Semisubmersibles are a type of floating vessel that is supported primarily on large pontoon-like structures submerged below the sea surface; whereas drillships and intervention vessels are typically a vessel modified to include a drilling rig and special station-keeping equipment. A jack-up rig is a type of mobile platform fitted with its legs extended in the 'up' position, then once on location the legs are extended down onto the seafloor, and the hull then 'jacked-up' a pre-determined height above the sea surface.

The other types of MODU will be positioned either by mooring using drag embedment anchors or kept on location with DP using thrusters.

Non-drilling activities occurring on the MODU will include:

- bunkering and bulk transfer of fuel, chemicals, and supplies
- transferring waste to supply vessels
- discharging:
  - sewage, greywater, and food waste
  - cooling water and reverse osmosis brine
  - deck drainage and bilge.
- helicopter operations.

A MODU will be in the OA throughout the drilling and decommissioning phases and will be used as needed during operations.

An estimated maximum of 170 personnel on board (POB) is expected on the MODU. The expected POB for the MODU is significantly smaller than for the largest vessel likely to be used (Section 4.3.6.2), so vessel POB estimates have been used for impact assessment.

4.3.6.2 Vessel operations

Vessels of different sizes and capabilities are required for various functions throughout all phases of the Development. The indicative types of vessels that will be used include:

- survey vessels

- operational support vessels such as transportation vessels, tugs, and barges (referred to as offshore support vessels (OSV) in the underwater sound impact assessment (Section 8.5))
- pipelay vessels (PLVs) and cable lay vessels
- construction vessels (referred to as offshore construction vessels (OCV) in the underwater sound impact assessment (Section 8.5))
- supply vessels (referred to as OSV in the underwater sound impact assessment (Section 8.5)).

Activities associated with these vessels include:

- bunkering and bulk transfer of fuel, chemicals, and supplies to the MODU
- collecting and potentially treating waste from the MODU
- discharging:
  - sewage, greywater, and food waste
  - cooling water and brine
  - deck drainage and bilge water
  - atmospheric emissions
- vessel positioning and anchoring
- installation and decommissioning activities
- supporting anchoring operations
- assisting in emergency response situations
- monitoring the 500 m safety exclusion zone
- IMR activities.

Vessels will typically use DP; however, in certain circumstances, anchoring may be required.

Vessels will use light marine fuel such as marine diesel oil (MDO) or marine gas oil (MGO), instead of heavy fuel oil. Fuels described in this OPP are presented based on current technologies. CAPL will continue to seek and assess emerging technologies that may provide future opportunities to reduce risk and impact. Any new fuel selected for the Development will be assessed and presented in subsequent applicable EPs.

Vessels transiting to and from the OA are managed under the *Navigation Act 2012* (Cth) and are not within the scope of this OPP.

All vessels are collectively termed ‘support vessels’. Larger vessels (e.g. PLVs, construction vessels) will be serviced by helicopters. Crew changes for smaller vessels (e.g. supply vessels, tugs) will typically be conducted at a port outside the OA. All vessels will initially mobilise and demobilise at the port. The largest vessel is likely to be a PLV with an indicative POB of ~700.

Vessels may be sourced domestically or internationally, depending on operational requirements and availability.

As with all activities, CAPL will continue to seek and assess emerging technologies. Unmanned surface vessels and Marine Autonomous Surface Ships (MASS) will be evaluated for future use in the Development.

4.3.6.3 Helicopter operations

Where required, helicopters may be used for crew transfers and minor supplies to and from facilities and vessels in the OA. Helicopters may be required to evacuate personnel in the event of an emergency.

Helicopters will typically operate from Barrow Island. Refuelling helicopters offshore is not planned.

Passenger and crew transfers for larger installation vessels (e.g. PLVs, construction vessels) will be supported by helicopter logistics. Helicopter flight frequency is estimated to be ~15-16 flights per week for the largest vessel, and ~5 flights per week for the MODU.

4.3.6.4 ROV operations

ROV and AUV operations may be conducted during all phases of the Development. ROVs and AUVs support activities such as site survey, installation, commissioning, start-up, IMR, subsea valve operations, recovery of dropped objects and decommissioning. They may also be required during an unplanned event, such as an LOWC.

As technology develops, future options for ROV and AUV activities will be evaluated; these options include resident ROVs, which do not require a support vessel.

ROVs generally do not contact the seabed, but in rare circumstances may be required to wet park within the long-term disturbance area. The ROV footprint is ~3 m × 3 m.

5 Alternatives analysis

This section describes the method used to identify and evaluate development alternatives to support Regulation 5A(5)(f) of the OPGGS(E)R, which requires the proponent to:

> 'describe any feasible alternative to the project, or an activity that is part of the project, including:
>
> i. a comparison of the environmental impacts and risks arising from the project or activity and the alternative; and
>
> ii. an explanation, in adequate detail, of why the alternative was not preferred.'

Consideration of alternatives for the Development was conducted in accordance with NOPSEMA's current OPP content requirements (Ref. 11).

This section addresses this requirement by analysing the feasible alternatives for the:

- development concept (Section 5.2)
- design and activity elements of the selected concept (Section 5.3).

5.1 Decision-making process

Various decision-making process options exist. Typically, these processes follow similar principles and involve evaluating available alternatives against a range of different criteria to enable selection of a preferred option. An overarching principle is that of multi-criteria decision analysis.

This method is commonly used within the industry for evaluating options for decommissioning (typically termed 'comparative assessment'), with net environmental benefit analysis used for spill response.

CAPL's assessment processes were adapted to develop the process described in the subsections below.

5.1.1 Assessment criteria

Factors that influenced CAPL's selection of feasible alternatives were based on these focus areas, which align with critical operational excellence (OE) risks:

- environment
- technical feasibility
- safety
- commercial
- social.

Each focus area is further divided into categories and assessment criteria, as listed in Table 5-1.

Table 5-1: Feasible alternatives assessment criteria

Focus area	Criteria
Environment	
Physical presence	• Seabed disturbance • Interaction with marine fauna (vessel movements)
Emissions	• Underwater sound emissions • Atmospheric emissions and GHG emissions • Light emissions
Discharges	• Planned liquid and solid discharges • Accidental releases
Introduction of invasive marine pests	• Invasive marine pests (IMPs)
Onshore physical presence[9]	• Ground disturbance • Non-indigenous species (NIS) • Fire • Interaction with terrestrial fauna
Lifecycle environmental impacts[10]	• Life-of-field impact spanning both infrastructure construction, in-place footprint, production operations and any abandonment legacy
Technical feasibility	
Operability and feasibility risk	• Technically feasible and ability to operate and maintain
Technical readiness	• Acceptable technology readiness level
Constructability, re-usability and decommissioning feasibility	• Feasibility to construct • Re-usability • Feasibility to decommission
Safety	
Safety and risk	• OHS and risk exposure • Process safety
Commercial	
Schedule risk	• Ability to meet the Development timeline
Cost risk	• Economic viability
Future flexibility risk	• Ability to accommodate future development including tie-ins for other fields
Social	
Socio-economic impacts	• Impact to other marine users
Reputation	• Social licence to operate
Cultural	• Impact to cultural heritage values

[9] *Relevant for development concepts with onshore components only.*
[10] *Relevant for development concept evaluation only.*

The assessment is carried out in 2 steps:

- undertake a comparative assessment of the alternatives against environmental criteria to identify the options with the least environmental impact
- further assess alternatives against the other criteria (technical feasibility, safety, commercial and social focus areas) to justify the final selected option.

Each option is assessed against the criteria and assigned a ranking score between 1 and 4 (Table 5-2). If there was no material difference between two or more options, each was given a score of 2.

Table 5-2: Scoring criteria for alternatives analysis

Score	Guidance
1	Few issues. Best in group
2	Good. Some minor issues. No material difference
3	Some more significant issues. More significant difference
4	Significant issues. Worst in group

5.2 Concept alternatives

CAPL considered 5 different development concepts during the alternatives analysis process. These concepts represent the primary development options for gas fields. Table 5-3 summarises each concept.

Floating LNG was not considered as a development concept option, as it is not commercially viable, does not have demonstrated feasibility, and does not have a robust operating record in the industry to date.

Table 5-3: Development concept alternatives overview

Concept	Overview
Option 1—FPSO	• Uses an offshore floating production storage and offloading (FPSO) unit similar to the North West Shelf (NWS) Okha facility. • Production fluids are gathered from wells via flowlines and risers to the FPSO. • Fluids are separated and treated; condensate is exported directly via the FPSO. • Gas is exported via existing GFP infrastructure to the Gorgon GTP, with capacity for carbon capture and storage (CCS). • Infield flowlines for Options 1, 2 and 4 are assumed to be similar.
Option 2—Offshore fixed facility	• Uses an offshore fixed structure, such as a tension-leg platform (TLP) or semisubmersible floating production system, similar to the Scarborough development. • Production fluids are gathered from wells via flowlines and risers to the TLP/semisubmersible. • Fluids are treated and exported via existing GFP infrastructure to the Gorgon GTP, with capacity for CCS. • Infield flowlines for Options 1, 2 and 4 are assumed to be similar.

Concept	Overview
Option 3—Subsea tieback to new GTP	• Uses subsea infrastructure tied back to a new gas treatment plant (GTP), similar to the original GFP) on Barrow Island or the mainland. • Production fluids are gathered from wells via flowlines, which are tied-in to a new trunkline. • Fluids are exported via the new trunkline to a new onshore GTP facility with no capacity for CCS.
Option 4—Subsea tieback to existing Gorgon GTP	• Selected concept (described in detail in Section 4). • Uses subsea infrastructure tied back to the existing Gorgon GTP. • Production fluids are gathered from wells via flowlines, which are tied-in to existing GFP subsea infrastructure. • Fluids are exported via GFP existing pipelines to existing Gorgon GTP, with capacity for CCS. • Infield flowlines for Options 1, 2 and 4 are assumed to be similar.
Option 5—Subsea tieback to existing third-party mainland GTP	• Uses subsea infrastructure tied back to an existing third-party GTP on the mainland, similar to the GFP development concept. • Production fluids are gathered from wells via flowlines, which are tied-in to a new trunkline. • Fluids are exported via the new trunkline to an existing GTP facility on the mainland, with no capacity for CCS.
Option 6–No development / lesser development	• No development or lesser development (i.e. of less fields).

Option 6 – No development / lesser development was not evaluated further for the reasons presented below.

CAPL is one of the largest energy suppliers to Australia and a significant supplier in the Asia Pacific region. The CAPL operated Gorgon gas plant has the capacity to produce approximately 300 terajoules of natural gas per day, about 25% of the current Western Australian domestic market gas supply, and 15.6 million tonnes of LNG per year, primarily for the Asia Pacific region.

The original Gorgon Gas Development Environmental Impact Statement/Environmental Review and Management Process (EIS/ERMP; Ref. 1) outlined that these fields would be developed once production from the Gorgon and Jansz-Io fields began their natural decline.

CAPL considered the impact of not developing the backfill fields for the Gorgon Gas Development. If the backfill fields are not developed, then gas production from the Gorgon and Jansz-Io fields will naturally decline, reducing the production capacity of the Gorgon LNG and domestic gas facilities on Barrow Island earlier than planned. Given the significant role the GFP plays in providing energy security for Western Australia and the Asia Pacific region, an earlier than expected reduction in gas production from the development will have a corresponding negative impact on the Western Australian and global gas markets.

The Australian Government recognises that continued development of natural gas resources is required to ensure consistent supply to the domestic market as well as ensuring supply internationally due to forecast global gas shortfalls. Australian gas will be critical for providing baseload power and grid stability in the energy system as the mix of energy sources changes. In the Asia Pacific region, growing global energy needs mean demand for Australian LNG will remain for existing customers, but demand will also come from other countries that look to use more LNG in their energy mix as coal assets are retired. As energy systems transition to a more diverse and lower carbon energy mix, it is critical that energy security is maintained, and the Gorgon Gas Development Backfill Fields supports this objective. In addition to this, CAPL also has an obligation to develop any commercially viable hydrocarbon reserves to satisfy offshore permit retention lease requirements.

Regarding the development of lesser fields, CAPL considered the intent of the Policy Statement Staged Developments – Split referrals: Section 74A of the EPBC Act (Ref. 85), To align with this Policy, CAPL prepared an OPP for the 7 fields to allow an appropriate and robust assessment of cumulative impacts. This approach ensures the long-term backfill plan for the Gorgon Gas Development is transparent and the potential cumulative impacts of the Development are not under-represented.

For these reasons, Option 6 was not considered further.

5.2.1 Analysis of concept alternatives

The common activities associated with all concepts were identified and have been grouped in Table 5-4.

Each activity was systematically mapped against the focus areas and the key criteria (as identified in Section 5.1.1), and the relevant concepts were identified. Table 5-5 details the qualitative ranking score for the environmental criteria for each concept. The lowest score indicates the best result from an environmental perspective. The totals ranged from 43 (Option 5) to 18 (Option 4), with a large difference between the lowest score of 18 and the next lowest score of 27 (Option 2).

The assessment shows that the most favourable outcome environmentally is Option 4—Subsea tieback to existing Gorgon GTP.

Table 5-4: Environmental criteria related to activities associated with each development concept

Activity	Related concept	Offshore physical presence		IMP risk	Emissions			Discharges		Onshore physical presence				Lifecycle environmental impacts
		Seabed disturbance	Interaction with marine fauna	IMP	Underwater sound	Atmospheric & GHG	Light	Planned discharges	Accidental releases	Ground disturbance	NIS	Interaction with terrestrial fauna	Fire	Life-of-field impact
Surveys														
Geophysical survey	1,2,3,4,5		✓	✓	✓	✓		✓	✓					
Geotechnical survey	1,2,3,4,5	✓	✓	✓	✓	✓		✓	✓					
Onshore surveys	3,5					✓				✓		✓		
Drilling														
Mobilisation and demobilisation of rig	1,2,3,4,5	✓	✓	✓		✓			✓					✓
Drilling of wells	1,2,3,4,5	✓			✓	✓	✓	✓	✓					✓
Well clean-up	1,2,3,4,5					✓	✓	✓	✓					✓
Installation, hook-up and commissioning														
Installing & commissioning of flowlines	3,5	✓	✓	✓	✓			✓	✓					✓
Installing piles and anchors	1,2	✓			✓									✓
Installing & commissioning production facilities	2,3	✓	✓	✓	✓	✓		✓	✓					✓
Installing mooring system	1,2	✓	✓	✓	✓			✓	✓					✓
Onshore construction and installation														
Clearing and site preparation	3,5					✓			✓	✓	✓	✓	✓	✓
Constructing new GTP and associated infrastructure	3					✓			✓	✓	✓	✓		✓
Shore crossing	3,5								✓	✓	✓	✓		✓
Installing onshore pipeline component	3,5								✓	✓	✓	✓		✓
Operations														
Produced water treatment and disposal	1,2,3,4,5	✓				✓		✓	✓					✓
Hydrocarbon extraction and processing	1,2,3,4,5					✓			✓				✓	✓
Decommissioning														
Plug and abandon wells	1,2,3,4,5	✓	✓	✓	✓			✓	✓					✓
Removing infrastructure	1,2,3,4,5	✓	✓	✓	✓			✓	✓					✓
Decommissioning and closure	3, 5					✓		✓	✓	✓		✓		✓
Rehabilitation	3, 5					✓						✓		✓
Support Operations														
Facility operations – offshore	1,2,3,4,5	✓	✓	✓	✓	✓	✓	✓	✓					
Facility operations – onshore	1,2,3,4,5	✓				✓	✓	✓	✓				✓	
Vessel operations	1,2,3,4,5	✓	✓	✓	✓	✓	✓	✓	✓					
Aircraft operations	1,2,3,4,5					✓								
ROV operations	1,2,3,4,5								✓					
Onshore equipment operations	3,5					✓			✓	✓	✓	✓	✓	

Table 5-5: Assessment of environmental criteria for development concept alternatives

Focus area	Criteria	Development concepts—qualitative ranking and justification									
		Option 1—FPSO		Option 2—Offshore fixed facility		Option 3—Subsea tieback to new GTP		Option 4—Subsea tieback to existing Gorgon GTP		Option 5—Subsea tieback to existing third-party mainland GTP	
Physical presence	Seabed disturbance	Localised development footprint. Similar infield flowline distance as Options 2 and 4. Mooring spread footprint from anchoring the FPSO.	2	Localised development footprint. Similar infield flowline distance as Options 1 and 4. Requires disturbance footprint for the fixed platform or mooring system.	2	Most seabed disturbance of all options, due to longest flowline/pipeline required. New flowline to Barrow Island/mainland, shore crossing and onshore pipeline component. Also requires large footprint of ground disturbance for a new GTP and associated infrastructure/utilities.	4	No FPSO mooring or fixed platform disturbance footprint. Similar infield flowline distance as Options 1 and 2.	2	Most seabed disturbance of all options, due to new pipeline required (longest of all options). New pipeline to the mainland, shore crossing and onshore pipeline component.	4
	Interaction with marine fauna	Permanent surface facilities	2	Permanent surface facilities	2	No surface facilities. Fauna interaction would peak during construction and decommissioning. Nearshore environment is sensitive during construction, shore crossing, dredging (if required). Longer duration and greatest spatial extent of vessel activities.	4	No surface facilities. Fauna interaction would peak during construction and decommissioning.	1	No surface facilities. Fauna interaction would peak during construction and decommissioning. Nearshore environment is sensitive during construction, shore crossing, dredging (if required). Longer duration and greatest spatial extent of vessel activities.	4
Emissions	Underwater sound	Permanent surface facilities including rotating equipment and onboard machinery noise. Subsea chokes.	3	Permanent surface facilities with onboard noise. Potential for dry trees or subsea chokes.	3	No surface facilities. Noise generated by subsea chokes and subsea processing. Noise generation from vessels during construction in shallow water.	2	No surface facilities. Noise generated by subsea chokes and subsea processing.	2	No surface facilities. Noise generated by subsea chokes and subsea processing. Noise generation from vessels during construction in shallow water.	2
	Atmospheric and GHG	Power generation and process emissions from operation of the offshore facility. The CO_2 injection system on Barrow Island can be used. Similar to the proposed Barossa Development—CO2 would have to be comingled to existing pipeline, not separated on FPSO.	3	Power generation and process emissions from operating the offshore facility. CO_2 injection system on Barrow Island can be used.	3	No facilities or emissions associated with subsea development. Minor fugitive emissions. Emissions generated by more significant construction footprint and much longer flowlines. Duplication of utilities. CO_2 injection not available.	4	No facilities or emissions associated with subsea development. Minor fugitive emissions. Processing is done at the existing GTP, and CO_2 injection system can be used.	2	No facilities or emissions associated with subsea development. Minor fugitive emissions. Processing is done at the existing third-party GTP on the mainland, which does not have a CO_2 injection system.	4
	Light	Permanent surface facilities. >60 km from Barrow Island. Assume would require flaring, and distance of change in ambient light is greater.	3	Permanent surface facilities. >60 km from Barrow Island.	2	Additional activities on Barrow Island or new mainland coastal GTP may have impact on turtle nesting beaches. Artificial light would peak during drilling, construction and decommissioning. New onshore facility lighting.	4	Minor temporary impact. Artificial light would peak during drilling, construction and decommissioning.	1	Minor temporary impact. Additional activities at new mainland coastal GTP may have impact on turtle nesting beaches, depending on proximity to coast and location. Artificial light would peak during drilling, construction and decommissioning. New onshore facility lighting.	3
Discharges	Planned discharges	Full range of emissions/discharges from FPSO. Normally-manned facility.	4	Moderate emissions of open non-hazardous drains, sewage, hydrotest and maintenance from permanent surface facilities. Assume minimally-manned or not normally manned (NNM).	3	During operations, subsurface discharges of control fluid, maintenance emissions and hydrotest emissions. Vessel discharges during vessel activity. Additional discharge sources from new GTP.	3	During operations, subsurface discharges of control fluid, maintenance emissions and hydrotest emissions. Vessel discharges during vessel activity.	1	During operations, subsurface discharges of control fluid, maintenance emissions and hydrotest emissions. Vessel discharges during vessel activity. Greater spatial extent and duration of vessel activities for new pipeline. Greatest hydrotest discharge volumes due to greatest distance (to mainland). Additional discharge sources from new GTP.	4
	Accidental releases	Large liquid hydrocarbon volumes maintained/stored on FPSO. Risk of spills during offloading. Hydrocarbon spill risk from wells and flowlines.	4	Small liquid hydrocarbon volumes maintained/stored on facility. Oil spill risk from wells and flowlines.	3	Low risk of subsea wells and flowline LOC / constrained inventory. Additional onshore GTP facilities incrementally increase the risk of accidental releases.	3	Low risk of subsea wells and flowline LOC / constrained inventory.	2	Low risk of subsea wells and flowline LOC / constrained inventory.	2

Focus area	Criteria	Development concepts—qualitative ranking and justification									
		Option 1—FPSO		**Option 2—Offshore fixed facility**		**Option 3—Subsea tieback to new GTP**		**Option 4—Subsea tieback to existing Gorgon GTP**		**Option 5—Subsea tieback to existing third-party mainland GTP**	
										Additional onshore GTP facilities incrementally increase the risk of accidental releases.	
Introduction of IMP	IMP	Permanent floating structure required, dry dock in international location means increased IMP risk. Construction and IMR fleet risk. IMP associated with export vessel movements. Deep water. Domestic supply vessel transit to facility also a vector.	3	Permanent fixed structure manufactured in foreign country. Construction and IMR fleet risk. Deep water. Domestic supply vessel transit to facility also a vector.	2	Construction and IMR fleet risk only.	1	Construction and IMR fleet risk only.	1	Construction and IMR fleet risk only.	1
Onshore physical presence	Ground disturbance	No onshore component.	1	No onshore component.	1	Requires ground disturbance onshore for a new shore crossing and onshore pipeline to connect to the existing GTP.	3	No onshore component.	1	Requires ground disturbance onshore for a new shore crossing and onshore pipeline and clearing and site preparation for the new GTP site, and all associated infrastructure.	4
	NIS	No onshore component.	1	No onshore component.	1	Risk of introducing NIS from ground-disturbing activities and physical presence on site.	3	No onshore component.	1	Risk of introducing NIS from ground-disturbing activities and physical presence on site.	4
	Fire	No onshore component.	1	No onshore component.	1	Risk of fire from onshore equipment and hot works (e.g. pipeline welding).	2	No onshore component.	1	Risk of fire from onshore equipment and hot works (e.g. welding). Fire/explosion risk from hydrocarbon processing at new GTP. May require flare system.	4
	Interaction with terrestrial fauna	No onshore component.	1	No onshore component.	1	Risk of injury/mortality to terrestrial fauna due to vehicle strike and entrapment in excavations.	3	No onshore component.	1	Risk of injury/mortality to terrestrial fauna due to vehicle strike and entrapment in excavations.	4
Lifecycle impacts	Life-of-field impact	Many sources of environmental risk and impact.	3	Many sources of environmental risk and impact.	3	Moderate sources of environmental risk and impact. Significant additional onshore and moderate seabed physical footprint. Highest GHG emissions.	4	Moderate sources of environmental risk and impact. Moderate seabed physical footprint.	2	Moderate sources of environmental risk and impact. Moderate seabed physical footprint.	3
Environment total			**31**		**27**		**40**		**18**		**43**

The next part of the assessment considered each concept against the remaining focus areas and corresponding criteria. Table 5-6 details the comparative assessment of the concept alternatives against these other criteria.

Table 5-6: Assessment of other focus area criteria for development concept alternatives

Focus area		Criteria	Development concepts – qualitative ranking and justification									
			Option 1—FPSO		Option 2—Offshore fixed facility		Option 3—Subsea tieback to new GTP		Option 4—Subsea tieback to existing Gorgon GTP		Option 5—Subsea tieback to existing third-party mainland GTP	
Third-Technical feasibility	Operability and feasibility	Technically feasible	Feasible. NWS has difficult metocean conditions.	2	Feasible. Water depth limits fixed facility options to a tension-leg platform or semisubmersible. NWS has difficult metocean conditions.	3	Feasible with some flow assurance challenges (long trunkline).	2	Feasible.	1	Feasible with some flow assurance challenges (long trunkline).	2
	Technical readiness	Technology readiness levels	Readily deployed technology.	1	Readily deployed technology.	1	Some subsea limitations to processing and technology e.g. Subsea compression/separation (if required) is emerging technology.	2	Some subsea limitations to processing and technology e.g. Subsea compression/separation (if required) is emerging technology.	2	Some subsea limitations to processing and technology e.g. Subsea compression/separation (if required) is emerging technology.	2
	Constructability, re-usability, decommissioning feasibility	Feasibility to construct	Less complex than fixed platform.	2	Requires an international fabrication yard, many more contractors and complex work.	3	Constructability of a new GTP is challenging. Shore crossing and nearshore construction challenging.	4	Least complex option to install.	1	Shore crossing and nearshore construction challenging.	3
		Re-usability	FPSO can be re-used. Flexible flowlines could be re-used.	1	Platform/facility could potentially be re-used (e.g. Angel platform for CCS), but more difficult than an FPSO (e.g. Bayu Undan).	2	No further difference between options (i.e. re-usability within the development is still feasible)	2	No further difference between options (i.e. re-usability within the development is still feasible)	2	No further difference between options (i.e. re-usability within the development is still feasible)	2
		Feasibility of decommissioning	Ability to remove all facilities (assume infield flowlines to one FPSO location). More difficult if anchors are piled.	2	Ability to remove all facilities. Feasibility challenges with decommissioning TLPs (see OHS row).	3	Significant length of flowlines may make full removal more challenging, or some equipment may be required to be left in situ. Shore crossing difficult to remove. Onshore facilities with foundations and undergrounds—full removal and remediation is challenging. Vegetation rehabilitation and ongoing monitoring is long-term.	4	Similar length of flowlines (Options 1, 2 and 4) may make full removal more challenging, or some equipment may be required to be left in situ.	2	Significant length of flowlines may make full removal more challenging, or some equipment may be required to be left in situ. Shore crossing difficult to remove.	3
Safety	Safety and risk	Occupational health and safety (OHS) and risk exposure	Personnel required offshore to operate facility (normally-manned). Highest number of exposure hours and maintenance.	3	Minimally manned facility to NNM facility. Offshore maintenance hours likely still required. Less offshore equipment and OHS risks than FPSO alternative.	2	Subsea facility offshore. Significant additional onshore manhours for construction and operations at the new GTP.	4	Subsea facility only – no topsides facilities to be manned. OHS risk from vessel activities.	1	Subsea facility only – no topsides facilities to be manned. OHS risk from vessel activities. Additional manhours to install trunkline and shore crossing.	1
		Process safety	Many new sources of risk. Likely to require disconnectable FPSO. Minimal separation distances available on FPSO (congestion). Higher inventory than fixed facility. Controls typically lower down hierarchy of control/inherently safe design requiring blast walls and blast overpressure management when compared to onshore facility.	4	Some offshore personnel – typically not-normally manned is likely. Many new sources of risk. Cyclone risk must be managed.	3	Subsea facility offshore. Additional onshore facilities introduce additional process safety risks. Separation distances possible onshore to manage blast overpressure and segregate people from the risk.	3	Subsea infrastructure only – no topsides facilities to be manned.	1	Subsea infrastructure only – no topsides facilities to be manned.	1

Focus area		Criteria	Development concepts – qualitative ranking and justification									
			Option 1—FPSO		Option 2—Offshore fixed facility		Option 3—Subsea tieback to new GTP		Option 4—Subsea tieback to existing Gorgon GTP		Option 5—Subsea tieback to existing third-party mainland GTP	
Commercial	Schedule risk	Ability to meet the development timeline	Facility and topsides construction likely to significantly increase schedule.	3	Facility and topsides construction likely to significantly increase schedule.	3	Construction of a new GTP and associated facilities significantly increases schedule. Components in State waters require State approvals. Onshore environmental approvals have a significant lead time.	4	No significant issues identified.	1	Some interface and ullage issues identified integrating with an existing third-party GTP. Trunkline/shore crossings in State waters require State approvals.	2
	Cost risk	Economic viability	Large amount of capital expenditure (CAPEX) required. i.e. new FPSO (vessel and topside facilities). Reduced availability due to disconnectable nature.	3	Large amount of CAPEX required. i.e. new surface facility (TLP / semisubmersible)	3	Construction of a new GTP facility. Duplication of infrastructure components from GFP.	4	Backfill to existing facility using major GFP components. Best commercial outcome.	1	Backfill to existing facility using major GFP components. Significant additional pipeline CAPEX.	2
	Future flexibility risk	Ability to accommodate future developments	No material difference.	2	No material difference.	2	No material difference.	2	No material difference.	2	No material difference.	2
Social	Socio-economic impacts	Impact to other marine users	Some restrictions on marine activities. Ongoing exclusion zone around facility.	3	Some restrictions on marine activities. Ongoing exclusion zone around facility.	3	Minimal restrictions on marine activities in Commonwealth waters. Disruption to coastal water users, potentially other port users depending on shore crossing location. Tourism.	4	Minimal restrictions on marine activities.	2	Minimal restrictions on marine activities in Commonwealth waters. Disruption to coastal water users, potentially other port users depending on shore crossing location. Tourism.	3
	Reputation	Social licence to operate	Additional floating visible structure.	3	Additional floating visible structure.	3	Requires new onshore development. Additional clearing, disruption to neighbours. GHG emissions may introduce further issues as there is no CCS.	4	Consistent with existing project. Minimal additional infrastructure. Availability of CCS may introduce further issues around GHG.	2	Consistent with existing project. Construction activities nearshore are more visible. GHG emissions may introduce further issues as there is no CCS.	3
	Cultural	Impact to cultural heritage values	Smaller seabed disturbance footprint. Greater potential impact to marine fauna, primarily due to underwater sound, GHG and light emissions, planned discharges and accidental releases from permanent surface facilities. No onshore or nearshore disturbance.	3	Smaller seabed disturbance footprint. Greater potential impact to marine fauna, primarily due to underwater sound, GHG and light emissions, planned discharges and accidental releases from permanent surface facilities. No onshore or nearshore disturbance.	2	Larger seabed disturbance footprint and therefore impact to benthic habitats. Some potential to impact onshore terrestrial environment and cultural heritage values due to onshore ground disturbance footprint. Disturbance to nearshore environment.	4	Smaller seabed disturbance footprint. Less potential to impact marine fauna from underwater sound and light emissions, planned discharges and accidental releases, due to no permanent surface facilities. No onshore or nearshore disturbance.	1	Larger seabed disturbance footprint and therefore impact to benthic habitats. Disturbance to nearshore environment. Larger potential to impact onshore terrestrial environment and cultural heritage values due to largest onshore ground disturbance footprint.	4
Other focus areas total				**32**		**33**		**43**		**19**		**30**

As with the environmental criteria scoring, the lowest score indicates the best outcome. As the totals in Table 5-6 show, the most favourable outcome with respect to the technical feasibility, safety, commercial and social focus areas is Option 4—Subsea tieback to existing Gorgon GTP.

Figure 5-1 shows the total qualitative ranking score for each concept against the criteria from all focus areas (environment, technical feasibility, safety, commercial and social). Option 4 is clearly the most favourable option when all criteria are considered.

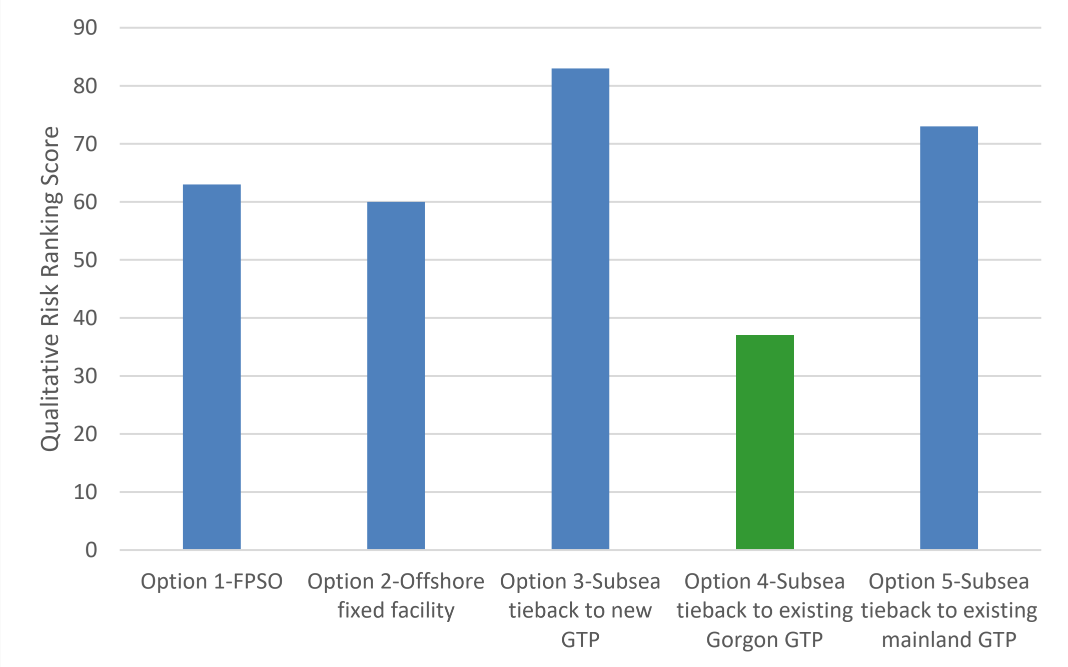

Figure 5-1: Qualitative ranking scores for Development concept alternatives against all focus areas

The most favourable concept identified though the ranking process was Option 4 for subsea tieback to the existing Gorgon GTP. Option 4 scores a ranking of 37. This option maximises the use of existing infrastructure, does not require additional surface process facilities, and requires no onshore crossing or additional lengthy pipeline installation, which notably reduces its lifecycle impacts.

Using existing subsea infrastructure already tied back to the current Gorgon GTP avoids seabed disturbance that would otherwise be associated with installing new pipelines, anchoring from an FPSO, or footings for a fixed platform. The lack of additional surface process structures and reduced vessel presence limits the potential interaction with marine fauna and the risk of introducing IMPs. The absence of a surface structure reduces the sources of artificial light.

The absence of an FPSO or platform removes additional noise sources such as rotating equipment and onboard machinery, which reduces the risk of behavioural change in, and injury to, fauna as a result of changes in ambient noise.

The design will not require local power generation or offshore processing, reducing the volume of emissions generated to minor fugitive emissions only. Because processing would take place at the existing GTP, the emissions generated would be managed through the existing CO_2 injection system.

With no offshore storage and processing, there is a far lower risk of accidental releases from subsea wells and flowline loss when compared with the volumes of liquid hydrocarbon stored and offloaded with an FPSO or stored on a permanent facility.

As most processing and technology requirements are ready for deployment, the project is technically feasible. The design is the least complex to install and the most economically viable. Safety and commercial risks are reduced greatly because no extra topside facilities, onshore facilities or onshore crossings are required. The limited new infrastructure components and the availability of existing CCS lessen the social impact of the design, which is further supported by the minimal restrictions expected to influence marine activities such as fishing, tourism, and other petroleum-based activities.

Table 5-7 summarises the key reasons for adopting or rejecting development concept alternatives.

Table 5-7: Summary of assessment of alternative development concepts

Concept	Summary of comparative assessment	
Option1—FPSO	• Although FPSOs are redeployable, the Development field size and field life are not deemed sufficient to support the costs associated with installing and recovering a mooring system and subsea flowline and riser architecture for an FPSO. • The elevated risk of accidental releases of large hydrocarbon volumes associated with an FPSO increases the negative operational environmental impact. • Removing the facility for cyclone events further reduces its economic viability over the anticipated short field life. • Tie-in to the existing GFP pipelines means this option avoids the environmental impact associated with a new pipeline and a new shore crossing. • The existing CO_2 injection system at the GTP can be used to capture the expected reservoir emissions. • Despite no new pipeline or new shore crossing and the use of CCS, the subsea construction activity and footprint result in greater overall environmental impact.	X
Option 2—Offshore fixed facility	• The field size and field life are not sufficient to support the cost of a fixed facility, topside construction and/or pipeline to the existing facility. • The inability to relocate the facility does not allow other isolated oil fields to be developed. • The lower section of a fixed platform (and subsea storage tank or pipelines if used) has the potential to remain in place if it is shown to have a lower environmental impact than removing it. • Tie-in to the existing GFP pipelines means this option avoids the environmental impact associated with a new pipeline and a new shore crossing. • The existing CO_2 injection system at the GTP can be used to capture the expected emissions. • Using a TLP or semisubmersible means this option is technically feasible; however, it requires more complex construction and a greater number of contractors.	X
Option 3—Subsea tieback to new GTP	• The field size and field life are not sufficient to support the cost of subsea development, a new trunkline, and a new onshore processing facility. • A large development footprint is associated with the pipeline and onshore facilities. • No CCS is available. • The requirement for a shore crossing and onshore component significantly increases the environmental impact.	X

Concept	Summary of comparative assessment	
Option 4—Subsea tieback to existing Gorgon GTP	• Using existing subsea infrastructure with tie back to the existing Gorgon GTP means this option is technically feasible; it does not require the deployment of any emerging or new technology. • Using tie-ins to the existing Gorgon pipelines means this option avoids the environmental impact associated with a new pipeline and a new shore crossing. • The existing CO_2 injection system at the GTP can be used to capture the expected emissions. • Lower schedule and commercial risk as CAPL are the operator of the existing Gorgon GTP, rather than a third-party. • The existing CO_2 injection system at the GTP can be used to capture the expected reservoir emissions.	✓
Option 5—Subsea tieback to existing mainland GTP	• Additional seabed disturbance is associated with installing a trunkline to the main line. • Using the existing GTP facility on the mainland reduces the development footprint. • Works would be undertaken in sensitive nearshore environments for the shore crossing and onshore pipeline components. • No CCS is available. • Although technically feasible, this option has potential flow assurance challenges associated with long trunklines and may require emerging technology in the form of subsea compression/separation. • There is a high schedule and commercial risk due to the need for agreements/contracts between CAPL and the third-party owner of the GTP.	X
No development / lesser development	• The Development is being undertaken to maintain the production capacity of the Gorgon LNG and domestic gas facilities on Barrow Island to enable continued supply of the Western Australian domestic market and world's LNG supply. • The titleholder must undertake certain petroleum exploration and production related activities towards commercialising the resource having regard to government policy, regulation, and international commitments in relation to reducing greenhouse gas emissions to net zero. • Submitting an OPP for fewer fields does not align with the Policy Statement Staged Developments – Split referrals: Section 74A of the EPBC Act (Ref. 85) - and understates the potential impact of the Development.	X

The concept determined to be the most favourable option, based on all criteria, and which has been selected for the Development, is Option 4—Subsea tieback to the existing Gorgon GTP.

5.3 Design and activity alternatives

Once the overall development concept (subsea tieback to the existing Gorgon GTP) was selected, the design features and activities with feasible alternatives were subject to a comparative assessment.

5.3.1 Design and activities not assessed

The following design features and activities were not considered for the alternatives assessment.

5.3.1.1 Well location and number

The indicative location of Development infrastructure, wells, and associated tie in infrastructure, is linked to and limited by the location of each fields reservoir (i.e. the field wells are located to minimize the number needed and maximise the optimisation of the reservoir). As such, only minimal well relocation is expected, and will be based on pre-installation verification of geophysical and topography data and further alternative analysis outside of this framework not considered optimal.

5.3.1.2 Temporary contingency power supply

There are 2 temporary contingency power supply options for the Development (subsea battery system and vessel downline). However, these are short-term solutions only, and are not intended to provide power for the whole field life. Therefore, the temporary contingency power supply options are not assessed below.

5.3.1.3 Activity specific ALARP demonstrations

While demonstration of acceptability is presented in the alternatives analysis (Ref. 11) as required of an OPP, the more detailed, activity-specific demonstrations that all reasonably practicable measures have been considered to reduce impacts and risks to ALARP will be presented in the subsequent EP for each activity that is part of the project. These more detailed activity options or alternatives present a lesser nature and scale in terms of generating environmental impacts and risks.

Examples of these lower order activity alternatives typically evaluated in the EP phase as part of the ALARP process include:

- evaluations on conducting an activity (often assessed as an ‘elimination ‘control). E.g.
  - eliminating where possible vessel-based activities, drilling, or production activities
  - eliminating pile-driving
  - not anchoring vessels
  - evaluating hydrotesting chemical additives
- drill fluid type (e.g. water-based or synthetic-based muds)
- eliminating the use of MDO in vessels.

5.3.2 Design and activities assessed

This section describes the key design and activity alternatives, and the associated comparative assessment.

The key design and activity elements of the Development include:

- MODU type
- hydrotest discharge
- flowline retrieval
- umbilical retrieval.

The following subsections outline the alternatives for each key element above and describe the comparative assessment that was carried out (as per Section 5.1). While decommissioning options have been presented, these options represent current methodologies. It is possible that new methodologies will be available and considered when the fields are ready to be decommissioned. Permission for these methodologies will be sought at the time through relevant EPs.

5.3.3 MODU type

CAPL will use a MODU for drilling, decommissioning and operations (if required) during the Development. The MODUs used may be semisubmersibles, drilling ships or intervention vessels. The method used for MODU positioning was considered in the alternatives analysis. Semisubmersibles, drilling ships and intervention vessels may be positioned using either a mooring system (i.e. anchors and mooring chains), or on DP (i.e. using thrusters to hold position).

Jack-up MODUs have legs which are extended down to sit on the seafloor. This MODU type is only suitable in shallower water depths, limited by the length of the legs.

Table 5-8 outlines the 3 alternatives that were considered.

Table 5-8: MODU alternatives overview

Concept	Overview
Option 1—Moored MODU	• MODU is moored to the seabed using anchors. • Up to 16 anchors are required, tethered to the MODU with mooring lines. • Total estimated footprint of anchors is ~28,480 m^2 per location.
Option 2—DP MODU	• MODU uses DP. • Thrusters are used to keep the MODU in position. • Noise from thrusters is continuous and additional to other onboard machinery.
Option 3—Jack-up MODU	• MODU has 3 legs with spud cans on the ends, which sit on the seabed. • Unsuitable in deeper water. • Total estimated footprint of anchors is ~950 m^2 per location.

Table 5-9 details the comparative assessment of these MODU alternatives against the environmental criteria (Section 5.1.1). Table 5-10 assesses them against the criteria for the other focus areas.

Table 5-9: Assessment of environmental criteria for MODU alternatives

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification					
		Option 1—Moored MODU		**Option 2—DP MODU**		**Option 3—Jack-up MODU**	
Physical presence	Seabed disturbance	Anchor spread/mooring footprint—assume 28,480 m^2 per well. Large spread in deep water.	4	No direct seabed disturbance.	1	Spud can footprint (typically 3 per jack-up rig)—assume 950 m^2 per well.	3
	Interaction with marine fauna	Physical presence. Potential for fauna entanglement in mooring lines.	3	Physical presence.	2	Physical presence.	2
Emissions	Underwater sound	Onboard machinery noise.	2	Continuous thruster noise from use of DP. Noise modelling was undertaken (Section 8.5) for worst case. Onboard machinery noise.	4	Onboard machinery noise, however, the hull is not in contact with the sea surface, limiting underwater noise.	1
	Atmospheric and GHG	Onboard power generation.	2	Increased fuel consumption for DP thrusters.	4	Onboard power generation.	2
	Light	No material difference.	2	No material difference.	2	No material difference.	2
Discharges	Planned discharges	No material difference.	2	No material difference.	2	No material difference.	2
	Accidental releases	No material difference.	2	No material difference.	2	No material difference.	2
Introduction of IMP	IMP	Slightly greater risk due to mooring chains and anchor spread in close contact with the seabed.	3	No contact with seabed. No additional risk to bring a MODU into the OA.	2	Slightly greater risk due to the spud cans contact with the seabed.	3
Environment total:			**20**		**19**		**17**

Table 5-10: Assessment of other focus area criteria for MODU alternatives

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification					
			Option 1—Moored MODU		Option 2—DP MODU		Option 3—Jack-up MODU	
Technical feasibility	Operability and feasibility	Technically feasible	No material difference.	2	No material difference.	2	Option is limited to shallower water depths; but the MODU would be contracted per campaign regardless.	2
	Technical readiness	Technology readiness levels	No material difference.	2	No material difference.	2	No material difference.	2
	Constructability, re-usability, and decommissioning feasibility	Feasibility to construct	No material difference.	2	No material difference.	2	No material difference.	2
		Re-usability	No material difference.	2	No material difference.	2	No material difference.	2
		Feasibility of decommissioning	No material difference.	2	No material difference.	2	No material difference.	2
Safety	Safety and risk	OHS and risk exposure	Anchor handling increases occupational exposure from anchor-handling and winching activities.	3	No anchor handling required.	1	No anchor handling required.	1
		Process safety	No material difference.	2	No material difference. Incremental risk of loss of DP station keeping; not considered a material difference.	2	No material difference.	2
Commercial	Schedule risk	Ability to meet the development timeline	No material difference.	2	No material difference.	2	No material difference.	2
	Cost risk	Economic viability	No material difference.	2	No material difference. Requires fewer support vessels to move and position MODU within field.	2	No material difference. Option is limited to shallower water depths, but rig will be contracted per campaign regardless.	2
	Future flexibility risk	Ability to accommodate	No material difference.	2	No material difference.	2	No material difference.	2

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification					
			Option 1—Moored MODU		Option 2—DP MODU		Option 3—Jack-up MODU	
		future developments						
Social	Socio-economic impacts	Impact to other marine users	No material difference.	2	No material difference.	2	No material difference.	2
	Reputation	Social licence to operate	No material difference.	2	No material difference.	2	No material difference.	2
	Cultural	Impact to cultural heritage values	Larger seabed disturbance footprint and therefore impact to benthic habitats. However, less potential impact to marine fauna, primarily from sound emissions.	3	No direct seabed disturbance; therefore, no impact to benthic habitats. Greater potential impact to marine fauna, primarily due to underwater sound and GHG emissions	3	Smaller seabed disturbance footprint. Less potential impact to marine fauna from underwater sound and physical interaction.	1
Other focus areas total:				**28**		**26**		**24**
Total score (including environmental scores):				**48**		**45**		**41**

The comparative environmental assessment shows a small difference in environmental ranking between the Option 1 and 2, as the only two options available for all fields and water depths; with Option 2–DP MODU ranked as slightly more favourable. This result was due to seabed disturbance, interaction with marine fauna and IMP risk, which together outweighed the potential noise and atmospheric/GHG impacts of Option 2. Option 3 – Jack-up MODU was ranked slightly better than both, with less impact from noise and a smaller disturbance footprint.

The comparative assessment based on the other focus areas (technical feasibility, safety, commercial and social) showed similar results, with Option 2 and 3 ranked slightly better than Option 1. This difference was due to the OHS risks from anchor handling for Option 1. However, Option 3 has limited applicability as it can only be used in shallower water, meaning it is not useable for most of the drilling required for the Development.

The total qualitative ranking score for each option shows Option 3 is ranked better than the other two options by a small margin. All options have been selected for assessment in the OPP, noting Jack-up MODU is only suitable in shallower water (see Section 5.3.7).

All options for MODU positioning were determined to be suitable for the Development and will be included in the OPP.

5.3.4 Hydrotest discharge

CAPL considered 2 alternatives for the discharge of hydrotest fluids, as outlined in Table 5-11.

Table 5-11: Hydrotest discharge alternatives overview

Concept	Overview
Option 1—Discharge to sea	• Hydrotest water is discharged at the seaward end of the test section at a controlled release rate. • Discharge occurs in deep ocean water. • Discharge occurs at the end of hydrotesting.
Option 2—Onshore disposal (deep well injection at Barrow Island)	• Hydrotest water is discharged via the GFP pipelines to Barrow Island. • Discharge occurs with process wastewater via deep well injection. • Discharge occurs at the end of hydrotesting.

Table 5-12 details the comparative assessment of these flowline retrieval alternatives against the environmental criteria (Section 5.1.1); Table 5-13 assesses them against the criteria for the other focus areas.

Table 5-12: Assessment of environmental criteria for hydrotest discharge alternatives

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification			
		Option 1—Discharge to sea		**Option 2—Onshore disposal**	
Physical presence	Seabed disturbance	No seabed disturbance.	2	No seabed disturbance.	2
	Interaction with marine fauna	Discharge to sea temporarily affecting water quality. Treated water contains chemical additives including biocide. The worst-case single discharge is for Chandon – ~35,000 m^3 (based on double the inventory of the longest flowline), which is significantly smaller than the volume modelled for the GFP (220,000 m^3) (Ref. 86). Based on the GFP modelling, subsea discharges are expected to be localised and rapidly diluted. Marine fauna are highly mobile and are not expected to be affected by minor increases in toxicity.	4	No discharge to sea.	1
Emissions	Underwater sound	No material difference.	2	No material difference.	2
	Atmospheric and GHG	No additional atmospheric emissions identified. Shutdown start-up of LNG plant avoided.	1	Flaring associated with process shutdown and start-up while dewatering pipeline. Additional power is required to inject water.	4
	Light	No material difference.	2	No material difference.	2
Discharges	Planned discharges	Discharge to sea temporarily affecting water quality. The worst-case single discharge is for Chandon – 35 000 m^3. This is significantly smaller than the volume modelled for the GFP (220,000 m^3) (Ref. 86). Based on the GFP modelling subsea discharges are expected to be localised and rapidly diluted	4	Discharge to a deep aquifer onshore at Barrow Island.	2
	Accidental releases	Planned discharge as above. Limited potential for accidental release	2	Potential accidental release to land while in transit to disposal well.	3
Introduction of IMP	IMP	No material difference.	2	No material difference.	2

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification			
		Option 1—Discharge to sea		Option 2—Onshore disposal	
Onshore Physical Presence	Ground Disturbance	No ground disturbance	1	New infrastructure required on BWI to facilitate disposal. Potential new clearing on Class A nature reserve	4
Environment total:			**20**		**22**

Table 5-13: Assessment of other focus area criteria for hydrotest discharge alternatives

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Discharge to sea		Option 2—Onshore disposal	
Technical feasibility	Operability and feasibility risk	Technically feasible	Feasible	1	Requires shutdown of gas production systems for the GFP. Potential issues with fluid incompatibility and solids formation in deep injection wells.	4
	Technical readiness	Technology readiness levels	No material difference.	2	No material difference	2
	Constructability, re-usability and decommissioning feasibility	Feasibility to construct	Install suitable pig launcher/receiver at relevant locations.	2	To discharge onshore, there needs to be a suitable pig receiver onshore at the GTP, and ability to divert the hydrotest fluids to enter the wastewater treatment plant and/or deep well injection. This would require additional onshore installation of supporting infrastructure.	4
		Re-usability	N/A		N/A	
		Feasibility of decommissioning	No material difference.	2	No material difference.	2
Safety	Safety and risk	OHS and risk exposure	No additional risks.	1	Flaring associated with process shutdown and start-up while dewatering pipeline and removal / treatment of fluid introduces additional occupational safety risks.	4

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Discharge to sea		**Option 2—Onshore disposal**	
		Process safety	No additional risks.	1	Flaring associated with process shutdown and start-up while dewatering pipeline introduces additional process safety risks.	4
Commercial	Schedule risk	Ability to meet the development timeline	No impact to schedule	2	Overall impact to schedule from loss of production from the GFP (and therefore the Development) during shutdown and re-start of the GTP.	4
	Cost risk	Economic viability	Most commercially viable.	1	Loss of production from the GFP (and therefore the Development) during shutdown and re-start of the GTP.	4
	Future flexibility risk	Ability to accommodate future developments	No material difference.	2	No material difference.	2
Social	Socio-economic impacts	Impact to other marine users	No material difference.	2	No material difference.	2
	Reputation	Social licence to operate	No material difference.	2	No material difference.	2
	Cultural	Impact to cultural heritage values	Greater potential impact to marine fauna from hydrotest discharge to sea. Discharges will be localised and rapidly diluted. Marine fauna are highly mobile and are not expected to be affected by minor increases in toxicity. Neither option impacts benthic habitats.	3	Less potential impact to marine fauna, due to no discharge to sea. However, this option does involve additional flaring, and deep well injection of hydrotest water under Barrow Island to deep aquifers. Neither option impacts benthic habitats.	2
Other focus areas total:				21		36
Total score (including environmental scores):				**41**		**58**

The comparative environmental assessment shows little difference in environmental criteria between the two options. This result was mainly due to Option 1 scoring poorly on planned discharges to sea, while Option 2 scored poorly on atmospheric/GHG emissions through flaring.

The comparative assessment based on the other focus areas (technical feasibility, safety, commercial and social) showed varying results, with Option 1 scoring more favourably than Option 2 overall. This difference was mainly due to technical feasibility, occupational safety and economic viability. CAPL identified a range of inherent risks to the operation of the GTP, including:

- requirement for production to mobilise hydrotest fluids to the inlet area, hydrate mitigation, and liquids management
- potential flow assurance issues
- insufficient slug catcher capacity for surge volumes
- requirement for water to be extracted from the MEG system, which risks hydrotest chemicals affecting the production chemistry
- requirement to take the GTP offline and cease production to transport hydrotest fluids to shore.

In addition, Option 2 would require substantial engineering design and installation work to allow receival, treatment and disposal of the hydrotest fluids at Barrow Island, making the feasibility of this option low. The hydrotest discharge Option 1—Discharge to sea was determined to be the only feasible option and has been selected for the Development.

5.3.5 Flowline retrieval

CAPL considered 2 alternatives for flowline retrieval, as outlined in Table 5-14.

Table 5-14: Flowline retrieval alternatives overview

Concept	Overview
Option 1—Cut and lift	• Flowline is cut into manageable segments on the seabed. • Segments lifted onto vessel using cranes. • Segments offloaded to a pipe supply vessel or barge and transported to disposal facility. • Removal rate depends on length of cut sections but is estimated to be ~500–600 m/day.
Option 2—Reverse S-lay / J-lay	• Flowline recovery tooling is deployed to recover flowline into the removal vessel stinger/J-lay tower. • Flowline is secured on vessel tensioners and cut into manageable segments on the vessel deck. • Segments offloaded to a pipe supply vessel or barge and transported to disposal facility. • Removal rate estimated to be ~2–2.4 km/day.

Table 5-15 details the comparative assessment of these flowline retrieval alternatives against the environmental criteria (Section 5.1.1); Table 5-16 assesses them against the criteria for the other focus areas.

Table 5-15: Assessment of environmental criteria for flowline retrieval alternatives

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification			
		Option 1—Cut and lift		**Option 2—Reverse S-lay/J-lay**	
Physical presence	Seabed disturbance	Physical disturbance of seabed and surrounds. Sections to be cut may need to be disturbed to access with machinery (e.g. by jetting / excavation). A small amount of debris may be released when cut, comprising concrete and coating materials, which may include epoxy and polypropylene.	3	Seabed disturbance for line removal but additional disturbance to gain access is only required at initial recovery and not at every cut location.	2
	Interaction with marine fauna	Extended duration of vessels in field.	3	Shorter duration.	2
Emissions	Underwater sound	Noise generation by underwater machinery—hydraulic shears or DWS. Noise source from vessel activities.	3	Minimal disturbance—noise source from vessel activities.	2
	Atmospheric and GHG	More emissions due to longer duration of vessel spread in field.	3	Less offshore time in field and therefore less overall GHG emissions	2
	Light	No material difference.	2	No material difference. Although the duration is longer, due to distance from shore (~60–190 km depending on which field), there is no difference in impact.	2
Discharges	Planned discharges	Residual fluid discharge to sea from pipe system. Pipeline contents flushed before recovery. Potential residual fluid discharge to vessel deck from pipe system. A small amount of debris may be released, comprising concrete and coating materials, which may include epoxy and polypropylene, mercury scale and NORM scale in very small quantities.	3	Residual fluid discharge to sea from pipe system. Pipeline contents flushed before recovery. Potential residual fluid discharge to vessel deck from pipe system. Debris may be released onto the deck from cutting segments and has to be contained.	2
	Accidental releases	Some potential for residual hydrocarbon and contaminant release to marine environment and seabed during cutting.	2	Some potential for residual hydrocarbon and contaminant release on vessel deck during cutting.	2

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification			
		Option 1—Cut and lift		Option 2—Reverse S-lay/J-lay	
Introduction of IMP	IMP	No material difference.	2	Removal of marine growth is required before passing through tensioners, meaning more marine growth debris is dislodged onto the seabed.	3
Environment total:			**21**		**17**

Table 5-16: Assessment of other focus area criteria for flowline retrieval alternatives

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Cut and lift		Option 2—Reverse S-lay / J-lay	
Technical feasibility	Operability and feasibility risk	Technically feasible	Established technology. Commonly used in Australian waters.	2	Not currently technically tested at scale at this water depth. As the flowlines are not concrete-coated, the Development may be a good candidate for this method. However, achieving the desired tension to recover the flowline becomes more challenging with greater water depth and presence of marine growth. Resistance to crushing and bending loads during recovery can be compromised due to reduced integrity of the flowline over its life.	4
	Technical readiness	Technology readiness levels	Established technology. Commonly used in Australian waters.	2	Not currently technically tested at scale at this water depth. Common method outside Australia in shallower water.	4
	Constructability, re-usability and decommissioning feasibility	Feasibility to construct	N/A		N/A	
		Re-usability	Pipeline is cut subsea—re-use is not possible. Recycling steel components would be targeted.	2	Pipeline is cut on board—re-use is not possible. Recycling steel components would be targeted. No material difference from a re-usability perspective.	2

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Cut and lift		Option 2—Reverse S-lay / J-lay	
			No material difference from a re-usability perspective.			
		Feasibility of decommissioning	N/A		N/A	
Safety	Safety and risk	OHS and risk exposure	More offshore work hours to complete, more lifts, and more handling of pipe sections.	3	Fewer offshore work hours; however, still significant handling of pipe joints. The pipe is under greater tension in deeper waters. There is potential for the tensioner to lose grip, causing the pipe section to be abandoned and removal started again.	3
		Process safety	N/A		N/A	
Commercial	Schedule risk	Ability to meet the development timeline	More offshore work hours to complete, more lifts, and more handling of pipe sections	3	No material difference.	2
	Cost risk	Economic viability	No material difference. Longer duration.	2	No material difference. Requires a higher specification vessel but is shorter duration. Acceptance of liability/risk of pipelay construction companies to use their equipment to recover flowline using a reverse S-lay technique—may lead to increased cost.	2
	Future flexibility risk	Ability to accommodate future developments	N/A		N/A	
Social	Socio-economic impacts	Impact to other marine users	No material difference.	2	No material difference.	2
	Reputation	Social licence to operate	No material difference.	2	No material difference.	2

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Cut and lift		**Option 2—Reverse S-lay / J-lay**	
	Cultural	Impact to cultural heritage values	More physical disturbance of seabed required therefore greater potential impact to benthic habitats. Also, greater potential impact to marine fauna, primarily from emissions and planned discharges.	4	Less physical disturbance of seabed required therefore less potential impact to benthic habitats. Also, less potential impact to marine fauna from emissions and discharges and physical interaction.	1
Other focus areas total:			22		22	
Total score (including environmental scores):			**43**		**40**	

The comparative environmental assessment shows a difference in environmental criteria between the two options, with Option 2 ranked as more favourable. Option 1 ranked poorly against several environmental criteria, including seabed disturbance and planned discharges, whereas Option 2 only ranked worse on IMP.

The comparative assessment based on the other focus areas (technical feasibility, safety, commercial and social) showed differences, with Option 1—Cut and lift scoring more favourably than Option 2. This difference was partly due to the technical feasibility and readiness for Option 2—Reverse S-lay/J-lay, which has not been demonstrated to be feasible in this water depth to date.

The total qualitative ranking score for each option shows Option 2 is ranked slightly better than Option 1. Although the environmental score also showed Option 2 was the preferable option, there are technical challenges associated with this unproven technique in deeper waters. If successful demonstration of reverse S-lay/J-lay is shown in deeper Australian waters in the future, it may prove to be a reliable option.

To ensure the option with the best environmental profile is used and to mitigate risks with unproven methodology, both options were selected for the OPP (see Section 5.3.7).

> The flowline retrieval option determined to be the most favourable, based on all criteria, is Option 2—Reverse S-lay/J-lay. However, this option has risks associated with the feasibility of the technique. To allow for potential future technological advancement, both options will be included in the OPP.

5.3.6 Umbilical retrieval

As discussed in the project description (Section 4), there are several potential options for umbilical retrieval. In the alternatives analysis, the overall impacts of using a reverse reel method or a recover and cut on vessel deck method were considered broadly similar. As a result, these options have been combined for consideration in the subsequent assessment. The 2 alternatives that CAPL considered for umbilical retrieval are outlined in Table 5-17.

Table 5-17: Umbilical retrieval alternatives overview

Concept	Overview
Option 1—Recover and cut on deck / reverse reel	• Umbilicals are recovered onto a reel or secured through tensioners, then cut on the vessel deck into manageable sections and bundled. • The cut sections are then offloaded to a supply vessel or barge for transportation to a disposal facility. • Recovery rate would be ~2.4–3 km/day.
Option 2—Reverse carousel	• Umbilicals are recovered onto a carousel on a vessel and delivered to quayside in the carousel vessel. • The umbilicals would then be unspooled onshore and cut into manageable sections for subsequent disposal. • Recovery rate would be ~6–7 km/day.

Table 5-18 details the comparative assessment of the umbilical retrieval alternatives against the environmental criteria (Section 5.1.1); Table 5-19 assesses them against the criteria for the other focus areas.

Table 5-18: Assessment of environmental criteria for umbilical retrieval alternatives

Focus area	Criteria	Evaluated concepts—qualitative ranking and justification			
		Option 1—Recover and cut on deck/Reverse reel		Option 2—Reverse carousel	
Physical presence	Seabed disturbance	Minimal seabed disturbance.	2	Minimal seabed disturbance.	2
	Interaction with marine fauna	Extended duration of vessels in field	3	Shorter duration.	2
Emissions	Underwater sound	Noise generation from vessel activity. Longer duration of vessel spread in the field.	3	Less offshore time in the field, therefore shorter duration of noise emissions.	2
	Atmospheric and GHG	More emissions due to longer duration of vessel spread in field.	3	Less offshore time in field and therefore less overall GHG emissions. A larger vessel may be required for the carousel option, which would use more fuel.	2
	Light	No material difference. Although the duration of this option is longer because of distance from shore (~60-190 km), there is no difference in impact.	2	No material difference.	2
Discharges	Planned discharges	No material difference.	2	No material difference.	2
	Accidental releases	Some potential for residual chemical release on vessel deck during cutting.	2	Minimal potential for residual chemical release on vessel deck due to significantly less cutting on the vessel.	1
Introduction of IMP	IMP	No material difference.	2	No material difference.	2
Environment total:			**19**		**15**

Table 5-19: Assessment of other focus area criteria for umbilical retrieval alternatives

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Recover and cut on deck/Reverse reel		Option 2—Reverse carousel	
Technical feasibility	Operability and feasibility	Technically feasible	Feasible.	1	Feasible.	1
	Technical readiness	Technology readiness levels	No material difference.	2	No material difference.	2

Focus area		Criteria	Evaluated concepts—qualitative ranking and justification			
			Option 1—Recover and cut on deck/Reverse reel		**Option 2—Reverse carousel**	
	Constructability, re-usability and decommissioning feasibility	Feasibility to construct	N/A		N/A	
		Re-usability	Umbilical is cut; limited re-usability.	4	Recovered as whole as it can be. Could potentially be repurposed, depending on capacity of the carousel and length of umbilical recovered.	3
		Feasibility of decommissioning	N/A		N/A	
Safety	Safety and risk	OHS and risk exposure	Greater risk to personnel of contaminants if cutting on deck. More cutting activities offshore.	3	Less cutting activities offshore; more cutting onshore.	2
		Process safety	N/A		N/A	
Commercial	Schedule risk	Ability to meet the development timeline	Slower recovery time but more flexibility in implementation.	2	Quicker recovery time, but vessel and reel availability may present challenges.	3
	Cost risk	Economic viability	Lower cost vessel spread, slightly lower recovery time, but likely more cost effective.	1	Higher cost vessel spread, but quicker recovery time.	2
	Future flexibility risk	Ability to accommodate future developments	No material difference.	2	No material difference.	2
Social	Socio-economic impacts	Impact to other marine users	No material difference.	2	No material difference.	2
	Reputation	Social licence to operate	No material difference.	2	No material difference.	2
	Cultural	Impact to cultural heritage values	Greater potential impact to marine fauna, primarily from underwater sound and GHG emissions and physical interaction. No material difference for impact to benthic habitats.	3	Less potential impact to marine fauna, primarily from underwater sound and GHG emissions and physical interaction. No material difference for impact to benthic habitats.	1
Other focus areas total:				22		20
Total score (including environmental scores):				**41**		**35**

The comparative environmental assessment shows a small difference in environmental criteria between the two options, with Option 2 ranked as more favourable. Option 2 involves an umbilical retrieval rate that is almost double that of Option 1. Therefore, impacts and risks associated with vessel activities are greater for Option 1 due to the longer duration of vessels in the field.

The comparative assessment based on the other focus areas (technical feasibility, safety, commercial and social) showed differences in individual criteria ranking but produced the same total score for both options.

The total qualitative ranking score for each option shows Option 2 is ranked better than Option 1, due to the lower environmental score. Option 2 relies on the availability of a suitable vessel and reel spread, both of which may present challenges. As a result, both options were selected for the OPP (see Section 5.3.7).

The umbilical retrieval option determined to be the most favourable, based on all criteria, is Option 2—Reverse carousel. However, this option has risks associated with the feasibility of the technique. To allow for potential future technological advancement, both options will be included in the OPP.

5.3.7 Options to be selected after OPP phase

OPPs are written early in project development, therefore some activity and design options will not be finalised until later in the project design phase, which will likely occur after the OPP phase.

The Development has a long project life (end of field life is ~2070) and the OPP framework under the OPGGS(E)R does not have a change mechanism. Consequently, the alternatives analysis process for the design and activity options (Section 5.3) identified some instances where multiple options need to be included in the OPP.

For the decommissioning options, CAPL considered methodologies and technologies that may not be feasible at the time of writing this OPP but may become available towards the end of field life. This allows flexibility to select the methodology with the best environmental outcome at the time.

Table 5-20 summarises the key options that will be selected after the OPP is submitted. All these options are included in the description (Section 4) and are within the scope of this OPP.

These options may have different impacts and risks; therefore Table 5-20 identifies which option presents the worst-case for specific key aspects. These options will be used for the impact assessment in Section 8 to ensure the option that presents the greatest potential environmental impact is assessed.

For example, the moored MODU option presents the worst-case for seabed disturbance; however, the DP MODU option presents the worst-case for underwater sound emissions. In this example, Section 8.1 Seabed Disturbance will assess the moored MODU option, and Section 8.5 Underwater Sound will assess the DP MODU option.

Table 5-20: Design and activity options included in the OPP

Activity / Design option	Option overview	Key aspects for impact assessment	Implications / discussion
MODU type	Moored MODU	Seabed disturbance	Moored and DP MODUs have similar total scores in the comparative environmental assessment, but the scores vary on some specific criteria. Moored MODUs impact the seabed due to anchoring and have greater potential to interact with marine fauna compared to a MODU on DP. Jack-up MODUs impact the seabed, but to a lesser extent than Moored MODUs. DP MODUs cause more underwater sound and atmospheric emissions compared to moored MODUs.
	DP MODU	Underwater sound Atmospheric emissions	
	Jack-up MODU	Seabed disturbance	
Flowline retrieval	Cut and lift	Seabed disturbance Planned emissions and discharges Physical presence	The cut and lift option is much slower than reverse lay. Therefore, impacts and risks associated with vessel activities are greater for cut and lift due to the longer duration of the decommissioning vessel spread in the field. For this reason, the duration of flowline retrieval used for impact assessment in Section 8 was based on the cut and lift option. Cut and lift also requires disturbance of the seabed around each cut site to allow access for the cutting tools. However, reverse lay for this size of pipe and water depth is not currently feasible at time of writing. It may become a more feasible option in future, which is why both options are selected.
	Reverse S-lay / J-lay	Introduction of IMPs	
Umbilical retrieval	Recover and cut on deck / reverse reel	Planned emissions and discharges Physical presence	Recover and cut on deck / reverse reel is slower than reverse carousel. Therefore, impacts and risks associated with vessel activities are greater for recover and cut / reverse reel due to the longer duration of the decommissioning vessel spread in the field. For this reason, the duration of umbilical retrieval used for impact assessment in Section 8 was based on the recover and cut on deck / reverse reel option. Both options are included in this OPP because the availability of the vessel capability and reel spread may present challenges.
	Reverse carousel	N/A. There is no material difference in key aspects.	

6 Description of the environment

6.1 Environment that may be affected

The environment that may be affected (EMBA) by the petroleum activity within scope of this OPP has been defined as an area where a change to environmental receptors may potentially occur as a result planned activities or unplanned events.

For this OPP, CAPL has defined sub-areas of the EMBA that are used to support the subsequent impact and risk assessments (Table 6-1, Figure 6-1; Figure 6-2). The term 'EMBAs' within this section refers to the definitions in Table 6-1.

Table 6-1: Description of EMBAs and associated areas for the Development

EMBA sub-area	Description and purpose
Operational Area (OA)	As described in Section 4.1.3, the OA is the area in which the petroleum activities will be undertaken.
Unplanned Hydrocarbon Release Ecological EMBA (Hydrocarbon Ecological EMBA)	The Hydrocarbon Ecological EMBA is relevant to the risk assessments for ecological receptors from unplanned hydrocarbon release events (Section 8.14 and 8.15), and is determined by the predicted spatial extent of hydrocarbon exposure at the relevant thresholds (Table 6-2, Figure 6-1).
Unplanned Hydrocarbon Release Social EMBA (Hydrocarbon Social EMBA)	The Hydrocarbon Social EMBA is relevant to the risk assessments for social, economic, and cultural receptors from unplanned hydrocarbon release events (Section 8.14 and 8.15), and is determined by the predicted spatial extent of hydrocarbon exposure at the relevant thresholds (Table 6-2, Figure 6-2). The Hydrocarbon Social EMBA incorporates lower thresholds for surface and shoreline hydrocarbon exposure that are associated with visible oil but are below concentrations at which ecological impacts are expected to occur.

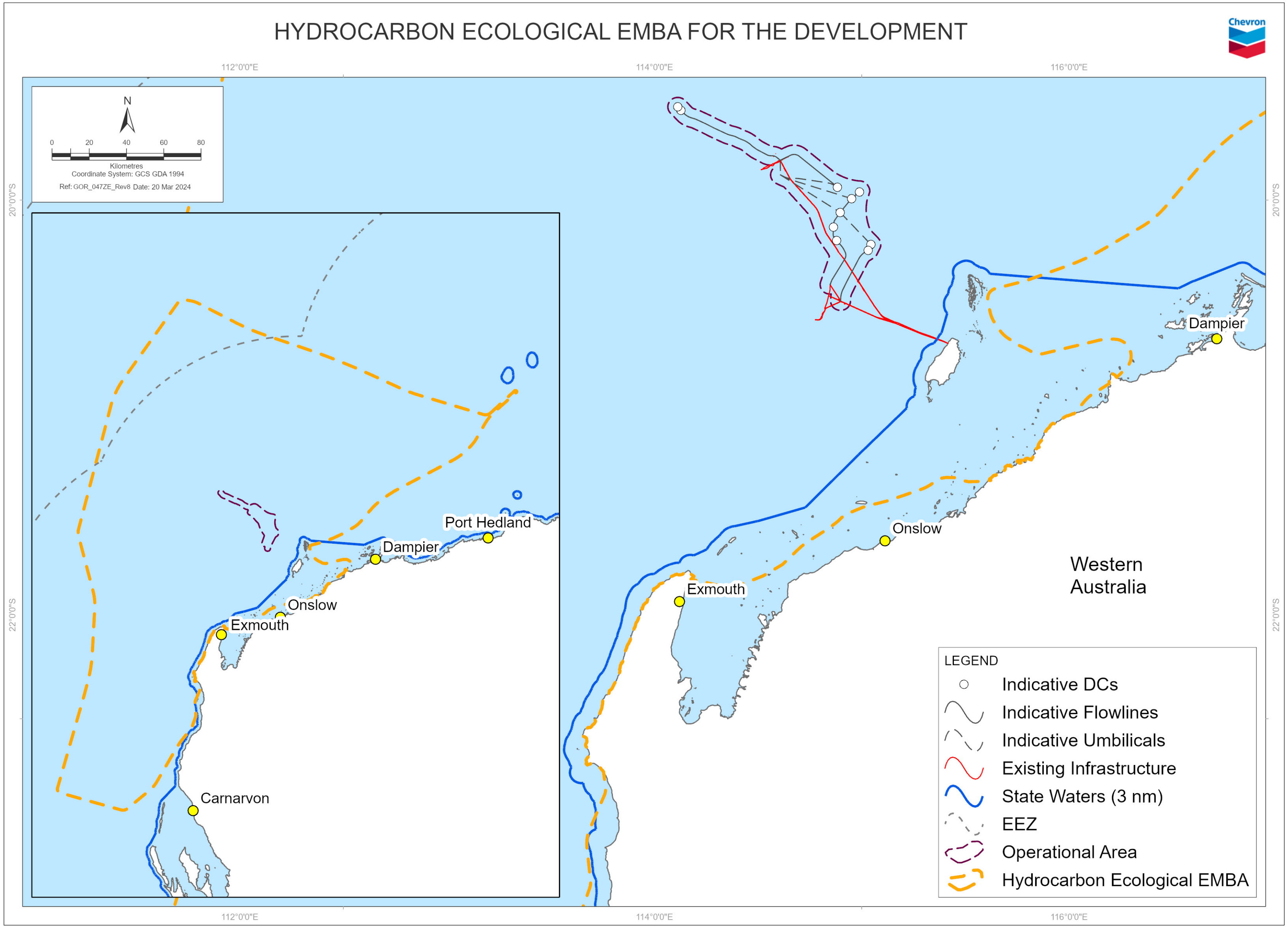

Figure 6-1: Hydrocarbon Ecological EMBA for the Development

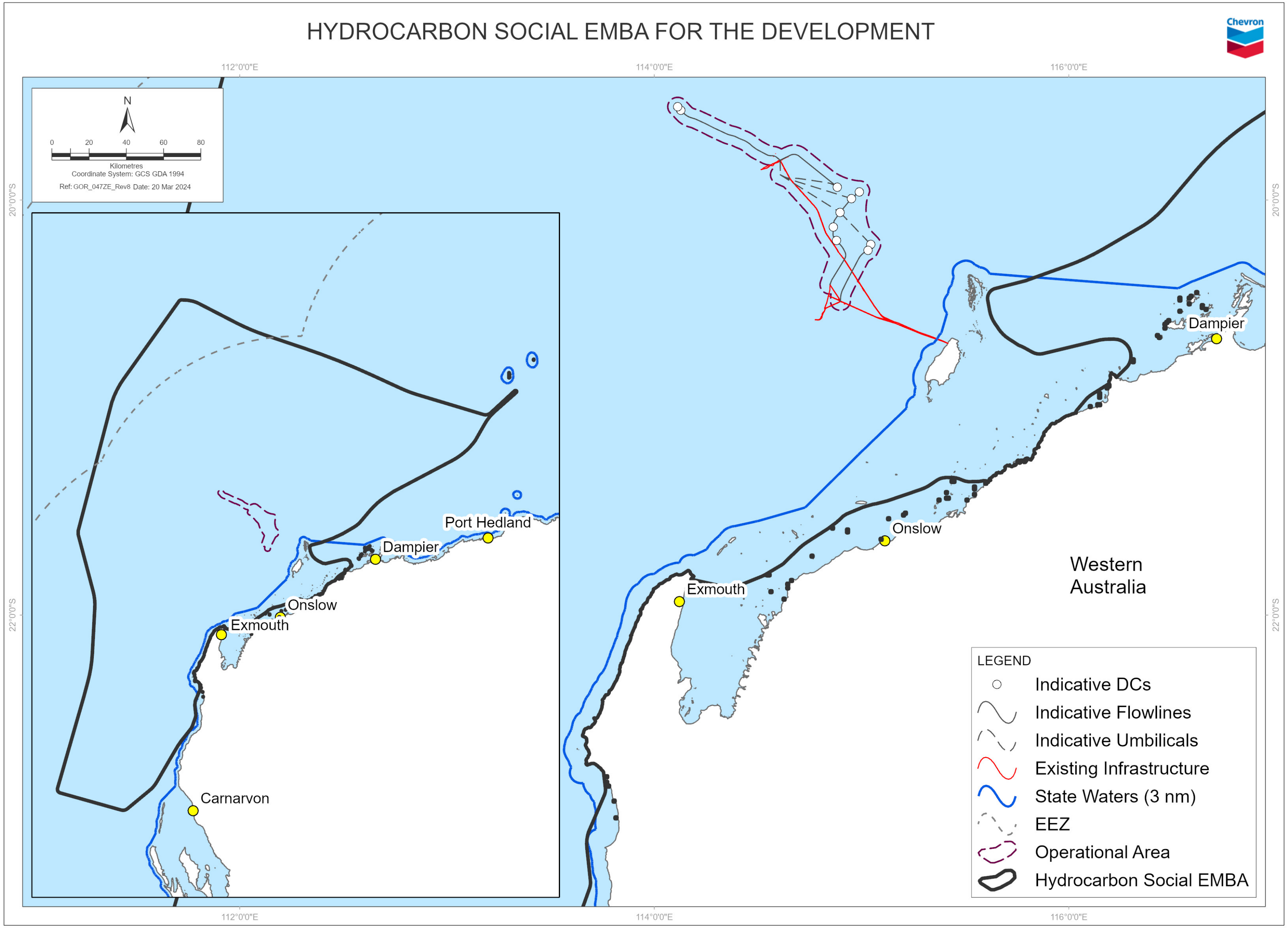

Figure 6-2: Hydrocarbon Social EMBA for the Development

The EMBAs above are determined by the predicted spatial extent of hydrocarbons from spill modelling (Appendix C). Table 6-2 describes the modelled hydrocarbon impact thresholds.

Table 6-2: Hydrocarbon environmental exposure thresholds

Impact threshold type	Impact threshold level	Justification
Hydrocarbon Social EMBA	Surface ≥1 g/m² (low)	In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 87), CAPL has set the surface impact threshold for socio-economic effects at ≥1 g/m², which is equivalent to ~1,000 L/km² or a layer thickness of ~1 µm. At this concentration, oil on the water surface is expected to be visible. The Bonn Agreement Oil Appearance Code (Ref. 88) describes a 0.3–5.0 µm thick oil layer as having a rainbow-coloured appearance. Due to this visibility, there is the potential to impact nature-based activities (such as tourism) via a reduction in aesthetics.
Hydrocarbon Ecological EMBA	Surface ≥10 g/m² (moderate)	In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 87), CAPL has set the surface impact threshold for ecological effects at ≥10 g/m², equivalent to ~10,000 L/km² or a layer thickness of ~10 µm. The Bonn Agreement Oil Appearance Code (Ref. 88) describes a 5–50 µm thick oil layer as having a metallic appearance. This threshold is considered by NOPSEMA to approximate the lower limit of harmful effects to birds and marine mammals (Ref. 87), and is consistent with observations within literature ranging from physical oiling to toxicity effects for marine fauna (e.g. French et al. [Ref. 89], French [Ref. 90] Engelhardt [Ref. 91], Clark [Ref. 92], Geraci and St. Aubin [Ref. 93] and Jenssen [Ref. 94]).
Hydrocarbon Ecological EMBA Hydrocarbon Social EMBA	In-water (dissolved) ≥50 ppb (moderate)	Laboratory studies have shown that dissolved oil exerts most of the toxic effects of oil on aquatic biota (e.g. Carls et al. [Ref. 95], Nordtug et al. [Ref. 96], Redman [Ref. 97]). Dissolved oil, which is soluble, can be taken up by organisms directly from the water column by absorption (through external surfaces and gills) and/or ingestion. In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 87), CAPL has set the in-water (dissolved) impact threshold for sublethal ecological effects at ≥50 ppb, which is considered by NOPSEMA to approximate potential toxic effects, particularly sublethal effects to sensitive species (Ref. 88). This threshold is based on an instantaneous concentration, and therefore only requires the dissolved oil to be at this concentration for one hour (based on minimum model time-step) to trigger this threshold.
Hydrocarbon Ecological EMBA Hydrocarbon Social EMBA	In-water (entrained) ≥100 ppb (high)	Entrained oil is insoluble droplets suspended in the water column—exposure pathways are direct contact with external tissue or direct oil consumption. In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 87), CAPL has set the in-water (entrained) impact threshold for sublethal ecological effects at ≥100 ppb, which is considered by NOPSEMA as appropriate for informing risk evaluation (Ref. 88). This threshold is based on an instantaneous concentration, and therefore only requires the entrained oil to be at this concentration for one hour (based on minimum model time-step) to trigger this threshold. French-McCay (Ref. 98) identified that if total hydrocarbons in entrained oil droplets was to be evaluated as a risk, 100 ppb would be an extremely conservative sublethal threshold.
Hydrocarbon Social EMBA	Shoreline ≥10 g/m² (low)	In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 87), CAPL has set the shoreline impact threshold for socio-economic effects at ≥10 g/m², equivalent to ~10 mL/m² or ~2 teaspoons/m². At this concentration, oil on the shoreline is expected to be visible. Due to this visibility, there is the potential to impact nature-based activities (such as tourism or recreational use) via a reduction in aesthetics.

Impact threshold type	Impact threshold level	Justification
Hydrocarbon Ecological EMBA	Shoreline ≥100 g/m^2 (moderate)	In accordance with NOPSEMA's oil spill modelling bulletin (Ref. 87), CAPL has set the shoreline impact threshold for ecological effects at ≥100 g/m^2, equivalent to ~100 mL/m^2 or 20 teaspoons/m^2. French et al. (Ref. 89) and French-McCay (Ref. 90) define shoreline oil accumulation at ≥100 g/m^2 as potentially harmful to wildlife (including invertebrates, birds, furbearing aquatic mammals and marine reptiles), based on studies for sublethal and lethal impacts. Impacts on vegetated habitats (such as saltmarsh and mangroves) have been observed at higher concentrations of shoreline oil. Observations by Lin and Mendelssohn (Ref. 99) demonstrated that loadings of >1,000 g/m^2 of oil during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing oil impacts on mangroves (e.g. Grant et al. [Ref. 100], Suprayogi and Murray [Ref. 101]).

The following sections describe the environment in relation to the OA and EMBAs for the Development.

6.2 Ecosystems and their constituent parts including people and communities

6.2.1 Benthic habitats and associated communities

Benthic communities are biological communities that inhabit the seabed and are important for primary or secondary production. Benthic habitats are areas of seabed that do or can support these communities. Benthic communities play important roles in maintaining the integrity of marine ecosystems and the supply of ecological services. There is strong evidence that benthic communities are important for maintaining biological diversity by providing structurally complex and diverse habitat, refuge for vulnerable life stages and a varied and increased food supply (Ref. 102).

The Hydrocarbon Ecological EMBA occurs within the North-west Marine Region (NWMR), which is typically characterised by shallow-water tropical marine ecosystems and high species richness (Ref. 103; Ref. 104). The high species richness is thought to be associated with the diversity of habitats available, such as limestone pavement, coral reefs, and pinnacles (Ref. 103). The broader benthic habitats and communities that may be present within the Hydrocarbon Ecological EMBA are summarised below, with additional data specific to the OA summarised in Section 6.2.1.1.

The geomorphology of Australia's continental margin is varied. Preliminary mapping of seabed geomorphology identified 8 broad geomorphic feature types—mostly bare sediments, bedforms, irregular seabed, mounds, depression/scours, rock veneer, rock reef and scarp (Ref. 105, Appendix A).The primary geomorphic features include the continental shelf, the upper, middle, and lower continental slope, the Kangaroo Syncline (deepwater area separating Barrow Island from the Exmouth Plateau), and the Exmouth Plateau (see Section 6.2.1.1; Ref. 105, Appendix A)

The composition, distribution, and movement of marine sediments is an important component of a marine ecosystem. These sediments can influence the primary biological production in the water column as well as the evolution and distribution of benthic habitats. The north-west region of WA comprises bio-clastic, calcareous, and organogenic sediments deposited from relatively slow and uniform sedimentation rates (Ref. 106). Sediments in the NWMR generally become finer with increasing water depth, ranging from sand and gravels on the continental shelf to mud on the continental slope and abyssal plain (Ref. 107).

Based on the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) marine benthic substrate database (Ref. 108), the predominant sea floor sediment type within the OA is 'calcareous gravel, sand and silt'. Within the Hydrocarbon Ecological EMBA, 4 sea floor sediment types were identified — 'calcareous gravel, sand and silt', 'calcareous ooze', 'Biosiliceous marl and calcareous clay', and 'mud and calcareous clay'.

The Integrated Marine and Coastal Regionalisation of Australia (IMCRA) is a biogeographic regionalisation of oceanic waters within Australia's exclusive economic zone (EEZ) (Ref. 109). The OA occurs within the Northwest Province and Northwest Shelf Province bioregions. Table 6-3 summarises the characteristics and features of ecological importance for each of these bioregions.

Listed Threatened Ecological Communities (TECs) are an MNES under the EPBC Act, and a particular value and sensitivity under the OPGGS(E)R. There are no known TECs within the Hydrocarbon Ecological EMBA.

Table 6-3: Features of provincial bioregions

IMCRA provincial bioregion[11]	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA
Northwest Province	✓	**0**	✓
Geomorphic and biological characteristics of the Northwest Province include: • bioregion occurs entirely on the continental slope and comprises muddy sediments • distinguished by a number of topographic features, such as the Exmouth Plateau, terraces and canyons (including the Swan and Cape Range canyons), as well as deep holes and valleys on the inner slope (including the Montebello Trough) • the benthic shelf and slope communities of this bioregion comprise both tropical and temperate species with a north-south gradient • the continental slope between North West Cape and the Montebello Trough has been identified as one of the most diverse slope habitats of Australia • the Exmouth Plateau is also likely to be an important area for biodiversity as it provides an extended area offshore for communities adapted to depths of ~1,000 m • based on information available on sediments in the bioregion: – benthic communities are likely to include filter feeders and epifauna – soft-bottom environments are likely to support patchy distributions of mobile epibenthos, such as sea cucumbers, ophiuroids, echinoderms, polychaetes and sea pens – biological communities within canyons in the bioregion are poorly understood. Features and areas of ecological importance within the Northwest Province are: • Exmouth Plateau • canyons on the slope, including the Cape Range Canyon • demersal fish communities associated with the slope. Of these features and areas within the Northwest Province, the demersal fish communities and Exmouth Plateau associated with the slope occurs within the OA and Hydrocarbon Ecological EMBA. The canyons on the slope also occur within the Hydrocarbon Ecological EMBA. Section 6.2.6.1 has further descriptions of these features.			

[11] Source: Ref. 109, Ref. 111, Ref. 104

IMCRA provincial bioregion[11]	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA
Northwest Shelf Province	✓	**0**	✓
Geomorphic and biological characteristics of the Northwest Shelf Province include: • bioregion occurs almost entirely on the continental shelf, except for a small area north of Cape Leveque that extends onto the continental slope • the continental shelf gradually slopes from the coast to the shelf break, but displays a number of sea floor features such as banks/shoals and holes/valleys, including: – Glomar Shoals, which occur in waters ~33–77 m deep and are distinguished by highly fractured molluscan debris, coralline rubble, and coarse carbonate sand (Ref. 110) – Leveque Rise (large plateau), one of only 2 shelf plateaux within the NWMR – tidal sandwaves or sandbanks (~5–10 m high), which occur on the innermost reaches of Exmouth Gulf, and are one of only 3 major occurrences of this type of feature in the NWMR – shelf, which also contains several terraces and steps that extend into adjacent bioregions and reflect ancient coastlines from when the sea level in the NWMR was lower; the most prominent of these occurs at a water depth of ~125 m. • sediment differentiation occurs on a north–south gradient: – south of Broome, sediment is relatively homogenous and dominated by sands with small proportion of gravel – north of Broome, sediment is highly variable with sand or gravel dominance in no discernible spatial pattern – mud increases within ~100 km of the coast and within ~100 km of the shelf break but is mostly absent from other areas. • sandy substrates on the shelf within this bioregion are thought to support low-density benthic communities of bryozoans, molluscs, and echinoids • sponge communities are also sparsely distributed on the shelf but are found only in areas of hard substrate. Features and areas of ecological importance within the Northwest Shelf Province are: • Browse Island and surrounding waters • Lacepede Islands and surrounding waters • Quondong Point, north of Broome and surrounding waters • west coast of the Dampier Peninsula, including Beagle and Pender bays and surrounding waters • Pilbara coast (between Exmouth and Broome) and surrounding waters • Exmouth Gulf—Muiron Islands and surrounding waters • ancient coastline at 125 m depth contour • Glomar Shoals. Of these features and areas within the Northwest Shelf Province, the ancient coastline at 125 m depth contour occurs within the OA and Glomar Shoals, Exmouth Gulf—Muiron Islands and surrounding waters (partially), and the Pilbara coast occur within the Hydrocarbon Ecological EMBA. Section 6.2.6.1 has further descriptions of these features.			
Northwest Transition	-	**56.6**	✓
Geomorphic and biological characteristics of the Northwest Transition include: • about half of the bioregion occurs on the continental slope, with smaller areas in the north-west of the bioregion located on the Argo Abyssal Plain and continental rise • encompasses a range of water depths, from the shelf break (~200 m water depth) to ~5,980 m over the Argo Abyssal Plain • other topographic features within the bioregion include rises, ridges, canyons and apron/fans • sediments of the slope are dominated by sands, whereas the sediments of the abyssal plain/deep ocean floor are dominated by muds			

<table>
<tr><th colspan="2">IMCRA provincial bioregion[11]</th><th>OA</th><th>Distance to OA (~km)</th><th>Hydrocarbon Ecological EMBA</th></tr>
<tr><td></td><td colspan="4">• the bioregion also has reefs such as Mermaid, Clerke, and Imperieuse reefs, which are collectively known as the Rowley Shoals
• the benthos of the deep ocean areas is likely to support meiofauna (e.g. nematodes), larger infauna (e.g. polychaete worms, isopods), and sparsely distributed epibenthic communities (e.g. sea pens)
• mobile benthic species (e.g. deepwater sea cucumbers, crabs, polychaetes) are likely to be associated with the sea floor, and the bioregion may support sparse populations of bentho-pelagic fish and cephalopods in low densities.
Features and areas of ecological importance within the Northwest Transition are:
• Rowley Shoals—Mermaid Reef Marine National Nature Reserve, Clerke and Imperieuse reefs and surrounding waters
• fish communities associated with the slope.
Of these features and areas within the Northwest Transition, the demersal fish communities associated with the slope occurs within the OA and Hydrocarbon Ecological EMBA. Section 6.2.6.1 has further descriptions of this feature.</td></tr>
<tr><td colspan="2">Central Western Transition</td><td>-</td><td>207.7</td><td>✓</td></tr>
<tr><td></td><td colspan="4">Geomorphic and biological characteristics of the Central Western Transition include:
• Ningaloo Reef.
Features and areas of ecological importance within the Central Western Transition are:
• Commonwealth waters adjacent to Ningaloo Reef
• canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula
• Wallaby Saddle.
Of these features and areas within the Central Western Transition, the Commonwealth waters adjacent to Ningaloo Reef occur within the Hydrocarbon Ecological EMBA. Section 6.2.6.1 has further descriptions of these features.</td></tr>
<tr><td colspan="2">Central Western Shelf Transition</td><td>-</td><td>128.2</td><td>✓</td></tr>
<tr><td></td><td colspan="4">Geomorphic and biological characteristics of the Central Western Shelf Transition include:
• Ningaloo Reef.
Features and areas of ecological importance within the Central Western Shelf Transition are:
• Commonwealth waters adjacent to Ningaloo Reef.
Of these features and areas within the Central Western Shelf Transition, the Commonwealth waters adjacent to Ningaloo Reef occur within the Hydrocarbon Ecological EMBA. Section 6.2.6.1 has further descriptions of this feature.</td></tr>
<tr><td colspan="2">Central Western Shelf Province</td><td>-</td><td>415.6</td><td>✓</td></tr>
<tr><td></td><td colspan="4">Geomorphic and biological characteristics of the Northwest Transition include:
• consists of the continental shelf between Kalbarri and Coral Bay
• most of the bioregion varies in depth between 50–100 m and has a predominantly flat, sandy substrate
Features and areas of ecological importance within the Central Western Shelf Province are:
• Shark Bay World Heritage Area.
None of these features of ecological importance occur within the Hydrocarbon Ecological EMBA.</td></tr>
</table>

6.2.1.1 Operational area

CAPL conducted extensive surveys to characterise the marine environment within the OA (Ref. 105, Appendix A).

Prior to surveys, a preliminary benthic habitat map was developed based on assessment of geomorphic features derived from sonar and seismic survey data (Figure 6-3). Field surveys were undertaken to collect data on benthic habitat, sediment, benthic infauna, marine water and fish assemblages within the OA.

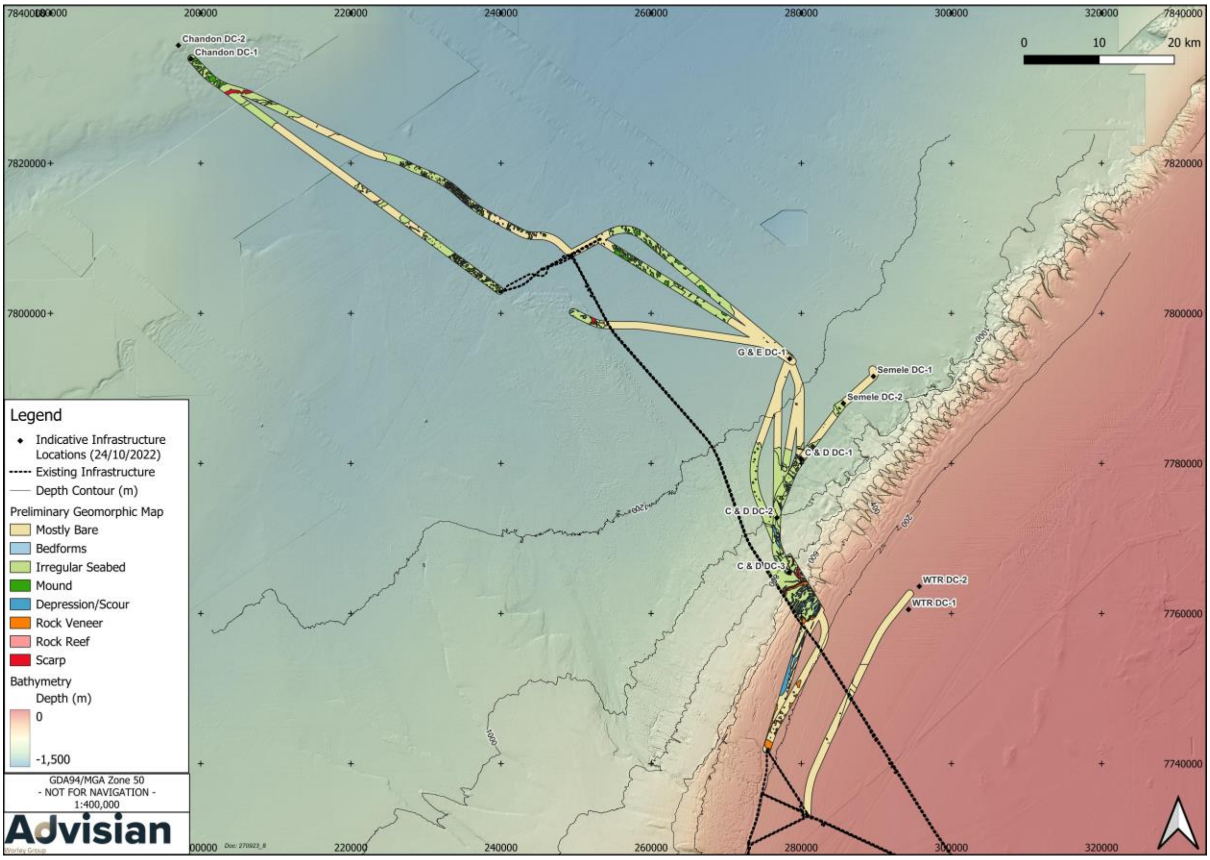

Figure 6-3: Preliminary benthic habitat map based on assessment of geomorphic features within the OA (Ref. 105, Appendix A)

Overall, the distribution of benthic habitat within the OA comprises mostly a mixture of flat sediment terrain with bioturbation or bare sediment, and isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Ref. 109; Ref. 112). The mapped benthic habitats were representative of known regional and local habitats and no new benthic habitats or communities to the bioregion were observed.

Benthic habitats were characterised within key ecological features (KEFs), at low slope areas, and at proposed DCs. The overall distribution of benthic habitats (using field survey results) are presented in Figure 6-4.

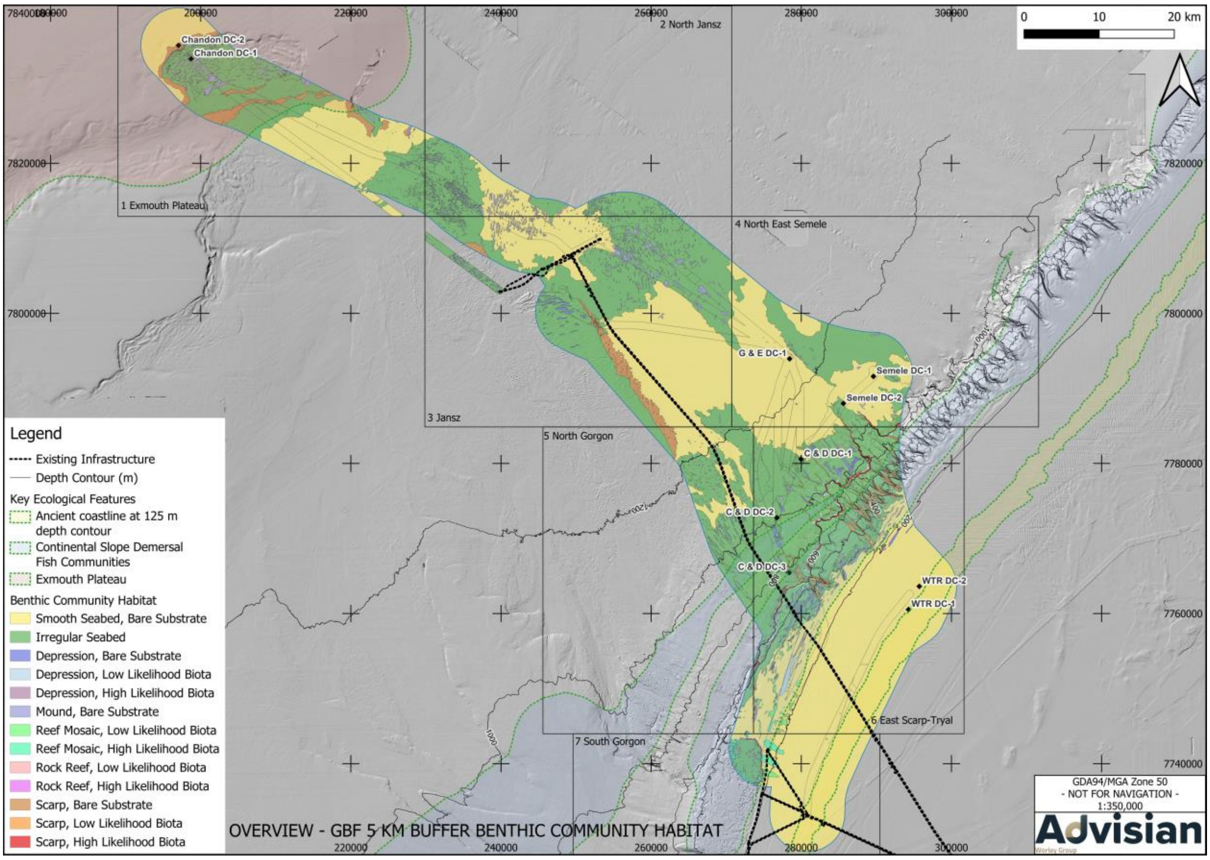

Figure 6-4 Overall distribution of benthic habitats within the Development OA, subdivided into seven broad areas (1 Exmouth Plateau, 2 North Jansz, 3 Jansz, 4 North East Semele, 5 North Gorgon, 6 East Scarp-Tryal, and 7 South Gorgon areas) (Ref. 105, Appendix A)

An ROV video survey was undertaken at the Jansz–Io field which overlaps the OA, in waters ~700–1,360 m deep, to assess the benthic habitats and fauna assemblages (Ref. 113). The video footage was collected between 2015 and 2018 across 37 sites (29 sites on existing infrastructure and 8 sites away from Jansz–Io pipelines). In line with other studies at similar depth contours around Australia, species richness, diversity and abundance decreased with depth (Ref. 113). However, standardised comparisons showed overall diversity, overall abundance, and species richness were typically greater at sites on the infrastructure (Ref. 113).

Benthic habitats and communities at KEFs

In the Exmouth Plateau KEF that lies within the OA, three large discrete scarps with bare substrate are present. Of these, two scarps ~5.5 km and 2.5 km from the KEF border, cross through the Chandon flowline from east to west, likely representing the edge of the Exmouth Plateau. The third scarp that runs from east to west is ~500 m wide and located ~1.4 km north of the Chandon DCs. Biota may be present on the scarps or steep slopes, however, was not detected along the transect in this area (Ref. 105, Appendix A).

The seabed immediately surrounding one of the Chandon DCs (out to ~5 km east and west, and ~6 km along the Chandon flowline), comprised of bioturbated irregular seabed and large patches of depressions over bare substrate. Little to no biota is predicted to occur in these bare substrates.

Where the OA overlaps the Continental slope demersal fish communities KEF, irregular and smooth seabed with bare substrates and discrete depressions of bioturbated sediments were the most dominant benthic features (Ref. 105, Appendix A).

Larger scarps (in relation to the scarp adjacent to the furthest south C&D DC) are evident north, south and east of this DC. A mixture of habitats and benthic communities extend along the indicative flowline from this DC to the C&D tie in location. This includes the presence of a continuous south-west to north-east scarp with low and high likelihood of biota, discrete patches of depressions over bare substrate, and reef mosaic adjacent to the scarps with a low likelihood of biota. Benthic transects within the KEF showed sections of rock reef mosaic that cross through the C&D flowline are colonised by sponges and cnidarians (Ref. 105, Appendix A).

Topographically complex scarps in a south-west to north-east orientation with low and high likelihood of biota are present traversing through the OA within the Continental slope demersal fish communities KEF between ~400–800 m depths. Ground-truthing transects verified the presence of cnidarians, echinoderms, sponges and a mixture of these biotic groups along these scarps in varying percent cover (from low [<10%] to high cover [>80%]) (Ref. 105, Appendix A).

Patches of reef mosaic with a low likelihood of biota, and rock reef and depressions with a high likelihood of biota are present to the west of the C&D flowline, which are likely to support sponges and cnidarians, as verified by benthic habitat transects. A scarp orientated north to south with a high likelihood of biota is present ~650 m west of the M1 tie in location and runs parallel to existing subsea infrastructure (Ref. 105, Appendix A).

Mapping of the survey area that lies within the Ancient coastline at 125 m depth contour KEF only captured the proposed tie-in location Gorgon Manifold PTS. The benthic habitat at Gorgon MPTS comprised smooth seabed with bioturbation and appeared to be devoid of epibenthic biota (Ref. 105, Appendix A).

These results are comparable to previous studies of the Exmouth Plateau (Ref. 110), Continental slope demersal fish communities (Ref. 103) and Ancient coastline (Ref. 114) that identified soft sediments (sand and mud/silt) as the dominant substrate type in deeper waters with less than 15% benthos cover and <1% cover of boulder/rock reef substrate (Ref. 105, Appendix A).

Benthic habitats and associated communities at low slope areas

Low slope areas are those within the OA that contain flowlines and umbilical corridors situated outside KEFs in the lower slope and Kangaroo Syncline area and are characterised by low structural complexity/rugosity and carbonate and clay muds (Ref. 105, Appendix A).

Habitat mapping showed a mixture of low structural habitats present within the Chandon DC-1 to JMT corridor. The benthic habitat within the Jansz to G&E corridors comprised smooth seabed with bioturbation and irregular seabed with bare substrate, with intermittent mounds with bare substrate and scattered patches of depressions over bare substrate. No epifauna were identified during the benthic surveys. The benthic habitats within the C&D to Gorgon corridor are predominantly characterised by smooth and irregular seabed with either bare substrate or bioturbation (Ref. 105, Appendix A).

Benthic habitats and associated communities at DCs

Across the 14 proposed DCs sites and tie-in locations in the benthic report (Ref. 105), bare sediment (soft unconsolidated sand/mud <2 mm) with no biota was the dominant benthic category.

The occasional presence of boulders over bare sediment was observed along some transects at Jansz JMT, Jansz DC-2, Semele DC-1 and Semele DC- 2, ranging between 50% and 100% percent cover. Bioturbation with cnidarians was observed at site Gorgon M1 where they contributed to 1% of the overall cover.

The benthic habitat around the proposed Semele DC-1 and Semele DC-2 associated flowlines is of low structural complexity and dominated by smooth seabed with bioturbation. Similarly, the G&E DC-1 is primarily comprised of smooth seabed with bioturbation and scattered patches of bedforms with bare substrate to the north and north-east of the proposed DC (Figure 6-5). Ground truthing transects at each of these locations did not reveal any epifaunal communities. Although higher or rougher topographic features were not identified in any of the captured still images, habitat mapping of C&D DC-3 and NTB3 proposed DCs suggests that consolidated and steep scarps are present and may support benthic communities (Ref. 105, Appendix A).

Despite the limited number of individuals collected, the benthic infauna found were primarily in both deep-sea sediments (1100–1200 m) around proposed DCs Semele DC-1, Semele DC-2, and shallower seabed (100–200 m) at WTR DC-1. The benthic infauna collected in this study, which included marine worms, a mollusc and polychaete worm, is similar to previous seabed surveys in the north-west shelf region (Ref. 110; Ref. 115; Ref. 116) whereby polychaetes and crustaceans are the dominant epibenthic and infaunal invertebrates of soft sediment habitats. While the survey used ROV push corers which capture a smaller surface area compared to traditional box corers, the results are consistent with other surveys in the NWS region which have also recorded a sparse distribution of epifaunal and infaunal benthic biota, with abundances ranging from one to 47 individuals (Ref. 116; Ref. 115) (Ref. 105, Appendix A). Furthermore, studies completed within the region indicate that benthic infauna composition in deep water habitats is generally lower in abundance than shallow water habitats of the region (Ref. 104; Ref. 107). Gage (1996) (Ref. 117) reported that the density of benthic fauna tends to be lower in deep water sediments (>200 m) than in shallower coastal sediments, but the diversity of communities may be similar. Regardless of the survey methodology associated with infauna, when considering the distribution of benthic habitat within the GBF project area comprises mostly a mixture of flat sediment terrain with bioturbation or bare sediment, and isolated areas of high structural complexity, which are typical of the Northern Carnarvon Basin (Ref. 110) and no new benthic habitats or communities to the bioregion were observed, it is also reasonable to assume the infauna communities within the wider operational area representative of infaunal communities within region.

The distribution of benthic habitats within Jansz DC-2 tie in location and G & E DC-1 are shown in Figure 6-5. Distribution of benthic habitats within WTR DC-1 is shown in Figure 6-6.

Figure 6-5: Distribution of benthic habitats within Jansz DC-2 tie in location (left) and G & E DC-1 (right) with representative images of the benthic communities and habitats (Ref. 105, Appendix A)

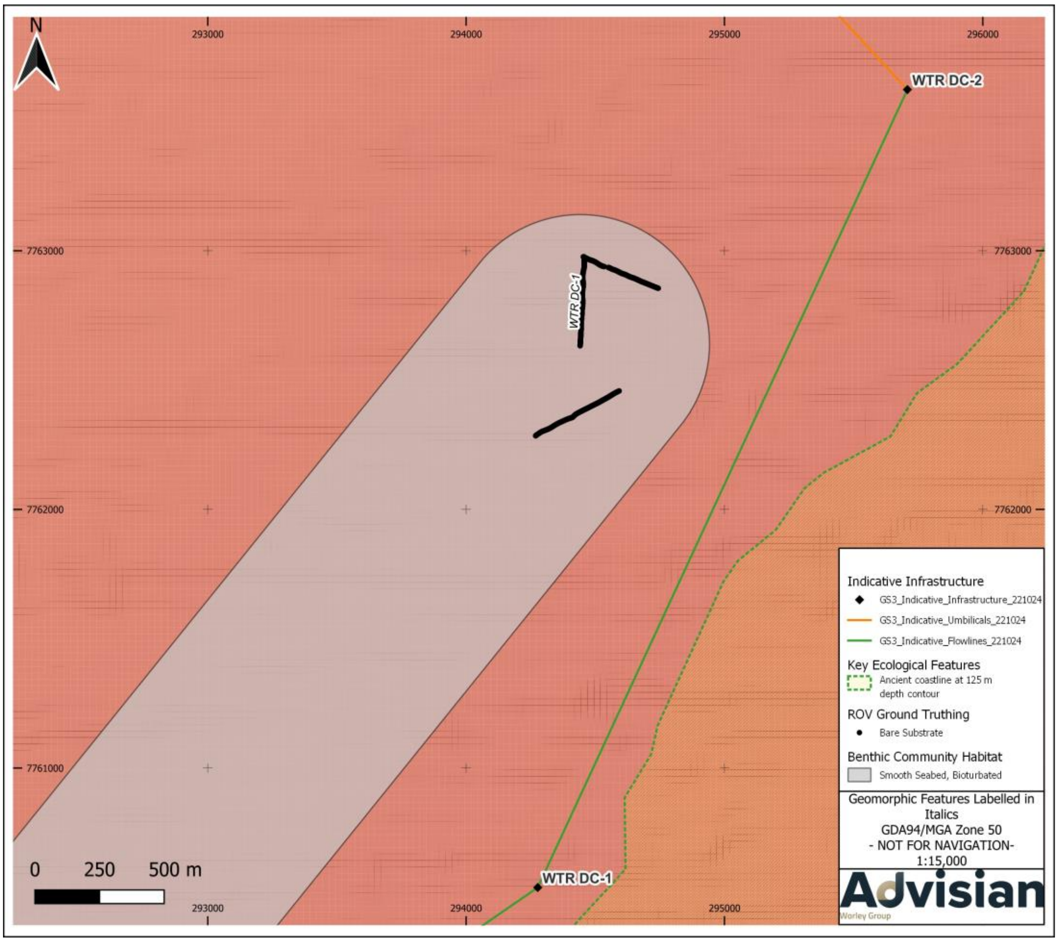

Figure 6-6: Distribution of benthic habitats within WTR DC-1 with a representative image of the benthic communities and habitats (Ref. 105, Appendix A)

6.2.1.2 Rankin Bank

Rankin Bank is ~55 km east of the OA. Although Rankin Bank is not protected and is not a KEF, it is the only large, complex bathymetrical feature on the outer western shelf of the west Pilbara region and represents habitats that are likely to play an important role in the productivity of the Pilbara region (Ref. 118). Rankin Bank has 3 submerged shoals delineated by the 50 m depth contour with water depths of ~18–30.5 m (Ref. 118). In 2013, AIMS and Woodside co-invested in a project to better understand the habitats and complexity of the submerged shoal ecosystems. Rankin Bank represents a diverse marine environment, predominantly comprising consolidated reef and algae habitat (~55% cover), followed by hard corals (~25% cover), unconsolidated sand/silt habitat (~16% cover), and benthic communities comprising macroalgae, soft corals, sponges, and other invertebrates (~3% cover) (Ref. 118). The proportion of cover at Rankin Bank was highest for macroalgae and hard corals, particularly at depths <40 m, and cover decreased with increasing depth (Ref. 119). Encrusting corals (reaching cover of ~12.5%) at depths <40 m and solitary corals (~10% cover) primarily at 40–60 m depths were also present (Ref. 119). Other benthic taxa, including soft corals and sponges, were present in lower proportions at all depths (Ref. 119). The high cover of macroalgae and hard corals in shallower water depths are likely due to greater light penetration and lower sand cover (Ref. 119).

6.2.2 Coastal habitats and associated communities

Coastal communities are biological communities that inhabit the coastal zone. Coastal habitats are areas of shoreline that can support these communities. Similarly to benthic communities (Section 6.2.1), coastal communities are likely to play roles in maintaining the integrity and diversity of coastal ecosystems, and in supplying ecological services.

The OA occurs offshore and does not have any overlap with the coast. However, the Hydrocarbon Ecological EMBA and the Hydrocarbon Social EMBA do overlap with coastal areas, specifically Barrow Island, Great Sandy Island, the Montebello Islands, Passage Islands, Cape Range National Park, Muiron Islands, and around the Point Cloates / Ningaloo Station area (Figure 6-7 and Figure 6-8). The Hydrocarbon Social EMBA includes additional shoreline points dispersed along the coast from North West Cape to islands in the Dampier Archipelago (including Enderby Island and Rosemary Island) (Figure 6-8).

The coastal habitats and communities that may be present within the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA are summarised below.

Based on Smartline (Ref. 120), a spatial database containing geomorphic classifications for Australia's coasts, the types of shoreline present within the Hydrocarbon Social EMBA and Hydrocarbon Ecological EMBA include:

- sandy and soft sediment shores (points along the coast from Tubridgi Point to Burrup Peninsula) (Hydrocarbon Social EMBA only; Figure 6-8)
- rocky coasts and sandy beaches (Barrow and Montebello islands and Lefroy Bay to North West Cape)
- sandy tidal flats (Point Cloates / Ningaloo Station).
- Shoreline types based on Smartline classifications (Figure 6-7 and Figure 6-8).

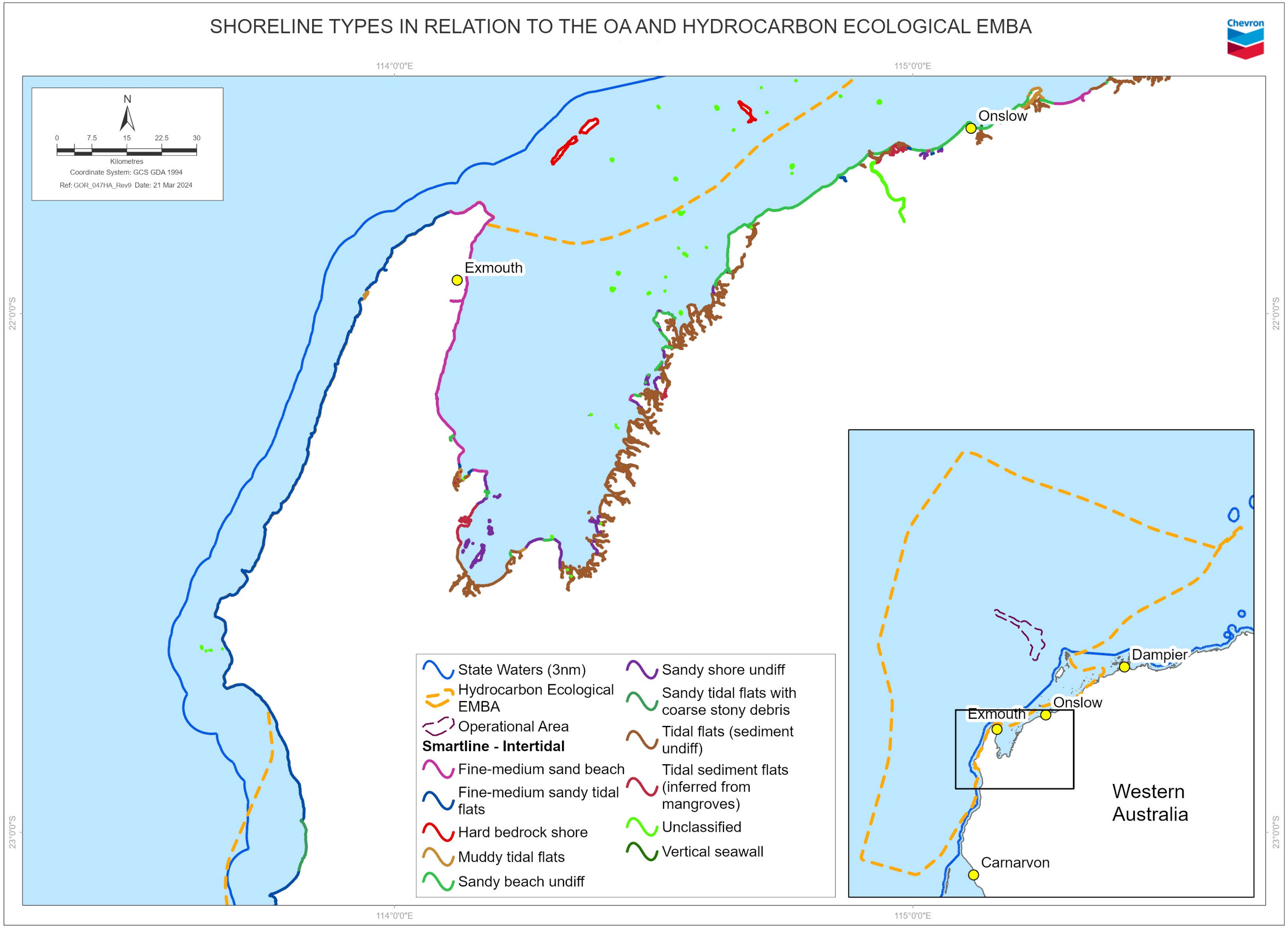

Figure 6-7: Shoreline types in relation to the OA and Hydrocarbon Ecological EMBA

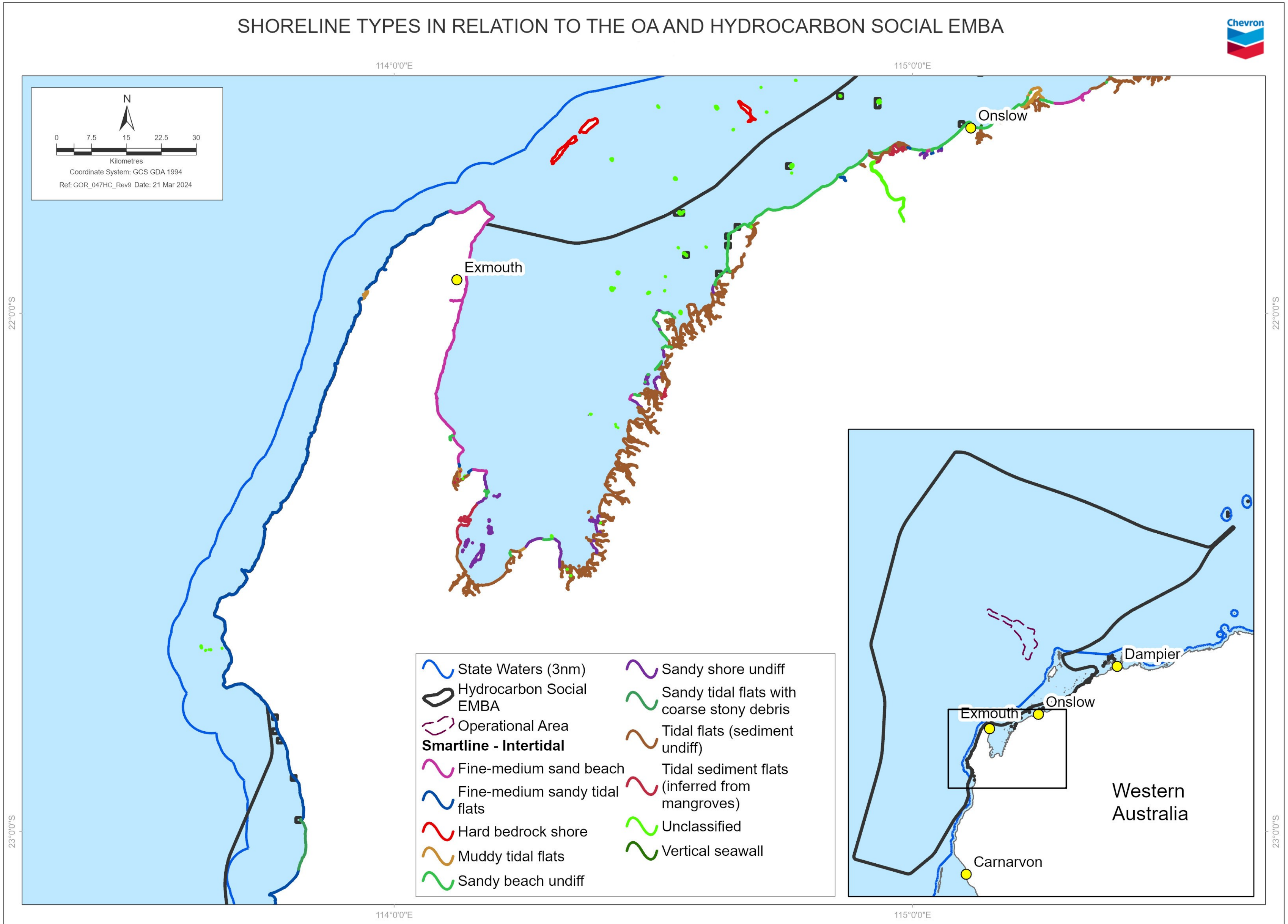

Figure 6-8: Shoreline types in relation to the OA and Hydrocarbon Social EMBA

The Seamap Australia spatial database collates and classifies marine and coastal habitats on the Australian continental shelf (Ref. 121). Based on this dataset, areas of saltmarsh may be present on Barrow Island, the Pilbara Coast, Dampier Archipelago Islands and Exmouth Gulf. Areas of mangroves may be present along the Pilbara coast and Exmouth Gulf and on several islands including the Montebello Islands, Muiron Islands, Barrow Island, and some of the Dampier Archipelago islands. Mangroves grow within the intertidal zone, typically within sheltered areas. The mangrove communities within the Montebello Islands are considered globally unique because they occur in the lagoons of offshore islands (Ref. 122).

Listed TECs and wetlands of international importance (Ramsar wetlands) are MNES under the EPBC Act, and a particular value and sensitivity under the OPGGS(E)R. There are no known TECs or Ramsar wetlands within the Hydrocarbon Social EMBA or the Hydrocarbon Ecological EMBA (Figure 6-9).

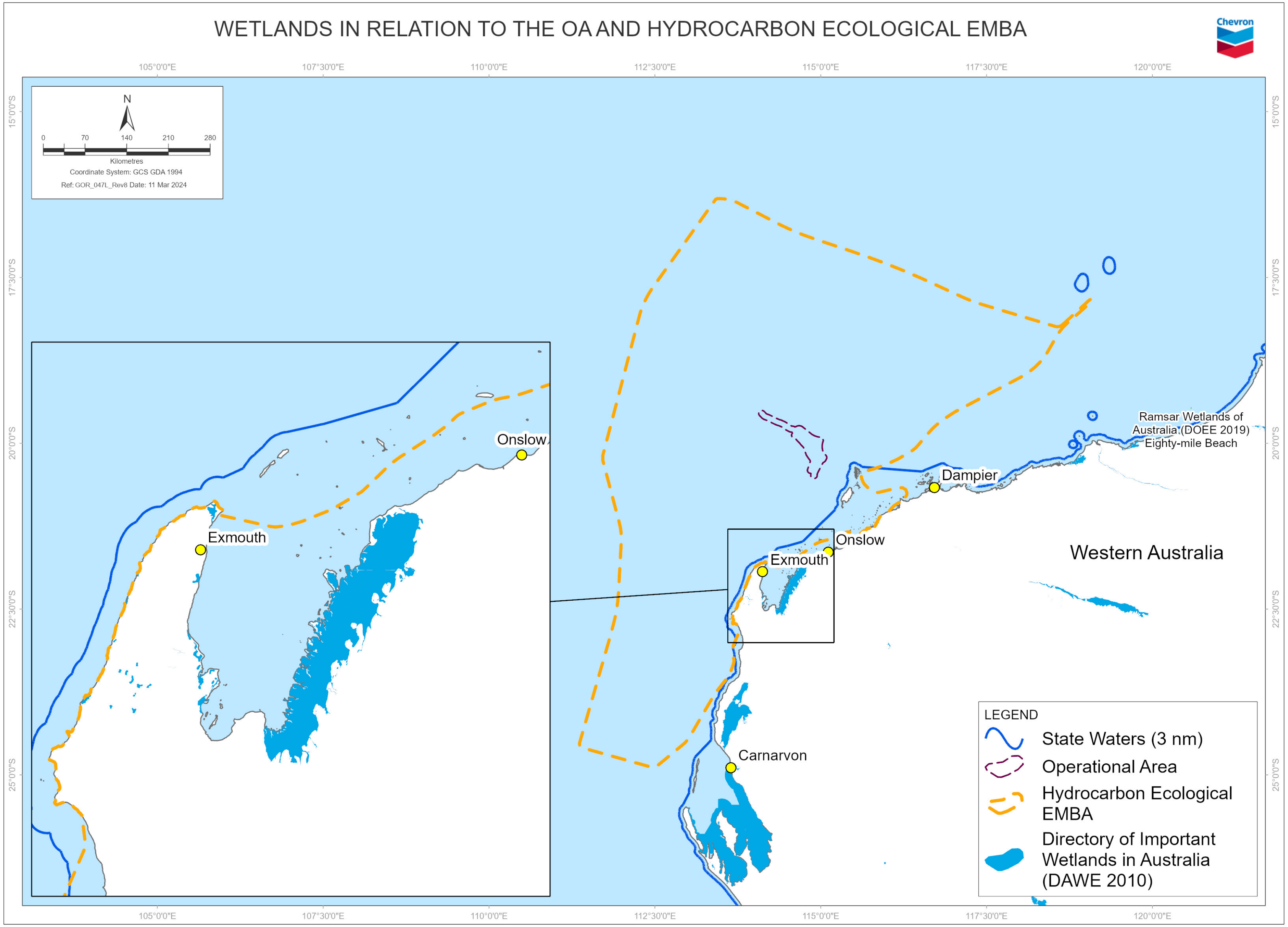

Figure 6-9: Wetlands in relation to the OA and Hydrocarbon Ecological EMBA

6.2.3 Marine fauna

Listed threatened or migratory species are MNES under the EPBC Act, and a particular value and sensitivity under the OPGGS(E)R. The following subsections detail the presence of these species and Biologically important areas (BIAs) within the OA and Hydrocarbon Ecological EMBA. BIAs are areas used at certain times by protected marine species for critical life functions, such as reproduction, feeding, migration and resting behaviours (DCCEEW, 2024). These behaviours are referred to as biologically important behaviours or critical behaviours.

6.2.3.1 Marine mammals

Based on searches of the EPBC Act protected matters database (Ref. 123, Appendix B), the threatened or migratory mammal species shown in Table 6-4 may be present within the OA and Hydrocarbon Ecological EMBA. Jansz-Io Soundscape monitoring in the area also detected three cetacean species that were present in the vicinity of the OA however were not listed in the protected matters search (Antarctic blue whale (*Balaenoptera musculus intermedia)*, Dwarf minke whale (*Balaenoptera acutorostrata* unnamed subsp) and Omura's whale (*Balaenoptera omurai*). Biologically important areas (BIAs) associated with marine mammal species are listed in Table 6-5.

Table 6-4: Presence of threatened or migratory marine mammals

Common name	Scientific name	EPBC Act presence	EPBC Act status				WA BC Act[12]
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation status
Cetaceans (whales)							
Antarctic minke whale, dark-shoulder minke whale	*Balaenoptera bonaerensis*	LO	LO	-	✓	✓	MI
Antarctic blue whale[1]	*Balaenoptera musculus intermedia*	-	-	E (as *Balaenoptera musculus)*	✓ (as *Balaenoptera musculus)*	✓ (as *Balaenoptera musculus)*	E (as *Balaenoptera musculus)*
Blainville's beaked whale, dense-beaked whale	*Mesoplodon densirostris*	MO	MO	-	-	✓	-
Blue whale	*Balaenoptera musculus* (and subsp. *Balaenoptera musculus brevicauda)*	KO	KO	E	✓	✓	E
Bryde's whale	*Balaenoptera edeni*	LO	LO	-	✓	✓	MI
Cuvier's beaked whale, goose-beaked whale	*Ziphius cavirostris*	MO	MO	-	-	✓	-
Dwarf sperm whale	*Kogia sima*	MO	MO	-	-	✓	-
Dwarf minke whale[1]	*Balaenoptera acutorostrata* unnamed subsp.	-	-	-	-	✓ (as *Balaenoptera acutorostrata*)	-
Fin whale	*Balaenoptera physalus*	LO	FLO	V	✓	✓	E
Gingko-toothed beaked whale	*Mesoplodon ginkgodens*	-	MO	-	-	✓	-
Humpback whale	*Megaptera novaeangliae*	KO	BKO	-	✓	✓	CD & MI
Longman's beaked whale	*Indopacetus pacificus*	N/A	MO	-	-	✓	-
Minke whale	*Balaenoptera acutorostrata*	MO	MO	-	-	✓	-

[12] *Species presence in OA identified in Jansz-Io Soundscape monitoring (Ref. 124) however did not appear in the PMST report.*

Common name	Scientific name	EPBC Act presence	EPBC Act status				WA BC Act[12]
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation status
Omura's whale[1]	*Balaenoptera omurai*	-	-	-	-	✓	-
Pygmy sperm whale	*Kogia breviceps*	MO	MO	-	-	✓	-
Sei whale	*Balaenoptera borealis*	LO	FLO	V	✓	✓	E
Southern right whale	*Eubalaena australis*	-	LO	E	✓	✓	V
Sperm whale	*Physeter macrocephalus*	MO	MO	-	✓	✓	V
Cetaceans (dolphins)							
Australian humpback dolphin	*Sousa sahulensis*	MO	KO	-	✓	✓	MI & P4
Australian snubfin dolphin	*Orcaella heinsohni*	MO	KO	-	✓	✓	MI & P4
Bottlenose dolphin	*Tursiops truncatus* s. str.	MO	MO	-	-	✓	-
Common dolphin, short-beaked common dolphin	*Delphinus delphis*	MO	MO	-	-	✓	-
False killer whale	*Pseudorca crassidens*	LO	LO	-	-	✓	-
Fraser's dolphin, sarawak dolphin	*Lagenodelphis hosei*	MO	MO	-	-	✓	MI
Indian Ocean bottlenose dolphin, spotted bottlenose dolphin	*Tursiops aduncus*	-	LO	-	-	✓	MI
Killer whale, orca	*Orcinus orca*	MO	MO	-	✓	✓	MI
Long-snouted spinner dolphin	*Stenella longirostris*	MO	MO	-	-	✓	MI & P4
Melon-headed whale	*Peponocephala electra*	MO	MO	-	-	✓	-
Pygmy killer whale	*Feresa attenuata*	MO	MO	-	-	✓	-
Risso's dolphin, grampus	*Grampus griseus*	MO	MO	-	-	✓	-
Rough-toothed dolphin	*Steno bredanensis*	MO	MO	-	-	✓	-

Common name	Scientific name	EPBC Act presence	EPBC Act status				WA BC Act[12]
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation status
Short-finned pilot whale	*Globicephala macrorhynchus*	MO	MO	-	-	✓	-
Spotted bottlenose dolphin (Arafura/Timor Sea populations)	*Tursiops aduncus (Arafura/Timor Sea populations)*	MO	KO	-	M	✓	MI
Spotted dolphin, pantropical spotted dolphin	*Stenella attenuata*	MO	MO	-	-	-	-
Striped dolphin, euphrosyne dolphin	*Stenella coeruleoalba*	MO	MO	-	-	-	-
Sirenians							
Dugong	*Dugong dugon*	-	BKO	-	M	✓	-

Likely Presence
MO: Species or species habitat may occur within area.
LO: Species or species habitat likely to occur within area.
KO: Species or species habitat known to occur within area.
BKO: Breeding known to occur within area.
FLO: Foraging likely to occur

Conservation Status:
CD: Conservation Dependent
E: Endangered
MI: Migratory
P4: Priority 4, Rare, Near Threatened and other species in need of monitoring
V: Vulnerable

Table 6-5: Presence of BIAs for marine mammals

Common name	BIA behaviour	Seasonal presence	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA
Humpback whale	Migration (north and south)	Northern migration, late July to September	✓	0	✓
	Resting	Winter	-	144	✓
Pygmy blue whale	Distribution	(Not defined in database)	✓	0	✓
	Foraging	(Not defined in database)	-	171.7	✓
	Migration	Northern migration (enter Perth Canyon Jan–May; pass Exmouth Apr–Aug; continue north to Indonesia). Southern migration (follow WA coastline from Oct–late Dec)	✓	0	✓
Southern right whale[13]	Migration	April to October	-	152.8	✓
	Reproduction	May to September	-	148	✓
Dugong	Breeding	Year round	-	141.5	✓
	Calving	Year round	-	141.5	✓
	Foraging (high-density seagrass beds)	Year round	-	141.5	✓
	Nursing	Year round	-	141.5	✓

6.2.3.1.1 Humpback whale

The humpback whale (*Megaptera novaeangliae*) is listed as migratory under the EPBC Act. In February 2022, the species was removed from the Vulnerable category and the threatened species list due to significant population recovery (Ref. 125). A migration BIA for the humpback whale overlaps the OA and Hydrocarbon Ecological EMBA, and a resting BIA overlaps the Hydrocarbon Ecological EMBA (Figure 6-10).

Humpback whales migrate north from their Antarctic feeding grounds along the WA coast around May each year and reach the waters of the NWMR in early June (Ref. 104). The exact timing of the migration period can vary from year to year. From North West Cape, northbound humpback whales travel along the edge of the continental shelf passing west of the Muiron, Barrow and Montebello islands, peaking in late July (Ref. 126). There has been no such peak observed during the southern migration with more diffuse and irregular movements of whales. Predominantly humpback whales migrate within 50 km of the coast of mainland Australia (Ref. 127).

Breeding and calving grounds are estimated to extend south from Camden Sound to at least North West Cape (Ref. 128), with breeding and calving occurring between August and September (Ref. 104). Exmouth Gulf and Shark Bay are both important resting areas for migrating humpbacks, particularly for cows and calves

[13] *These are updated BIAs published on the National Conservation Values Atlas (NCVA) October 2023. These BIAs are not included in the EPBC Southern Right Whale Management Plan (Ref. 19) at the time of writing.*

on the southern migration (Ref. 104). The southerly migration, from around the Lacepede Islands (north of Broome) extends parallel to the coast around the 20–30 m depth contour (Ref. 126; Ref. 104). An increase in southerly migrating individuals may be observed between the North West Cape and the Montebello Islands around November (Ref. 126).

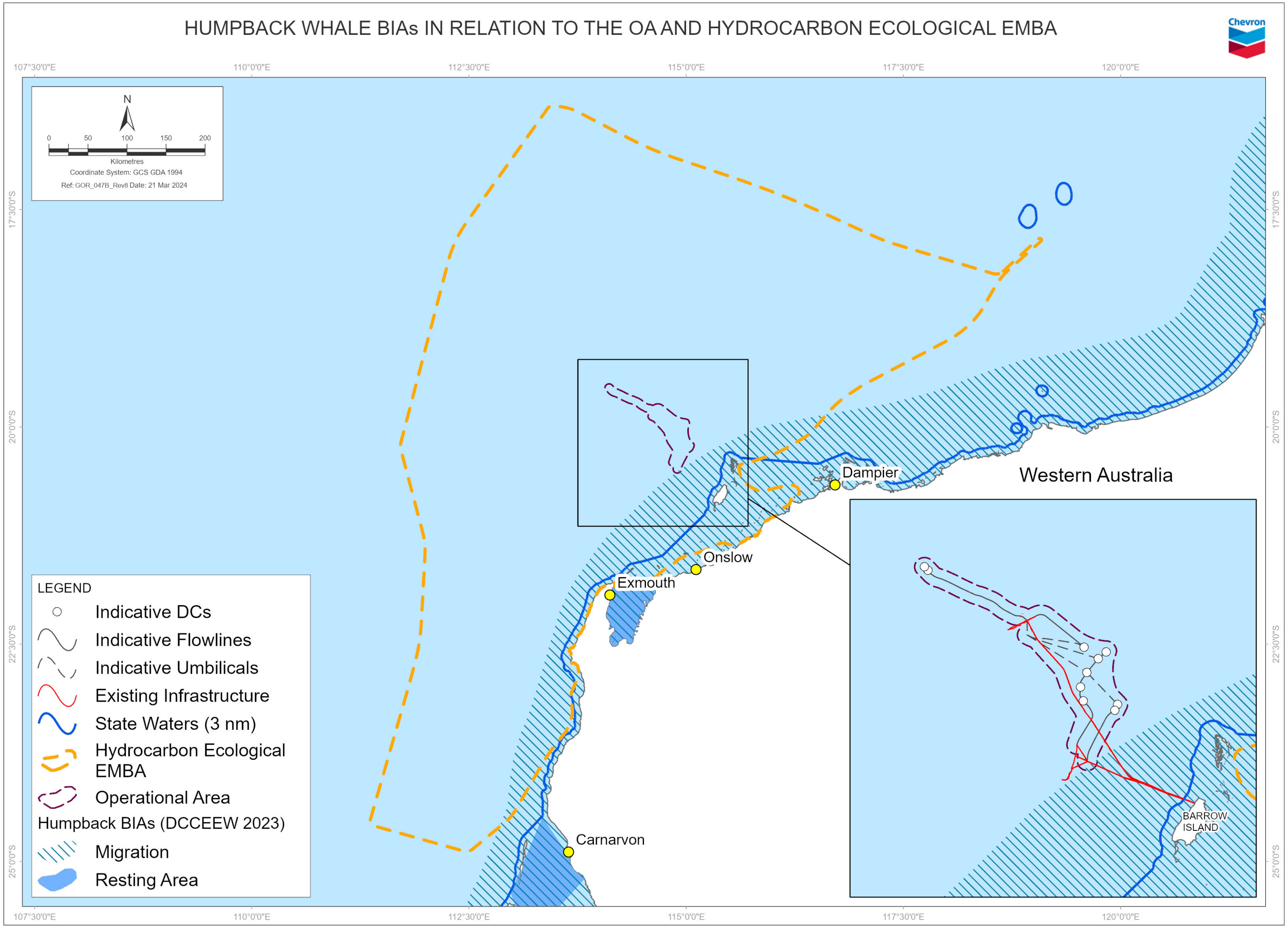

Figure 6-10: Humpback whale BIAs in relation to the OA and Hydrocarbon Ecological EMBA

6.2.3.1.2 Pygmy blue whale

The Pygmy blue whale (*Balaenoptera musculus brevicauda*) is a subspecies of the blue whale. The blue whale is listed as endangered and migratory under the EPBC Act. Migration and distribution BIAs for the pygmy blue whale overlap the OA and Hydrocarbon Ecological EMBA (Figure 6-11). A foraging BIA overlaps the Hydrocarbon Ecological EMBA (Figure 6-11).

Pygmy blue whales have a widespread distribution throughout the Indian Ocean and migrate between Australian and Indonesian waters along the WA coastline (Ref. 129). They migrate north to their breeding grounds near the Indonesian Archipelago from mid-February to early June, then south to their feeding grounds in the Southern Ocean from mid-November to early-January (Ref. 130). Information collected from satellite tags shows that the Banda and Molucca seas in Indonesia are the likely destination for the northern migration of whales that feed off the Perth Canyon (Ref. 131; Ref. 132; Ref. 133). These seas are considered the northern terminus of the migration and potentially the whales' breeding and calving ground, but may also act as a feeding area (Ref. 129; Ref. 134).

Acoustic monitoring conducted by McCauley and Jenner (Ref. 135) in the Exmouth and northern Montebello Islands region identified a peak period in the northern migration of pygmy blue whales from April to August, and from November through to late December during the southern migration. It was estimated by McCauley and Jenner (Ref. 135) that between 700 and 1,500 pygmy blue whales migrated southward past Exmouth in 2004.

A study in 2022, which incorporated data collected from both passive acoustic monitoring and satellite telemetry data, showed the 'most important area' for migration along the WA coast as an almost continuous stretch from southern WA to around the latitude of Rowley Shoals; further north, their migration was more dispersed (Ref. 136).

Pygmy blue whales aggregate around seasonal upwellings that have high concentrations of prey (Ref. 137). Important areas for foraging, breeding, and resting include the Perth Canyon, the shelf edge off Geraldton, the shelf edge from Ningaloo Reef to the Rowley Shoals and the Banda Sea (Ref. 136). Thums et al. (Ref. 136) also observed a migrating pygmy blue whale with low move persistence in areas surrounding the OA which may infer foraging and/or resting/breeding behaviours.

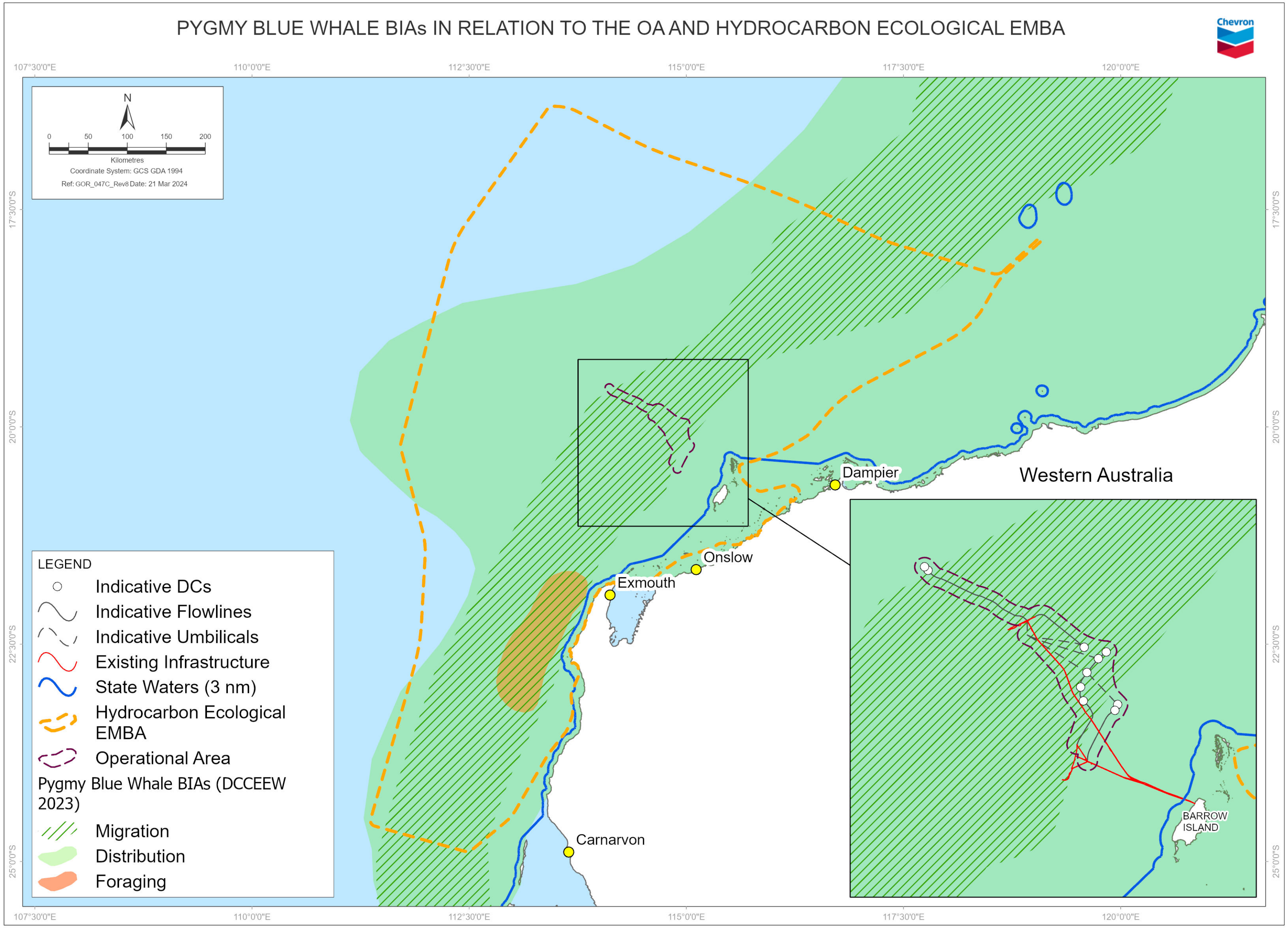

Figure 6-11: Pygmy blue whale BIAs in relation to the OA and Hydrocarbon Ecological EMBA

6.2.3.1.3 Southern right whale

The Southern right whale (*Eubalaena australis*) is listed as endangered and migratory under the EPBC Act (Table 6-4).There are no BIAs intersecting the Hydrocarbon Ecological EMBA for the southern right whale based on the existing Conservation Management Plan and Draft National Recovery Plan (Ref. 19, Ref. 20).

Updated BIAs for the southern right whale were published on the National Conservation Values Atlas (NCVA) in October 2023 however these are not published under any EPBC Act documents (including management plans, conservation or listing advice) (Ref. 138). The updates published on the NCVA include BIAs for migration and reproduction which overlap the Hydrocarbon Ecological EMBA (Figure 6-12). There is no overlap with the OA. The BIAs published on NCVA are shown in relation to the Hydrocarbon Ecological EMBA in Figure 6-12.

The southern right whale occurs seasonally in coastal waters of Australia, with circumpolar distribution between latitudes of 16°S and 65°S (Ref. 19). Southern right whales occupy calving and nursing grounds from May to October (although can occur as early as April and late as November), primarily in shallow waters of <10 m, within 1 km of the coastline (Ref. 19; Ref. 20). Female-calf pairs generally stay within the calving ground for 2-3 months and females have a calving interval of 3 years on average (Ref. 19). Female southern right whales have demonstrated strong site fidelity for breeding areas (Ref. 19).

Migration occurs between habitat used for foraging and breeding. Foraging ecology is poorly understood, with coastal Australian waters not believed to be used for feeding (Ref 19). The draft recovery plan references multiple datasets which indicate that southern right whales are likely to forage south of Australia (Ref. 20).

There is evidence of population increase in the western population, however southern right whale abundance is still below estimated historic abundance (Ref. 20).

Updated data from the NCVA (not referenced in current or draft recovery plans) indicates a reproductive area in the Exmouth Gulf, overlapping the Hydrocarbon Ecological EMBA for the Development (Figure 6-12).

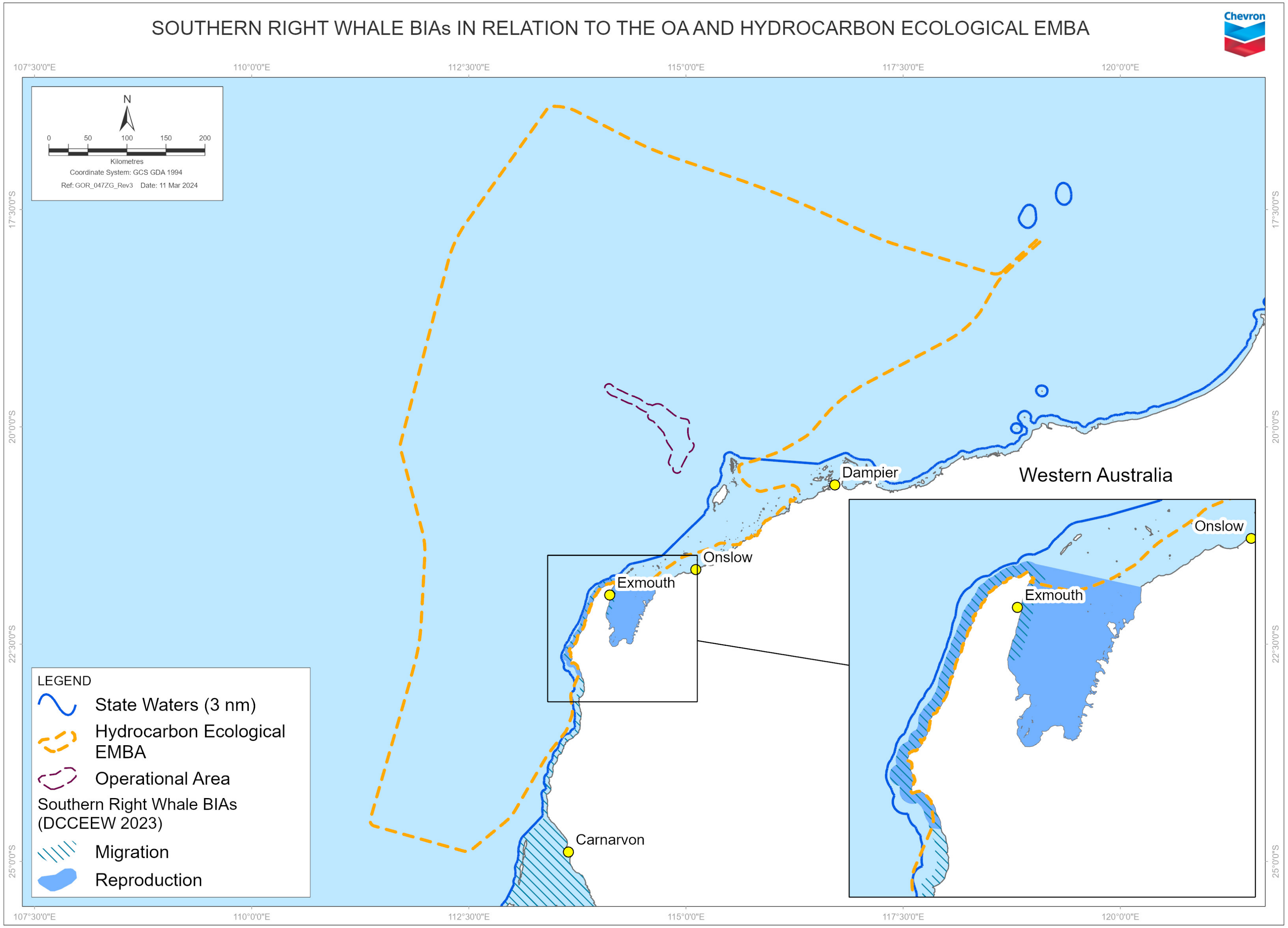

Figure 6-12: Southern right whale BIAs (as updated on the NCVA, not in EPBC management plans) in relation to the OA and Hydrocarbon Ecological EMBA

6.2.3.1.4 Dugong

The dugong (*Dugong dugon*) is listed as marine and migratory under the EPBC Act. There are no dugong BIAs overlapping the OA; however several BIAs overlap the Hydrocarbon Ecological EMBA (Figure 6-13). BIAs overlapping the Hydrocarbon Ecological EMBA are for breeding, nursing, calving and foraging (high- density seagrass beds) (Table 6-5). These BIAs are in the Exmouth Gulf and along the coast from North-west Cape to Coral Bay (Figure 6-13).

Dugongs inhabit seagrass meadows in coastal waters, estuarine creeks and streams, and offshore at Ashmore Reef (Ref. 104). Dugongs are predominantly distributed in coastal and island waters from Shark Bay in Western Australia to Moreton Bay in Queensland (Ref. 139). Specific areas supporting dugongs in WA include Shark Bay; Ningaloo and Exmouth Gulf; the Pilbara coast (Exmouth Gulf to De Grey River (Ref. 139); and Eighty Mile Beach and Kimberley Coast Region, including Roebuck Bay (Ref. 139).

Dugongs are highly migratory and are capable of moving over relatively large distances, with the maximum recorded movement of more than 400 km in around 40 days (Ref. 104). Although dugong migration patterns aren't well known in WA, it is believed that water temperature and the presence of seagrass can influence their movements (Ref. 104).

Dugongs have low breeding rates and long-term care of calves. Female dugongs give birth to a single calf at long intervals of between three to seven years and calves stay with their mother until one or two years of age. Dugongs can reach full adult size between four and 17 years old (Ref. 140).

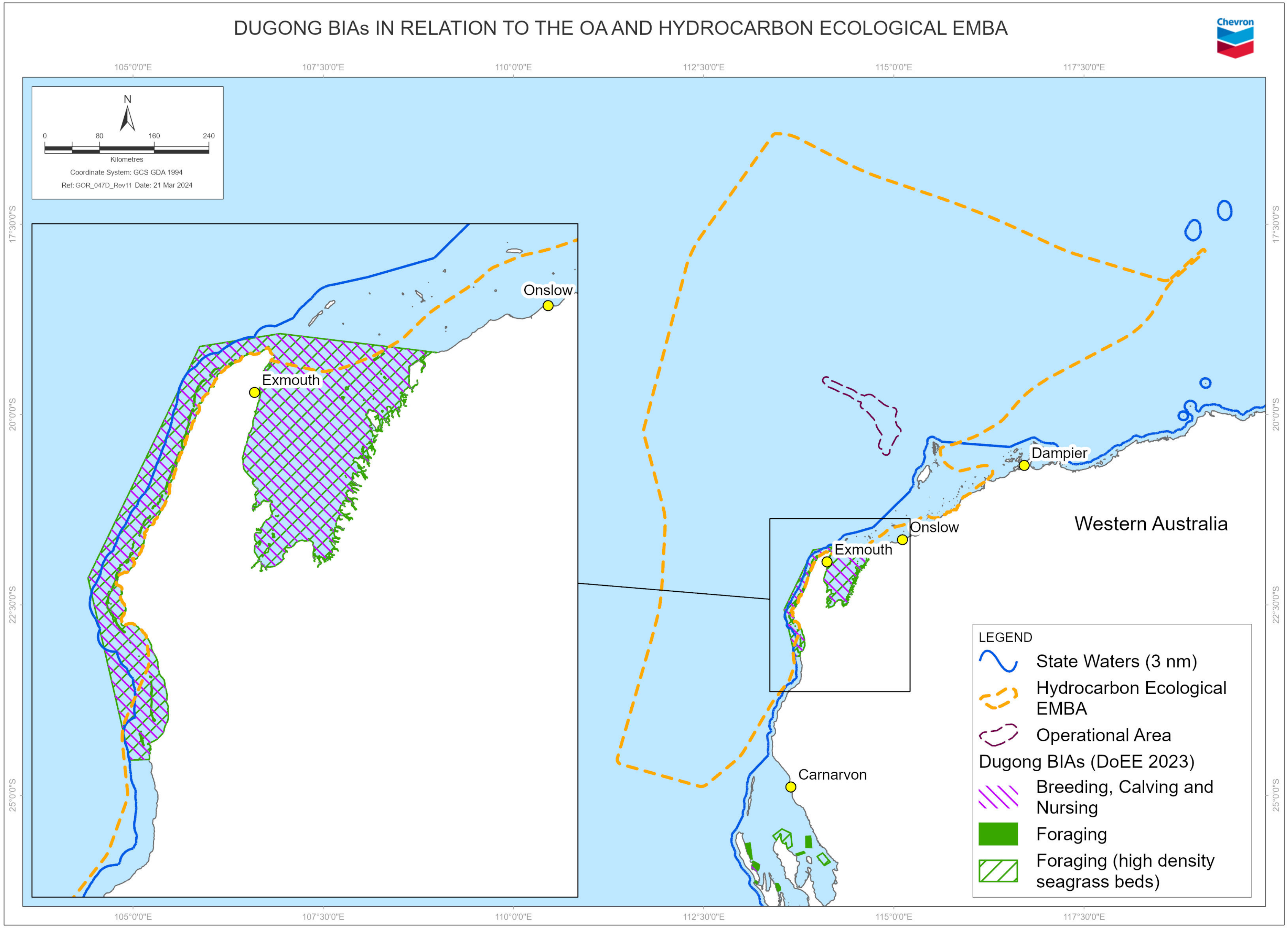

Figure 6-13: Dugong BIAs in relation to the OA and Hydrocarbon Ecological EMBA

6.2.3.2 Reptiles

Based on searches of the EPBC Act protected matters database (Ref. 123, Appendix B), the threatened or migratory reptile species shown in Table 6-6 may be present within the OA and Hydrocarbon Ecological EMBA. Habitat critical to the survival of a species (habitat critical) and BIAs associated with marine reptile species are listed in Table 6-7 and Table 6-8 respectively.

Table 6-6: Presence of threatened or migratory reptiles

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation status
Turtles							
Flatback turtle	*Natator depressus*	AKO	BKO	V	✓	✓	V
Green turtle	*Chelonia mydas*	KO	BKO	V	✓	✓	V
Hawksbill turtle	*Eretmochelys imbricata*	KO	BKO	V	✓	✓	V
Leatherback turtle	*Dermochelys coriacea*	LO	KO	E	✓	✓	V
Loggerhead turtle	*Caretta*	KO	BKO	E	✓	✓	E
Sea snakes							
Black-ringed sea snake	*Hydrelaps darwiniensis*	-	MO	-	-	✓	-
Brown-lined sea snake	*Aipysurus tenuis*	-	MO	-	-	✓	-
Dubois' sea snake	*Aipysurus duboisii*	MO	MO	-	-	✓	-
Elegant sea snake	*Hydrophis elegans*	MO	MO	-	-	✓	-
Fine-spined sea snake, Geometrical sea snake	*Hydrophis czeblukovi*	MO	MO	-	-	✓	-
Horned sea snake	*Hydrophis peronii*	MO	MO	-	-	✓ (as *Acalyptophis peronii*)	-
Leaf-scaled sea snake	*Aipysurus foliosquama*	-	KO	CE	-	✓	CE
North-western mangrove sea snake	*Ephalophis greyi*	MO	MO	-	-	✓	-
Mangrove sea snake	*Ephalophis greyae*	MO	MO	-	-	✓ (as *Ephalophis greyi*)	-
Mosaic sea snake	*Aipysurus mosaicus*	MO	MO	-	-	✓ (as *Aipysurus eydouxii)*	-

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation status
Olive sea snake	*Aipysurus laevis*	MO	MO	-	-	✓	-
Olive-headed sea snake	*Hydrophis major*	MO	MO	-	-	✓ (as *Disteira major)*	-
Shark Bay sea snake	*Aipysurus pooleorum*	-	MO	-	-	✓	-
Short-nosed sea snake	*Aipysurus apraefrontalis*	MO	KO	CE	-	✓	CE
Small-headed sea snake	*Hydrophis macdowelli*	-	MO	-	-	✓	-
Spectacled sea snake	*Hydrophis kingii*	MO	MO	-	-	✓ (as *Disteira kingii)*	-
Spotted sea snake, ornate reef sea snake	*Hydrophis ornatus*	MO	MO	-	-	✓	-
Stokes' sea snake	*Hydrophis stokesii*	MO	MO	-	-	✓ (as *Astrotia stokesii)*	-
Eastern turtle-headed sea snake	*Emydocephalus annulatus*	MO	MO	-	-	✓	-
Yellow-bellied sea snake	*Hydrophis platurus*	MO	MO	-	-	✓ (as *Pelamis platurus)*	-

Likely Presence *AKO: Aggregation know to occur within area.* *BKO: Breeding known to occur within area.* *FLO: Foraging likely to occur within area.* *KO: Species or species habitat known to occur within area.* *LO: Species or species habitat likely to occur within area.* *MO: Species or species habitat may occur within area.*	***Conservation Status:*** *CE: Critically Endangered* *E: Endangered* *V: Vulnerable*

Table 6-7: Habitat critical to the survival of marine turtles

Common name	Nesting location	Internesting buffer	Seasonal presence	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA
Flatback turtle	Barrow Island, Montebello Islands, coastal islands from Cape Preston to Locker Island	60 km	Oct–Mar	✓	0	✓
	Dampier Archipelago, including Delambre Island and Hauy Island	60 km	Oct–Mar	-	85.4	✓
Green turtle	Barrow Island, Montebello Islands, Serrurier Island, and Thevenard Island	20 km	Nov–Mar	-	26.6	✓
	Dampier Archipelago	20 km	Nov–Mar	-	125.4	✓
	Exmouth Gulf and Ningaloo Coast	20 km	Nov–Mar	-	137.8	✓
Hawksbill turtle	Cape Preston to mouth of Exmouth Gulf including Montebello Islands and Lowendal Islands	20 km	Oct–Feb	-	26.6	✓
	Dampier Archipelago	20 km	Oct–Feb	-	125.4	✓
Loggerhead turtle	Exmouth Gulf and Ningaloo Coast	20 km	Nov–May	-	137.8	✓
	Gnaraloo Bay and beaches	20 km	Nov–May	-	348	

Table 6-8: Presence of BIAs for reptiles

Common name	BIA behaviour	Seasonal presence	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA
Flatback turtle	Aggregation	(Not defined in database)	-	44.5	✓
	Foraging	(Not defined in database)	-	44.5	✓
	Internesting	(Not defined in database)	-	44.5	✓
	Internesting buffer	Summer	✓	0	✓
	Mating	(Not defined in database)	-	44.5	✓
	Nesting	Summer	-	46.5	✓
Green turtle	Aggregation	(Not defined in database)	-	44.5	✓
	Basking	Summer	-	47.6	✓
	Foraging	Summer around Montebello Islands, Year round within inshore tidal and shallow subtidal areas around Barrow Island	-	41.9	✓

Common name	BIA behaviour	Seasonal presence	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA
	Internesting	Summer	-	41.9	✓
	Internesting buffer	Summer	-	23	✓
	Mating	Summer	-	41.9	✓
	Nesting	Summer	-	41.9	✓
Hawksbill turtle	Foraging	Year round (shallow water coral reef and artificial reef (pipeline) habitat), spring early summer within Lowendal Island Group	-	46.5	✓
	Internesting	Spring and early summer	-	58.8	✓
	Internesting buffer	Year round, spring, early summer	-	27.6	✓
	Mating	Year round within Barrow Island, spring and early summer within Lowendal Island Group	-	46.5	✓
	Nesting	Year round within Thevenard Island, spring and early summer within Ah Chong and South East Is, Barrow Island, and Lowendal Island Group	-	46.5	✓
Loggerhead turtle	Internesting buffer	(Not defined in database)	-	31.4	✓
	Nesting	(Not defined in database)	-	50.4	✓

6.2.3.2.1 Flatback turtle

The flatback turtle (*Natator depressus*) is listed as vulnerable and migratory under the EPBC Act. An internesting buffer BIA and habitat critical for the flatback turtle overlaps the OA and Hydrocarbon Ecological EMBA (Figure 6-14 and Figure 6-15). Aggregation, foraging, internesting, mating, migration corridor and nesting BIAs overlap the Hydrocarbon Ecological EMBA (Figure 6-14 and Figure 6-15).

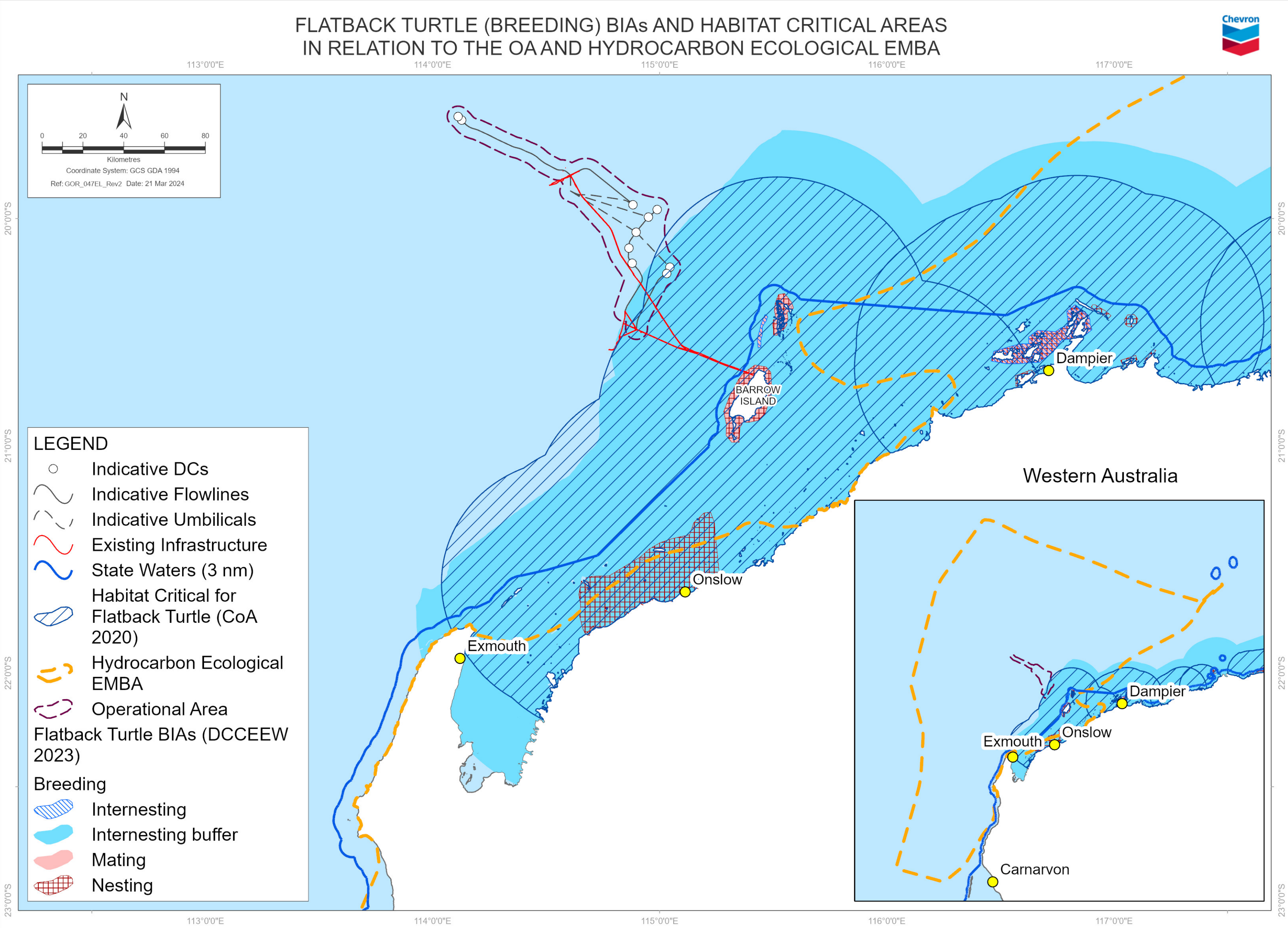

Figure 6-14: Flatback turtle (breeding) BIAs and habitat critical areas in relation to the OA and the Hydrocarbon Ecological EMBA

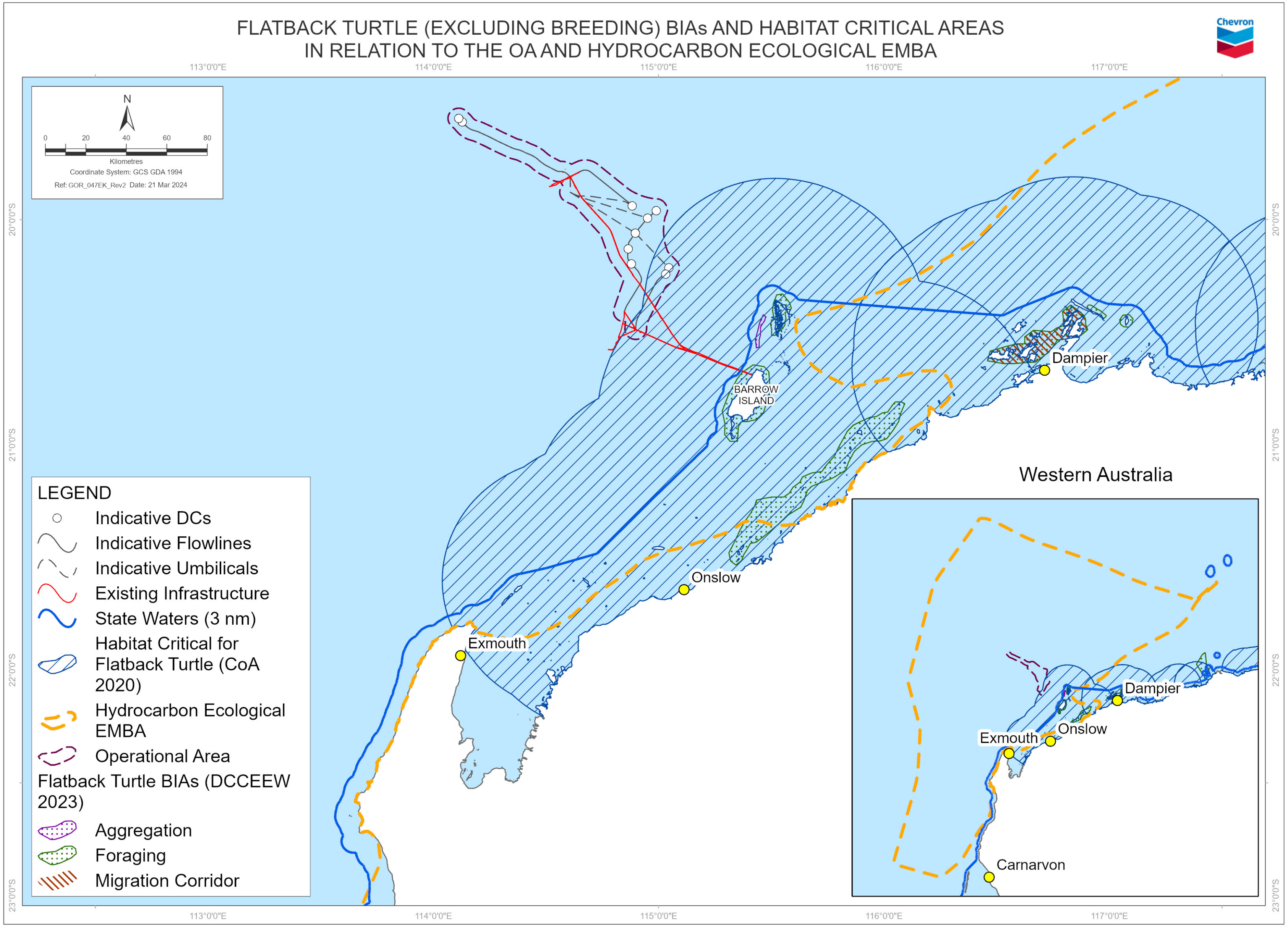

Figure 6-15: Flatback turtle (excluding breeding) BIAs and habitat critical areas in relation to the OA and the Hydrocarbon Ecological EMBA

Flatback turtles are only found in the tropical waters of northern Australia (Ref. 141). Populations are distributed throughout the continental shelf waters, extending from the Pilbara region of WA, northwards around the Northern Territory and into Queensland waters (Ref. 142). In WA, important nesting areas include the Kimberley region, Cape Domett and Lacrosse Island (Ref. 141). Flatbacks are the most widespread nesting marine turtle species in the Northern Territory, and they nest on a wide variety of beach types around the entire coastline (Ref. 143).

Flatback turtles live in soft-bottom habitat and require sandy beaches for nesting, with sand temperatures between 25 C and 33 C needed for egg incubation (Ref. 141). Most females return to the same beach in successive breeding seasons and show a fidelity to the area where they were born. This means that a first-time nesting turtle might return to their 'predetermined' nest site that they emerged from, regardless of the nesting suitability of the location (Ref. 144).

The OA overlaps the 60 km internesting buffer and an internesting buffer BIA around Barrow Island and the Montebello Islands (Figure 6-14; Figure 6-15). Typically, flatback turtle nesting on Barrow Island occurs between October and March, with peak nesting activity occurring between November and January. On Barrow Island, nesting activity is concentrated on the east coast on sandy, low-sloped, low-energy beaches with wide, shallow intertidal zones (Ref. 145; Ref. 146). Limited nesting activity has also been recorded on the south-west, north, and north-east beaches of Barrow Island (Ref. 147).

During internesting, turtles remain close to the nesting beach or rookery (Ref. 148). The 60 km internesting buffer defined within the Recovery Plan for Marine Turtles in Australia (Ref. 148) is based primarily on the movements of tagged internesting flatback turtles in WA (Ref. 149). The study tracked 56 turtles from 4 different rookeries, which demonstrated varying internesting movements, with distances ranging from 3–62 km, with some turtles at all 4 rookeries remaining within 10 km of their nesting beaches. However, tracking data showed these movements were largely longshore movements in nearshore coastal waters or travel between island rookeries and the adjacent mainland, which represent the greater distances (Ref. 149). There is no evidence to suggest that flatback turtles move to deep offshore waters during internesting periods.

A habitat suitability modelling study for internesting flatback turtles in the NWS region of WA (Ref. 151; Ref 150) was conducted to identify areas of suitable flatback turtle internesting habitat and determine overlap with identified industrial hazards. The study used a turtle tracking dataset of 47 nesting female turtles from 5 important rookeries in the NWS study area, including Barrow Island. The results showed internesting flatback turtles from all rookeries remained within water depths of <44 m, with a mean depth of <10 m (Ref. 151; Ref 150). Results also showed internesting turtles from all rookeries remained within <28 km of the nearest coast, with a mean distance from the coast of <6.1 km. The habitat suitability modelling study defined suitable flatback turtle internesting habitat as water depths of between 0 and 16 m, within 5 –10 km of the coast. Unsuitable flatback turtle internesting habitat was defined as waters >25 m deep and >27 km from the coast (Ref. 151; Ref 150).

Other previous studies (e.g. Ref. 152; Ref. 153; Ref. 154) have also presented findings that internesting behaviour was only observed in water depths of <40 m.

The OA is located in water depths of >150 m and is at closest ~50 km from the west coast of Barrow Island, and ~45 km from the Montebello Islands. The majority of the OA is located in deeper waters and further offshore than where previous studies have recorded internesting behaviour (Ref. 151, Ref.152; Ref. 153; Ref. 154).

6.2.3.2.2 Green turtle

The green turtle (*Chelonia mydas*) is listed as vulnerable, marine, and migratory under the EPBC Act. There are no green turtle BIAs or habitat critical overlapping the OA (Figure 6-16 and Figure 6-17). Aggregation, basking, foraging, interesting, internesting buffer, mating and nesting BIAs and habitat critical overlap the Hydrocarbon Ecological EMBA (Figure 6-16 and Figure 6-17).

Green turtles are distributed across 9 genetically distinct stocks (Ref. 148). The Northwest Shelf (NWS) stock is one of the largest green turtle stocks in the world and the largest in the Indian Ocean (Ref. 155 in Ref. 148). Nesting for the NWS stock occurs over a large geographic range with nesting on offshore islands and the mainland (Ref. 148). The Hydrocarbon Ecological EMBA overlaps with BIAs and habitat critical for the NWS stock, including key nesting and interesting areas as identified in Table 6-7. The seasonal presence for these areas is generally November to May (Ref. 148). The closest nesting areas to the OA are Barrow Island and Montebello Islands (Table 6-8). These are identified as nesting habitat critical to the survival of the species, as is the 20 km internesting buffer surrounding the islands (Table 6-7).

Green turtle nesting usually occurs on the west and north-east coasts of Barrow Island between October and March each year, with a remigration interval of approximately five years (Ref. 156) and peak nesting activity occurring between December and February (Ref. 157; Ref. 145). During the internesting period, turtles remain close to the nesting beaches (Ref. 148). Satellite tracking data from Barrow Island shows that the internesting habitat for this area is found throughout the rocky intertidal and subtidal zones common on the west coast, and around north-eastern beaches and waters (Ref. 145). Internesting green turtles around Barrow island were recorded to remain in the shallow waters, 5 km off Barrow Island, while tracking of post-nesting green turtles, around Barrow and Sandy Island, show that they feed between 200-1000 km from the nesting beaches (Ref. 145). Following the nesting period on Barrow Island, these turtles were recorded to migrate to foraging grounds, ranging from Legendre Island in the Dampier Archipelago to waters around Southern Kimberley (Ref. 145).

Foraging habitat for juvenile and adult green turtles includes tidal/sub-tidal habitats with coral reef, mangrove, sand, rocky reefs and mudflats where there are algal turfs or seagrass meadows present (Ref. 148). Some turtles may remain in the open ocean (Ref. 158 in Ref. 148). The stock is classed as stable in the Recovery Plan for Marine Turtles 2017-2027 (Ref. 148).

Once the breeding and nesting periods are complete, green turtles return to their preferred foraging areas (Ref. 157) so presence in the OA is expected to be transitory.

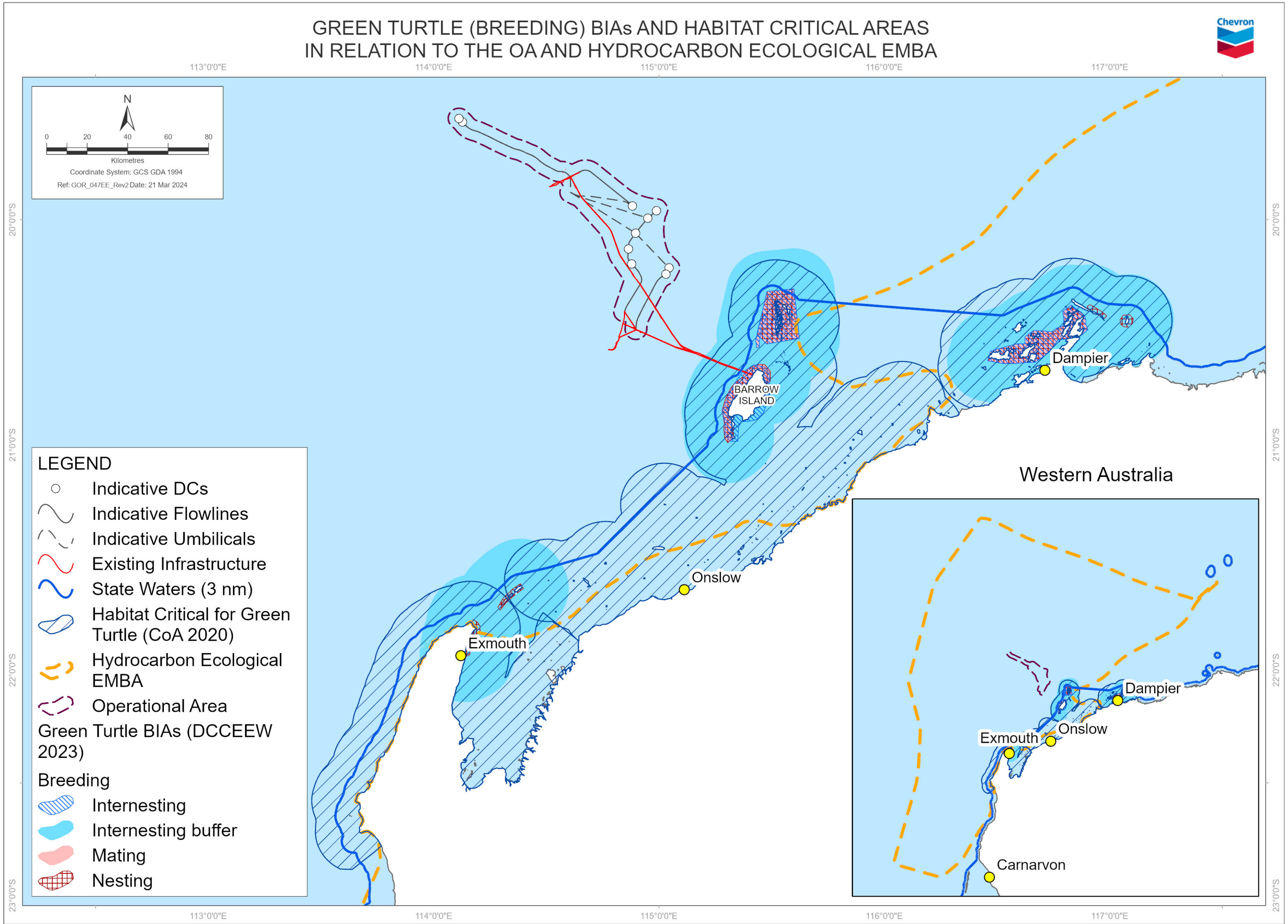

Figure 6-16: Green turtle (breeding) BIAs and habitat critical areas in relation to the Hydrocarbon Ecological EMBA

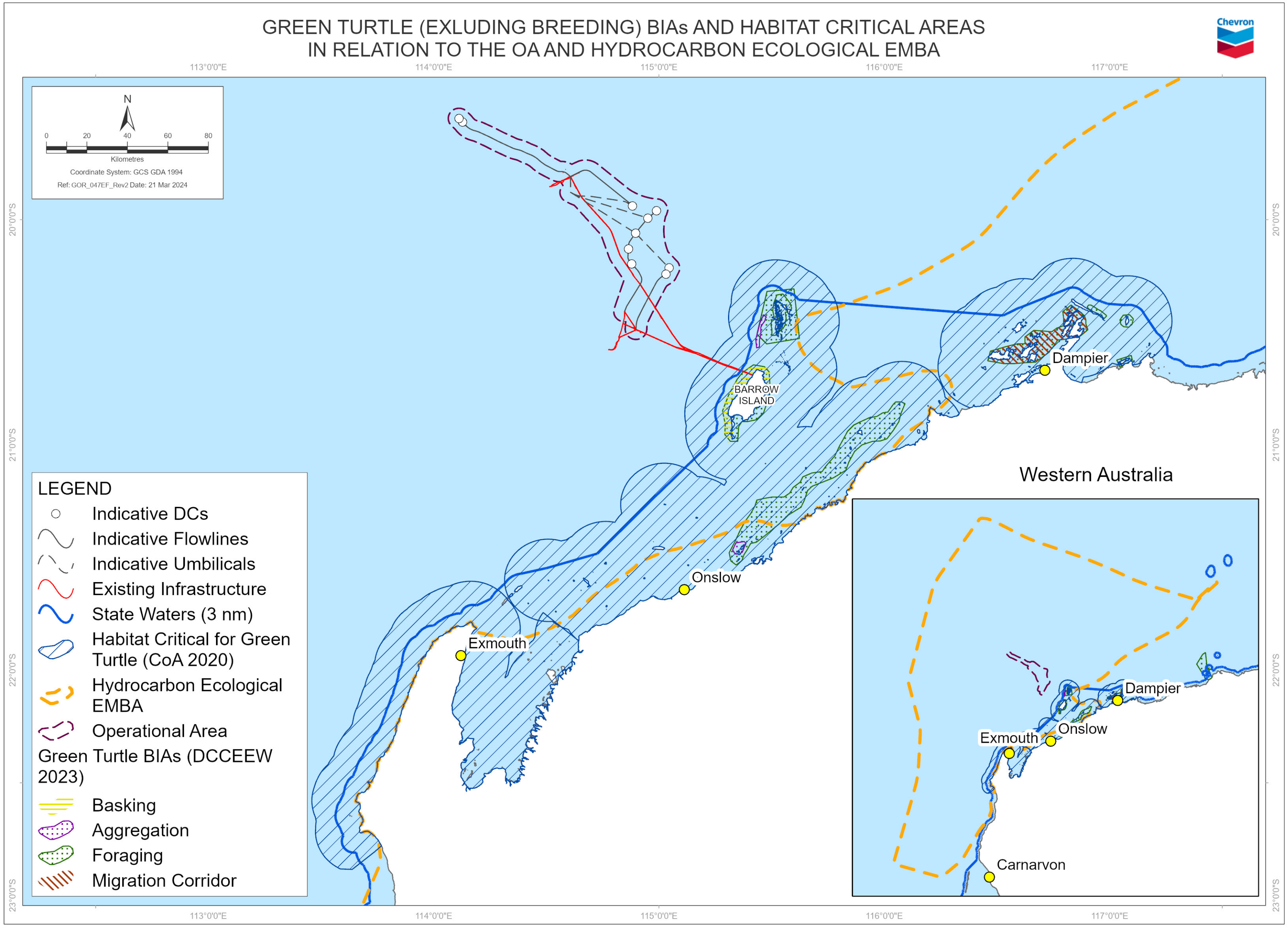

Figure 6-17: Green turtle (excluding breeding) BIAs and habitat critical areas in relation to the Hydrocarbon Ecological EMBA

6.2.3.2.3 Hawksbill turtle

The hawksbill turtle (*Eretmochelys imbricata*) is listed as vulnerable, marine, and migratory under the EPBC Act. There are no hawksbill turtle BIAs or habitat critical overlapping the OA (Figure 6-18 and Figure 6-19). Foraging, internesting buffer, internesting, nesting and mating BIAs and habitat critical overlap the Hydrocarbon Ecological EMBA (Figure 6-18 and Figure 6-19).

Australia supports the largest hawksbill turtle nesting aggregations worldwide, with approximately 2000 females nesting annually in Western Australia, 4000 in Queensland and 2500 in the Northern Territory (Ref. 159). The majority of nesting for the Western Australia hawksbill turtle stock is located in the Pilbara (Ref. 148). The key nesting and internesting areas in Australia include the Dampier Archipelago, the Ningaloo and Jurabi Coasts, and Thevenard, Barrow, Lowendal and Montebello Islands (Ref. 159). The estimated size of the reproductive population of Western Australia stock is small (Ref. 320). For example, it has been estimated an overall reproductive population at Barrow Island of 100, an additional 1,000 in the Lowendal Islands, and 1,300 in the Montebello Islands exist (Ref. 145 Ref. 320).

Monitoring of Barrow Island hawksbill turtle nesting has found that nesting activity is more temporally and spatially diffuse than flatback and green turtle nesting activity and occurs predominantly on small, rocky, east coast beaches. Nesting on Barrow Island peaks in October (Ref. 462). The internesting interval for the hawksbill turtle is approximately 14.5 days with a remigration interval of approximately three years (Ref. 157; Ref. 159). During internesting turtles remain close to the nesting beach or rookery (Ref. 148). Satellite tracking of hawksbill turtles supports this and found that individuals remained in shallow coastal waters (<10 m deep) post nesting (Ref. 145).

The hawksbill turtle is recorded to migrate up to 2400 km between foraging areas and their nesting beaches (Ref. 160). Hawksbill turtles prefer shallow, tropical, and subtropical waters, settling and foraging in tropical tidal and sub-tidal coral and rocky reef habitats, although, they have also been found in seagrass habitats of coastal waters, as well as deeper waters (Ref. 161). In Western Australia, reefs located west of Cape Preston and south of Onslow are recorded as important feeding grounds for the species (Ref. 148). Satellite tracking data shows that the turtles migrating between Western Australia rookeries remained on the continental shelf, with majority following the coast and dispersing north-east, with some from the Montebello Archipelago and Lowendals moving south-west and stopping around Barrow Island (Ref. 162).

Although BIAs have been identified (Table 6-8), hawksbill turtle mating, internesting, and foraging grounds have not been identified for Barrow Island (Ref. 320). However, data from hawksbill turtles tracked from nearby Varanus Island indicate potential internesting habitat in waters north-east of Barrow Island (Ref. 145). This internesting is consistent with the internesting habitat critical for the survival of the species that has been identified to overlap the Hydrocarbon Ecological EMBA (Table 6-7).

As hawksbill turtle nesting occurs predominantly on east coast beaches on Barrow Island, it is expected that any presence of these species within the OA would be of a transitory nature.

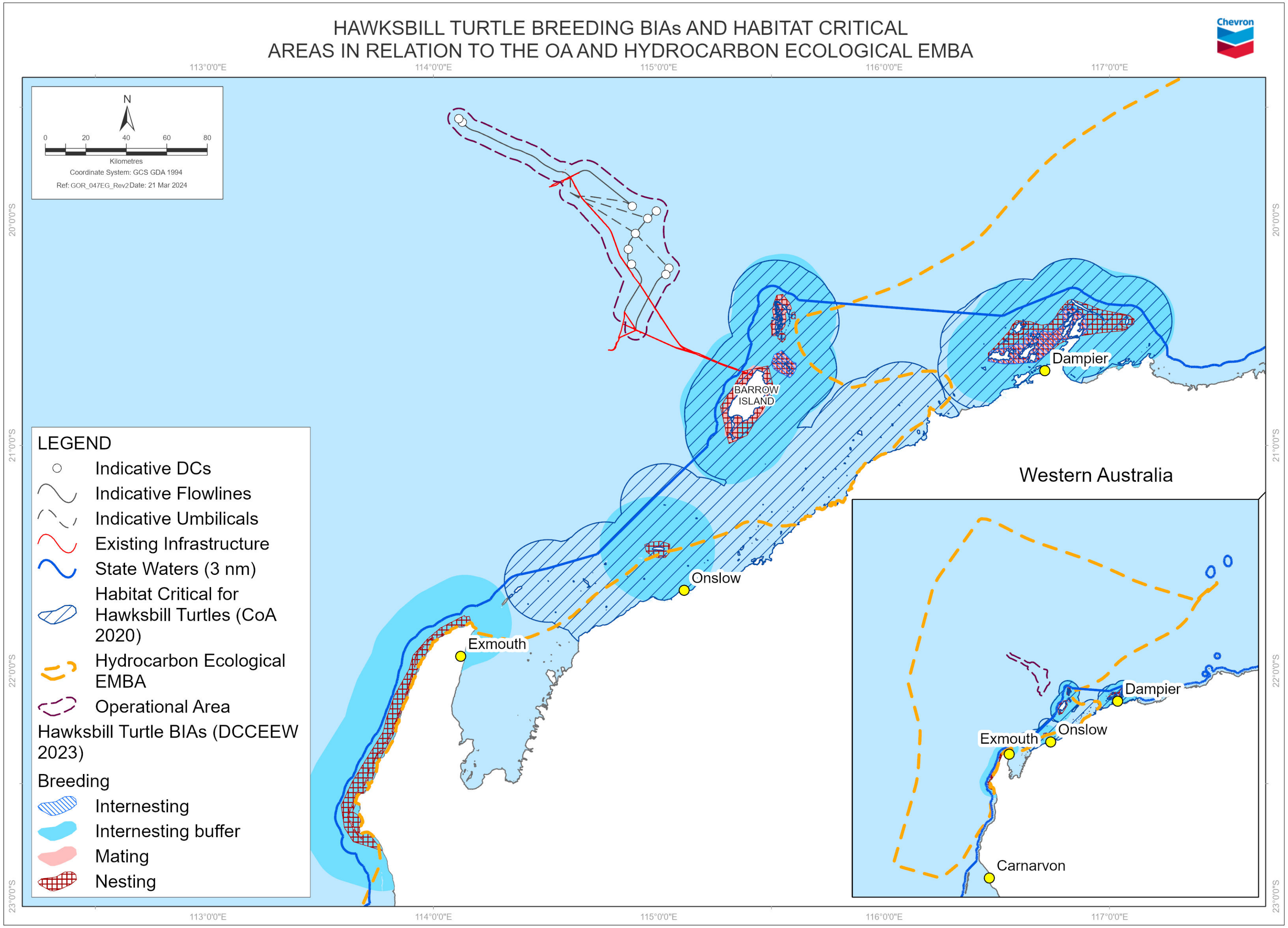

Figure 6-18: Hawksbill turtle (breeding) BIAs and habitat critical areas in relation to the Hydrocarbon Ecological EMBA

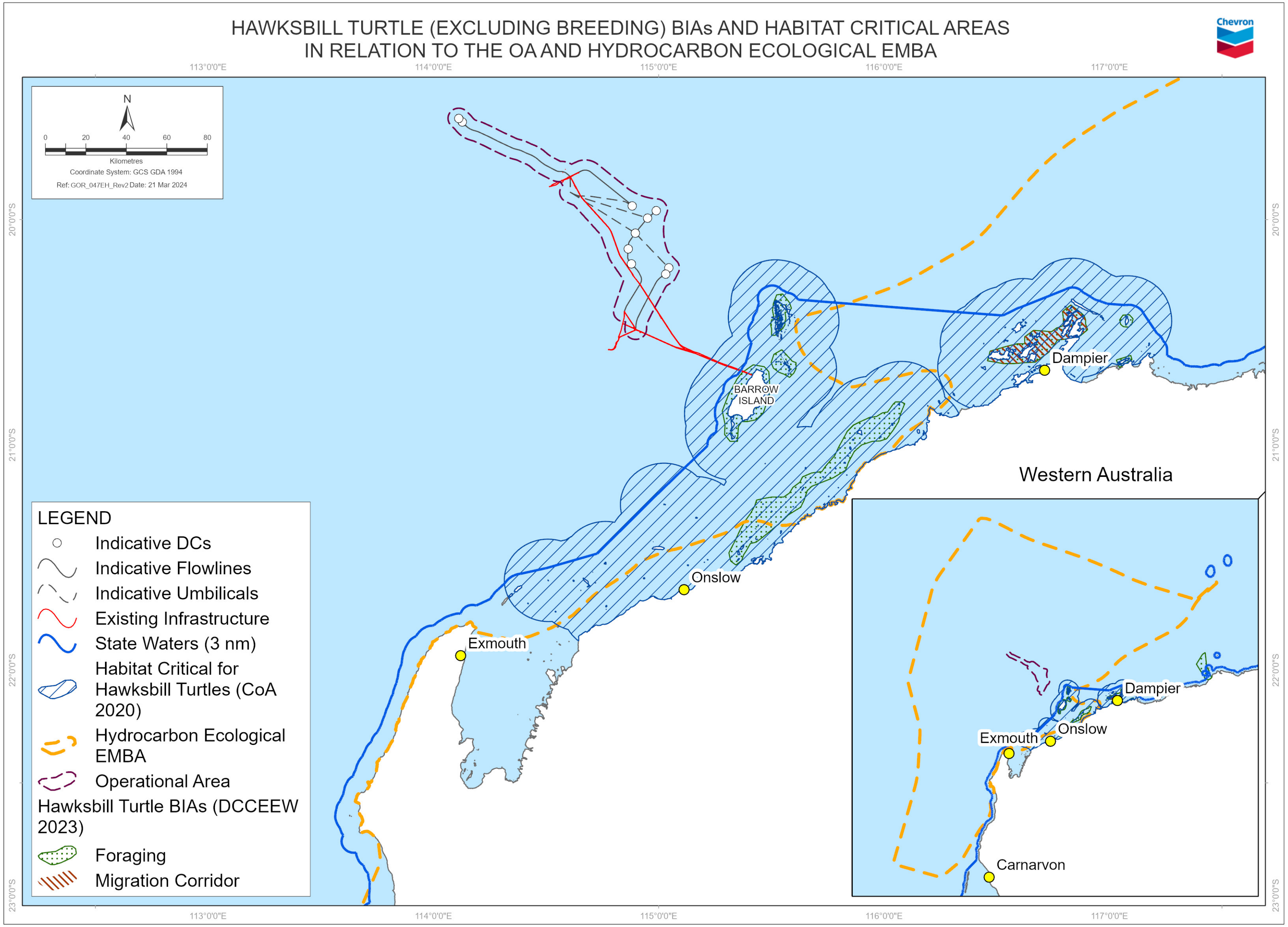

Figure 6-19: Hawksbill turtle (excluding breeding) BIAs and habitat critical areas in relation to the Hydrocarbon Ecological EMBA

6.2.3.2.4 Loggerhead turtle

The loggerhead turtle (*Caretta caretta*) is listed as endangered, marine, and migratory under the EPBC Act. There are no loggerhead turtle BIAs or habitat critical that overlap the OA (Figure 6-20 and Figure 6-21). Internesting buffer and nesting BIAs and habitat critical overlap the Hydrocarbon Ecological EMBA (Figure 6-20 and Figure 6-21).

Loggerhead turtles are globally distributed in tropical, sub-tropical and temperate waters. In Australia, the species can be found in eastern, northern, and western waters in coral and rocky reefs, seagrass beds, and muddy bays (Ref. 163). There are two genetically distinct stocks of loggerhead turtles that nest in Australia (Ref. 148): the south-west Pacific stock, that nest in southern Queensland, and the Western Australian stock, that nest between Shark Bay and North West Cape. Interbreeding between stocks does not occur.

The species nest on sandy beaches (Ref. 164). In Western Australia nesting occurs from Shark Bay (including on the mainland near Steep Point) to the North West Cape, with major nesting at Dirk Hartog Island; Gnaraloo Bay; Muiron Island; and the beaches of the North West Cape (Ref. 165). Occasional late summer nesting crawls have also been recorded as far north as Barrow Island, the Lowendal Islands and Dampier Archipelago (Ref. 166). During internesting, turtles remain close to the nesting beach or rookery (Ref. 148). Once breeding and nesting is complete, turtles migrate back to their favoured foraging areas, sometimes over distances in excess of 1000 km, showing strong fidelity to their feeding and breeding areas (Ref. 167).

Loggerheads are carnivorous, feeding primarily on benthic invertebrates in habitats ranging from nearshore to 55 m depth (Ref. 168). Loggerhead turtles forage in all coastal states and the Northern Territory (Ref. 148).

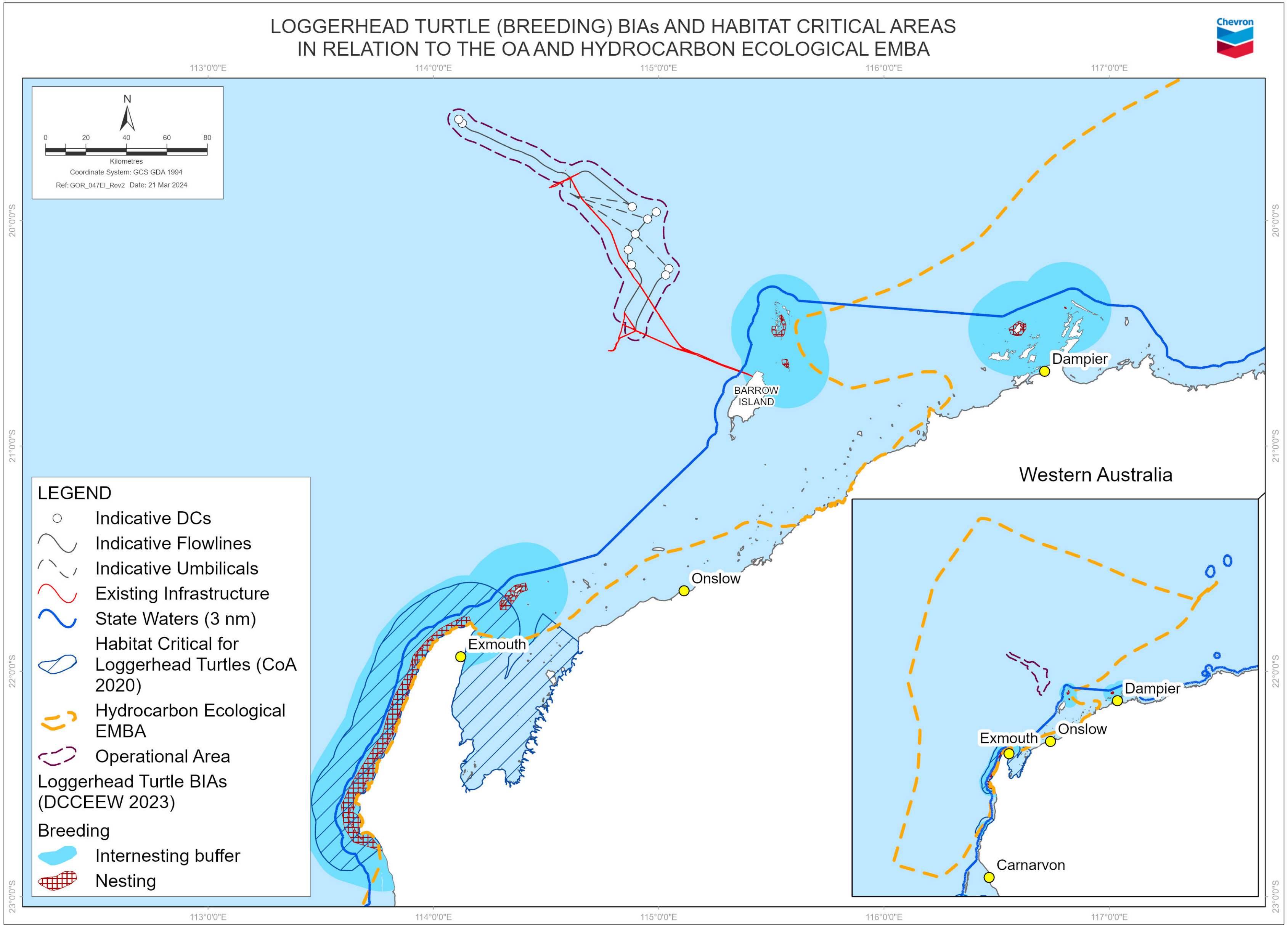

Figure 6-20: Loggerhead turtle (breeding) BIAs and habitat critical in relation to the Hydrocarbon Ecological EMBA

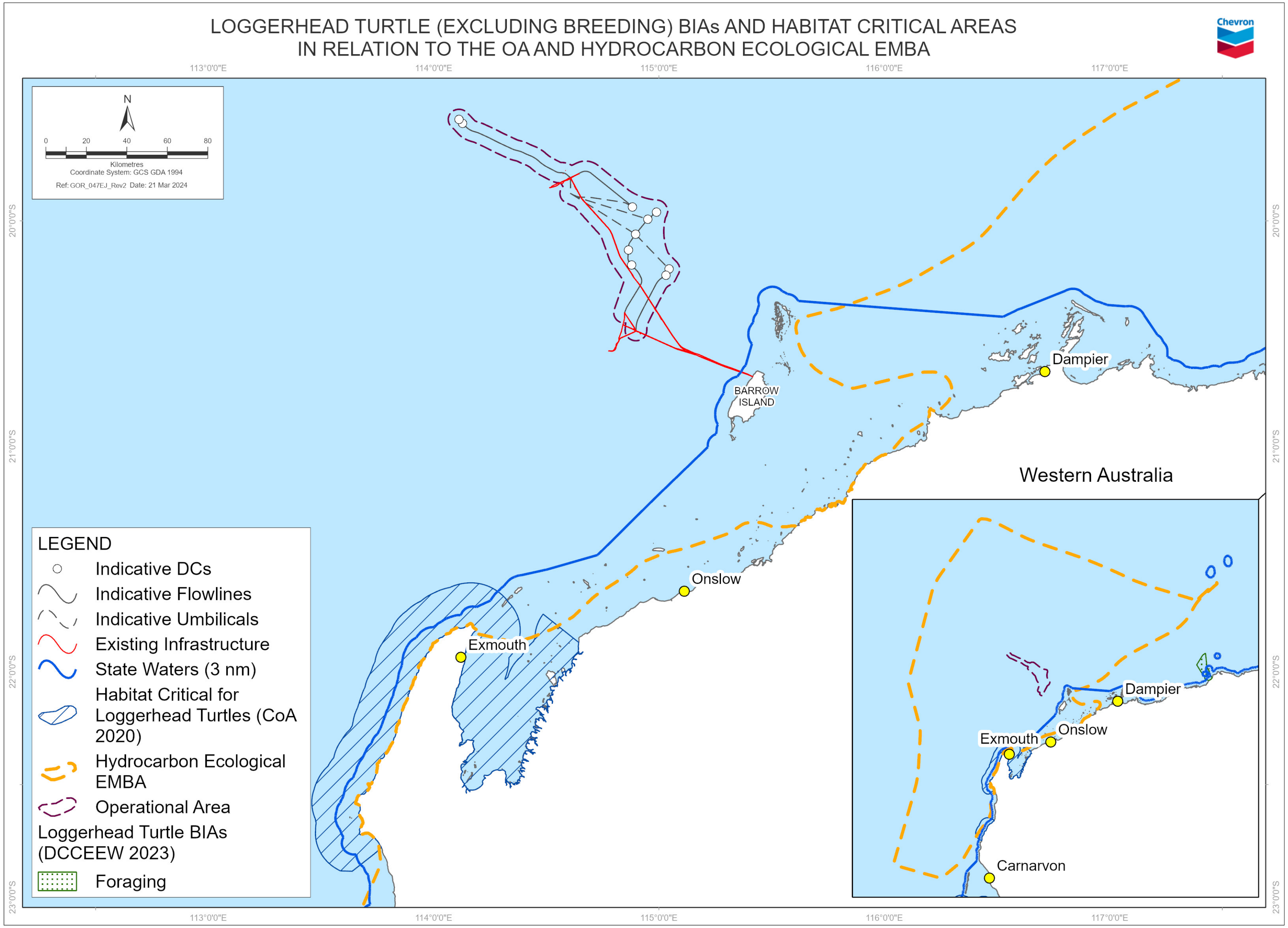

Figure 6-21: Loggerhead turtle (excluding breeding) BIAs and habitat critical areas in relation to the Hydrocarbon Ecological EMBA

6.2.3.3 Fishes, including sharks and rays

Based on searches of the EPBC Act protected matters database (Ref. 123, Appendix B), the threatened or migratory fish species shown in Table 6-9 may be present within the OA and Hydrocarbon Ecological EMBA. BIAs associated with fish species are listed in Table 6-10.

Table 6-9: Presence of threatened or migratory fishes, including sharks and rays

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation status
Fish, sharks and rays							
Dwarf sawfish, Queensland sawfish	*Pristis clavata*	KO	KO	V	✓	-	MI & P1
Freshwater sawfish, largetooth sawfish, river sawfish, Leichhardt's sawfish, northern sawfish	*Pristis pristis*	MO	LO	V	✓	-	MI & P3
Giant manta ray, Chevron manta ray, Pacific manta ray, pelagic manta ray, Oceanic manta ray	*Mobula birostris*	LO	KO	-	✓	-	MI
Green sawfish, dindagubba, narrowsnout sawfish	*Pristis zijsron*	KO	KO	V	✓	-	V
Grey nurse shark (west coast population)	*Carcharias taurus* (west coast population)	KO	CKO	V	-	-	V
Little gulper shark	*Centrophorus uyato*	-	LO	CD	-	-	-
Longfin mako	*Isurus paucus*	LO	LO	-	✓	-	MI
Narrow sawfish, knifetooth sawfish	*Anoxypristis cuspidata*	MO	KO	-	✓	-	MI
Oceanic whitetip shark	*Carcharhinus longimanus*	LO	LO	-	✓	-	-
Porbeagle, mackerel shark	*Lamna nasus*	-	MO	-	✓	-	MI
Reef manta ray, coastal manta ray, inshore manta ray, Prince Alfred's ray, resident manta ray	*Mobula alfredi*	LO	KO	-	✓	-	MI
Scalloped hammerhead	*Sphyrna lewini*	LO	KO	CD	-	-	-
Shortfin mako, mako shark	*Isurus oxyrinchus*	LO	LO	-	✓	-	MI
Southern bluefin tuna	*Thunnus maccoyii*	-	BKO	-	-	✓	-
Whale shark	*Rhincodon typus*	FKO	FKO	V	✓	-	MI
White shark, great white shark	*Carcharodon carcharias*	MO	KO	V	✓	-	V

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation status
Pipefish/ Pipehorse/ Seahorse							
Australian messmate pipefish, banded pipefish	*Corythoichthys intestinalis-*		MO	-	-	✓	-
Banded pipefish, ringed pipefish	*Doryrhamphus dactyliophorus*	MO	MO	-	-	✓	-
Beady pipefish, steep-nosed pipefish	*Hippichthys penicillus*	MO	MO	-	-	✓	-
Bentstick pipefish, bend stick pipefish, short-tailed pipefish	*Trachyrhamphus bicoarctatus*	MO	MO	-	-	✓	-
Black rock pipefish	*Phoxocampus belcheri*	MO	MO	-	-	✓	-
Blind cave eel	*Ophisternon candidum*	-	KO	V	-	✓	-
Bluestripe pipefish, Indian blue-stripe pipefish, Pacific blue-stripe pipefish	*Doryrhamphus excisus*	MO	MO	-	-	✓	-
Bonyhead pipefish, bony-headed pipefish	*Nannocampus subosseus*	-	MO	-	-	✓	-
Braun's pughead pipefish, pug-headed pipefish	*Bulbonaricus brauni*	MO	MO	-	-	✓	-
Brock's pipefish	*Halicampus brocki*	MO	MO	-	-	✓	-
Cape Range cave gudgeon, blind gudgeon	*Milyeringa veritas*	-	KO	V	-	✓	V
Corrugated pipefish	*Bhanotia fasciolata*	-	MO	-	-	✓	
Cleaner pipefish, Janss' pipefish	*Doryrhamphus janssi*	MO	MO	-	-	✓	-
Double-end pipehorse, double-ended pipehorse, alligator pipefish	*Syngnathoides biaculeatus*	MO	MO	-	-	✓	-
Fijian banded pipefish, brown-banded pipefish	*Corythoichthys amplexus*	-	MO	-	-	✓	-
Flagtail pipefish, Masthead Island pipefish	*Doryrhamphus negrosensis*	MO	MO	-	-	✓	-
Flat-face seahorse	*Hippocampus planifrons*	MO	MO	-	-	✓	-
Gale's pipefish	*Campichthys galei*	-	MO	-	-	✓	-

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation status
Glittering pipefish	*Halicampus nitidus*	MO	MO	-	-	✓	-
Gunther's pipehorse, Indonesian pipefish	*Solegnathus lettiensis*	MO	MO	-	-	✓	-
Hedgehog seahorse	*Hippocampus spinosissimus*	MO	MO	-	-	✓	-
Helen's pygmy pipehorse	*Acentronura larsonae*	MO	MO	-	-	✓	-
Ladder pipefish	*Festucalex scalaris*	MO	MO	-	-	✓	-
Many-banded pipefish	*Doryrhamphus multiannulatus*	MO	MO	-	-	✓	-
Mud pipefish, Gray's pipefish	*Halicampus grayi*	MO	MO	-	-	✓	-
Muiron Island pipefish	*Choeroichthys latispinosus*	MO	MO	-	-	✓	-
Pacific short-bodied pipefish, short-bodied pipefish	*Choeroichthys brachysoma*	MO	MO	-	-	✓	-
Pallid pipehorse, Hardwick's pipehorse	*Solegnathus hardwickii*	MO	MO	-	-	✓	-
Pig-snouted pipefish	*Choeroichthys suillus*	MO	MO	-	-	✓	-
Prophet's pipefish	*Lissocampus fatiloquus*	-	MO	-	-	✓	-
Red-hair pipefish, Duncker's pipefish	*Halicampus dunckeri*	-	MO	-	-	✓	-
Reticulate pipefish, yellow-banded pipefish, network pipefish	*Corythoichthys flavofasciatus*	MO	MO	-	-	✓	-
Ribboned pipehorse, ribboned seadragon	*Haliichthys taeniophorus*	MO	MO	-	-	✓	-
Robust ghost pipefish, blue-finned ghost pipefish,	*Solenostomus cyanopterus*	MO	MO	-	-	✓	-
Roughridge pipefish	*Cosmocampus banneri*	MO	MO	-	-	✓	-
Schultz's pipefish	*Corythoichthys schultzi*	-	MO	-	-	✓	-
Spiny seahorse, thorny seahorse	*Hippocampus histrix*	MO	MO	-	-	✓	-
Spiny-snout pipefish	*Halicampus spinirostris*	MO	MO	-	-	✓	-
Spotted pipefish, gulf pipefish, peacock pipefish	*Stigmatopora argus*	-	MO	-	-	✓	-

Common name	Scientific name	EPBC Act presence		EPBC Act status			WA BC Act
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation status
Spotted seahorse, yellow seahorse	*Hippocampus kuda*	MO	MO	-	-	✓	-
Straight stick pipefish, long-nosed pipefish	*Trachyrhamphus longirostris*	MO	MO	-	-	✓	-
Three-keel pipefish	*Campichthys tricarinatus*	MO	MO	-	-	✓	-
Three-spot seahorse, low-crowned seahorse, flat-faced seahorse	*Hippocampus trimaculatus*	MO	MO	-	-	✓	-
Tidepool pipefish	*Micrognathus micronotopterus*	MO	MO	-	-	✓	-
Tiger pipefish	*Filicampus tigris*	MO	MO	-	-	✓	-
Western spiny seahorse, narrow-bellied seahorse	*Hippocampus angustus*	MO	MO	-	-	✓	-

Likely Presence

AKO: Aggregation know to occur within area.

BKO: Breeding known to occur within area.

FLO: Foraging likely to occur within area.

KO: Species or species habitat known to occur within area.

LO: Species or species habitat likely to occur within area.

MO: Species or species habitat may occur within area.

Conservation Status:

CD: Conservation Dependent

CE: Critically Endangered

E: Endangered

P1: Priority 1, Poorly-known species

P3: Priority 3, Poorly-known species

P4: Priority 4, Rare, Near Threatened and other species in need of monitoring

MI: Migratory

V: Vulnerable

Table 6-10: Presence of BIAs for fishes, including sharks and rays

Common name	BIA behaviour	Seasonal presence	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA
Whale shark	Foraging	Spring	✓	0	✓
	Foraging (high-density prey)	Apr–Jun, autumn	-	166.5	✓

6.2.3.3.1 Whale shark

The whale shark (*Rhincodon typus*) is listed as vulnerable and migratory under the EPBC Act. The OA and Hydrocarbon Ecological EMBA overlap a foraging BIA for the whale shark. In addition, a foraging (high-density prey) BIA overlaps the Hydrocarbon Ecological EMBA (Figure 6-22).

The whale shark has a global distribution in tropical and warm temperate seas (Ref. 169). In Australian waters, whale sharks form seasonal aggregations at Ningaloo Reef (March to July), Christmas Island (December to January), and in the Coral Sea (November to December) (Ref. 30). Ningaloo Reef is considered the main known seasonal aggregation area (Ref. 170). Whale sharks aggregate off Ningaloo Reef between March and July each year to feed (Ref. 171; Ref. 172). Their presence off Ningaloo Reef has been linked to coral mass spawning timing (Ref. 171). Following the aggregation period around Ningaloo Reef, their distribution is largely unknown, although 3 migration routes from Ningaloo Reef have been identified (Ref. 173):

- north-west, into the Indian Ocean
- directly north, towards Sumatra and Java
- north-east, passing through the NWS region, travelling along the shelf break and continental slope.

The foraging BIA that overlaps the OA runs northward from Ningaloo along the 200 m isobath. Migration to the north-west broadly follows the 200 m isobath and typically occurs between July and November (Ref. 30).

The whale shark is a suction filter feeder, with a diet comprising planktonic and nektonic prey, and feeds at or close to the water's surface by swimming forward with mouth agape, sucking in prey (Ref. 171). Although the species is generally encountered close to or at the surface, it will regularly dive and move through the water column. Research has found that whale sharks at Ningaloo Reef move between the sea surface and deeper water, spending 40% of their time in the upper 15 m of the water column and 50% of their time at 30 m or less (Ref. 174; Ref. 171). Off the outer NWS, whale sharks spend much of their time swimming near the sea floor and can dive to around 1,000 m (Ref. 171). Deep dives are thought to be primarily for prey, such as krill, lantern fish, squid and jellyfish (Ref. 171).

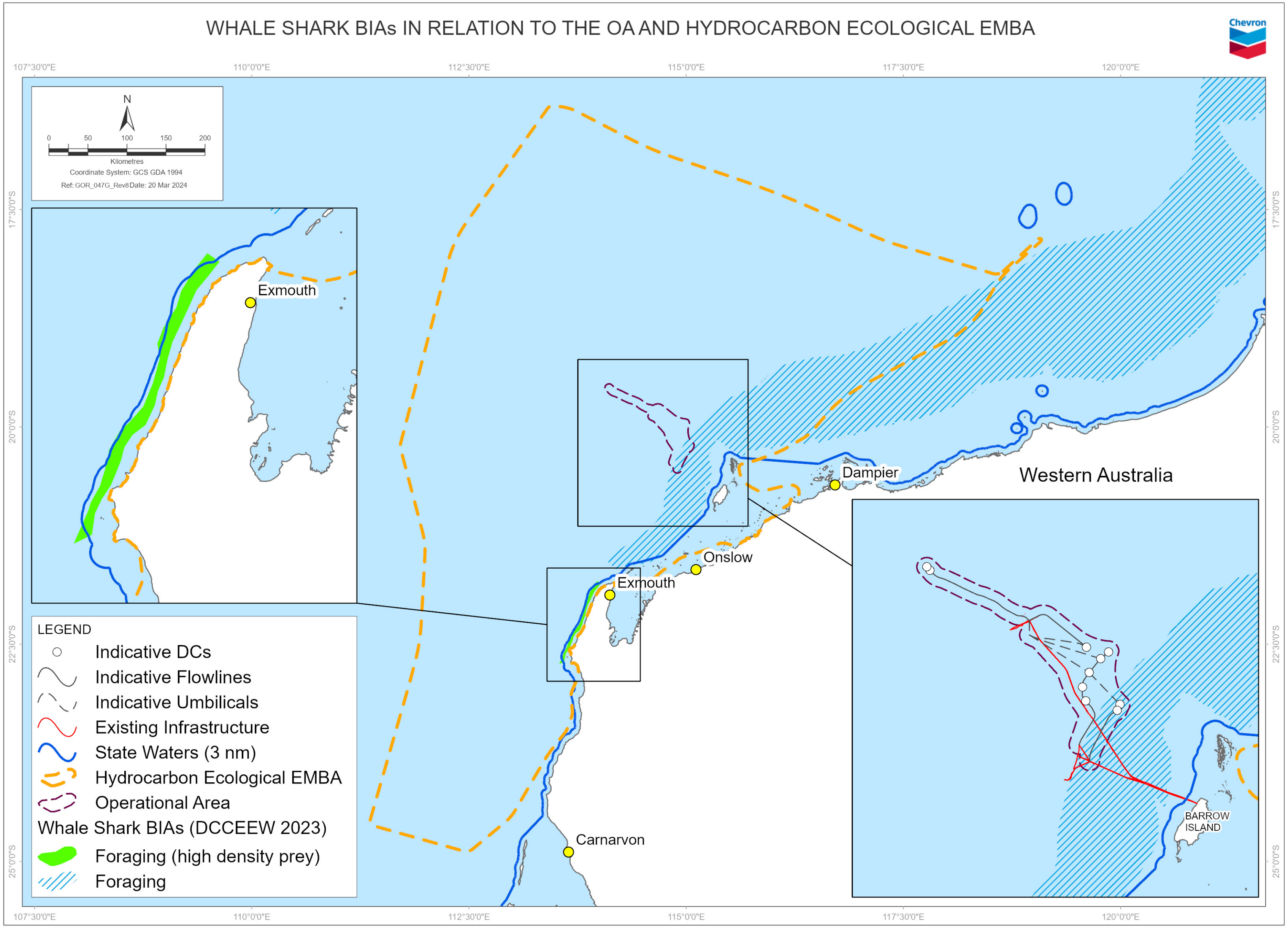

Figure 6-22: Whale shark BIAs in relation to the OA and Hydrocarbon Ecological EMBA

6.2.3.4 Seabirds and shorebirds

Based on searches of the EPBC Act protected matters database (Ref. 123, Appendix B), the threatened or migratory seabird and shorebird species shown in Table 6-11 may be present within the OA or Hydrocarbon Ecological EMBA. BIAs associated with seabird and shorebird species are listed in Table 6-12.The BIAs and/or known occurrence of seabirds are shown in the following figures:

- Wedge-tailed shearwater— Figure 6-23
- Lesser frigatebird and white-tailed tropicbird—Figure 6-24
- Fairy tern—Figure 6-25
- Lesser crested tern—Figure 6-26
- Roseate tern—Figure 6-27

Table 6-11: Presence of threatened or migratory seabirds and shorebirds

Common name	Scientific Name	EPBC Act presence		EPBC Act Status			*Biodiversity Conservation Act 2016*
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation Status
Abbott's booby	*Papasula abbotti*	-	MO	E	-	✓	-
Asian dowitcher	*Limnodromus semipalmatus*	-	KO	V	✓	✓	MI
Australian fairy tern	*Sternula nereis nereis*	FLO	BKO	V	-	-	V
Australian painted snipe	*Rostratula australis*	-	LO	E	-	✓ (as *Rostratula benghalensis (sensu lato)*)	E
Barn swallow	*Hirundo rustica*	-	MO	-	✓	✓	MI
Bar-tailed godwit	*Limosa lapponica*	-	KO	-	✓	✓	MI
Black-browed albatross	*Thalassarche melanophris*	-	MO	V	✓	✓	E
Black-eared cuckoo	*Chalcites osculans*	-	KO	-	-	✓ (as *Chrysococcyx osculans)*	-
Bridled tern	*Onychoprion anaethetus*	-	KO	-	✓	✓ (as *Sterna anaethetus*)	MI
Campbell albatross, Campbell black-browed albatross	*Thalassarche impavida*	-	MO	-	✓	✓	V
Caspian tern	*Hydroprogne caspia*	-	BKO	-	✓	✓ (as *Sterna caspia*)	MI

Common name	Scientific Name	EPBC Act presence		EPBC Act Status			*Biodiversity Conservation Act 2016*
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation Status
Cattle egret	*Bubulcus ibis*	-	MO	-	-	✓ (as *Ardea ibis*)	-
Christmas Island white-tailed tropicbird, golden bosunbird	*Phaethon lepturus fulvus*	MO	MO	E	-	✓	-
Common greenshank, greenshank	*Tringa nebularia*	-	LO	E	✓	✓	MI
Common noddy	*Anous stolidus*	MO	LO	-	✓	✓	MI
Common sandpiper	*Actitis hypoleucos*	MO	KO	-	✓	✓	MI
Curlew sandpiper	*Calidris ferruginea*	MO	KO	CE	✓	✓	CE
Eastern curlew, far eastern curlew	*Numenius madagascariensis*	MO	KO	CE	✓	✓	CE
Fairy tern	*Sternula nereis*	-	BKO	-	-	✓ (as *Sterna nereis*)	V
Flesh-footed shearwater	*Ardenna carneipes*	-	LO	-	✓	✓ (as *Puffinus carneipes)*	V
Fork-tailed swift	*Apus pacificus*	-	LO	-	✓	✓	MI
Great frigatebird, greater frigatebird	*Fregata minor*	-	MO	-	✓	✓	MI
Greater crested tern	*Thalasseus bergii*	-	MO	-	✓	✓ (as *Sterna bergii*)	MI
Greater sand plover, large sand plover	*Charadrius leschenaultii*	-	KO	V	✓	✓	V
Grey falcon	*Falco hypoleucos*	-	KO	V	-	-	V
Greg wagtail	*Motacilla cinerea*	-	MO	-	✓	✓	MI

Common name	Scientific Name	EPBC Act presence		EPBC Act Status			*Biodiversity Conservation Act 2016*
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation Status
Indian yellow-nosed albatross	*Thalassarche carteri*	-	MO	V	✓	✓	E
Lesser crested tern	*Thalasseus bengalensis*	-	BKO	-	-	✓ (as *Sterna bengalensis*)	-
Lesser frigatebird, least frigatebird	*Fregata ariel*	LO	KO	-	✓	✓	MI
Little tern	*Sternula albifrons*	-	MO	-	✓	✓ (as *Sterna albifrons*)	MI
Night parrot	*Pezoporus occidentalis*	-	MO	E	-	-	CE
Northern Siberian bar-tailed godwit, russkoye bartailed godwit	*Limosa lapponica menzbieri*	-	KO	CE	-	-	CE
Oriental plover, oriental dotterel	*Charadrius veredus*	-	MO	-	✓	✓	MI
Oriental pratincole	*Glareola maldivarum*	-	MO	-	✓	✓	MI
Osprey	*Pandion haliaetus*	-	BKO	-	✓	✓	MI
Pacific gull	*Larus pacificus*	-	BKO	-	-	✓	-
Pectoral sandpiper	*Calidris melanotos*	MO	LO	-	✓	✓	MI
Rainbow bee-eater	*Merops ornatus*	-	MO	-	-	✓	-
Red goshawk	*Erythrotriorchis radiatus*	-	MO	V	-	-	-
Red knot	*Calidris canutus*	MO	KO	V	✓	✓	E

Common name	Scientific Name	EPBC Act presence		EPBC Act Status			*Biodiversity Conservation Act 2016*
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation Status
Red-tailed tropicbird	*Phaethon rubricauda westralis*	MO	KO	E	-	-	MI & P4 (as *Phaethon rubricauda*)
Roseate tern	*Sterna dougallii*	-	BKO	-	✓	✓	MI
Sharp-tailed sandpiper	*Calidris acuminata*	MO	KO	V	✓	✓	MI
Shy albatross	*Thalassarche cauta*	-	MO	E	✓	✓	V
Silver gull	*Chroicocephalus novaehollandiae*	-	BKO	-	-	✓ (as *Larus novaehollandiae*)	-
Soft-plumaged petrel	*Pterodroma mollis*	-	FLO	V	-	✓	-
Sooty tern	*Onychoprion fuscatus*	-	BKO	-	-	✓ (as *Sterna fuscata*)	-
Southern giant petrel	*Macronectes giganteus*	MO	MO	E	✓	✓	MI
Streaked shearwater	*Calonectris leucomelas*	LO	LO	-	✓	✓	MI
Wedge-tailed shearwater	*Ardenna pacifica*	-	BKO	-	✓	✓ (as *Puffinus pacificus*)	MI
White-bellied sea-eagle	*Haliaeetus leucogaster*	-	KO	-	-	✓	-
White-capped albatross	*Thalassarche steadi*	-	MO	V	✓	✓	-
White-tailed tropicbird	*Phaethon lepturus*	MO	KO	-	✓	✓	MI

Common name	Scientific Name	EPBC Act presence		EPBC Act Status			*Biodiversity Conservation Act 2016*
		OA	Hydrocarbon Ecological EMBA	Threatened	Migratory	Marine	Conservation Status
White-winged fairy-wren (Barrow Island), Barrow Island black-and-white fairy-wren	*Malurus leucopterus edouardi*	-	LO	V	-	-	V
Wood sandpiper	*Motacilla flava*	-	MO	-	✓	✓	MI

Likely Presence	**Conservation Status:**
AKO: Aggregation know to occur within area.	CE: Critically Endangered
BKO: Breeding known to occur within area.	E: Endangered
FLO: Foraging likely to occur within area.	MI: Migratory
KO: Species or species habitat known to occur within area.	P4: Priority 4, Rare, Near Threatened and other species in need of monitoring
LO: Species or species habitat likely to occur within area.	V: Vulnerable
MO: Species or species habitat may occur within area.	

Table 6-12: Presence of BIAs for seabirds and shorebirds

Common name	BIA behaviour	Seasonal presence	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA
Fairy tern	Breeding	Jul–late Sep	-	36.1	✓
Lesser crested tern	Breeding	Mar–Jun	-	34	✓
Roseate tern	Breeding	Mid-Mar–Jul. Birds from South-west Marine Region dispersing north in winter	-	39.8	✓
Wedge-tailed shearwater	Breeding	Mid-Aug–Apr (Pilbara) or mid-May (Shark Bay)	✓	0	✓
White-tailed tropicbird	Breeding	May and Oct	-	376.7	✓

6.2.3.4.1 Wedge-tailed Shearwater

The wedge-tailed shearwater (*Ardenna pacifica*) is listed as migratory under the EPBC Act. A breeding BIA for the wedge-tailed shearwater overlaps the OA and Hydrocarbon Ecological EMBA (Figure 6-23).

Wedge-tailed shearwaters are a pelagic, migratory visitor to WA; estimates indicate more than one million shearwaters migrate to the Pilbara islands each year (Ref. 175) out of an estimated global population of five million (Ref. 176). The wedge-tailed shearwaters typically begin arriving at their WA colonies around August each year and will excavate burrows on vegetated islands for nesting. Peak egg laying typically occurs during November and they will typically leave nests between early-April and early-May and travel north (Ref. 177; Ref. 178).

When foraging, wedge-tailed shearwaters fly <10 m above the water and will dive to depths around 2–3 m. They have been observed to settle on the surface of the water after feeding or before migration. They mostly consume fish, cephalopods, insects, jellyfish and prawns (Ref. 179).

One of the closest colonies to the OA is Double Island (east of Barrow Island). Baseline monitoring (during pre-construction of the GFP) recorded ~20–50 wedge-tailed shearwater nesting burrows on North Double Island and ~300 on South Double Island (Ref. 180; Ref. 181). CAPL (Ref. 1; Ref. 181) estimated 500 burrows over a 2 ha portion of the north-eastern corner of South Double Island, supporting 5,000–10,000 pairs of wedge-tailed shearwaters.

This species forages relatively close to breeding islands; however, more recent studies have indicated bimodal foraging. A study on foraging behaviour of wedge-tailed shearwaters during the 2018 nesting season on the Muiron Islands showed a bimodal foraging strategy that incorporated both short (<4 days) and long (>7 day) trips (Ref. 178). The foraging trips of the wedge-tailed shearwaters from the Muiron Islands were recorded over a large area, extending from the Cape Range Canyon to the Indonesian Archipelago; a consistent pattern of foraging near seamounts was observed (Ref. 178). This area is also part of the foraging extent used by the wedge-tailed shearwaters from both Pelsaert and Houtman Abrolhos islands (Ref. 182; Ref. 178). The use of a bimodal foraging strategy suggests that prey availability close to the colony (i.e. areas that would be used on short trips) is inadequate for the large numbers of breeding shearwaters (Ref. 178).

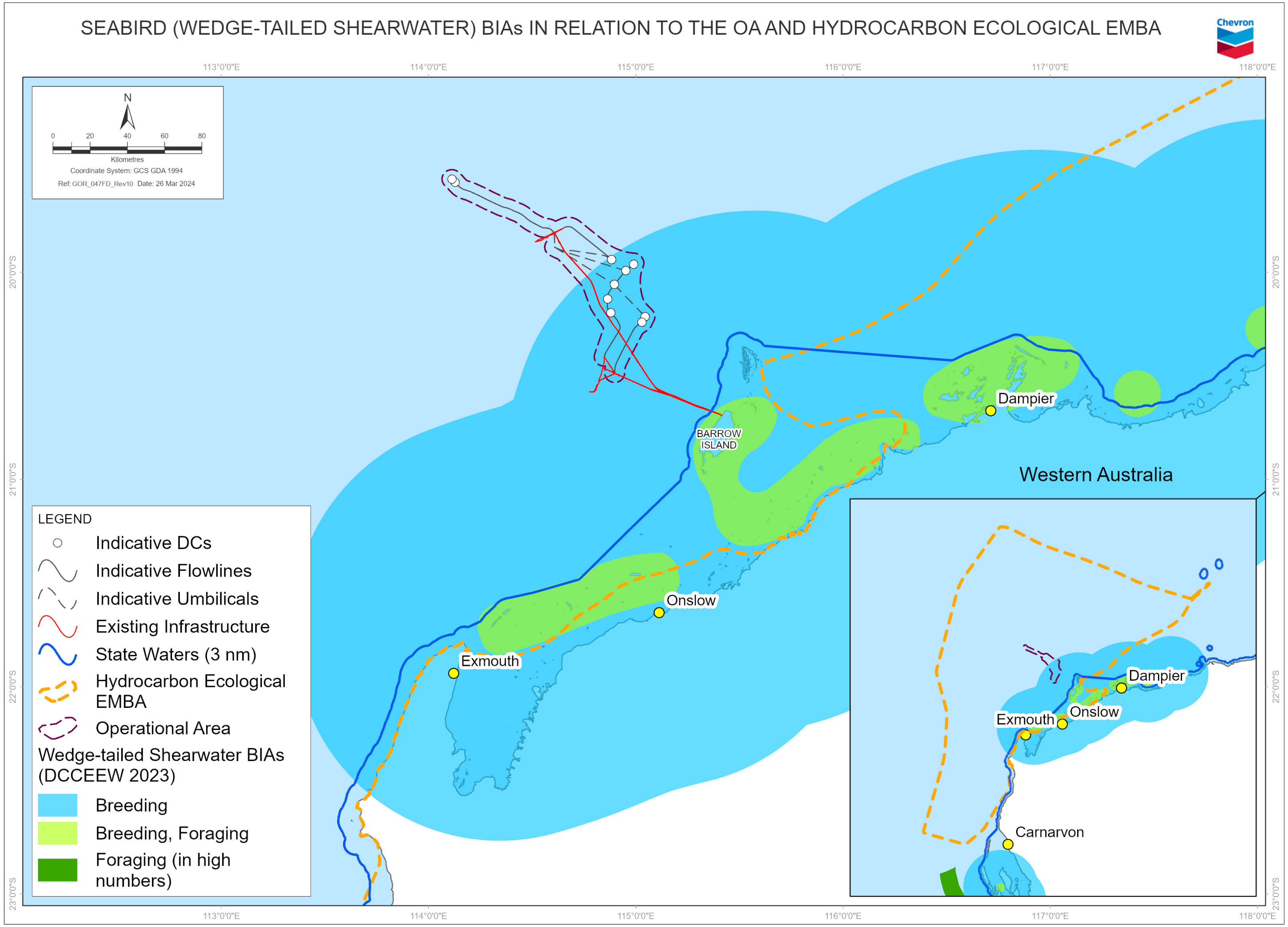

Figure 6-23: Seabird (wedge-tailed shearwater) and BIAs in relation to the OA and Hydrocarbon Ecological EMBA

6.2.3.4.2 White-tailed tropicbird

The white-tailed tropicbird (*Phaethon lepturus*) is listed as marine and migratory under the EPBC Act and BC Act. There are no BIAs for the white-tailed tropicbird that overlap the OA (Figure 6-24). A breeding BIA for the white-tailed tropicbird overlaps the Hydrocarbon Ecological EMBA (Figure 6-24).

The global population is estimated at over 50,000 individuals, with the Australian population poorly known (Ref. 35). The species is pantropical and tends to breed in many locations in low numbers (Ref. 35). The white-tailed tropicbird can be found most commonly off northern WA and occasionally around the Coral Sea and east coast of Australia. Although the species is mostly oceanic, it comes inshore to breed. A variety of habitats are used during nesting, including rainforest canopies, sandy beaches, and rocky terrain (Ref. 35). Adults breed throughout the year with breeding periodicities around 10 month (Ref. 183). Both parents share the incubation of the egg, with the nesting cycle from egg laying to fledgling taking approximately 18 weeks. White-tailed tropicbird breeds for the first time around four years of age (Ref. 184).

White-tailed tropicbirds are plunge divers in deep water and feed on fish and cephalopods. The foraging patterns in Australia, including distance from breeding sites, are not well known (Ref. 185). However, based on observations in Puerto Rico, white-tailed tropicbirds when breeding foraged up to 89 km away from their nesting location and moved further distances when not breeding (Ref. 186). Further, it has been noted that birds originating from Christmas Island foraged between 1,400 and 1,600 km south-east of the island (Ref. 187).

The overlapping white-tailed tropicbird BIA is located in the North-west Marine Region. The BIA is used as a breeding and foraging area for the species with resident and visitor birds.

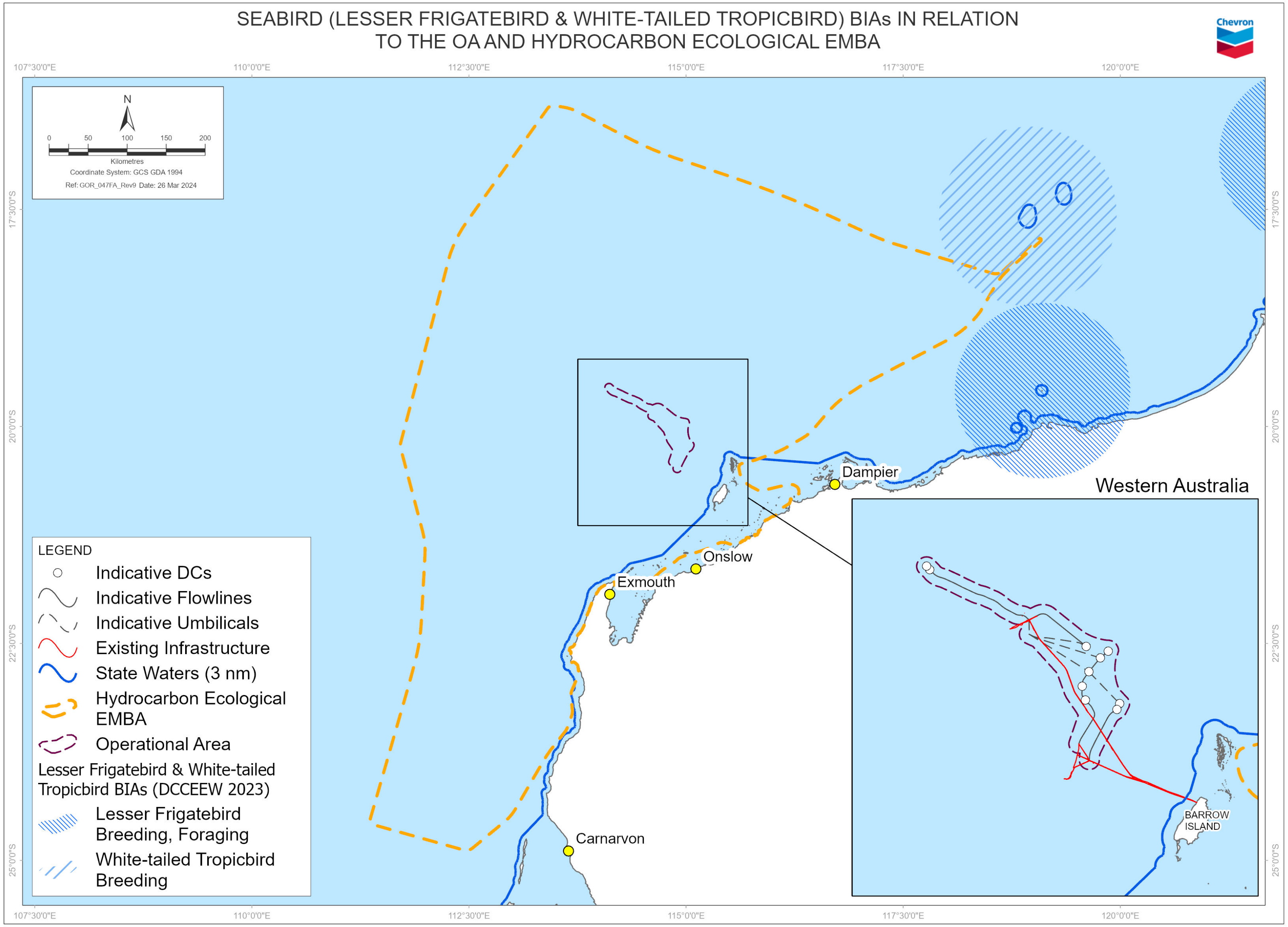

Figure 6-24: Seabird (lesser frigatebird & white-tailed tropicbird) BIAs in relation to the OA and Hydrocarbon Ecological EMBA

6.2.3.4.3 Fairy tern

The fairy tern (*Sternula nereis*) is listed as marine under the EPBC Act. There are no BIAs for the fairy tern that overlap the OA (Figure 6-25). A breeding BIA for the fairy tern overlaps the Hydrocarbon Ecological EMBA (Figure 6-25).

The fairy tern has a large geographical range between Australia, New Zealand and New Caledonia. Three subspecies have been identified based on phenotypic, genotypic and geographic differences (Ref. 188), only one of which (the Australian fairy tern) occurs in WA. The Australian fairy tern subspecies is listed as vulnerable under the EPBC Act. In Australia, the fairy tern can be found along the coasts of Victoria, South Australia, Tasmania, and WA with an estimated area occupancy of 1,150 km^2 (Ref. 188).

The Australian fairy tern has been found in embayments of a variety of habitats including offshore, estuarine, or lacustrine (lake) islands, wetlands, and mainland coastline (Ref. 189). The Australian fairy tern nests on sheltered sandy beaches, spits and banks above the high tide line and below vegetation (Ref. 188). Typically, fairy terns lay between one and three eggs with an incubation period of around 18 days (Ref. 190).

Within WA, there appear to be two subpopulations:

- a sedentary subpopulation based along the Pilbara and upper Gascoyne coasts from Exmouth Gulf to the Dampier Archipelago, including Barrow, Montebello, and Lowendal islands; these Australian fairy terns nest from late-July to late-September
- a migratory subpopulation that disperses south along the coast from Shark Bay to breed between the Houtman Abrolhos Islands to the Recherche Archipelago between September and May, with active breeding flocks appearing at various locations between October and February (Ref. 41).

Australian fairy terns are reported from Barrow Island throughout the year and primarily from the south-east to south-west of the island, with high counts between November and April (Ref. 181). Australian fairy terns may nest on offshore islands between Barrow Island and the Montebello Islands (Ref. 191), including intermittently nesting on North and/or South Double Island (Ref. 181).

Australian fairy terns are diurnal plunge diving feeders that predate exclusively on small (<60 mm) surface schooling bait fishes throughout their range. Australian fairy terns feed almost entirely on fish in near-shore waters adjacent to nesting colonies and around island archipelagos (Ref. 41).

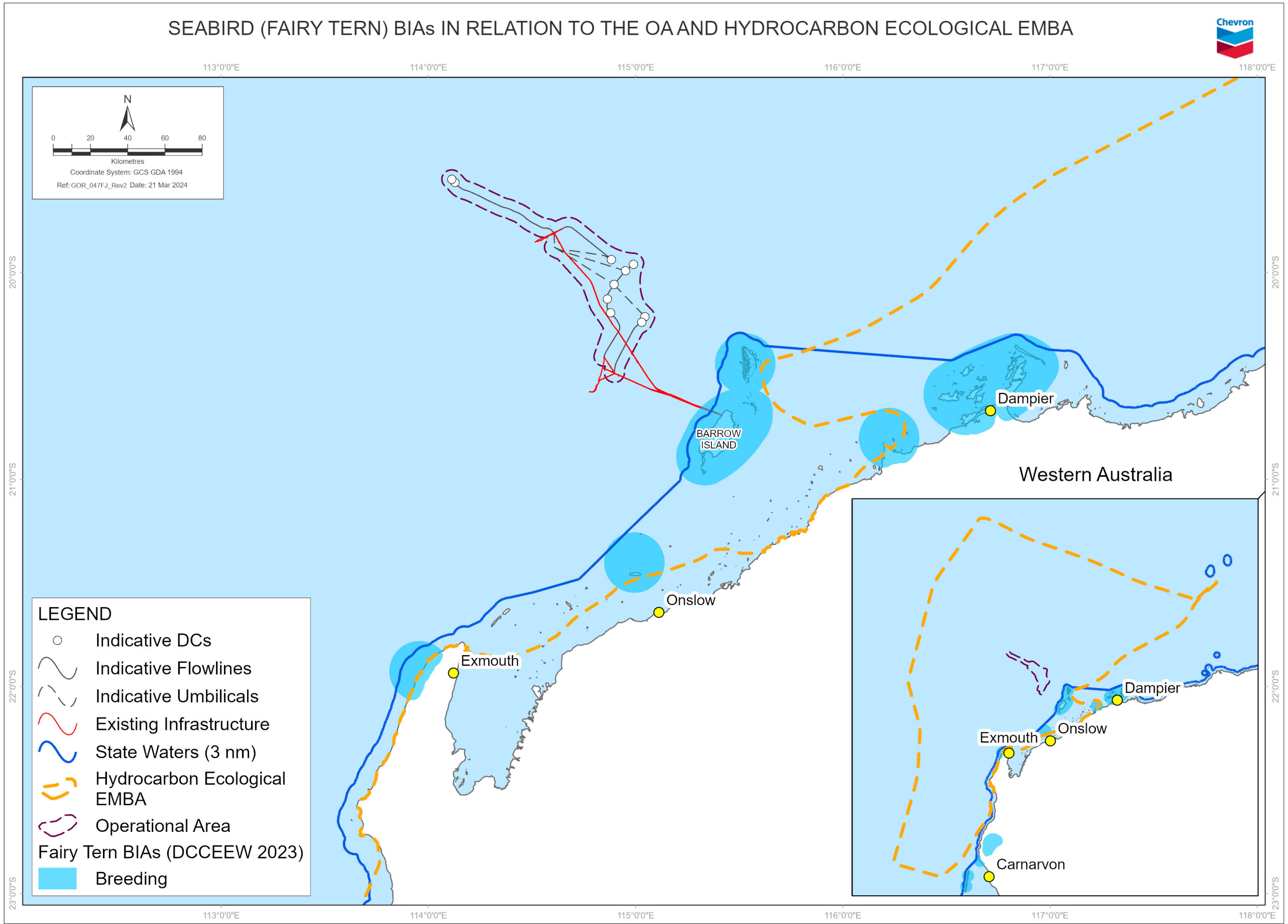

Figure 6-25: Seabird (fairy tern) BIAs in relation to the OA and Hydrocarbon Ecological EMBA

6.2.3.4.4 Lesser crested tern

The lesser crested tern (*Thalasseus bengalensis*) is listed as marine under the EPBC Act. There are no BIAs for the lesser crested tern that overlap the OA (Figure 6-26). A breeding BIA for the lesser crested tern overlaps the Hydrocarbon Ecological EMBA (Figure 6-26).

The population size is large and stable with the global population estimate for lesser crested tern sitting around 225,000 pairs, more than half of which are found in Australia (Ref. 35). The species breed in subtropical coastal areas, generally from the Red Sea across the Indian Ocean to the western Pacific Ocean and Australia. The species inhabits tropical and subtropical coasts and estuaries, breeding on low-lying offshore islands (Ref. 35). The breeding season is between March and June and occurs on islands off north and west Kimberley, Bedout Island, Lowendal Islands, Thevenard Island, and Dirk Hartog Islands (Ref. 192).

Lesser crested terns forage in the surf of the ocean and on the surface of offshore waters feeding primarily on small pelagic fish and shrimp (Ref. 193).

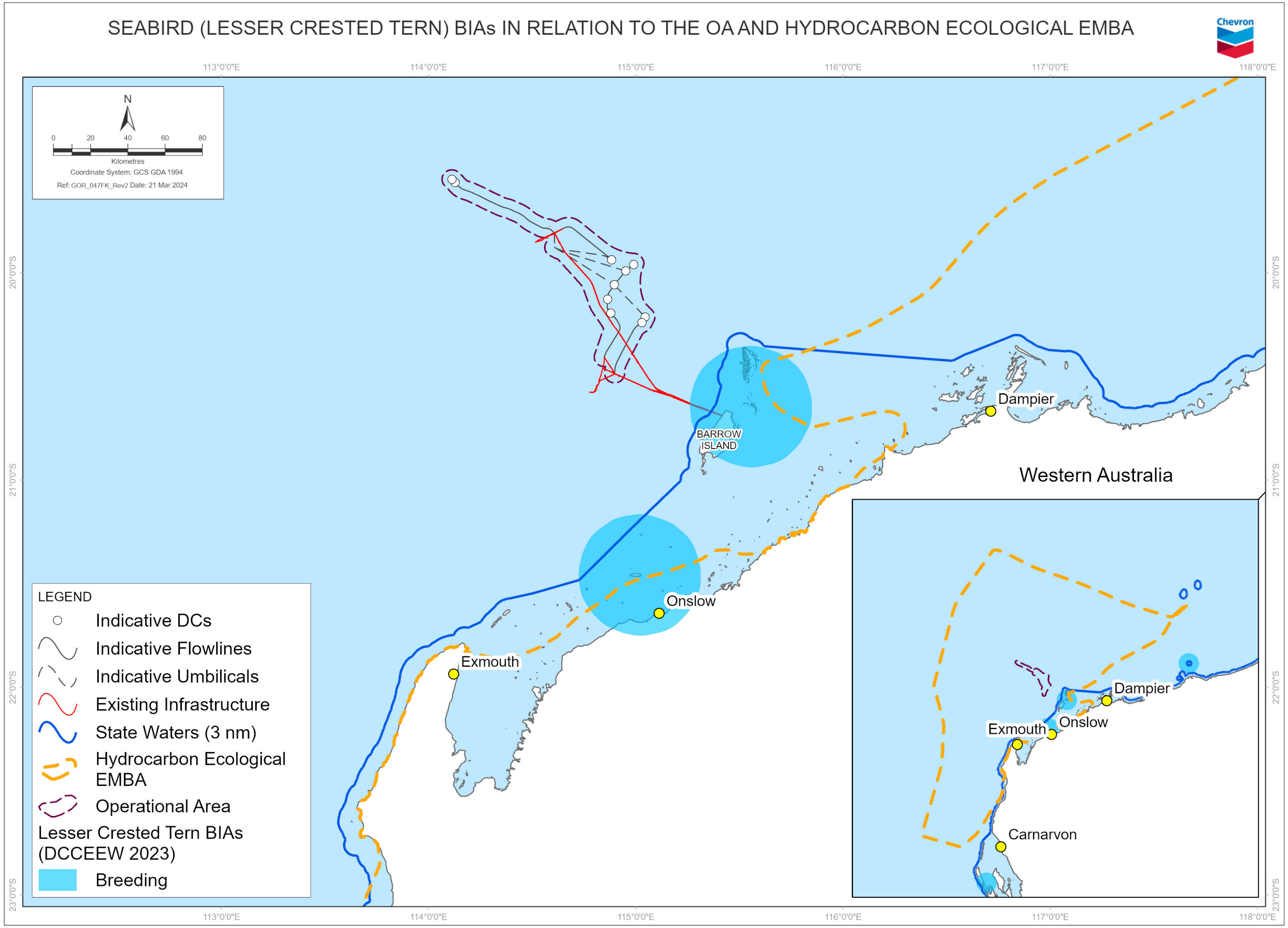

Figure 6-26: Seabird (lesser crested tern) BIAs in relation to the OA and Hydrocarbon Ecological EMBA

6.2.3.4.5 Roseate tern

The roseate tern (*Sterna dougalli*) is listed as marine and migratory under the EPBC Act and BC Act. There are no BIAs for the roseate tern that overlap the OA (Figure 6-27). A breeding BIA for the roseate tern overlaps the Hydrocarbon Ecological EMBA (Figure 6-27).

The roseate tern occurs in coastal and marine areas in subtropical and tropical seas. The species inhabits rocky and sandy beaches, coral reefs, sand cays and offshore islands (Ref. 189). The roseate tern is a migratory species, though the movement patterns are not well known. Birds are known to usually move away from breeding colonies following breeding, however their non-breeding range is not well defined (Ref. 189).

In the North-west Marine Region breeding populations of roseate terns have been recorded at Ashmore Reef, Napier Broome Bay, Bonaparte Archipelago, Lacepede Island, Bedout Island, Dampier Archipelago, Lowendal Island, Frazer Island, Koks Island, Mary Anne Island and Meade Island (Ref. 176).

The largest breeding colony in WA is located in the Houtman Abrolhos Islands (Ref. 194). Other large colonies breed within the Lowendal Island and Montebello Island region and a large breeding colony has also been recorded on Goodwyn Island on the Dampier Archipelago (Ref. 189). Roseate Terns breed in the Pilbara region from March to July and October (Ref. 195; Ref. 196).

Different islands can be chosen for the breeding colony from year to year. As roseate terns do not forage widely from their breeding colonies, suitable nesting islands may be chosen because of nearby aggregations of their pelagic fish prey (Ref. 197). The roseate tern mainly forages on fish and sometimes crustaceans. The species forages during the day up to 60 km from their colony and tend to favour deeper waters rather than shallow water closer to the shore (Ref. 198).

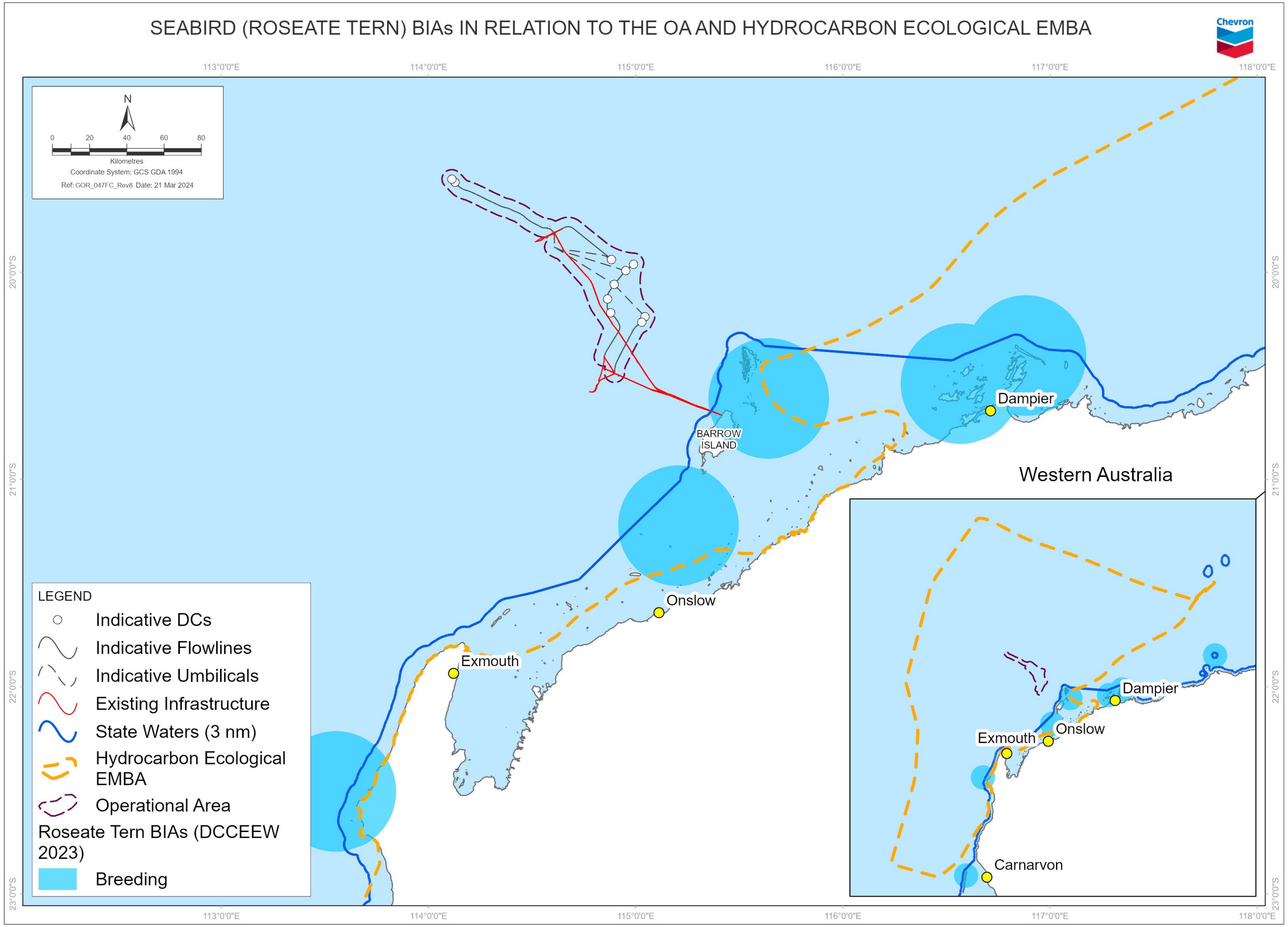

Figure 6-27: Seabird (roseate tern) BIAs in relation to the OA and Hydrocarbon Ecological EMBA

6.2.3.5 Summary of marine fauna seasonal sensitivities

Periods of the year coinciding with key biologically important behaviours for EPBC Act listed threatened and/or migratory species that may potentially be present within the OA and Hydrocarbon Ecological EMBA are presented in Table 6-13.

Table 6-13: Seasonal Presence of marine fauna with biologically important behaviours within the OA and Hydrocarbon Ecological EMBA

Biologically Important Behaviour	January	February	March	April	May	June	July	August	September	October	November	December	OA	Hydrocarbon Ecological EMBA
Humpback whale														
Migration and Distribution[14]													✓	✓
Resting[15]													-	✓
Pygmy blue whale														
Migration and Distribution[16]													✓	✓
Foraging[17]													-	✓
Southern right whale														
Migration[18]													-	✓
Reproduction[18]													-	✓
Dugong														
Breeding, Calving and Nursing[19]													-	✓
Foraging (high-density seagrass beds) [19]													-	✓

[14] *Humpback whale migration along the WA coast typically occurs between May and November (Ref. 199; Ref. 127). Predicted peak migration periods for the Montebello Islands region are late-July (northern) and early-September (southern) (Ref. 126).*

[15] *Important resting areas have been identified during the southern migration including, but not limited to, Exmouth Gulf and the southern Kimberly region (Ref. 199; Ref. 127).*

[16] *Pygmy blue whales migrate north along the WA coast between February and August (Ref. 130; Ref. 135) with predicted highest densities in the Montebello Island region during May and June (Ref. 136). Pygmy blue whales migrate south between November and January (Ref. 130; Ref. 135), with predicted highest densities in the Montebello Island region during November and December (Ref. 136).*

[17] *Utilisation of the 'Most important areas' for foraging for the pygmy blue whale were identified to be correlated to the species' northern and southern migrations (Ref. 136).*

[18] *These are updated BIAs published on the National Conservation Values Atlas (NCVA) (Ref. 192). These BIAs are not included in the EPBC Southern Right Whale Management Plan (Ref. 19) at the time of writing.*

[19] *Dugongs are diffusely seasonal breeders, and the seasonality of breeding is more marked in the sub-tropics (mostly spring, early summer calving) than in the tropics (Ref. 1), however the species may participate in reproductive behaviours year-round. Where sea grass beds are present foraging is expected to occur year-round.*

Biologically Important Behaviour	January	February	March	April	May	June	July	August	September	October	November	December	OA	Hydrocarbon Ecological EMBA
Flatback turtle														
Internesting and nesting[20]													✓	✓
Mating aggregations[20]													-	✓
Foraging[21]													-	✓
Green turtle														
Internesting and nesting[22]													-	✓
Mating aggregations[22]													-	✓
Foraging[23]													-	✓
Basking[24]													-	✓
Hawksbill turtle														
Internesting and nesting[25]													-	✓
Mating[25]													-	✓
Foraging[26]													-	✓

[20] *Nesting locations for the flatback turtle Pilbara genetic stock include, but are not limited to, the Montebello Islands, Barrow Island and Dampier Archipelago (Ref. 21). Each nesting location has an internesting buffer of 60 km where the species is predicted to occur between October and March each year with peak nesting to occur between November and January (Ref. 21). Further, mating has been defined to occur between September and January (Ref. 21).*

[21] *Satellite telemetry was used to follow the movements of flatback turtles after nesting to objectively define internesting, migration and foraging behaviour (Ref. 200).*

[22] *Nesting locations for the green turtle North West Shelf genetic stock include, but are not limited to, the Montebello Islands and Browse Islands (Ref. 148). Each nesting location has an internesting buffer of 20 km where the species is predicted to occur between November and March each year with peak nesting to occur between December and February (Ref. 21). Further, mating has been defined to occur between September and December (Ref. 21).*

[23] *Following the breeding and nesting periods, green turtles return to preferred foraging areas (Ref. 201).*

[24] *In WA, at least some of the basking appears to coincide with courtship time (Ref. 202), however, basking areas may also be located close to preferred foraging areas to allow for relatively undisturbed periods (Ref. 203). Therefore, it is assumed basking may occur year-round.*

[25] *Nesting locations for the hawksbill turtle Western Australia genetic stock include, but are not limited to, Dampier Archipelago and the Montebello Islands (Ref. 21). Each nesting location has an internesting buffer of 20 km where the species is predicted to occur all year with peak nesting to occur between October to January (Ref. 21). Further, mating has also been defined to occur year-round (Ref. 21).*

[26] *The hawksbill turtle migrates between foraging areas and nesting beaches. Breeding male and females move from their feeding grounds to areas near nesting beaches for mating. The males then return to their feeding grounds and the females come up onto the beach to lay their eggs (Ref. 144).*

Biologically Important Behaviour	January	February	March	April	May	June	July	August	September	October	November	December	OA	Hydrocarbon Ecological EMBA
Loggerhead turtle														
Internesting and nesting[27]													-	✓
Whale shark														
Foraging[28]													✓	✓
Fairy tern														
Breeding[29]													-	✓
Lesser crested tern														
Breeding[30]													-	✓
Roseate tern														
Breeding[31]													-	✓
White-tailed tropicbird														
Breeding[32]													-	✓
Wedge-tailed shearwater														
Breeding[33]													✓	✓
	Species may be present and display biologically important behaviour in the region													
	Predicted peak period													

[27] *Nesting locations for the Loggerhead Turtle Western Australia genetic stock include, but are not limited to, the southern North-West Shelf and South Muiron Island (Ref. 21). Each nesting location has an internesting buffer of 20 km where the species is predicted to occur between November to March each year with peak nesting to occur in January (Ref. 21).*

[28] *Whale sharks aggregate seasonally off Ningaloo Reef between March and July each year to feed (Ref. 171; Ref. 172). The number of whale sharks reaches a peak about two weeks after this coral spawning (Ref. 171).*

[29] *The Pilbara and upper Gascoyne sedentary population of Australian fairy terns nests from late-July to late-September (Ref. 41).*

[30] *Lesser crested terns breed in the Pilbara region from March to June (Ref. 195; Ref. 196).*

[31] *Roseate terns breed in the Pilbara region from March to July and October (Ref. 195; Ref. 196).*

[32] *Breeding has been recorded in Western Australia in May and October (Ref. 185).*

[33] *Wedge-tailed shearwaters breed in the Pilbara region from November to April (Ref. 195); peak egg laying typically occurs during November (Ref. 177; Ref. 178).*

6.2.4 Marine environmental quality

The term 'environmental quality' refers to the level of contaminants, or changes to the physical or chemical properties relative to a natural state (Ref. 204). Sediment and water quality were surveyed in the Gorgon Backfill Fields Benthic Survey (Ref. 105, Appendix A).

6.2.4.1 Water quality

Water clarity on the NWS is variable according to movement, depth and sediment; however, nearshore waters in the NWS may have high turbidity due to local current-induced resuspension of fine sediments and episodic run-off from adjacent rivers (Ref. 205).

Wenziker et al. (Ref. 206) estimated natural background concentrations for potential contaminants in waters around the Dampier Archipelago, which provided baseline water quality information for the nearshore waters of the NWS. The survey identified low background concentrations of metals and organic chemicals, with localised elevations of some contaminants (metals) near coastal industrial centres and ports (e.g. Dampier). Except for a few select constituents, such as relatively high natural levels of cadmium, the concentrations of metals were low (Ref. 206).

Water quality data were collected in the benthic survey to understand background concentrations of marine water quality near proposed infrastructure (Ref. 105, Appendix A). Concentrations were compared to ANZG (2018) default guideline values (DGVs) for 99% species protection (Ref. 65). Metal and hydrocarbon concentrations were below laboratory limits of reporting or below available 99% species protection DGVs (with the exception of copper and cobalt at a small subset of sampling locations), which is typical of an undisturbed offshore tropical environment. Elevated copper and cobalt at two and one sites respectively could either reflect natural background levels given the absence of anthropogenic activities in the area or a result of sampling contamination (Ref. 105, Appendix A). Nutrient concentrations were consistently low across the survey area.

Water quality profiles indicate that surface waters correspond with the southward-flowing Leeuwin Current and the deeper south Indian central water mass along with the subsurface Leeuwin Undercurrent, which moves towards the equator along the WA coast at deeper depths (Ref. 105, Appendix A).

6.2.4.2 Sediment quality

Sediment chemistry data were collected during the benthic survey to understand background concentrations of sediment quality (Ref. 105, Appendix A). The concentrations of hydrocarbons, metals and metalloids within the sediment at the proposed DC and tie-in locations were below the environmental guidelines (Ref. 65) at all sites and for all parameters tested, except nickel, which was above the ANZG (2018) environmental guideline at one location (Chandon DC-1). Given that this was a baseline study and no previous activities have occurred in the proposed DCs and tie-in locations, the concentration of nickel recorded likely represents natural background levels (Ref. 105, Appendix A).

6.2.4.3 Air quality

Air quality within the OA and EMBAs is expected to be representative of the typically high air quality found in offshore areas, away from industrial point sources.

As part of the Ambient Air Quality Monitoring Program on Barrow Island, there were no recorded exceedances for nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), carbon monoxide (CO), hydrogen sulfide (H_2S) or aromatic hydrocarbons (benzene, toluene, ethylbenzene and xylene) against the relevant National Environment Protection Measure (NEPM) standards (Ref. 207). There have been elevations of PM_{10} levels around facilities on Barrow Island, however these are likely associated with vehicle traffic and regional weather events (Ref. 207).

It is expected that these low levels of contamination would continue throughout the EMBA, unless within the immediate vicinity of an offshore point source such as a vessel or offshore petroleum activity where presence of atmospheric emissions would be slightly elevated.

6.2.5 People and communities

People and communities, and specifically their social, economic, and cultural features, are included within the definition of environment within the OPGGS(E)R. People and communities have been identified and described to the extent that they directly affect or are affected by the existing physical and biological environments in the OA and EMBAs.

The NWMR supports a range of economic, social, and cultural activities. At present, industries within the NWMR include petroleum exploration and production, commercial and recreational fishing, tourism, ports, and shipping (Ref. 103). These uses of the NWMR make an important economic and social contribution to settlements along the coast (Ref. 103). Section 6.3 identifies and describes the industrial, recreational, and traditional activities that occur within the Hydrocarbon Social EMBA.

6.2.5.1 Land use

The OA occurs offshore and does not have any overlap with coastline. As described in Section 6.2.2, the Hydrocarbon Ecological EMBA and the Hydrocarbon Social EMBA overlap with some coastal areas, specifically Barrow Island, Great Sandy Island, the Montebello Islands, Muiron Islands, Passage Islands, Cape Range National Park and around the Point Cloates / Ningaloo Station area (Figure 6-1 and Figure 6-2). The Hydrocarbon Social EMBA includes additional shoreline points dispersed along the coast from North West Cape to islands in the Dampier Archipelago (including Enderby Island and Rosemary Island) (Figure 6-2). The Hydrocarbon Social EMBA typically only extends landward to the high water mark (HWM).

The land uses that may be present within the Hydrocarbon Social EMBA are summarised below.

The Montebello Islands are protected under WA jurisdiction; the islands are a Conservation Park (International Union for Conservation of Nature classification II [IUCN II]) (Section 6.4.3), and they are surrounded by the Montebello Islands Marine Park (IUCN II) (Section 6.4.1). The Conservation Park is gazetted to the HWM. Because of the natural values of the islands and surrounding waters, recreational activities may occur, such as shore-based fishing, beach walking, picnics, and wildlife viewing (Ref. 209). Camping is permitted on some islands (with some restrictions during turtle nesting season) (Ref. 209).

Barrow, Double, Middle and Boodie islands are also protected under WA jurisdiction; the islands are Nature Reserves (IUCN Ia) (Section 6.4.3) and are surrounded by the Barrow Island Marine Park (IUCN Ia) and Barrow Island Marine Management Area (IUCN VI) (Section 6.5.1). These nature reserves are gazetted to the low water mark. Access to Barrow, Double, Middle, and Boodie islands is not encouraged due to numerous natural and artificial hazards, including the operation of an oilfield and the Gorgon Gas Development (Ref. 209). Camping is not permitted on any of these islands (Ref. 209).

The Ningaloo Coast is protected as part of the World Heritage property and National Heritage place (Section 6.5.1). The waters surrounding the coast are protected under WA jurisdiction as the Nyinggulara (Ningaloo) Marine Park (IUCN II) (Section 6.4.2). Because of the natural and heritage values of the coast, recreational activities may occur, such as shore-based fishing, beach walking, and wildlife viewing (Ref. 210).

The Dampier Archipelago islands have rich Traditional Owner culture and history. Today, the islands are used for recreational activities such as boating, camping, canoeing, and kayaking, fishing, scuba diving, snorkelling, and swimming (Ref. 211). The Hydrocarbon Ecological EMBA and the OA do not overlap the Dampier Archipelago islands. Of the 41 islands in the Dampier Archipelago, the Hydrocarbon Social EMBA overlaps the west coast of Rosemary Island, West Lewis Island, Goodwyn Island, Enderby Island, Egret Island, Brigadier Island, and Kendrew Island, all of which are Nature Reserves (IUCN Ia) (Section 6.4.3).

The Pilbara islands comprise over 170 islands, islets, rocks and cays between Exmouth Gulf and Regnard Islands (Ref. 212). This includes 20 nature reserves with 92 islands. None of these islands overlap the OA, but some do overlap the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA, including Great Sandy Island Nature Reserve and Muiron Islands (IUCN Ia) (Section 6.4.3). These islands have a rich cultural history and are important to Traditional Owners. The islands have high conservation value for turtle nesting and for hosting migratory and resident shorebirds (Ref. 212). They are also used for recreational activities, including fishing, scuba diving, snorkelling, and camping (Ref. 212).

The Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA overlap 2 native title determinations (WCD2019/016 and WCD2018/006). WCD2019/016 extends over the Ningaloo Coast area and WCD2018/006 runs across Mardie and Gnoorea coast (Section 6.5.3). The Hydrocarbon Social EMBA also has a small section of shoreline contact in 2 other native title determinations (WCD2015/007 across the Dampier Archipelago and WCD2008/003 just outside Exmouth Gulf). The determination areas contain places of special significance, such as mythological and ceremonial sites and natural resources (Ref. 213) (Section 6.5.3).

6.2.5.2 Heritage

Australia’s heritage includes places, values, traditions, events, and experiences that capture and give context to where the community has come from, where they are now and where they are headed (Ref. 214).

Places on the World Heritage, National Heritage and Commonwealth Heritage Lists as well as Underwater Cultural Heritage protected by the UCH Act, Indigenous Protected Areas and Registered Aboriginal Sites are described in Section 6.5. The following subsections summarise other known heritage values identified within the Hydrocarbon Social EMBA.

6.2.5.2.1 First Nations cultural activities, connections, and obligations

The land adjacent to the NWMR has been inhabited by Traditional Owners for at least 50,000 years, and they continue to use the NWMR and adjacent coastal resources with an ongoing connection to these areas (Ref. 103).

While outside the EMBA, Australia's first confirmed First Nations underwater archaeological sites were identified in 2020 in waters offshore from Murujuga (Burrup Peninsula) during the Deep History of Sea Country Project (Ref. 215). These findings confirmed an understanding that First Nations people would have lived on lands that are now submerged in water from rising seas after the last glacial maximum (LGM). The period of the LGM in Australia is described as 24,000 to 18,000 years ago (Ref. 216). At the LGM sea level was ~125 m below present (Ref. 217), which coincides with the ancient coastline at 125 m depth KEF (Section 6.2.6.1).

Archaeological deposits from Boodie Cave on Barrow Island, reveal some of the oldest evidence for human occupation of Australia, as well as illustrating the early use of marine resources (Ref. 218). First occupation on Barrow Island has been dated as occurring between 51,100 and 46,200 years ago, overlapping with earliest dates for occupation of Australia (Ref. 218). There is evidence of marine resources (e.g. shellfish, fish) being incorporated into dietary assemblages by 42,500 years ago on Barrow Island, which continued through all periods of occupation (Ref. 218). The caves on Barrow Island (including Boodie Cave) and others on nearby Montebello Islands were abandoned by 6,800 years ago when rising sea levels reached their present levels (Ref. 218).

Recent studies at Murujuga have demonstrated that archaeological material remains on the seabed, predating inundation by rising seas (Ref. 215; Ref. 219). Previous geomorphological work (which was based on the analysis of available 3D seismic data) on the mid to outer shelf regions proximal to Barrow Island, demonstrated the presence of a highly complex and geomorphically mature coastal landscape preserved at depths of 70–75 m below sea level, including coastal barrier dunes, lagoonal systems, tidal flats, and estuarine channels (Ref. 217). Such feature preservation has significant geoheritage value (Ref. 217).

Traditional Owners have a culture that relates to a connectedness of land and sea in a holistic way (Ref. 220). The term ‘Country’ refers to more than just a geographical area, and includes values, places, resources, stories, and cultural obligations associated with that geographical area (Ref. 221). For Traditional Owners, the term ‘Country’ includes both land and sea, and coastal areas are connected with the traditional Country of a group or clan. Both Country and Sea Country contain evidence of the ancient events by which all geographic features, animals, plants and people were created (Ref. 220).

There are several coastal language groups or clans in northwest WA, including Thalanyji (associated with the Ashburton coastal plain, Exmouth Gulf, and surrounding areas). Based on engagement with Traditional Owner groups, CAPL understands that Thalanyji (represented by the Buurabalayji Thalanyji Aboriginal Corporation Registered Native Title Body Corporate (RNTBC) for native title rights and interests) and Mardudhunera and Yaburara people (represented by the Wirrawandi Aboriginal Corporation RNTBC for native title rights and interests) have connections to Barrow Island (Table 6-14).

It should be noted that the archaeological research discussed above is primarily concerned with the identification of tangible UCH and Aboriginal Sites. Tangible values are those with a physical nature (such as artefacts and engravings); while intangible values are those that do not have a physical component (such as songlines and dances). Songlines are a feature of Traditional Owner culture, linking people, places, and practices (Ref. 222). Certain songlines are referred to as ‘Dreaming pathways’ because of the tracks forged by Creator Spirits during the Dreaming. These Dreaming songlines have specific ancestral stories attached to them (Ref. 223).

First Nations oral traditions have documented sea level rise over the last 7,000 years (Ref. 224). Seabed mapping near Murujuga (Burrup Peninsula) identified two submerged waterholes that were identified by local senior elders as belonging to the Kangaroo songline (Ref. 225).

The cultural, customary, and spiritual significance of species and the ecological communities they form are diverse and varied for Traditional Owners and their stewardship of Country (Ref. 20). For example, some First Nations people have a strong connection to whales, which has significance as totemic ancestors to some groups (Ref. 20). The arrival of whales along Australia's coast marked the arrival of the "elders of the sea", which follows a songline that traces the journeys of ancestral spirits as they created the land, animals, and lore (Ref. 20).

Traditional Owners in northwest WA continue to rely on coastal and marine environments and resources of the region for their cultural identity, health and wellbeing, and their domestic and commercial economies (Ref. 221). Their commitment to their Sea Country is demonstrated through their native title claims and their many initiatives to regain their role as managers of the cultural and natural values of northwest WA (Ref. 221).

The Traditional Owners of northwest WA engage in a diverse range of marine resource use activities, including hunting, egg collecting, fishing and gathering shellfish. Activities also continue on lands and waters where they have ceremonial and spiritual connections (Ref. 221).

Consultation with Traditional Owner groups and individuals has identified that Sea Country is of importance to their people (Table 6-14). These values include coastal areas, offshore islands, marine fauna, and traditional stories (e.g. it is believed that the Dreamtime serpent which created the rivers and inland springs is now in its resting place off the Pilbara coast; and as such, if the sea is protected, then the serpent is also being protected). It is acknowledged that Traditional Owners who are the custodians of this knowledge have the rights to decide how it is shared and used.

Table 6-14: Cultural values or features identified through consultation

Source	Cultural value or feature
Baiyungu Aboriginal Corporation	Protecting land and Sea Country is a significant focus of the BAC. The Baiyungu coastal area, Sea Country, and adjacent islands are highly valuable to the Baiyungu people.
Buurabalayji Thalanyji Aboriginal Corporation	The Thalanyji people have a deep connection to Sea Country north of Onslow, extending out into the islands off the coast of the Pilbara including the Montebello Islands, Barrow Island, and Mackerel Islands.
Kariyarra Aboriginal Corporation (KAC)	KAC have noted the importance of protecting marine fauna during an emergency event. KAC are interested in flatback turtles and the impact of rubbish in the sea.

Malgana Aboriginal Corporation	Malgana Aboriginal Corporation identified Shark Bay seagrass as significant.
Mardathoonera Cultural Heritage Pty Ltd	Consultation with Mardathoonera representatives for other CAPL activities has identified a connection with Barrow Island and surrounding waters; specific values described include: • the creation story starts on Barrow Island • Barrow Island is a place that connects saltwater and freshwater together • Barrow Island is connected to Murujuga; both are considered by Coastal Mardudhunera as women's places • Biggada Creek is significant and connected to the Fortescue River; and that the rock formations in the creek are protectors • women's sites and ancestor spirits are present on Barrow Island • Identified that Barrow Island was a hill in ancient times and is a sister hill to two hills on the mainland, and Old people would walk across before the sea levels rose and the island drifted; because of this, there will be artefacts and stories underwater • Identified cultural importance of traditional stories, songlines, ocean, and marine fauna: – the sea is the source of energy for all life, it holds the codes that are encrypted in each person's body, the songlines, and is the lifeforce for the world – the places where the saltwater from the sea and the freshwater from the land connect are where the biggest energy lines are, and that connection is a force of creation relevant to a Dreaming story – songlines extend out from the land, through the sea, and around the globe – songlines connect places, people, and animals to each other, creating migratory patterns for animals and telling animals of the right time to birth and eat – freshwater that flows underneath the seabed carries the songlines – there is a large energy line that exists off the coast of Murujuga and runs through the area that CAPL operates in – there are songlines that go through Barrow Island and offshore and connect Barrow Island to the mainland; this includes a whale songline – Mardudhunera people are connected to songlines—if the songlines are disrupted, their widdart (heart) is disconnected, like the whales, their feet get lost, and they don't know where to go anymore • Country owns people and we are all connected by energy – different frequencies connect all beings on earth and everything on earth is connected – if you protect country, it will protect you women hold the energy connected to water
Murujuga Aboriginal Corporation (MAC)	No specific areas have been identified through consultation however MAC has noted the cultural importance of Sea Country and the need to ensure it is protected.
Nganhurra Thanardi Garrbu Aboriginal Corporation (NTGAC)	No specific areas have been identified through consultation however NTGAC has noted the cultural importance of Sea Country and the need to ensure it is protected.
Ngarluma Aboriginal Corporation (NAC)	NAC has noted that offshore islands are culturally significant.
Ngarluma Yindjibarndi Foundation Ltd	The people from the land speak for and care about the marine animals, even if they are far out to sea.

	Identified that marine fauna, specifically whales, dugongs, and turtles are species of importance. The nature of many traditional narratives have origins and connection to the seascape, and impacts to the seascape, can have cultural repercussions. Identified the presence and importance of intangible values, such as Barrimirndi (the serpent), which is an important part of dreaming for Ngarluma and Yindyibarndi people. Identified the interconnectedness of the cultural landscape, whereby Traditional Owners from the western Pilbara are held to account by other Nyambali (cultural bosses) when proponents impact land and sea. Cultural responsibilities transcend Native Title and other boundaries.
Robe River Kuruma Aboriginal Corporation	The waters extending seaward from the Jajiwurra (Robe River) river mouth. Values beyond the Hydrocarbon Social EMBA boundary included: • Jajiwurra (Robe River) • ecological integrity of Jajiwurra • the area within their Kuruma Marthudunera native title claim.
Wirrawandi Aboriginal Corporation	The coastal area, Sea Country, and adjacent islands are highly valuable to the Yaburara and Mardudhunera people. Identified a connection to Barrow Island.

6.2.5.2.2 European heritage

Early European exploration of the NWMR and adjacent coast occurred in the 1600s; however, explorers concluded at the time that resources and conditions were not appropriate for settlement (Ref. 103). British colonisation did not begin in the Pilbara until 1860s, with pastoralism as the first major industry, followed by small ports and service centres (Ref. 103). The pearling industry began in the late 1800s and remains a significant contributor to the economy of north-west WA (Ref. 103). Similarly, small fishing fleets were common from the 1860s onwards; the commercial fishing industry also remains a significant economic input for north-west WA, particularly from prawn and demersal finfish fisheries (Ref. 103). Petroleum discovery and development started in the 1950s, with both onshore and offshore discoveries (Ref. 103).

The marine and coastal industries that still exist and operate within the NWMR are further described in Section 6.3.

6.2.6 Commonwealth marine area

The Commonwealth marine area is an MNES under the EPBC Act, and a particular value and sensitivity under the OPGGS(E)R. The OA, Hydrocarbon Social EMBA and Hydrocarbon Ecological EMBA for this activity occur within waters off WA that are part of the NWMR.

The NWMR comprises the Commonwealth waters and seabed from the WA–Northern Territory border south to Kalbarri (Ref. 103). The NWMR is characterised by shallow-water tropical marine ecosystems with high species richness. Most of the region’s species are tropical and are also found in other parts of the Indian and western Pacific oceans (Ref. 103). The region is a tropical carbonate margin that comprises an extensive area of shelf, slope, and abyssal plain/deep ocean floor, as well as complex areas of bathymetry such as plateau, terraces, and major canyons (Ref. 103).

The region experiences a tropical monsoonal climate towards its northern extent, transitioning to tropical arid and subtropical arid within its central and southern areas (Ref. 103). In summer (September–March), average daily temperatures range from 21–36°C. During winter (May–July), mean daily temperatures range from 14–29°C (Ref. 226; Ref. 2). The cyclone season in north-west WA runs from November to April, with an average of 5 tropical cyclones per year (Ref. 227). Summer thunderstorms can have associated winds with gusts exceeding 20 m/s, but these winds are usually of short duration.

Conservation values of the Commonwealth marine area include:

- protected species and/or their habitat (Section 6.2.3)
- protected places including AMPs (Section 6.4.1) and heritage places (Section 6.5)
- KEFs (Section 6.2.6.1).

6.2.6.1 Key ecological features

Key ecological features (KEFs) are elements of the Commonwealth marine environment that are considered to be of importance for a region's biodiversity or its ecosystem function and integrity. KEFs are not MNES and have no legal status in their own right; however, they may be considered as components of the Commonwealth marine area.

KEFs meet one or more of these criteria (Ref. 228):

- a species, group of species, or a community with a regionally important ecological role (e.g. a predator or prey that affects a large biomass or number of other marine species)
- a species, group of species, or a community that is nationally or regionally important for biodiversity
- an area or habitat that is nationally or regionally important for:
  - enhanced or high productivity (such as predictable upwellings—an upwelling occurs when cold nutrient-rich waters from the bottom of the ocean rise to the surface)
  - aggregations of marine life (such as feeding, resting, breeding or nursery areas)
  - biodiversity and endemism (species that only occur in a specific area)
- a unique sea floor feature, with known or presumed ecological properties of regional significance.

The Australian Government has identified KEFs based on scientific advice about the ecological processes and characteristics of the area (Ref. 228).

Table 6-15 describes the values of KEFs within the OA and EMBAs. Results of the Gorgon Backfill Fields Benthic Survey (Ref. 105, Appendix A), which describes the presence of benthic KEF values within the OA, are further detailed in Section 6.2.1.1. Figure 6-28 shows the KEFs which are in the vicinity of or overlap the OA and EMBAs.

Table 6-15: Key ecological features in the vicinity of the OA and EMBAs

Key ecological feature	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Ancient coastline at 125 m depth contour (Ancient coastline KEF)	✓	**0**	✓	✓
Parts of the ancient coastline, particularly rocky escarpments, are thought to provide biologically important habitats in areas otherwise dominated by soft sediments. The topographic complexity of these escarpments may also facilitate vertical mixing of the water column, providing relatively nutrient-rich local environments (Ref. 103). The ancient, submerged coastline provides areas of hard substrate and therefore may provide sites for higher diversity and enhanced species richness relative to surrounding areas of predominantly soft sediment. Little is known about fauna associated with the hard substrate of the escarpment, but it is likely to include sponges, corals, crinoids, molluscs, echinoderms and other benthic invertebrates representative of hard substrate fauna in the NWS (Ref. 103). **Values:** Unique sea floor feature with ecological properties of regional significance. The benthic survey found that no Ancient coastline KEF features were detected at survey locations within the OA (Ref. 105, Appendix A).				
Continental slope demersal fish communities	✓	**0**	✓	✓
The diversity of demersal fish assemblages on the continental slope in the Timor Province, the Northwest Transition and the Northwest Province is high compared to elsewhere along the continental slope. The continental slope between North West Cape and the Montebello Trough has more than 500 fish species, 76 of which are endemic, which makes it the most diverse slope bioregion in Australia (Ref. 229). The demersal fish species occupy 2 distinct demersal community types associated with the upper slope (water depths: 225–500 m) and the mid-slope (750–1,000 m). Bacteria and fauna present on the continental slope are the basis of the food web for demersal fish and higher-order consumers in this system (Ref. 103). **Values:** High levels of endemism with a diversity of fish assemblages. The benthic survey found that topographically complex scarps where the OA crosses the Continental slope demersal fish communities KEF hosts typical deep-sea benthic biota. For fish assemblages, the Continental slope demersal fish communities KEF within the survey area recorded a total of 468 fish belonging to 25 taxa, with the fish assemblage dominated by Trevallies (Carangidae) with four species from three genera accounting for 256 of the individuals observed (Ref. 105, Appendix A). In comparison to the other KEFs within the OA, there was no significant difference in the mean number of fish taxa within the Continental slope demersal fish communities KEF (Ref. 105, Appendix A).				
Exmouth Plateau	✓	**0**	✓	✓
The Exmouth Plateau is a regionally and nationally unique deep-sea plateau (water depths: 800–4,000 m) in tropical waters. The plateau is a very large topographic obstacle that may modify the flow of deep waters, generating internal tides and may contribute to upwelling of deeper-water nutrients closer to the surface, thus serving an important ecological role (Ref. 103). The topography of the plateau (with valleys and channels), in addition to potentially comprising a range of benthic environments, may provide conduits for moving sediment and other material from the plateau surface through the deeper slope to the abyss. The Exmouth Plateau is generally an area of low habitat heterogeneity; however, it is likely to be an important area of biodiversity as it provides an extended area offshore for communities adapted to water depths of ~1,000 m. Sediments on the plateau suggest that biological communities include scavengers, benthic filter feeders and epifauna (Ref. 103). Fauna in the pelagic waters above the plateau are likely to include small pelagic species and nekton (Ref. 107). **Values:** Unique sea floor feature with ecological properties of regional significance. The benthic survey found a large scarp with 3-dimensional hard structure (i.e. rock) crosses through the indicative Chandon flowline from east to west. This may provide biota with suitable habitat,				

Key ecological feature		OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
	although no epibenthic fauna were detected along the survey transect in this area (Ref. 105, Appendix A).				
Commonwealth waters adjacent to Ningaloo Reef		**-**	**143.5**	✓	✓
	The Commonwealth waters adjacent to Ningaloo reef include Ningaloo Commonwealth Marine Reserve (Commonwealth waters) and encompass an area of 2,435 km². This feature lies adjacent to the Ningaloo Marine Park (state waters) margin at the 3 nm limit. **Values:** The Commonwealth waters adjacent to Ningaloo Reef and associated canyons and plateau are interconnected and support the high productivity and species richness of Ningaloo Reef. The Leeuwin and Ningaloo currents interact on the seaward side of the reef, leading to areas of enhanced productivity which support aggregations and migration pathways of whale sharks, manta rays, humpback whales, sea snakes, sharks, large predatory fish and seabirds (Ref. 230; Ref. 231; Ref. 232; Ref. 233). Detrital input from phytoplankton production in surface waters and from higher-trophic consumers cycles back to the deeper waters of the shelf and slope (Ref. 107). Deepwater biodiversity includes fish, molluscs, sponges, soft corals and gorgonians. Some of these sponge and filter-feeding communities appear to be significantly different to those of the Dampier Archipelago and Abrolhos Islands, indicating that the Commonwealth waters of Ningaloo Marine Park have some particular areas of potentially high and unique sponge biodiversity (Ref. 234).				
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula		**-**	**101.2**	✓	✓
	The canyons on the slope of the Cuvier Abyssal Plain and Cape Range Peninsula are connected to the Commonwealth waters adjacent to Ningaloo Reef and may also have connections to Exmouth Plateau. **Values:** The canyons are thought to interact with the Leeuwin Current to produce eddies inside the heads of the canyons, resulting in waters from the Antarctic intermediate water mass being drawn into shallower depths and onto the shelf (Ref. 107). These waters are cooler and richer in nutrients and strong internal tides may also aid upwelling at the canyon heads (Ref. 107). The narrow shelf width (about 10 km) near the canyons facilitates nutrient upwelling. This nutrient-rich water interacts with the Leeuwin Current at the canyon heads. Aggregations of whale sharks, manta rays, humpback whales, sea snakes, sharks, large predatory fish and seabirds are known to occur in this area and are related to productivity (Ref. 235; Ref. 236).				
Glomar Shoals		**-**	**165.3**	✓	✓
	The Glomar Shoals are a submerged littoral feature located ~150 km north of Dampier on the Rowley shelf at depths of 33–77 m (Ref. 237; Ref. 110). Values: The shoals are known to be an important area for a number of commercial and recreational fish species such as rankin cod, brown striped snapper, red emperor, crimson snapper, bream and yellow-spotted triggerfish (Ref. 237; Ref. 110; Ref. 238). These species have recorded high catch rates associated with the Glomar Shoals, indicating that the shoals are likely to be an area of high productivity.				

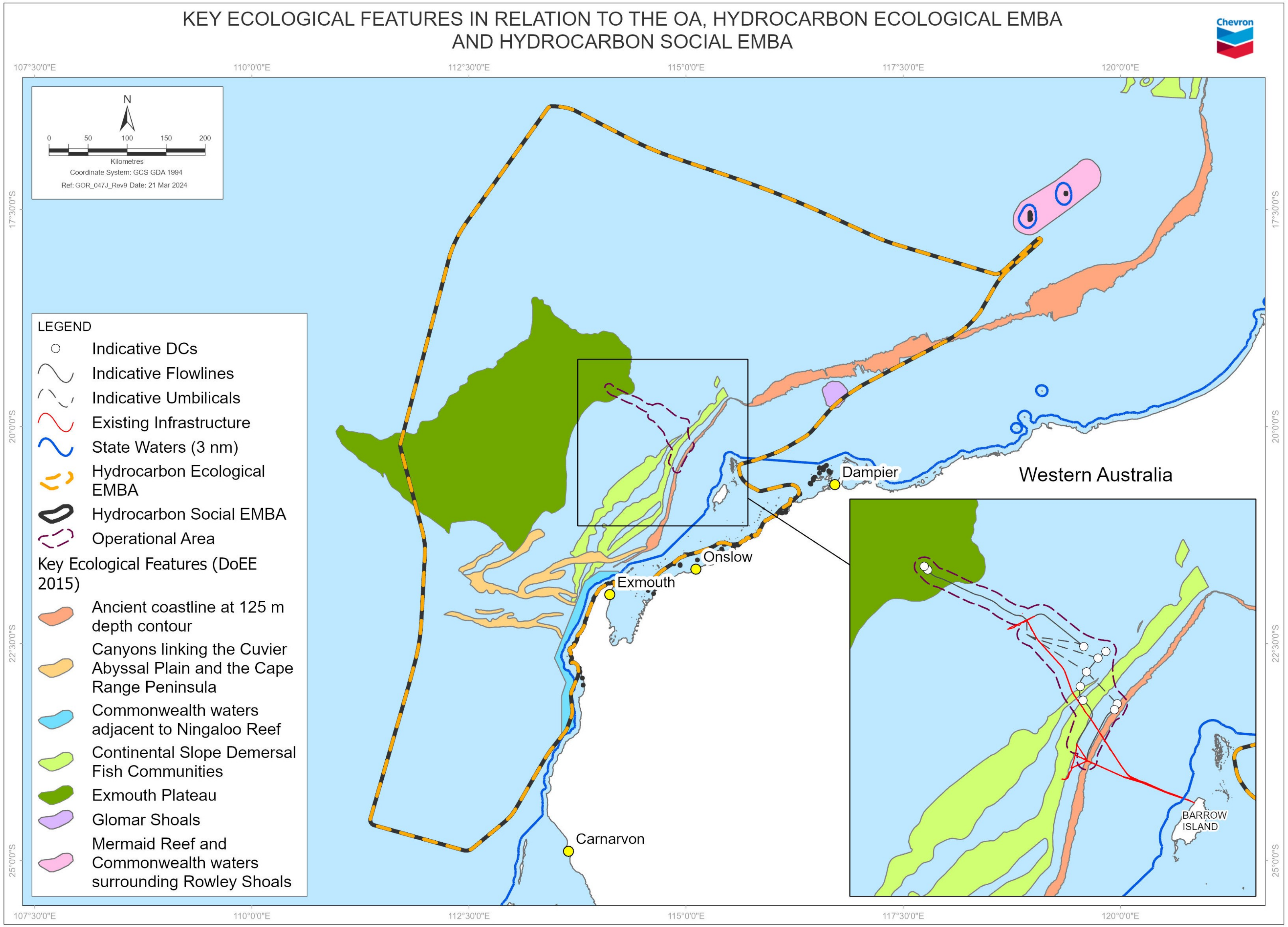

Figure 6-28: Key ecological features in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.2.7 Commonwealth land area

Commonwealth land[34] is a particular value and sensitivity under the OPGGS(E)R. No Commonwealth lands overlap the OA. Based on spatial review and searches of the EPBC Act protected matters database (Ref. 123, Appendix B), Commonwealth lands that overlap the Hydrocarbon Social EMBA and Hydrocarbon Ecological EMBA are outlined in Table 6-16.

Table 6-16 Commonwealth land areas in the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

Commonwealth Land Area	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Defence—Exmouth VLF transmitter station	✓	✓
Defence—Exmouth administration and HF transmitting	-	✓
Defence—Learmonth radar site—Vlamingh Head	✓	✓
Defence—Learmonth—air weapons range	✓	✓
Commonwealth land ID 52236 (unknown agency).	✓	✓
Commonwealth land ID 50385 (unknown agency).	-	✓
Commonwealth land ID 51104 (unknown agency).	-	✓

6.3 Natural and physical resources

Natural and physical resources are described as substances occurring in nature that can be exploited for economic gain—these may include such resources as fishing stocks, petroleum reservoirs, or values of the Commonwealth marine area. Marine and coastal industries have been developed based on natural and physical resources. These industries are described in relation to the Hydrocarbon Social EMBA in the following subsections.

6.3.1 Commercial fisheries

6.3.1.1 Commonwealth-managed fisheries

No Commonwealth-managed commercial fisheries had fishing effort recorded during 2010–2020 (Ref. 239) within the OA and EMBAs, <5 vessels were operating and therefore data are considered confidential (as advised by the Department of Agriculture, Fisheries and Forestry (DAFF)) (Ref. 240). The OA and EMBAs did overlap reporting grids for multiple fisheries. The maximum area fished indicates reporting grids for the total area where fishing occurred. Reporting grids have a resolution of one degree (~111 × 111 km). Table 6-17 identifies the fisheries with reporting grids (maximum area fished) overlapping the OA and EMBAs.

[34] *Commonwealth land includes land owned or leased by the Commonwealth or a Commonwealth agency, land in the Jervis Bay Territory, land in the Christmas Island, Ashmore and Cartier Islands, Coral Sea Islands, Cocos (Keeling) Islands, Australian Antarctic Territory and Heard and McDonald Islands external territories, and any other area of land that is included in a Commonwealth reserve.*

Table 6-17: Presence of reporting grids overlapping the OA and EMBAs recorded within Commonwealth-managed commercial fisheries (2010–2020)

Fishery	OA	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
North-West Slope Trawl Fishery	✓	✓	✓
Western Deepwater Trawl	✓	✓	✓
Western Tuna and Billfish Fishery	✓	✓	✓

6.3.1.1.1 North-west Slope Trawl Fishery

The North West Slope Trawl Fishery (NWSTF) uses bottom (or demersal) trawl methods to target deepwater prawn and scampi, typically in water depths of 350–600 m. The primary species landed in the NWSTF is the Australian scampi (*Metanephrops australiensis*), with smaller quantities of velvet scampi (*M. velutinus*), Boschma's scampi (*M. boschmai*) and mixed scampi (*Metanephrops spp.* and *Nephropsis spp.)* also landed. A quantity of prawns is also harvested each season, and squid is becoming an increasingly significant component of the catch. Mixed snappers (*Lutjanidae*) and redspot emperor (*Lethrinus lentjan*) have historically been an important component of the NWSTF catch. Fishing for scampi occurs over soft, muddy sediments or sandy habitats, using demersal trawl gear on the continental slope.

Fishing intensity data for the NWSTF is only available for the 2020 reporting period and this data does not overlap the EMBAs. All other reporting periods had <5 vessels operating and therefore data are considered confidential. The maximum area fished shows reporting grids for the total area where fishing occurred. Reporting grids have a resolution of one degree (~111 × 111 km).

The OA overlaps one reporting grid per year during the 2010–2014 and 2016–2019 seasons (Figure 6-29). During each of the 2015 and 2020 seasons the OA overlapped only 2 reporting grids. No NWSTF intensity data overlaps the OA. The EMBAs overlap multiple reporting grids of the NWSTF (Figure 6-29).

The total catch for the 2021-2022 season was 85.8 t, down from 87.05 t in the 2020-2021 season, with three vessels operating over 196 days. According to the ABARES Fishery Status Report 2023, the NWSTF is not subject to overfishing (Ref. 241).

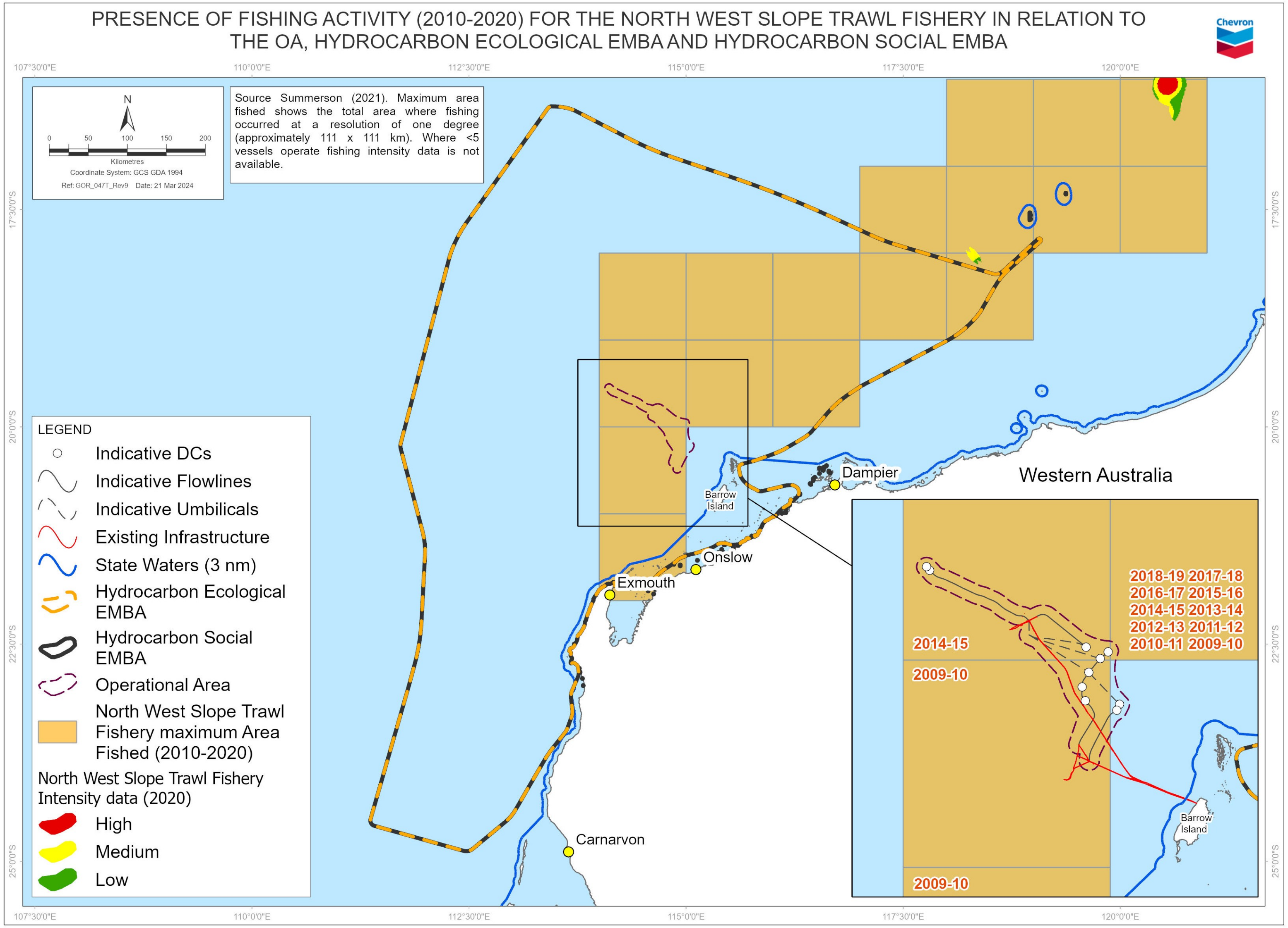

Figure 6-29: Presence of fishing activity (2010–2020) for the North West Slope Trawl Fishery in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.3.1.1.2 Western Deepwater Trawl

Operators within the Western Deepwater Trawl Fishery (WDTF) use demersal trawl methods and catch more than 50 species in waters seaward of a line approximating the 200 m isobath (Ref. 242).

There is no available intensity data for the WDTF as all reporting periods had <5 vessels operating, and therefore data are considered confidential. As previously stated, the maximum area fished shows reporting grids for the total area where fishing occurred. Reporting grids have a resolution of one degree (~111 × 111 km). Data for maximum area fished for the WDTF are available for the reporting periods from 2010–2014 and 2017–2020.

The OA overlaps with only one reporting grid, which is during the 2018 season (Figure 6-30). The EMBAs overlap multiple reporting grids of the WDTF (Figure 6-30).

The total catch for the 2021- 2022 season was 12 t, up from 5 t in the 2020-2021 season. Two vessels were active with 76 trawl hours. According to the ABARES Fishery Status Report 2023, the WDTF is not subject to overfishing (Ref. 243).

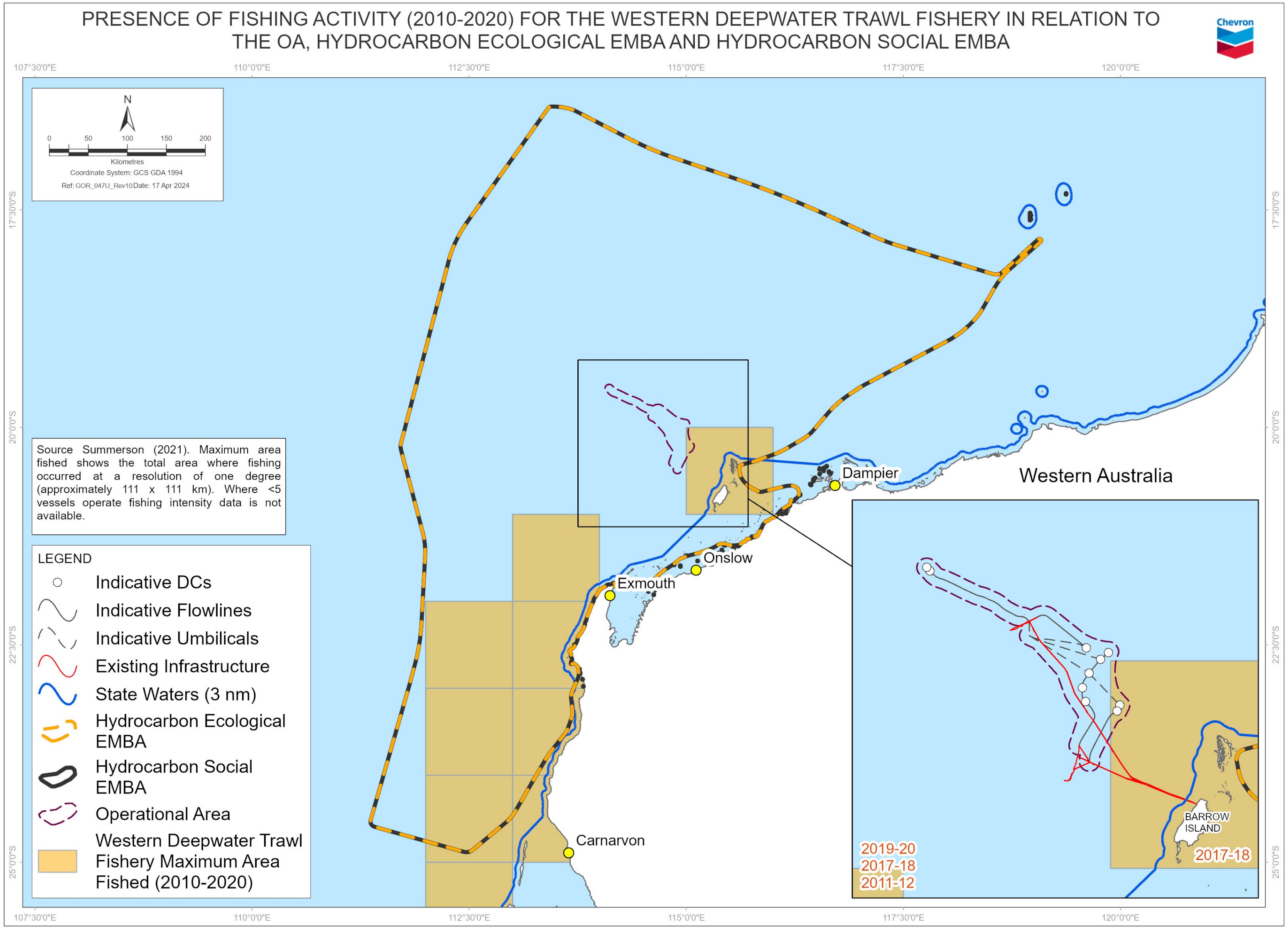

Figure 6-30: Presence of fishing activity (2010-2020) for the Western Deepwater Trawl Fishery in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.3.1.1.3 Western Tuna and Billfish Fishery

The main fishing gear in the Western Tuna and Billfish Fishery (WTBF) is pelagic longline, with low levels of minor-line fishing (Ref. 244). The species targeted include bigeye tuna (*Thunnus obesus*), Swordfish (*Xiphias gladius*) and yellowfin tuna (*Thunnus albacares*). striped marlin (*Kajikia audax* or *Tetrapturus audax*) is a minor component of the catch. Catch of albacore (*Thunnus alalunga*), a non-quota species, can approach levels similar to yellowfin tuna catch in some years.

There is no available intensity data for the WTBF as all reporting periods had <5 vessels operating, and therefore data are considered confidential. As previously stated, the maximum area fished shows reporting grids for the total area where fishing occurred. Reporting grids have a resolution of one degree (~111 × 111 km). Data for maximum area fished for the WTBF are available for the reporting periods from 2010–2020.

The OA overlaps with only 2 reporting grids, which were during the 2013 season (Figure 6-31). The EMBAs overlap 8 reporting grids of the WTBF in 2013 and one in 2016 and 2019 (Figure 6-31).

The total catch for the 2021- 2022 season was 139 t, down from 248 t in the 2020-2021 season. There were five active vessels. According to the ABARES Fishery Status Report 2023, of the 5 indicator species within the WTBF, the bigeye tuna, striped marlin and yellowfin tuna are classified as overfished. The swordfish and albacore are not subject to overfishing (Ref. 245).

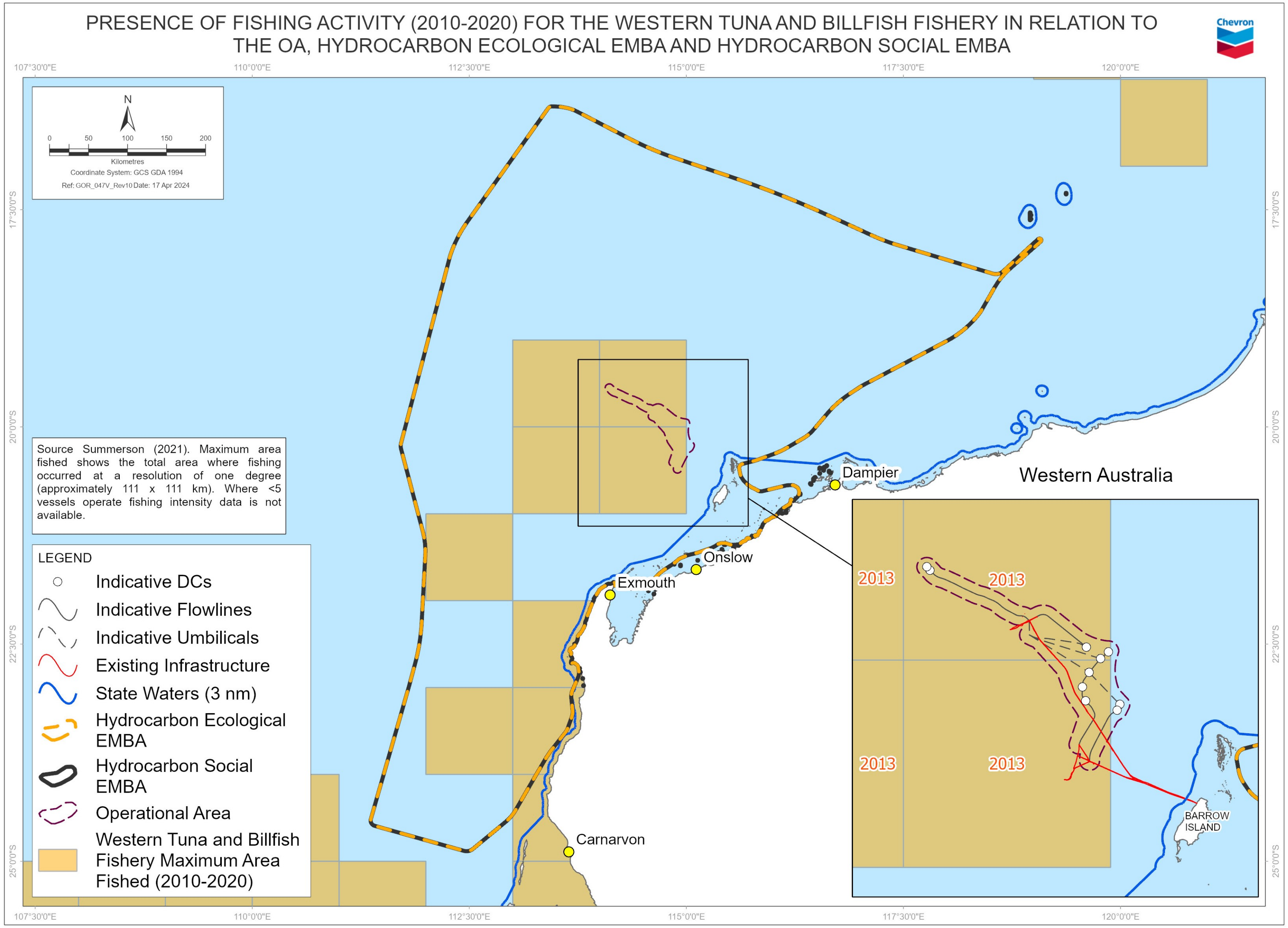

Figure 6-31: Presence of fishing activity (2010-2020) for the Western Tuna and Billfish Fishery in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.3.1.1.4 Southern bluefin tuna Fishery

The Southern Bluefin Tuna Fishery is active within waters in the Great Australian Bight and south-eastern Australia (i.e. not within the OA or EMBAs); however, the spawning grounds for southern bluefin tuna (*Thunnus maccoyii*) are in the north-east Indian Ocean (Ref. 246). This indicative spawning area extends into the OA and EMBAs.

6.3.1.2 State-managed fisheries

The State-managed commercial fisheries with fishing management areas that overlap the OA and EMBAs, and that have fishing effort recorded over a 10-year period (2012–2021) (Data supplied to Chevron by DPIRD) are listed in Table 6-18. Data are reported via 10 × 10 nm reporting grids.

One fishery was identified as having reporting grids indicating activity within the OA over the past 10 years (Mackerel Managed Fishery) (Figure 6-32). Fishing activity for the Mackerel Managed Fishery was recorded overlapping the OA between 2012 and 2018. For each of these years, <3 vessels were active; therefore, data are considered confidential due to the limited number of vessels present (in accordance with the *Fish Resources Management Act 1994* (WA) Section 250). No fishing activity was recorded overlapping the OA between 2019 and 2021. Table 6-18 also shows the maximum number of vessels recorded per fishery per year within the OA and EMBAs.

Table 6-18: Presence of fishing effort recorded during 2012–2021 within State-managed commercial fisheries

Fishery	Maximum number of vessels recorded per fishery per year (2012–2021)		
	OA	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
North Coast Bioregion			
Mackerel Managed Fishery	<3	<3	<3
Onslow Prawn Managed Fishery	-	<3	<3
Pilbara Fish Trawl (Interim) Managed Fishery	-	4	4
West Australian Sea Cucumber (Beche-De-Mer) Fishery	-	<3	<3
Gascoyne Bioregion			
Exmouth Gulf Prawn Managed Fishery	-	6	6
Gascoyne Demersal Scalefish Fishery	-	4	5
State-wide			
West Coast Deep Sea Crustacean Fishery	-	<3	<3

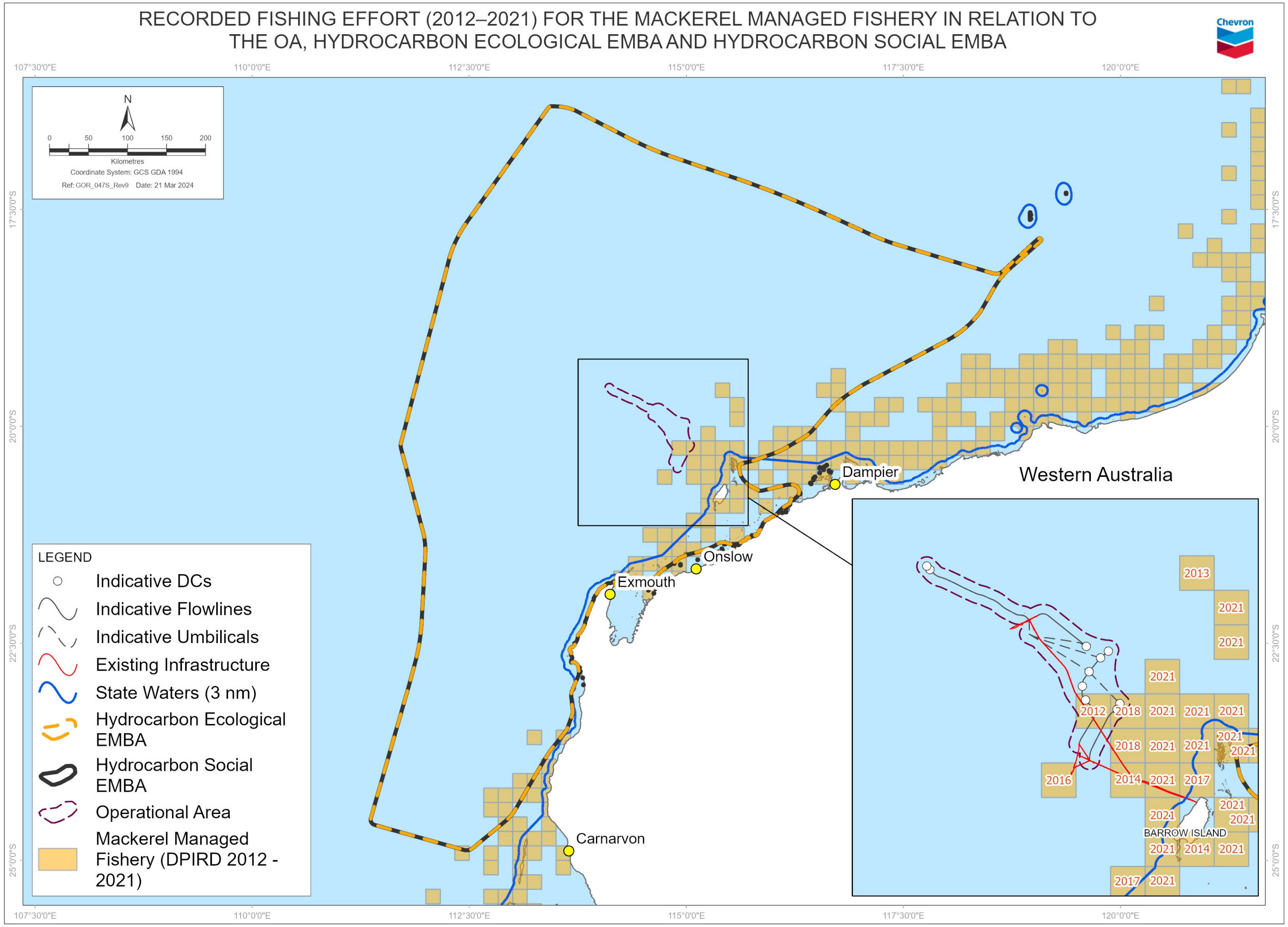

Figure 6-32: Recorded fishing effort (2012-2021) for the Mackerel Managed Fishery in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.3.2 Recreational fisheries

Recreational fishing is one of the most popular activities in WA—an estimated one-third of the population fishes recreationally (Ref. 247). DPIRD conducts state-wide recreational fishing surveys every 2 years, with the first survey completed in 2011. The survey collects information from more than 3,000 boat-based recreational fishers who record their catches in logbooks over a 12-month period. DPIRD also conducts interviews throughout the State and monitors the number of boat launches and retrievals using cameras at various boat ramps.

The OA and EMBAs are located in the North Coast and Gascoyne Coast bioregions. The September 2020–August 2021 survey report identified that most boat-based recreational fishing effort occurred in nearshore habitat (46% and 54% for North Coast and Gascoyne Coast respectively), followed by inshore demersal habitats (32% and 39% for North Coast and Gascoyne Coast respectively) (Ref. 248). Most fishing effort was attributed to line fishing (87% and 91% for North Coast and Gascoyne Coast respectively), during autumn for the Gascoyne Coast (36%) and during winter for the North Coast (42%) (Ref. 248).

Due to the offshore location of the Development, recreational fishing is not expected in the OA. Some shore-based fishing may occur within the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA (Section 6.2.5.1).

6.3.3 Traditional fisheries

A Customary Fishing Policy has been incorporated into the *Fish Resources Management Act 1994* (WA), which allows for customary fishing by applicable persons to occur within a sustainable fisheries management framework. According to the policy, customary fishing applies to a person of ‘aboriginal descent’ who is ‘fishing in accordance with the traditional law and custom of the area being fished’, and is ‘fishing for personal, domestic, ceremonial, educational or non-commercial needs’ (Ref. 249; Ref. 250). This customary fishing policy includes fish and does not apply to other species of marine fauna (e.g. crocodile, turtle, or dugong).

Under amendments made in 2012 to the *Conservation and Land Management Act 1984* (WA) Traditional Owners can undertake customary activities including hunting (except in marine sanctuary zones or marine nature reserves) for dugong, turtle, or crocodiles in WA.

As described in Section 6.2.5.2.1, ongoing use of marine and coastal resources, including fish, is expected to occur in the NWMR and adjacent coastal waters. Much of this activity is expected to occur in shallow coastal waters, so is not likely to overlap the OA; however, it may overlap the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA. Shore-based fishing may overlap the EMBAs.

The OA and EMBAs do not overlap the Memorandum of Understanding (MoU) Box that allows traditional Indonesian fishers to fish within Australian waters. The MoU Box is managed via a bilateral agreement between the Australian and Indonesian governments.

6.3.4 Commercial shipping

AMSA collects vessel traffic data from various sources, including satellite shipborne automated identification system data, across Australia's search and rescue region. This data was used to develop Figure 6-33, which shows vessel traffic for 2022 within the vicinity of the OA and the Hydrocarbon Social EMBA. Figure 6-33 shows that the OA within the vicinity of the proposed G&E to Jansz pipeline overlaps part of the NWS shipping fairway system.

The Hydrocarbon Social EMBA (Figure 6-33) covers several sections of the NWS shipping fairway system.

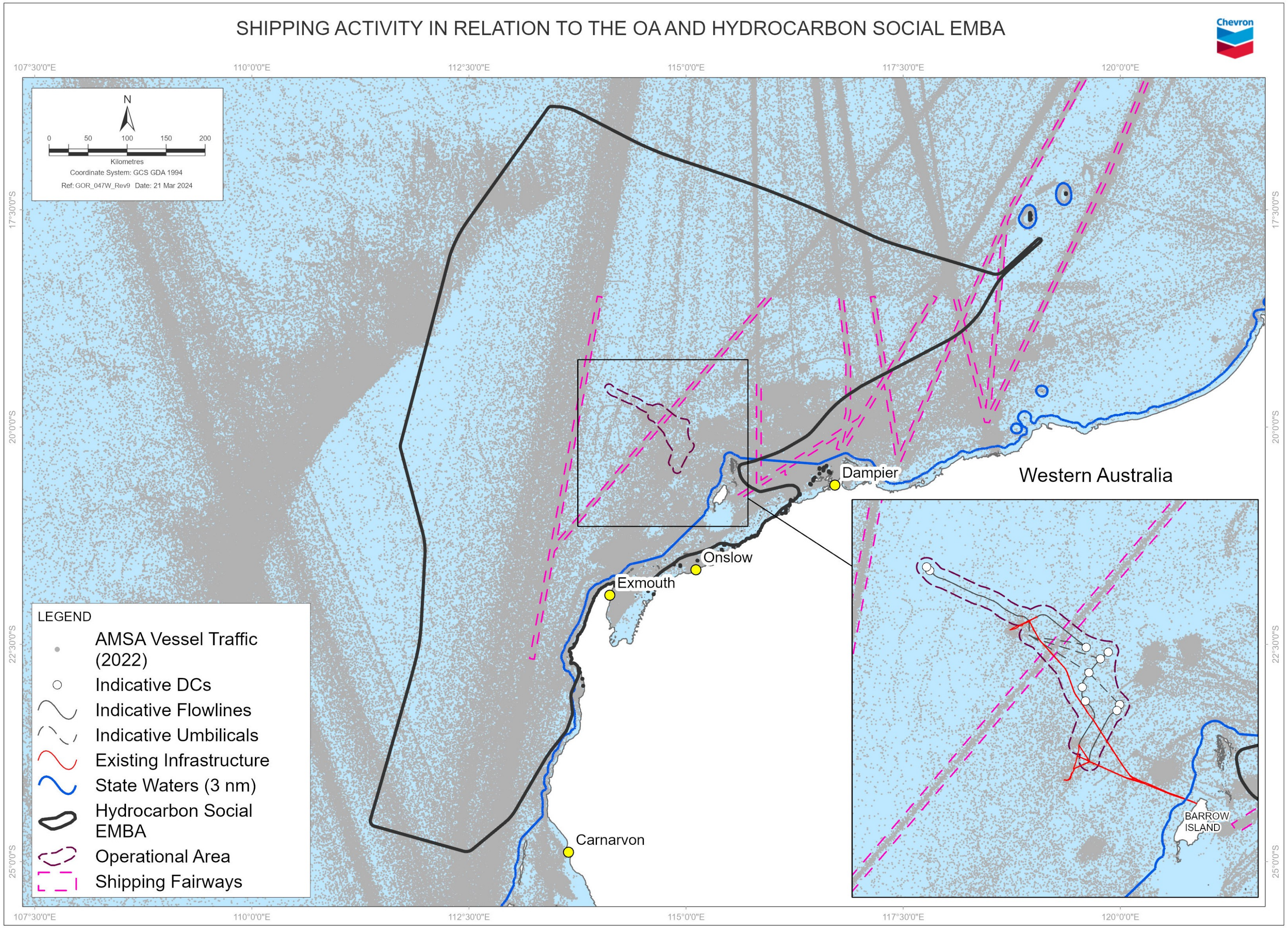

Figure 6-33: Shipping activity in relation to the OA and Hydrocarbon Social EMBA

6.3.5 Tourism and recreation

Tourism is an important industry for WA, directly employing 56,300 people and indirectly employing a further 22,100 (Ref. 251). Charter fishing, diving, snorkelling, wildlife watching, and cruising are some of the commercial tourism activities in and adjacent to the NWMR (Ref. 103). Except for offshore charter fishing, most marine tourism activities occur in the shallower State waters (Ref. 103).

The OA occurs offshore and does not have any connection with nearshore waters or the mainland coast—no tourism and recreational activities are expected within the OA. The Hydrocarbon Ecological EMBA and the Hydrocarbon Social EMBA do overlap with some coastal areas, specifically Barrow Island, Great Sandy Island, the Montebello Islands, Passage Islands, Cape Range National Park, Muiron Islands and around the Point Cloates / Ningaloo Station area (Figure 6-1 and Figure 6-2), as well as some shoreline points from North West Cape to islands in the Dampier Archipelago (see Section 6.2.2). As described in Section 6.2.5.1, tourism and recreational activities may occur around these shoreline areas, particularly the Montebello Islands, Point Cloates / Ningaloo Station, and the Dampier Archipelago islands.

The Gascoyne and Pilbara regions are popular visitor destinations for both Australian and international tourists. The main marine nature-based tourist activities within the Gascoyne Region are concentrated around and within the Ningaloo Coast World Heritage property (~127 km south-west of the OA; Section 6.5). Tourism activities include recreational fishing, snorkelling and scuba diving, wildlife watching and encounters (including whale sharks, manta rays, humpback whales, and turtles) (Ref. 252), as well as beach access, surfing and paddling sports. Recreational fishing within the Pilbara region tends to be concentrated in State waters adjacent to population centres. Charter vessels may also frequent the waters surrounding the Montebello Islands (Ref. 122).

6.3.6 Other marine and coastal industries

Several other marine and coastal industries may be present within the Hydrocarbon Social EMBA (Table 6-19). No offshore renewable energy facilities, ports, salt mines, or onshore processing facilities were identified within the Hydrocarbon Social EMBA.

An offshore cable has been installed as part of Vocus' fibre optic cable network, connecting the existing North West Cable System and Australia Singapore Cable. The cable route overlaps the OA, ~2.2 km north of Chandon infrastructure.

Table 6-19: Presence of industries

Industry	OA	Hydrocarbon Social EMBA
Petroleum exploration and production	✓	✓
Defence	-	✓

6.3.6.1 Petroleum industry

The OA is located in the Northern Carnarvon Basin. The basin is Australia’s premier hydrocarbon-producing province and contains an established network of oil, condensate and gas production infrastructure (Ref. 253) run by various operators.

Oil and gas activities in the vicinity of the OA are outlined in Table 6-19.

Table 6-20: Petroleum activities overlapping the OA and Hydrocarbon Social EMBA

Petroleum Activity	Key Characteristics	OA	Distance to OA (~km)	Hydrocarbon Social EMBA
CAPL – Gorgon Foundation Project (GFP) (Ref. 8)	• Commissioning and start-up activities occurred in 2015 and operations are expected to continue for the nominal operational design life of 50 years. • The Development ties into the GFP. • Similar activities to the Development operations phase.	✓	0	✓
CAPL— Jansz-Io Compression (J-IC) (Ref. 254).	• J-IC will involve the construction and installation of a floating Field Control Station (FCS), subsea compression infrastructure and a 135 km submarine power cable linked to Barrow Island. It is considered part of the GFP. • Installation is scheduled to occur from mid-2024 to mid-2026 and is expected to be operational before the Development commences.	✓	0	✓
Woodside – Scarborough Development (Ref. 255)	• Development of Scarborough will include the installation of a floating production unit (FPU) with eight wells drilled in the initial phase and thirteen wells drilled over the life of the Scarborough field, with all wells tied back to a semi-submersible FPU moored in 950 m of water close to the Scarborough field. • A trunkline runs ~430 km from the FPU to Pluto LNG on the Burrup Peninsula. • The Scarborough Seabed Intervention and Trunkline Installation EP is under assessment with NOPSEMA at time of writing and includes include surveys, trenching, dredging, pipelay, and structures installation (Ref. 256). The proposed trunkline route crosses the Chandon flowline.	✓	95	✓
Woodside – Julimar Development Project (Ref. 257)	• Operation includes inspection, monitoring, maintenance and repair during operations. • Located within licence areas WA-49-L, WA-26-PL and WA-29-PL. Vessel based operations may be undertaken within WA-356-P and WA-34-L.	✓	0	✓

Petroleum Activity	Key Characteristics	OA	Distance to OA (~km)	Hydrocarbon Social EMBA
	• Commenced production in 2016 with a field life of 25 years and operates 24 hours a day, every day of the year. • The western edge of WA-49-L overlaps the OA with several production wells and associated subsea infrastructure within the OA.			
Woodside – Julimar Appraisal Drilling and Surveys (Ref. 258)	• Activities include drilling an appraisal well, decommissioning and survey activities • Planned to commence in Q3 2023 (contingency for 2024 and 2025) and will take ~50 days. Wellhead decommissioning activities (removal) could occur up to 3-years post drilling and will take up to 2 days. • Geotechnical and geophysical surveys could involve a range of survey techniques and will occur between 2023 and 2025 and take ~45 days • The OA, including some anchor lines from the moored MODU, and a very small portion of the survey area are expected to overlap a small part of the OA.	✓	0	✓
Santos – Varanus Island Hub Operations in Commonwealth waters (Ref. 259)	• Consists of the John Brookes, Spartan and Greater East Spar (GES) gas fields which export well fluids from the production wells to the processing facilities on Varanus Island • Infrastructure includes WHPs, wells, umbilicals and flowlines for all fields	-	15.6	✓
Woodside – Pluto Offshore Facility (Ref. 260)	• The Pluto offshore facility has been in production since 2012. Currently produces gas and condensate from the Pluto and Xena gas fields which is transported via trunkline to the onshore Pluto Gas Plant. • End of life of the Pluto, Xena and Pyxis fields is un-known, however is not expected during the life of the approved EP (until 2024). •	-	28	✓
CAPL – Wheatstone Development (Ref. 261)	• The Wheatstone offshore facilities gather and partially process gas and associated condensate from the Wheatstone and Iago fields via trunkline to the GTP at Onslow. The platform also receives fluids	✓	29	✓

Petroleum Activity	Key Characteristics	OA	Distance to OA (~km)	Hydrocarbon Social EMBA
	from Woodside's Julimar Development Project. • Part of the trunkline is within the OA, running along the south-eastern border. • Indicative duration is for operations until 2046, with operations 24 hours a day every day and IMR activities when required.			

There are several exploration and production permits and leases throughout Commonwealth waters that overlap the Hydrocarbon Social EMBA.

Existing petroleum infrastructure, permits and licences are shown in Figure 6-34.

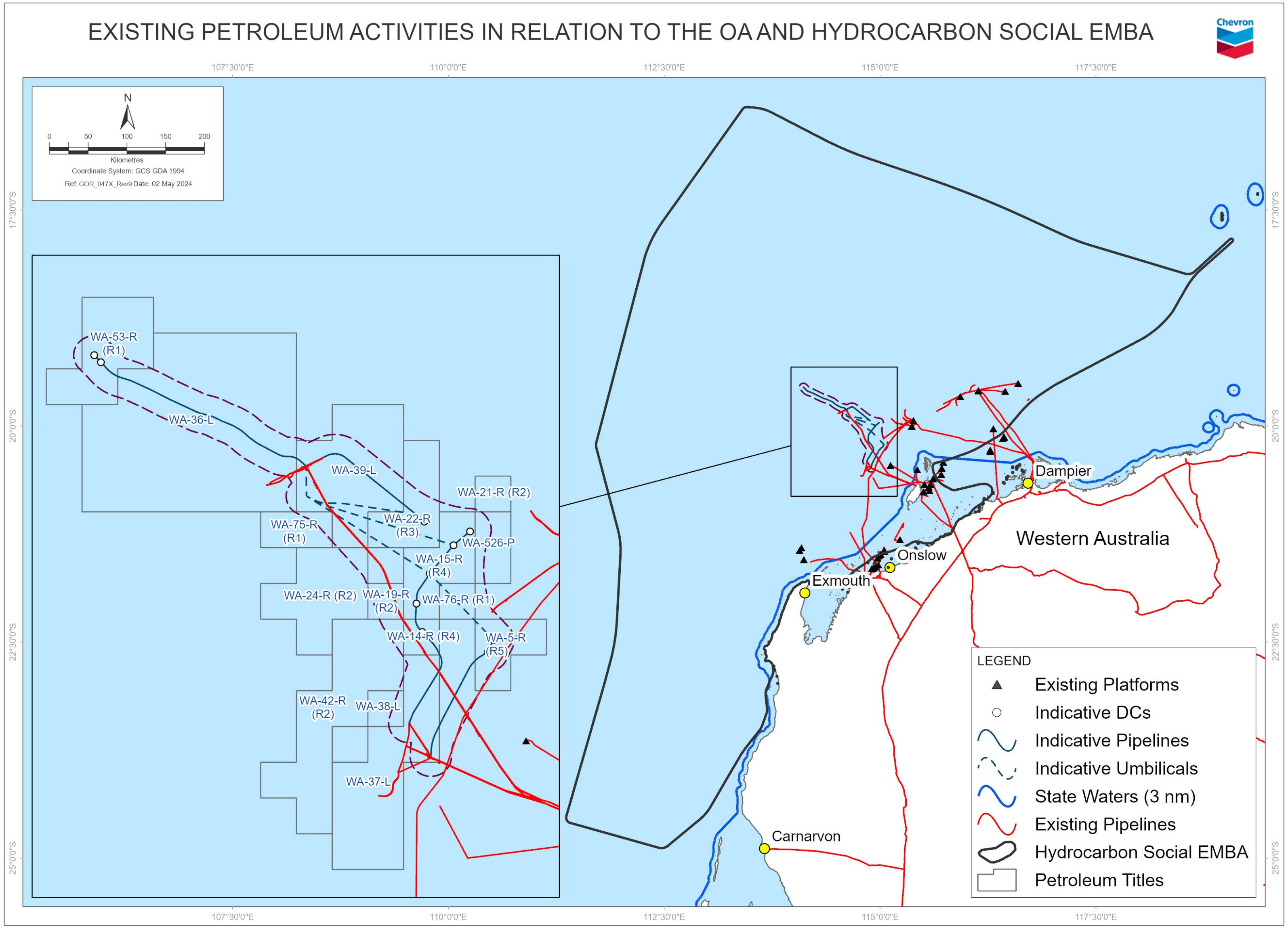

Figure 6-34: Existing petroleum activities in relation to the OA and Hydrocarbon Social EMBA

6.3.6.2 Defence

The Royal Australian Air Force has a base at Learmonth, and there is a designated maritime firing practices and exercise area associated with this base (Ref. 262).

The EPBC protected matters search identified the following defence areas that overlap the Hydrocarbon Social EMBA (Ref. 123, Appendix B):

- Defence—Exmouth VLF transmitter station
- Defence—Exmouth admin and HF transmitting
- Defence—Learmonth radar site, Vlamingh Head
- Defence—Learmonth air weapons range.

There are no known sites of unexploded ordnance (UXO) within the OA; however, several potential UXO sites overlap the Hydrocarbon Social EMBA (Figure 6-35) (Ref. 263).

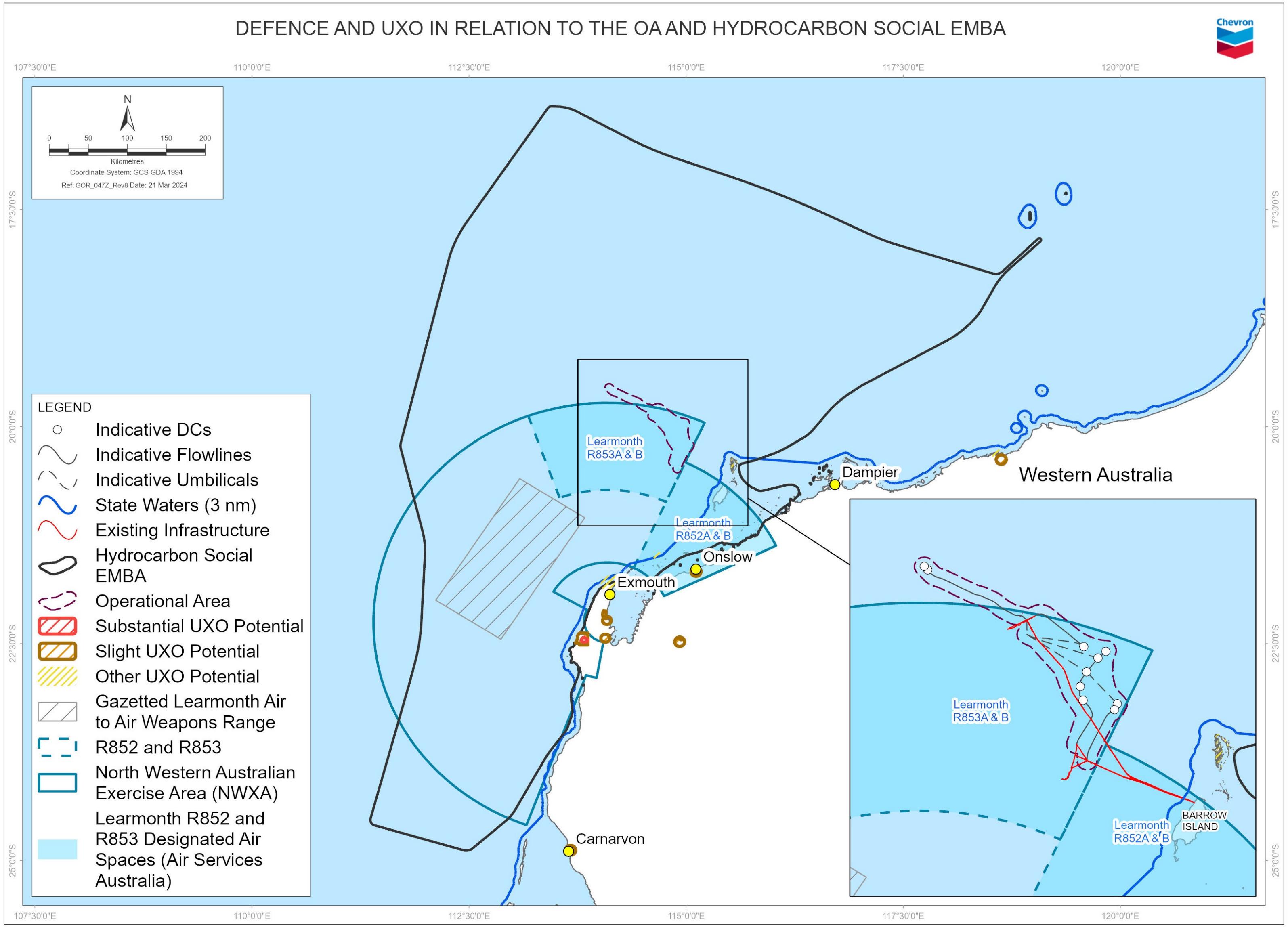

Figure 6-35: Defence and UXO in relation to the OA and Hydrocarbon Social EMBA

6.4 Qualities and characteristics of locations, places and areas

6.4.1 Australian Marine Parks

Marine parks help conserve marine habitats and the species that live within and rely on these habitats. Marine parks also provide places for people to watch wildlife, dive, and go boating, snorkelling, or fishing (Ref. 264).

Australian Marine Parks (AMPs) occur within Commonwealth waters; they were proclaimed under the EPBC Act in 2007 and 2013. Table 6-21 describes the AMPs present within the OA and EMBAs and summarises their values (Ref. 83).

There are no AMPs within the OA; the closest is the Montebello Marine Park located ~16 km from the south-eastern edge of the OA. Australian Marine Parks in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA are shown in Figure 6-36.

Table 6-21: Presence and values of AMPs within the OA and EMBAs

Australian Marine Park		OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Gascoyne (Multiple Use Zone [IUCN VI])], Habitat Protection Zone [IUCN IV])		**-**	**114**	✓	✓
	The Gascoyne Marine Park is ~20 km off the west coast of the Cape Range Peninsula, adjacent to the Ningaloo Reef Marine Park and the WA Ningaloo Marine Park and extends to the limit of Australia's EEZ. The area of this marine park is 81,766 km² and its waters are 15 – 6,000 m deep. **Natural values** This marine park includes examples of ecosystems that are representative of: • Central Western Shelf Transition—continental shelf with waters up to 100 m deep and a significant transition zone between tropical and temperate species • Central Western Transition—characterised by large areas of continental slope; a range of topographic features such as terraces, rises, and canyons; seasonal and sporadic upwelling; and benthic slope communities comprising tropical and temperate species • Northwest Province—an area of continental slope comprising diverse and endemic fish communities. The marine park includes 4 KEFs characterised by seasonal and sporadic upwelling, nutrient-rich water and aggregations of marine life and a high diversity of demersal fish assemblages. The marine park supports a range of species including those listed as threatened, migratory, marine, or cetacean under the EPBC Act. BIAs within this marine park include breeding habitat for seabirds, internesting habitat for marine turtles, a migratory pathway for humpback whales, and foraging habitat and migratory pathway for pygmy blue whales. **Cultural values** Sea country is valued for cultural identity, health and wellbeing of Traditional Owners. Across Australia, Traditional Owners have sustainably used and managed their sea country for tens of thousands of years. The Baiyungu, Thalanyji and Yinikurtura People have responsibilities for sea country in this marine park. **Heritage values** No international, Commonwealth or National Heritage listings apply to the marine park; however, it is adjacent to the Ningaloo Coast, which has international, Commonwealth and national heritage values.				
Montebello (Multiple Use Zone [IUCN VI])		**-**	**16.7**	✓	✓
	The Montebello Marine Park is offshore from Barrow Island and 80 km west of Dampier extending from the State water boundary and is adjacent to the WA Barrow Island and Montebello Islands Marine Parks. The area of this marine park is 3,413 km² and its waters range from <15–150 m deep.				

Australian Marine Park		OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
	Natural values This marine park includes examples of ecosystems representative of the Northwest Shelf Province—a dynamic environment influenced by strong tides, cyclonic storms, long-period swells, and internal tides. The bioregion includes diverse benthic and pelagic fish communities, and ancient coastline. The Ancient coastline at the 125 m depth contour KEF overlaps the north-west boundary of the park, thought to be an important sea floor feature and migratory pathway for humpback whales (Section 6.2.6.1). The marine park supports a range of species including those listed as threatened, migratory, marine, or cetacean under the EPBC Act. BIAs within this marine park include breeding habitat for seabirds; internesting, foraging, mating, and nesting habitat for marine turtles; a migratory pathway for humpback whales; and foraging habitat for whale sharks. **Cultural values** Sea country is valued for cultural identity, health, and wellbeing of Traditional Owners. Across Australia, Traditional Owners have sustainably used and managed their sea country for tens of thousands of years. At the time of writing there was limited information about the cultural significance of this marine park. **Heritage values** No international, Commonwealth or national listings apply to this marine park; however, it is adjacent to the WA Barrow Island and the Montebello–Barrow Island Marine Conservation Reserves, which have been nominated for National Heritage listing. **Social and economic values** Tourism, commercial fishing, mining and recreation are important activities in the marine park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.				
Shark Bay (Multiple Use Zone [IUCN VI])		**-**	**456.2**	✓	✓
	The Shark Bay Marine Park is ~60 km offshore from Carnarvon, adjacent to the Shark Bay World Heritage property and National Heritage place and extending out from the State water boundary. The area of this marine park is 7,443 km² and its waters are 15–220 m deep. **Natural values** This marine park includes examples of ecosystems representative of: • Central Western Shelf Transition—a predominantly flat, sandy and low-nutrient area, in waters 50–100 m deep; the bioregion is a transitional zone between tropical and temperate species • Central Western Transition—characterised by large areas of continental slope; a range of topographic features such as terraces, rises and canyons; seasonal and sporadic upwelling; and benthic slope communities comprising tropical and temperate species. Ecosystems represented in the marine park are influenced by the Leeuwin, Ningaloo and Capes currents. This marine park supports a range of species including those listed as threatened, migratory, marine or cetacean under the EPBC Act. BIAs within this marine park include breeding habitat for seabirds, internesting habitat for marine turtles, and a migratory pathway for humpback whales. The marine park and adjacent coastal areas are also important for shallow-water snapper. **Cultural values** Sea country is valued for cultural identity, health, and wellbeing of Traditional Owners. Across Australia, Traditional Owners have sustainably used and managed their sea country for tens of thousands of years. The Gnulli and Malgana people have responsibilities for sea country in this marine park. The Yamatji Marlpa Aboriginal Corporation is the Native Title Representative Body for the Yamatji region. **Heritage values**				

Australian Marine Park		OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
	No international, Commonwealth or National Heritage listings applied to the marine park at the commencement of this plan, but it is adjacent to the Shark Bay, WA World Heritage Property and Shark Bay, WA National Heritage Place. This marine park contains ~20 known shipwrecks listed under the *Historic Shipwrecks Act 1976* (Cth). **Social and economic values** Tourism, commercial fishing, mining and recreation, including fishing, are important activities in the marine park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.				
Ningaloo (Recreational Use Zone [IUCN IV], National Park Zone [IUCN II])		**-**	**143.5**	✓	✓
	The Ningaloo Marine Park stretches ~300 km along the west coast of the Cape Range Peninsula and is adjacent to the Western Australian Ningaloo Marine Park and Gascoyne Marine Park. The area of this marine park is 2,435 km² and its waters are 30–500 m (or more) deep. **Natural values** This marine park includes examples of ecosystems representative of: • Central Western Shelf Transition—continental shelf of water up to 100 m deep, and a significant transition zone between tropical and temperate species • Central Western Transition—characterised by large areas of continental slope; a range of topographic features such as terraces, rises and canyons; seasonal and sporadic upwelling; and benthic slope communities comprising tropical and temperate species • Northwest Province—an area of continental slope comprising diverse and endemic fish communities • Northwest Shelf Province—a dynamic environment, influenced by strong tides, cyclonic storms, long-period swells and internal tides. The bioregion includes diverse benthic and pelagic fish communities, and ancient coastline thought to be an important sea floor feature and migratory pathway for humpback whales. The marine park overlaps with 3 KEFs, valued for upwelling of nutrient-rich water, high biodiversity, and endemism. Ecosystems represented in the marine park are influenced by interaction of the Leeuwin Current, Leeuwin Undercurrent, and the Ningaloo Current. This marine park supports a range of species including those listed as threatened, migratory, marine or cetacean under the EPBC Act. BIAs within this marine park include breeding and or foraging habitat for seabirds, internesting habitat for marine turtles, a migratory pathway for humpback whales, foraging habitat and migratory pathway for pygmy blue whales, breeding, calving, foraging, and nursing habitat for dugong and foraging habitat for whale sharks. **Cultural values** Sea country is valued for cultural identity, health, and wellbeing of Traditional Owners. Across Australia, Traditional Owners have sustainably used and managed their sea country for tens of thousands of years. The Gnulli people have responsibilities for sea country in this marine park. The Yamatji Marlpa Aboriginal Corporation is the Native Title Representative Body for the Yamatji region. **Heritage values** This marine park is within the Ningaloo Coast World Heritage property, recognised for its outstanding universal heritage values, meeting World Heritage listing criteria vii and x. In addition to the marine park, the World Heritage area includes the WA Ningaloo Marine Park, the Muiron Islands, the WA Cape Range National Park and other terrestrial areas. The area is valued for high terrestrial species endemism, marine species diversity and abundance, and the interconnectedness of large-scale marine, coastal and terrestrial environments. The area connects the limestone karst system and fossil reefs of the ancient Cape Range to the nearshore reef system of Ningaloo Reef, to the continental slope and shelf in Commonwealth waters. The Ningaloo Coast overlaps this marine park and was established on the National Heritage List in 2010, meeting the National Heritage listing criteria A, B, C, D, and F.				

Australian Marine Park	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
	The Ningaloo Marine Area (Commonwealth waters) was established on the Commonwealth Heritage List in 2004, meeting Commonwealth heritage listing criteria A, B and C. The Ningaloo Marine Area overlaps the marine park. This marine park contains >15 known shipwrecks listed under the *Historic Shipwrecks Act 1976* (Cth). **Social and economic values** Tourism, commercial fishing, mining and recreation, including fishing, are important activities in this marine park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.			
Argo–Rowley Terrace (Multiple Use Zone [IUCN VI])	**-**	**280**	✓	✓
	The Argo–Rowley Terrace Marine Park is ~270 km north-west of Broome and extends to the limit of Australia's EEZ. The marine park is adjacent to the Mermaid Reef Marine Park and the WA Rowley Shoals Marine Park. The area of this marine park is 146,003 km^2 and its waters are 220–6000 m deep. **Natural values** This marine park includes examples of ecosystems representative of: • Northwest Transition—an area of shelf break, continental slope, and the majority of the Argo Abyssal Plain. Key topographic features include Mermaid, Clerke and Imperieuse Reefs, which collectively are a biodiversity hotspot • Timor Province—an area dominated by warm, nutrient-poor waters. Canyons are an important feature in this area of the marine park and are generally associated with high productivity and aggregations of marine life. The marine park overlaps 2 KEFs, valued for upwelling of nutrient-rich water and high species productivity. This marine park supports a range of species including those listed as threatened, migratory, marine, or cetacean under the EPBC Act. BIAs within this marine park include resting and breeding habitat for seabirds and a migratory pathway for the pygmy blue whale. **Cultural values** Sea country is valued for cultural identity, health, and wellbeing of Traditional Owners. Across Australia, Traditional Owners have sustainably used and managed their sea country for tens of thousands of years. As at the commencement of this OPP there was limited information about the cultural significance of this marine park. **Heritage values** Mermaid Reef–Rowley Shoals was established on the Commonwealth Heritage List in 2004, meeting Commonwealth heritage listing criteria A, B, C and D. This marine park contains one known shipwreck (*Lively*, wrecked in 1810) listed under the *Historic Shipwrecks Act 1976* (Cth). **Social and economic values** Tourism, recreation, and scientific research are important activities in the marine park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.			

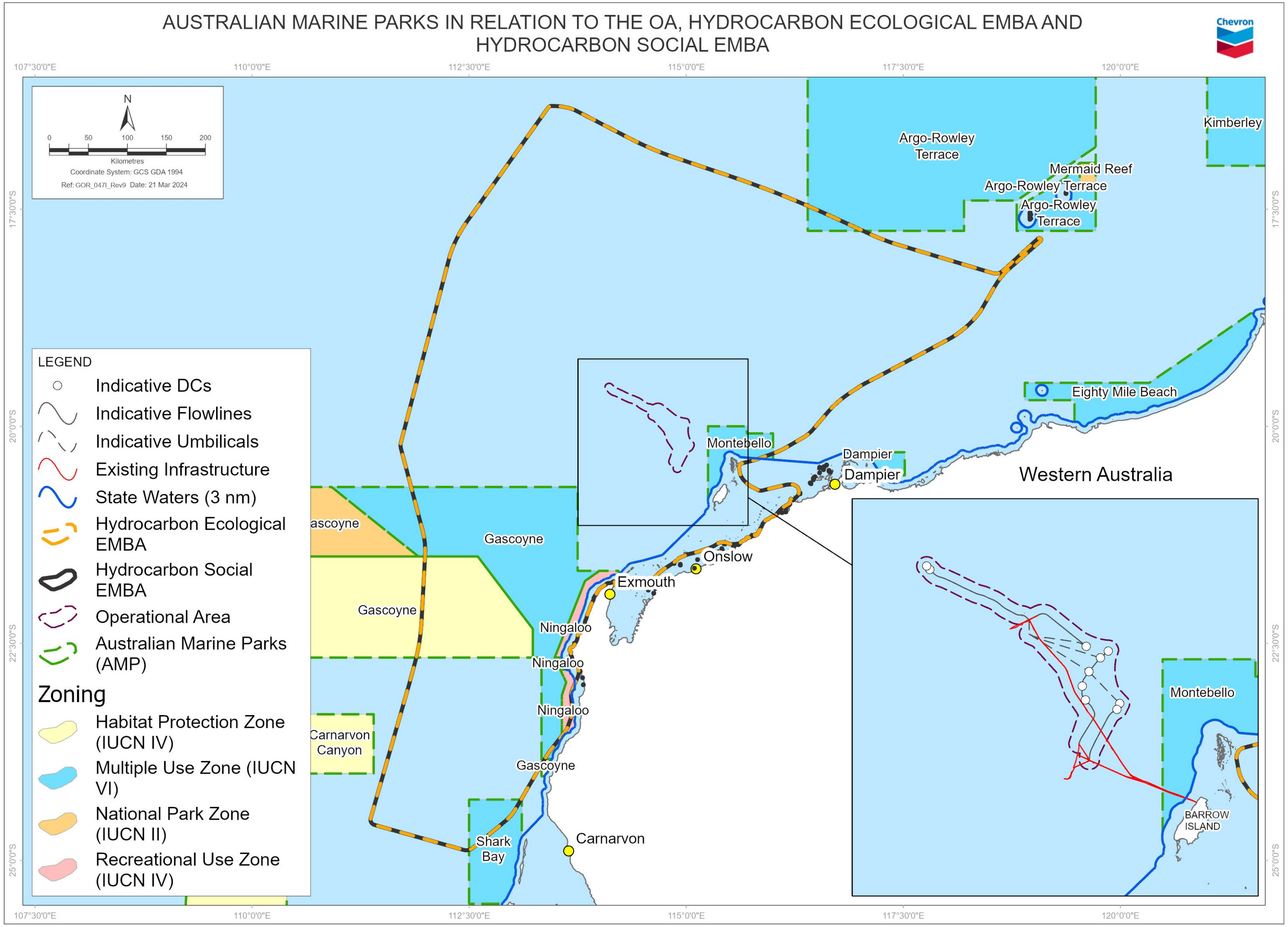

Figure 6-36: Australian Marine Parks in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.4.2 State marine protected areas

State marine parks, management areas, and reserves are proclaimed under the *Conservation and Land Management Act 1984* (WA) (CALM Act), are located in State waters, and vested in the WA Conservation and Parks Commission.

There are no state marine parks, management areas and reserves within the OA; the closest is the Montebello Marine Park (General Use Zone IUCN II), which is ~40 km from the south-eastern edge of the OA. Table 6-22 lists the marine parks, management areas and reserves present within the OA and EMBAs. State Marine Protected Areas in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA are shown in Figure 6-37.

Table 6-22: Presence of State marine parks, management areas and reserves

State marine parks, management areas and reserves	Zone type (IUCN category)	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Barrow Island Marine Park	Unassigned (IUCN Ia)	-	44.2	✓	✓
Barrow Island Marine Management Area	Unassigned (IUCN VI)	-	40.9	✓	✓
Montebello Islands Conservation Park	Unassigned (IUCN II)		46.4	✓	✓
Montebello Islands Marine Park	General Use Zone (IUCN II)	-	38.6	✓	✓
	Sanctuary Zone (IUCN Ia)	-	40.7	✓	✓
	Special Purpose Zone – Pearling (IUCN VI)	-	48.5	✓	✓
	Recreation Zone (IUCN II)	-	52.6	✓	✓
	Special Purpose Zone (Benthic Protection) (IUCN IV)	-	39.3	✓	✓
Ningaloo Marine Park	General Use (IUCN II)	-	157.7	✓	✓
	Sanctuary Zone (IUCN Ia)	-	156.5	✓	✓
	Recreation Area (IUCN II)	-	157	✓	✓
	Special Purpose Zone (Shore-based Activities) (IUCN II)	-	155.7	✓	✓
	Unassigned (IUCN II)	-	172.5	✓	✓
	Unassigned (IUCN IV)	-	268.4	✓	✓
	Special Purpose Zone (Benthic	-	200	✓	✓

State marine parks, management areas and reserves	Zone type (IUCN category)	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
	Protection) (IUCN IV)				
Great Sandy Island Nature Reserve	Unassigned (IUCN Ia)	-	83.3	✓	✓
Thevenard Islands Nature Reserve	Unassigned (IUCN Ia)	-	101.1	✓	✓
Muiron Islands Marine Management Area	Conservation Area (IUCN Ia)		134	✓	✓
	Unassigned (IUCN VI)	-	127.2	✓	✓
Rowley Shoals Marine Park	Sanctuary Zone (IUCN Ia)	-	479.3	-	✓

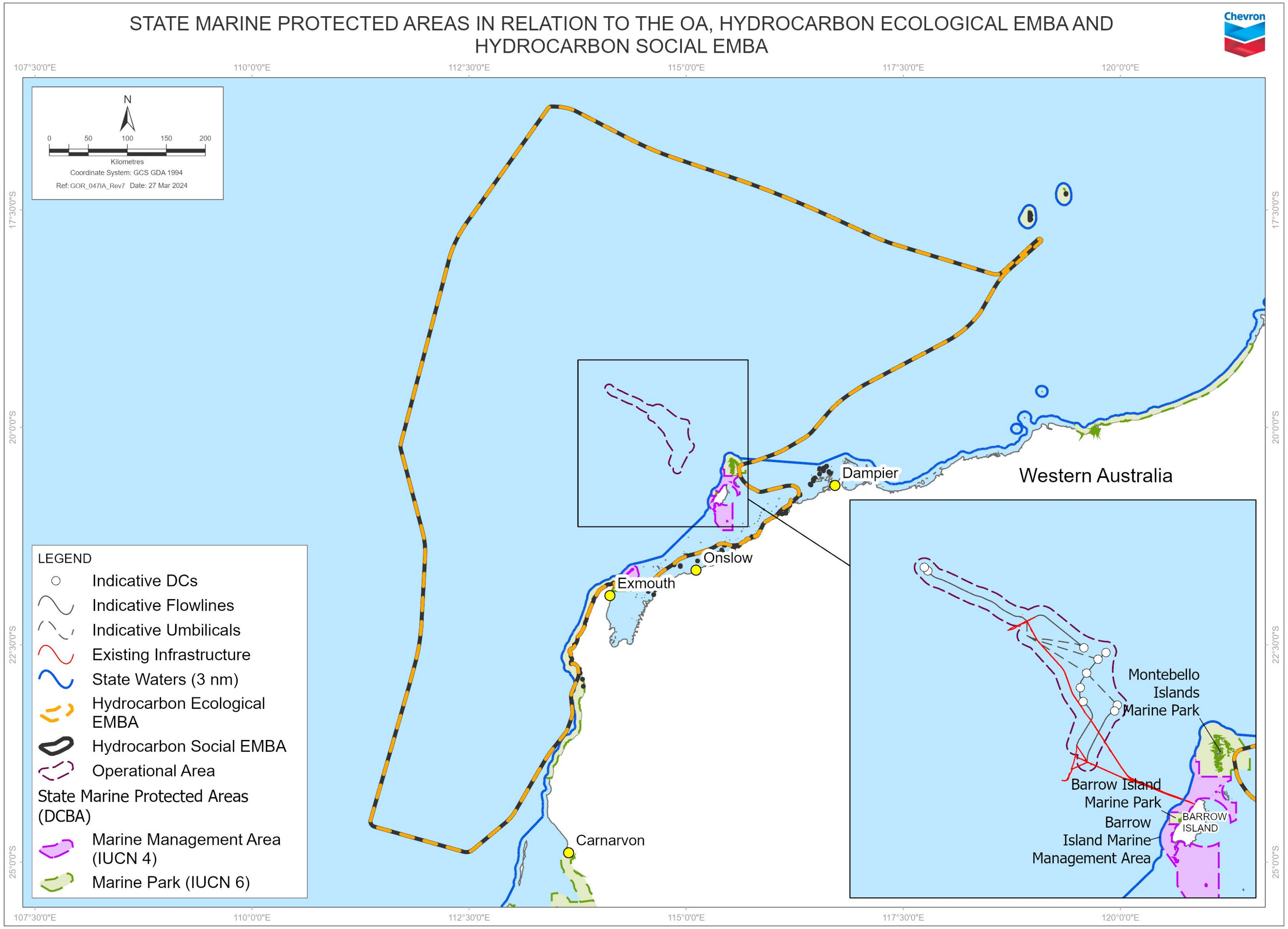

Figure 6-37: State Marine Protected Areas in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.4.3 State terrestrial protected areas

Terrestrial protected areas, proclaimed under the CALM Act, are located in State lands, and vested in the WA Conservation and Parks Commission.

The OA occurs offshore and does not have any overlap with the mainland coast. The Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA do overlap with the coastal areas of islands (described in Section 6.2.2) (Figure 6-1 and Figure 6-2 respectively). Table 6-23 lists the State terrestrial protected areas that are present within the EMBAs. State terrestrial protected areas in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA are shown in Figure 6-38.

Table 6-23: Presence of State terrestrial protected areas

State terrestrial parks, management areas and reserves	Zone type (IUCN category)	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Barrow Island Nature Reserve	Nature Reserve (IUCN Ia)	-	50.6	✓	✓
Boodie, Double Middle Islands Nature Reserve	Nature Reserve (IUCN Ia)	-	58.2	✓	✓
Montebello Islands Conservation Park	Conservation Park (IUCN II)	-	46.6	✓	✓
Serrurier Island Nature Reserve	Nature Reserve (IUCN Ia)	-	119.7	✓	✓
Muiron Islands Nature Reserve	Nature Reserve (IUCN Ia)	-	131.7	✓	✓
Cape Range National Park	National Park (IUCN II)	-	179.2	✓	✓
Cape Range National Park (South)	National Park (IUCN II)	-	243.7	✓	✓
Lowendal Islands Nature Reserve	Nature Reserve (IUCN Ia)	-	61.7	✓	✓
Jurabi Coastal Park	5(1)(h) Reserve (IUCN II)	-	161	✓	✓
Airlie Island Nature Reserve	Nature Reserve (IUCN Ia)	-	91.5	✓	✓
Little Rocky Island Nature Reserve	Nature Reserve (IUCN Ia)	-	112.7	-	✓
Locker Island Nature Reserve	Nature Reserve (IUCN Ia)	-	131.5	-	✓
North Sandy Island Nature Reserve	Nature Reserve (IUCN Ia)	-	98.6	✓	✓
Nyingguulu (Ningaloo) Coastal Reserve	5(1)(h) Reserve (IUCN II)	-	269.5	-	✓
Bessieres Island Nature Reserve	Nature Reserve (IUCN Ia)	-	110.4	✓	✓
Round Island Nature Reserve	Nature Reserve (IUCN Ia)	-	125.8	✓	✓
Unnamed WA36913	Nature Reserve (IUCN Ia)	-	148	-	✓

State terrestrial parks, management areas and reserves	Zone type (IUCN category)	OA	Distance to OA (~km)	Hydrocarbon Ecological EMBA	Hydrocarbon Social EMBA
Unnamed WA36915	Nature Reserve (IUCN Ia)	-	145.4	-	✓
Unnamed WA36910	5(1)(h) Reserve (IUCN II)	-	167.3	-	✓
Unnamed WA40322	5(1)(h) Reserve (IUCN II)	-	91.8	✓	✓
Unnamed WA41080	5(1)(h) Reserve (IUCN II)	-	47.2	✓	✓
Unnamed WA44665	5(1)(h) Reserve (IUCN II)	-	111.2	✓	✓
Unnamed WA40828	5(1)(h) Reserve (IUCN II)	-	54.4	✓	✓
Unnamed WA44667	5(1)(h) Reserve (IUCN II)	-	99	✓	✓
Weld Island Nature Reserve	Nature Reserve (IUCN Ia)	-	114.7	-	✓

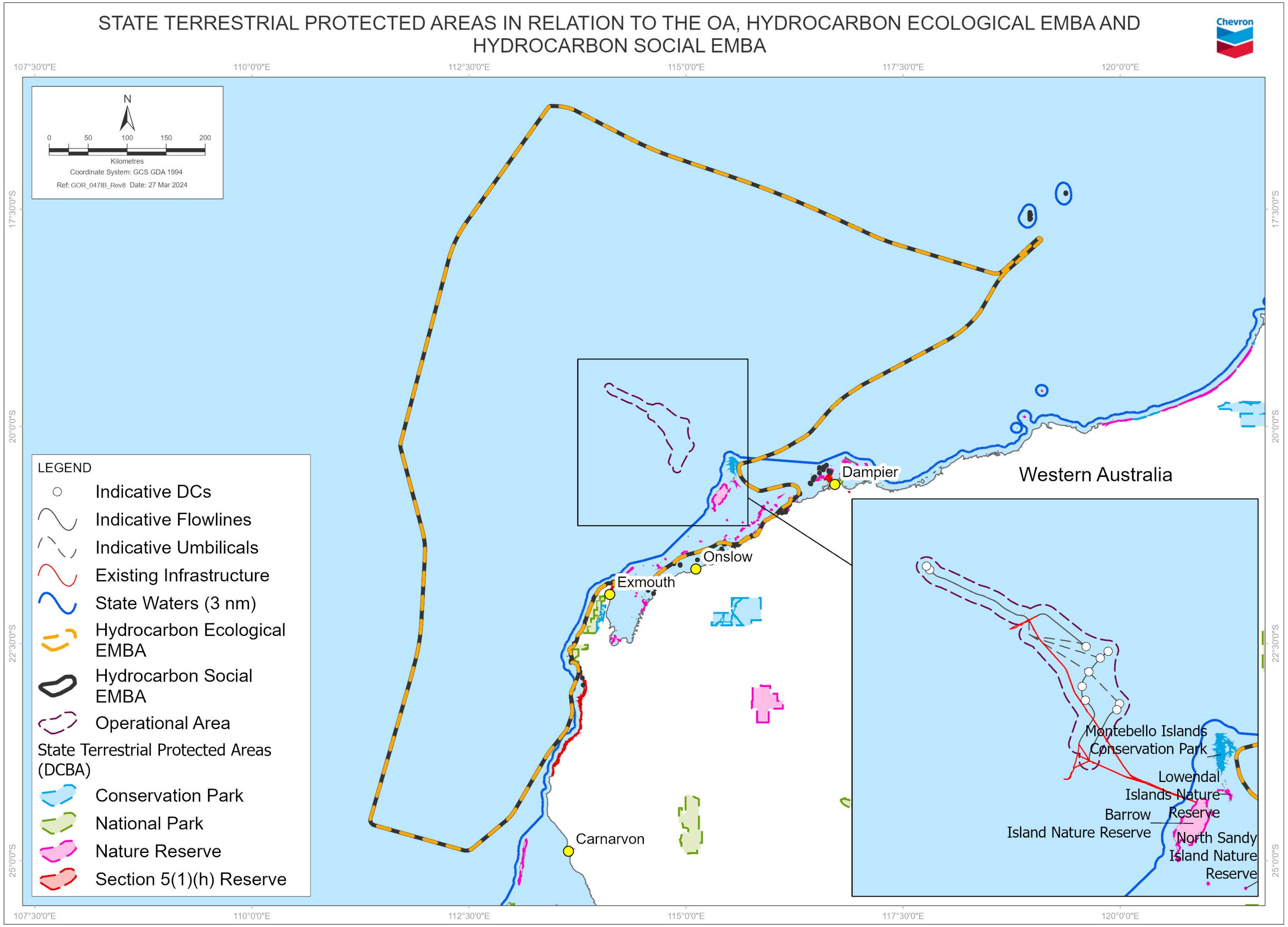

Figure 6-38: State terrestrial protected areas in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.5 Heritage value of places

Listed World Heritage properties, National Heritage places, Commonwealth Heritage places, UCH and Indigenous Protected Areas are MNES under the EPBC Act, and a particular value and sensitivity under the OPGGS(E)R. Table 6-24 lists those heritage properties and other marine or coastal heritage protected places that are present within the OA and EMBAs. Heritage places in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA are shown in Figure 6-39. The Aboriginal Cultural Heritage Inquiry System (ACHIS) was searched for the OA, and the EMBAs (Ref. 265). The full results of these searches are available in Appendix F.

Table 6-24: Presence of heritage properties within the OA and EMBAs

Feature	OA	Distance to OA (~km)	Hydrocarbon Social EMBA	Hydrocarbon Ecological EMBA
World Heritage property				
The Ningaloo Coast	-	127.2	✓	✓
National Heritage place-				
The Ningaloo Coast	-	127.8	✓	✓
Dampier Archipelago		149.2	✓	
Commonwealth Heritage				
Ningaloo Marine Area – Commonwealth Waters	-	143.5	✓	✓
Learmonth Air Weapons Range Facility	-	230.2	✓	✓
Indigenous protected areas				
N/A		(none identified within OA or EMBAs)		
Sites or artefacts protected under the *Underwater Cultural Heritage Act 2018* (Cth)				
Historic shipwrecks (>75 years old)	-	13.9	✓	✓
Shipwrecks	-	13.9	✓	✓
Sunken aircraft		(none identified within OA or EMBAs)		
In situ artefacts		(none identified within OA or EMBAs)		
Sites or artefacts protected under the *Aboriginal Heritage Act 1972* (WA) and *Aboriginal Cultural Heritage Act 2021* (WA)				
Determined areas under the *Native Title Act 1993* (Cth)	-	51.9	✓	✓
ACHIS directory sites[35]	-	51.8	✓	✓
ACHIS pending sites[36]		-	-	-
ACHIS historic sites[37]	-	49.5	✓	✓

[35] *ACH Directory: Aboriginal cultural heritage place or cultural landscape.*
[36] *Pending: Aboriginal cultural heritage place or cultural landscape with information in a verification stage.*
[37] *Historic: Aboriginal heritage places determined to not meet the criteria of Section 5 of the Aboriginal Heritage Act 1972. Includes places that no longer exist as a result of land use activities with existing approvals.*

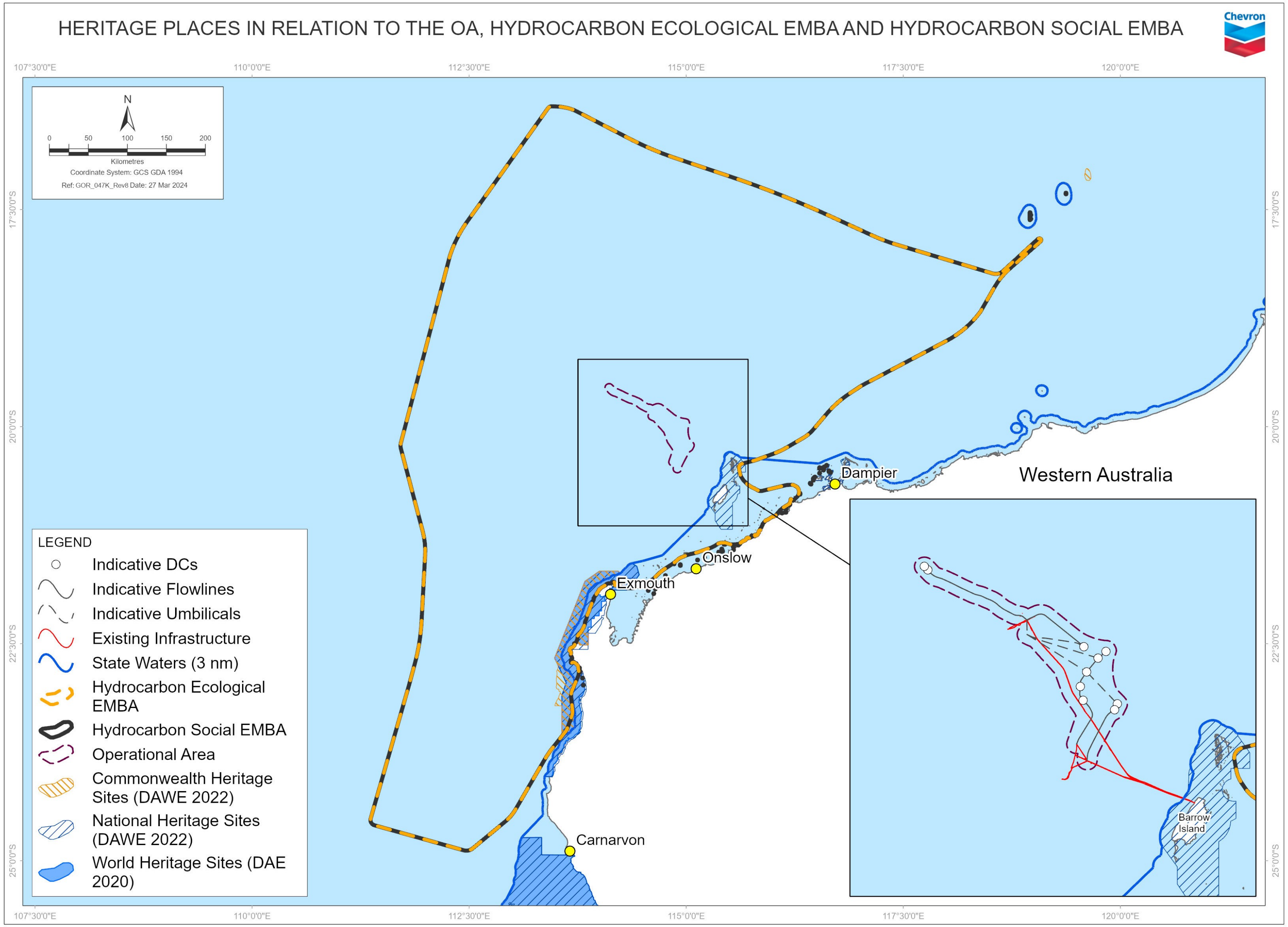

Figure 6-39: Heritage places in relation to the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA

6.5.1 Ningaloo Coast

The Ningaloo Coast is located in WA adjacent to the eastern Indian Ocean. The area has a high level of terrestrial species endemism, and high marine species diversity and abundance (Ref. 266). The Ningaloo Reef and Exmouth Peninsula karst system is a cohesive limestone structure that is at the heart of the natural heritage significance of the Ningaloo Coast (Ref. 267).

The marine portion of the World Heritage property contains a high diversity of habitats that includes lagoon, reef, open ocean, the continental slope, and the continental shelf (Ref. 266). Intertidal systems such as rocky shores, sandy beaches, estuaries, and mangroves are also present (Ref. 266). The most dominant marine habitat is Ningaloo Reef, which sustains both tropical and temperate marine fauna and flora, including marine reptiles and mammals (Ref. 266).

The main terrestrial feature of the Ningaloo Coast is the extensive karst system and network of underground caves and water courses of the Cape Range (Ref. 266). The karst system includes hundreds of separate features such as caves, dolines, and subterranean water bodies and supports a rich diversity of highly specialised subterranean species (Ref. 266). Above ground, the Cape Range Peninsula belongs to an arid ecoregion recognised for its high levels of species richness and endemism, particularly birds and reptiles (Ref. 266).

In addition to the natural values of the Ningaloo Coast, values of Traditional Owners are identified under the National Heritage listing (Ref. 267). Archaeological deposits in the rock shelters on Cape Range show Traditional Owners had a sophisticated knowledge of marine resources between 35,000 and 17,000 years ago. The rock shelters are considered to provide the best evidence in Australia for the use of marine resources during the Pleistocene (Ref. 267).

6.5.2 Underwater cultural heritage

Australia’s underwater cultural heritage (UCH) is protected under the *Underwater Cultural Heritage Act 2018* (Cth) (UCH Act). This legislation protects shipwrecks, sunken aircraft, and other types of underwater heritage, including Traditional Owners underwater cultural heritage in Australian waters. The UCH Act applies to all Australian waters, including both State waters (coastal waters) and Commonwealth waters (extending from coastal waters to the edge of continental shelf).

Under section 15 of the UCH Act, underwater cultural heritage is defined as ‘any trace of human existence that has a cultural, historical, or archaeological character, and is located under water’. The UCH Act protects physical sites and artefacts; intangible heritage values with no physical component are not protected under the Act (Ref. 68).

A search of the online Australasian Underwater Cultural Heritage Database (Ref. 268) was undertaken to determine the presence of underwater cultural heritage within the Development EMBAs. Based on the search, both historic (>75 years old) shipwrecks and other shipwrecks were identified in the EMBAs. No sunken aircraft or other artefacts were identified within the EMBAs. No underwater cultural heritage was identified within the OA. The results of the search are listed in Table 6-24.

At the time of writing, CAPL understands through consultation with the relevant Traditional Owner groups that there are no known underwater cultural heritage sites within the EMBA.

6.5.3 Native Title

Native Title recognises the rights and interests of Native Title Holders in land and waters according to their traditional laws and customs and is administered under the *Native Title Act 1993* (Cth), including their rights to maintain and protect cultural sites.

The Hydrocarbon Social EMBA overlaps 2 native title determinations (WCD2019/016 and WCD2018/006) and has a small section of shoreline contact in 2 other native title determinations (WCD2015/007 across Dampier Archipelago and WCD2008/003 just outside Exmouth Gulf) (Figure 6-40). Native Title WCD2018/006 runs across Mardie and Gnoorea coast and WCD2019/016 along the Ningaloo Coast area.

Cultural values and features were identified during consultations with representatives of these Native Tile Holders; summarised in Table 6-14.

6.5.3.1 Native Title WCD2019/016

The Gnulli, Gnulli # 2 and Gnulli # 3 – Yinggarda, Baiyungu and Thalanyji People Native Title determination (WCD2019/016) extends over the Ningaloo Coast area. The Yinggarda, Baiyungu, and Thalanyji people received recognition as Native Title holders over an area of 71,354 m^2. The determination area encompasses several pastoral leases, mining tenements, roads, and reserves, as well as portions of the Kennedy Range and Cape Range national parks, Ningaloo Marine Park, Lake MacLeod, and waters in the Exmouth Gulf and Ningaloo Marine Park (Ref. 213). The Yinggarda, Baiyungu and Thalanyji people have each maintained a physical presence in their respective part of the determination area and have a continuing physical or spiritual involvement in that area (Ref. 213). The determination area contains places of special significance, such as mythological and ceremonial sites and natural resources (Ref. 213).

The relevant Prescribed Bodies Corporate are the Nganhurra Thanardi Garrbu Aboriginal Corporation (representing the Baiyungu and Thalanyji people) and the Yinggarda Aboriginal Corporation.

6.5.3.2 Native Title WCD2018/006

The Yaburara and Mardudhunera People Native Title determination (WCD2018/006) extends over the Mardie coast area. The Yaburara and Mardudhunera people received recognition as a Native Title holder over an area of 5,683 km^2. The determination area encompasses several pastoral leases, mining tenements, roads, reserves, and unallocated Crown land. The Yaburara and Mardudhunera People have maintained a physical presence in their respective part of the determination area and have a continuing physical or spiritual involvement in that area (Ref. 269). The determination area contains places of special significance, such as cultural, spiritual, and ceremonial sites and natural resources.

The relevant Prescribed Bodies Corporate is the Wirrawandi Aboriginal Corporation.

6.5.3.3 Native Title WCD2015/007

The Ngarluma People Native Title determination (WCD2015/007) comprises of multiple dispersed areas (~21.4 km^2) within or adjacent to Dampier, Karratha, Wickham, and Point Sampson townsites. The rights and interests held by the Ngarluma People are divided into 3 regions or areas with various rights granted including (but not limited to): to hunt, fish, forage, access land, camp, live on and engage in cultural practices.

The relevant Prescribed Bodies Corporate is the Ngarluma Aboriginal Corporation Registered Native Title Bodies Corporate (RNTBC).

6.5.3.4 Native Title WCD2008/003

The Thananyji People Native Title determination (WCD2008/003) extends an area (18,432 km^2) of land and sea and is in the Pilbara region of Western Australia in the vicinity of Onslow. The determination area comprises of group and communal rights and interests held by the Thalanyji people, who have connection with the land and waters in the determination area, in accordance with the traditional laws acknowledged and the traditional customs observed by the Thalanyji. The determination area encompasses pastoral leases, mining tenements, roads, and reserves. The determination confers non-exclusive rights of the Native Title holders to enter, travel, erect camps, gather traditional resources (hunt, fish, gather) and engage in ritual and ceremony on, and in relation to, the land and waters of the determination area.

The relevant Prescribed Bodies Corporate is the Buurabalayji Thalanyji Aboriginal Corporation RNTBC.

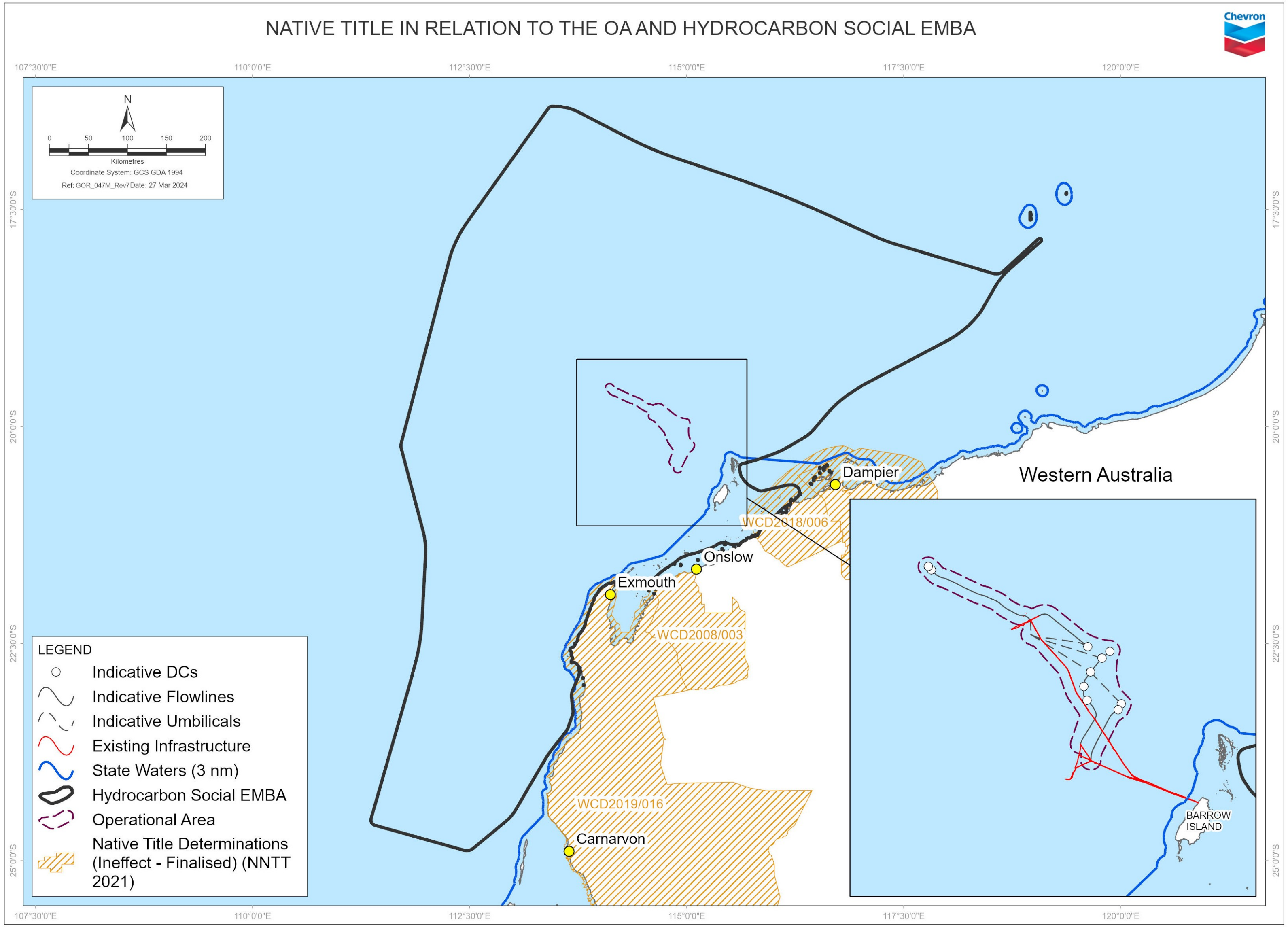

Figure 6-40: Native title in relation to the OA and Hydrocarbon Social EMBA

7 Environmental impact and risk assessment methodology

This section describes the methods used to identify and evaluate the environmental impacts and risks associated with the Development.

Table 7-1 defines the common terms applied during the impact and risk assessment process (general terms used in this OPP and their definitions are defined in Section 11).

Table 7-1: Impact and risk assessment terms

Term	Definition
Acceptability	An 'acceptable level' is the specified amount of environmental impact and risk that an activity may have that is tolerable, is consistent with all relevant principles, and does not compromise the environmental performance outcomes (EPOs). A definition of receptor-specific acceptable levels adopted in this OPP is provided in Section 8.
Consequence	The possible effect of an event, accident scenario or ongoing condition on the environment.
Hazard	A chemical, biological or physical condition that has the potential to cause harm to the environment.
Hydrocarbon Ecological EMBA	The Hydrocarbon Ecological EMBA (Figure 6-1) is relevant to the risk assessments for ecological receptors from unplanned hydrocarbon release events (for MDO and condensate) and is determined by the predicted spatial extent of hydrocarbon exposure at these thresholds: • Surface/floating: ≥10 g/m^2 (moderate) • Shoreline: ≥100 g/m^2 (moderate) • Dissolved: ≥50 ppb (medium) • Entrained: ≥100 ppb (high).
Hydrocarbon Social EMBA	The Hydrocarbon Social EMBA (Figure 6-2) is relevant to the risk assessments for social, economic, and cultural receptors from unplanned hydrocarbon release events (for MDO and condensate) and is determined by the predicted spatial extent of hydrocarbon exposure at these thresholds: • Surface/floating: ≥1 g/m^2 (low) • Shoreline: ≥10 g/m^2 (low) • Dissolved: ≥50 ppb (medium) • Entrained: ≥100 ppb (high). The Hydrocarbon Social EMBA incorporates lower thresholds for surface and shoreline hydrocarbon exposure that are associated with visible oil, but these thresholds are below concentrations at which ecological impacts are expected to occur.
Impact	Any change to the environment, whether adverse or beneficial, wholly or partly resulting from the planned activity.
Likelihood	The chance/probability of an unplanned consequence occurring.
OA	Operational area—the area in which all petroleum activities associated with the Development occur. The OA extends to a 5 km radius around the outermost expected position of subsea infrastructure. The OA is relevant to the impact and risk assessments for all planned activities and unplanned events except where an aspect-specific EMBA is defined.
Planned activity	The activity to be undertaken, including the services, equipment, products, assets, personnel, timing, duration, and location.
Risk	Applies to unplanned events. Risk is a function of the likelihood of the unplanned event occurring and the severity (consequence) of the environmental impact that arises from that event.

Term	Definition
Unplanned event	An event that results in some level of environmental impact and that may occur despite preventive safeguards in place. An unplanned event is not intended to occur during the activity.

7.1 Identification and description of the petroleum activity

All Development activities and potential emergency conditions relevant to the scope of this OPP were described and evaluated during the impact and risk assessment. For the purposes of description and evaluation, the activities associated with the Development were grouped into these phases:

- surveys
- drilling
- installation and commissioning
- operations
- decommissioning
- support activities (undertaken during all phases).

Support activities (Section 4.3.6) may occur throughout all phases of the Development and cover common activities on vessels, the MODU, helicopters or ROVs that are not process related, such as accommodation, sewage discharge, navigational lighting and refuelling.

These common activities generated by support activities are considered separately to avoid repetition in the impact and risk assessment. For example, this avoids repetition in the assessment of vessel strike in Physical presence–marine fauna for the numerous phases and activities that use vessels.

The activities described in this document are presented based on current technologies. CAPL will continue to seek and assess emerging technologies that may provide future opportunities to reduce risk and impact. Any new technology selected for the Development will be assessed and presented in subsequent applicable EPs.

The Development is described in detail in Section 4.

7.2 Identification of particular values and sensitivities

The presence of environmental values and sensitivities within the OA, Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA (the impact areas) is documented in Section 6 (Figure 6-1 and Figure 6-2). In accordance with Regulation 5(A) of the OPGGS(E)R, the particular values and sensitivities were identified as:

- the values of a declared World Heritage property within the meaning of the EPBC Act
- the values of a National Heritage place within the meaning of the EPBC Act
- the presence of a listed threatened species or listed threatened ecological community within the meaning of the EPBC Act
- the presence of a listed migratory species within the meaning of the EPBC Act

- any values and sensitivities that exist in, or in relation to, part or all of a Commonwealth marine area within the meaning of the EPBC Act
- other values, including social, economic, and cultural values.

7.3 Identification of relevant aspects

CAPL defines an aspect as an element of CAPL’s activities, products, or services related to an operation that has the potential to interact with the environment now or later (e.g. discharge, GHG emission).

After the Development was described, an assessment was done to identify potential interactions between the Development and the receiving environment by identifying the environmental aspects. The outcomes of stakeholder consultation also contributed to this scoping process.

Potential interactions with safety, health, and assets are outside the scope of this OPP.

Environmental aspects categorised for inclusion in the impact and risk assessment of this Development include:

- physical presence
- seabed disturbance
- air emissions
- GHG emissions
- light emissions
- underwater sound
- invasive marine pests
- planned discharges
- unplanned release.

Table 7-2 maps these environmental aspects against Development activities.

Table 7-2: Scoping of relationship between aspects and activities

Phase	Surveys		Drilling										Installation and commissioning								Operations					Decommissioning					Support activities (all phases)			
Aspect / Activity	Geophysical survey	Geotechnical survey	MODU positioning	Drilling top- and bottom-holes	Drilling fluids and cuttings	Cementing operations	Pressure-control equipment	Well suspension	Completions installation	Production tree installation	Well clean-up and testing	Well evaluation	Pre-lay works	Excavation and trenching	Installation of flowlines and pipelines	Installation of subsea structures	Post-lay works	Hydrotest & pre-commissioning	Commissioning	Start-up	Hydrocarbon system	Inspection	Maintenance and repair	Major repairs	Well intervention	Flush and clean	Well suspension and P&A	Flowline and MEG pipeline decommissioning	Umbilical decommissioning	Other subsea structures decommissioning	MODU operations	Vessel operations	Helicopter operations	ROV operations
Seabed disturbance		✓	✓	✓						✓			✓	✓	✓	✓	✓						✓	✓			✓	✓	✓	✓		✓		✓
Air emissions								✓			✓							✓							✓						✓	✓	✓	
GHG emissions											✓										✓				✓		✓				✓	✓	✓	
Light emissions											✓														✓						✓	✓		
Underwater sound	✓		✓	✓								✓		✓																	✓	✓	✓	
Planned discharges—MODU and vessels																															✓	✓		
Planned discharges—Subsea operations																✓		✓	✓			✓	✓	✓				✓		✓				
Planned discharges—Drilling				✓	✓	✓	✓		✓	✓	✓														✓		✓							
Physical presence—Other marine users																					✓										✓	✓		
Physical presence—Marine fauna																		✓					✓								✓	✓	✓	
Invasive marine pests																														✓	✓	✓		
Unplanned release—Solid objects													✓			✓								✓				✓	✓	✓	✓	✓		
Unplanned release—Minor LOC																✓		✓					✓								✓	✓		✓
Unplanned release—Vessel collision (MDO)																															✓	✓		
Unplanned release—Hydrocarbon system (condensate)				✓			✓		✓												✓				✓	✓	✓							

7.4 Identification of relevant environmental impacts and risks

Potential impacts and risks arising from the aspects were identified during a scoping exercise and then evaluated in detail. Table 7-3 shows the credible interactions between aspects, impact and risks, and receptors.

A detailed evaluation of the impact or risk is provided in the corresponding assessment in Section 8.

Table 7-3: Scoping of relationship between aspects and receptors

	Receptors	Physical						Biological						Commercial interests					Qualities		Heritage
Aspects	Impact/risk	Water quality	Sediment quality	Air quality	Climate	Ambient light	Ambient noise	Benthic habitats and associated communities	Coastal habitats and associated communities	Seabirds and shorebirds	Fishes, including sharks and rays	Marine reptiles	Marine mammals	Commercial fisheries	Shipping	Petroleum activities	Defence	Tourism	AMPs	KEFs	Heritage values
Seabed disturbance	Alteration of benthic habitats and associated communities							✓												✓	
	Localised and temporary reduction in water quality	✓																			
	Injury or mortality of marine fauna							✓			✓									✓	
	Localised and temporary reduction in sediment quality																				
	Change to values and sensitivities of KEFs																			✓	
	Change to cultural heritage values																				✓
Air emissions	Localised and temporary reduction in air quality			✓																	
GHG emissions	Contribution to the reduction of the global atmospheric carbon budget				✓																
	Contribution to the anthropogenic influence on the global climate system				✓																
Light emissions	Localised and temporary change in ambient light					✓															
	Attraction of light-sensitive species and in turn a change in predator–prey dynamics									✓	✓	✓									
	Change to cultural heritage values																				✓
Underwater sound	Localised and temporary change in ambient underwater sound						✓														
	Change to behaviour										✓	✓	✓								
	Auditory impairment, temporary / permanent threshold shift, recoverable or non-recoverable injury to marine fauna												✓								
	Change to cultural heritage values																				✓
Planned discharges—MODU and vessels	Localised and temporary reduction in water quality	✓																			
Planned discharges—Subsea operations	Localised and temporary reduction in water quality	✓																			
	Injury or mortality of marine fauna							✓													
	Localised and temporary reduction in sediment quality		✓																		
	Changes to values and sensitivities of KEFs		✓																	✓	

Aspects	Receptors	Physical						Biological						Commercial interests					Qualities		Heritage
	Impact/risk	Water quality	Sediment quality	Air quality	Climate	Ambient light	Ambient noise	Benthic habitats and associated communities	Coastal habitats and associated communities	Seabirds and shorebirds	Fishes, including sharks and rays	Marine reptiles	Marine mammals	Commercial fisheries	Shipping	Petroleum activities	Defence	Tourism	AMPs	KEFs	Heritage values
	Change to cultural heritage values		✓																		✓
Planned discharges—Drilling	Localised and temporary reduction in water quality	✓																			
	Localised and temporary reduction in sediment quality		✓																		
	Injury or mortality of marine fauna							✓			✓	✓	✓							✓	
	Alteration of benthic habitats and associated communities							✓													
	Change to values and sensitivities of KEFs																			✓	
	Change to cultural heritage values																				✓
Physical presence—Other marine users	Change to the functions, interests and activities of other marine users													✓		✓					
Physical presence—Marine fauna	Injury or mortality of marine fauna									✓	✓	✓	✓								
	Change to cultural heritage values																				✓
Introduction of invasive marine pests	Displacement of, or competition with, endemic species							✓													
	Change to values and sensitivities of KEFs																			✓	
	Change to cultural heritage values																				✓
Unplanned release—Solid objects	Alteration of benthic habitats and associated communities							✓													
	Localised and temporary reduction in water quality	✓																			
	Injury or mortality of marine fauna									✓		✓									
	Change to values or sensitivities of KEFs																			✓	
	Change to cultural heritage values																				✓
Unplanned release—Minor LOC	Alteration of benthic habitats and associated communities							✓												✓	
	Localised and temporary reduction in water quality	✓																			
	Injury or mortality of marine fauna										✓	✓	✓								
	Change to the functions, interests and activities of other marine users													✓							

Aspects	Receptors	Physical						Biological						Commercial interests					Qualities		Heritage
	Impact/risk	Water quality	Sediment quality	Air quality	Climate	Ambient light	Ambient noise	Benthic habitats and associated communities	Coastal habitats and associated communities	Seabirds and shorebirds	Fishes, including sharks and rays	Marine reptiles	Marine mammals	Commercial fisheries	Shipping	Petroleum activities	Defence	Tourism	AMPs	KEFs	Heritage values
	Change to cultural heritage values																				✓
Unplanned release—Vessel collision (MDO)	Alteration of benthic habitats and associated communities							✓											✓	✓	✓
	Alteration of coastal habitats and associated communities								✓												
	Localised and temporary reduction in water quality	✓																			
	Localised and temporary reduction in sediment quality		✓																		
	Injury or mortality of marine fauna									✓	✓	✓	✓								
	Change to the functions, interests and activities of other marine users													✓	✓	✓	✓	✓			✓
	Change to values and sensitivities of AMPs																		✓		
	Change to values and sensitivities of KEFs																			✓	
	Change to values and sensitivities of the Ningaloo Coast																				✓
	Change to cultural heritage values																				✓
Unplanned release—Hydrocarbon system (condensate)	Alteration of coastal habitats and associated communities								✓										✓	✓	✓
	Localised and temporary reduction in water quality	✓																	✓	✓	✓
	Injury or mortality of marine fauna							✓		✓	✓	✓	✓						✓	✓	✓
	Change to the functions, interests and activities of other marine users													✓	✓	✓	✓	✓	✓		✓
	Changes to values and sensitivities of AMPs																		✓		
	Change to values and sensitivities of KEFs																			✓	
	Change to values and sensitivities of the Ningaloo Coast																				✓
	Change to cultural heritage values																				✓

7.5 Evaluation of impacts and risks

After identifying the credible interactions between aspects, impact and risks, and receptors, each impact and risk was evaluated. This evaluation involved determining the source of each impact and risk, consequence level of each impact and risk and, for risks, the likelihood of the consequence occurring. The overall risk level was then determined using the Integrated Risk Prioritization Matrix (Table 7-4).

Table 7-4: Chevron Corporation's Integrated Risk Prioritization Matrix

1. The matrix shall only be applied by qualified personnel within an appropriate qualitative risk assessment framework
2. The matrix guidance is intended to assist users in the differentiation among consequence categories and factual circumstances or conditions of a particular scenario may warrant a different categorization than is presented in this guidance. In such circumstances, the consequence language of the matrix itself controls.

Likelihood Descriptions	Expected to occur *Once in 1–10 times the activity is performed*	Likely	**1**	6	5	4	3	2	1
	Conditions may allow to occur *Once in 10–100 times the activity is performed*	Occasional	**2**	7	6	5	4	3	2
	Exceptional conditions may allow to occur *Once in 100–1,000 times the activity is performed*	Seldom	**3**	8	7	6	5	4	3
	Reasonable to expect will not occur *Once in 1,000–10,000 times the activity is performed*	Unlikely	**4**	9	8	7	6	5	4
	Has occurred once or twice in the industry *Once in 10,000–100,000 times the activity is performed*	Remote	**5**	10	9	8	7	6	5
	Rare or unheard of *Once in 100,000–1,000,000 times the activity is performed*	Rare	**6**	10	10	9	8	7	6

	6	**5**	**4**	**3**	**2**	**1**
Consequence Descriptions*	Incidental	Minor	Moderate	Major	Severe	Catastrophic
	Limited impact	Localised, short-term impact	Localised, long-term impact or widespread, short-term impact	Localised, persistent impact or widespread long-term impact	Widespread, persistent impact or landscape-scale, long-term impact	Landscape-scale, persistent impact
Examples are given to help guide the user on assessing the appropriate consequence category and should not be interpreted as definitive bounds. *This guidance should be considered within the specific scenario context and supported by subject matter expert advice.*	*Negligible disturbance or impact, and/or the impact is reversable within a very short period of time (e.g., days to months).*	*Impact occurs at a local scale or affects a minor part of a species habitat or population, but the impact is recoverable in the short-term (e.g., <2 years).*	*Impact occurs at a local scale or affects a minor part of a species habitat or population, but the impact is recoverable in the long-term (e.g., 2-10 years),* ***or*** *impact affects a wide area, or affects a significant proportion of a habitat or population (e.g., >10%) but the impact is recoverable in the short-term (e.g., <2 years).*	*Impact occurs at a local scale or affects a minor part of a species habitat or population, and the impact is persistent (e.g., >10 years for recovery or never expected to fully recover),* ***or*** *impact affects a wide area, or affects a significant proportion of a habitat or population (e.g., >10%) but where the impact is recoverable in the long-term (e.g., 2-10 years).*	*Impact affects a wide area or affects a significant proportion of a species habitat or population (e.g., >10%) and the impact is persistent (e.g., >10 years or never expected to fully recover),* ***or*** *impact affects a very large area, or the majority or all of a habitat type or population and/or results in loss of ecosystem function, and lasts long-term (e.g., 2-10 years).*	*Impact affects a very large area or the majority or all of a species, habitat type.*
Definitions	An individual is an organism; a population is a group of individuals of one species that occupy a given area at the same time; a community is an association of interacting populations; and an ecosystem is the organisms (populations) in a community and the associated abiotic (non-living) factors with which they interact.					
***Note**	Consequence category needs to account for the resilience of the receptor. For example, impacts to long-lived, RTE (Rare, Threatened and Endangered) species with low resilience may be ranked higher than impacts to the same number of individuals of short-lived, common species with high resilience. Localized, widespread or landscape scale may be considered relative to the distribution and abundance of the receptors examined. For example, if a receptor is endemic to a small area and is impacted, this would potentially be considered a 'landscape-scale' impact for that receptor, rather than localized.					

7.5.1 Source of impact or risk

The Development includes phases and associated activities that are common, well-understood situations, which are normal business for CAPL. CAPL is competent in applying these phases and has continuous proven experience of undertaking these phases in accordance with current good practice, in the OA.

Although the Development represents normal business for CAPL, the timing of each phase within each field is undefined and presents some uncertainty. This uncertainty is addressed by conservative assumptions of the source of each impact and risk for the Development, such that the precautionary approach is applied to define the source of each impact and risk (Ref. 270). The source of each impact and risk will be evaluated to determine the worst-case scenario that can be realised, such as the maximum number of vessels within the OA at one time or the longest duration for a phase for a field.

Similarly, as the exact location of infrastructure is not yet known, or multiple locations are under consideration; the OA has been defined based on a 5 km buffer around the outermost or longest routes. This gives a conservative spatial extent to use for impact assessment.

The conservative assumption for the source of each impact and risk is then defined and used to evaluate the consequence of each impact and risk and likelihood for each risk. This approach will ensure, under the precautionary principle, the worst-case scenario is used for the characterisation of the source of the aspect to ensure confidence in the next stages of the impact and risk evaluation process.

7.5.2 Consequence

The consequence levels, which are briefly described in the Integrated Risk Prioritization Matrix (Table 7-4), are determined by considering:

- the spatial scale or extent of potential interactions within the receiving environment
- the nature of the receiving environment (within the spatial extent), including proximity to sensitive receptors, relative importance, and sensitivity or resilience to change
- the impact mechanisms (cause and effect) of the aspect within the receiving environment (e.g. persistence, toxicity, mobility, bioaccumulation potential)
- the duration and frequency of potential effects and time for recovery
- the potential degree of change relative to the existing environment or to acceptability criteria.

To inform the consequence evaluation, data may be drawn from engineering analysis, generic industry data and operator-specific data to provide confidence in the assigned consequence level. Different techniques to inform the consequence evaluation may be required for complex aspects, such as consequence modelling to define the spatial scale of underwater sound relative to sensitive receptors (Ref. 270).

Particular values and sensitivities may be grouped together in the same impact assessment row in Section 8, if they have the same consequence ranking and it is appropriate to nature and scale (e.g. ‘marine fauna’).

7.5.3 Likelihood

For environmental impacts where a planned emission or discharge results in a known change to the environment no likelihood factor is added to the assessment.

For risks where the aspect or event may lead to environmental impacts under certain circumstances, the likelihood (probability) of the defined consequence occurring is determined. The likelihood is considered by assuming that all control measures are in place. The likelihood of a consequence occurring was identified using one of the six likelihood categories, as shown in Table 7-4.

Note: An aspect can result in both environmental impacts and risks. Each impact and/or risk is defined and evaluated—an impact is ranked with a consequence level only, whereas a risk includes an evaluation of both consequence and likelihood.

7.5.4 Quantification of the level of risk

The Integrated Risk Prioritization Matrix (Table 7-4) was applied during the environmental risk assessment workshops. This matrix uses consequence and likelihood rankings of 1 to 6, which when combined, result in a residual risk level between 1 (highest risk) and 10 (lowest risk) (Table 7-5). Risk assessment outcomes are based solely on assessment of risk to the environment (as defined under the OPGGS(E)R).

Table 7-5: Residual risk descriptors

Residual risk level	1	2	3	4	5	6	7	8	9	10
Descriptor	Very high			High		Moderate	Low		Very low	

7.6 Impact and risk acceptance criteria

Regulation 5D (6) of the OPGGS(E)R requires that this OPP:

(d) sets out appropriate environmental performance outcomes that:

(i) are consistent with the principles of ecologically sustainable development; and

(ii) demonstrate that the environmental impacts and risks of the project will be managed to an acceptable level.

NOPSEMA's guidance (Ref. 11) on defining an acceptable level of impact and risk indicates that an acceptable level is the specified amount of environmental impact and risk (evaluated in accordance with AS/NZS ISO 31000:2018 (Ref. 271) and HB 203:2012 (Ref. 272)) that the project may have regarding all relevant contexts including, but not limited to:

- principles of ecologically sustainable development (ESD)
- legislative and other requirements (including laws, policies, standards, conventions)
- internal context (titleholder policy, culture, processes, standards and systems)
- external context (existing environment, stakeholder expectations).

In the EP phase, there is also a requirement to demonstrate that the environmental impacts and risks for each activity are reduced to As Low As

Reasonably Practicable (ALARP) (Ref. 273). The ALARP framework considers the magnitude of impacts and risks along with these guiding factors:

- activity type
- risk and uncertainty
- stakeholder influence.

7.6.1 Principles of ESD

The principles of ESD are considered in Table 7-6 in relation to acceptability evaluations.

Under the EPBC Act, the decision-maker must also consider the precautionary principle in determining whether to approve the taking of an action. The precautionary principle (section 391(2) of the EPBC Act) is that lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment where there may be threats of serious or irreversible environmental damage.

Table 7-6: Principles of ESD in relation to petroleum activity acceptability evaluations

Principles of ESD	How they have been applied
(a) decision-making processes should effectively integrate both long-term and short-term economic, environmental, social, and equitable considerations	CAPL's impact and risk assessment process integrates long-term and short-term economic, environmental, social, and equitable considerations. This is demonstrated through the Integrated Risk Prioritization Matrix (Table 7-4), which includes provision for understanding the long-term and short-term impacts associated with its activities. As this principle is inherently met by applying the assessment process, it is not considered separately for each evaluation.
(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation	Evaluate if there is the potential for: • threats of serious or irreversible environmental damage: – consequence level between Severe [2] and Catastrophic [1] and • lack of full scientific certainty. If there is scientific uncertainty, use a precautionary approach to implement control measures to mitigate the threat of serious or irreversible environmental damage. The Development includes phases and associated activities that are common, well-understood situations that are normal business for CAPL. However, details on the timing of each phase within each field for the Development are not known and introduces some uncertainty. Evaluation of all aspects against this principle will be conducted as a precautionary approach.
(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations	Evaluate if there is the potential to affect the maintenance of health, diversity, and productivity of the environment; by determining if there is potential for threats of serious or irreversible environmental damage: – consequence level between Severe [2] and Catastrophic [1]. The OPP assessment process also provides for public comment on the Development and all associated impacts and risks. The views, concerns, perceptions, and values of stakeholders will be addressed and assessed in the final OPP following the public comment period. A summary of relevant public comments and stakeholder feedback and how they have been addressed in the Development

Principles of ESD	How they have been applied
	against each aspect is demonstrated against the external context acceptability criteria. This process will enable the present generation to ensure the effects of health, diversity, and productivity of the environment is maintained.
(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making	Provide evidence that the impact and risk assessment of all aspects during alternatives analysis and impact and risk evaluation assessments considers the potential effects on biological diversity and ecological integrity.
(e) improved valuation, pricing, and incentive mechanisms should be promoted	Not considered relevant for the Development acceptability demonstrations.

7.6.2 Legislative and other requirements

Legislative and other requirements include:

- requirements from Australian legislation and regulations
- relevant Commonwealth government policies
- relevant Commonwealth government guidance
- relevant industry standards
- relevant international conventions.

Matters protected under Part 3 of the EPBC Act are also considered under this acceptability criterion such that impacts and/or risks are consistent with relevant policies, guidelines, threatened species recovery plans, management plans, management principles and so on.

Evaluation of this acceptability criterion against all aspects will confirm and recognise CAPL as a competent organisation with proven ability and experience to apply current good practice to manage well-understood impacts and risks arising from the Development.

7.6.3 Internal context

The impact and risk assessment for this OPP was undertaken in accordance with CAPL's ABU OE Risk Management Process (Ref. 274) and using Chevron Corporation's Integrated Risk Prioritization Matrix (Table 7-4). This approach generally aligns with the processes outlined in ISO 31000:2018 Risk management—Principles and guidelines (Ref. 271) and the HB 203:2012 Managing environment-related risk (Ref. 272).

This approach will include a review of the aspect against requirements under CAPL's management systems and will ensure that impact and risk management is consistent with company policy, culture, and standards.

The impact and risk assessment process involved consulting with CAPL's Health, Safety and Environment (HSE), commissioning, start-up, operations, maintenance, engineering, and emergency response personnel who have gained experience during the GFP and GS2, and more broadly from Chevron's operations globally.

7.6.4 External context

The impact and risk assessment process was also informed by stakeholder engagement (Section 3).

Existing and new stakeholders for the Development were consulted when developing this first iteration of the OPP, which is published for public comment (Stage 1 of the OPP assessment). Feedback received during the public comment period will be reviewed and summarised in the OPP during Stage 2 of the assessment by the regulator.

7.6.5 Defined acceptable level

The acceptable level of impact and/or risk is a function of the magnitude of the impact and/or risk, stakeholder concerns/issues, ESD principles and legislative requirements.

If an aspect associated with the Development is listed as a threat to a protected matter under a document made or implemented under the EPBC Act or identified as an aspect of concern to a listed conservation value under an EPBC Act Marine Bioregional Plan, CAPL will define an acceptable level of impact and risk that is consistent with those documents or plans.

CAPL will consider these types of documents when defining the acceptable level of impact and/or risk:

- bioregional plans
- AMP plans
- conservation advice
- recovery plans
- government guidelines.

Receptors that are protected matters under the EPBC Act generally have defined objectives listed in “Relevant environmental legislation and other requirements” for relevant aspects. If there are defined objectives under the EPBC Act for the protected matter (receptor), they will be adopted as the defined acceptable level. Receptors not considered protected matters under the EPBC Act will adopt the overall objective for the receptor in relevant legislative requirements.

7.6.6 Summary of acceptance criteria

Table 7-7 outlines the criteria that CAPL used to demonstrate that impacts and risks from each identified aspect are acceptable.

Table 7-7: Acceptability criteria

Criteria	Test
Principles of ESD	Evaluate all aspects of the Development against ESD principles (b), (c) and (d) (Table 7-6).
Relevant environmental legislation and other requirements	Confirm that impact and risk management is consistent with relevant Australian environmental management laws and other regulatory or statutory requirements.
Internal context	Confirm that all required control measures were identified for this aspect through CAPL’s management systems, and that impact and risk management is consistent with company policy, culture, and standards.
External context	Consider any feedback regarding this aspect made by stakeholders, and how they can be addressed.

Criteria	Test
Defined acceptable level	Summarise the outcomes of the above acceptability criteria to confirm the aspect is consistent with the defined receptor objectives highlighted in relevant environmental legislation and other requirements.

7.7 Environmental performance outcomes

The OPGGS(E)R defines environmental performance outcomes (EPOs) that relate to the management of the identified environmental risks, as:

‘a measurable level of performance required for the management of environmental aspects of an activity to ensure that environmental impacts and risks will be of an acceptable level.’

For risks, the EPO will be that the risk event does not occur. For impacts to protected matters, the EPO will be based on the performance requirement as detailed in the relevant EPBC management plan.

Adopted controls provide details of the way EPOs will be achieved and are subsequently provided in EPs. They are required to have environmental performance standards (EPSs) set with appropriate measurement criteria to monitor the performance of the control measures and determine whether the EPOs and EPSs have been met during the activity. No further information about control measures, EPSs and measurement criteria are presented in the OPP.

The implementation strategy (Section 10) ensures arrangements are in place to ensure the EPOs are achieved, and control measures and EPSs defined in subsequent EPs are effective.

8 Environmental risk assessment and management strategy

Each environmental aspect assessment is organised into these subsections:

- source—describes the activities that may lead to the aspect occurring
- impact and risk evaluation—describes the potential impacts arising from the aspect and the receptors that may be impacted
- determination of acceptability—provides justification for the determination of acceptability
- environmental performance—provides the EPOs and adopted control measures.

The impact and risk assessments in this OPP are based on conservative assumptions of Development activities, as understood at the time of writing. Evaluations in subsequent EPs will revalidate levels of impact and risk and acceptability, as needed.

Table 8-1 summarises the worst-case impacts and risks that were identified and evaluated for each aspect.

Table 8-1: Summary of impact and risk evaluation

Section	Aspect	Impact	Risk			Acceptable
		C	C	L	RR	
8.1	Seabed disturbance	4	5	4	7	Yes
0	Air emissions	6	-	-	-	Yes
0	Greenhouse gas emissions	6	-	-	-	Yes
0	Light emissions	6	6	5	10	Yes
0	Underwater sound	5	5	3	7	Yes
0	Planned discharges—MODU and vessels	6	6	6	10	Yes
0	Planned discharges—Subsea operations	6	5	5	9	Yes
8.8	Planned discharges—Drilling	5	5	3	7	Yes
0	Physical presence—Other marine users	-	6	3	8	Yes
0	Physical presence—Marine fauna	-	6	3	8	Yes
0	Introduction of invasive marine pests	-	3	6	7	Yes
0	Unplanned release—Solid objects	-	5	5	9	Yes
0	Unplanned release—Minor LOC	-	5	5	9	Yes
0	Unplanned release—Vessel collision (MDO)	-	5	5	9	Yes
0	Unplanned release—Hydrocarbon system	-	5	5	9	Yes

C = Consequence; L = Likelihood; RR = Residual Risk

8.1 Seabed disturbance

8.1.1 Source

Development activities on the seabed (including sampling, excavating, and placing equipment or infrastructure) have the potential to cause seabed disturbance.

Seabed disturbance is considered in this impact assessment as either long-term disturbance (e.g. from infrastructure likely to remain on the seabed for the life of the Development) or short-term disturbance (e.g. from anchoring).

The Development's exact direct disturbance footprint from placing subsea infrastructure is not yet finalised given the early stage in the Development process. CAPL will provide more precise areas of seabed disturbance and document these in activity-related EPs. To allow for environmental impact assessment in the OPP, CAPL has proposed a conservative long-term disturbance area, which is described in Section 8.1.1.7.

Table 8-2 identifies activities within each phase that have the potential for seabed disturbance in the OA.

Table 8-2: Phases and activities that have the potential for Seabed disturbance

Phase	Activity
Surveys	Geotechnical survey
Drilling	MODU positioning Drilling top- and bottom-holes Completions installation
Installation and commissioning	Pre-lay works Excavating and trenching Installation of flowlines and pipelines Installation of subsea structures Post-lay works
Operations	Maintenance and repairs Major repairs
Decommissioning	Well suspension and P&A Flowline and MEG pipeline decommissioning Umbilical decommissioning Other subsea infrastructure decommissioning
Support activities	Vessel operations ROV operations

8.1.1.1 Surveys

Geotechnical surveys comprise in situ testing and sampling of the sediments of the sea floor. The indicative footprint associated with geotechnical equipment is ~2 m^2 per deployment. Multiple deployments may be required at each location, giving a conservative footprint of ~20 m^2 per survey location.

If drilling cores are taken, the footprint for the borehole sampling unit is expected to be ~14 m^2 at each location. The sampling equipment disturbs the sea floor because it removes the shallow or surface sediments and rock.

Geotechnical surveys are conducted at various times during the Development, including before drilling and installation for each field.

Transponders are used to help position the MODU above the proposed well location. They are attached to clump weights and lowered to the seabed temporarily and then retrieved after positioning the MODU.

The geotechnical survey identifies final locations for the subsea infrastructure, so it is assumed that these small areas of seabed disturbance will be included in the footprint of the actual infrastructure, except in the case of unsuitable sites.

The area of disturbance and impact caused by geotechnical sampling from any unsuitable sample sites will be limited (<20 m^2 each), and within the long-term disturbance area and therefore, is not discussed further in this section.

8.1.1.2 Drilling

Drilling is done using a MODU, which will either be moored using drag embedment anchors, kept on location with DP using thrusters, or connected to the seabed via legs with spud cans (for a jack-up).

If a mooring system is used, up to 16 drag embedment anchors will be required per location. The indicative footprint of the 16 anchors is estimated to be 28,480 m^2 (0.02848 km^2) per DC. If the DP option is used, there will be no seabed disturbance from the MODU. If the jack-up system is used, the indicative footprint of the 3 legs is estimated to be 950 m^2 per DC.

The wellhead will be installed on the seabed at each well. The total footprint of the wells at each field is estimated to be 336 m^2.

The disturbance for the well top-holes is included in the long-term disturbance area; however, the disturbance from positioning of the MODU (if undertaken) is considered short-term (Section 8.1.1.7).

Discharge of drilling cuttings, fluids and cement to the seabed is also planned for the Development. The environmental impacts associated with planned drilling discharges is evaluated in Section 8.8.

8.1.1.3 Installation and commissioning

Flowlines, MEG pipelines and other subsea infrastructure may remain on the seabed for the Development’s whole life. Any stabilisation materials, such as concrete mattresses, placed on the seabed during pre- or post-lay works may also remain for the duration of the Development.

Mattresses, grout bags, foundations, adjustable pipe supports, and global buckling mitigation structures used in pre-lay and post-lay works have indicative footprints up to 2,100 m^2 each, though most will be significantly smaller. The total number to be used is unknown at this stage.

Excavation and trenching will be required at the scarp crossing of the C&D flowline and MEG pipeline. This trench is estimated to be ~12 m wide, ~50 m long and ~8 m deep (~600 m^2 excavation). Spoil generated from the excavation will be left in situ. Excavation and trenching may also be required at other points along the flowline and MEG pipeline routes but is unlikely.

The largest flowline to be used in the Development will have a 24″ diameter. The diameters of MEG pipelines and umbilicals will be significantly smaller. Subsea infrastructure will sit on the seabed; this infrastructure has various dimensions and is described in Section 4.2.

A conservative area of direct seabed disturbance around subsea infrastructure and equipment has been adopted for the impact assessment. The long-term disturbance area (Section 8.1.1.7) is a 250 m radius around the DCs and tie-in locations of each flowline, and a 30 m wide corridor along flowline, MEG pipeline and umbilical routes, with a contingency built in. The total long-term disturbance area is ~18.86 km^2. The intent of the long-term disturbance area is to allow for the footprint of all these structures (e.g. pipeline termination structures, in-line tees, MEG pipelines) and flowline stabilisation equipment (e.g. concrete mattresses, grout bags).

An initiation anchor or suction pile will be deployed to fix the end of the flowline or MEG pipeline in place at the beginning of the lay; these are short-term as they will be recovered from the seabed at the end of the lay process. Initiation anchors and wires are estimated to cause a footprint of ~30,000 m^2.per flowline or MEG pipeline. One anchor and initiation wire per flowline or MEG pipeline is expected to be used and these will be positioned outside of the long-term disturbance area. The anchor or pile may need to be repositioned in the event that load testing prior to the commencement of pipelay is unsuccessful.

If a cyclone occurs during subsea infrastructure installation, some infrastructure may need to be temporarily stored on the seabed, so that installation vessels can safely demobilise (known as ‘wet parking’). This is not a planned activity; however, if wet parking is required, the footprint of the largest individual structure is no more than 2,100 m^2. This may occur outside the long-term disturbance area.

8.1.1.4 Operations

The maintenance and repair activities that may be required during the operations phase include installing foundations, grout bags and concrete mattresses, excavating alongside infrastructure, adding equipment adjacent to infrastructure, and water jetting to remove growth or deposits. The frequency and scale of such activities is unknown.

In the unlikely event of major repairs, equipment may be stored temporarily on the seabed (wet parked) beside the area of flowline that needs to be repaired. It is estimated that the footprint of this disturbance would be ~800 m^2. This area of short-term laydown would be outside the long-term disturbance area (Section 8.1.1.7).

If a battery system is required for temporary power supply, it will be positioned within the long-term disturbance area. If a vessel downline is used, ~13,600 m^2 will be located outside the long-term disturbance area; and will be retrieved after use (Section 4.2.5.1).

8.1.1.5 Decommissioning

Well suspension and P&A may be carried out using a MODU similar to that used for drilling.

Flowlines, umbilicals, and other subsea structures may require preparatory works using jetting, MFE or mechanical grab to remove sediment build-up. Flowlines may be decommissioned using the cut and lift method. Cutting flowlines and the possible capping of sections causes disturbance to the seabed in the area of the flowline.

The footprint of seabed disturbance from decommissioning is estimated to be the same as for mooring activities (if the MODU is moored), and installation of flowlines, umbilicals, and other subsea structures (Section 8.1.1.3). These activities re-disturb an already disturbed area; therefore, this area was not included in the total seabed disturbance footprint in Section 8.1.1.7.

CAPL's decommissioning philosophy is described in Section 4.3.5.1.

8.1.1.6 Support activities (all phases)

Vessels are required in all phases of the Development and typically use DP. In some unlikely circumstances, vessels may require anchoring, so it is included here as a contingency.

Vessels may be moored using a swing anchor, where a single anchor is connected to a chain that sits on the seabed and can drag in all directions around the anchor while the vessel is moored. A vessel anchored with a swing anchor at a depth of 80 m could have a disturbance area of up to ~57,000 m^2. This conservative value is considered in the impact assessment. Anchoring is considered a short-term disturbance.

In the unlikely event that an ROV is required to park on the seabed, this will occur within the long-term disturbance area.

8.1.1.7 Seabed disturbance area

To allow for environmental impact assessment in the OPP, seabed disturbance has been classified as either long-term disturbance or short-term disturbance.

As described in Section 4.1.3.1, given the Development's exact long-term infrastructure disturbance footprint is not yet known, a conservative disturbance area has been adopted for the impact assessment. The long-term disturbance area comprises the direct footprint of infrastructure that may remain on the seabed from installation through to decommissioning as well as a buffer area either side of the flowlines, pipelines and umbilicals, and an area around the DCs and tie-ins. Assigning this buffer to all corridors and tie-in points, even those requiring less infrastructure, provides a conservative estimate.

The long-term disturbance area has been calculated using the following assumptions:

- a 30 m wide lay corridor along the production flowline, MEG pipeline and umbilical routes (i.e. ~15 m either side from the centre point of the infrastructure). While the flowlines, pipelines and umbilicals range from approximately 5" – 24" wide, the corridor allows for all other infrastructure or equipment associated with the production flowlines, MEG pipelines and umbilicals, including:
  - concrete mattresses/grout bags/adjustable pipe supports
  - in-line tees, global buckling mitigation structures
  - spoil from trenching (if required).
- a 250 m radius around the DCs and GFP tie-in locations. This footprint is wider than the flowline/umbilical corridor to allow for associated infrastructure and equipment that may include:
  - foundations
  - manifolds
  - production trees and tie-in structures
  - pipeline end terminations (PLET), pipeline end manifolds (PLEM)

- pipeline termination structures
- jumpers/spools
- control distribution units (CDUs)
- slug catchers
- over-pressure protection structures
- some contingency power supply infrastructure (Section 4.2.5.1).

Short-term disturbance is caused when infrastructure or equipment has contact with the seabed during a particular phase but is removed at or before the end of that phase. Where short-term equipment will contact the seabed within the long-term disturbance footprint, it is implicitly accounted for in the long-term disturbance area. Hence, the short-term disturbance area includes only short-term disturbance that will occur outside of the long-term disturbance area described above.

CAPL has included a 50% contingency to calculate both the long-term and short-term disturbance areas. The long-term disturbance area contingency allows for additional infrastructure that may go beyond the radius at some tie-in locations and the potential for some MEG pipelines to run in a separate route to the production flowlines. The short-term disturbance area contingency allows for any changes to footprints or placement of short-term infrastructure or equipment. For clarity, it is not intended that the 50% contingency will be used at a single site within the OA but will be used, when required, across the Development activities.

Table 8-3 summarises the total area of seabed disturbance for the long-term and short-term disturbance areas.

Table 8-3: Total area of seabed disturbance – long-term and short-term

Phase	Description	Approx. disturbance footprint (m^2)
Long-term subsea infrastructure (long-term disturbance area)		
Installation to decommissioning	Assumes 30 m corridor for flowlines, MEG pipelines and umbilicals, 250 m radius around DCs and GFP tie-in locations, Includes all installed equipment and infrastructure.	12,566,886
Total long-term disturbance plus 50% contingency		18,850,329
Short-term Disturbance (temporary disturbance outside long-term disturbance area)		
Drilling, installation, operations, support activities and decommissioning	Includes short-term activities associated with drilling, installation, operations, support activities and decommissioning.	644,700
Total short-term disturbance plus 50% contingency		967,050

8.1.2 Impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the OA that may be impacted by seabed disturbance:

- water quality
- benthic habitats and associated communities
- fishes, including sharks and rays
- KEFs
- Cultural heritage value: Traditional Owners.

The OA represents the boundary within which all final routes and infrastructure will be located post final design (Section 4.2.1). As such, the benthic survey (Appendix A) and other baseline reports for the Development cover the full extent of the OA to ensure that all impacts and risks within the OA are adequately assessed. While the total long- and short-term disturbance footprint (including the 50% contingency) (Table 8-3) represents ~0.007 % of the total OA area, the impacts and risks of the Development have been assessed over the entire extent of the OA to ensure that all potential final infrastructure locations have been evaluated. Table 8-4 details the impact and risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to seabed disturbance in the OA.

Marine mammals and marine reptiles include species that may feed on the seabed, but they are not demersal species and can occur and transit vertically through the entire water column. Although a reduction in food source may have an indirect effect on mammals and reptiles, there is no significant source of benthic foraging habitat (e.g. seagrass) within the OA. Therefore, seabed disturbance is not expected to result in injury or mortality to these values.

Although fish may potentially be impacted by seabed disturbance (Table 8-4), the area of influence will be highly localised and is not expected to result in a change in the viability of the population of commercially important species. Only one State- and 3 Commonwealth-managed fisheries have recorded historical fishing effort in the OA.

Therefore, impacts to marine mammals, marine reptiles and commercial fisheries from seabed disturbance are not expected, and are not evaluated further.

Table 8-4: Risk evaluation for Seabed disturbance

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Seabed disturbance may result in: • Localised and temporary reduction in water quality	6	A localised and temporary reduction in water quality may result in: • Injury or mortality of marine fauna	5	4	Low (8)
Seabed disturbance may result in: • Alteration of benthic habitats and associated communities	4	An alteration of benthic habitats and associated communities may result in: • Injury or mortality of marine fauna	5	4	Low (8)

Impact and/or risk level summary					
		An alteration of benthic habitats and associated communities may result in: • Change to values and sensitivities of KEFs	4	4	Low (7)
		Seabed disturbance may result in: • Change to cultural heritage values	4	4	Low (7)

Risk evaluation
Water quality
Localised and temporary reduction in water quality Reduction in water quality is expected to occur when sediment on the seabed is disturbed and becomes suspended in the water column when infrastructure or equipment (such as anchors) is placed on, or removed from the seabed, and during excavation and trenching. The resulting turbidity will remain until the suspended sediments settle back onto the sea floor. Water profiles were consistent across the OA and quality is generally representative of the surrounding region (Ref. 105, Appendix A). Water column turbidity is variable, and storms and cyclones often cause large amounts of sediment to be lifted into the water column over large areas. The impacts will be localised to around the infrastructure, anchoring positions and trenching locations. The impacts will be temporary, with increased turbidity expected during the relevant activities. After the activities are completed, sediments will gradually settle back to the seabed and water quality will return to background levels. Excavation and trenching are required where flowlines, pipelines or umbilicals are required to cross the scarp to create a suitable seabed profile for the flowline. The trench required is estimated to be no more than 12 m wide, 50 m long and 8 m deep (~600 m^2 excavation). Spoil generated from the excavation will be left in situ adjacent to the excavation—it will not be collected and transported to a spoil ground. Excavation or trenching may be required at other locations along the route of the flowlines but is unlikely to be used along the vast majority of the length. Sediments may also be resuspended during decommissioning, in particular from water jetting and MFE used to unbury structures. Trenching, which results in suspended sediment, is likely to cause more significant water quality changes than other Development activities. A turbidity survey was conducted as part of the Wheatstone Project to record variations in the turbidity levels during trenching operations (Ref. 275; Ref. 276). The results showed that turbidity levels may reach 80 Formazin Turbidity Units (FTU) (with a maximum background turbidity level of 5 FTU) 50 m from the trench area. However, the average turbidity level 50 m from the trench area was recorded at ~15 FTU. The results also suggested that a turbid plume may be evident up to 70 m from the trenching location, depending on environmental conditions. Within 2 hours of ceasing trenching operations, the turbidity level had returned to background or very close to background level (Ref. 275; Ref. 276). Hence, even with the most significant changes to water quality (resulting from trenching), the impact is likely to last no more than a few hours and be localised within 70 m of the infrastructure footprint. In addition, compared to natural events such as storms and cyclones, the turbidity generated from installation represents only a minor source of localised resuspended sediment at any location. The potential impact associated with seabed disturbance is limited to a short-term, direct reduction in water quality within a localised area immediately adjacent to the Development’s activities. No regional scale impacts to water quality are expected. The consequence of seabed disturbance causing a change in water quality has been evaluated as Incidental (6).
Benthic habitats and associated communities
Alteration of benthic habitats and associated communities Alteration of benthic habitats and communities occurs when infrastructure or equipment is placed on the seabed, or the seabed surface is disrupted by activities including trenching and excavation.

Risk evaluation
The total estimated area of the conservative long-term disturbance area where infrastructure and equipment will be installed is ~18.86 km^2. In addition to this long-term physical presence of infrastructure, there is also ~0.97 km^2 of short-term seabed disturbance outside the long-term disturbance area (within the OA). Temporary placement of equipment on the seabed from MODU mooring, vessel anchoring, and geotechnical surveys will result in localised, short-term, small-scale habitat alteration. MODU mooring will have the largest total estimated footprint 28,480 m^2 per DC. Results of the benthic survey found benthic habitats in the OA comprises mostly a mixture of flat bare substrates, and isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Ref. 110; Ref. 112; Ref. 105, Appendix A). A literature review conducted by National Energy Resources Australia (Ref. 277) suggests that where seabed sediments are soft and there are no sensitive communities or other underwater obstructions, damage caused by anchoring is likely to be minimal and any disturbance is generally short-term. The open ocean environment in the OA contains underlying conditions that support recolonisation and recovery; full recovery of soft sediment assemblages from physical disturbance could take 64–208 days following physical disturbances of different intensities (Ref. 277; Ref. 278). Infrastructure will be installed on the seabed and remain throughout the life of the Development, resulting in a long-term interaction. This infrastructure includes manifolds, wellheads and other infrastructure around tie-in and DC locations, plus production flowlines, MEG pipelines and umbilicals. Excavation and trenching will be required at the scarp crossing, and spoil that is removed will be placed onto the adjacent seabed. A seven-year field survey on sedimentation-induced burial of marine pipelines was undertaken in the NWS region. Results indicated that subsea pipelines experienced significant lowering into the seabed due to sediment mobility and scour, with most lowering occurring within 2 years of pipelay (Ref. 279; Ref. 280). This appeared to result from sustained ambient tidal and soliton currents as opposed to large storms. Biological activity such as tunnelling under equipment by crustaceans and demersal fish also contributed to embedment. The low profile of flowlines (~24″) means it is likely that partial, if not total, burial will occur over time. The highest structure to be installed during the Development is estimated to be ~13 m above the seabed—burial is not likely at this height. However, there is potential for these larger subsea structures to provide artificial structural habitat (refer to Fishes assessment, below). The total footprint of this infrastructure has been conservatively estimated (based on the long-term disturbance area) to be ~18.86 km^2 (Section 8.1.1.7). The seabed areas where this infrastructure will be installed is mostly soft unconsolidated sand/mud and is highly represented in the North-west Marine Region (NWMR), which covers ~1,070,000 km^2 (Ref. 103; Ref. 104). Consequently, the indicative seabed disturbance area represents significantly <0.001% of the footprint of the NWMR. The potential disturbance from infrastructure installation and spoil left in situ is considered relatively localised given the location in the open ocean containing mostly bare sediment, against the widespread nature of soft sediment infauna communities characteristic of the NWS region. Any impact will be limited to the immediate vicinity of the disturbance, and thus the extent of potential impact is relatively localised. Even though soft sediment habitats are not known to be sensitive to disturbance given the long-term presence of infrastructure the impact was determined as Moderate (4).
Injury or mortality of marine fauna Injury or mortality of epifauna and infauna may occur when infrastructure or equipment are placed on the seabed, or the seabed surface is disrupted by activities including trenching and excavation, or from sedimentation and spoil left in situ. Results of the benthic survey found benthic habitats in the OA comprise mostly a mixture of flat bare substrates, and isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Ref. 110; Ref. 112; Ref. 105, Appendix A). Video footage undertaken as part of the benthic survey showed the most dominant benthic feature of flat bare substrates to contain little to no biota (Ref. 105, Appendix A). However ground-truthing transects along areas of isolated high structural complexity between ~400–800 m depths verified the presence of cnidarians, echinoderms, sponges and a mixture of these biotic groups in varying percent cover (from low [<10%] to high cover [>80%]) (Ref. 105, Appendix A). These biota are widespread and well represented in the region, which has underlying conditions that support recolonisation and recovery (Ref. 278). A limited number of benthic infauna were observed in the sediment samples taken from potential DC sites and tie-in locations (14 sites altogether). Benthic infauna were found primarily in deep-sea sediments (1,100–1,200 m) around Semele DC-1 and Semele DC-2, and shallower seabed (100–200 m) at WTR DC-1. The benthic infauna collected included marine worms, polychaete worms and molluscs (Ref. 105, Appendix A). These findings are consistent with previous seabed surveys in the NWS region (Ref. 116; Ref. 110; Ref. 115) where polychaetes and crustaceans are the dominant, albeit sparsely distributed, epibenthic and infaunal invertebrates of soft sediment habitats (Ref. 105, Appendix A).

Risk evaluation
An EPBC PMST report (Ref. 123, Appendix B) did not identify any epifaunal of infaunal threatened or migratory species, or any TECs within the OA. Epifauna and infauna within a 70 m buffer of the infrastructure placement are susceptible to smothering from sedimentation or placement of spoil. Mobile invertebrates are less vulnerable to sedimentation than sessile species because they can move to areas with less sediment accumulation (Ref. 281). Some sessile invertebrates, such as sponges, have the capacity to filter out or to physically remove particulates (Ref. 282). The loss of epifauna and infauna within the infrastructure footprint is considered localised given the widespread nature of soft sediment infauna communities characteristic of the NWS region. When considering the infrastructure footprint against the widespread nature of soft sediment epifauna and infauna communities characteristic of the NWS region, the potential of injury or mortality to epifauna and infauna is considered localised. In addition, after decommissioning, full recovery of soft sediment assemblages from physical disturbance could take 64–208 days (Ref. 278). Therefore, the consequence of injury or mortality of marine fauna has been evaluated as Minor (5). The benthic survey found the OA to predominantly contain soft sediments with sparsely distributed, epibenthic and infaunal invertebrates highly represented throughout the region, and highly mobile demersal fish species; therefore, the likelihood of seabed disturbance leading to injury or mortality of marine fauna is assessed as Unlikely (4). Overall, the risk of seabed disturbance to benthic habitats and associated communities is Low (8).
Fishes, including sharks and rays
Injury or mortality of marine fauna The alteration of marine habitats from installing infrastructure and short-term disturbance of the seabed has the potential to disturb or modify nearby fish assemblages within close proximity to the area of disturbance. A short-term increase in turbidity and sediment suspension can potentially result in impacts to fish through affecting ability to forage, hunt and avoid predators, and physiological impacts such as gill impairment. There will be short-term and longer-term alteration of benthic substrate due to seabed disturbance for the Development (~0.97 km^2 and ~18.86 km^2 respectively). The alteration of marine habitats within the OA is considered insignificant considering the vast area of similar substrate present within the NWS. A reduction in water quality when installing subsea infrastructure, as previously detailed, has been shown to be brief and highly localised. Therefore, any impacts on fish species or their food sources is considered minor. Sediment disturbance may also act as a potential short-term attractant to demersal fish due to an increase in foraging opportunities on disturbed infauna and epifauna. The installed subsea structures and equipment will provide relatively complex artificial structural habitat in an area predominately devoid of complex seabed features. This may result in an increase in the diversity and abundance of fish assemblage in the immediate vicinity of this infrastructure. An ROV video survey was undertaken at the Jansz–Io field, in waters ~700–1,360 m deep, to assess the benthic habitats and fauna assemblages (Ref. 113). The video footage was collected between 2015 and 2018 across 37 sites (29 sites on existing infrastructure and 8 sites away from Jansz–Io pipelines). In line with other studies at similar depth contours around Australia, species richness, diversity and abundance decreased with depth (Ref. 113). However, standardised comparisons showed overall diversity, overall abundance, and species richness were typically greater at sites on the infrastructure, supporting the assumption that the structures may act as an attractant to biota (Ref. 113). The values and sensitivities within the OA with the potential to be affected by seabed disturbance include: • whale shark BIA (foraging) • fish communities (associated with the various KEFs). Generally, whale sharks are encountered close to or at the surface, but they will regularly dive and move through the water column. Off the outer NWS, whale sharks spend much of their time swimming near the sea floor and make dives to around 1,000 m depth (Ref. 171). Although the eastern edge of the OA overlaps a foraging BIA, interactions with whale sharks are very unlikely due to the OA's distance from the preferred foraging areas around Ningaloo Reef and deeper oceanic waters. The area of overlap of the OA is not significant compared to the size of the BIA (218,911 km^2) and represents ~0.21% of the BIA. The long-term disturbance area, within which the infrastructure will sit, is a much smaller area than the OA (~0.008%) and therefore corresponds to an even smaller percentage. The possible increase in fish assemblage diversity is not expected to have any negative consequences due to the very small project footprint within the region. The potential of injury or mortality to fish from seabed disturbance is considered localised. Therefore, the consequence of injury or mortality of marine fauna has been evaluated as Minor (5).

Risk evaluation
It is not expected that whale sharks would be directly impacted by this small area of seabed disturbance. All EPBC PMST report (Ref. 123, Appendix B) listed species are highly mobile; therefore, none are expected to be affected by minor seabed disturbance. The likelihood of seabed disturbance leading to the injury or mortality of marine fauna is assessed as Unlikely (4). Overall, the risk of seabed disturbance to fishes, including sharks and rays is Low (8).
KEFs
Change to values and sensitivities Seabed disturbance may result in changes to the values and sensitivities of KEFs through alteration of benthic habitats and associated communities or injury or mortality to marine fauna. Three KEFs overlap some of the OA: • Ancient coastline at 125 m depth contour KEF (Ancient coastline KEF) • Exmouth Plateau KEF • Continental slope demersal fish communities KEF. The Ancient coastline and Exmouth Plateau KEFs both have benthic habitat values. The Chandon DCs and part of the Chandon flowline are within the Exmouth Plateau KEF. The OA around the WTR DC, WTR flowline and one of the Gorgon tie-in points overlaps the Ancient coastline KEF. Therefore, activities at only 2 of the 5 fields have the potential to impact these 2 KEFs by seabed disturbance. Benthic habitat surveys of the OA area within the Ancient coastline KEF showed that the benthic habitat comprises smooth seabed with bioturbation and with no epibenthic biota observed. Values associated with the Ancient coastline KEF were not detected within the OA benthic survey (Ref. 105, Appendix A). Although the 5 km buffer of the OA overlaps a small portion of the Ancient coastline KEF (<1% of the total KEF area), most of the indicative WTR flowline route itself was located to avoid this KEF. Benthic habitat surveys of the OA area within the Exmouth Plateau KEF showed that the benthic habitat is dominated by irregular seabed with bioturbation, irregular seabed floor with bare substrates, and depressions on the sea floor of bare substrate. Within the Exmouth Plateau KEF, a large scarp with 3-dimensional hard structure (i.e. rock) crosses through the indicative Chandon flowline from east to west, likely providing biota with suitable habitat, although no biota were detected along the transect in this area. These results are comparable to previous studies of the Exmouth Plateau KEF (Ref. 105, Appendix A). The OA overlaps ~230 km^2 of the Exmouth Plateau KEF, which is <1% of the KEF's total area. The long-term disturbance area, within which the infrastructure will sit, is a much smaller area than the OA (~0.008%) and therefore corresponds to an even smaller percentage. As the values of the Exmouth Plateau KEF were not detected in the OA, the installation of subsea infrastructure is not expected to impact Exmouth Plateau KEF values. The Continental slope demersal fish communities KEF has values relating to fish that live and feed near the sea floor. The Continental slope demersal fish communities KEF will overlap with the OA at the C&D flowline, C&D DC-3, WTR umbilical and one of the Gorgon tie-in points. Where the OA crosses with the Continental slope demersal fish communities KEF, benthic habitat mostly comprises irregular and smooth seabed with bare substrates and discrete depressions of bioturbated sediments (Ref. 105, Appendix A). These benthic habitats do not represent site-attached fish habitat and is consistent with observations of few benthic biota (Ref. 105, Appendix A). Low densities of pelagic and demersal fish species (Ref. 105, Appendix A), which are generally considered transient (pelagic fish species) and highly mobile (pelagic and demersal fish) (Ref. 283) were observed. C&D flowline infrastructure to be installed in the Continental slope demersal fish communities KEF occupies a limited amount of seabed within the KEF. The long-term disturbance area overlaps ~5.5 km^2 of the Continental slope demersal fish communities KEF, which is <0.02% of the KEF's total area (33,182 km^2). These benthic habitats and biota are widespread and well represented in the region and have underlying conditions that support recolonisation and recovery (Ref. 278). Despite the OA overlapping 3 KEFs, observations from the benthic survey (Ref. 105, Appendix A) highlights KEF values with the potential to be impacted are limited to deep-sea benthic habitats and pelagic and demersal fish species of the Continental slope demersal fish communities KEF. These habitats and biota are widespread and well represented in the region; and thus, the extent of any potential impact is relatively localised, with the OA only covering from between ~0.02–1% of these 3 KEFs. Although the conditions to support recolonisation and recovery are present, due to the long-term presence of the infrastructure the impact to benthic habitat values of relevant KEFs was determined as Moderate (4). As the OA predominantly contain soft sediments with sparsely distributed, epibenthic and infaunal invertebrates highly represented throughout the region, and highly mobile pelagic and demersal fish species the likelihood of seabed disturbance leading to injury or mortality of marine fauna values of relevant KEFs is assessed as Unlikely (4). Overall, the risk of seabed disturbance to KEFs is Low (8).

Risk evaluation
Cultural heritage value: Traditional Owners
Change to cultural heritage values No protected underwater cultural heritage sites or artefacts protected by the UCH Act have been identified within the OA (Section 6.5.2). At the time of writing, CAPL understands through consultation with the relevant Traditional Owner groups that there are no known artefacts or specific sites of cultural value associated with the seabed within the OA. Therefore, no impacts to tangible seabed-based cultural heritage (e.g. shipwrecks or archaeology) are expected; and no further evaluation has been undertaken. Based on the outcomes of Phase 1 stakeholder consultation (Section 6.2.5.2.1), CAPL considers that indirect impacts to intangible Traditional Owners cultural values may occur due to alterations to benthic habitats and associated communities and impacts to marine fauna. The consequence evaluations to these receptors are provided above, and the highest consequence level for alteration of benthic habitats and communities from seabed disturbance was evaluated as Moderate (4). As such, the consequence for cultural heritage values is evaluated as consistent with that for benthic habitat and associated communities, as Moderate (4). Any impact will be limited to the immediate vicinity of the disturbance, and thus the extent of potential impact is relatively localised. A significant adverse change to cultural values attributed to the offshore marine area is not predicted to occur, though the infrastructure will be in place for a long time. Therefore, the likelihood of the consequence occurring as Unlikely (4). The risk of seabed disturbance to Traditional Owner cultural heritage values is Low (7).

8.1.3 Determination of acceptability

The acceptable level of impact and risk is a function of the magnitude of residual risk, principles of ESD, internal and external context, and legislative requirements.

Table 8-5 details the determination of acceptability for seabed disturbance.

Table 8-5: Determination of acceptability for Seabed disturbance

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence level for seabed disturbance was evaluated as Moderate (4). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures, and the benthic habitat survey provides scientific certainty for the impact and risk evaluation for seabed disturbance. • Prevention measures for seabed disturbance are well regulated and managed in Australian waters. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations
	The Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the impact and risk of seabed disturbance based on relevant environmental legislation and other requirements as listed below. • The regulation and management of seabed disturbance in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures. • The highest consequence level for seabed disturbance was evaluated as Moderate (4).

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="3"></td><td colspan="2">Any relevant stakeholder feedback in relation to seabed disturbance has been incorporated in the OPP and assessed in the external context acceptability criteria.
To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="5">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Environment Protection (Sea Dumping) Act 1981 (Cth)
A sea dumping permit is required if any objects are planned to be left in situ.</td><td rowspan="3">Legislative requirements to manage seabed disturbance are addressed by adopting these control measures:
CM01: Prior to drilling or installation, surveys will be conducted to verify that no emergent seabed features / obstacles are present. Where these features are identified, infrastructure location may be amended if practicable.
CM02: Mooring analysis for the MODU will be undertaken prior to anchoring activities commencing.
CM03: Vessels will meet crew competency, navigation equipment, and radar requirements of the Chevron Marine Standard Non Tankers (Ref. 284).
CM04: Seabed footprint to be reduced within the limits of technical requirements and practicability, as well as safety constraints in line with operational procedures.
CM05: Implement CAPL's Asset Retirement philosophy, which aligns with legislative requirements.</td></tr>
<tr><td>Offshore Petroleum Decommissioning Guideline (DISER) (Ref. 76)
Decommissioning options other than complete removal may be considered, if the titleholder demonstrates that the alternative decommissioning approach delivers equal or better environmental, safety and well integrity outcomes, and that the approach complies with all other legislative and regulatory requirements.</td></tr>
<tr><td>Section 572 Maintenance and removal of property Policy (NOPSEMA) (Ref. 81)
all property is designed, installed and operated with the intention of being removed when it is no longer in use
when a field permanently ceases production, all remaining property is removed if it is not to be used in connection with the operations
a comparative assessment may be used in an EP as a method to evaluate feasible alternatives to removing property
when an evaluation of impacts and risks are required by the OPGGS(E)R, they must incorporate a holistic evaluation of the impacts and risks of the alternative arrangements (including those impacts and risks that may arise from removing or relocating property outside the title area) and consider community interest.</td></tr>
</table>

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="6"></td><td></td><td></td></tr>
<tr><td>Conservation Advice Rhincodon typus Whale Shark (Ref. 144)
Identifies habitat disruption as a key threat. No explicit relevant objectives.
Management action: Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations (Ningaloo Reef, Christmas Island and the Coral Sea) and along the northward migration route that follows the northern WA coastline along the 200 m isobath (as set out in the Conservation Values Atlas (Ref. 138)).</td><td rowspan="5">EPBC management plan requirements to manage seabed disturbance are addressed by adopting these control measures:
CM01: Prior to drilling or installation, surveys will be conducted to verify that no emergent seabed features / obstacles are present. Where these features are identified, infrastructure location may be amended if practicable.
CM02: Mooring analysis for the MODU will be undertaken prior to anchoring activities commencing.
CM03: Vessels will meet crew competency, navigation equipment, and radar requirements of the Chevron Marine Standard Non Tankers (Ref. 284).
CM04: Seabed footprint to be reduced within the limits of technical requirements and practicability, as well as safety constraints in line with operational procedures.
CM05: Implement CAPL's Asset Retirement philosophy, which aligns with legislative requirements.
Therefore, the Development is not considered to be inconsistent with the EPBC management plans.</td></tr>
<tr><td>Recovery Plan for the Grey Nurse Shark (Carcharias taurus) (Ref. 29)
Review the level and spatial extent of protection measures at key aggregation sites to ensure appropriate levels of protection, and a consistent approach to the designation and implementation of protective measures, are applied.
Use Biologically Important Areas (BIA) to help inform the development of appropriate conservation measures, including through the application of advice in the marine bioregional plans on the types of actions which are likely to have a significant impact on the species and updating such conservation measures as new information becomes available.</td></tr>
<tr><td>Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25)
Management action 5C: Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.
Management action 5D: Implement measures to reduce adverse impacts of habitat degradation and/or modification.</td></tr>
<tr><td>Approved Conservation Advice for Pristis pristis (largetooth sawfish) (Ref. 27)
Implement measures to reduce adverse impacts of habitat degradation and/or modification</td></tr>
<tr><td>Approved Conservation Advice on Pristis clavate (Dwarf Sawfish) (Ref. 26)</td></tr>
<tr><td>Internal context</td><td colspan="2">This CAPL procedure was identified as relevant for this aspect:
• Chevron Marine Standard Non Tankers (Ref. 284)</td></tr>
<tr><td>External context</td><td colspan="2">CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment.</td></tr>
</table>

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.2.5 and 6.5.2).
Further, CAPL has also since included an adaptive management control measure for underwater cultural heritage sites/artefacts in the OPP (CM07 and CM08).
No further feedback was received in relation to seabed disturbance from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.</td></tr>
<tr><td rowspan="4">Defined acceptable level</td><td colspan="2">The consequence of seabed disturbance is inherently acceptable because the highest consequence level is Moderate (4).
Additionally, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan.
The risk evaluation does not identify scientific uncertainty against risks of seabed disturbance for each receptor.
However, because habitat disturbance is listed as a threat to protected matters under documents made or implemented under the EPBC Act, CAPL will define an acceptable level of impact that aligns with the objectives of these documents. Objectives of the relevant documents are shown below and were considered during the impact and risk evaluation.</td></tr>
<tr><td>Plan and relevant objectives</td><td>Demonstration of requirement</td></tr>
<tr><td>Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25)
<u>Primary objective</u>: To assist the recovery of sawfish and river sharks in Australian waters with a view to:
• improving the population status leading to removal of the sawfish and river shark species from the threatened species list of the EPBC Act
• ensuring that anthropogenic activities do not hinder recovery in the near future or impact the conservation status of the species in the future.
<u>Specific objectives:</u>
• Objective 5: Reduce, and where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species</td><td rowspan="2">CAPL considers the impacts of seabed disturbance to not be inconsistent with the relevant objectives of these EPBC management plans.
By applying EPO01, impacts and risks to habitat degradation / modification from seabed disturbance will be managed at or below the defined acceptable level.</td></tr>
<tr><td>Recovery Plan for the Grey Nurse Shark (Carcharias taurus) (Ref. 29)
<u>Primary objective</u>: To assist the recovery of the grey nurse shark in the wild, throughout its range in Australian waters, with a view to:
• improving the population status, leading to future removal of the grey nurse shark from the threatened species list of the EPBC Act
• ensuring that anthropogenic activities do not hinder the recovery of the grey nurse shark in the near future or</td></tr>
</table>

Determination of acceptability		
	impact the conservation status of the species in the future. Specific Objectives: • Objective 8: Continue to identify and protect habitat critical to the survival of the grey nurse shark and reduce the impact of threatening processes within these areas.	
	Conservation Advice *Rhincodon typus* Whale Shark (Ref. 30) Approved Conservation Advice for Pristis pristis (largetooth sawfish) (Ref. 27)	This EPBC management plan for a species that may occur within the OA identifies habitat disturbance as a threat but does not identify any relevant objectives.
	Therefore, CAPL has defined these acceptable levels of impact such that they are not inconsistent with these documents: • management of impacts of the Development must not be inconsistent with the relevant EPBC management plans identified above • no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery • no adverse effect to an important or substantial area of habitat such that a significant impact on marine ecosystem functioning or integrity results • no significant adverse impact to cultural heritage values attributed to the offshore marine area. CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets these acceptable levels.	

8.1.4 Environmental performance

Table 8-6 lists the EPO defined for seabed disturbance and the adopted control measures to achieve the outcome.

Table 8-6: Environmental performance for Seabed disturbance

EPO	Adopted control measure
EPO01: Reduce the risk of impacts to sensitive benthic receptors within the OA from the Development activities.	**CM01**: Prior to drilling or installation, surveys will be conducted to verify that no emergent seabed features / obstacles are present. Where these features are identified, infrastructure location may be amended if practicable. **CM02**: Mooring analysis for the MODU will be undertaken prior to anchoring activities commencing. **CM03**: Vessels will meet crew competency, navigation equipment, and radar requirements of the Chevron Marine Standard Non Tankers (Ref. 284). **CM04**: Seabed footprint to be reduced within the limits of technical requirements and practicability, as well as safety constraints in line with operational procedures. **CM05:** Implement CAPL's Asset Retirement philosophy, which aligns with legislative requirements.
EPO02: No impacts to underwater cultural heritage from the Development activities.	**CM06:** Prior to drilling or installation, studies, and surveys (as necessary) will be conducted to verify that no identifiable or reasonably detectable underwater cultural heritage (as defined in the *Underwater Cultural Heritage Act 2018* (Cth)) is present within areas of the seabed expected to be disturbed. Results will be incorporated

EPO	Adopted control measure
EPO03: No adverse change to First Nations cultural heritage values from the Development activities.	into relevant subsequent EPs and, based on assessed risks, additional control measures may be adopted, or infrastructure locations may be amended if practicable. **CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08:** If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development. **CM09:** A protocol to manage underwater cultural heritage will be developed, which will include a decision framework in the event of unexpected finds *in situ* during seabed-disturbing activities.

8.2 Air emissions

8.2.1 Source

The MODU, vessels and machinery produce air emissions that contain atmospheric pollutants.

Air emissions can be classified as GHG and non-GHG emissions or atmospheric pollutants. GHG emissions are evaluated in Section 8.3. The atmospheric pollutants considered in this section include:

- nitrogen dioxide (NO_2), as representative pollutant for nitrogen oxides (NO_x), which is a generic term for the mono-nitrogen oxides, i.e. nitric oxide (NO) and NO_2
- airborne particulate matter (PM), which includes particulate matter of size 10 microns and lower
- sulfur dioxide (SO_2), as representative pollutant for sulfur oxides (SO_x), which include sulfur monoxide (SO), sulfur trioxide (SO_3), and other combinations of sulfur and oxygen
- non-methane volatile organic compounds (NMVOCs), including aliphatic hydrocarbons (propane and longer straight chain hydrocarbons) and aromatic hydrocarbons such as benzene, toluene, ethylbenzene, and xylene (collectively known as BTEX)
- carbon monoxide (CO)
- mercury (Hg)
- ozone-depleting substances (ODS).

Table 8-7 lists the activities in each phase that have the potential to generate air emissions that contain the atmospheric pollutants listed above.

Table 8-7: Phases and activities that generate Air emissions

Phase	Activity
Drilling	Well suspension Well clean-up and testing
Installation and commissioning	Hydrotest and pre-commissioning
Operations	Well intervention
Support activities	MODU operations Vessel operations Helicopter operations

8.2.1.1 Drilling

Flaring may be undertaken during well clean-up and flowback activities. During well clean-up and flowback activities, the well is cleaned to remove contaminants including drilling or completions fluids, debris, and solids that come from the formation. These contaminants are circulated back to the MODU. Removing contaminants from the well may also remove hydrocarbon gas—this gas is then flared. Air emissions from gas flaring during flowback may contain NO_x, SO_2, NMVOCs, CO and Hg (Ref. 285).

If flaring is required, it will be from one well at a time and may take ~1 day per well to complete.

The volume of emissions that are released to the environment from flaring will depend on the field and well site. The indicative estimated volume of flared reservoir gas, based on 1 day of flaring, is 60 MMscf per well.

During well suspension, small volumes of reservoir methane gas may need to be handled back to the rig. The indicative estimated volume of cold vented reservoir methane gas is 0.1 MMscf per well.

8.2.1.2 Installation and commissioning

During pre-commissioning, nitrogen gas and compressed air from the flowline may be vented at the sea surface via a downline. An estimated 5,250,000 m^3 of nitrogen gas or compressed air may be vented per event. This volume is based on estimates for the longest Chandon flowline, and volumes would be less at the other fields.

8.2.1.3 Operations

Flaring may be required as part of well intervention (similar to during drilling). Air emissions from gas flaring during well intervention activities may contain NO_x, SO_2, NMVOCs, CO and Hg (Ref. 285).

If well intervention is required, it will be infrequent, and if flaring is required, it may take ~1 day per well. Cold venting of small volumes of reservoir methane gas may also be required.

The volume of emissions that are released to the environment from flaring and cold venting will depend on the field and well site. As above, the indicative estimated volume of flared reservoir gas, based on 1 day of flaring, is 60 MMscf per well. The indicative estimated volume of cold vented reservoir methane gas is 0.1 MMscf per well.

8.2.1.4 Support activities (all phases)

Vessels, helicopters and the MODU use diesel or gas to generate power for operation. Vessels will use marine diesel oil (MDO) or marine gas oil (MGO). Combustion of these fuels releases atmospheric pollutants including NO_x, PM, SO_2, NMVOCs and CO (Ref. 285).

Vessels and the MODU may also be a source of fugitive emissions from the diesel storage tanks on board. Fugitive emissions may contain NMVOCs and Hg.

Vessels and the MODU have low potential for ODSs to be present on board; ODSs are typically found in old refrigeration and air conditioning equipment.

The MODU will be present in the OA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well interventions). The MODU will move between fields but will spend most of the time at the DCs. The MODU may be kept on location using anchoring or DP. The impact evaluation for air emissions will consider the MODU using DP as the worst-case scenario for air emissions.

Vessels are present in the OA during all phases of the Development. A variety of vessels will be used, and they will typically use DP. The highest number of vessels working concurrently across the OA is estimated at 5–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation may take as long as 15 months per field and while concurrent activities are possible during this time, they will be intermittent and would occur for only a small portion of the overall duration.

Helicopters operate during drilling, installation and commissioning, operations and decommissioning phases, but are far less frequent during operations. During drilling, installation and commissioning, and decommissioning, helicopters may need to service the MODU ~5 times per week and ~15-16 times per week for larger vessels.

8.2.2 Impact and risk evaluation

The scoping exercise (Section 7.4) identified this receptor within the OA that may be impacted by air emissions:

- air quality.

CAPL has concluded that air emissions from the Development are not expected to pose a risk to marine fauna because exposure is limited to the immediate vicinity of the source, emissions are temporary, and the OA is located in the offshore marine environment where long-term air pollutant exposure to air-breathing marine fauna is not credible due to the absence of critical habitat and site-attached marine fauna in the OA.

Therefore, impacts to marine fauna from air emissions are not expected, and are not evaluated further.

Table 8-8 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to air emissions in the OA.

Table 8-8: Risk evaluation for Air emissions

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Air emissions may result in: • localised and temporary reduction in air quality.	6	N/A			

Risk evaluation
Air quality
Localised and temporary reduction in air quality Air emissions containing atmospheric pollutants from the Development activities will result in localised and temporary reduction in air quality within the OA. MODU, vessel and helicopter operations will release exhaust air emissions containing atmospheric pollutants including NO_x, PM_{10}, SO_2, NMVOCs and CO. Modelling was undertaken for NO_x emissions for MODU power generation for another offshore project (Ref. 286). The modelling focused on NO_x based on larger predicted emission volumes compared to other pollutants (i.e. PM_{10}, SO_2, NMVOCs and CO). Modelling of PM_{10}, SO_2, NMVOCs and CO was not deemed necessary as concentrations are expected to be very low based on using low sulfur diesel for MODU operations. Although this modelling was carried out for a different MODU, the modelled distances provide a good measure of the order of magnitude over which an increase in ambient concentration could be predicted for hourly rate of operation of a MODU and a conservative estimate for vessels and helicopter operations. The results of this modelling indicate that on an hourly average, there is the potential for an increase in ambient NO_2 concentrations of 0.0005 ppm within 10 km of the emission source and an increase of <0.1 µg/m^3 (0.00005 ppm) in ambient NO_2 concentrations >40 km away. NEPM ambient air quality standards [National Environment Protection (Ambient Air Quality) Measure] recommend that hourly exposure to NO_2 is <0.08 ppm with annual average exposure <0.015 ppm.

Risk evaluation
The results of this modelling indicate the highest hourly averages (0.00039 ppm or 0.74 µg/m^3) were restricted to a distance of ~5 km from the MODU (Ref. 286), which is below NEPM standards [National Environment Protection (Ambient Air Quality) Measure]. The volume of fuel required for power generation for vessels and helicopters is expected to be significantly less than for MODU operations, and it is expected that the concentration of atmospheric pollutants generated from vessel and helicopter operations, even where multiple vessels are present at one time, is likely to be lower. Air emissions from MODU, vessel and helicopter movements across the OA are expected to disperse rapidly and are not expected to result in noticeable increases in atmospheric pollutants locally or regionally. Hydrocarbon storage tanks on vessels and subsea infrastructure may release fugitive emissions containing NMVOCs and Hg atmospheric pollutants. Fugitive emissions are not considered to be major sources of atmospheric pollutants due to the expected low emission rates (fugitive emissions) and limited overall volumes anticipated. Well clean-up is a once-off activity for each well. Well interventions will be infrequent during the operations phase (no more than once a year per well) and flaring may not be required. If flaring occurs, it may be for ~1 day per well. ODSs may be present on board vessels that have old refrigeration and air conditioning equipment. However, the release of ODSs during the Development is not planned or anticipated. Nitrogen gas, which is released during pre-commissioning, is not considered a pollutant, as it makes up ~78% of the atmosphere and is not expected to have any impact to the environment. Similarly, any compressed air released during pre-commissioning is not considered to have any impact on the environment. Air quality in the OA is expected to be high and typical of an unpolluted offshore marine environment. Wind patterns vary with the season, but average speeds are 6–13 m/s. Wind conditions experienced in the open offshore marine environment of the OA, which is >115 km from the Pilbara coast, are expected to rapidly disperse any air emissions temporarily generated during the Development. Air quality is expected to return to baseline levels after air emissions cease. The potential impact associated with air emissions is limited to a short-term, direct reduction in air quality within a localised area. No regional scale impacts to air quality are expected. Therefore, the consequence of air emissions causing a change in air quality has been evaluated as Incidental (6).

8.2.3 Determination of acceptability

The acceptable level of impact is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-9 details the determination of acceptability for air emissions.

Table 8-9: Determination of acceptability for Air emissions

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence level for air emissions was evaluated as Incidental (6). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the impact evaluation for air emissions. • Prevention measures for air emissions are well regulated and managed in Australian waters. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations
	The Development is consistent with principle of ESD (c) for this aspect as:

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="3"></td><td colspan="2">

- The Development is committed to applying measures to prevent the impact and risk of air emissions based on relevant environmental legislation and other requirements as listed below.
- The regulation and management of air emissions in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
- The highest consequence level for air emissions was evaluated as Incidental (6).
- Any relevant stakeholder feedback in relation to air emissions has been incorporated in the OPP and assessed in the external context acceptability criteria.

To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="5">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>AMSA Marine Order 97: Marine Pollution Prevention – Air Pollution
Sets out the requirements for preventing air pollution by vessels including certification requirements, reporting requirements, incineration on board a vessel, energy efficiency, servicing and record keeping.</td><td rowspan="3">Legislative requirements to manage air emissions are addressed by adopting these control measures:
CM10: Fuel with a reduced sulfur content will be used when available.
CM11: Comply with the requirements of Marine Order 97 (MARPOL 73/78 Annex VI) in relation to air pollution.</td></tr>
<tr><td>Navigation Act 2012 (Cth) – Chapter 4 (Prevention of Pollution)
Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment and gives effect to the requirements under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) in Australia.</td></tr>
<tr><td>Ozone Protection and Synthetic Greenhouse Gas Management Act 1989 (Cth)
Reduces emissions of ozone depleting substances (ODSs) and synthetic GHGs. It controls the manufacture, import and export of ODSs and synthetic GHGs and products containing these gases.</td></tr>
<tr><td>Internal context</td><td colspan="2">This CAPL environmental performance standard/procedure was deemed relevant for this aspect:

- Chevron Marine Standard Non Tankers (Ref. 284)</td></tr>
<tr><td>External context</td><td colspan="2">CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing</td></tr>
</table>

Determination of acceptability		
	and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment. No feedback was received in relation to air emissions from Phase 1 stakeholder consultation.	
Defined acceptable level	The consequence of air emissions is inherently acceptable because the highest consequence level is Incidental (6). The impact evaluation does not identify scientific uncertainty against impacts of air emissions for the receptor. There are no relevant EPBC management plans for this aspect.	
	Plan and relevant objective	**Demonstration of requirement**
	EPBC recovery plans / conservation advice for threatened and/or migratory MNES species that may occur in the OA do not identify air emissions as a key threat or have any explicit relevant objectives or management actions.	
	Therefore, CAPL has defined the acceptable level of impact as: • no substantial changes in air quality that may adversely impact on biodiversity, ecological integrity, social amenity or human health as a result of the Development. CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets this acceptable level.	

8.2.4 Environmental performance

Table 8-10 lists the EPO defined for air emissions and the adopted control measures to achieve the outcome.

Table 8-10: Environmental performance for Air emissions

EPO	Adopted control measure
EPO04: Planned air emissions from vessel operations during the Development activities will meet MARPOL requirements.	**CM10:** Fuel with a reduced sulfur content will be used when available. **CM11:** Comply with the requirements of Marine Order 97 (MARPOL 73/78 Annex VI) in relation to air pollution.

8.3 Greenhouse gas emissions

8.3.1 Source

Greenhouse gas (GHG) emissions refer to any gas that absorbs infrared radiation in the atmosphere (Ref. 287). Greenhouse gases include, but are not limited to:

- carbon dioxide (CO_2)
- nitrous oxide (N_2O)
- methane (CH_4)
- sulphur hexafluoride (SF_6)
- hydrofluorocarbons (HFCs)
- perfluorocarbons (PFCs).

Table 8-11 list the activities within each phase that have the potential to generate GHG emissions.

Table 8-11: Phases and activities that generate GHG emissions

Phase	Activity
Drilling	Well clean-up and flowback
Operations	Operation of the hydrocarbon system Well intervention
Support Activities	MODU operations Vessel operations Helicopter operations[38]
Decommissioning	Well suspension and P&A

8.3.1.1 Drilling

Flaring may be undertaken during well clean-up and flowback activities. During well clean-up and flowback activities, the well is flowed to remove contaminants, which may include drilling or completions fluids, debris and solids that come from the formation. These contaminants are circulated back to the MODU. Hydrocarbon gas may also be returned to the MODU during these activities; for safety purposes this gas is flared.

Flaring is a contingency activity and if required, it will be undertaken from one well at a time, with an estimated duration of approximately one day per well. Unforeseen circumstances such as weather events, may cause an additional flaring. As flaring is not planned to be undertaken at all wells, the emissions estimate for flaring remains based on approximately one day per well as this should not impact the overall emissions envelope.

8.3.1.2 Operations

Flaring may be required as part of well suspension and intervention, similar to drilling. If well intervention is required, it will be infrequent, and will be undertaken from one well at a time, with an estimated duration of approximately one day per

[38] *'Helicopter operations (as described in Section 8.3.1.3) may be associated with IMR activities for personnel transfer associated with the Development, these are not a routine planned activity and are only associated with longer IMR scopes (e.g. repairs), and therefore have not been accounted for within this emissions inventory'*

well. Unforeseen circumstances such as weather events, may cause an additional flaring. As flaring is not planned to be undertaken at all wells, the emissions estimate for flaring remains based on approximately one day per well as this should not impact the overall emissions envelope.

During well suspension and intervention, small volumes of gas may need to be transferred back to the MODU. If the volume is too small to flare, it will be cold-vented to atmosphere.

8.3.1.3 Support Activities (all phases)

Vessels, helicopters and the MODU use diesel or gas to generate power for operation. Vessels will use marine diesel oil (MDO) or marine gas oil (MGO).

Vessels and the MODU have diesel storage tanks on board, which may also be a source of fugitive emissions.

The assessment in the following sections categorises the support activities into individual phases, i.e. vessel operations for survey, drilling, installation and commissioning, operations, and decommissioning.

8.3.1.4 Assessment boundary

Typically, emissions are defined as (Ref. 288):

- Direct:
  - Scope 1 GHG emissions are the emissions released to the atmosphere as a direct result of an activity, or series of activities.
- Indirect:
  - Scope 2 GHG emissions are the emissions released to the atmosphere from the indirect consumption of a purchased energy commodity.
  - Scope 3 emissions are indirect GHG emissions other than Scope 2 emissions that are generated in the wider economy. They occur as a consequence of the activities of a facility, but from sources not owned or controlled by that facility's business.

One of the main principles of GHG accounting and reporting is relevance, of which an integral aspect is defining an appropriate GHG emissions inventory boundary (Ref. 289).

The GFP has been operating since 2016. This OPP assesses the GHG emissions associated with the addition of the Development. To provide a complete picture of the Gorgon Gas Development GHG emissions, and consistent with the previous primary approvals (Section 8.3.2.4), the indirect emissions associated with the GTP, and the indirect downstream emissions, are presented in the context of the entire Gorgon Gas Development.

Consistent with the Gorgon and Jansz Feed Gas Pipeline and Wells Operations (Commonwealth Waters) Environment Plan (Ref. 8), this OPP applies direct and indirect emissions naming convention, as opposed to Scope 1, 2 and 3 definitions.

Figure 8-1 shows the assessment boundary, which is summarised as:

- Direct emissions are planned project emissions that directly result from the Development, including survey, drilling, installation and commissioning, operations, and decommissioning. These emissions originate from flaring and fuel combustion (MDO) on the MODU and vessels within Commonwealth waters and some international transit. As described in Section 8.3.3, CAPL has defined the emissions boundary for assessing direct GHG emissions in relation to the planned petroleum activities[39] within the OA (these petroleum activities are described in Section 3). Any unplanned activities, including repairs or emergency events, are excluded from the emissions inventory.

- Direct GHG emissions from the operations phase of the Development only include the emissions from vessel use within Commonwealth waters during IMR—other operations emissions are included in indirect emissions associated with gas processing at the GTP on Barrow Island[40] (see below).
- Indirect emissions associated with gas processing at the GTP on Barrow Island are those associated with GTP operations (oil and gas processing and support activities within WA jurisdiction).
- Indirect downstream emissions are associated with the transport and third-party end use of LNG, condensate and domestic gas produced by the Gorgon Gas Development.

No indirect emissions from indirect consumption of a purchased energy commodity are associated with the Development (Note: Energy commodity associated with the Development may be supplied by the Gorgon Gas Development).

[39] *Where 'petroleum activity' is as defined within Regulation 4 of the OPGGS(E)R.*

[40] *Gas processing at the GTP on Barrow Island incorporates several emission sources, including gas turbine drivers, gas turbine generators (GTGs), heating, flaring, venting, diesel consumption, fugitive emissions, marine operations and marine vessels. The GTGs also provide electricity to the offshore infrastructure within the scope of this OPP.*

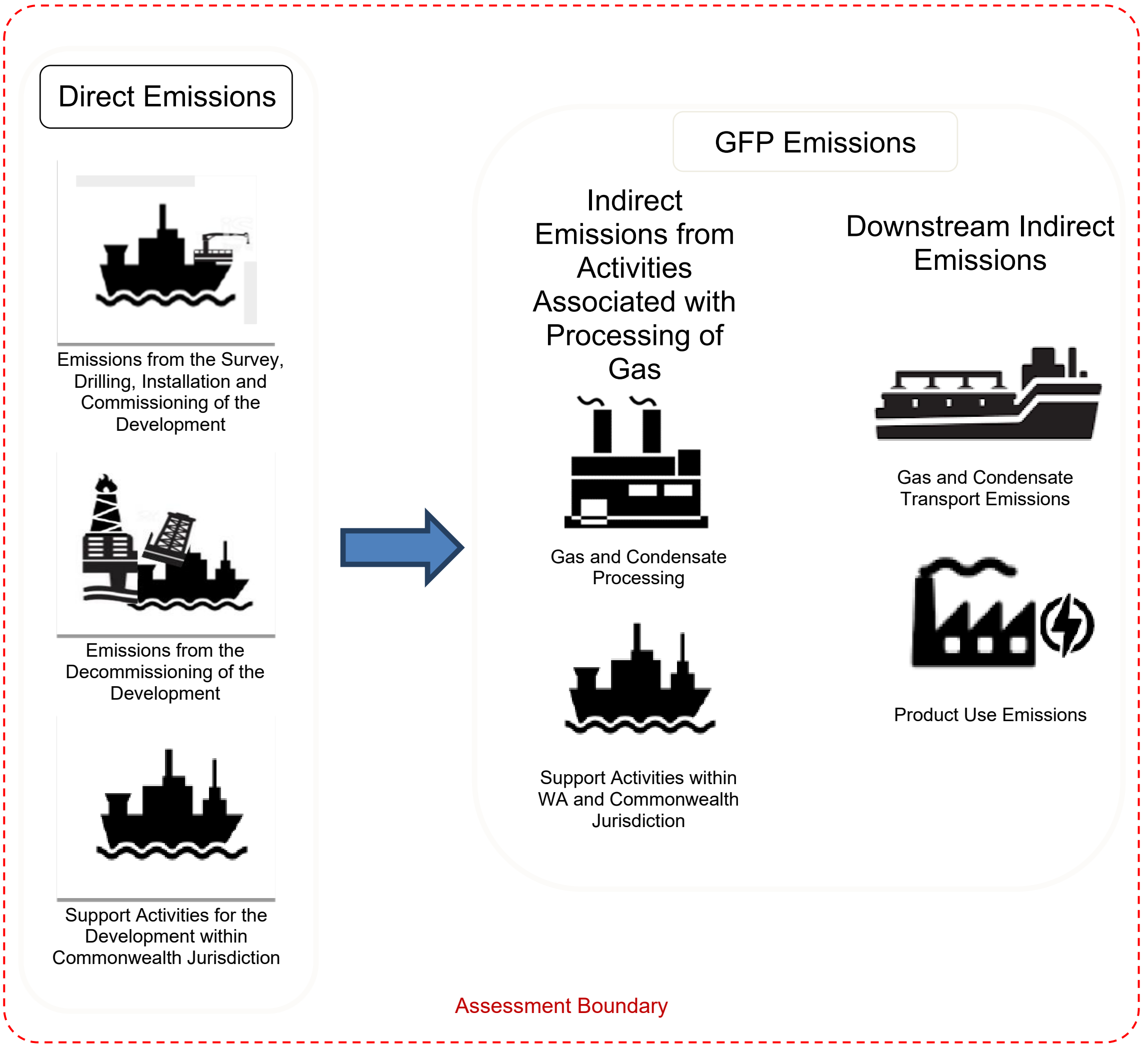

Figure 8-1: GHG emissions assessment boundary

8.3.2 Relevant GHG legislative and policy framework

The following subsections are specifically relevant to the GHG emissions legislative framework and are intended to be read in combination with the information in Section 2.1.

8.3.2.1 Paris Agreement

Australia is a signatory to the Paris Agreement. The Parties to the Paris Agreement acknowledge that climate change is a common concern of humankind, and the Parties should consider their respective obligations. The objective of the Paris Agreement includes to "hold [] the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" (Article 2). The Commonwealth government acknowledges that "[a]chieving the Paris Agreement's global goals, including limiting warming to well below 2°C and reaching global net zero, will require practical action from all countries. Australia will play its part in the global effort to reach net zero emissions by 2050" (Ref. 290). If Australia achieves its efforts to meet net zero by 2050, then it will contribute to global efforts to keep warming to the Paris Agreement target of below 2°C above pre-industrial levels and reduce the risks and impacts of climate change.

Implementation of the Paris Agreement requires economic and social transformation, based on the best available science. The Paris Agreement works on a 5-year cycle of increasingly ambitious climate action carried out by countries. Countries submit their plans for climate action—these plans are known as Nationally Determined Contributions (NDCs). In their NDCs, countries communicate actions they will take to reduce their GHG emissions to reach the goals of the Paris Agreement. Countries also communicate in the NDCs actions they will take to build resilience to adapt to the impacts of rising temperatures.

Australia is party to the Paris Agreement, and therefore must submit NDCs. Australia submitted its first NDC to the UNFCCC in 2015 and submitted an update in July 2022. The update commits Australia to reduce its emissions to 43% below 2005 levels by 2030.

8.3.2.2 Climate Change Act 2022

The *Climate Change Act 2022* (Cth) sets out Australia's GHG emissions reduction targets in a manner consistent with the Paris Agreement and Australia's NDC under that agreement.

Australia's GHG emissions reduction targets are:

- reduce net GHG emissions to 43% below 2005 levels by 2030, which is implemented as a point target as well as an emissions budget covering the period 2021–2030.
- reduce Australia's net GHG emissions to zero by 2050.

8.3.2.3 National Greenhouse and Energy Reporting (NGER) Act 2007

The NGER Act is a single national framework for reporting and dissemination of information related to GHG emissions and to contribute to the achievement of Australia's greenhouse gas emissions reduction targets.

The NGER (Safeguard Mechanism) Rule 2015 applies to all facilities with direct emissions of more than 100,000 tCO_2-e per year.

The Safeguard Mechanism places an obligation on Australia's GHG emitters with facilities that emit more than 100,000 tCO_2-e per year to keep net emissions below their emissions baseline.

The emissions reductions established under the Safeguard Mechanism are designed to be consistent with Australia's NDC under the Paris Agreement (Ref. 291).

Resetting emissions baselines for individual Safeguard Mechanism facilities and applying an annual decline rate to baselines, currently set at 4.9% each year to 2030, with annual decline rates after 2030 subject to further consultation.

The Gorgon Gas Development is registered as a facility under the NGER Act and Safeguard Mechanism, which includes the offshore wells and associated subsea infrastructure, and onshore GTP and associated facilities.

8.3.2.4 Primary Approvals

The Jansz Feed Gas Pipeline was approved by the WA Minister for the Environment on 28 May 2008 by way of Ministerial Statement No. 769 (MS 769) and by the Commonwealth Minister for the Environment and Water Resources on 22 March 2006 (EPBC 2005/2184).

The 2-train Gorgon Gas Development was referred, pursuant to the EPBC Act and EP Act, on 23 November 2003 and 19 November 2003, respectively. The Ministers' delegates set the assessment approach as assessment by environmental impact statement under the EPBC Act, and an environmental review and management program under the EP Act. Section 13 of the Draft Environmental Impact Statement / Environmental Review and Management Programme for the Proposed Gorgon Development (Ref. 1) and the Final Environmental Impact Statement / Response to Submissions on the Environmental Review and Management Programme for the Proposed Gorgon Development (Ref. 292) set out the environmental impact assessment of GHG emissions. In that assessment it was estimated that the Gorgon Gas Development would emit ~4.0 Mtpa CO_2-e of direct GHG emissions. The Gorgon Gas Development was approved with conditions (EPBC 2003/1294 and MS 748) by the relevant Ministers on 3 October 2007 and 6 September 2007, respectively. The approval has effect until 1 January 2070.

The 3-train Revised Gorgon Gas Development was subsequently referred, pursuant to the EPBC Act and EP Act, on 14 April 2008 and 22 February 2008, respectively. The Ministers' delegate set the assessment approach as assessment by public environmental review. Chapter 12 of the Gorgon Gas Development Revised and Expanded Proposal Public Environmental Review (PER) (Ref. 2) set out the environmental impact assessment of GHG emissions. The processing of gas from gas fields in the Greater Gorgon Area by the GTP was the development premise articulated in the PER. In that assessment it was estimated that the Gorgon Gas Development would emit ~5.45 Mtpa CO_2-e of direct GHG emissions. The Revised Gorgon Gas Development was approved with conditions (EPBC 2008/4178 and MS 800) by the relevant Ministers on 26 August 2009 and 10 August 2009, respectively. The approval has effect until 26 August 2070. The approved life span for the Revised Gorgon Gas Development contemplated that backfill fields would be required in the future, and would be processed at the GTP, although development of those backfill fields was not assessed and approved as part of the Revised Gorgon Gas Development. Consequently, further assessment and approval steps are required, and this OPP constitutes the primary Commonwealth approval mechanism for the backfill fields (the Development).

The Gorgon Gas Development Fourth Train Expansion Proposal was subsequently referred, pursuant to the EPBC Act and EP Act, on 27 April 2011 and 28 April 2011, respectively. The Ministers' delegate set the assessment approach as assessment by environmental impact statement under the EPBC Act, and public environmental review, under the EP Act. Chapter 11 of the Gorgon Gas Development Fourth Train Expansion Proposal Public Environmental Review / Draft Environmental Impact Statement (Ref. 5) set out the environmental impact assessment of GHG emissions. In that assessment it was estimated that the Gorgon Gas Development would emit ~7.6 Mtpa CO_2-e of direct GHG emissions for 4-trains. Emissions estimated for the 3-train proposal were revised to a total emissions footprint of ~9.5 Mtpa CO_2-e with no abatement in place, and ~6.1 Mtpa CO_2-e incorporating CO_2 reinjection estimates within the Gorgon Gas Development and Jansz Feed Gas Pipeline: Greenhouse Gas Abatement Program (Ref. 293), which was approved by the Minister's delegate of the WA Environmental Protection Authority in May 2015. The Gorgon Gas Development Fourth Train Expansion was approved with conditions (EPBC 2011/5942 and MS

1002) by the Minister on 12 May 2016 and 30 April 2015, respectively. The approval has effect until 1 January 2070.

In October 2022, the WA Minister for Environment, pursuant to section 46 of the EP Act approved an amendment to the implementation conditions by way of MS 1198 including:

- Replacing condition 26 of MS 800 with a new condition 26 requiring the proponent to:
  - implement all practicable means to inject underground all reservoir CO_2
  - implement all measures that are necessary to achieve, and which are reasonably available and/or able to be implemented, the injection underground of at least 80% of reservoir CO_2
  - Offset the quantity of reservoir CO_2 that was not injected underground.
- Replacing condition 27 of MS 800 with a new condition 27 requiring measures to ensure that Net GHG emissions do not exceed:
  - 5,220,000 tonnes of CO_2-e / year for the period until 30 June 2030
  - 4,250,000 tonnes of CO_2-e / year for the period between 1 July 2030 and 30 June 2035
  - 3,220,000 tonnes of CO_2-e / year for the period between 1 July 2035 and 30 June 2040
  - 2,120,000 tonnes of CO_2-e / year for the period between 1 July 2040 and 30 June 2045
  - 1,090,000 tonnes of CO_2-e / year for the period between 1 July 2045 and 30 June 2050
  - zero tonnes of CO_2-e / year for every five-year period from 1 July 2050 onwards.
- Annual and five-yearly reporting of GHG emissions, emissions intensities, volumes of CO_2 that have been injected, avoided or reduced through certified improvements.
- A graphical comparison of GHG emissions reduction commitments in the GHGMP to achieve the required reduction in GHG emissions by 2030 and net-zero GHG emissions by 2050 with actual GHG emissions.

8.3.3 GHG Modelling

8.3.3.1 Methodology

GHG emissions have been calculated based on the methodologies outlined in the National Greenhouse and Energy Reporting (Measurement) Determination 2008.

A GHG Emissions Inventory Technical Report has been prepared and is provided in Appendix E.

As described in Section 8.3.1.4, CAPL has defined the emissions boundary for the assessment of GHG emissions in relation to the Development as described in Section 4. Any unplanned activities, including repairs, or emergency events, are considered out of scope of the emissions inventory.

Any equipment (e.g. AUV, ROV) used to support IMR activities is expected to be powered by the support vessel itself, these do not represent an additional emission source to those already accounted for by the vessel.

CAPL acknowledges that fugitive emissions may occur from the Development subsea hydrocarbon system in Commonwealth waters, but these are considered to represent a minor proportion of fugitive emissions for the entire Gorgon Gas Development. Fugitive emissions for the Gorgon Gas Development are estimated as per the NGER Measurement Determination for an LNG station, and therefore, any offshore components cannot easily be separated. As such, fugitive emissions estimates have been fully incorporated into the inventory for indirect GHG emissions associated with gas processing at the GTP on Barrow Island.

8.3.3.2 Direct emissions

Based on the boundary (Section 8.3.1.4) and methodology (Section 8.3.3.1), the estimate of direct GHG emissions for the Development is 3.7 Mt CO_2-e.

Figure 8-2 shows the direct GHG emissions for the whole project life of the Development per phase.

Approximately 89% of the direct emissions are attributed to fuel combustion during Support Activities (vessels and MODU), and ~11% are attributable to flaring and venting during Drilling, Operations and Decommissioning.

Apart from the Support Activities, no direct emissions are expected from the Development's Operations phase.

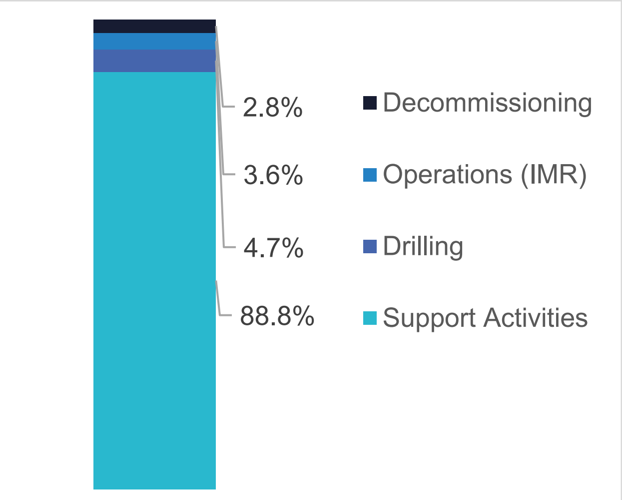

Figure 8-2: Direct Emissions from the Development[41]

When considering the timing of the Support Activities across the different stages of the Development, the direct emissions are as outlined in Figure 8-3.

[41] For the emissions estimate, support activities are included in each relevant phase they are supporting, and not shown as a separate part of this figure.

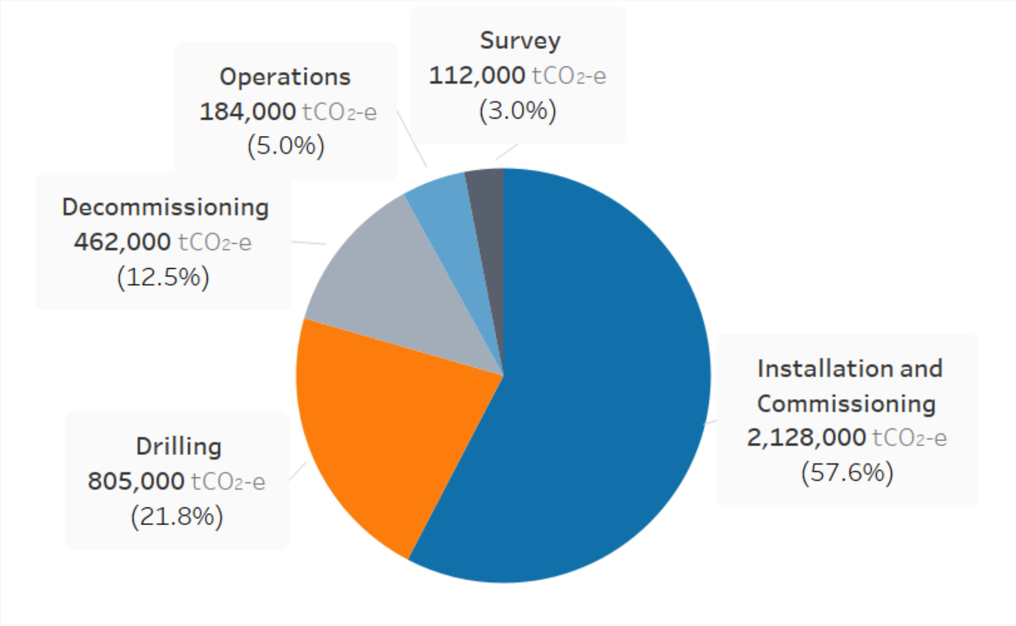

Figure 8-3: Direct Emissions from the Development with Support Activities assigned to the stages in which they occur

For additional details, refer to the GHG Emissions Inventory Technical Report in Appendix E.

8.3.3.3 Indirect emissions associated with gas processing at the GTP on Barrow Island

Indirect emissions from the Gorgon Gas Development, including those from the Development, were assessed and approved under the EIS/ERMP 4 Train development proposal (Ref 5) as the backfill fields were contemplated as part of the Gorgon Gas Development. Given there are no additional indirect emissions associated with the Development above those already approved, the following presents the remainder of life summation for the GTP.

Indirect emissions associated with gas processing at the GTP on Barrow Island have been estimated to be 211 MtCO2-e for the remainder of the life of the Gorgon Gas Development. The remainder of the life of the Gorgon Gas Development refers to the operations of the Gorgon Gas Development, including the Development, up to the approved operational life until 2070 (Section 8.3.2.4). Gas turbines, which are used in liquefaction and power generation, generate >75% of these GHG emissions (Figure 8-4).

GHG emissions intensity, calculated based on a total of 34 MMTJ of gas to be produced at the GTP, has been estimated to be 6.2 tCO_2-e/TJ.

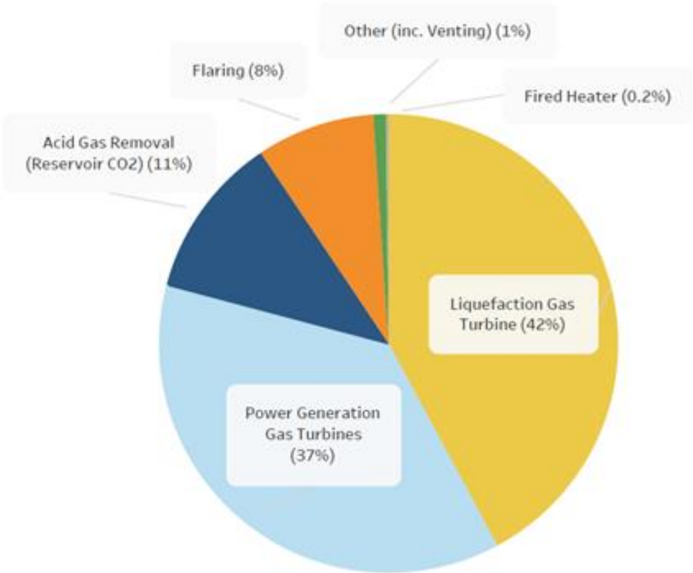

Figure 8-4: Indirect emissions associated with gas processing at the GTP on Barrow Island

As required under condition 27.1 of MS 800 as amended by MS 1198, the net GHG emissions are estimated at 92 Mt CO_2-e for the remainder of the life of the Gorgon Gas Development[42], and the corresponding net GHG emissions intensity is 2.7 t CO_2-e/TJ. The net GHG emissions intensity represents the emissions intensity after this condition has been met.

8.3.3.4 Downstream indirect emissions

As the Gorgon Gas Development supplies both the Australian domestic market and the international market, these third-party indirect emissions may occur across multiple national and global locations. A large percentage of LNG produced by the Gorgon Gas Development is supplied internationally under long-term contracts. This long-term export market is primarily Japan, with some exports to other countries including China, Taiwan, and South Korea. These indirect emissions would be direct emissions for the end consumers, who would operate under their respective regulatory regimes to manage their emissions and any associated impacts.

Customer markets are key to understanding where downstream indirect emissions occur. Under the Paris Agreement, each country is responsible for reporting and reducing emissions within its jurisdiction. This means that the Paris Agreement is the framework that manages downstream indirect emissions associated with Gorgon LNG and condensate use.

For the Gorgon Gas Development as a whole, including the Development, the estimate of downstream indirect GHG emissions associated with transport and third-party end of use of products is an annual average of ~38 Mtpa, or ~49 Mtpa for a representative production year of the 3-train operation. These figures are consistent with the approved Gorgon Gas Treatment Plant GHG MP (Ref. 66). This estimate corresponds to total potential downstream indirect emissions and do not take into account any emissions mitigations and reductions associated with

[42] *The remainder of the life of the Gorgon Gas Development refers to the operations of the Gorgon Gas Development, including the Development, up to the approved operational life until 2070 (Section 8.3.2.4).*

shipping or undertaken by the end user. It is important to note that the primary long-term export markets have net zero commitments to manage emissions in their jurisdictions.

For additional details, refer to the GHG Emissions Inventory Technical Report provided in Appendix E.

8.3.4 Impact and risk evaluation

One of the main causes of climate change is the concentration of GHG emissions in the global atmosphere. The assessment is framed within the national and international legally binding Paris Agreement treaty to limit global warming, and country-specific emissions reduction policies and regulation to reduce GHG emissions in line with the long-term temperature goal of the Paris Agreement, of which Australia is a signatory.

The scoping exercise (Section 7.3) identified climate as the receptor within the OA that may be impacted by GHG emissions.

Table 8-12 details the risk evaluation and the level of consequence to receptors found to be susceptible to GHG emissions.

Table 8-12: Risk evaluation for GHG emissions

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
GHG emissions may result in: • contribution to the reduction of the global atmospheric carbon budget (by the amount of direct and indirect GHG emissions associated with activities under this OPP).	6	GHG emissions may result in: Contribution to the anthropogenic influence on the global climate system			N/A

Risk evaluation
Contribution to the reduction of the global atmospheric carbon budget
The IPCC defines the term 'carbon budget' as: '[T]he maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to a given level with a given probability, taking into account the effect of other anthropogenic climate forces. This is referred to as the total carbon budget when expressed starting from the pre-industrial period, and as the remaining carbon budget when expressed from a recent specified date. Historical cumulative CO_2 emissions determine to a large degree warming to date, while future emissions cause future additional warming. The remaining carbon budget indicates how much CO_2 could still be emitted while keeping warming below a specific temperature level.' As the Working Group I contribution to the Sixth Assessment Report (WGI AR6) of the Intergovernmental Panel on Climate Change (IPCC) acknowledges, "[c]limate change is a global phenomenon, but manifests differently in different regions" (Ref. 294). Moreover, the Summary for Policymakers to the same report states that "[h]istorical cumulative CO_2 emissions determine to a large degree warming to date, while future emissions cause future additional warming" (Ref. 295). Future emissions are relevant to remaining carbon budgets, which vary based on emissions scenarios, and "indicate[] how much CO_2 could still be emitted while keeping warming below a specific temperature level" (Ref. 295). The global annual mean CO2 concentration in 2021 was 414.4 ppm—a 50% increase from the concentration of 277 ppm in 1750.

Risk evaluation
Other non-CO_2 GHGs include methane and nitrous oxide. In 2021, the global annual mean concentration of methane was 1,890 parts per billion (ppb) and 334 ppb for nitrous oxide. Respectively, these are rises of 158% and 22% above their 1750 levels of 731 ppb and 273 ppb. Direct GHG emissions from the Development are estimated to be 3.7 Mt CO_2-e, which is predicted to be an annual average of ~0.07 Mtpa CO_2-e. This is equivalent to ~0.015% of national Australian emissions (when compared to the 2022 national inventory of 490.5 MtCO_2-e). Indirect emissions associated with gas processing at the GTP on Barrow Island are estimated to be within the ~9.5 Mtpa CO_2-e GFP emissions approved under EPBC 2011/5942 and MS 1002. These emissions represent ~1.9% of national Australian emissions (when compared to the 2022 inventory). In the near to medium term the State Ministerial Conditions are likely to provide a greater net emissions reduction than contemplated under the Safeguard Mechanism reform. The emissions reductions established under the Safeguard Mechanism are designed "to deliver emissions reductions consistent with Australia's Nationally Determined Contribution under the Paris Agreement" (Ref. 291). The downstream indirect GHG emissions from the transport and third-party end-use of LNG, condensate and domestic gas are estimated to be ~49 Mtpa CO2-e based on a representative year of three Train operation. AR6 Working Group 3, published in April 2022, outlined that the remaining carbon budgets for a 50% likelihood to limit global warming to 1.5°C, 1.7°C, and 2°C are 500 GtCO_2-e, 850 Gt CO_2-e, and 1350 Gt CO_2-e, respectively (Ref. 296). The total direct and indirect GHG emissions from activities associated with the Development are ~60 Mtpa CO_2-e, which represents ~0.14–0.4% reduction in the total remaining global carbon budget, which is a de minimis decrease. It is noted that this estimated contribution to the total global carbon budget is based on emissions estimates (as shown in this OPP), and with no allowance for future mitigation (including net zero requirements, future technology or operational efficiencies, or future Australian regulatory or international policy requirements). According to the IEA (Ref. 297), an estimated 1.2Gt CO_2-e could be abated in the short term by switching from coal to existing gas-fired plants if relative prices and regulation are supportive. Although the IEA states that switching between unabated consumption of fossil fuels, on its own, does not provide a long-term solution, there is significant CO_2 and air quality benefits, from using less emission-intensive fuels such as natural gas (Ref. 297). As such, the use of gas produced from the Gorgon Gas Development, including the Development, supports Australia in providing short-term CO_2 emissions reduction by displacing more emission intensive fuels. When used as a primary energy source, LNG has several benefits over other fossil fuels, including lower emissions of sulphur dioxide, particulate matter and GHG emissions. Downstream indirect emissions associated with the transport and third-party end-use of LNG, condensate and domestic gas products is the largest category of emissions associated with CAPL's activities (Appendix E). Downstream indirect emissions are driven by global demand, which is in turn driven by economics, policy, regulation, and consumer behaviour on a global scale (Ref. 298). In summary, due to the relatively lower emissions intensity of natural gas compared to other fossil fuel alternatives, that natural gas is part of Australia's long-term emissions reduction plan (in the absence of a new Net Zero Reduction Plan), and that it can be considered as supporting the global transition to lower carbon intensive fuels, and the overall de minimis contribution to the reduction of the global carbon budget from the Gorgon Gas Development, the impact of contribution to the global carbon budget has been evaluated as having the potential to result in an Incidental (6) consequence.
Contribution to the anthropogenic influence on the global climate system
<u>Changes to climate systems</u> As the Working Group I contribution to the newly released Sixth Assessment Report (WGI AR6) of the Intergovernmental Panel on Climate Change (IPCC) acknowledges, "[c]limate change is a global phenomenon, but manifests differently in different regions" (Ref. 294). Moreover, the Summary for Policymakers to the same report states that "[h]istorical cumulative CO_2 emissions determine to a large degree warming to date, while future emissions cause future additional warming" (Ref. 295). Future emissions are relevant to remaining carbon budgets, which vary based on emissions scenarios, and "indicate[] how much CO_2 could still be emitted while keeping warming below a specific temperature level" (Ref. 295). The physical risks of climate change are varied and widespread, and CAPL acknowledge that disruption from natural or human causes beyond its control, include physical risks from hurricanes, severe storms, floods, heat waves, other forms of severe weather, wildfires, ambient temperature increases, and sea level rise (Ref. 298). According to the IPCC, among other things, global changes to the climate system can include the following: increase in global surface temperatures, changes to frequency and intensity of precipitation, sea level rise, retreat of glaciers and artic sea ice, changes to the intensity and frequency of certain extreme weather events and droughts (Ref. 294). Specifically, the IPCC projections for the Australia include:

Risk evaluation
• Droughts: Additional regional changes in Australasia [. . .] include a significant decrease in April to October rainfall in southwest Western Australia, observed from 1910 to 2019 and attributable to human influence (high confidence43), which is very likely to continue in future. Agricultural and ecological and hydrological droughts have increased over southern Australia (medium confidence), and meteorological droughts have decreased over northern and central Australia (medium confidence). (. . .) Agricultural and ecological droughts are projected to increase in southern and eastern Australia (medium confidence) for a 2°C GWL."[44] • Fire Weather Conditions: "The number of evident attribution studies on compound events is limited. There is medium confidence that weather conditions that promote wildfires have become more probable in southern Europe, northern Eurasia, the USA, and Australia over the last century. In Australia a number of event attribution studies show that there is medium confidence of increase in fire weather conditions due to human influence.".[45] (. . .) Fire weather is projected to increase throughout Australia (high confidence) . . . .[17] • Precipitation: "In the future, heavy precipitation and pluvial flooding are very likely to increase over northern Australia and central Australia, and they are likely to increase elsewhere in Australasia for global warming levels (GWLs) exceeding 2°C and with medium confidence for a 2°C GWL."[46] • Relative Sea Level Rise: "Relative sea level has increased over the period 1993–2018 at a rate higher than GMSL around Australasia (high confidence). Sandy shorelines have retreated around the region, except in southern Australia, where a shoreline progradation rate of 0.1 myr–1 has been observed."[47] . . . "Relative sea-level rise is virtually certain to continue in the oceans around Australasia, contributing to increased coastal flooding in low-lying areas (high confidence) and shoreline retreat along most sandy coasts (high confidence)."[48] • Snowfall: "Snowfall is expected to decrease throughout the region at high altitudes in [] Australia (high confidence)."[49] (. . .) "Observations in Australia show that the snow season length has decreased by 5% in the last five decades. Furthermore, the date of peak snowfall in Australia has advanced by 11 days over the last 5 decades."[50] • Tropical Cyclones: "In Australia, the number of [tropical cyclones] has generally declined since 1982, and the frequency of intense TCs that make landfall in north eastern Australia has declined significantly since the 19th century (medium confidence). There is high confidence that cyclones making landfall along north eastern and north Australian coastlines will decrease in number and low confidence of an increase I their intensities for a 2°C global warming level as well as for the mid-century period with scenarios RCP4.5 and above, with the amplitude of changes increasing from RCP4.5 to RCP8.5. Decreases in frequency are projected for 'east coast lows.'"[51]

<u>Values and sensitivities vulnerable to climate change</u>
The Working Group II contributions to the IPCC's Fifth Assessment Report (WGII AR5) provides a summary of the observed impacts, vulnerability and exposure, and adaptive responses observed to date (Ref. 299). Observed impacts to which climate change may have contributed and are reported within the Australasian region include:
• Snow and ice, rivers and lakes, floods, and drought:
  – "Significant decline in late-season snow depth at 3 of 4 alpine sites in Australia (1957–2002) (medium confidence, major contribution from climate change)
  – Intensification of hydrological drought due to regional warming in southeast Australia (low confidence, minor contribution from climate change)

[43] "*The following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%, more likely than not >50–100%, and extremely unlikely 0–5%) may also be used when appropriate.*" IPCC AR6, SPM-4.

[43] IPCC AR6, WG1, TS-93.

[44] IPCC AR6, WG1, TS-74.

[45] IPCC AR6, WG1, TS-93.

[46] IPCC AR6, WG1, TS-93.

[47] IPCC AR6, WG1, TS-93.

[48] IPCC AR6, WG1, 12-57.

[49] IPCC AR6, WG1, TS-93.

[50] IPCC AR6, WG1, TS-93-94.

[51] IPCC AR6, WG1, 12-54, 55.

Risk evaluation

- Reduced inflow in river systems in southwestern Australia (since the mid-1970s) (high confidence, major contribution from climate change)"

- Terrestrial ecosystems:
  - "Changes in genetics, growth, distribution, and phenology of many species, in particular birds, butterflies, and plants in Australia, beyond fluctuations due to variable local climates, land use, pollution, and invasive species (high confidence, major contribution from climate change)
  - Expansion of some wetlands and contraction of adjacent woodlands in southeast Australia (low confidence, major contribution from climate change)
  - Expansion of monsoon rainforest at expense of savannah and grasslands in northern Australia (medium confidence, major contribution from climate change)
- Coastal erosion and marine ecosystems:
  - "Southward shifts in the distribution of marine species near Australia, beyond changes due to short-term environmental fluctuations, fishing, and pollution (medium confidence, major contribution from climate change)
  - Change in timing of migration of seabirds in Australia (low confidence, major contribution from climate change)
  - Increased coral bleaching in Great Barrier Reef and western Australian reefs, beyond effects from pollution and physical disturbance (high confidence, major contribution from climate change)
  - Changed coral disease patterns at Great Barrier Reef, beyond effects from pollution (medium confidence, major contribution from climate change)"
- Food production and livelihoods:
  - "Advanced timing of wine-grape maturation in recent decades, beyond advance due to improved management (medium confidence, major contribution from climate change)
  - Shift in winter vs. summer human mortality in Australia, beyond changes due to exposure and health care (low confidence, major contribution from climate change)
  - Relocation or diversification of agricultural activities in Australia, beyond changes due to policy, markets, and short-term climate variability (low confidence, minor contribution from climate change)."

DAWE identified climate change as a key threat (Ref. 300), specifically:

- '[a] changing climate is impacting our threatened animals, plants, and environments. It is reducing the number of animals and plants and reducing the places where they occur'
- '[t]he changing climate is driving changes in species distribution and the composition and functioning of ecological communities, exacerbating the impacts of other pressures such as habitat fragmentation and invasive species'.

Climate change is identified as a threat to some protected species, including marine turtles and whales:

- The Recovery Plan for Marine Turtles in Australia (Ref. 148) states that '[c]limate change is of particular concern to marine turtles because it is likely to have impacts across their entire range and at all life stages. Climate change is expected to cause changes in dispersal patterns, food webs, species range, primary sex ratios, habitat availability, reproductive success, and survivorship'.
- The Conservation Management Plan for the Blue Whale (Ref. 16) states: '[c]limate change is expected to cause changes in migratory timing and destinations, population range, breeding schedule, reproductive success, and survival of baleen whales, including blue whale species and subspecies'.
- The Conservation Advice for Humpback Whale (Ref. 127) states that '[c]limate change may lead to changes in species abundance, migration timing and range, species distribution, changes to prey/predator relationships, prey availability and reproductive timing and success, which could impact on the health and survival of species'.
- The North-west Marine Parks Network Management Plan 2018 (Ref. 83) identifies climate change as a pressure that may impact marine park values. The management plan states that '[t]he impacts of climate change on the marine environment are complex and may include changes in sea temperature, sea level, ocean acidification, sea currents, increased storm frequency and intensity, species range extensions or local extinctions, all of which have the potential to impact on marine park values'.

Anthropogenic influence on the climate system

Anthropogenic changes to the global climate system cannot be directly attributed to any one development or emission source or product, as they are the result of the net accumulation of global GHGs (emissions minus sinks) in the atmosphere since the industrial revolution.

Risk evaluation
Growing populations, rising incomes, and urbanisation are the principal forces behind energy-demand growth, as they typically lead to greater use of transportation, heating, cooling, lighting, and refrigeration (Ref. 298). The changing regulatory and international initiatives on climate change (e.g., which may result in changing reduction targets and timeframes) will also influence the total global GHG emissions into the future – making a future prediction of changes to climate systems, inaccurate. Summary As a contribution to the anthropogenic influence on the global climate system cannot be directly attributed to any one development, no further assessment has been completed.

8.3.5 Determination of acceptability

The acceptable level of impact is a function of the magnitude of impact and residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-13 details the determination of acceptability for GHG emissions.

Table 8-13: Determination of acceptability for GHG emissions

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The highest consequence level for GHG emissions was evaluated as Incidental (6). CAPL have adopted **CM17** to address residual uncertainty associated with the impacts and risks of GHG emissions; committing to undertake an annual adaptive management review, specifically including: • monitoring the historical and forecast global energy mix and associated emissions, including the role of Gorgon product types • review of the accuracy of estimated downstream indirect GHG emissions associated with the Gorgon Gas Development to validate the estimates used as the basis for the impact and risk assessment • review of the environmental impact and risk assessment for GHG emissions to ensure that GHG emissions are being reduced to ALARP and managed to an acceptable level in future EPs. The acceptable level of impact from GHG emissions has been agreed by the international community in Article 2 of the Paris Agreement. Australia has ratified the Paris Agreement and the Doha Amendment to the Kyoto Protocol and set a target to reduce GHG emissions by 43% below 2005 levels by 2030, as outlined in the *Climate Change Act 2022* (Cth). The Development is consistent with the *Climate Change Act 2022* (Cth) by: • providing low emission energy exports (LNG) to support the global transition to lower carbon intensive fuels, and the overall de minimis contribution to the reduction of the global carbon budgets, the Development will support Australia's global efforts to reach net zero by 2050. • The Gorgon Gas Development, with a regulated net zero pathway and large proportion of emissions reduction through technical abatement (under State Ministerial conditions and Federal legislation), has more substantive measures compared with many other similar projects. • Chevron Corporation supports the global net zero ambitions of the Paris Agreement. Principle of ESD (b) is applied for this aspect, despite the Incidental (6) residual risk, through the adoption of controls detailed below
	(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations

Determination of acceptability		
	Considering economic development that safeguards the welfare of future generations, the Development is considered to align with the core objectives of ESD by: • Providing a lower carbon intensity and reliable energy source. Chevron Corporation contribute to the SDGs through their operations, partnership initiatives and social investments (Ref. 301). Chevron Corporation invest in health, education, and economic development with the goal of creating measurable and enduring value. Through membership in International Petroleum Industry Environmental Conservation Association (IPIECA), Chevron Corporation have worked with the World Business Council for Sustainable Development on the creation of an SDG Roadmap for the oil and gas sector. The Roadmap identifies how IPIECA, as an industry association, and Chevron Corporation can work toward a lower-emissions future while contributing to the 2030 Agenda.	
	(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making	
	Feasible Development alternatives were considered, comparing environmental impacts and risks of each option. The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk to the environment (Section 5). Principle of ESD (d) is applied through the consideration of conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5. By producing progressively lower carbon intensity products through time, the Gorgon Gas Development is supporting the *Climate Change Act 2022* (Cth) and Paris Agreement's goal of holding the "global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels".	
Relevant environmental legislation and other requirements	Legislation and other requirements considered relevant for this aspect are listed below. The OPP will implement controls to address relevant item/objective/action within each of the listed legislative requirements considered relevant to this aspect.	
	Requirement	**Demonstration of requirement**
	Paris Agreement/ Equivalent Legislation Japan, China, South Korea, and Taiwan are presently the main markets for Gorgon LNG. However, there are emerging regional markets where demand for LNG is expected to grow in the future. These include India, Indonesia, Bangladesh, Thailand, Malaysia, Vietnam, and The Philippines. As most of the countries that are likely to receive the Gorgon product have ratified the Paris Agreement or have legislation with similar obligations, the emissions resulting in the combustion and usage of the product will be managed under the respective country's domestic and international GHG control frameworks. The Paris Agreement works on a 5-year cycle of increasingly ambitious climate action through the setting of NDCs, and other methods such as an emissions trading scheme, carbon tax and offsets. Whilst Gorgon's main export is LNG, a small volume of condensate is also produced. Based on historical trade, condensate from Gorgon will likely be exported to regional refineries in	Legislative requirements to manage GHG emissions are addressed by adopting these control measures: **CM17**: CAPL will undertake an annual adaptive management process to address the residual uncertainty associated with impacts and risks from the generation of GHG emissions, specifically including: • monitoring the historical and forecast global energy mix and associated emissions, including the role of Gorgon product types • review of the accuracy of estimated downstream indirect GHG emissions associated with the Gorgon Gas Development to validate the estimates used as the basis for the impact and risk assessment • review of the environmental impact and risk assessment for GHG emissions to ensure that GHG emissions are being reduced to ALARP and managed to an acceptable level in future EPs. **CM15:** CAPL will evaluate opportunities to partner with organizations that promote and address GHG emissions reduction and carbon offsets in the LNG value chain, and

Determination of acceptability		
	Singapore, with a small likelihood of being exported to refineries in Thailand and South Korea. Thailand and South Korea have established NDCs under the Paris Agreement. Singapore has also ratified the Paris Agreement and committed to reduce its emissions intensity by 36% from 2005 levels by 2030 and stabilise its emissions with the aim of peaking around 2030 at 65Mt CO_2-e. The fact that CO_2 injection was part of the original development premise, has been constructed and is operational with conditioned GHG emissions limits with a trajectory to net zero by 2050 puts the Gorgon Gas Development, and the Development, ahead of many other projects to provide lower carbon intensity energy into the future.	advocate for LNG and natural gas as fuels of choice. **CM16:** CAPL is committed to continual improvement and adaptive management processes, and regularly monitors for revised or contemporary Australian regulatory and/or relevant international guidelines or standards in relation to GHG and carbon management.
	***Climate Change Act 2022* (Cth)** Sets out Australia's GHG emissions reduction targets in a manner consistent with the Paris Agreement and Australia's NDCs. Chevron Corporation support the global net zero ambitions of the Paris Agreement and adopted a 2050 net zero aspiration for equity upstream Scope 1 and 2 emissions. Chevron Corporation support a price on carbon, applied as widely and broadly as possible, as the best approach to reduce emissions. The Gorgon Gas Development is aligned with the Paris Agreement objectives, which require the Gorgon Gas Development to reduce direct emissions progressively through time and reach net zero from 2050.	
	***Environmental Protection Act 1986* (EP Act)** The production of the Greater Gorgon Gas Fields, including the Development, and its processing at the GTP was described within EPBC Reference: 2003/1294 and MS 748. Downstream indirect emissions associated with those contemplated backfill fields were similarly outlined within EPBC Reference: 2003/1294 and MS 748. While development of the backfill fields was articulated under previous primary approvals documentation, this OPP constitutes the primary approval document for these fields. In October 2022, the WA Minister for Environment, pursuant to section 46 of the EP Act approved the amendment to the implementation conditions for MS 1198 including:	Because implementation of the EP Act approval is a regulatory requirement, no specific control measure has been adopted for this requirement.

Determination of acceptability		
	• Replacing condition 26 of MS 800 with a new condition 26 requiring: – implement all practicable means to inject underground all reservoir CO_2 – implement all measures that are necessary to achieve, and which are reasonably available and/or able to be implemented, the injection underground of at least 80% of reservoir CO_2 – Offset the quantity of reservoir CO_2 that was not injected underground. • Requiring measures to ensure that Net GHG emissions do not exceed: – 5,220,000 tonnes of CO_2-e / year for the period until 30 June 2030 – 4,250,000 tonnes of CO2-e / year for the period between 1 July 2030 and 30 June 2035 – 3,220,000 tonnes of CO_2-e / year for the period between 1 July 2035 and 30 June 2040 – 2,120,000 tonnes of CO_2-e / year for the period between 1 July 2040 and 30 June 2045 – 1,090,000 tonnes of CO_2-e / year for the period between 1 July 2045 and 30 June 2050 – zero tonnes of CO_2-e / year for every five-year period from 1 July 2050 onwards. • Annual and five-yearly reporting of GHG emissions, emissions intensities, volumes of CO_2 that have been injected, avoided, or reduced through certified improvements. • A graphical comparison of GHG emissions reduction commitments in the GHGMP to achieve the required reduction in GHG emissions by 2030 and net-zero GHG emissions by 2050 with actual GHG emissions. The conditions provided in Ministerial approvals under the EP Act provide substantial emissions abatement requirements.	

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td>National Greenhouse and Energy Reporting (NGER) Act 2007
The Gorgon Gas Development is required to report GHG emissions under the NGER Act 2007.
A revised Safeguard Mechanism baseline for Gorgon Operations is currently undergoing audit by the Clean Energy Regulator delegate. Once approved, this baseline will apply. Consequently, CAPL will continue to monitor and report GHG emissions, and maintain a baseline, under this legislation.</td><td>Because NGER reporting is a regulatory requirement, no specific control measure has been adopted for this requirement.
The Safeguard Mechanism baseline is a requirement that needs to be met and sets a GHG baseline. Any exceedance is required to be offset through multi-year averaging, banking/borrowing provisions, or the purchase of ACCUs or Safeguard Mechanism credits.</td></tr>
<tr><td></td><td>Navigation Act 2012 (Cwlth) – Chapter 4 (Prevention of Pollution)
Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment and gives effect to the requirements under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) in Australia.</td><td>CM14: Comply with the requirements of Marine Order 97 (MARPOL 73/78 Annex VI) in relation to GHG emissions:
• vessels will hold a valid International Air Pollution Prevention (IAPP) certificate and a current international energy efficiency (IEE) certificate
• all vessels (as appropriate to vessel class) will have a Ship Energy Efficiency Management Plan (SEEMP) as per MARPOL 73/78 Annex VI.</td></tr>
<tr><td>Internal Context</td><td colspan="2">These CAPL environmental performance standards or procedures were deemed relevant for this aspect:
• Climate Change Resilience (Ref. 302)
• Chevron Marine Standard Non Tankers (Ref. 284).</td></tr>
<tr><td>External context</td><td colspan="2">CAPL has maintained long-term external stakeholder relationships for the Gorgon Gas Development since the inception of engagement during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation where relevant as part of the Stage 1 assessment.
No feedback was received in relation to GHG emissions from Phase 1 stakeholder consultation.</td></tr>
<tr><td rowspan="2">Defined acceptable level</td><td>Plan and Relevant Objective</td><td>Demonstration of Requirement</td></tr>
<tr><td>Climate Change Act 2022 (Cth)
EPBC Act</td><td>The Gorgon Gas Development, including the development of the Greater Gorgon Gas Fields (including the Development) via the GTP, was described within conditions under EPBC References 2003/1294.
CAPL and the Development will comply with Australian National and Western Australian GHG legislative requirements, supporting acceptability. Indirect emissions associated with processing gas at Barrow Island are managed via regulatory instruments such as MS 1198.
MS 1198 provides a framework that manages Western Australian State jurisdiction indirect emissions from the GTP on an ongoing basis consistently with progress towards net zero.</td></tr>
</table>

Determination of acceptability		
		The Gorgon Gas Development, with a large portion of technical abatement through carbon capture and storage, and net zero pathway with tangible actual and percentage reductions required by MS1198.
	Recovery Plans / Conservation Advices for threatened and / or migratory MNES species that may occur in the OA identify potential impacts and risks from climate change to those MNES species. As a reduction in the global carbon budget may result in changes to global climate systems, CAPL has defined an acceptable level of impact such that it is not inconsistent with these documents.	
	Therefore, CAPL has defined the following acceptable level of impact as: • not materially or substantially contributing to Australia's GHG emissions, and as such, subsequently not preventing Australia meeting international GHG emission commitments. Australia is a signatory to the Paris Agreement and is currently committed to reducing GHG emissions by 43% below 2005 levels by 2030. The objective of the Paris Agreement includes to limit "the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" (Article 2). The Commonwealth government acknowledges that "[a]chieving the Paris Agreement's global goals, including limiting warming to well below 2°C and reaching global net zero, will require practical action from all countries. Australia will play its part in the global effort to reach net zero emissions by 2050" (Ref. 290). Australia's plan and the global context is that "Australia recognises we must reduce emissions while accommodating countries' economic development goals, especially in the Asia- Pacific and Indo-Pacific regions. As well as reducing our own emissions, our plan focuses on how Australia can play a global leadership role through low emissions energy exports and contributions to innovation" (Ref. 290). Moreover, Australia has already reduced emissions by 20% since 2005 (Ref. 290). By providing low emission energy exports (LNG) s, the Gorgon Gas Development will support Australia's global efforts to reach net zero by 2050. If Australia achieves its efforts to meet net zero by 2050, then it will contribute to global efforts to keep warming to the Paris Agreement target of well below 2°C above pre-industrial levels and significantly reduce the risks and impacts of climate change. As discussed within the above consequence evaluation, based on the predicted emissions, the Development has a de minimis contribution to the reduction of the global carbon budget. Given that anthropogenic changes to the global climate system cannot be directly attributed to any one development or emission source or product, CAPL considers that the Development will meet the defined "acceptable level of impact as not materially or substantially contributing to Australia's GHG emissions, and as such, subsequently not preventing Australia meeting international GHG emission commitments" as required by MS 1198. Additionally, there are other regulatory reporting mechanisms (i.e., NGER scheme) in place to ensure that GHG emissions from the Gorgon Gas Development, including the Development, are adaptively managed in line with best practice and contemporary legislative and other requirements. CAPL considers that the Development, with the control measures as described for this aspect in place, meet this acceptable level.	

8.3.6 Environmental performance

Table 8-14 provides the EPOs defined for GHG emissions and the adopted control measures to achieve the outcome.

Table 8-14: Environment performance for GHG emissions

Environmental performance outcome	Adopted control measure
EPO05: Do not materially or substantially contribute to Australia not meeting its international GHG emissions commitments by managing direct or indirect GHG emissions associated with the Development in Australia[52] consistent with the emissions targets outlined in MS 1198 and the Safeguard Mechanism	**CM12:** CAPL will implement its emissions reduction review to identify emissions reduction opportunities (within its operational control) for the Gorgon Gas Development to be included in an enterprise-wide selection process.
	CM13: CAPL will support Chevron's corporate aspiration of managing global upstream emissions by implementing management strategies, projects, or improvements for the Gorgon Gas Development selected during an enterprise-wide selection process.
	CM14: Comply with the requirements of Marine Order 97 (MARPOL 73/78 Annex VI) in relation to GHG emissions: • vessels will hold a valid International Air Pollution Prevention (IAPP) certificate and a current international energy efficiency (IEE) certificate • all vessels (as appropriate to vessel class) will have a Ship Energy Efficiency Management Plan (SEEMP) as per MARPOL 73/78 Annex VI.
	CM15: The tender evaluation for vessel and MODU contracts will include an evaluation of CO_2 emissions.
	CM16: CAPL is committed to continual improvement and adaptive management processes, and regularly monitors for revised or contemporary Australian regulatory and/or relevant international guidelines or standards in relation to GHG and carbon management.
EPO06: Manage downstream indirect GHG emissions[53] associated with the Development consistent with the objectives of the Paris Agreement.	**CM17:** CAPL will undertake an annual adaptive management process to address the residual uncertainty associated with impacts and risks from the generation of GHG emissions, specifically including: • monitoring the historical and forecast global energy mix and associated emissions, including the role of Gorgon product types • review of the accuracy of estimated downstream indirect GHG emissions associated with the Gorgon Gas Development to validate the estimates used as the basis for the impact and risk assessment • review of the environmental impact and risk assessment for GHG emissions to ensure that GHG emissions are being reduced to ALARP and managed to an acceptable level in future EPs.
	CM18: CAPL will evaluate opportunities to partner with organizations that promote and address GHG emissions reduction and carbon offsets in the LNG value chain, and advocate for LNG and natural gas as fuels of choice
	CM19: CAPL will report production and emissions data from the Gorgon Gas Development to Chevron Corporation annually for inclusion in the calculation of its portfolio carbon intensity metric.

[52] Where 'direct and indirect GHG emissions associated with Gorgon Gas Development in Australia' refers to the direct emissions associated with activities within this OPP plus the indirect emissions from processing gas at the GTP on Barrow Island.

[53] Where 'downstream indirect GHG emissions' refers to the emissions associated with transport, and third-party end-use of LNG, condensate and domestic gas products.

8.4 Light emissions

8.4.1 Source

Light is a form of energy that is emitted over a particular band of frequencies and wavelengths of the electromagnetic spectrum. Fauna perceive light differently to humans. Depending on the species, the visible spectrum for fauna can vary between the ultraviolet and infrared spectra (i.e. wavelengths between ~300 and >700 nanometres) (Ref. 75).

Factors affecting how wildlife perceive light include the type of cells used to detect light (photopic versus scotopic vision); whether the light is viewed directly from the source or as reflected light; how the light interacts with the environment; and the distance from the light source (Ref. 75).

The potential impact from artificial light emissions can vary depending on:

- the specific characteristics of the source (e.g. light intensity, wavelength)
- the sensitivities of the receptor.

Figure 8-5 shows the sensitivity of different species to different wavelengths, with most species sensitive to short wavelength light (i.e. in the ultraviolet/violet/blue spectra).

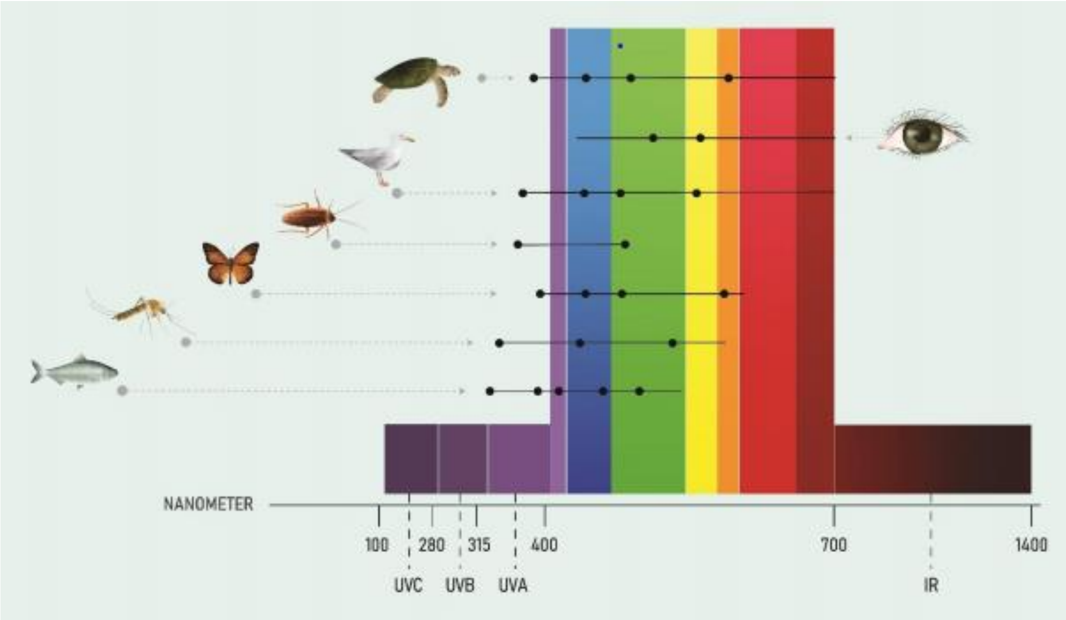

Figure 8-5: Ability of different fauna groups to perceive different wavelengths of light

Source: Ref. 75. Ability to perceive different wavelengths of light in humans and wildlife is shown by horizontal lines. Black dots represent reported peak sensitivities

Two sources of artificial light are associated with the Development:

- navigational and operational lighting on vessels and MODU
- gas flaring from the MODU.

Table 8-15 list the activities within each phase that have the potential to generate light emissions.

Table 8-15: Phases and activities that generate Light emissions

Phase	Activity
Drilling	Well clean-up and testing
Operations	Well intervention
Support activities	MODU operations Vessel operations

8.4.1.1 Drilling

Flaring may be undertaken during well clean-up and flowback activities, when the well is cleaned to remove contaminants including drilling or completions fluids, debris, and solids that come from the formation. These contaminants are circulated back to the MODU. Removing contaminants from the well may also remove hydrocarbon gas—this gas is then flared. Flaring of flammable gas will generate light emissions.

If flaring is required, it will be from one well at a time and may take ~1 day to complete. Light emissions will be more pronounced if flaring is undertaken at night.

Unlike navigational/operational lighting, which is provided for safe access and working conditions, and which has specific light emissions defined by manufacturers, gas flares are not designed for lighting purposes and light emissions are not specified by flare manufacturers.

There is limited published information regarding light characteristics of flares. In contrast to facility lighting, most light energy emitted from natural gas flares has a wavelength >600 nanometres due to the high temperatures of natural gas combustion; this puts it in the visible and ultra-red spectra (Ref. 303; Ref. 304; Ref. 305). Natural gas flares have been measured to have a higher peak spectral signature than facility lighting, typically within the invisible infrared range (750–900 nanometres), with lower levels of light emitted within the lower (and visible) wavelength ranges (Ref. 306; Ref. 307).

Based on the information above, the peak spectral emissions from both navigational/operational lighting and gas flares are not expected to occur within the lower wavelength bands of blue, violet and ultraviolet light.

Modelling analogues

MODU specifications will not be known until closer to drilling or well intervention campaigns being undertaken. MODU types that may be used during the Development include a semisubmersible, drill ship or well intervention vessel or jack-up (Section 4.3.6.1). The height of the flare tip, flaring rate, and flame height are also not yet known, and are expected to vary between fields.

Therefore, relevant analogues were used to evaluate the most suitable spatial extent for flaring light emissions during the Development. These examples include light modelling undertaken for 3 other OPPs—Dorado Development (Ref. 308), Corowa Development (Ref. 309) and Amulet Development (Ref. 310).

The development concept for these developments includes permanent facilities (i.e. FPSOs or platforms) above the sea surface, and routine flaring. In contrast, the Development concept for this OPP is subsea tiebacks with no above-surface permanent facilities, and non-routine flaring only (for ~1 day at a time). Table 8-16 summarises the modelling scope and outputs.

The visibility of an artificial light does not necessarily imply a measurable change in ambient light (and therefore a potential impact). There are currently no published or accepted thresholds at which artificial light may impact fauna. Consequently, the minimum threshold used to describe a change in ambient light conditions within this artificial light assessment is an illuminance equivalent to a new moon / moonless clear night sky (0.001 lux); beyond this threshold no impact to light-sensitive fauna is assumed. This threshold (0.001 lux) was selected because it is considered representative of ambient light levels that marine fauna are adapted to.

Table 8-16: Flaring light modelling analogues

Development	Description	Line of sight	Potential impact area
Dorado Development	Included a scenario for flaring light emissions associated with an FPSO and permanently staffed wellhead platform (Ref. 311). Non-routine flaring events were assumed to be <48 hours in duration, at a rate of ~125 MMscf/d. The flare height was conservatively estimated as 110 m above sea level.	Modelling predicted that the flare is no longer visible at 42.4 km, when the flare drops below the horizon, and at this distance, the radiance is equivalent to 0.25 of a full moon. As the flare drops below the horizon, radiance declines rapidly and is no longer visible (Ref. 311).	Not assessed.
Corowa Development	Modelling was based on a jack-up rig [Mobile Operational Production Unit (MOPU)] with a maximum flare tip height of ~80 m above sea surface, with a peak flaring rate of 15–17 MMscf/d. This is equivalent to a flame height of ~20–25 m above the flare tower tip, resulting in a total flare height of 100-105 m above sea level.	The maximum distance the light is visible was modelled at 36.5 km (Ref. 312 undertaken for Ref. 309).	Beyond 31.3 km there was no measurable change to the ambient light intensity levels (i.e. less than 0.001 lux). In recognition that photometric measurements are biased towards the human eye response to light, the potential impact area for flare lighting at 17 MMscf/d was defined as 34.2 km from the expected position of the MOPU.
Amulet Development	Modelling used the same facility as Corowa, but with a peak flaring rate of ~1.6 MMscf/d. This is equivalent to a flare flame height of ~3 m above the MOPU flare tower tip; resulting in a total flare height of ~83 m above sea level.	The maximum distance the light is visible was modelled at 32.5 km (Ref. 312 undertaken for Ref. 309).	Beyond 9.8 km there was no measurable change to the ambient light intensity levels. The potential impact area for flare lighting at 1.6 MMscf/d was defined as 10.8 km from the expected position of the MOPU.

Given the difference in the modelling outputs and methodology between the 3 projects, and the uncertainty on flaring specifications for the Development, the more conservative spatial extent of 42.4 km was adopted as the spatial extent to assess the environmental impacts from flaring light emissions. The maximum flaring and light extent from DCs in relation to the BIAs and habitat critical of light sensitive species is shown in the following figures:

- Flatback turtle—Figure 8-6 and Figure 8-7; loggerhead turtle—Figure 8-8 and green turtle—Figure 8-9 and Figure 8-10
- Wedge-tailed shearwater—Figure 8-11; fairy tern—Figure 8-12 and lesser crested tern—Figure 8-13
- Whale shark—Figure 8-14

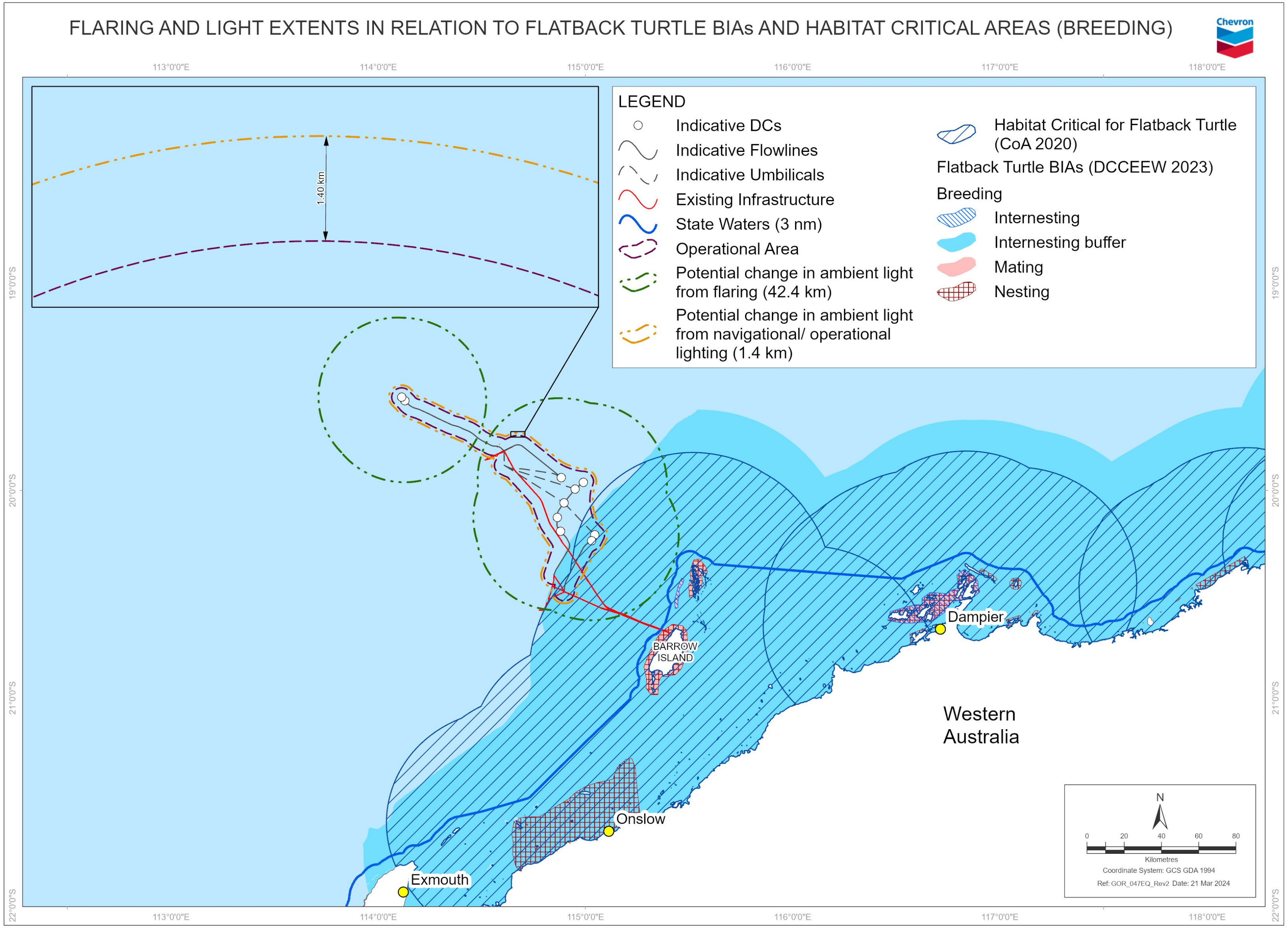

Figure 8-6: Flaring and light extents in relation to flatback turtle BIAs and habitat critical areas (breeding)

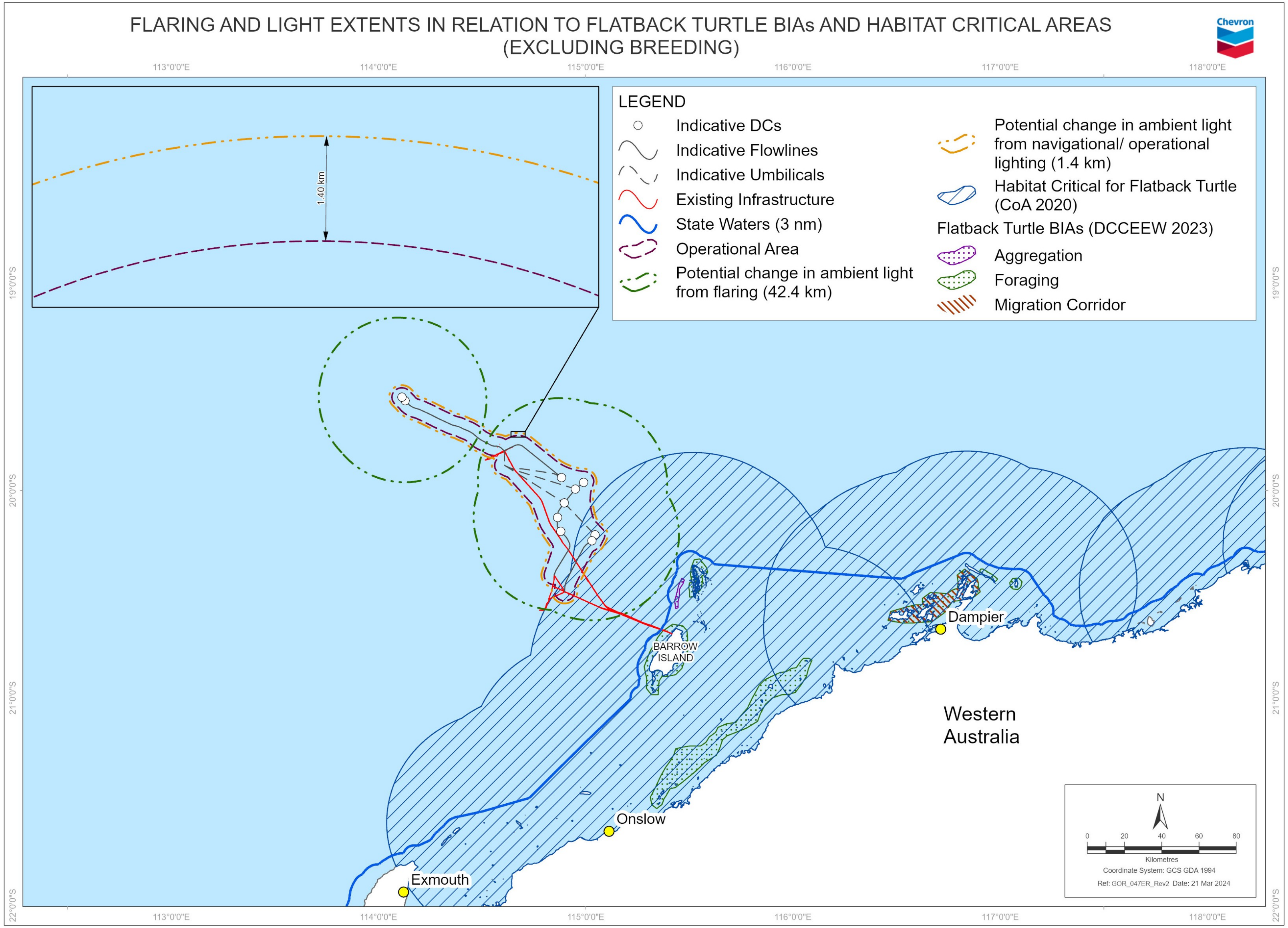

Figure 8-7: Flaring and light extents in relation to flatback turtle BIAs and habitat critical areas (excluding breeding)

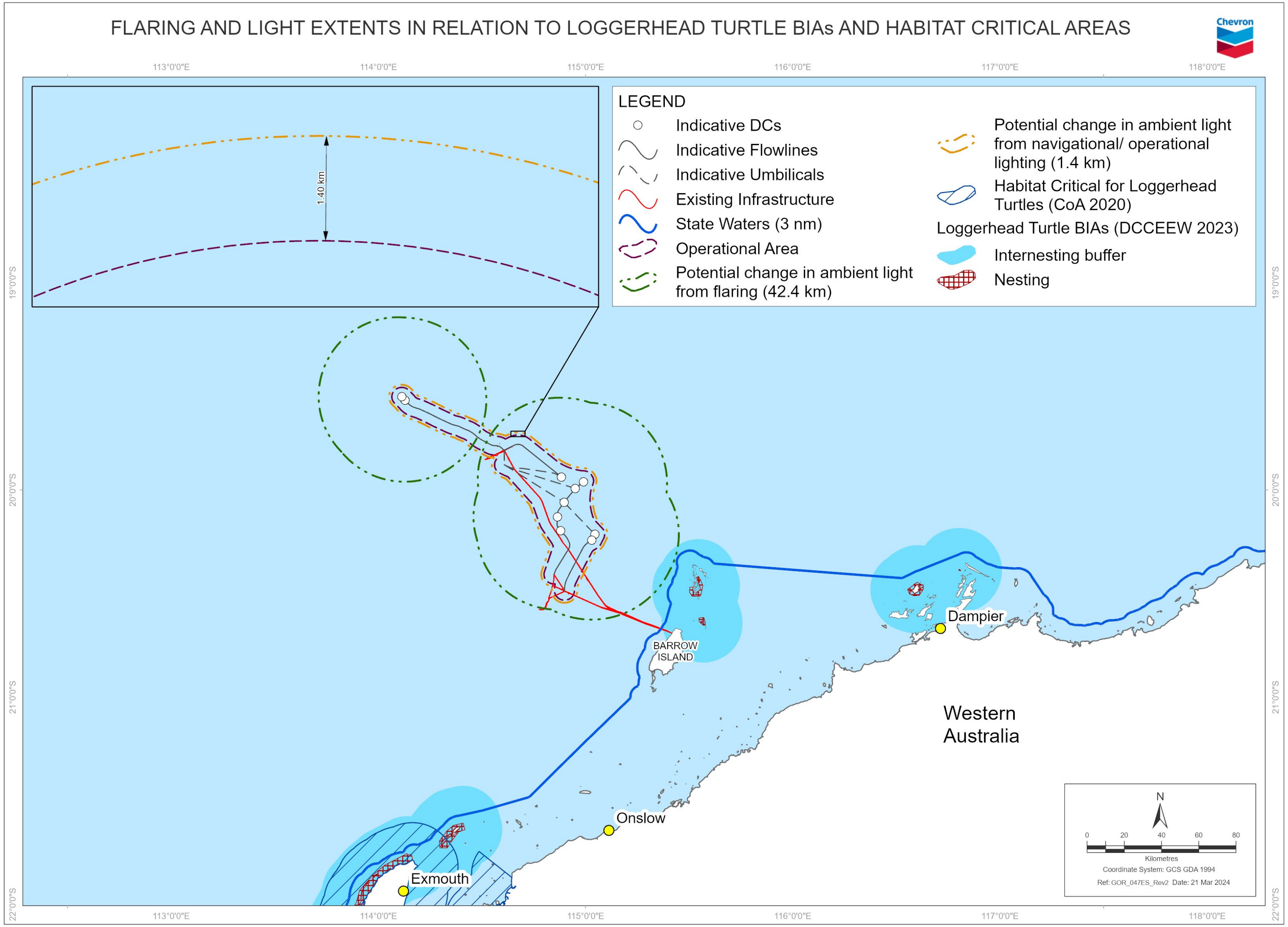

Figure 8-8: Flaring and light extents in relation to loggerhead turtle BIAs and habitat critical areas

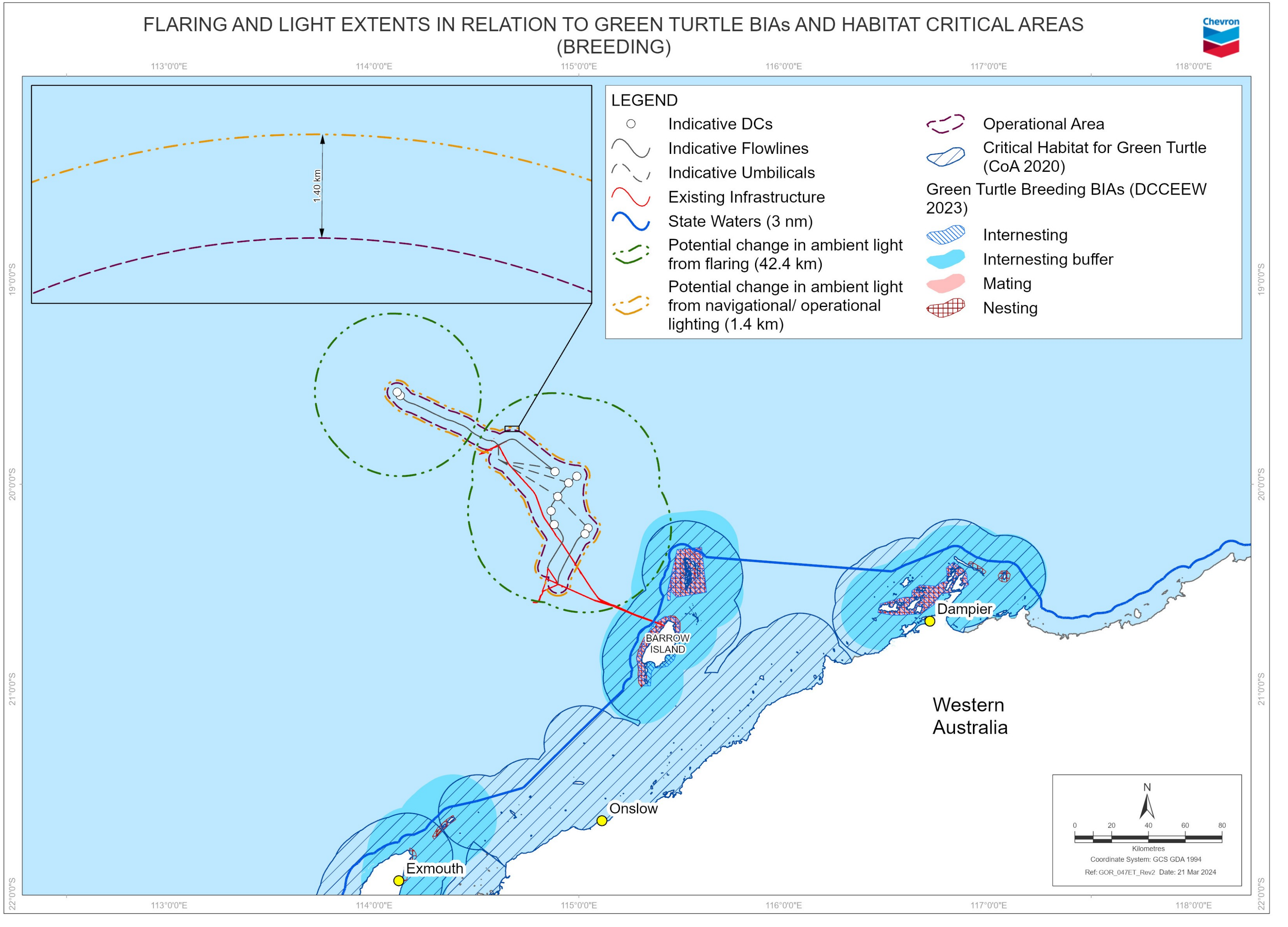

Figure 8-9: Flaring and light extents in relation to green turtle BIAs and habitat critical areas (breeding)

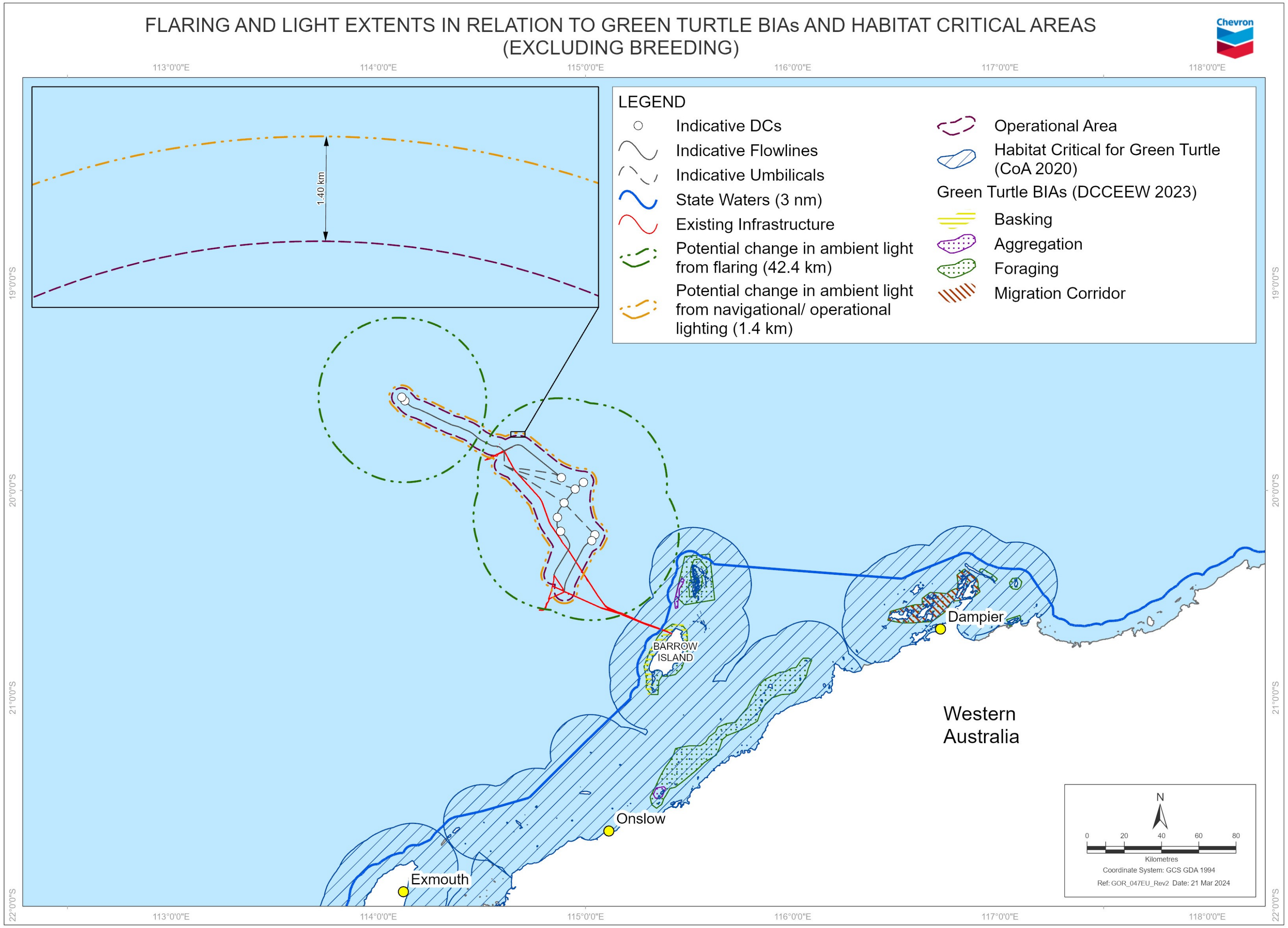

Figure 8-10: Flaring and light extents in relation to green turtle BIAs and habitat critical areas (excluding breeding)

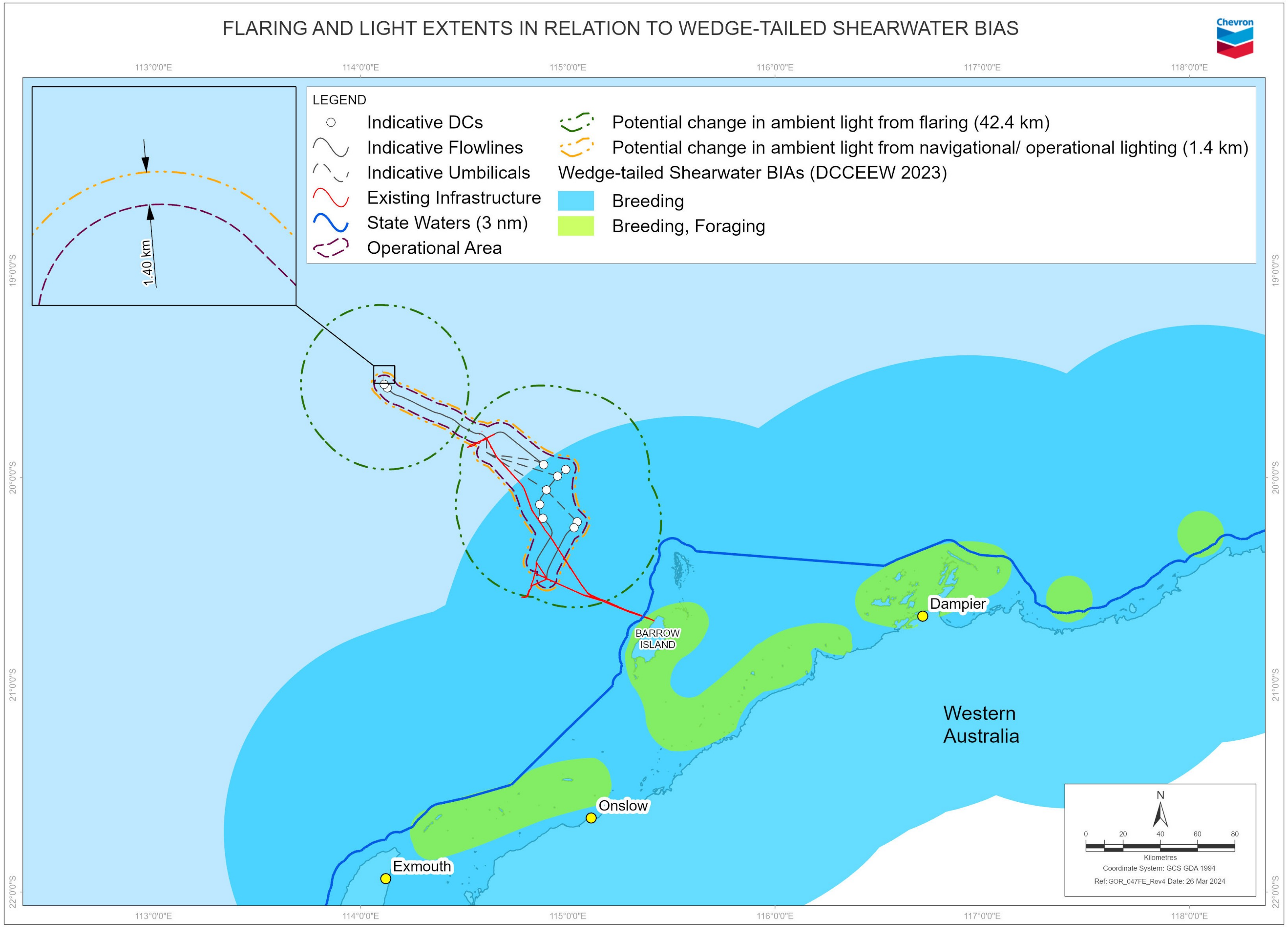

Figure 8-11: Flaring and light extents in relation to wedge-tailed shearwater BIAs

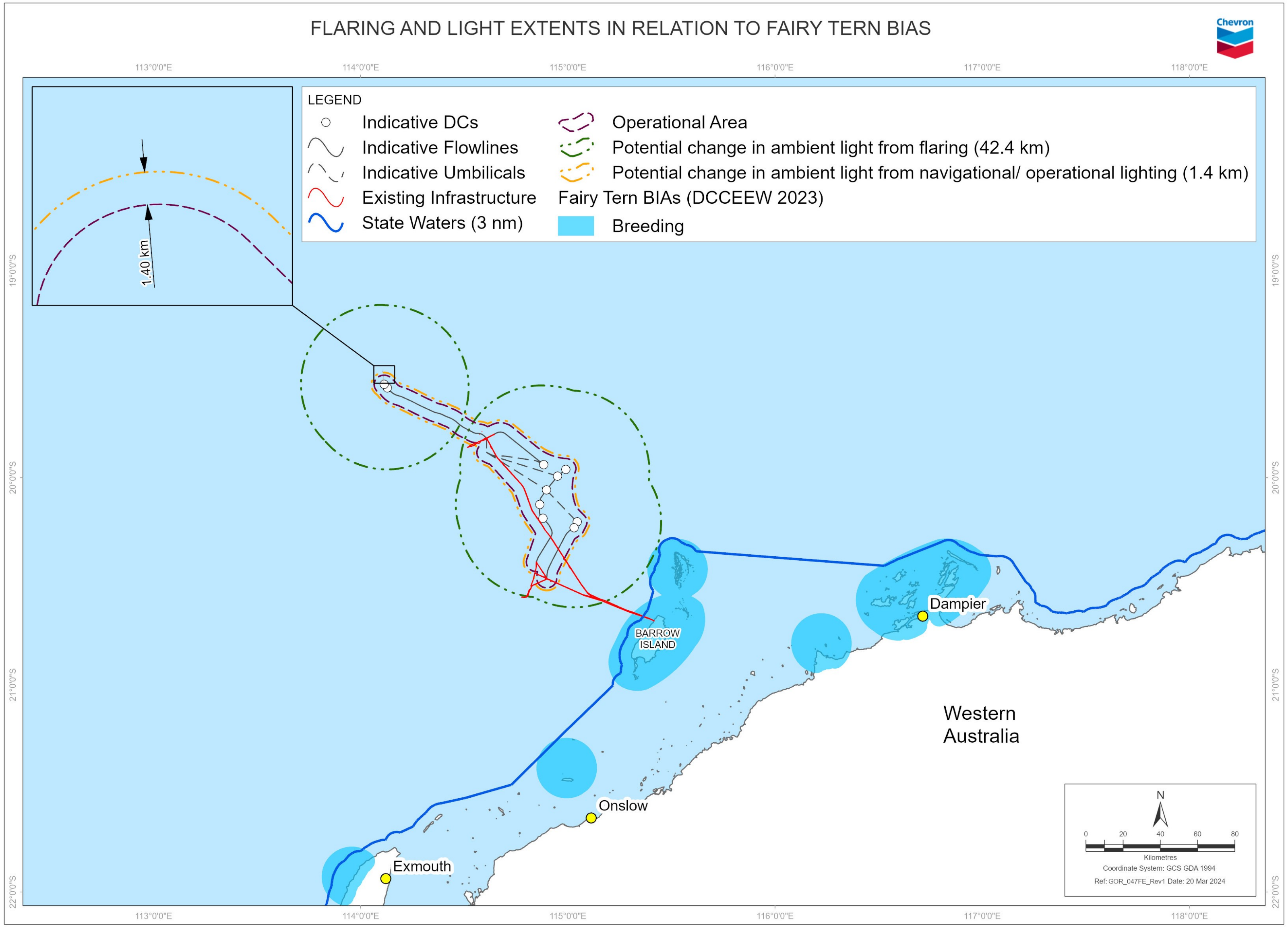

Figure 8-12: Flaring and light extents in relation to fairy tern BIAs

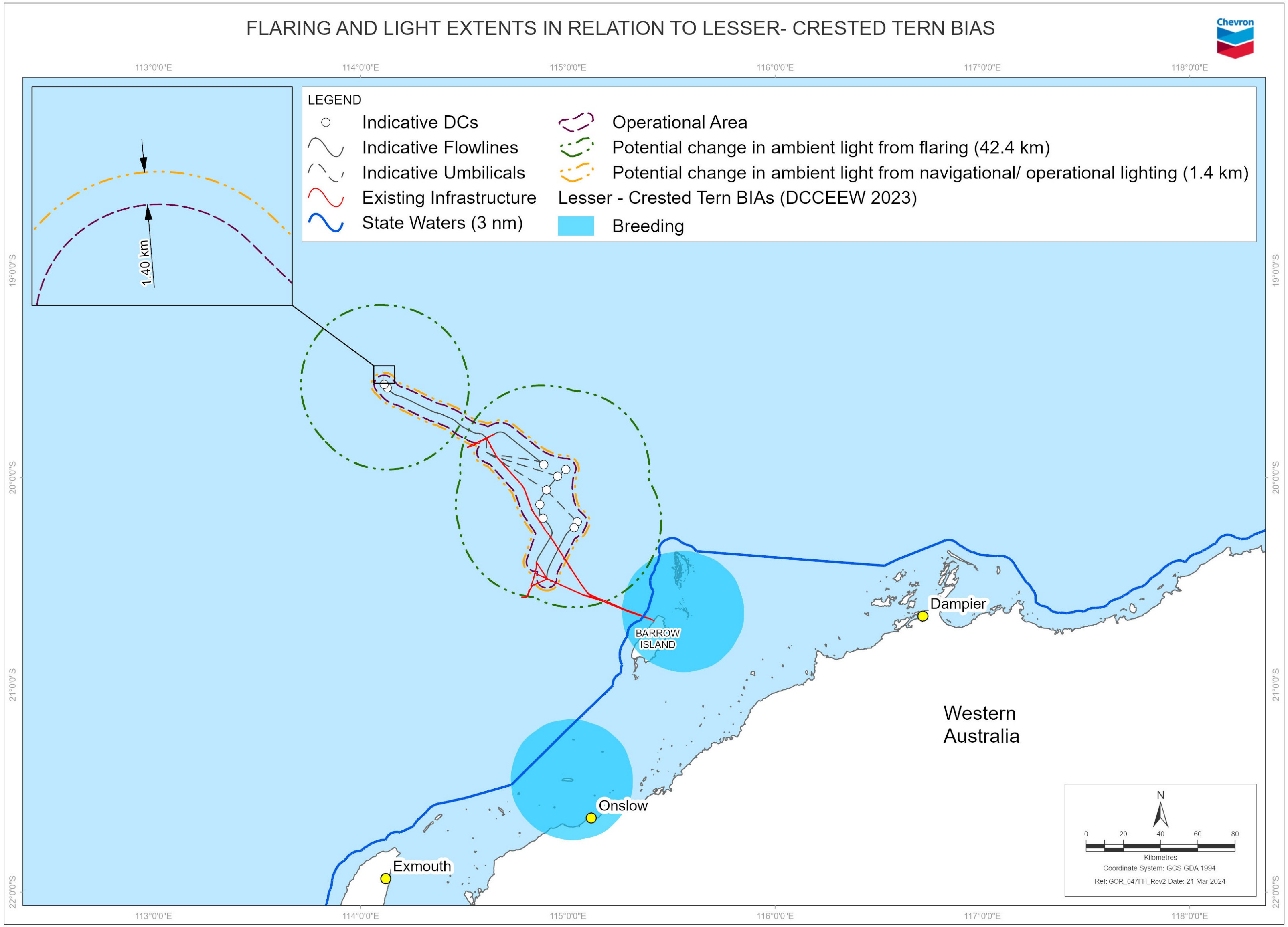

Figure 8-13: Flaring and light extents in relation to lesser crested tern BIAs

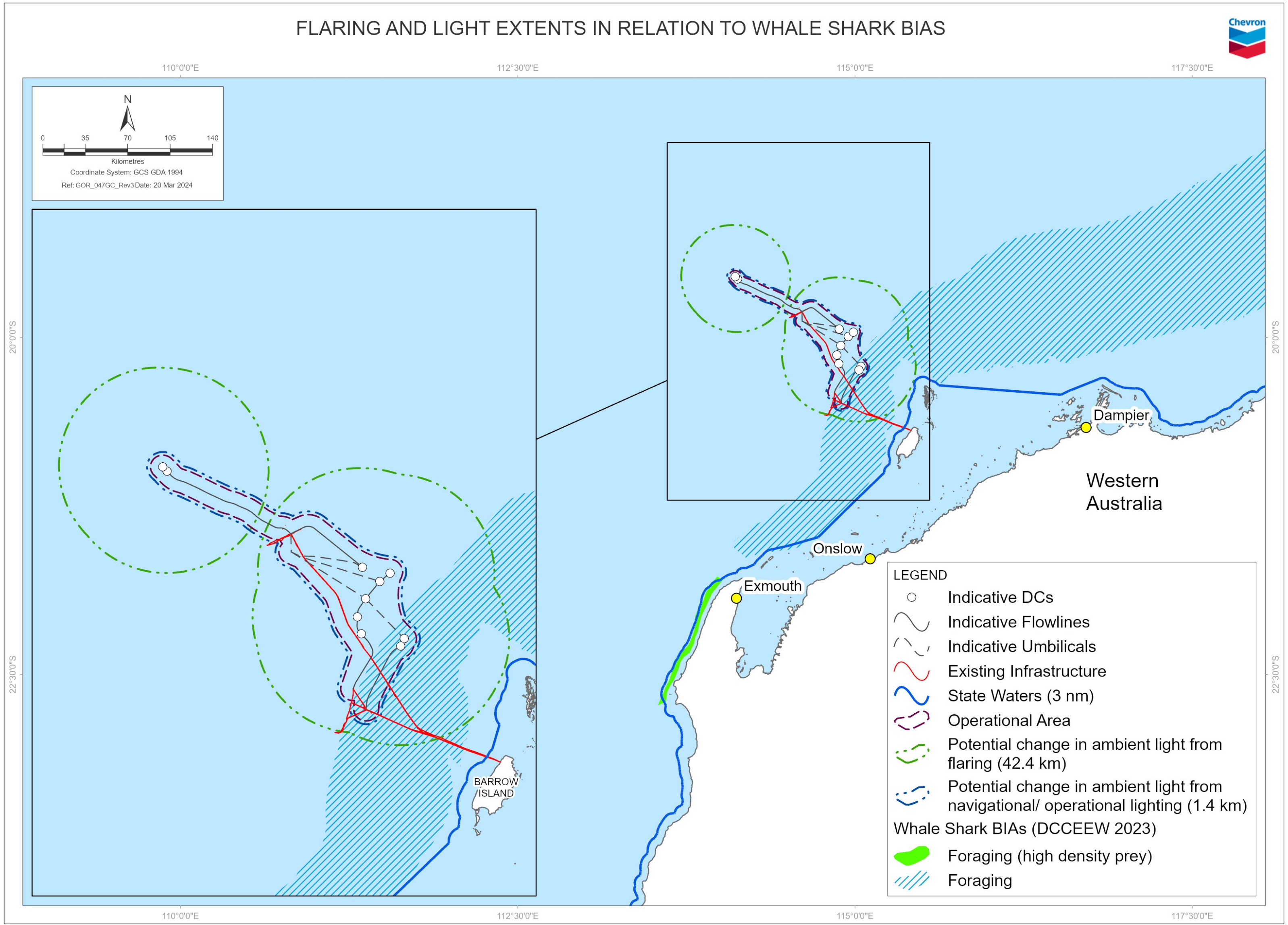

Figure 8-14: Flaring and light extents in relation to whale shark BIAs

8.4.1.2 Operations

Flaring may be required as part of well intervention. If required, it will be infrequent, and the duration may be ~1 day per well.

As stated above, the modelling from the Dorado Development OPP was adopted as the maximum spatial extent of flaring light emissions at 42.4 km. This analogue provides additional conservatism for the impact assessment.

8.4.1.3 Support activities (all phases)

Vessels are present in the OA during all phases of the Development. The highest number of vessels working concurrently across the OA is estimated at 5–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation may take as long as 15 months per field (C&D field) and while concurrent activities are possible during this time, they will be intermittent and would occur for only a small portion of the overall duration.

The MODU will be present in the OA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well workovers). The MODU will move between fields but will spend most of the time at the DCs, with each well taking ~3 months to drill. The MODU is expected to have the tallest structure above sea level compared to vessels.

External lighting is used on vessels and the MODU for safe navigation and to provide safe working conditions. Vessel and facility lighting are considered standard practice. Lighting used during offshore operations is generally bright white light such as light emitting diodes, halogens, fluorescent and metal halide lights and would be similar to lighting used by other offshore mariners (e.g. shipping and fishing). Although MODU specifications will not be confirmed until closer to drilling and well intervention campaigns, typically the small navigation lights on the derrick are the tallest source of navigation/operational lighting.

Light emissions from navigational and operational lighting on the MODU and vessels for the Development is expected to be comparable to that of the Woodside-operated Torosa drilling rig. Monitoring undertaken by Woodside (Ref. 313) indicates that light density from navigational lighting on a MODU attenuated to below 1.0 lux and 0.03 lux at distances of ~300 m and ~1.4 km, respectively. This has been shown as a buffer around the OA in relation to BIAs and habitat critical of light sensitive species in Figure 8-6 through Figure 8-14.

Light densities of 1.0 lux and 0.03 lux are comparable to natural light densities experienced during deep twilight and during a quarter moon. Navigational lighting is expected to be less on support vessels than on the MODU.

Previous measurements of facility lighting emitted from an offshore drilling rig indicated that the peak spectral signature was within the 530–620 nanometre wavelength range (Ref. 313; Ref. 315).

8.4.2 Impact and risk evaluation

The scoping exercise (Section 7.4) identified receptors that are susceptible to light emissions within the ~1.4 km spatial extent for navigational/operational lighting and the conservative 42.4 km spatial extent adopted for flaring; these are:

- ambient light
- marine reptiles

- seabirds and shorebirds
- fishes, including sharks and rays
- cultural heritage value: Traditional Owners.

The National Light Pollution Guidelines for Wildlife (Ref. 75) recommend species-specific impacts should be assessed where there is important habitat for listed species that are known to be affected by artificial light within 20 km of a project. The 20 km threshold provides a precautionary limit based on observed effects of sky glow on marine turtle hatchlings (demonstrated to occur at 15–18 km) and fledgling seabirds grounded in response to artificial light 15 km away.

Table 8-17 details the impact and risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to light emissions in the relevant spatial extent.

The National Light Pollution Guidelines (Ref. 75) do not provide specific guidance for assessing impacts to plankton, marine invertebrates, or marine mammals and, consequently, it is considered that impacts to these species are not likely to be of a level that requires assessment.

Exposure to people and communities (from impacts such as reduced visual amenity) will not credibly occur because light emissions will not be visible from any residential areas on the mainland.

Although fish may potentially be impacted by light emissions, they are not considered particularly sensitive to light, light is likely restricted to localised areas of direct light spill on the sea surface, and there is no specific guidance in the National Light Pollution Guidelines (Ref. 75). Therefore, light emissions are not expected to result in a change in the viability of the population of commercially important fish species, or a change in values and sensitivities of the fish assemblage values of the Continental slope demersal fish communities KEF.

Therefore, impacts from light emissions to commercial fisheries, people, and communities, KEFs and marine mammals are not expected, and are not evaluated further.

Table 8-17: Risk evaluation for Light emissions

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Light emissions may result in: • localised and temporary change in ambient light.	6	A localised and temporary change in ambient light may result in: • change to behaviour in marine reptiles	6	5	Very low (10)
		A localised and temporary change in ambient light may result in: • change to behaviour in birds	6	5	Very low (10)
		A localised and temporary change in ambient light may result in: • change to behaviour in fish	6	5	Very low (10)
		A localised and temporary change in ambient light may result in: • change to cultural heritage values	6	5	Very low (10)

Risk evaluation
Ambient light
Change in ambient light The MODU, vessels and flaring associated with the Development will generate light emissions, resulting in a change to ambient light. *Navigational/operational lighting* Navigational and operational lighting from the MODU and vessel operations are a temporary source of light, as the Development has no permanent above-surface facilities, unlike a platform or FPSO. The MODU will take ~3 months to drill each well. Vessels will be used throughout all phases of the Development, but navigational lighting is expected to be less on support vessels than on the MODU. The external lighting used by vessels and MODUs will be the same as those used by existing shipping and fishing vessels within the OA. Monitoring undertaken by Woodside (Ref. 315) indicates that light density from navigational lighting on a MODU attenuated to below 1.0 lux and 0.03 lux at distances of ~300 m and ~1.4 km, respectively. Light densities of 1.0 lux and 0.03 lux are comparable to natural light densities experienced during deep twilight and during a quarter moon. As such, based on Woodside (Ref. 315), CAPL expects vessel and MODU operations for the Development will result in temporary changes to ambient light emissions no larger than a radius of ~1.4 km from vessels and the MODU. Light emissions from vessels and MODU operations are very localised and are not predicted to impact ambient light conditions on the mainland or Barrow Island (>124 km and >54 km from the boundary of the 1.4 km spatial extent respectively). *Flaring* Flaring during drilling and well intervention operations will be an infrequent, short-term occurrence, for ~1 day per well. Flaring is only undertaken from one well at a time, and during drilling is a one-time occurrence per well. As MODU flare tip height and flaring specifications for the Development are not yet known, modelling analogues were identified (Table 8-16). Modelling of routine flaring from an FPSO for the Dorado Development predicted the flare is no longer visible at 42.4 km, when the flare drops below the horizon. Modelling of routine flaring from a MOPU for the Amulet and Corowa Developments predicted that the potential impact area (i.e. a measurable change in ambient light) was between 10.8 km and 34.2 km respectively, for different flaring rates (Ref. 310; Ref. 309). Based on the Dorado Development modelling (Ref. 308), CAPL expects flaring during well clean-up and flowback and well intervention activities for the Development will result in temporary changes to ambient light emissions no larger than a radius of 42.4 km from the DCs. Light emissions within a 42.4 km radius of the DCs are not predicted to impact ambient light conditions on the mainland or Barrow Island (>80 km and >10 km from the boundary of the 42.4 km spatial extent respectively). Lighting from vessels and MODUs is temporary. MODUs will be the tallest structure present for ~3 months per well. Flaring is visible for a greater distance, but it is non-routine, very short-term (~1 day at a time) and infrequent. Because of the limited extent of the change arising from light emissions, CAPL determined the impacts associated with a direct change in ambient light levels to have an Incidental (6) consequence level.
Marine reptiles
Change to behaviour Light emissions have the potential to change behaviour in marine reptiles such as inhibiting nesting by adult females and disrupting the orientation and sea-finding behaviour of hatchlings (Ref. 75; Ref. 148; Ref. 316). Navigational/operational lighting from vessels and MODU operations will result in temporary changes to ambient light emissions no larger than a radius of ~1.4 km from vessels and the MODU (Ref. 315). For flaring, as described above, modelling for the Dorado Development predicted the flare is no longer visible at 42.4 km, when the flare drops below the horizon. Modelling for the Amulet and Corowa Developments predicted that the potential impact area was between 10.8 km and 34.2 km respectively, for different flaring rates (Table 8-16). The EPBC threatened short-nosed sea snake or leaf-scaled sea snake are not expected to be present within the OA given known habitat preferences for shallow water and reef habitat; light has also not been identified as a threat for either species (Ref. 24; Ref. 23). While other EPBC marine listed sea snake species may occur in broader habitats within the NWMR, snakes are inactive at night (Ref. 317). As such, light is not considered to be a significant factor in sea snake behaviour or survival. Five marine turtle species listed as threatened and/or migratory under the EPBC Act have the potential to occur within the spatial extents for both navigational/operational lighting and the worst-case extent for flaring:

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• flatback turtle • green turtle • hawksbill turtle • loggerhead turtle • leatherback turtle. The flatback turtle has an internesting buffer BIA and habitat critical that overlaps the 1.4 km spatial extent for navigational/operational lighting (Figure 8-6, Figure 8-7). These additional BIAs and habitat critical overlap with the 42.4 km spatial extent adopted for flaring: loggerhead turtle BIA (internesting buffer) and habitat critical (Figure 8-8) • green turtle BIA (internesting buffer) and habitat critical (Figure 8-9, Figure 8-10). The Recovery Plan for Marine Turtles in Australia (Ref. 148) identifies light emissions as a key threat because it can disrupt critical behaviours, such as nesting, hatchling orientation, sea finding, and dispersal; and defines the habitat critical to the survival of a species for nesting for each species at a stock level. Light pollution is of less concern to turtles during offshore activities in open waters away from nesting beaches (Ref. 317). The general guidance is that turtles require naturally illuminated beaches for successful nesting and sea-finding behaviour (Ref. 148; Ref. 318; Ref. 319). The closest critical nesting habitats to the OA include Barrow, Montebello and Lowendal islands, which have been identified as nesting habitat for flatback, green, and/or hawksbill turtles (Ref. 148). At its closest, the OA is located ~ 47 and ~55 km from nesting habitat at the Montebello and Barrow Islands respectively. Because navigational/operational lighting is expected to result in a change to ambient conditions up to a maximum of ~1.4 km from the vessel/MODU, no coastal areas (and therefore no adult nesting turtles, or turtle hatchlings) are expected to be exposed to light emissions from support activities. The conservative flaring spatial extent adopted (42.4 km) is much larger than the navigational/operational lighting spatial extent (~1.4 km). However, flaring is a very short-term activity (~1 day per well) and infrequent (once per drilling of each well, and during well interventions). The boundary of the flaring spatial extent is ~10 km and ~20 km from, but does not overlap with, the Montebello and Barrow Islands respectively. In addition, neither the mainland nor other islands in the NWS are overlapped by this spatial extent. Habitat critical for internesting is defined as a distance seaward from critical nesting habitat—60 km for flatbacks and 20 km for other marine turtle species (Ref. 148). Studies have indicated that the internesting behaviour of flatback turtles on the NWS appears more spatially restricted (Ref. 148). Whittock et. al. (Ref. 151; Ref 150) reported that flatback turtles prefer habitats nearer the coast and at relatively shallow depths during internesting periods. Unsuitable flatback turtle internesting habitat was defined by Whittock (Ref. 151; Ref 150) as waters >25 m deep and >27 km from the coast. Navigational/operational lighting emissions (with a ~1.4 km spatial extent) along WTR and C&D infrastructure overlaps the flatback turtle internesting buffer BIA. Despite the overlap, the offshore area within ~1.4 km of WTR and C&D infrastructure is considered unsuitable flatback internesting habitat as waters are >25 m deep and >27 km from the coast. Therefore, it would be very unlikely that internesting flatback turtles would aggregate within navigational/operational lighting spatial extent. As a result, only a small number of transient individual marine turtles are expected to be present within the navigational/operational lighting spatial extent. Short-term and infrequent flaring may generate light emissions that may overlap suitable offshore flatback turtle internesting habitat i.e. in waters <25 m deep and within 27 km from the coast (i.e. Barrow Island) (Figure 8-6, Figure 8-7). As the water depths at the boundary of the conservative spatial flaring extent are >25 m (unsuitable for internesting) and as flatback turtle nesting is more common on the east coast beaches of Barrow Island (i.e. opposite side of the island to the OA), the area of overlap may not represent preferred internesting habitat for this species. As a result, only a small number of transient individual marine turtles are expected to be present within the navigational/operational lighting spatial extent. CAPL has undertaken a marine turtle monitoring program and an annual light monitoring program, under the Gorgon Gas Development: Long-term Marine Turtle Management Plan (Ref. 320), which was required by the EPBC Act and EP Act approval of the GFP (Section 1.4.2). The monitoring program has been carried out since operation of the Gorgon Gas Development marine facilities adjacent to the east coast of Barrow Island (including materials offloading facility/LNG Jetty and vessels within the Port of Barrow Island) began in 2016. No adverse impacts have been reported to flatback turtle populations for nesting and hatching due to night-time light emissions (Ref. 207). Consequently, exposure of internesting flatback turtles to light emissions from flaring within the OA is not expected to result in adverse impacts to flatback turtle populations. As the flaring spatial extent is limited to offshore waters and does not overlap mainland nor other island marine turtle nesting habitats, onshore nesting turtles will not be exposed to flaring light emissions and sea-finding behaviours for hatchlings or nesting by adult females will not be disrupted. As light pollution is of less concern to turtles during offshore activities in open waters away from nesting beaches (Ref. 317), the exposure of light

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emissions from flaring to internesting loggerhead turtles and internesting green turtles is also not expected to result in adverse impacts to turtle populations (Figure 8-8, Figure 8-9 and Figure 8-10). In addition, the spectrum of light emissions from the Development, particularly for the gas flare (>600 nanometres), are not within the most sensitive range for turtle species (i.e. blue-green [500 nm], violet [400 nm], ultraviolet [360 nm], spectra) (Ref. 307, Ref: 314). Given the spatial extents adopted for navigational/operational lighting and flaring do not overlap onshore nesting habitats for marine turtles, any behavioural disturbance for marine turtles would be limited to temporary disturbance to individuals within the interesting buffer. As such, the consequence associated with this impact has been evaluated as Incidental (6). The spatial extent of light emissions from the Development does not overlap mainland nor other island marine turtle nesting habitat and is limited to deeper offshore waters that are unsuitable for internesting behaviour. In addition, the Development activities are relatively short and discrete campaigns. Therefore, the likelihood of exposing marine turtles to Incidental impacts was evaluated as Remote (5). The risk ranking of the potential to change to behaviours for marine reptiles from light emissions is Very Low (10).
Seabirds and Shorebirds
Change to behaviour Light emissions have the potential to change behaviour in seabirds and shorebirds such as disruption to foraging, breeding or migration behaviours. Based on the offshore location of the OA, the spatial extents of navigational/operational lighting and flaring (i.e. ~1.4 km and 42.4 km, respectively) only overlaps offshore waters. Anthropogenic disturbance (including artificial lighting) is identified as a threat within the Wildlife Conservation Plan for Migratory Shorebirds (Ref. 67), and light pollution is identified as a threat within the Wildlife Conservation Plan for Seabirds (Ref. 35). Light emissions can confuse nocturnal seabirds (including most shearwater, petrel and albatross species [order: Procellariiformes]) by disrupting critical behaviours (foraging, breeding and migration) and attracting fledglings away from habitat critical, resulting in some individuals becoming grounded (where individuals may land on vessel decks, from which they are unable to take off) (Ref. 322; Ref. 323). Light emissions can also displace migratory shorebirds from suitable nocturnal roosts and foraging sites which adversely increases energy costs to migratory travel, and again may result in some individuals becoming grounded of vessel decks (Ref. 75). No BIAs for migrating shorebirds overlap the spatial extents for navigational/operational lighting and flaring. The 1.4 km spatial extent for navigational/operational lighting and the 42.4 km spatial extent adopted for flaring overlap the wedge-tailed shearwater breeding BIA with a foraging buffer (Figure 8-11). The conservative flaring extent also has a small overlap with a further 2 seabird species breeding BIA buffer areas: • fairy tern BIA (breeding) (Figure 8-12) • lesser crested tern BIA (breeding) (Figure 8-13). Presence of the wedge-tailed shearwater is seasonal, typically occurring between mid-August to April in the Pilbara, and they are known to forage relatively close to breeding islands or over a large area, depending on prey availability. The main fledgling period for shearwaters in Australia is during April/May (Ref. 75). wedge-tailed shearwaters are known to breed on islands off Barrow Island (Mushroom, Double and Boodie islands), and the Montebello Islands. The overlap of the wedge-tailed shearwater breeding BIA is limited to open offshore water environments used for foraging and does not overlap onshore nesting islands (i.e. not with a nesting location itself) (Figure 8-11). The boundary of the worst-case spatial extent for flaring is ~10 km and ~20 km from, but does not overlap with, the closest nesting islands (Montebello and Barrow respectively). CAPL undertakes annual wedge-tailed shearwater monitoring to determine burrow density, breeding participation and fledging success, under the influence of lights and gas flares present as part of the Gorgon Gas Development. Since operations began in 2016, monitoring has not detected an adverse impact (attributable to the Gorgon Gas Development) to the burrow density, breeding participation, and fledging success of wedge-tailed shearwaters (Ref. 207). The exposure of light emissions from navigational/operational lighting and flaring during the Development is also not expected to result in adverse impacts to the burrow density, breeding participation, and fledging success of wedge-tailed shearwaters. As a result, light emissions during the Development are not expected to disrupt critical breeding behaviours for the wedge-tailed shearwater. The fairy and lesser crested tern breeding BIAs overlapped by the flaring spatial extents are also associated with foraging buffers extending from breeding/nesting islands (e.g. the Montebello Islands) (Ref. 35) (Figure 8-12, Figure 8-13). Given the navigational/operational lighting and flaring spatial extents do not overlap onshore breeding islands, exposure of nesting adult terns or emerging fledglings to light emission from the

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Development is not expected to occur. As a result, disruption of critical breeding behaviours for the fairy and lesser crested tern are not expected to occur. The spectral characteristics of light emissions from the Development, particularly for the gas flare, are not within the most sensitive range for seabird species (i.e. blue/violet/ultraviolet spectra) (Ref. 75). Light emissions from both navigational/operational lighting and flaring in the offshore open waters of the OA are not expected to change foraging behaviours for seabirds and shorebirds. Behavioural changes to seabirds and shorebirds are expected to be limited to the attraction of nocturnally active seabirds and migratory shorebirds opportunistically foraging on bioluminescent prey attracted to lighting in the OA. This is not considered a significant change to normal offshore foraging behaviours for seabirds and migratory shorebirds. Seabirds and migratory shorebirds are known to forage over large offshore areas and the attraction of individuals to the navigational/operational lighting and flaring spatial extents is expected to result in minor alterations to their normal foraging behaviours. Procellariiformes forage at night on bioluminescent prey, and therefore are attracted to light of any kind (Ref. 324; Ref. 323). Marquenie et al. (Ref. 325) estimated that a change in migratory behaviour of birds was limited to <5 km from the source. Therefore, minor changes to normal foraging behaviours for seabirds and shorebirds is expected to be spatially restricted to the immediate vicinity of the OA and affect only individuals (rather than populations) due to the absence of seabird aggregation areas in the spatial extents. Because light emissions have the potential to cause temporary and minor impacts to a small number of protected bird species over the course of the Development, the consequence associated with this impact has been evaluated as Incidental (6). The spatial extent of light emissions from the Development does not overlap any nesting habitat for seabirds or shorebirds and thus changes to nesting and fledgling emergence are not expected. In addition, the Development activities are relatively short and discrete campaigns. Therefore, the likelihood of exposing seabirds and shorebirds to incidental impacts was evaluated as Remote (5). The risk ranking of the potential to change to behaviours for seabirds and shorebirds from light emissions is Very Low (10).
Fishes, including sharks and rays
Change to behaviour Light emissions are not known to change behaviour in adult offshore pelagic fishes, including sharks and rays. The National Light Pollution Guidelines do not specifically address light impacts to fish species, although it is recognised that light can cause changes in fish assemblages (Ref. 75). Light-sensitive fishes may instinctively be attracted to and move towards light emission sources or prey on other species that aggregate at the edges of artificial light halos, while some species are known to avoid light (Ref. 326). Light emissions from navigational/operational lighting and flaring (i.e. ~1.4 km and 42.4 km, respectively is expected to result in temporary and minor changes to adult fish behaviours such as attraction, avoidance, and opportunistic feeding at night. Light emissions may also change migratory behaviours of zooplankton. Zooplankton are negatively phototactic, such that when exposed to light zooplankton will swim away from the light source (Ref. 326; Ref. 327). Light emissions at night are known to potentially limit the initiation and magnitude of the Diel Vertical Migration (DVM) i.e. vertical migration of zooplankton to surface waters (Ref. 326). Listed threatened and/or migratory fish species under the EPBC Act have the potential to occur within both navigational/operational lighting and flaring spatial extents (Section 6.2.3.3). Both spatial extents overlap the whale shark foraging BIA (Figure 8-14). Nocturnal surface feeding behaviours by whale sharks have been reported when the vertical migration of zooplankton attracts whale sharks to the surface (Ref. 328). Light emissions from the Development may limit the initiation and magnitude of DVM, which may in-turn, temporarily reduce the opportunity of foraging whale sharks to feed on zooplankton in areas immediately surrounding vessels or MODU during the Development. However, light has not been identified as a key threat for the whale shark (Ref. 30). The area of impact of limiting the initiation and magnitude of DVM is likely to be restricted to areas where light is directly visible to fishes including fish larvae/zooplankton. Light spill on the ocean surface is only visible to fishes immediately surrounding the vessels or MODU. This area of light spill is considered highly localised and temporary based on the presence of vessels in the OA at night during the Development. As a result, the potential to limit the initiation and magnitude of DVM is also considered highly localised and temporary. The localised and temporary loss of zooplankton for potential foraging whale sharks in areas surrounding vessels or MODU is considered an insignificant impact, given phytoplankton which are positively phototactic (i.e. attracted to light) may be attracted to light sources in the OA, which may also attract schools of small fishes (krill, sardines, anchovies), which are food sources for whale sharks (Ref. 75, Ref. 326). The effects of light emissions including zooplankton avoiding areas of light spill and replaced with attraction of phytoplankton to areas of light spill, will have minor follow-on effects to foraging whales sharks within the light emission

Risk evaluation
spatial extents for the Development. The potential to either limit or increase localised areas for whale shark foraging is not considered a disruption to critical behaviours and not expected to result in population-level effects. Because light emissions have the potential to cause temporary, localised and minor changed to foraging behaviours of whale sharks and other fishes over the course of the Development, the consequence associated this impact has been evaluated as Incidental (6). Although the spatial extents for navigational/ operational lighting and flaring overlap the whale shark foraging BIA, this species is not identified as sensitive to light. In addition, as the Development activities are relatively short and discrete campaigns, and only transient individuals could be exposed the likelihood of the consequence occurring has been evaluated as Remote (5). The risk ranking of behavioural disruption to fishes, including sharks and rays from light emissions is Very Low (10).
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from light emissions includes indirect impacts to intangible Traditional Owner heritage from the change in behaviour of marine fauna. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of marine fauna (Section 6.2.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural values may occur from the potential change in behaviour of marine fauna from light emissions. Consequence evaluations of light emissions resulting in the change in behaviour of marine reptiles, birds and fish are provided above. The highest consequence level was Incidental (6), as such, the consequence of changes to cultural heritage values from light emissions is also evaluated as Incidental (6). Light emissions from navigational/operational lighting (from vessels and MODUs) and flaring are temporary, non-routine, infrequent and of short duration. Because of the limited extent of the change arising from light emissions, significant adverse changes to cultural heritage values from light emissions is not predicted to occur. Therefore, the likelihood of the consequence occurring is evaluated as consistent with that of the highest consequence ranking – i.e. the likelihood is assessed as Remote (5). The risk of light emissions to Traditional Owner cultural heritage values is Very Low (10).

8.4.3 Determination of acceptability

The acceptable level of impact and risk is a function of the magnitude of impact and/or residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-18 details the determination of acceptability for light emissions.

Table 8-18: Determination of acceptability for Light emissions

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence level for light emissions to marine reptiles, birds and fish was evaluated as Incidental (6). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the impact and risk evaluation for light emissions. • Prevention measures for light emissions are well regulated and managed in Australian waters. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="4"></td><td colspan="2">(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations</td></tr>
<tr><td colspan="2">The Development is consistent with principle of ESD (c) for this aspect as:
The Development is committed to applying measures to prevent the impact and risk from light emissions based on relevant environmental legislation and other requirements as listed below.
The regulation and management of light emissions in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
The highest consequence level for light emissions to marine reptiles, birds and fish was evaluated as Incidental (6).
Any relevant stakeholder feedback in relation to light emissions has been incorporated in the OPP and assessed in the external context acceptability criteria.
To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="5">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Navigation Act 2012 (Cth)
Requires navigational and safety lighting for vessels.</td><td>Legislative requirements to manage light emissions are addressed by adopting these control measures:
CM20: MODUs and vessels will meet lighting requirements of the Chevron Marine Standard Non Tankers (Ref. 284) for sufficient lighting for navigational, safety and emergency requirements.</td></tr>
<tr><td>National Light Pollution Guidelines for Wildlife (Ref. 75)
Recommends:
best-practice lighting design to reduce light pollution and minimise the effect on wildlife
undertaking an environmental impact assessment for effects of artificial light on listed species for which artificial light has been demonstrated to affect behaviour, survivorship, or reproduction.</td><td rowspan="2">EPBC management plan requirements to manage light emissions are addressed by adopting these control measures:
CM21: MODUs and vessels working at night within a marine turtle BIA will be required to reduce external lighting to the minimum required for safe operations and navigation.
Therefore, the Development is not considered to be inconsistent with the EPBC management plans.</td></tr>
<tr><td>Recovery Plan for Marine Turtles in Australia 2017–2027 (Ref. 148)
Identifies light pollution as a threat.
Action Area A8 (minimise light pollution) relevant management actions:</td></tr>
</table>

Determination of acceptability		
	• artificial light within or adjacent to habitat critical to the survival of marine turtles will be managed such that marine turtles are not displaced from these habitats • develop and implement best-practice light management guidelines for existing and future developments adjacent to marine turtle nesting beaches • identify the cumulative impact on turtles from multiple sources of onshore and offshore light pollution.	
	Conservation Advice Rhincodon typus Whale Shark (Ref. 30) Identifies light spill as an information and research priority. No explicit relevant requirements.	
	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 67) Identifies anthropogenic disturbance (including from artificial lighting) as a threat. Management action 3f: Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes.	
	Wildlife Conservation Plan for Seabirds (Ref. 35) Identifies light pollution as a threat. Management action 2d: Ensure all areas of important habitat for seabirds are considered appropriately and consistently in the development assessment process.	
	National Recovery Plan for Albatrosses and Petrels (Ref. 37)	The EPBC management plan for this species that may occur within the light exposure areas identifies light pollution as a threat but does not identify any relevant actions.
Internal context	These CAPL procedures were identified as relevant for this aspect: • Gorgon Gas Development and Jansz Feed Gas Pipeline: Long-term Marine Turtle Management Plan (Ref. 320) • Chevron Marine Standard Non Tankers (Ref. 284)	
External context	CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.2.5 and 6.5.2). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM07** and **CM08**). No further feedback was received in relation to light emissions from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	

Determination of acceptability		
Defined acceptable level	The consequence of light emissions is inherently acceptable because the highest consequence level is Incidental (6). Additionally, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan for values and sensitivities in the light exposure areas that identify light pollution as a threat. The impact/risk evaluation does not identify scientific uncertainty against impacts/risks of light emissions for each receptor. Light pollution has been identified as a relevant threat to protected matters under documents made or implemented under the EPBC Act; therefore, CAPL will define an acceptable level of impact that aligns with the objectives of these documents. Objectives of the relevant documents are listed below:	
	Plan and relevant objectives	**Demonstration of requirement**
	National Light Pollution Guidelines for Wildlife (Ref. 75) The aim of the Guidelines is that artificial light will be managed so wildlife is: • not disrupted within, nor displaced from, important habitat • able to undertake critical behaviours such as foraging, reproduction and dispersal.	CAPL considers the impacts of light emissions to not be inconsistent with the relevant objectives of these EPBC management plans. By applying EPO07, impacts and risks associated with light pollution will be managed at or below the defined acceptable level.
	Recovery Plan for Marine Turtles in Australia 2017–2027 (Ref. 148) Recovery objective: Artificial light within or adjacent to habitat critical to the survival of marine turtles will be managed such that marine turtles are not displaced from these habitats.	
	National Recovery Plan for Albatrosses and Petrels (Ref. 37) Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced.	
	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 67) Objective 3: Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	
	Wildlife Conservation Plan for Seabirds (Ref. 35) Objective 2: Seabirds and their habitats are identified, protected, and managed in Australia	
	Conservation Advice Rhincodon typus Whale Shark (Ref. 30)	The EPBC management plan for this species that may occur within the spatial extents adopted for navigational / operational and flaring identifies light pollution as a threat but does not identify any relevant objectives.
	Therefore, CAPL has defined these acceptable levels of impact such that they are not inconsistent with the above documents:	

Determination of acceptability	
	• management of impacts of the Development must not be inconsistent with relevant EPBC management plans identified above • no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery • no displacement of marine turtles, or disruption of biologically important behaviours of marine turtles, from BIAs, important habitats, or habitat critical to the survival of a species • no disruption of biologically important behaviours of migratory shorebirds or seabirds within important habitats • no significant adverse impact to cultural heritage values attributed to the offshore marine area. CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets these acceptable levels.

8.4.4 Environmental performance

Table 8-19 lists the EPO defined for light emissions and the adopted control measures to achieve the outcome.

Table 8-19: Environmental performance for Light emissions

EPO	Adopted control measure
EPO07: No displacement of marine fauna, or disrupting biologically important behaviours of marine fauna, from BIAs, important habitats, or habitat critical to the survival of a species from light emissions associated with the Development activities.	**CM20**: MODUs and vessels will meet lighting requirements of the Chevron Marine Standard Non Tankers (Ref. 284) for sufficient lighting for navigational, safety and emergency requirements. **CM21**: MODUs and vessels working at night within a marine turtle BIA will be required to reduce external lighting to the minimum required for safe operations and navigation.
EPO03: No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.

8.5 Underwater sound

8.5.1 Source

Underwater sound emissions generated by the Development will include both impulsive and continuous (non-impulsive) sounds. This section considers the impacts and risks from both impulsive and continuous underwater sound emissions.

Impulsive underwater sounds are characterised by brief and intense bursts of sound energy that occur over a short duration (Ref. 329). The Development will generate these underwater sounds from activities including VSP operations during well evaluation, use of transponders in positioning and geophysical survey activities (Table 8-20).

Continuous underwater sounds are steady and uninterrupted sounds that occur continuously over a period of time (Ref. 329). The Development will generate underwater sounds from vessel operations (associated with propeller cavitation, thrusters, hydrodynamic flow around the hull), operation and decommissioning of subsea infrastructure, drilling and the operation of machinery and equipment (Table 8-20).

Underwater sound emissions from the Development will add to the existing ambient sound in the region. Ambient sound includes natural physical (e.g. wind, waves, rain), biological (e.g. echolocation, communication) and pre-existing anthropogenic (e.g. shipping) sources.

The largest changes in ambient sound as a result of the Development are associated with the use of vessels and/or MODUs, and as such will be temporary. The ongoing sound emissions from the operation of the hydrocarbon system only result in small ensonified areas within the immediate vicinity of subsea infrastructure.

Table 8-20 identifies activities within each phase that have the potential to generate impulsive and continuous underwater sound within the OA.

Table 8-20: Phases and activities that generate Underwater sound

Phase	Activity	Type of Sound Emission
Surveys	Geophysical survey	Impulsive
Drilling	MODU positioning (transponders) Drilling top- and bottom-holes Well evaluation (VSP)	Impulsive Continuous Impulsive
Installation and commissioning	Excavation and trenching	Continuous
Operations	Operation of the hydrocarbon system Maintenance and repairs (excavation) Well intervention (drilling)	Continuous Continuous Continuous
Decomissioning	Flowline and MEG pipeline decommissioning (excavation) Umbilical decommissioning (excavation) Other subsea infrastructure decommissioning (excavation) Well plug and abandonment (cutting)	Continuous Continuous Continuous Continuous

Phase	Activity	Type of Sound Emission
Support activities	MODU operations Vessel operations Helicopter operations ROV operations	Continuous Continuous Continuous Continuous

8.5.1.1 Surveys

Geophysical surveys of the activity locations may be required at various times during the life of the Development, such as:

- during engineering design
- before drilling
- before pipelay / structures installation
- after pipelay / structures installation
- pre-commissioning
- during operations IMR
- before decommissioning
- after decommissioning.

Surveys are undertaken from a support vessel and are supported by ROVs or AUVs.

Geophysical survey techniques proposed for the Development that generate impulsive underwater sound emissions (and approximate frequency and source levels) include:

- side-scan sonar (SSS):
  - transmission frequency 70–400 kHz
  - SPL: 205 dB re 1 μPa @ 1 m
  - per pulse SEL: 176 dB re 1 μPa2s @ 1 m
  - peak pressure levels (PK): 210 dB re 1 μPa @ 1 m
- sub-bottom profiler with boomer
  - transmission frequency 100–1,000 kHz
  - SPL: 203.3 dB re 1 μPa @ 1 m
  - per pulse SEL: 172.6 dB re 1 μPa^2s @ 1 m
- sub-bottom profiler with CHIRP
  - transmission frequency 2–16 kHz
  - SPL: 191.7 dB re 1 μPa
  - PK: 215 dB re 1 μPa^2m^2
- multibeam echo sounder (MBES)
  - transmission frequency 200–400 kHz
  - SPL: 221 dB re 1 μPa @1 m

- per pulse SEL: 130 dB re 1 μPa^{2}s @ 40 m
- PK: 170 dB re 1 μPa @ 40 m

8.5.1.2 Drilling

The drilling activities listed in Table 8-20 will generate underwater sound from the use of the MODU's DP and support vessel's DP (both described in Section 8.5.1.4); the action of the drill whilst drilling and the use of VSP.

As described in Section 4.3.2.1, the type of MODU has not yet been finalised and may be a semisubmersible, drill ship, or jack-up. Where a DP MODU is selected for use, the thrusters will generate continuous underwater sound for the duration of the activity. The MODU under DP option will have the highest source level and will be evaluated for the purposes of impact and risk assessment.

The indicative sound source level used to represent a MODU under DP and associated drilling sound is the broadband (10 Hz to 31 kHz) source level of 188.0 dB re 1 μPa^{2}m^2 s (Ref. 330). The source level adopted for the purposes of this risk evaluation is considered conservative (over estimation of expected source level) for a DP MODU; as this source value is based on conservatively measured levels in offshore deepwater Novia Scotia of the Stena IceMAX concurrently with four OSVs, all operating in dynamic positioning (DP) mode (Ref. 331).

Transponders may be used to accurately position the MODU over the proposed well locations and emit short pulses of medium to high frequency sound. Transmissions are not continuous but consist of short 'chirps' when active and do not emit any sound when on standby. Typical emitted SPLs for positional equipment range from 187 to 204 dB re 1 μPa @ 1 m (Ref. 332)

VSP (a source of impulsive sound) may be used for well evaluations during drilling. A 750 in^3 VSP source suspended at a depth of 5 m was modelled with JASCO's Airgun Array Source Model (AASM, Ref. 330). The AASM indicates most energy will be produced at frequencies below 300 Hz, with a peak source level of ~239 dB re 1 μPa m (Ref. 330). VSP operations (excluding downtime) will not exceed 24 hours per well.

8.5.1.3 Installation and commissioning

The indicative source level for excavation and trenching operations is based on the combination of broadband noise, machinery tones and rock breaking sounds resulting in an approximate broadband source level of 183.5 dB re 1 μPa @ 1 m (Ref. 332). Positioning transponders may be used to accurately position subsea equipment and emit short pulses of medium to high frequency sound (19 to 50 kHz). Transmissions are not continuous but consist of short 'chirps' when active and do not emit any sound when on standby. Typical emitted SPLs for positional equipment range from 187 to 204 dB re 1 μPa @ 1 m (Ref. 332).

8.5.1.4 Operations

Operations will generate continuous sound emissions from wellheads and subsea infrastructure as well as during maintenance and repairs and well intervention activities.

APPEA's report (Ref. 333) summarises underwater sound studies from different stages of petroleum activities, including one study undertaken by McCauley (2002) that measured sound produced by an operational wellhead and associated pipework. The broadband sound level of the wellhead was 113 dB re 1 μPa rms

(Ref. 333). Sound emissions from the pipeline were a weaker signal and difficult to differentiate from the noise of a nearby platform (Ref. 333) which suggests that sound levels are marginally above that of a platform.

Sound emissions measured by Woodside from operating choke valves (Ref. 334) indicated choke valves produce continuous sound, and the frequency and intensity of sound emitted depends on the rate of production from the well. Sound intensity at low production rates (16% and 30% choke positions) was ~154–155 dB re 1 µPa @ 1 m, with higher production rates (85% and 74% choke positions) resulting in lower sound levels (141–144 dB re 1 µPa @ 1 m). Sound from operating choke valves was broadband in nature, with most acoustic energy concentrated above 1 kHz.

Sound emissions from excavation during maintenance and repairs and from well intervention activities are not different from those mentioned in Section 8.5.1.3 and 8.5.1.2 respectively.

8.5.1.5 Decommissioning

During decommissioning continuous underwater sound is generated from excavation and cutting of infrastructure such as flowlines, pipelines, and umbilicals, and from abrasive cutting while well plug and abandonment occurs. Sound emissions from excavation during decommissioning are comparable to those mentioned in Section 8.5.1.3. Sound emissions generated by jet cutting of a wellhead below the seabed, in water depths of 80 m, produced broadband sound from approximately 10 Hz to more than 10 kHz and had a broad peak centred around 1 kHz. The estimated broadband source level was 189 dB re 1 µPa rms @ 1 m. (Ref. 333).

8.5.1.6 Support activities

Vessel and MODU support activities vary for each phase and source levels are described below.

Vessel activities

The installation and commissioning phase for each field will take ~12-15 months.

Within the 12–15 month timeframe, continuous underwater noise will be generated by vessels during the installation of flowlines, MEG pipelines, PLETs, PLEMs, subsea structures and excavation and trenching activities (Table 8-20).

The indicative source levels and associated considerations in brackets, used to represent vessels operating under DP during installation and commissioning activities are the following broadband (10 Hz to 31 kHz) source levels of:

- pipelay vessel—188.0 dB re 1 µPa^{2}m^2 s (derived from measured values of the world’s largest pipelay vessel the Sel Solitaire and several pipelay support vessels during the Nord stream construction in the Swedish Baltic Sea (Ref. 335)
- construction vessel—194.0 dB re 1 µPa^{2}m^2 s (derived from measure values of the Siem Saphire on DP in the Otway basin; no context provided on the measurement window statistical variability, sea state, thruster utilization or concurrent vessel activity within the measured report (Ref. 336)
- resupply vessel (OSV)—182.7 dB re 1 µPa^{2}m^2 s
- support tug—184.4 dB re 1 µPa^{2}m^2 s

- support vessels (including IMR vessels)—181.2 dB re 1 μPa^{2}m^2 s (Ref. 330).

During drilling, there will be multiple support vessels with the MODU.

The indicative source level used to represent the support vessel's DP is the broadband (10 Hz to 31 kHz) source level of 181.2 dB re 1 μPa^{2}m^2 s (Ref. 330).

During the operations phase, inspections will be undertaken with a frequency determined based on risk. Inspections are typically conducted more often during early operations, with the frequency likely to decrease during steady-state operations, depending on previous inspection results.

The exact frequency of maintenance and repair activities depends on the results of inspections. If minor maintenance or repair is required, vessels may remain on site for an estimated ~6 months. If major maintenance or repair is required – including for contingency power supply – vessels may be on site for an estimated ~12 months.

Decommissioning of flowlines, umbilicals and other subsea structures may be carried out using pipelay, construction and support vessels similar to that used for installation and commissioning phase described above.

MODU activities

Drilling activities are required to establish multiple wells in each field and may take an estimated 24 months per field (~3 months to drill each well). The maximum number of wells per field is 8.

Drilling is carried out by a MODU, which will be positioned either by mooring using gravity anchors, kept on location under DP using thrusters, or if a jack-up is used, by extending its legs to the seabed. If a mooring system is used, generation of continuous underwater sound from the thrusters will be limited to assist the MODU to get to location and will not be used for the entire duration of the activity. A jack-up MODU may be used in shallower water only and would likely be towed into position by support vessels, then the hull 'jacked-up'.

If the DP option is used, the thrusters will generate continuous underwater sound for the entire duration of the activity. The DP option is considered to be the worst-case for continuous sound emissions and will be evaluated for the purposes of impact and risk assessment.

The indicative sound source level used to represent MODU's under DP and the associated drilling noise is the broadband (10 Hz to 31 kHz) source level of 188.0 dB re 1 μPa^{2}m^2 s (Ref. 330).

Well suspension and P&A may be carried out using a MODU, such as an intervention vessel, and support vessels similar to that used for drilling. Underwater sound emissions from these activities are estimated to be the same as those predicted for the drilling phase (refer to Section 8.5.1.2).

Helicopter activities

Helicopter operations are limited to the drilling, installation, and decommissioning phases of the Development where installation vessels (pipelay and construction vessels) and the MODU will be serviced by helicopters. Helicopter flight frequency may be ~15 to16 times per week for an installation vessel, whereas the MODU may be serviced by ~5 flights per week.

Helicopter operations will generate underwater sound emissions during take-off and landing on the installation vessels and MODU. During take-off and landing, the helicopter will ascend/descend to the helideck where air borne engine sound emissions will ensonify the water column.

Underwater sound frequencies from helicopter operations are expected to be below 500 Hz (Ref. 337). Based on a study by Richardson et al. (Ref. 337), audible underwater sound emissions from helicopter operations are limited to a very short time period (~38 seconds) during take-off or landing, resulting in a broadband source level of up to 162 dB re 1 µPa @ 1 m (Ref. 337; Ref. 332).

8.5.2 Underwater sound level modelling

JASCO Applied Sciences (JASCO) undertook a modelling study of underwater sound levels associated with vessel, drilling and VSP activities for the Development (herein termed 'noise modelling') (Ref. 330). Geophysical survey techniques such as SSS and MBES also generate noise emissions, however these are high frequency impulsive noise emissions which attenuate rapidly in water and the area of exposure is within the immediate vicinity of the activity. As such, VSP, which is a higher intensity low frequency impulsive noise source, has been modelled to conservatively represent loudest impulsive noise sources associated with the Development. The extent of predicted underwater sound levels from the Development to noise effect thresholds for marine fauna was used to inform the risk assessment.

The vessel sound source levels used in the modelling are indicative of the general vessel types that may be used for the activities covered by the OPP. Revised modelling may be undertaken during the EP phase once specific vessels are identified.

The noise modelling study considered 36 individual vessel scenarios (scenarios 1 to 36), 4 combined vessel scenarios (scenarios 37 to 40) and 3 VSP scenarios (scenarios A, B and C) across 5 representative areas within the OA. The 5 representative areas capture the variability of the marine environment (e.g. depth, bathymetry sediment type) across the Development footprint and consider how sound attenuates in each area.

The individual scenarios were modelled to encompass all Development phases and potential vessel configurations. The 4 combined scenarios consider the potential for concurrent activities during the Development. Given the Development considers the entire project life, 2 or 3 fields may have Development activities occurring at the same time; such that if one field is in the operation phase, another field may be under installation and commissioning phase. CAPL have also considered the potential for multiple Development activities occurring at the same time within a single field and combined vessel scenario 40 represents this event.

In addition to noise modelling, a more realistic prediction of continuous underwater water sound exposures for migrating pygmy blue whales was undertaken using animal movement modelling ('animat modelling') for 5 of the 40 vessel scenarios (Ref. 330).

The noise and animat modelling study assessed distances from activities where underwater sound levels reached effect thresholds corresponding to levels of potential impact to marine fauna. The marine fauna considered was based on a review of receptors that may be impacted by continuous and impulsive sound, these were marine mammals, turtles, and fish. The exposure criteria selected for the modelling and the impact assessment were selected as they have been accepted by regulatory agencies and because they represent current best available science (Ref. 330).

Where several modelled scenarios are representative of vessel activities, such as where location, season or type and number of vessels has been varied in the modelling parameters, the furthest distance from the source that fauna may be exposed to sound levels above the exposure criteria has been selected for evaluation of potential impacts. Where modelled ranges are presented as maximum horizontal distance, they represent the maximum received level over depth, therefore in many scenarios the maximum range may only be specific to a narrow section of the water column and exhibit a specific directivity away from the source. As described within Section 8.5.1.2 and Section 8.5.1.6 the source levels assigned to the individual pipelay vessel and DP MODU are based on measured values that also included 3-4 offshore support vessels on DP during the measurement window and typically in locations attributable to significant sea states (Novia Scotia and Swedish Baltic Sea), therefore the modelled scenarios generated for the purposes of this risk evaluation are considered an overestimation of the actual sound generated in many of these scenarios.

Table 8-21 summarises the modelling scenarios applicable to each Development Phase that has the potential to generate impulsive and continuous underwater sound within the OA.

Table 8-21: Modelling scenarios for each Development phase

Scenario No.	Phase	Modelled scenario
1, 9, 17, 29	Drilling	MODU
2, 10, 18, 30	Drilling Support operations	MODU with offshore support vessel (OSV)
3, 11, 19, 25, 31	Installation and commissioning	Pipelay vessel
4, 12, 20, 26, 32	Installation and commissioning Support operations	Pipelay vessel with OSV
5, 13, 21, 27, 33	Installation and commissioning Support operations	Pipelay vessel with 2 OSVs
6, 14, 22, 28, 34	Operations	IMR vessel
7, 15, 23, 35	Installation and commissioning Decommissioning	Construction vessel
8, 16, 24, 36	Installation and commissioning Decommissioning Support operations	Construction vessel with 3 support vessels (transportation or tugs)
37 (combined scenarios 5 and 18)	Drilling Installation and commissioning Support operations	MODU with offshore support vessel (OSV) Pipelay vessel with 2 OSVs
38 (combined scenarios 8, 14 and 18)	Drilling Installation and commissioning Decommissioning/Operations Support operations	MODU with offshore support vessel (OSV) Construction vessel with 3 support vessels (transportation or tugs) IMR vessel
39 (combined scenarios 18 and 33)	Drilling Installation and commissioning Support operations	MODU with offshore support vessel (OSV) Pipelay vessel with 2 OSVs
40	Drilling Installation and commissioning	MODU with offshore support vessel (OSV) Pipelay vessel with 2 OSVs

Scenario No.	Phase	Modelled scenario
(combined scenarios 30 and 33)	Support operations	
A	Drilling	VSP (continental shelf, 142.6 m water depth)
B	Drilling	VSP (continental slope, 923.7 m water depth)
C	Drilling	VSP (off continental slope, 1,153 m water depth)

Potential effect criteria investigated in the noise modelling and in this section include:

- change to behaviour by masking marine fauna communication, eliciting avoidance behaviours (i.e. avoiding 'noisy' areas) and/ or causing a change in swimming patterns (Ref. 338; Ref. 339, Ref. 340)
- Temporary Threshold Shift (TTS); which is defined as a temporary reduction in an animal's hearing sensitivity due to receptor hair cells in the cochlea becoming fatigued (Ref. 338, Ref. 339, Ref. 340)
- Permanent Threshold Shift (PTS); which is defined as a physical injury to an animal's hearing organs (Ref. 338, Ref. 339, Ref. 340).

8.5.2.1 Noise modelling results summary

For all data presented in this section the source levels used to determine maximum over depth horizontal distances are based on indicative source levels associated with the specific activity and/or vessel type (Ref. 330).

All effect criteria threshold metrics were reviewed to define the maximum horizontal distances from sound sources that fauna may be exposed to sound levels above the relevant effect criteria for sound sensitive marine fauna.

Table 8-22 and Table 8-23 summarise the maximum horizontal distances from sound sources to all marine fauna effect criteria for impulsive and continuous noise respectively; and provides the expected duration of each activity.

Table 8-22: Maximum horizontal distance to effect criteria—Impulsive noise sources

Activity	Maximum horizontal distance to effect criteria[54]	Expected duration per activity
Geophysical survey	2.37 km[55] using VSP as a conservative distance	~ 3 weeks
Well evaluation (VSP)	2.37 km	<24 hours per well (Ref. 341)

[54] Behavioural response criterion for marine mammals (Ref. 342) is the lowest threshold, therefore maximum horizontal distances to effect criteria are based on the behavioural response criterion for marine mammals.
[55] Used VSP maximum horizontal distance to marine mammals effect criteria as a conservative distance.

Table 8-23: Maximum horizontal distance to effect criteria—Continuous noise sources

Vessel operations	Maximum horizontal distance to effect criteria[56]	Expected duration per activity
MODU	10.0 km	~ 3 months
MODU with OSV	12.1 km	Intermittent activity (<24 hrs/event) during MODU activities
Pipelay vessel	12.2 km	~ 6 months
Pipelay vessel with OSV	12.8 km	Intermittent activity (<24 hrs/event) during Pipelay activities
Pipelay vessel with 2 OSVs	18.26 km	Intermittent activity (<24 hrs/event) during Pipelay activities
IMR vessel	3.76 km	~ 6 months (minor maintenance) ~ 12 months (major maintenance)
Construction vessel	17.0 km	~ 4 months
Construction vessel with 3 support vessels (transportation or tugs)	17.3 km	Intermittent activity (<24 hrs/event) during construction activities

8.5.2.1.1 Maximum horizontal extent to benthic invertebrate effect criteria

Table 8-24 summarises the maximum horizontal distances to benthic invertebrate effect criteria from impulsive sound sources.

The metrics associated with the longest distance to effect criteria is limited to peak to peak pressure (PK-PK) effect threshold criteria based on available literature at the time of undertaking the noise modelling study (Ref. 330).

Available literature suggests particle motion, rather than sound pressure, is a more important factor for crustacean and bivalve hearing (Ref. 330). Information is only available to define levels for assessment for impulsive sources and given the water depths in the OA, continuous sound sources at sea surface are not considered further.

Table 8-24: Maximum horizontal distance to noise exposure criteria for benthic invertebrates—Impulsive Noise Sources

Hearing group	Effect Criteria	Metric associated with longest distance to criteria	Max. Horizontal Distance
Benthic invertebrates	No effect (Ref. 343)	202 dB re 1 µPa PK-PK	0.06 km
	Impairment in crustaceans (Ref. 344)	209–212 dB re 1 µPa PK-PK	Not reached
	Impairment in crustaceans (Ref. 345)	213 dB re 1 µPa	Not reached

[56] Behavioural response for marine mammals (Ref. 342) is the most sensitive threshold, therefore maximum horizontal distances to effect criteria are based on the behavioural response criterion for marine mammals.

8.5.2.1.2 Maximum horizontal extent to fishes effect criteria

Root mean square (RMS) sound pressure level (SPL within a defined period) and 24 hour sound exposure level (SEL_{24h}) effect criteria metrics were reviewed to identify the maximum horizontal distances. SEL_{24h} effect criteria were found to result in the maximum horizontal distances to fishes effect criteria for impulsive sound. RMS SPL effect criteria were found to result in maximum horizontal distances to fishes effect criteria for continuous sound.

Currently, quantitative threshold criteria do not exist for:

- behavioural responses of fishes (all hearing groups) from impulsive and continuous sound
- mortality/potential mortal injury of fishes (all hearing groups) from continuous sound
- mortality/potential mortal injury and injury (recoverable injury, TTS) of fishes eggs and larvae and fishes with no swimbladder or swimbladders not involved in hearing from continuous sound (Ref. 338).

In the absence of quantitative threshold criteria for the above listed effects on fishes, qualitative ranges to effects have been used to assess relative risk based on guidance from the ANSI accredited report of sound exposure guidelines for fishes and sea turtles (Ref. 338). Section 8.5.3 and Table 8-32 provides relevant details on the relevant qualitative ranges used for impact and risk evaluation for each fishes hearing group.

Table 8-25 and Table 8-26 summarise the maximum horizontal distances to fishes effect criteria from impulsive and continuous sound sources respectively. The maximum distance to effect criteria for relevant fish for impulsive and continuous sound is shown in Figure 8-15 and Figure 8-16 respectively.

Table 8-25: Maximum horizontal distance to noise exposure criteria for fishes—Impulsive noise sources

Hearing group	Effect Criteria[57]	Metric associated with longest distance to criteria	Max. Horizontal Distance
Fishes with swimbladder involved with hearing and with swimbladder not involved with hearing	Mortality/potential mortal injury	>210 dB SEL_{24h}	0.03 km
	Recoverable injury	>203 dB SEL_{24h}	0.05 km
	TTS	>186 dB SEL_{24h}	0.57 km
Fishes with no swimbladder	Mortality/potential mortal injury	>219 dB SEL_{24h}	Not reached
	Recoverable injury	>216 dB SEL_{24h}	Not reached
	TTS	>186 dB SEL_{24h}	0.57 km
Fishes eggs and larvae	Injury	>210 dB SEL_{24h}	0.05 km*

[57] Popper et al. (Ref. 338) cites varying accumulation periods for a number of sound events at particular time intervals. For this assessment 24 h was used based on the independent, expert peer review by Popper (Ref. 346) that concluded that a 24-hour period to assess SELcum and any associated effects is likely to be conservative for assessing the potential effects to fish.

Table 8-26: Maximum horizontal distance to noise exposure criteria for fishes—Continuous

Hearing group	Effect Criteria	Metric associated with longest distance to criteria	Max. Horizontal Distance
Fishes	Recoverable injury for fish with a swim bladder involved in hearing (Ref. 338)	170 dB SPL for 48 h	0.05 km
	TTS for fish with a swim bladder involved in hearing (Ref. 338)	158 dB SPL for 12 h	0.09 km

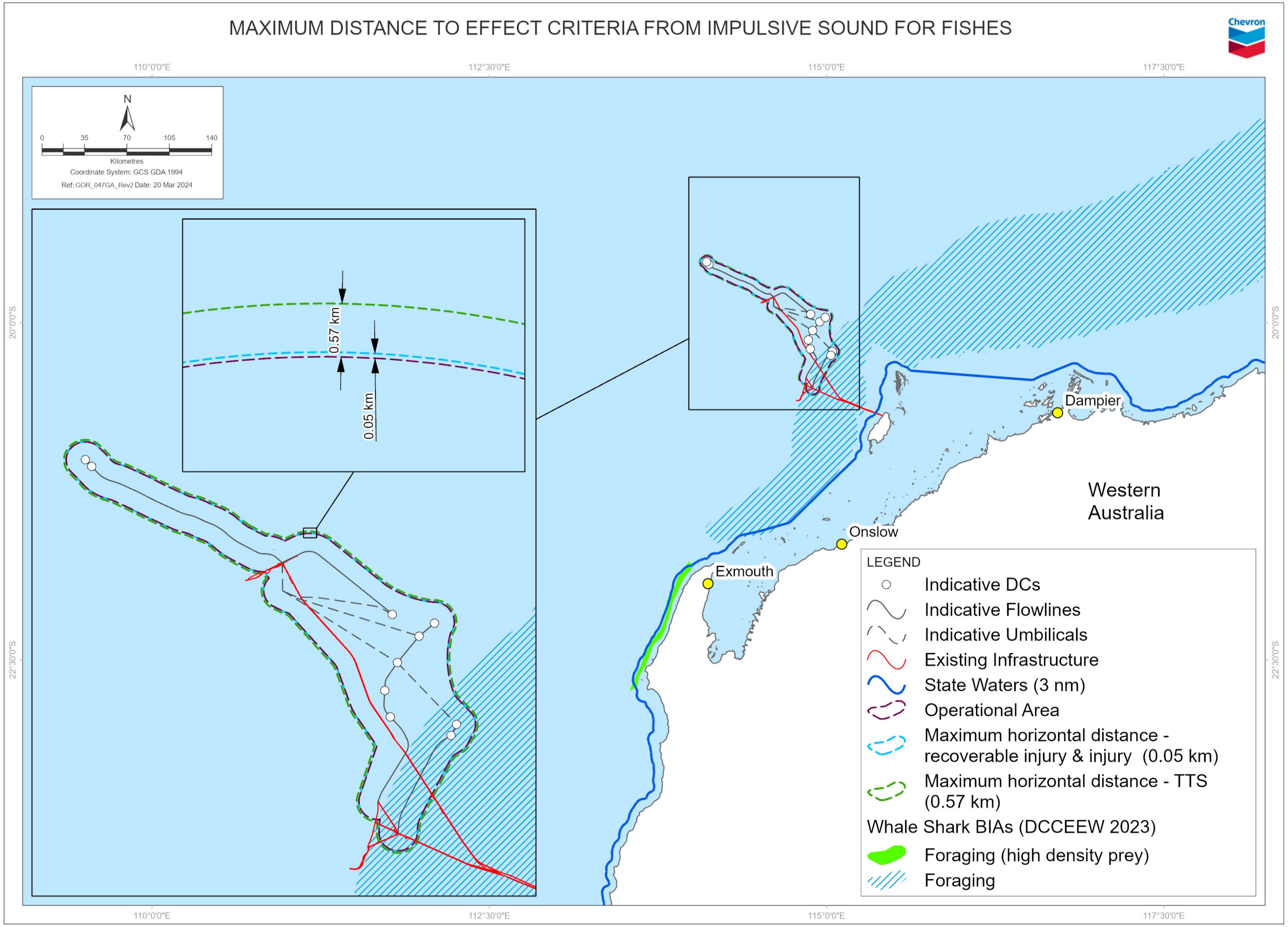

Figure 8-15: Maximum distance to effect criteria from impulsive sounds for fishes

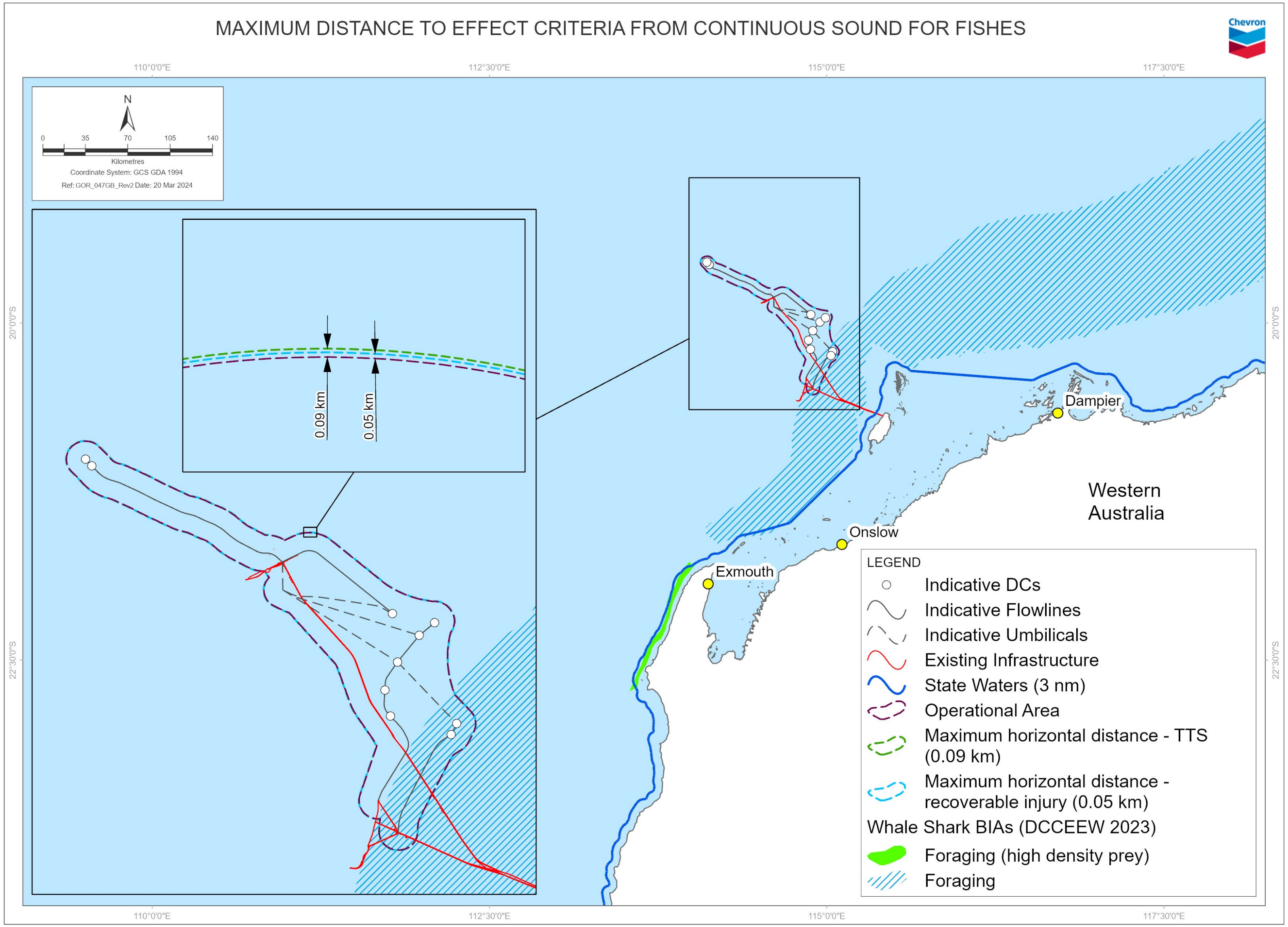

Figure 8-16: Maximum distance to effect criteria from continuous sound for fishes

8.5.2.1.3 Maximum horizontal extent to reptile effect criteria

Unweighted sound pressure level (SPL), SEL_{24h}, and peak pressure (PK) effect criteria metrics were reviewed to identify the maximum horizontal distances from sound sources to marine reptile effect criteria.

Currently, quantitative threshold criteria do not exist for:

- mortality/potential mortal injury of marine turtles from impulsive sound
- mortality/potential mortal injury and behavioural responses of marine turtles from continuous sound (Ref. 338).

In the absence of quantitative threshold criteria for the above listed effects on marine reptiles, qualitative ranges to effects have been used to assess relative risk based on guidance from the ANSI accredited report of sound exposure guidelines for fishes and sea turtles (Ref. 338). Section 8.5.3 and Table 8-32 provides relevant details on the relevant qualitative ranges used for impact and risk evaluation for marine turtles.

Table 8-27 and Table 8-28 summarises the maximum horizontal distances to marine turtle effect criteria from impulsive and continuous sound sources respectively. The maximum distance to effect criteria for relevant marine reptiles for impulsive and continuous sound is shown in Figure 8-17, Figure 8-18, Figure 8-19 and Figure 8-20 respectively.

Table 8-27: Maximum horizontal distance to noise exposure criteria for marine turtles—Impulsive

Hearing group	Effect Criteria	Metric associated with longest distance to criteria	Max. Horizontal Distance
Marine turtles	Behavioural response (Ref. 347)	166 dB SPL	1.03 km
	Behavioural disturbance (Ref. 347)	175 dB SPL	0.27 km
	24 h threshold for TTS Impairment (Ref. 348)	189 dB SEL_{24h}	0.24 km
	24 h threshold for PTS Impairment (Ref. 348)	204 dB SEL_{24h}	0.03 km
	Peak threshold for TTS onset (Ref. 348)	226 dB PK re 1 µPa	Not reached
	Peak threshold for PTS onset (Ref. 348)	232 dB re 1 µPa	Not reached

Table 8-28: Maximum horizontal distance to noise exposure criteria for marine turtles—Continuous

Hearing group	Effect Criteria	Metric associated with longest distance to criteria	Max. Horizontal Distance
Marine turtles	24 h threshold for TTS Impairment (Ref. 348)	200 dB SEL_{24h}	0.18 km
	24 h threshold for PTS Impairment (Ref. 348)	220 dB SEL_{24h}	0.14 km

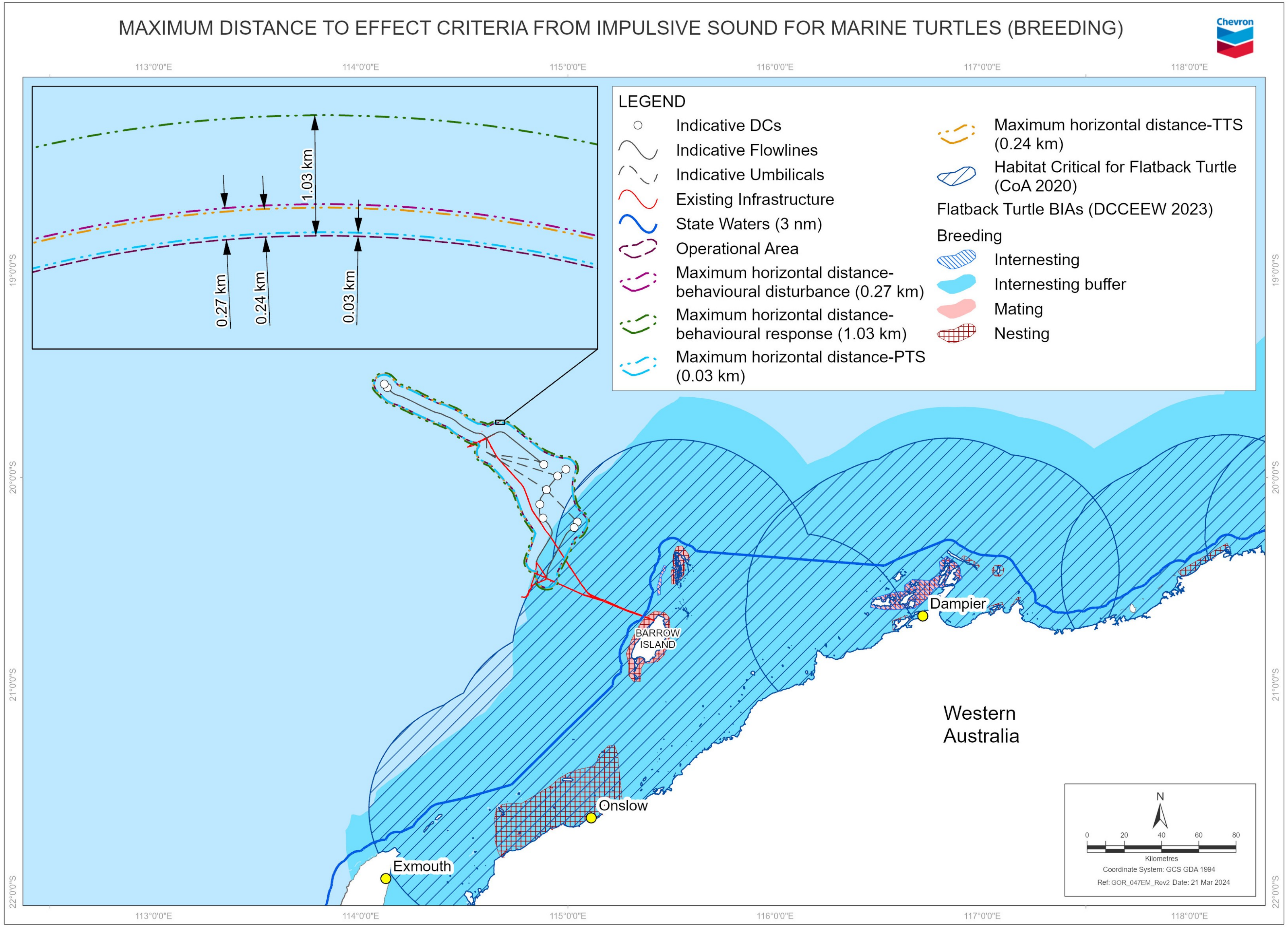

Figure 8-17: Maximum distance to effect criteria from impulsive sound for marine turtles (breeding)

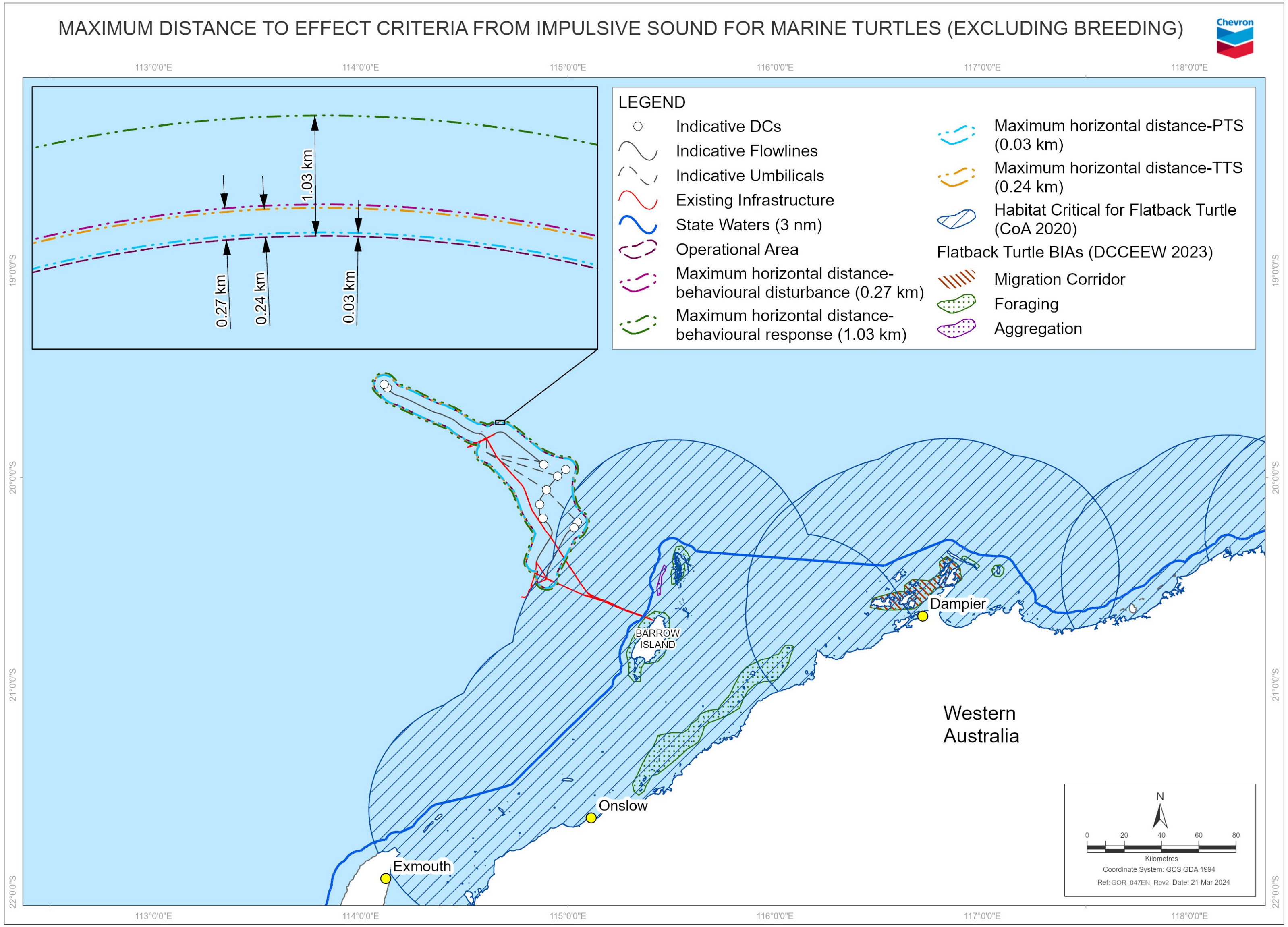

Figure 8-18: Maximum distance to effect criteria from impulsive sound for marine turtles (excluding breeding)

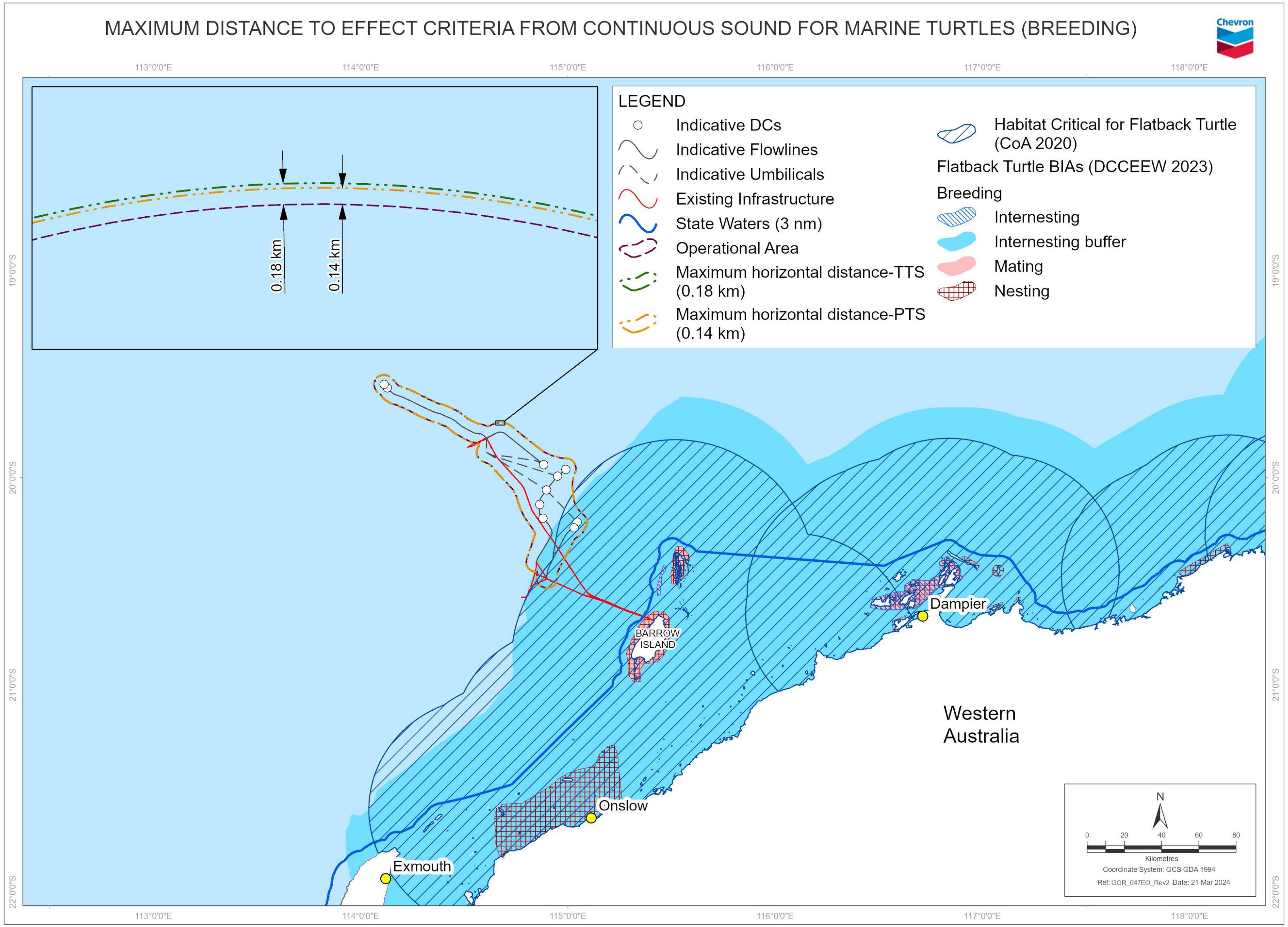

Figure 8-19: Maximum distance to effect criteria from continuous sound for marine turtles (breeding)

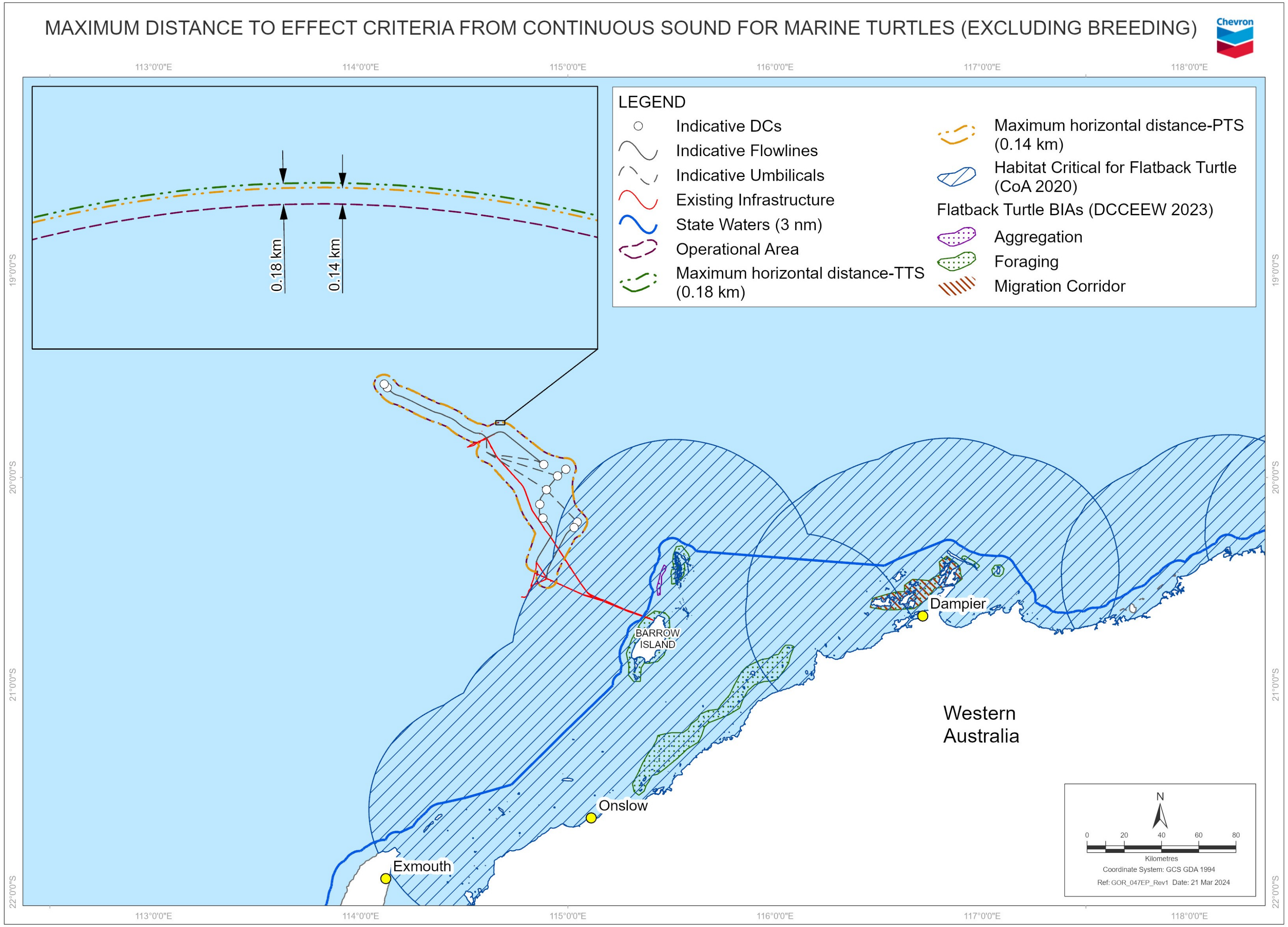

Figure 8-20: Maximum distance to effect criteria from continuous sound for marine turtles (excluding breeding)

8.5.2.1.4 Maximum horizontal extent to marine mammal effect criteria

SPL, SEL_{24h}, and PK effect criteria metrics were reviewed to identify the maximum horizontal distances. Table 8-29 and Table 8-30 detail the metric that results in the maximum horizontal distance for impulsive and continuous sounds. The maximum distance to effect criteria for relevant marine mammals for impulsive and continuous sound is shown in Figure 8-21 and Figure 8-22 respectively.

Table 8-29: Maximum horizontal distance to noise exposure criteria for marine mammals—Impulsive

Hearing group	Effect Criteria	Metric associated with longest distance to criteria	Max. Horizontal Distance
Marine mammals	Behavioural response (Ref. 342)	160 dB SPL	2.37 km
Low-frequency cetaceans i.e. pygmy blue and humpback whales	24 h threshold for TTS onset (Ref. 339)	168 dB SEL_{24h}	3.20 km
	24 h threshold for PTS onset (Ref. 339)	183 dB SEL_{24h}	0.48 km
	Peak threshold for TTS onset (Ref. 339)	213 dB PK	Not reached
	Peak threshold for PTS onset (Ref. 339)	219 dB PK	Not reached
High-frequency cetaceans i.e. dolphins, sperm whales, and beaked whales	24 h threshold for TTS onset (Ref. 339)	170 dB SEL_{24h}	Not reached
	24 h threshold for PTS onset (Ref. 339)	185 dB SEL_{24h}	Not reached
	Peak threshold for TTS onset (Ref. 339)	224 dB PK	Not reached
	Peak threshold for PTS onset (Ref. 339)	230 dB PK	Not reached
Very-high frequency cetaceans i.e. pygmy and dwarf sperm whales	Peak threshold for TTS onset (Ref. 339)	196 PK	0.13 km
	Peak threshold for PTS onset (Ref. 339)	202 PK	0.06 km

Table 8-30: Maximum horizontal distance to noise exposure criteria for marine mammals—Continuous

Hearing group	Effect Criteria	Metric associated with longest distance to criteria	Max. Horizontal Distance
Marine mammals	Behavioural response (Ref. 342)	120 dB SPL	18.26 km
Low-frequency cetaceans i.e. pygmy blue and humpback whales	24 h threshold for TTS onset (Ref. 339)	179 dB SEL_{24h}	4.58 km
	24 h threshold for PTS onset (Ref. 339)	199 dB SEL_{24h}	0.21 km
High-frequency cetaceans	24 h threshold for TTS onset (Ref. 339)	178 dB SEL_{24h}	0.19 km

Hearing group	Effect Criteria	Metric associated with longest distance to criteria	Max. Horizontal Distance
i.e. dolphins, sperm whales, and beaked whales	24 h threshold for PTS onset (Ref. 339)	198 dB SEL_{24h}	0.16 km
Very-high frequency cetaceans i.e. pygmy and dwarf sperm whales	24 h threshold for TTS onset (Ref. 339)	153 dB SEL_{24h}	3.33 km
	24 h threshold for PTS onset (Ref. 339)	173 dB SEL_{24h}	0.21 km

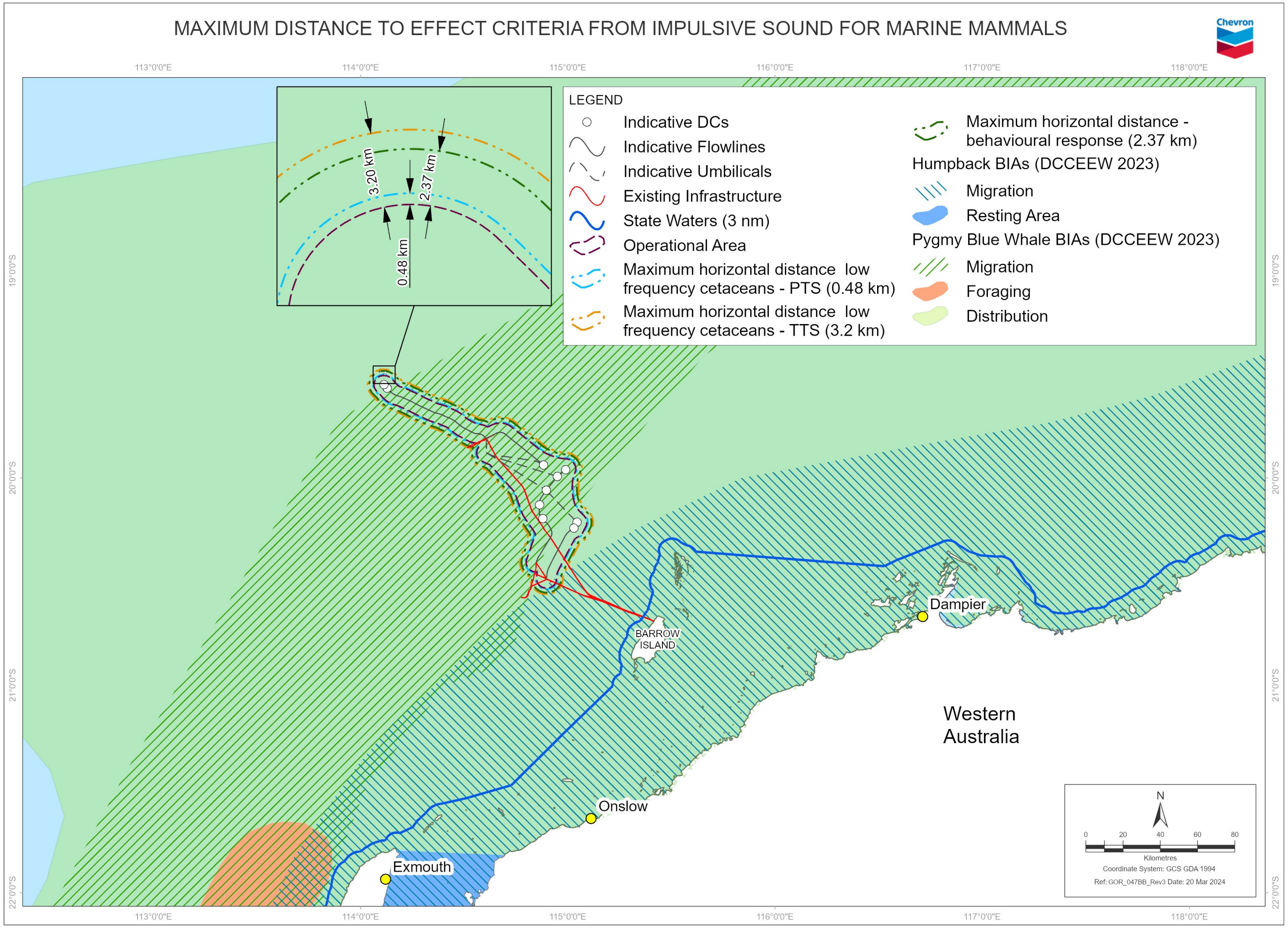

Figure 8-21: Maximum distance to effect criteria from impulsive sound for marine mammals

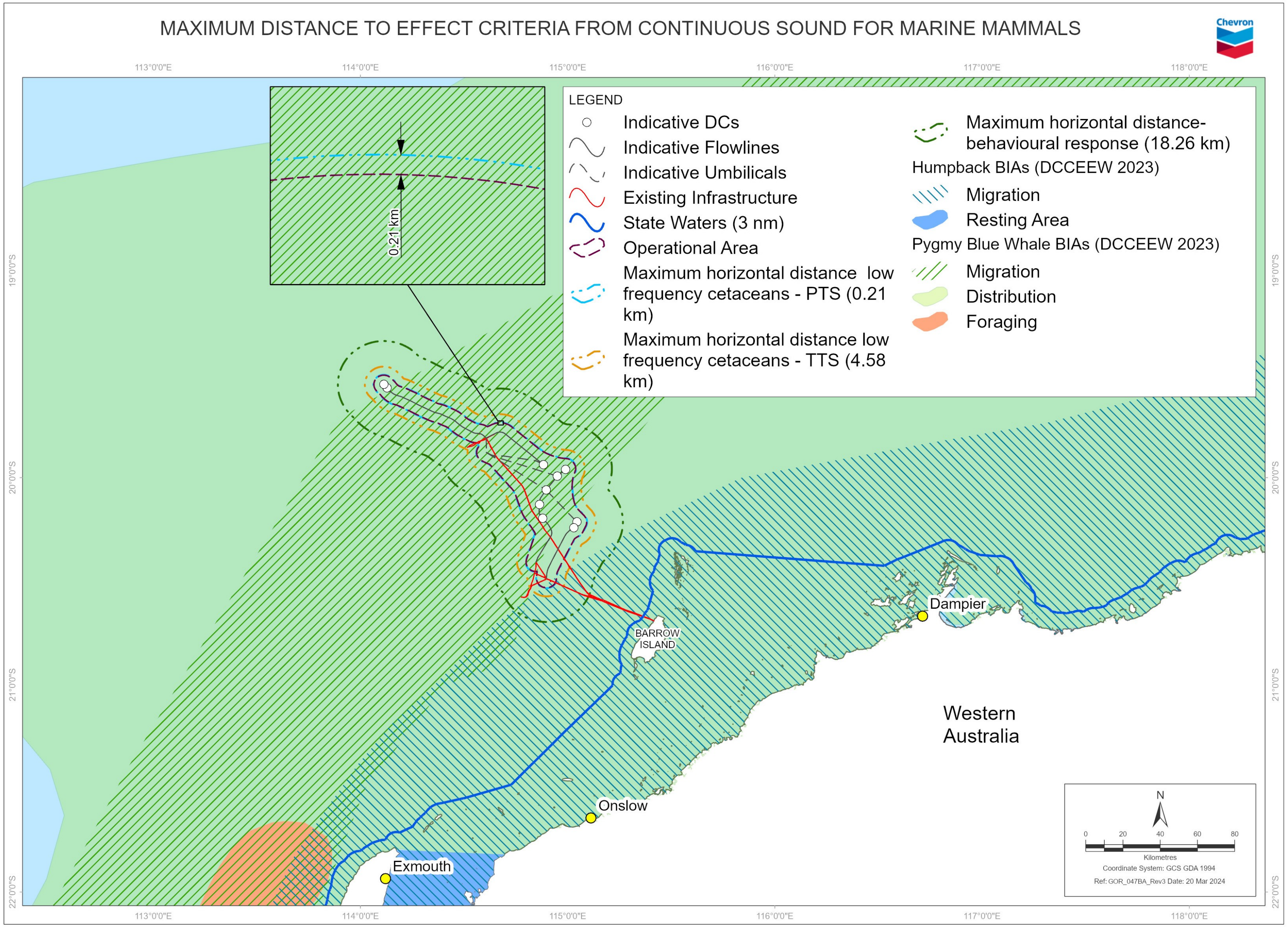

Figure 8-22: Maximum distance to effect criteria from continuous sound for marine mammals

8.5.2.2 Animat modelling results summary

In addition to the acoustic modelling study, JASCO undertook an acoustic exposure analysis for migrating pygmy blue whales (Ref. 330), which describes the modelled predictions of sound levels that individual pygmy blue whales may receive during the Development activities.

Sound exposure distribution estimates are determined by moving large numbers of simulated animals (‘animats’) through a modelled time-evolving sound field, computed using specialised sound source and sound propagation models (Ref. 330). This approach provides the most realistic prediction of the maximum expected SPL, and the temporal accumulation of sound exposure level (SEL_{24h}) for comparison against the relevant thresholds (Ref. 330).

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to model the movement of pygmy blue whales through the predicted sound field. Biologically meaningful movement rules were applied to each animat in the model to represent whale behaviours. This included swim speeds, direction, diving and ascent rates, dive depths (for both migratory dives near the surface and deeper exploratory or feeding dives), and time spent at or near the surface before diving again. The animats, were set to simulate the real-world movements of migrating pygmy blue whales within their migratory BIA.

The modelled 95th percentile exposure ranges ($ER_{95\%}$) from the sound source for Scenario 8 (Area 1, Construction vessel with 3 support vessels) to the relevant noise effect criteria for pygmy blue whales are shown in Table 8-31. Within the $ER_{95\%,}$ there is generally some proportion of animats that do not exceed the threshold criteria. This occurs for several reasons, including the spatial and temporal characteristics of the sound field and the way in which the animats are exposed to the sound field over time, both vertically and horizontally. The probability that an animat within the $ER_{95\%}$ was exposed above threshold was also computed and is shown in Table 8-31.

Marine mammal effect criteria metrics for continuous sound are limited to SPL and SEL_{24h} for behavioural response and injury (TTS and PTS), respectively, based on available literature at the time of undertaking the noise modelling study (Ref. 330).

Table 8-31: Animat modelling maximum exposure range to noise exposure criteria for low frequency cetaceans—Continuous

Hearing group	Effect Criteria	Metric associated with longest distance to criteria	Max. Exposure Range and Probability
Marine mammals	Behavioural response (Ref. 342)	120 dB SPL	12.4 km (99%)
Low-frequency cetaceans i.e. pygmy blue whales	24 h threshold for TTS onset (Ref. 339)	179 dB SEL_{24h}	0.04 km (67%)
	24 h threshold for PTS onset (Ref. 339)	199 dB SEL_{24h}	Not reached

8.5.3 Impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the area that may be impacted by underwater sound emissions:

- ambient sound
- benthic invertebrates
- fishes, including sharks and rays (and plankton)
- marine reptiles
- marine mammals
- cultural heritage value: Traditional Owners.

Although fish may potentially be impacted by underwater sound, the area of influence is localised and is not expected to result in a change in the viability of the population of commercially important species or the Continental slope demersal fish communities KEF. Only one State- and 3 Commonwealth-managed fisheries have recorded historical fishing effort in the OA. In addition, modelling indicates injury effect criteria for fish are only exceeded within 10’s of metres of the source for all activities. Therefore, impacts to commercial fisheries or a change in values and sensitivities of the fish assemblage values of the Continental slope demersal fish communities KEF from underwater sound are not expected; and are not evaluated further.

Table 8-32 details the impact and risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to underwater sound in the sound area.

Table 8-32: Impact and risk evaluation for Underwater sound

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Underwater sound emissions may result in: • localised and temporary change in ambient underwater sound	5	A localised and temporary change in ambient underwater sound may result in: • change to behaviour in benthic invertebrates	6	2	Low (7)
		A localised and temporary change in ambient underwater sound may result in: • change to behaviour in fishes, including sharks and rays (and plankton)	6	2	Low (7)
		A localised and temporary change in ambient underwater sound may result in: • change to behaviour in marine reptiles	6	2	Low (7)
		A localised and temporary change in ambient underwater sound may result in: • change to behaviour in marine mammals	5	3	Low (7)
		A localised and temporary change in ambient underwater sound may result in:	5	6	Very Low (10)

Impact and/or risk level summary						
Impacts	**C**	**Risks**	**C**	**L**	**RR**
		• TTS, PTS, recoverable or non-recoverable injury to marine fauna			
		A localised and temporary change in ambient underwater sound may result in: • change to cultural heritage values	5	3	Low (7)

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Ambient sound

Localised and temporary change in ambient underwater sound

Continuous and impulsive underwater sound emissions from the Development will locally and temporarily increase underwater sound levels from ambient levels within the sound area.

Archival underwater acoustic recordings between 2006 and 2017 from the North West Shelf (NWS) found natural physical processes (e.g. wind), anthropogenic (e.g. ships) and biological noise (e.g. whale song) contributed to the soundscape for the region (Ref. 349).

Underwater broadband ambient sound spectrum levels range from 45–60 dB re 1 µPa in quiet regions (light shipping and calm seas) to 80–100 dB re 1 µPa for more typical conditions, and >120 dB re 1 µPa during periods of high winds, rain or 'biological choruses' (many individuals of the same species vocalising near simultaneously in reasonably close proximity to each other) (Ref. 350). Low-frequency ambient sound levels (20–500 Hz) are frequently dominated by distant shipping plus some great whale species. Light weather-related sounds will be in the 300–400 Hz range, with wave conditions and rainfall dominating the 500–50,000 Hz range (Ref. 350).

Impulsive underwater sound

The temporary generation of impulsive underwater sound (Table 8-22) from the Development will introduce and replicate existing oil and gas activities' contributions to ambient sound levels in the OA. Impulsive underwater sound sources from the Development includes VSP (<24 hours each well), use of transponders (e.g. in MODU positioning) and geophysical surveys, such as SSS and MBES (~3 weeks).

Transponders, SSS and MBES emit high frequency, impulsive noise between 2 and 1000 kHz (Section 8.5.1.1). High frequency sound attenuates rapidly in water and, while these activities may be undertaken intermittently over a period up to 3 weeks, the area of exposure above marine fauna effect criteria will be within the immediate vicinity of the activity (Ref. 351).

Vertical seismic profiling is a low frequency impulsive sound source and the most intensive impulsive sound source associated with the Development, and as such, has been conservatively used to represent the loudest impulsive noise source Noise modelling of VSP found the largest radii to effect criteria (marine mammal behavioural response threshold criteria) was 2.37 km from the source.

The consequence of causing a change in ambient underwater sound has been assessed as Minor (5) as it will result in localised environmental impacts limited to the duration of survey activities and will return to ambient levels upon completion of work.

Continuous underwater sound

Continuous underwater sound will be generated through the use of vessels, MODUs, ROVs, helicopters and in the operation and decommissioning of subsea infrastructure associated with the Development. The NWS shipping fairway crosses the proposed G&E to Jansz pipeline and is expected to significantly influence ambient sound levels in this section of the OA (Figure 6-33). A review of ships using the shipping fairway during January 2023 found up to 13 container ships a day passed through the OA (Ref. 352).

A study measuring underwater radiated noise from modern commercial ships including container ships, bulk carriers and tanker ships found a 54 kGT container ship had the highest broadband source level at 188 dB re 1 µPa @ 1 m (Ref. 353). Review of broadband source levels generated by the Development (Section 8.5.1) against the broadband source level of a 54 kGT container ship finds most of the vessels (including MODUs) used for the Development will introduce continuous sound sources that are equal to or below container ship sound source levels. The exception is the use of the construction vessel during the Development which is expected to have a maximum source level of 194 dB re 1 µPa @1 m (Ref. 354).

Noise modelling of underwater sound levels associated with vessel activities for the Development found the largest radii to effect criteria (marine mammal change to behaviour) was 18.26 km (Pipelay vessel with 2 OSVs) for short durations (<24 hrs) over an approximate 4 month period (Table 8-23). Concurrent activities in a single field may result in the overlapping of ensonified areas to create one larger merged ensonified area, as

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predicted for combined scenario 40. If the distance between concurrent activities are smaller than the sum of the effect radii of the individual activities, modelling indicates that the resulting merged ensonified area may be up to 12.9% greater in area compared to the ensonified area of individual scenarios. Although there is potential for merged ensonified areas from concurrent activities, changes in underwater sound levels will be temporary, will be similar to the sound levels associated with commercial shipping in the area and will return to ambient levels upon completion of activities. Sound emitted from helicopter operations is typically below 500 Hz (Ref. 355). The peak-received level diminishes with increasing helicopter altitude, but the duration of audibility often increases with increasing altitude. Estimates of SPL for helicopters range 149–162 dB re 1 µPa (Ref. 356; Ref. 357). Richardson et al. (Ref. 356) report that helicopter sound was audible in air for four minutes before it passed over underwater hydrophones, but detectable under water for only 38 seconds at 3 m depth, and 11 seconds at 18 m depth. Underwater sound emissions associated with ROV use, operation of subsea infrastructure and cutting of subsea infrastructure during decommissioning are minimal compared to other sound sources (Section 8.5.1) and are not considered further. Taking the above into consideration, the consequence of a localised and temporary change in ambient underwater sound has been assessed as Minor (5).
Benthic invertebrates
Change to behaviour A review of sound sources generated by the Development found VSP has the potential to acoustically induce particle motion stimuli for benthic invertebrates (Ref. 330) within a close distance to the acoustic source. Given the water depths in the OA, continuous sound sources located at the sea surface are not expected to impact benthic invertebrates at the sea floor and are therefore not considered further. The duration of VSP will be <24 hours for each well. Noise modelling for VSP found impairment in crustaceans effect criteria were not reached and no effect criteria were only exceeded within 61 m of the source, so the focus of this evaluation is on behavioural change. <u>Impulsive underwater sound</u> Benthic habitat surveys indicate the OA is predominantly characterised by smooth and irregular seabed with either bare substrate or bioturbation, however in some areas epifauna were identified including, sponges, cnidarians, and echinoderms in varying percent cover (from low [<10%] to high cover [>80%]) (Ref. 105, Appendix A). Research is ongoing into the relationship between sound and its effects on benthic invertebrates, including the relevant metrics for both effect and impact. Marine invertebrates lack a gas-filled bladder and are unable to detect the pressure component of sound waves (Ref. 358; Ref. 359) or "hear" sound in the way that mammals and fish can. However, it is considered credible that impulsive underwater noise associated with the Development may result in temporary and localised change to behaviour in benthic invertebrates within discrete and relatively shallow areas of the OA (~150 m deep) where VSP is undertaken. An EPBC PMST report did not identify any benthic invertebrate threatened or migratory species, or any TECs within the OA. Given benthic habitats within the OA are widely represented in the NWS region, and as change to behaviour will be limited to the duration of VSP, the consequence associated with this aspect has been determined to be Incidental (6). The likelihood of the consequence occurring is assessed as Occasional (2) noting benthic invertebrates were observed in some areas of the OA during benthic habitat surveys. Overall, the risk of impulsive underwater sound resulting in a change to behaviour in benthic invertebrates is Low (7).
Fishes, including sharks and rays (and plankton)
Sounds that fishes may detect are mostly confined to low frequencies (often no more than 800–1,000 Hz) (Ref. 360; Section 8.5.1) and a review of sound sources generated by the Development found VSP operation and decommissioning of subsea infrastructure, drilling, vessel and helicopter operations will generate sounds within fish hearing frequencies. Maximum horizontal distances from Development activities to noise exposure criteria for fishes for impulsive and continuous sources (Section 8.5.2.1.1) may overlap the following BIAs for fishes, including sharks and rays: • whale shark BIA (foraging). The overlap is limited to noise emissions from activities within the WTR section of the OA. Sharks are assessed against the effect criteria for fish with no swimbladder (Table 8-25). Site-attached fish habitat does not appear to be common in the OA, given the benthic environment in the OA was found to be dominated by low topographic features with few benthic biota (Ref. 105, Appendix A). The fish species observed were predominantly pelagic and demersal species (Ref. 105, Appendix A), which are

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generally considered transient and highly mobile as they are adapted to living and moving through open water habitats (Ref. 283).

Change to behaviour

Behavioural responses of fishes to anthropogenic sound are generally exhibited as a startle response or avoidance of the sound source (Ref. 361; Ref. 362).

Impulsive underwater sound

Impulsive underwater sound sources associated with the Development that are audible to fishes include VSP, and high frequency impulsive noise associated with geophysical survey techniques (i.e. MBES, SSS).

Currently, quantitative threshold criteria for behavioural responses of fishes (and fish larvae) from impulsive sound do not exist (Ref. 338). Fishes are highly likely to exhibit a behavioural response within tens of metres from loud impulsive sound sources (e.g. seismic sources) and a low likelihood of displaying a behavioural response to lower intensity impulsive noise sources (Ref. 338). Whereas fishes larvae are moderately likely to exhibit behavioural response within tens of metres from loud impulsive sound sources and have a low likelihood of displaying a behavioural response to lower intensity impulsive noise sources (Ref. 338).

It is expected that any impacts to transient and highly mobile fishes from VSP (as a conservatively loudest impulsive noise source) in the OA (including whale sharks within the WTR section of the OA) would be limited to temporary behavioural responses such as startle response or avoidance behaviour (Ref. 360) and only at very close range to the sound source. Larval fishes (including other zooplankton) behavioural responses are expected to be limited to minor changes in swimming patterns or have little or no effect (Ref. 363 Ref. 364). Any effects to plankton have to be assessed in the context of natural mortality rates, which are generally considered high and variable. Plankton also have a patchy distribution linked to localised and seasonal productivity that produces sporadic bursts in populations (Ref. 103). Sound emissions on sparse plankton populations are unlikely to cause a significant change in behaviour at a measurable level.

As such, the Development has the potential to cause temporary change to behaviour in transient fishes, including foraging whale sharks and plankton within the OA, therefore resulting in an Incidental (6) consequence.

The likelihood of the consequence occurring is assessed as Occasional (2).

Overall, the risk of impulsive underwater sound resulting in a change to behaviour in fishes, including sharks and rays is Low (7).

Continuous underwater sound

Continuous sources generated by the Development including vessel activities, drilling activities, operation and decommissioning of subsea infrastructure and helicopter operations are expected to be audible to transient and highly mobile fishes in the OA. The loudest continuous broadband sound source for the Development will be generated by vessel activities. Vessel activities will result in the greatest area ensonified by continuous sources and was modelled to define the maximum horizontal distance to fish effect criteria for continuous underwater sound (Ref. 330).

Transient and highly mobile fishes including occasional whale sharks may be present within the OA. If transient fishes are present within proximity to vessels, DCs during drilling activities and helidecks during helicopter landing/take-off (i.e. within 10's of metres as noted in Table 8-26), sound from these activities may result in a change to behaviour such as a change in swimming speed and direction or change in schooling behaviours (Ref. 360; Ref. 365). Behavioural responses of larval fishes (including other zooplankton) may include minor changes in swimming patterns, however feeding behaviours are not expected to be influenced from exposure to continuous sound (Ref. 366). There are no habitats or features within the OA that would restrict fishes from moving away from continuous sound sources generated by the Development.

Currently, quantitative threshold criteria for behavioural responses of fishes from continuous sound do not exist (Ref. 338). Fishes are highly likely to exhibit behavioural responses, however only within close proximity (tens of metres) from continuous sound sources (Ref. 338). Whereas fishes larvae are moderately likely to exhibit behavioural response within tens of metres of continuous sound sources (Ref. 338).

As such, the Development has the potential to cause temporary change to behaviour in transient fishes, including whale sharks within the OA and plankton, therefore resulting in an Incidental (6) consequence.

The likelihood of the consequence occurring is assessed as Occasional (2).

Overall, the risk of continuous underwater sound resulting in temporary change to behaviour in fishes, including sharks and rays is Low (7).

Concurrent Impacts

While the Development will be staged so that not all fields will be developed in a single campaign, different phases of the activities may occur concurrently. For example, drilling may be occurring at one field, while installation and commissioning operations have already begun at a different field or both drilling and

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installation and commissioning operations may be occurring at a single field (herein termed 'concurrent campaigns'). Underwater sound from concurrent activities in the WTR and C&D fields may have the potential to cause a change to behaviour in transient whale sharks within the OA. Concurrent campaigns introduce the potential for the occurrence of multiple ensonified areas at a single time during the Development. T Concurrent behavioural impacts to occasional foraging whale sharks are expected to be limited to temporary displacements which are unlikely to result in any real biological cost to the animals. The whale shark foraging BIA covers a large area and the part of the foraging BIA overlapped by the OA is in the open offshore water environment where avoidance behaviours will not be impeded. As a result, continuous underwater sound may displace foraging whale sharks outside of the foraging BIA to surrounding areas of known suitable foraging habitat, however it is unlikely to affect individual energetics or fitness or have any population-level effect. Underwater noise associated with the Development has the potential to cause temporary change to behavioural in fishes, including foraging whale sharks and plankton within the OA, therefore resulting in an Incidental (6) consequence. The likelihood of the consequence occurring is assessed as Occasional (2). Overall, the risk of continuous underwater sound resulting in a change to behaviour in fishes, including sharks and rays is Low (7).
TTS, PTS and recoverable or non-recoverable injury Underwater sound can cause injury or mortality of fishes via auditory impairment (TTS, PTS), or other recoverable or non-recoverable injury. Temporary threshold shift (TTS) is a temporary change in hearing sensitivity and can occur in fishes as a result of multiple exposure to intense sounds or long-term exposure to less intense sounds. While experiencing TTS, fishes may have decreased fitness through impaired communication, prey and predator detection (Ref. 338). However, Popper and Hawkins (Ref. 365) report that fish that showed TTS recovered to normal hearing levels within hours to several days. Permanent threshold shift (PTS) does not occur in fish due to hair cells within the ear constantly being added and replaced when damaged (Ref. 338). <u>Impulsive underwater sound</u> Impulsive underwater sound sources associated with the Development that are audible to fishes includes VSP (<24 hours each well) and geophysical (e.g. SSS, MBES) surveys (~3 weeks). Noise modelling of underwater sound levels associated with VSP (as a conservatively loudest impulsive noise source) for the Development was conducted against fish effect criteria from the American National Standards Institute (ANSI) accredited report of sound exposure guidelines for fishes and sea turtles (Ref. 338) (refer to Section 2.2 of Appendix D, Ref. 330). The SEL_{24} effect criteria for mortality/potential mortal injury (i.e. non-recoverable injury), recoverable injury and TTS to adult fishes with swimbladders was reached within 30, 50 and 570 m from the source, respectively. For fishes without swimbladders (e.g. sharks and rays) only the SEL_{24} TTS effect criteria was reached within 570 m from the source. Based on the modelling results and due to the water depths in the OA, it is not considered credible that mortality/potential mortal injury or recoverable injury in fish will occur from VSP operations. In addition, transient and highly mobile sharks, and rays (fishes without swimbladders) are not expected to remain within close enough proximity to the VSP source for a period long enough to experience TTS. At the WTR DCs where water depths are ~150 m deep, TTS may occur in demersal fish when VSP is undertaken. However, as VSP will only be conducted for 24 hours per well, fish are expected to experience TTS for a short period and recover from sound exposure soon after VSP operations are completed. Based on noise modelling predictions, fishes eggs and larvae may be injured within 50 m of an impulsive sound source. Turnover rates for zooplankton are naturally high with distribution often patchy and linked to localised and seasonal productivity that produces sporadic bursts in zooplankton populations (Ref. 104). Therefore, zooplankton populations are expected to recover quickly from any impacts from impulsive sound. The temporary onset of TTS to demersal fish and localised impacts to zooplankton within close proximity to the source has been determined to be a Minor (5) consequence. The likelihood of the consequence occurring is assessed as Occasional (2). Overall, the risk of impulsive underwater sound resulting in TTS in fish and impacts to plankton is Low (7). <u>Continuous underwater sound</u> Vessel activities will result in the greatest area ensonified by continuous sources and were modelled to define the maximum horizontal distance to fish effect criteria for continuous underwater sound (Ref. 330). To demonstrate the iterative effect of multiple vessel activities during a phase and the potential for multiple phases to occur concurrently, noise modelling for the Development considered 36 individual vessel activity

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scenarios representing all Development phases and geoacoustic areas (Scenarios 1-36) and 4 combined vessel scenarios incorporating multiple individual vessel activity scenarios (Scenarios 37-40) (refer to Appendix D, Ref. 330). Noise modelling for the Development used fish effect criteria from the ANSI accredited report of sound exposure guidelines for fishes and sea turtles (Ref. 338) (refer to Section 2.2 of Appendix D, Ref. 330). Results of the modelling found the only effect criteria reached for fishes were recoverable injury and TTS to adult fishes with swimbladders (Ref. 330). The effect criteria for mortality/potential mortal injury (i.e. non-recoverable injury/PTS) to fishes with swimbladders was not reached. Based on noise modelling predictions, recoverable injury, and TTS to fishes with swimbladders is limited to 50 and 90 m from the continuous source, respectively (Table 8-26) and only where fishes remain within this range for a 12 hour (TTS) or 48 hour (recoverable injury) period. It is important to note that the modelled continuous vessel noise source values assume the radiating vessel noise is emanating from a single point source, whereas in reality the noise will be emanating from each individual thruster, some of which have significant spatial separation beyond the range of recoverable injury and TTS predicted, reflective of the length of the vessels. Accordingly in real world conditions it is considered not credible that levels associated with recoverable injury or TTS would be reached. Given the water depths of the OA, the modelled ensonified areas at recoverable injury and TTS thresholds for continuous noise from vessels will not reach the seafloor. As a result, potential impacts to fishes will be limited to pelagic, more mobile species. However, for drilling activities on the seabed, benthopelagic species are also considered within ensonified areas at recoverable injury and TTS thresholds for continuous noise. Based on noise modelling predictions, injury and mortality to individual transient and highly mobile fishes with swimbladders may occur, however would require fish to remain within close proximity to the source for periods >12 hours. This potential impact is not considered to be at a population level given the uncommon occurrence of site-attached fish habitats in the OA, low abundance of fish observed during benthic habitat surveys in most areas of the OA and the absence of BIAs for fishes with swimbladders in the OA. Currently, quantitative threshold criteria for injury/mortality to sharks and rays (fishes without swimbladders) from continuous sound do not exist (Ref. 338) however, Popper et al (Ref. 338) does provide a qualitative relative risk of noise exposures resulting in a mortality, recoverable injuries or TSS. Modelling of the various continuous noise sources within the Development suggests the risk of recoverable injury and mortality to sharks and rays is low while the risk of TTS to sharks and rays is moderate within tens of metres from continuous sound sources (Ref. 338). However, TTS thresholds would only be exceeded if sharks and rays remain within close proximity to the source for extended periods. On this basis, neither TTS nor recoverable injury to fish from continuous sound sources from vessels are considered credible and have therefore not been considered further.
Marine reptiles
Review of sound sources generated by the Development found only VSP, ROV tracking acoustics and drilling, vessel and helicopter sound sources will generate sounds at frequencies within marine reptile hearing frequencies. Sounds that marine reptiles hear are mostly confined to low frequencies (between 50 and 1500 Hz in water) (Ref. 338). As a result, geophysical survey techniques operating at high frequencies (e.g. SSS, MBES) will not be audible to marine reptiles. However, the potential effects of geophysical survey techniques will be evaluated against marine reptiles in the event low frequency techniques (e.g. sub bottom profile) are used. Maximum horizontal distances to noise exposure criteria for reptiles for impulsive (VSP) and continuous (drilling and vessels) sources (Section 8.5.2.1.4) overlaps the following BIAs for reptiles: • flatback turtle BIA (internesting buffer). The Development does not overlap any other marine turtle BIAs. The OA overlaps habitat critical to the survival of flatback turtles, given the OA is within the 60 km internesting buffer to nesting locations at Barrow Island (Table 6-7). Although the OA overlaps the flatback turtle internesting BIA, Whittock et al. (Ref. 151) reported that flatback turtles prefer habitats in proximity to the coast and at relatively shallow depths during internesting periods. The study found the maximum distance from the nearest coast and maximum water depth of 27.8 km and <44 m, respectively, was recorded for an internesting flatback turtle. The mean maximum distance away from the coast and mean water depth observed during the study was less than 6.1 km and <10 m, respectively (Ref. 151). This suggests that although the OA overlaps the extent of habitat critical to the survival of flatback turtles, due to the distance offshore and water depths within the Development (~150–1,400 m) it would be on rare occurrences that flatback turtles would be undertaking internesting behaviours within the OA. Consequently, only a small number of transient marine turtles are expected to be present. The threatened short-nosed sea snake or leaf-scaled sea snake are not expected to be present within the OA given known habitat preferences for shallow water and reef habitat; underwater sound has also not been identified as a threat for either species (Ref. 23; Ref. 24). Other EPBC marine listed sea snake species may

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occur in broader habitats within the NWMR, however noise pollution has not been identified as a pressure for sea snake species (Ref.317). As such, underwater sound is not considered to be a significant factor in sea snake behaviour or survival. **Change to behaviour** Some field evidence suggests that marine turtles avoid impulsive sound, where change in diving behaviours have been interpreted as avoidance (Ref. 367). There is also evidence that turtles avoid vessels (Ref. 368), it is assumed this is a result of underwater noise generated by the vessel. <u>Impulsive underwater sound</u> Impulsive sources audible to marine reptiles include VSP (<24 hours each well) and low frequency geophysical surveys (~3 weeks). The highest energy impulsive source is VSP. VSP activities will result in the greatest area ensonified by impulsive sources and was modelled (Ref. 330) against marine turtles noise effect criteria for behavioural response and disturbance (Ref. 347). Refer to Section 2.2 of Appendix D for further detail on noise effect criteria. The maximum horizontal distance to marine turtles noise effect criteria for behavioural response and disturbance from VSP activities is predicted to be 1.03 km and 0.27 km respectively (Table 8-27). Therefore, behavioural responses of marine turtles to impulsive underwater noise during the Development is anticipated to be limited to within ~1 km of the DCs and geophysical surveys. The limited extent to marine turtle effect criteria ensures potential impacts to reptiles will be within the OA. If individual transient marine turtles are present within proximity (i.e. <1.03 km) to VSP activities or an operating ROV in the OA, behavioural responses such as temporary increased swimming activity and avoidance may occur. As such, the Development has the potential to cause temporary change to behaviour in transient marine turtles within the OA, therefore resulting in an Incidental (6) consequence. The likelihood of the consequence occurring is assessed as Occasional (2). Overall, the risk of impulsive underwater sound resulting in a change to behaviour in marine reptiles is Low (7). <u>Continuous underwater sound</u> Continuous sources generated by the Development including vessel activities, operation and decommissioning of subsea infrastructure, drilling activities and helicopter operations are expected to be audible to marine turtles. Marine turtles are expected to display avoidance behaviours such as moving away from vessels, DCs during drilling activities and the helideck during helicopter landing/take-off. Currently, quantitative threshold criteria for behavioural responses of marine turtles from continuous sound do not exist (Ref. 338). Marine turtles are highly likely to exhibit behavioural changes within tens of metres from continuous sound sources (Ref. 338). Changes to behaviour in marine turtles from underwater sound are therefore localised and limited to the OA. Individual transient marine turtles in the OA are likely to exhibit avoidance responses from continuous sounds generated from the Development (Ref. 369). Hazel et al. (Ref. 369) observed marine turtles to flee from an approaching vessel travelling at speeds representative of those proposed in the OA. Despite overlapping habitat critical to the survival of flatback turtles, the OA does not overlap preferred shallow coastal habitats for internesting marine turtles, therefore risks of continuous underwater sound is limited to transient individual marine turtles. The consequence has been determined to be Incidental (6) and the likelihood of the consequence occurring is assessed as Occasional (2). Overall, the risk of continuous underwater sound impacting marine reptiles is Low (7). ***Concurrent Impacts*** Concurrent campaigns introduce the potential for the occurrence of multiple ensonified areas within the flatback turtle internesting BIA at a single time during the Development. However as noted above, the OA does not overlap preferred shallow coastal habitats for interesting marine turtles. Concurrent behavioural impacts to individual transient marine turtles are expected to be limited to temporary displacements which are unlikely to result in any real biological cost to the animals. The overlap of concurrent ensonified fields from WTR to the flatback turtle internesting BIA is in the open offshore water environment where avoidance behaviours will not be impeded. As a result, continuous underwater sound may displace individual transient marine turtles to immediately adjacent areas of known suitable internesting habitat and is unlikely to result in significant impacts to individual energetics of fitness or any impacts at the population level. The Development has the potential to cause temporary change to behaviour in transient marine turtles within the OA, therefore resulting in an Incidental (6) consequence. The likelihood of the consequence occurring is assessed as Occasional (2). Overall, the risk of continuous underwater sound resulting in a change to behaviour in marine reptiles is Low (7).

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TTS, PTS and recoverable or non-recoverable injury Underwater sound can cause injury or mortality of marine reptiles via auditory impairment, TTS, PTS, or recoverable or non-recoverable injury. Little is known about injury, PTS or TTS in marine turtles due to a lack of studies being conducted that examine these physiological effects (Ref. 338). The thresholds developed for these effects have been developed from audiograms and are theoretical effects (Ref. 348). Southall et al (Ref. 339) and NOAA (Ref. 340) define PTS as a permanent change in hearing and for the purpose of demonstrating acceptability, PTS is considered a form of injury in marine turtles. Popper et al (Ref. 338) define TTS as a temporary reduction in hearing sensitivity caused by temporary changes in hair cells. Impulsive underwater sound Impulsive sources audible to reptiles (marine turtles) include VSP (<24 hours each well) and low frequency geophysical surveys (~3 weeks). Noise modelling of underwater sound levels associated with VSP for the Development was conducted against marine turtle noise effect criteria for PTS and TTS (Ref. 348). Refer to Section 2.2 of Appendix D for further detail on noise effect criteria. Table 8-27 highlights the maximum horizontal distance to marine turtle PTS and TTS effect criteria from VSP activities which is predicted to be 0.03 and 0.24 km, respectively and turtles would need to remain within this range for 24 hours. Given the predicted distances are small, and the need for fauna to be exposed at these levels for extended durations before auditory impairments or injuries occur, TTS and PTS to marine turtles from impulsive sound is not considered credible and is not evaluated further. Continuous underwater sound The highest continuous broadband sound source for the Development will be generated by vessel activities. Vessel activities will result in the greatest area ensonified by continuous sources and was modelled (Ref. 330) against marine turtles noise effect criteria for PTS and TTS (Ref. 348). Popper et al. (Ref. 338) detail that there is no direct evidence of mortality or potential mortal injury to marine turtles from ship sound emissions however do suggest threshold criteria for PTS and TTS. The maximum horizontal distance to marine turtle PTS and TTS SEL_{24} effect criteria from all modelled vessel activity scenarios including combined scenarios to reflect concurrent activities is predicted to be 140 and 180 m (Table 8-28), respectively and the extent of the ensonified area above the noise effect criteria is only within the OA. An exceedance of the PTS and TTS effect criteria is based on cumulative sound exposure over a 24 hour period, i.e. to receive noise levels above the PTS and TTS criteria thresholds, marine turtles would need to remain within 140 m and 180 m respectively, of the vessel for a 24 hour period. This is not considered a credible event given marine turtles are likely to exhibit avoidance behaviours within hundreds of metres of an approaching vessel (Ref. 369; Ref. 338).
Marine mammals
Review of sound sources generated by the Development found all sound sources will generate sounds at frequencies within marine mammal hearing frequencies. Two cetacean species have BIAs that overlap the OA, and a further 26 cetacean species (or species habitat) may or are likely to occur within the OA. Maximum horizontal distances to noise exposure criteria for marine mammals for impulsive and continuous sources (Section 8.5.2.1.4) overlaps the following BIAs for marine mammals: • humpback whale BIA (migration (north and south) • pygmy blue whale BIAs (distribution, migration). Marine mammals that may or are likely to occur within ensonified areas generated by the Development include: • Low-frequency cetaceans: – Antarctic blue whale – Antarctic minke whale – Bryde's whale – fin whale – humpback whale – minke whale – omura whale – pygmy blue whale – southern right whale – sei whale

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- High and very-high frequency cetaceans:
  - dolphins
  - Blainville’s beaked whale
  - Cuvier's beaked whale
  - dwarf sperm whale
  - gingko-toothed beaked whale
  - Longman’s beaked whale
  - pygmy sperm whale
  - sperm whale

Based on PMST searches (Appendix B), no biologically important areas and associated behaviours were identified for high and very-high frequency cetaceans within OA. Although it is anticipated that the migratory presence of high and very-high frequency cetaceans may be within the OA, there is no evidence of high-site fidelity for high and very-high frequency cetaceans within the OA. However, high and very-high frequency cetaceans may be expected to transit through the area (Section 6.2.3.1).

Low-frequency cetaceans, specifically humpback and pygmy blue whales, are known to be present within the OA during peak migration periods:

- Northbound humpback whales are expected to pass the Development (i.e. Muiron, Barrow and Montebello Islands), peaking in late July (Ref. 126). An increase in southerly migrating individuals may be observed passing the OA (i.e. between the North West Cape and the Montebello Islands) around November (Ref. 126). However, it is noted that OA overlaps a very limited area of the humpback whale migration BIA.
- Northbound pygmy blue whales are expected to pass the Development (i.e. highest densities of detections transiting to the west of the Montebello Islands) during the months of June and July (Ref. 135). Southbound pygmy blue whales are expected to pass the Development (i.e. highest densities of detections transiting to the west of the Montebello Islands) occurring from November–December (Ref. 135).

‘Possible Foraging Areas’ as defined within the Conservation Management Plan for the Blue Whale (Ref. 16), and characterised as foraging BIAs, occur >200 km southwest and >870 km northeast of the Development area. Data from a recent study (Ref. 136) identified ‘most important areas’ for foraging for the pygmy blue whale based on proxy indicators. There is some overlap between these ‘most important areas’ for foraging and the predicted ensonified area associated with the Development.

Potential for a change to behaviour

Behavioural changes to marine mammals from underwater noise may include alterations of dive patterns, swim speeds, swim orientation, group cohesiveness, and changes in acoustic behaviour (Ref. 370). McCauley et al (Ref. 371) reported humpback whales began avoidance manoeuvres in response to impulsive seismic generated sound and exhibited general avoidance responses likely due to the presence of vessels (Ref. 372). Goldbogen et al (Ref. 373) found blue whales changed orientation and horizontal displacement when exposed to mid-frequency sonar sound. Southall et al (Ref. 374) also found baleen whales showed directional avoidance of a stationary sonar sound source and were more likely to do this if there was not a concentrated food source present.

Auditory masking impacts may occur when there is a reduction in audibility for one sound (signal) caused by the presence of another sound (noise), impeding the ability of an animal to perceive a signal (Ref. 375, Ref. 376). For this to occur, the noise must be loud enough and have a similar frequency to the signal and both signal and noise must occur at the same time. Masking and the potential effects of masking on communication and listening space of marine mammals are not fully understood and remain an area of active research (Ref. 377, Ref. 378, Ref. 379, Ref. 380). Currently, there are no specific received level thresholds for reliably assessing or regulating masking responses to underwater sound (Ref. 381). A study undertaken by Clark et al (Ref. 382), suggests that masking impacts from vessel noise can be extended to non-continuous sources of noise (e.g. the low-frequency energy from VSP). This study considers the potential for masking and communication impacts is classified as high near the vessel (within tens of metres), moderate within hundreds of metres, and low within thousands of metres (Ref. 382). Some cetaceans might respond acoustically to underwater sound in a range of ways, including by increasing the amplitude of their calls (Lombard effect), changing their spectral (frequency content) or temporal vocalisation properties, and in some cases, cease vocalising (Ref. 383, Ref. 384, Ref. 385, Ref. 386, Ref. 387). Given the relatively small predicted ensonified area for masking effects (i.e. up to hundreds of metres from activities), and the mobile nature of cetacean species, it is considered highly unlikely underwater sound associated with the Development will result in auditory masking impacts.

<u>Impulsive underwater sound</u>

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Impulsive sources associated with the Development that may be audible to marine mammals include VSP (<24 hours each well) , use of transponders and geophysical surveys (~3 weeks). As described in earlier sections, VSP is the most intensive low frequency impulsive noise source and has been modelled as the conservative loudest impulsive noise source (Ref. 330) against marine mammal noise effect criteria for behavioural response (Ref. 342). Refer to Section 2.2 of Appendix D for further detail on noise effect criteria. The maximum horizontal distance over which the marine mammal behavioural response effect criteria may be reached from VSP activities is predicted to be 2.37 km (Table 8-29). Geophysical surveys have the longest duration of impulsive sound during the Development. Therefore, the maximum temporal period for impulsive sound exposure to marine mammals is evaluated using ~3 weeks based on the potential duration of geophysical surveys. ***Low-frequency cetaceans*** As above, a variety of low-frequency cetaceans may occur within the OA. The 2.37 km radius maximum distance to behavioural effect thresholds for low frequency cetaceans from the expected position of subsea infrastructure overlaps the humpback whale BIA for migration and pygmy blue whale BIAs for distribution and migration. No other marine mammal BIAs were identified within the OA (Ref. 136). At any one time, behavioural responses such as temporary avoidance of localised areas in the OA (up to 2.37 km from the source) may occur due to short-term impulsive underwater sound sources. The largest potential ensonified area associated with an individual activity (i.e. VSP activities over a 24 hour period) that may be above the marine mammal noise effect criteria for behavioural response overlaps with ~4. 1% of the humpback whale migration BIA corridor and ~4.5% of the pygmy blue whale migration BIA corridor, at any one time. It should be noted that this ensonified overlap is conservatively based upon the maximum over depth horizontal distance and therefore doesn't take into consideration that only a narrow portion of the water column will be ensonified at the maximum ranges. Impacts to low frequency cetaceans from impulsive noise associated with Development activities are expected to be limited to localised and short-term behavioural responses including alterations of dive patterns, swim speeds, swim orientation, group cohesiveness, and changes in acoustic behaviour (Ref. 370). Very low energy expenditure is anticipated for migrating whales to avoid the Development associated impulsive noise sources (e.g. swimming around a VSP activity) given that the VSP ensonified area only accounts for a small area of the humpback whale and pygmy blue whale migration BIAs. and due to the short duration of VSP operations (<24 hours). Avoidance of the source is a potential behavioural response and not necessarily exhibited at all times when low frequency cetaceans are exposed to levels associated with the behavioural response threshold, and in such scenarios, the energetic cost of avoiding the impulsive source is likely to be small in the context of the greater migratory movements of humpback whales and pygmy blue whales migrating through the area. Impacts to other transient low frequency cetaceans are also expected to be of a similar nature. The radius of the behavioural effect ensonified area is ~2.37 km therefore a whale avoiding the source may make small spatial deviations over a migration of many thousands of kilometres (Ref. 389). Taking the above into consideration, a change to behaviour is highly unlikely to alter the overall energy budget of migrating low frequency cetaceans. ***High and very-high frequency cetaceans*** High and very-high frequency cetaceans, such as dolphins and toothed whales, may occur in the OA, but no BIAs or evidence of species specific high-site fidelity were identified in the PMST. As such, high and very-high frequency cetaceans may transit through the OA in low numbers however are not expected to remain for extended periods (Section 6.2.3.1). At any one time, behavioural responses such as temporary avoidance of highly localised areas in the OA (up to 2.37 km from the source) may occur from impulsive underwater sound sources. Behavioural impacts to high and very-high frequency cetaceans such as avoiding the area may occur, however, such temporary displacements are unlikely to result in any real biological cost to the animals and no BIAs for these species have been identified in the OA. Impacts to these species are predicted to be temporary avoidance of highly localised areas in the OA during the Development. ***Risk evaluation: Change to behaviour – Impulsive underwater sound*** As outlined above, the OA intersects the pygmy blue whale and humpback whale migration BIAs. The potential energetic cost of avoiding impulsive sources is likely to be small in the context of the greater migratory movements of humpback whales and pygmy blue whales migrating through the area. Other cetaceans transiting through the area may temporarily avoid highly localised areas in the OA, however there are no BIAs for other cetaceans in the OA and any behavioural impacts are unlikely to result in significant energetic impacts at the individual or population level. The Development has the potential to cause limited change to behaviour in marine mammals within the OA, therefore resulting in an Incidental (6) consequence.

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The likelihood of the consequence occurring is assessed as Occasional (2), as peak migration periods for humpback whales and pygmy blue whales in the OA may allow the consequence to occur. Overall, the risk of impulsive underwater sound resulting in a change to behaviour in marine mammals is Low (7). <u>Continuous underwater sound</u> Continuous sources generated by the Development including vessel activities, drilling activities, operation and decommissioning of subsea infrastructure and helicopter operations are expected to be audible to marine mammals. The highest continuous broadband sound source for the Development will be generated by vessel activities. Vessel activities will result in the greatest area ensonified by continuous sources and was modelled (Ref. 330) against marine mammal noise effect criteria for behavioural response (Ref. 342). Refer to Section 2.2 of Appendix D for further detail on noise effect criteria. Modelled ensonified areas for vessels will provide a conservative evaluation for other operations. ***Low-frequency cetaceans*** Review of modelling predictions for low-frequency cetaceans found the maximum horizontal distance to behavioural response effect criteria was 18.26 km from the source (i.e. for pipelay operations with multiple vessels). Within the worst-case 18.26 km radius around the expected position of subsea infrastructure, where these activities will occur, migration BIAs were identified for the pygmy blue whale and humpback whale. No other BIAs for low-frequency cetaceans were identified (refer to Section 6.2.3.1). Low-frequency cetaceans are expected to display avoidance behaviours such as changing swimming direction and speed so that animals may avoid the ensonified area generated by activities in the OA (Ref. 388). *Humpback whales* The largest potential ensonified area associated with an individual activity (i.e. pipelay operations with multiple vessels) that may be above the marine mammal noise effect criteria for behavioural response overlaps with ~0.29% of the humpback whale migration BIA (~466 km^2 of total 159,099 km^2) at any one time. Impacts to migrating humpback whales are expected to be limited to localised and short-term behavioural impacts including alterations of dive patterns, swim speeds, swim orientation, group cohesiveness, behavioural state and changes in acoustic behaviour (Ref. 370). In some contexts, these behavioural responses have the potential to represent avoidance strategies and potentially an increase in energy expenditure for migrating humpback whales. However, the energetic cost of avoiding the source is likely to be small in the context of the greater migratory movements of humpback whales migrating through the area. Furthermore, the maximum extent of potential ensonified area conservatively represents the maximum over depth and therefore in reality only a very narrow portion of the water column will be ensonified above the behavioural response threshold at these maximum distances/areas. The worst-case radius of the behavioural effect ensonified area is ~18.26 km, therefore, in the event behavioural response does results animal avoidance, a whale avoiding the source will alter its path by tens of kilometres at most over a migration of many thousands of kilometres (Ref. 389). Therefore, this level of behavioural avoidance within the humpback whale migration BIA is highly unlikely to alter the overall energy budget of migrating whales. *Pygmy blue whales* A more realistic prediction of continuous underwater water sound exposures for migrating pygmy blue whales was undertaken using animal movement modelling ('animat modelling') (Ref. 330). Using the ensonified areas modelled for continuous source scenarios, an additional model (JASMINE) was used to program animats to behave like migrating pygmy blue whales through the ensonified areas. JASMINE predicts the accumulated exposure of the animats to sound in the modelled ensonified areas. It should be noted that JASMINE model does not implement potential avoidance behaviour, in which case the animat moving through the ensonified area would potentially dive to water depths or horizontal planes where it is quieter (i.e. outside of the ensonified area). Accordingly results of the animat modelling are still conservative by design as potential avoidance behaviour would result in less sound accumulation and exposure ranges that are significantly shorter than the acoustic ranges to noise effect criteria for pygmy blue whales. For further details refer to Section 3.5 of Appendix D. Furthermore, the scenarios and source levels applied within the modelling do not consider the fact continuous acoustic sources such as dynamic positioning thrusters are highly dynamic over time in response to changing metocean conditions; therefore, in most cases actual source levels will be significantly lower than the source levels adopted within the model for the purposes of this risk evaluation. Animat modelling predicted maximum exposure range to behavioural effects for migrating pygmy blue whales to be within 12.4 km of the source (Ref. 330). The maximum exposure range to behavioural effects for pygmy blue whales associated with the Development overlaps with ~0.16% of the pygmy blue whale migration BIA (~483 km^2 of total 308,652 km^2) at any one time. Impacts to migrating pygmy blue whales are expected to be limited to localised and short-term behavioural impacts including alterations of dive patterns, swim speeds, swim orientation, group cohesiveness,

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behavioural state and changes in acoustic behaviour (Ref. 370). These behavioural responses can represent avoidance strategies and potentially an increase in energy expenditure for migrating pygmy blue whales. However, very low energy expenditure is anticipated for migrating whales to avoid the noise sources (e.g. swimming around vessel operations) given that the maximum exposure range only accounts for ~0.16% of the pygmy blue whale migration BIA. The energetic cost of avoiding the source is likely to be small in the context of the greater migratory movements of pygmy blue whales migrating through the area. The maximum exposure range is ~12.4 km therefore a whale avoiding the source will alter its path by tens of kilometres at most over a migration of many thousands of kilometres (Ref. 389). Therefore, this level of behavioural avoidance within the pygmy blue whale migration BIA is highly unlikely to alter the overall energy budget of migrating whales. Data from a recent study (Ref. 136) identified 'most important areas' for foraging for the pygmy blue whale based on proxy indicators. There is some overlap between these 'most important areas' for foraging and the predicted ensonified area associated with the Development. However, the use of these areas is not expected to be continual throughout the year but associated with pygmy blue whale migration timing and may not overlap with the duration of planned activities. Furthermore, foraging areas are known to be dynamic given their dependence on presence of prey (Ref. 136; Ref. 390). ***Concurrent Impacts*** The noise modelling considered the aggregate contribution of noise emissions from combined vessel scenarios to represent the potential for concurrent campaigns during the Development (Scenarios 37–40) (refer to Appendix D, Ref. 330). Results of the combined scenarios found ensonified areas will not merge if distances between concurrent campaigns are larger than the sum of the effect radii of the individual activities. However, the combined scenarios modelled predicted increases to the marine mammal behavioural response criteria from individual scenarios of up to 4% if the ensonified areas do not overlap. If the ensonified areas do overlap, the resultant larger ensonified area has the potential to increase by up to 12.9% compared to the individual scenarios. Based on further analysis of the individual scenarios, the largest potential ensonified area is considered to be concurrent pipelay (Scenario 13), drilling and construction activities (Scenarios 18 and 24). This was assessed by combining the area derived from the maximum range (R_{max}) of each individual modelled scenarios and applying the 12.9% increase to the aggregate area. *Humpback Whales* The OA overlaps a small section of the humpback whale migration BIA. The only credible scenario where a change in ambient sound within the humpback whale migration BIA may occur during the Development is limited to individual activities conducted at the most southern flowline extent for WTR. Ensonified areas generated in other fields associated with the Development will not overlap the humpback whale migration BIA. Therefore, no concurrent impacts to the humpback whale migration BIA from underwater sound is credible. *Pygmy Blue Whales* Underwater sound from concurrent activities may have the potential to elicit a behavioural response in transient pygmy blue whales. Concurrent campaigns introduce the potential for the occurrence of up to 3 separate ensonified areas within the pygmy blue whale migration BIA at a single time during the Development. As described above, based on the modelling of individual scenarios and allowing for the aggregate increase in combined ensonified areas described in the combined modelled scenarios, the largest potential ensonified area associated with concurrent campaigns (i.e. concurrent pipelay/drilling/construction activities) that may be above the marine mammal noise effect criteria for behavioural response overlaps with ~0.61% of the pygmy blue whale migration BIA (~1,887 km^2 of total 308,652 km^2). However, percentage ingress of ensonified areas above the marine mammal noise effect criteria for behavioural response overlaps ~43% of the width of the pygmy blue whale migration BIA. Thums et al. (Ref. 136) observed pygmy blue whale movement off north-west Western Australia (specifically within ~50 km of the Development) was predominantly relatively fast, directed travel (high move persistence), this implies migrating pygmy blue whales will travel rapidly past the Development. Studies have inferred a much wider migratory corridor than defined by the current pygmy blue whale migration BIA. Gavrilov et al. (Ref. 130) reported southbound migrating pygmy Blue Whale distribution extended up to 400 km off the mainland, inferring a much wider southbound migratory corridor than defined by the migratory BIA. DAWE and NOPSEMA released guidance on key terms within the Conservation Management Plan for the Blue Whale (Ref. 16). This guidance recognises BIA maps do not represent a species' full geographic range, implying migrating pygmy blue whales are not necessarily confined to the designated migratory corridor. Therefore, underwater sound associated with the Development may result in migrating pygmy blue whales to make small spatial deviations within the migration BIA, however it is unlikely to result in any real biological cost to the animals. As above, there is some overlap between these 'most important areas' for foraging and the predicted ensonified area associated with the Development. However, the use of these areas is not expected to be continual throughout the year but associated with pygmy blue whale migration timing. Furthermore, foraging areas are known to be dynamic given their dependence on presence of prey (Ref. 136; Ref. 390).

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High and very high-frequency cetaceans

High and very-high frequency cetaceans may occur within the 18.26 km of multiple sources (i.e. vessel operating during concurrent campaigns) where ensonified areas from concurrent campaigns exceed the marine mammal behavioural effect criterion. No BIAs for high and very-high frequency cetaceans were identified within the OA and there is no evidence of high-site fidelity for high and very-high frequency cetaceans within the ensonified areas (Section 6.2.3.1).

Predicted impacts would, therefore, be limited to behavioural response such as temporary avoidance of the ensonified areas (based on the worst-case range of up to 18.26 km from the source) during vessel activities, drilling activities and helicopter operations.

Risk evaluation: Change to behaviour – Continuous underwater sound

As outlined above, the OA intersects the pygmy blue whale and humpback whale migration BIAs. The Development has the potential to cause a change to behaviour in marine mammals within a worst-case 18.26 km radius around the expected position of subsea infrastructure to be installed and may affect larger areas where multiple activities are concurrently undertaken.

The energetic cost of avoiding continuous source is likely to be small in the context of the greater migratory movements of pygmy blue and humpback whales migrating through the area. Other cetaceans transiting through the area may temporarily avoid continuous sound sources at no biological cost. The consequence associated with temporary and localised behavioural change as a result of continuous underwater sound has been determined to be Minor (5).

The likelihood of the consequence occurring is assessed as Seldom (3), as exceptional conditions are required to result in a change to behaviour in marine mammals such as the temporary occurrence of concurrent campaigns during peak migration and when a whale is passing within 18.26 km of vessel operations as opposed to different section of the wider BIA.

Overall, the risk of a change to behaviour in marine mammals from continuous underwater sound is Low (7).

TTS, PTS and recoverable or non-recoverable injury

For marine mammals, PTS and TTS are defined as:

- Permanent threshold shift (PTS): Physiological impacts such as physical damage to the auditory apparatus, e.g. loss of hair cells or permanently fatigued hair cell receptors, can occur in marine mammals when they are exposed to intense or moderately intense sound levels and could cause permanent or temporary loss of hearing sensitivity. PTS is non-recoverable hearing loss to marine fauna (permanent hair cell or receptor damage). Southall et al (Ref. 339) and NOAA (Ref. 340) define PTS as an irreversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range above a previously established reference level. Available data from humans and other terrestrial mammals indicate that a 40 dB threshold shift approximates PTS onset. For the purpose of demonstrating acceptability, PTS is considered a form of injury. More recently PTS has been formally redefined as Auditory injury (AUD INJ) and is now considered damage to the inner ear that can result in destruction of tissue, such as the loss of cochlear neuron synapses or auditory neuropathy (Ref. 391; Ref. 392; Ref 393). Auditory injury may or may not result in a permanent threshold shift (PTS). For the purposes of this risk evaluation the term PTS has been adopted throughout, however this terminology is considered to incorporate the definition of auditory injury, which includes non PTS effects such as the loss of cochlear neuron synapses or auditory neuropathy.
- Temporary threshold shift (TTS): A temporary, reversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range above a previously established reference level (Ref. 394; Ref. 395). Based on data from cetacean TTS measurements (Ref. 339), a TTS of 6 dB is considered the minimum threshold shift clearly larger than any day-to-day or session-to-session variation in a subject's normal hearing ability (Ref. 396; Ref. 397; Ref. 398). Guidance on key terms within the Blue Whale Conservation Management Plan (Ref. 399) defines TTS as a temporary reduction in hearing sensitivity and considers TTS a form of injury, contrary to more recent published literature demonstrating TTS does not constitute injury and the recent scientific determination to change the nomenclature of PTS to more broadly refer to 'Auditory Injury' (Ref. 391; Ref. 392; Ref 393). TTS can occur instantaneously near the source or through cumulative exposure. TTS is completely recoverable and with 24 hours thought to be sufficient for recovery to occur (Ref. 340; Ref. 339).

<u>Impulsive underwater sound</u>

Impulsive sources audible to marine mammals include VSP (<24 hours each well), use of transponders and geophysical surveys (before pipelay, after pipelay and before decommissioning for ~3 weeks).

As described in earlier sections, VSP is the most intensive low frequency impulsive noise source and has been modelled as the conservative loudest impulsive noise source (Ref. 330) against marine mammal noise

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effect criteria for PTS and TTS (Ref. 339). Refer to Section 2.2 of Appendix D for further detail on noise effect criteria. Table 8-29 highlights the maximum horizontal distances to marine mammal PTS and TTS effect criteria (SEL_{24}) from VSP activities which is predicted to be 0.48 and 3.20 km, respectively, and the extent of the ensonified area above the noise effect criteria is within the OA (Ref. 330). ***Low-frequency cetaceans*** As outlined above, the OA overlaps the humpback whale and pygmy blue whale, migration BIAs. The largest potential ensonified area associated with an individual activity (i.e. VSP) that may be above the low-frequency cetacean noise effect criteria for TTS and PTS overlaps ~0.01% of the humpback whale migration BIA (~2 km^2 of total 159,099 km) and only ~0.01% of the pygmy blue whale migration BIA (~32 km^2 of total 308,652 km^2), at any one time. Modelling indicates low-frequency cetaceans may experience TTS if they remain within 3.2 km of VSP for 24 hours and within 0.48 km for 24 hours for PTS. Migrating humpback and pygmy blue whales are expected to transit across the OA (Ref. 136; Ref. 391). Migrating humpback and blue whales typically swim at about 5 and 8 km/h, respectively (Ref. 391; Ref. 400). A tagging study of blue whales showed that migrating individuals can travel 50–100 km per day (Ref. 131), which equates to an average swimming speed of 2–4 km/h over a 24-hour period. If a migrating humpback or pygmy blue whale passes through the ensonified area above effect criteria for TTS and PTS, the migrating whale is expected to remain in the ensonified area for a maximum of 2 hours. Recognising migrating humpback and pygmy blue whales in the OA are expected to pass through relatively fast (Ref. 136), it is unlikely that migrating low-frequency cetaceans would remain within proximity to an impulsive sound source for a sufficient period of time for the onset of TTS or PTS to occur. No other BIAs for low frequency cetaceans have been identified in the OA. Taking the above into consideration, TTS and PTS is not considered credible and is not assessed further. ***High and very-high frequency cetaceans*** High and very-high frequency cetaceans may occur in the OA, but no BIAs were identified. VSP modelling results did not predict instantaneous TTS and PTS effect criteria for high-frequency cetaceans to be reached (Ref. 330). However, modelling results predicted instantaneous TTS and PTS effect criteria for very high-frequency cetaceans to be reached within 130 and 60 m of the source, respectively (Ref. 330). It is considered unlikely that very-high frequency cetaceans would experience the onset of TTS or PTS from VSP operations, due to the short duration of operations (<24 hours) and short distances to which the effect criteria are exceeded. If exposure was to occur, impacts would be limited to individuals and therefore the consequence is assessed as Incidental (6). The likelihood of the risk occurring is assessed as Remote (5). The residual risk is assessed as Very Low (10). <u>Continuous underwater sound</u> Continuous sources generated by the Development including vessel, drilling, operation and decommissioning of subsea infrastructure and helicopter operations are expected to be audible to marine mammals. The highest continuous broadband sound source for the Development will be generated by vessel activities. Vessel activities will result in the greatest area ensonified by continuous sources and was modelled (Ref. 330) against marine mammal noise effect criteria for PTS and TTS (Ref. 339) and behavioural response (Ref. 342). Refer to Section 2.2 of Appendix D for further detail on noise effect criteria. Modelled ensonified areas for vessels has also been used as a conservative proxy ensonified area for drilling activities and helicopter operations. ***Low-frequency cetaceans*** Table 8-30 highlights the maximum horizontal distance to low-frequency cetacean SEL_{24} PTS and TTS effect criteria which is predicted to be 0.21 and 4.58 km, respectively. Note this distance assumes the cetacean remains within proximity to the noise source continuously for 24 hours (Ref. 330). The maximum horizontal distance also assumes that the continuous noise sources (typically vessel DP thrusters) will be operating consistently at the source levels derived within Section 8.5.1.2 and Section 8.5.1.6. In reality DP thrusters are highly dynamic in response to varying metocean conditions; accordingly, it is highly unlikely the source levels will be constant at the specific source levels modelled over a 24 hour period, further emphasised by the fact the source levels adopted within this risk evaluation are considered highly conservative (higher than anticipated) when compared to atypical operating conditions (as outlined within Section 8.5.1.2 and Section 8.5.1.6). It is also important to note that the modelled source values assume the radiating vessel noise is emanating from a single point source, whereas in reality the noise will be emanating from each individual thruster, some of which have significant spatial separation beyond the range of PTS predicted, reflective of the length of the vessels. Migrating humpback and blue whales typically swim at about 5 and 8 km/h, respectively

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(Ref. 391; Ref. 400). A tagging study of blue whales showed that migrating individuals can travel 50–100 km per day (Ref. 131). Which equates to an average swimming speed of 2-4 km/hr over a 24 hour period. If a migrating humpback or pygmy blue whale passes through the ensonified area above effect criteria for TTS and PTS, the migrating whale is expected to remain in the ensonified area for short periods of time (<5 hours based on average swim speeds). No other low frequency cetacean BIAs have been identified within the OA and any individuals passing through the area are expected to be transient. Animat modelling, which simulates a typical pygmy blue whale's movements during migrations through the Pilbara offshore area, determined a pygmy blue whale would need to pass within 40 m of the sound source to receive sound exposure levels at or above the TTS effect criterion and remain there for an extended period (~24 hours) (Ref. 330). In addition, Animat modelling predicted no exposures above the PTS effect criterion for migrating pygmy blue whales. Animat movements in the ensonified area considers the migratory behaviours of pygmy blue whales, however, does not include potential avoidance behaviours as substantiated by peer-reviewed literature suggesting low-frequency hearing whales actively avoid anthropogenic sound (Ref. 371; Ref. 372; Ref. 373; Ref. 374; Ref. 388). As discussed above, migrating pygmy blue whales may display avoidance behaviours at higher received levels closer to the vessel, which may preclude them from getting close enough to the vessel for TTS to occur (Ref. 330; Ref. 373; Ref. 374). The 40 m TTS range predicted using animat modelling also conservatively assumes that the continuous noise sources (typically vessel DP thrusters) will be operating consistently at the source levels derived within Section 8.5.1.2 and Section 8.5.1.6. In reality DP thrusters are highly dynamic in response to varying metocean conditions; accordingly, it is highly unlikely the source levels will be constant at the specific source levels modelled over a 24 hour period, further emphasised by the fact the source levels adopted within this risk evaluation are considered highly conservative (higher than anticipated) when compared to atypical operating conditions (as outlined within Section 8.5.1.2 and Section 8.5.1.6). It is also important to note that the sound propagation modelling adopted for this risk evaluation simplifies radiating vessel noise by assuming all individual sources (i.e. individual vessel thrusters) are emanating from a single point source in space. In actuality radiated noise from each vessel will be emanating from each individual thruster which are spatially separated beyond the animat modelled range of TTS (40 m); reflective of the larger length of the vessels. Accordingly based on the above considerations and the results of the animat modelling conducted to inform this risk evaluation, it is not considered credible that a pygmy blue whale would be exposed to continuous sound exposure levels associated with TTS. Recognising migrating humpback and pygmy blue whales in the OA are expected to pass through relatively fast (Ref. 136), there are no other low frequency cetacean BIAs in the OA and whales are likely to actively avoid anthropogenic sound (vessels), and would need to remain in close proximity to vessels for extended periods, it is not considered credible that low-frequency cetaceans would experience the onset of TTS or PTS and therefore this is not considered further. ***Concurrent Impacts*** As above, the OA overlaps the humpback and pygmy blue whale migration BIAs. WTR is the closest field to the humpback whale migration BIA. Combined scenario 40 predicts the extent of underwater noise from concurrent drilling and pipelay campaigns within WTR. Despite the prediction of a larger merged ensonified area, the ensonified area does not overlap the humpback whale migration BIA. The only credible scenario where change in ambient sound within the humpback whale migration BIA can occur during the Development is limited to individual activities conducted at the most southern flowline extent for WTR. Ensonified areas generated in other fields associated with the Development will not overlap the humpback whale migration BIA. Therefore, concurrent impacts to the humpback whale migration BIA from underwater sound is not credible. As part of the Development, concurrent campaigns may be located across the pygmy blue whale migration BIA and may occur during peak migration periods. Noise modelling of concurrent campaigns predicted the Development may temporarily (<24 hours) introduce up to 3 separate ensonified areas across the OA and within the pygmy blue whale migration BIA at a single time. Noise modelling included several potential concurrent campaigns, either concurrent activities within a field or concurrent activities across two or more fields (Appendix D, Ref. 330). To exceed the 24 hour onset of TTS and PTS, a migrating pygmy blue whale is required to be exposed to ensonified areas above effect criteria for TTS and PTS for 24 hours. As evaluated above, migrating pygmy blue whales are expected to travel rapidly across the OA (Ref. 136). A tagging study of blue whales showed that migrating individuals can travel 50–100 km per day (Ref. 131), which equates to an average swimming speed of 2-4 km/hr over a 24 hour period. If a migrating pygmy blue whale passes through all 3 ensonified areas above effect criteria for TTS and PTS generated by the concurrent campaign, the migrating whale may be exposed to sound above the effect criteria for TTS and PTS for a maximum of ~2 hours. However, based on the results of the animat modelling and associated risk evaluation concluding that PTS or TTS is not credible due to the predicted small ranges and the inherent conservatisms within the modelling (i.e. vessels are not point sources, source levels will not be constant at the source levels modelled). Accordingly, it is not considered credible that low-frequency cetaceans would experience the onset of TTS or PTS and therefore this is not considered further.

Risk evaluation
High and very high-frequency cetaceans
High and very-high frequency cetaceans may occur in the OA, but no BIAs were identified. Modelling results predicted continuous TTS and PTS SEL_{24} effect criteria for high-frequency cetaceans to be reached within 190 and 160 m of the source, respectively (Ref. 330). Modelling results predicted continuous TTS and PTS SEL_{24} effect criteria for very high-frequency cetaceans to be reached within 3.33 and 0.21 km of the source, respectively (Ref. 330). It is not considered credible that high and very-high frequency cetaceans in an area with no known BIAs will remain at 3.33 km or 0.21 km of a continuous sound source for extended periods up until the onset of TTS or PTS. Therefore, this risk was not considered credible and has not been assessed further.
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from underwater sound includes indirect impacts to intangible Traditional Owner cultural heritage from a change to behaviour in marine fauna. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of marine fauna (Section 6.2.5.2.1). Intangible cultural heritage refers to the "practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage" (Ref. 401). Specific intangible values of Sea Country identified through consultation on other CAPL activities included Dreamtime stories and songlines. In particular, relevant persons have previously identified the existence of songlines that go through Barrow Island and offshore. No impact pathway to a change in access to Country from the emission of underwater sound is anticipated. The consequence evaluations for marine fauna are provided above and were assessed as having a localised and minor environmental impact and is not expected to affect the overall population of the species. Further, as described in the above evaluations, the source of underwater sound emissions within the OA is temporary and is not expected to affect the long-term underwater soundscape of the marine environment. As such, it is anticipated that intangible heritage values such as songlines and connection to Country would not be significantly adversely affected from underwater sound emissions within the OA. Given the offshore location of the OA and temporary nature of the activities, a significant adverse change to cultural heritage values attributed to the offshore marine area from underwater sound emissions is not predicted to occur. The highest consequence level was Minor (5) for a change in behaviour in marine mammals, as such, the consequence of changes to cultural heritage values from underwater sound is also evaluated as Minor (5). Exceptional conditions are required for underwater sound to elicit a change in behaviour in marine fauna. For example, the temporary occurrence of concurrent campaigns may result in marine mammals making small spatial deviations during peak migration when passing the OA. Therefore, the likelihood of the consequence occurring is evaluated as consistent with that of the highest consequence ranking for marine mammals – i.e. the likelihood is assessed as Seldom (3). The risk of underwater sound to cultural heritage values is Low (7).

8.5.4 Determination of acceptability

The acceptable level of impact and risk is a function of the magnitude of residual risk, principles of ESD, internal and external context, and legislative requirements.

Table 8-33 details the determination of acceptability for underwater sound.

Table 8-33: Determination of acceptability for Underwater sound

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence for underwater sound was evaluated as Minor (5), for marine mammals.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">While quantitative underwater sound threshold criteria currently do not exist for fish, fish eggs and larvae and marine turtles, the qualitative criteria outlined in the 2014 Popper et al paper (Ref. 338) are widely accepted as appropriate for use in impact and risk evaluations and have been used in this assessment to address scientific uncertainty.
Prevention measures for underwater sound are well regulated and managed in Australian waters.
To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations</td></tr>
<tr><td></td><td colspan="2">The Development is consistent with principle of ESD (c) for this aspect as:
The Development is committed to applying measures to prevent the impact and risk of underwater sound based on relevant environmental legislation and other requirements as listed below.
The regulation and management of underwater sound in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
The highest consequence for underwater sound was evaluated as Minor (5).
Any relevant stakeholder feedback in relation to underwater sound has been incorporated in the OPP and assessed in the external context acceptability criteria.
To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="3">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans
The requirements to manage interactions between vessels and cetaceans are detailed in the EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans. These regulations describe strategies to ensure cetaceans are not harmed during offshore interactions with people.
Vessels will implement caution and no approach zones, where practicable:
caution zone (300 m either side of whales; 150 m either side of dolphins)–vessels must operate at ≤6 knots within this zone, maximum of 3 vessels within zone, and vessels should not enter if a calf is present</td><td>Legislative requirements to manage underwater sound with cetaceans are addressed by adopting the following control measure:
CM22: In accordance with EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans, vessels and helicopters will implement caution and no approach zones, where practicable.</td></tr>
</table>

Determination of acceptability		
	• no approach zone (300 m to the front and rear of whales and 100 m either side; 300 m for whale calves; 150 m to the front and rear of dolphins and 50 m either side)–vessels should not enter this zone, should not wait in front of the direction of travel of an animal or pod, nor follow directly behind. Helicopters will adhere to EPBC Regulations 2000 – Part 8 Division 8.1 interacting with cetaceans in relation to distances to cetaceans.	
	EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines (Ref. 402) VSP operations will implement precaution zones and management procedures, where practicable: Precaution zones based on modelling results where Rmax for low power zone assessment criteria is within 1 km of source: • Observation zone: 3+ km horizontal radius from the acoustic source. • Low power zone: 2 km horizontal radius from the acoustic source. • Shut-down zone: 500 m horizontal radius from the acoustic source. Following management procedures: • Pre start-up visual observation • Soft start • Start-up delay • Operations • Power- down and Stop work	Legislative requirements to manage underwater sound with cetaceans are addressed by adopting this control measure: **CM23:** In accordance with the EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and whales: Industry Guidelines, VSP operations will implement precaution zones and management procedures, where practicable.
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) <u>Management action A.2.2</u> Assessing the effect of anthropogenic noise on blue whale behaviour. Section 8.5.2 assesses the effects of anthropogenic noise from the Development on blue whale behaviour. <u>Management action A.2.3</u> Anthropogenic noise in biologically important areas will be managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging area. Section 8.5.2 demonstrates that the Development can be conducted in a manner that is consistent with the conservation management plan and will not result in injury of pygmy blue whales from migration/distribution BIA or	EPBC management plan requirements to manage underwater sound with blue whales are addressed by adopting this control measure: **CM24:** Where required, appropriate acoustic mitigation and adaptive management measures will be developed in the EP phase in alignment with the Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16). Therefore, the Development is not considered to be inconsistent with this EPBC management plan.

Determination of acceptability		
	displacement of pygmy blue whales from a foraging BIA. • For the purpose of interpreting and applying Action Area A.2 of the blue whale CMP, injury is both permanent and temporary hearing impairment (Permanent Threshold Shift and Temporary Threshold Shift) and any other form of physical harm arising from anthropogenic sources of underwater noise (Ref. 399).	
	Conservation Management Plan for the Southern Right Whale (Ref. 19) Assess and address anthropogenic noise: shipping, industrial and seismic noise.	
	Draft National Recovery Plan for the Southern Right Whale (Ref. 20) Marine infrastructure development projects need to consider habitat requirements of southern right whales and BIAs at early stages of planning. Actions within and adjacent to southern right whale BIAs and HCTS should demonstrate that it does not prevent any southern right whale from utilising the area or cause injury (TTS and PTS) and/or disturbance.	
	Conservation Advice Megaptera novaeangliae Humpback Whale (Ref. 127) Identifies noise interference as a threat. No explicit relevant requirements.	These EPBC listing advice for species that may occur within the relevant spatial extent for underwater noise identify anthropogenetic noise/noise interference as a threat, but do not identify relevant actions.
	Conservation Advice Balaenoptera borealis Sei Whale (Ref. 18) Identifies anthropogenic noise and acoustic disturbance as a minor threat. No explicit relevant requirements.	
	Conservation Advice Balaenoptera physalus Fin Whale (Ref. 17) Identifies anthropogenic noise and acoustic disturbance as a minor threat. No explicit relevant requirements.	
	Conservation Advice Rhincodon typus Whale Shark (Ref. 30) Identifies chronic noise as an information and research priority. No explicit relevant requirements.	
	Recovery Plan for Marine Turtles in Australia (Ref. 148) Identifies noise interference as minor to moderate threat. No explicit relevant requirements.	
Internal context	This CAPL procedure was identified as relevant for this aspect: • Chevron Marine Standard Non Tankers (Ref. 284).	

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td>External context</td><td colspan="2">CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment.
During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.2.5 and 6.5.2).
Further, CAPL has also since included an adaptive management control measure for underwater cultural heritage sites/artefacts in the OPP (CM07 and CM08).
No further feedback was received in relation to underwater sound emissions from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.</td></tr>
<tr><td rowspan="5">Defined acceptable level</td><td colspan="2">The consequence of underwater sound is inherently acceptable because the highest consequence level is Minor (5).
Additionally, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan.
While quantitative underwater sound threshold criteria currently do not exist for fish, fish eggs and larvae and marine turtles, the qualitative criteria outlined in the 2014 Popper et al paper (Ref. 338) are widely accepted as appropriate for use in impact and risk evaluations and have been used in this assessment to address scientific uncertainty. These criteria were used in the impact/risk evaluation of underwater sound for each receptor.
Because underwater sound is listed as a threat to protected matters under documents made or implemented under the EPBC Act, CAPL will define an acceptable level of impact that aligns with the objectives of these documents. Objectives of the relevant documents are shown below.</td></tr>
<tr><td>Plan and relevant objectives</td><td>Demonstration of requirement</td></tr>
<tr><td>Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16)
Long-term recovery objective: Minimise anthropogenic threats to allow for the conservation status of blue whales to improve so that they can be removed from the EPBC Act threatened species list.
Interim objective 4: Anthropogenic threats are demonstrably minimised.</td><td rowspan="3">CAPL considers the impacts of underwater sound emissions to not be inconsistent with the relevant objectives of these EPBC management plans.
By applying EPO08 and EPO09, impacts and risks associated with underwater sound pollution will be managed at or below the defined acceptable level.</td></tr>
<tr><td>Conservation Management Plan for the Southern Right Whale (Ref. 19)
<u>Long-term recovery objective</u>:
The population has increased in size to a level that the conservation status has improved, and the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria.
<u>Interim recovery objective 5</u>:
Anthropogenic threats are demonstrably minimised.</td></tr>
<tr><td>Draft National Recovery Plan for the Southern Right Whale (Ref. 20)
<u>Long-term recovery objective</u>:
The population has increased in size to a level that the conservation status has improved, and the species no longer</td></tr>
</table>

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="4"></td><td>qualifies for listing as threatened under any of the EPBC Act listing criteria.
<u>Interim recovery objective 2</u>:
Anthropogenic threats are managed consistent with ecologically sustainable development principles and do not impede recovery of Southern Right Whales</td><td rowspan="2"></td></tr>
<tr><td>Recovery Plan for Marine Turtles in Australia (Ref. 148)
• <u>Long-term recovery objective:</u> Minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list.
• <u>Interim objective 3:</u> Anthropogenic threats are demonstrably minimised.</td></tr>
<tr><td>• Conservation Advice Megaptera novaeangliae Humpback Whale (Ref. 127)
• Conservation Advice Balaenoptera borealis Sei Whale (Ref. 18)
• Conservation Advice Balaenoptera physalus Fin Whale (Ref. 17)
• Conservation Advice Rhincodon typus Whale Shark (Ref. 30)</td><td>These EPBC management plans for species that may occur within the modelled ensonified areas identify underwater sound as a threat; but do not identify any relevant objectives.</td></tr>
<tr><td colspan="2">Therefore, CAPL has defined these acceptable levels of impact such that they are not inconsistent with the above documents:
• management of impacts of the Development must not be inconsistent with relevant EPBC management plans identified above
• no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery
• no displacement of marine turtles, or disruption of biologically important behaviours of marine turtles, from BIAs, important habitats, or habitat critical to the survival of a species
• no auditory injury (TTS or PTS) to pygmy blue whales within a BIA resulting from underwater sound as a result of the Development
• no displacement of pygmy blue whales from foraging areas resulting from underwater sound as a result of the Development
• no significant adverse impact to cultural heritage values attributed to the offshore marine area.
CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meet these acceptable levels.</td></tr>
</table>

8.5.5 Environmental performance

Table 8-34 provides the EPOs defined for underwater sound and the adopted control measures to achieve the outcome.

Table 8-34: Environmental performance for Underwater sound

Environmental performance outcome	Adopted control measure
EPO08: No displacement or disruption of marine fauna undertaking biologically important behaviours within BIAs or habitat critical to the survival of a species from underwater sound generated by the Development activities. **EPO09:** No injury to marine fauna undertaking biologically important behaviours within BIAs or habitat critical to the survival of a species from underwater sound generated by the Development activities.	**CM22:** In accordance with EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans, vessels and helicopters will implement caution and no approach zones, where practicable. **CM23:** In accordance with the EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and whales: Industry Guidelines, VSP operations will implement precaution zones and management procedures, where practicable. **CM24:** Where required, appropriate acoustic mitigation and adaptive management measures will be developed in the EP phase in alignment with the Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16).
EPO03: No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.

8.6 Planned discharges—MODU and vessels

8.6.1 Source

The MODU and support vessels produce discharges such as:

- sewage and greywater
- food waste
- cooling and brine water
- deck drainage and treated bilge
- firefighting foam.

These materials are discharged to the marine environment and have the potential to cause a localised and temporary change to the water quality within the OA.

The indicative personnel on board (POB) for the largest expected vessel was assumed for estimating discharge volumes. Personnel numbers will peak during drilling, installation and commissioning, and decommissioning phases, and will be lowest during operations.

Table 8-35 lists activities within each phase where MODU and vessel operations occur in the OA.

Table 8-35: Phases and activities that generate Planned discharges—MODU and vessels

Phase	Activity
Support activities	MODU operations Vessel operations

8.6.1.1 Support activities (all phases)

Vessels are present in the OA during all phases of the Development. The MODU will be present in the OA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well workovers). The MODU will move between fields but will spend most of the time at the DCs.

The types of planned vessel discharges include deck wash water, firefighting foam, sewage, greywater, food wastes, cooling water and oily bilge water.

Sewage and greywater

Sewage and greywater will be produced as a result of ablution, laundry, and galley activities on the MODU and vessels. Sewage and greywater may include nutrients such as ammonia, nitrite, nitrate, and orthophosphate, which can lead to eutrophication (Ref. 403). This waste will be treated before discharge to the environment as per guidelines under the MARPOL 73/78 Annex IV and *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cth).

MODUs and vessels typically discharge 0.04–0.45 m^3 of treated wastewater (comprising sewage and greywater) per day per person (Ref. 404). The largest vessel or facility that is expected to be used for the Development is a large PLV; with an indicative POB of ~700. This gives a maximum discharge of 28–315 m^3/day, for ~15 months (expected installation and commissioning duration).

Sewage has the potential to change water quality with subsequent impacts including change in fauna behaviour and change in aesthetic value.

Food waste

Food waste will be produced by galley facilities on the MODU and vessels. The average volume of food waste discharged into the marine environment is expected to be ~1–2 kg per person per day (Ref. 403). Food waste will be disposed of overboard according to MARPOL requirements.

Food waste has the potential to change water quality with subsequent impacts including change in fauna behaviour and change in aesthetic value.

Cooling water and brine

Cooling water and brine are used on the MODU and support vessels. They are routinely discharged to the marine environment where they are likely to interact with the ecosystem.

The processing facilities and the machinery on board MODUs and vessels require a cooling media, which will be circulated through a central cooling system. Once the cooling media has completed its cycle, it is discharged into the marine environment.

The cooling media most commonly used is sea water; however, a different fluid may be used within a closed circuit and further cooled by sea water within a separate seawater cooler. Sea water used for cooling is dosed with chlorine following intake and discharged with low residual chlorine concentrations that are rapidly diluted by prevailing water currents. Cooling water is typically 2–5 °C above ambient seawater temperature. However, upon discharge, it will be subjected to turbulent mixing and transfer of heat to the surrounding waters.

A study undertaken by Woodside (Ref. 405) detailed temperature dispersion modelling, which showed that the water temperature of discharged water will decrease rapidly as it mixes with the receiving waters. The study showed discharge waters were <1° C above background levels within 100 m (horizontally) of the discharge point. Vertically, the discharge was within background levels within 10 m of the discharge point (Ref. 405).

Most MODU and vessels used in the resources industry have capability for reverse osmosis, desalination, or distillation of sea water to produce demineralised potable water. The process of converting sea water to potable water will produce reject brine, which will be discharged to the marine environment.

Volumes of produced and discharged reject brine are relatively low, with salinity levels typically 20–50% higher than that of the surrounding sea water (depending on technique) (Ref. 315).

Cooling water and brine have the potential to cause a localised and temporary change in water quality.

Deck drainage and treated bilge

Deck drainage generally comprises water and fluids from rainfall, ocean spray and water used for wash downs. Water used during wash downs may contain small amounts of particulate matter and dirt, plus chemicals such as cleaning fluids, lubricating oils and grease. These fluids are normally discharged directly to the marine environment.

Bilge water is a collective term for a mixture of fresh water, sea water, oil, sludge, chemicals and various other fluids from machinery and storage areas. The bilge system is designed to safely collect, contain, and dispose of oily water from hazardous areas to avoid discharging hydrocarbons to the marine environment. These fluids may contain contaminants such as oil, detergents, solvents, chemicals, and solid waste, typically at low levels.

Bilge water will be processed via an oil-in-water separator, to meet MARPOL Annex 1 requirements. Treated bilge water is discharged to the marine environment. Discharge occurs infrequently.

Deck drainage and treated bilge have the potential to cause a localised and temporary change in water quality.

Firefighting foam

The MODU and vessels will be equipped with firefighting foam extinguishing capability as required under international standards for fire equipment on vessels. Several types of firefighting foam are available, including aqueous film forming foam units, which are used on flammable and combustible liquids such as oil. These foam systems will be used in the event of an incident, and during infrequent fire system testing.

Firefighting foam has the potential to cause a localised and temporary change in water quality.

8.6.2 Impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the OA that may be impacted by MODU and vessel discharges:

- water quality
- seabirds and shorebirds
- fishes, including sharks and rays
- marine reptiles
- marine mammals.

Although fish may potentially be impacted by MODU and vessel discharges, the area of influence is highly localised and is not expected to result in a change in the viability of the population of commercially important species or demersal fish assemblages. Only one State- and 3 Commonwealth-managed fisheries have recorded historical fishing effort in the OA. Therefore, impacts to commercial fisheries or a change in values and sensitivities of the fish assemblage values of the Continental slope demersal fish communities KEF from MODU and vessel discharges are not expected; and are not evaluated further.

Table 8-36 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to Planned discharges—MODU and vessels in the OA.

Table 8-36: Risk evaluation for Planned discharges–MODU and vessels

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Planned discharges from the MODU and vessels may result in: • localised and temporary reduction in water quality.	6	A localised and temporary reduction in water quality may result in: • changes to predator–prey dynamics.	6	6	Very low (10)

Risk evaluation
Water quality
Localised and temporary reduction in water quality Planned MODU and vessel discharges may impact ambient water quality as they can include chemicals and nutrients (e.g. ammonia, nitrite, nitrate, and orthophosphate), which may lead to an increased nutrient load and eutrophication. The number of vessels/ MODU will be dependent on the phase of the Development, with the highest number of vessels expected during the short-term drilling and installation phases. Fewer vessels will be required during the operations phase. Open marine waters, such as those in the OA, are typically influenced by regional winds and large-scale ocean current patterns resulting in the rapid mixing of surface and near-surface waters. Vessel discharges will occur in these surface and near-surface waters (Ref. 403). Therefore, nutrients from sewage, or other similar, discharges will not accumulate or lead to eutrophication due to the highly dispersive environment (Ref. 403). This outcome was verified by sewage discharge monitoring for another offshore project (Ref. 315), which determined that a 10 m^3 sewage discharge reduced to ~1% of its original concentration within 50 m of the discharge location. In addition, monitoring at distances 50 m, 100 m, and 200 m downstream, and at 5 different water depths, confirmed that discharges were rapidly diluted and no elevations in water quality monitoring parameters (e.g. total nitrogen, total phosphorous, and selected metals) were recorded above background levels at any station. The study states that this is a comparatively small discharge, but it shows that rates of dilution and mixing in the open ocean are highly likely to be enough to prevent larger discharges from causing long-term impacts. Discharged particulate matter in the form of macerated food plus sewage and greywater may cause an increase in turbidity. This increase will be localised and temporary—discharges will be diluted and dispersed by wave action and local currents. Monitoring of desalination brine and continuous wastewater discharges (including cooling water) undertaken by Woodside for its Torosa South-1 drilling program in the Scott Reef complex found that discharge water temperature decreases quickly as it mixes with the receiving waters, with the discharge water temperature being <1° C above ambient temperature within 100 m (horizontally) of the discharge point, and 10 m vertically (Ref. 315). Brine discharges are likely to sink through the water column, rapidly mix with receiving waters and be dispersed by currents. As a result, salinity differences are likely to be temporary and limited to the area close to the source. A vessel's bilge system is designed to safely collect, contain, and dispose of oily water so as to minimise or avoid discharging hydrocarbons to the marine environment. Bilge water is processed via an oil-water separator before being discharged to sea. Discharge is intermittent and occurs at or near surface waters. These oily bilge discharges are expected to readily dilute and disperse under the action of waves and currents in surface waters, and any volatile components of the oil will readily evaporate once exposed to air. The planned discharge of firefighting foam offshore is limited to the on-board testing of firefighting deluge systems. This testing may lead to a release of firefighting foams offshore. Toxicological effects from these types of foams are typically only associated with prolonged or frequent exposures, such as on land and in watercourses near firefighting training areas (Ref. 406; Ref. 407). These conditions are not consistent with the infrequent use of the systems over the life of the Development. In their diluted form (as applied in testing or if there is a fire), firefighting foams are generally considered to have a relatively low toxicity to aquatic species (Ref. 408; Ref. 409); further dilution of the foam mixtures in dispersive aquatic environments may then occur before there is any substantial demand for dissolved oxygen (Ref. 410). Consequently, the change in water quality from these standard discharges is limited to a localised area, has low levels of toxicity, and is rapidly diluted, quickly returning to ambient conditions after the discharge has ceased; therefore, any impacts are Incidental (6).
Marine fauna
Changes to predator–prey dynamics The overboard discharge of sewage and macerated food waste has the potential to create localised eutrophication as well as a localised and temporary food source for scavenging marine fauna or seabirds. Eutrophication can result in increased growth of primary producers such as phytoplankton, which in turn results in changes in biological diversity. Numbers of these species may temporarily increase as a result of this food source, thus increasing the food source for predatory species. However, the rapid consumption of this food waste by scavenging fauna and physical and microbial breakdown ensures that the impacts of food waste discharges are insignificant and temporary and that all receptors that may potentially be in the water column are not impacted.

Risk evaluation
The values and sensitivities within the OA with the potential to be affected by changes in predator–prey dynamics include: • humpback whale BIA (foraging) • pygmy blue whale BIA (distribution and migration) • flatback turtle BIA (internesting buffer) and habitat critical • whale shark BIA (foraging) • wedge-tailed shearwater BIA (breeding) • fish communities (associated with various KEFs). Effects on environmental receptors along the food chain—fish, reptiles, birds, and cetaceans—are not expected beyond the immediate vicinity of the discharge in open waters (Ref. 403). Studies into the effects of nutrient enrichment from offshore sewage discharges indicate that the influence of nutrients in open marine areas is much less significant than that experienced in enclosed areas (Ref. 411). These studies also suggest that zooplankton composition and distribution in areas associated with sewage dumping grounds are not affected. However, if any changes in phytoplankton or zooplankton abundance and composition occur, they are expected to be localised, typically returning to background conditions within tens to a few hundred metres of the discharge location (Ref. 412; Ref. 413; Ref. 414). Consequently, subsequent indirect impacts to other marine fauna are not expected, and thus are not considered further. Although the OA overlaps the flatback turtle internesting buffer, Whittock (Ref. 151; Ref 150) defined unsuitable flatback turtle internesting habitat as waters >25 m deep and >27 km from the coast. Additionally, only the WTR and C&D fields, which are at depths >25 m deep and further than 27 km the closest coast, have infrastructure within the internesting buffer. Therefore, it would be very unlikely that turtles would be aggregating within the OA during their internesting period. Consequently, only a small number of transient marine turtles are expected to be present. Although fish are likely to be attracted to these discharges, any attraction and consequent change to predator–prey dynamics is expected to be limited to close to the release and thus is expected to result in localised impacts to species. Any increased predation is not expected to result in more than a limited environmental impact; therefore, the consequence is Incidental (6). As effects are not expected beyond the immediate vicinity of the discharge, the likelihood that changes to predator–prey dynamics will be impacted is considered Rare (6). Overall, the risk of Planned discharges—MODU and vessels to changes to predator–prey dynamics is Very Low (10).

8.6.3 Determination of acceptability

The acceptable level of impact and risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-37 details the determination of acceptability for Planned discharges—MODU and vessels.

Table 8-37: Determination of acceptability for Planned discharges—MODU and vessels

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence level for Planned discharges—MODU and vessels was evaluated as Incidental (6). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the impact and risk evaluation for Planned discharges–MODU and vessels. • Prevention measures for Planned discharges—MODU and vessels are well regulated and managed in Australian waters. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="4"></td><td colspan="2">(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations</td></tr>
<tr><td colspan="2">The Development is consistent with principle of ESD (c) for this aspect as:
The Development is committed to applying measures to prevent the impact and risk of Planned discharges—MODU and vessels based on relevant environmental legislation and other requirements as listed below.
The regulation and management of vessel discharges in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
The highest consequence level for Planned discharges—MODU and vessels was evaluated as Incidental (6).
Any relevant stakeholder feedback in relation to planned discharges from MODU and vessels has been incorporated in the OPP and assessed in the external context acceptability criteria.
To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="4">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address relevant requirement/action within each of the listed legislative requirements considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Navigation Act 2012 (Cth) – Chapter 4 (Prevention of Pollution)
Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment and gives effect to the requirements under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) in Australia.</td><td rowspan="2">Legislative requirements to manage Planned discharges–MODU and vessels are addressed by adopting these control measures:
CM25: MODUs and vessels will comply with the requirements of Marine Order 96 (MARPOL 73/78 Annex IV) in relation to sewage discharge.
CM26: MODUs and vessels will comply with the requirements of Marine Order 95 (MARPOL 73/78 Annex V) in relation to food waste discharge.
CM27: MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to oily bilge water discharges.</td></tr>
<tr><td>Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (Cth) – Section 26F (implements MARPOL Annex I)
Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution.
It also invokes certain MARPOL requirements including those relating to discharge of noxious liquid substances, sewage, garbage and air pollution.
This Act requires ships >400 gross tonnes to have in place pollution emergency plans, and</td></tr>
</table>

Determination of acceptability		
	also provides for emergency discharges from ships.	
	AMSA Marine Orders 91, 95 and 96 Sets out the requirements of the prevention of pollution of the environment for regulated Australian vessels, domestic commercial vessels and Australian recreational vessels. Marine Order 91 (Marine Pollution Prevention – Oil) Marine Order 95 (Marine Pollution Prevention – Garbage) Marine Order 96 (Marine Pollution Prevention – Sewage)	
	Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148) Management action A1: Maintain and improve efficacy of legal and management protection: • manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to their survival • manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue.	EPBC management plan requirements to minimise habitat degradation / modification are addressed by adopting these control measures: **CM25:** MODUs and vessels will comply with the requirements of Marine Order 96 (MARPOL 73/78 Annex IV) in relation to sewage discharge. **CM26:** MODUs and vessels will comply with the requirements of Marine Order 95 (MARPOL 73/78 Annex V) in relation to food waste discharge. **CM27:** MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to oily bilge water discharges. Therefore, the Development is not considered to be inconsistent with the EPBC management plans.
	Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Sea Snake) (Ref. 24) Identifies habitat degradation / modification as a key threat. Management action: Ensure there is no anthropogenic disturbance in areas where the short-nosed sea snake occurs, excluding necessary actions to manage the conservation of the species.	
	Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 23) Identifies habitat degradation / modification as a key threat. Management action: Ensure there is no anthropogenic disturbance in areas where the leaf-scaled sea snake occurs, excluding necessary actions to manage the conservation of the species.	
	Conservation Advice *Rhincodon typus* Whale Shark (Ref. 30). Identifies habitat disruption as a threat. Management action: Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations (Ningaloo Reef, Christmas Island and the Coral Sea) and along the northward migration route that follows the northern WA coastline along the 200 m	

Determination of acceptability		
	isobath (as set out in the Conservation Values Atlas [Ref. 138])	
	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29) Review the level and spatial extent of protection measures at key aggregation sites to ensure appropriate levels of protection, and a consistent approach to the designation and implementation of protective measures, are applied. Use Biologically Important Areas (BIA) to help inform the development of appropriate conservation measures, including through the application of advice in the marine bioregional plans on the types of actions which are likely to have a significant impact on the species and updating such conservation measures as new information becomes available.	
	Approved Conservation Advice for *Pristis pristis* (largetooth sawfish) (Ref. 27) Implement measures to reduce adverse impacts of habitat degradation and/or modification	
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25) Management action 5C: Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks. Management action 5D: Implement measures to reduce adverse impacts of habitat degradation and/or modification.	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 17) Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 18) National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*) (Ref. 41) Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish) (Ref. 26) Approved Conservation Advice for *Milyeringa veritas* (Blind Gudgeon) (Ref. 33)	These EPBC management plans for species that may occur within the OA identify habitat degradation / modification as a threat, but do not identify relevant actions.
Internal context	These CAPL procedures were identified as relevant for this aspect: • Chevron Marine Standard Non Tankers (Ref. 284)	
External context	CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment. No feedback was received in relation to planned discharges—MODU and vessels from Phase 1 stakeholder consultation.	
Defined acceptable level	The consequence of planned discharges—MODU and vessels is inherently acceptable because the highest consequence level is Incidental (6).	

Determination of acceptability

Additionally, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan.

The impact/risk evaluation does not identify scientific uncertainty against impacts/risks of planned MODU and vessel discharges for the receptors.

Although planned MODU and vessel discharges are not listed as a threat to protected matters under documents made or implemented under the EPBC Act, these discharges can impact water quality and therefore modify the marine habitat for some species. Habitat degradation / modification has been identified as a relevant threat to protected matters under documents made or implemented under the EPBC Act; therefore, CAPL will define an acceptable level of impact that aligns with the objectives of these documents. Objectives of the relevant documents are shown below and were considered during the impact and risk evaluation.

Plan and relevant objective	Demonstration of requirement
Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) Recovery objective: Minimise anthropogenic threats to allow for their conservation status to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 4: Anthropogenic threats are demonstrably minimised.	CAPL considers the impacts of planned MODU and vessel discharges to not be inconsistent with the relevant objectives of these EPBC management plans. By applying EPO10, impacts and risks to habitat degradation / modification from Planned discharges—MODU and vessels will be managed at or below the defined acceptable level.
Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148) Long-term recovery objective: Minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 3: Anthropogenic threats are demonstrably minimised.	
Wildlife Conservation Plan for Migratory Shorebirds (Ref. 67) Objectives: Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	
Wildlife Conservation Plan for Seabirds (Ref. 35) Objectives: Seabirds and their habitats are identified, protected, and managed in Australia	
National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*) (Ref. 41) Long-term vision: The Australian Fairy Tern population has increased in size to such an extent that the species no longer qualifies for listing as threatened.	
Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25) Primary objective: To assist the recovery of sawfish and river sharks in Australian waters with a view to: • improving the population status leading to removal of the sawfish and river shark	

Determination of acceptability		
	species from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder recovery in the near future. or impact the conservation status of the species in the future. <u>Specific objectives:</u> Objective 5: Reduce, and where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species.	
	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29) <u>Primary objective</u>: To assist the recovery of the grey nurse shark in the wild, throughout its range in Australian waters, with a view to: • improving the population status, leading to future removal of the grey nurse shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the grey nurse shark in the near future or impact the conservation status of the species in the future. <u>Specific objectives</u>: Objective 8: Continue to identify and protect habitat critical to the survival of the grey nurse shark and reduce the impact of threatening processes within these areas.	
	Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 17) Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 18) Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Sea Snake) (Ref. 24) Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 23) Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish) (Ref. 26) Approved Conservation Advice for *Pristis pristis* (largetooth sawfish) (Ref. 27) Approved Conservation Advice for *Milyeringa veritas* (Blind Gudgeon) (Ref. 33) Conservation Advice *Rhincodon typus* Whale Shark (Ref. 30)	These EPBC management plans for species that may occur within the OA identify habitat degradation / modification as a threat, but do not identify any relevant objectives.
	Therefore, CAPL has defined these acceptable levels of impact such that they are not inconsistent with these documents: • management of impacts of the Development must not be inconsistent with the relevant EPBC management plans identified above • no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery	

Determination of acceptability	
	• no adverse effect to an important or substantial area of habitat such that a significant impact on marine ecosystem functioning or integrity results • no significant adverse impact to cultural heritage values attributed to the offshore marine area. CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets these acceptable levels.

8.6.4 Environmental performance

Table 8-38 lists the EPO defined for Planned discharges—MODU and vessels and the adopted control measures to achieve the outcome.

Table 8-38: Environmental performance for Planned discharges—MODU and vessels

EPO	Adopted control measure
EPO10: Planned discharges from MODU and vessel operations within the OA during the Development will meet MARPOL requirements.	**CM25:** MODUs and vessels will comply with the requirements of Marine Order 96 (MARPOL 73/78 Annex IV) in relation to sewage discharge. **CM26:** MODUs and vessels will comply with the requirements of Marine Order 95 (MARPOL 73/78 Annex V) in relation to food waste discharge. **CM27:** MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to oily bilge water discharges.

8.7 Planned discharges—Subsea operations

8.7.1 Source

Planned operational discharges will be released to the marine environment from Development subsea infrastructure during installation and commissioning, operations, and decommissioning.

The types of releases from these activities include:

- treated water (fresh water or sea water with chemical additives which may include biocide, oxygen scavenger, corrosion inhibitor, dye, and buffering solutions)
- hydraulic control fluids
- MEG
- marine growth removal fluids
- pigging fluids (treated water, gel, MEG)
- sea water with residual flushing and cleaning contaminants
- nitrogen gas, methane, and compressed air.

Planned operational discharges will be released to the marine environment throughout the life of the Development. The key discharge streams are discussed in further detail in Section 8.7.2 and are considered to represent the largest planned discharges associated with the Development. The full range of potential planned operational discharge sources that may be released at different phases of the Development will be assessed and defined as the engineering design progresses in subsequent EPs.

Table 8-39 lists the activities within each phase where planned discharges from subsea operations occur in the OA.

Table 8-39: Phases and activities that generate Planned discharges—Subsea operations

Phase	Activity
Installation and commissioning	Installation of subsea structures Hydrotesting and pre-commissioning Commissioning
Operations	Inspection Maintenance and repair Major repairs
Decommissioning	Flowline and MEG pipeline decommissioning Other subsea structures decommissioning

8.7.1.1 Installation and commissioning

Following installation, the flowlines and MEG pipelines undergo FCGT, leak testing and pre-commissioning (conditioning). Planned discharges are predominantly subsea, at water depths ranging from 150–1,400 m depending on the field. The planned discharges will generally be released at controlled discharge rates.

Discharges are of the following types:

Treated water

Treated water may be discharged during the installation and commissioning phase during FCGT, leak testing and dewatering activities, at the end of pre-commissioning; and from dewatering following the unlikely event of a ruptured pipeline.

Treated water may contain a range of chemical additives such as biocide, oxygen scavenger, corrosion inhibitor, dye, and buffering solutions. These additives are required to maintain pipeline integrity by avoiding metal corrosion, preventing bacterial growth and the accumulation of scale on internal surfaces. All chemicals will be subject to CAPL's ABU Hazardous Materials Management Procedure (Ref. 415).

The expected largest volume of treated water released during FCGT, leak testing and dewatering is ~35,000 m^3, which is double the volume of the inventory of the longest flowline (Chandon)—it accounts for dewatering the full inventory once and a contingency for flushing a second time. This is also the largest volume likely for a single release of treated water.

In the unlikely event of a buckle or rupture during installation, sea water may enter the flowline or MEG pipeline and then be released. The expected discharge volume for a rupture event is also ~35,000 m^3 (based on double the inventory of the longest flowline).

Treated water will also be released before commissioning starts, during flowline and MEG pipeline conditioning; however, this would be a much smaller volume.

Nitrogen and Methane

During commissioning of the production flowlines, dry hydrocarbon gas (methane) may be used to pressurise the flowline in readiness for the start-up phase. This hydrocarbon gas will compress the nitrogen gas used during the pre-commissioning phase towards the end of the flowline. There may be a requirement to purge some or all of the pre-commissioning nitrogen gas and methane at the end of the flowline at the seabed. This would result in a maximum release of ~25,000 m^3 of nitrogen gas, followed by a maximum of ~25,000 m^3 of methane.

MEG

Small volumes of MEG may be discharged during the installation and commissioning phase from FCGT, leak testing or flowline and/or MEG pipeline pre-commissioning activities (Sections 4.3.3.6 and 4.3.3.7).

In the unlikely event of a wet buckle or rupture, dewatering of the flowlines or MEG pipelines may result in residual MEG being discharged.

Hydraulic control fluid

During the installation and commissioning phase, small volumes of hydraulic control fluid may be discharged during control system leak testing, BOP function testing, valve function testing and umbilical installation.

BOPs release small volumes of water-based hydraulic control fluid near the seabed during function and pressure testing (Section 4.3.2.5). The control fluid is typically diluted to 1–3% using potable water and is fully biodegradable.

Umbilicals will be reeled off the vessel and connected to the CDU or manifold. There is potential for a small volume of hydraulic control fluid to be released when the umbilical is connected to the CDU. The umbilical will then be leak tested using hydraulic control fluid, releasing a small volume (~2.5 m^3). This is the largest estimated release of hydraulic control fluid in a single event.

Marine growth removal fluids

Before installing subsea structures, any marine growth and calcareous build-up present on existing structures will be removed via mechanical cleaning, acid wash or similar (Section 4.3.3.4). Only small volumes of chemicals will be used for acid washing, and these chemicals will be applied directly to infrastructure. The volume will depend on which infrastructure needs to be cleaned of marine growth but is expected to be no more than 1 m^3 per application.

8.7.1.2 Operations

Treated water

Treated water may be released in the operations phase from maintenance and repair activities. The frequency of maintenance and repair activities depends on the results of inspections (Section 4.3.4.3).

Major repairs are very unlikely to be needed; however, worst-case discharges were assessed. Major repair of a flowline involves temporary decommissioning, repair, then recommissioning (Section 4.3.4.4).

Following a major defect or full-bore rupture, the flowline would be temporarily decommissioned. It would then be flooded with treated water that will propel a pig towards the defect. This may result in treated water, sea water, residual gas condensate and MEG discharges at the location of the defect. Discharges of treated water from this activity would be smaller than the 2 full line volumes assessed for pipeline recommissioning (~35,000 m^3).

Installing the replacement section would include leak testing and then dewatering and pre-commissioning the flowline (Section 4.3.3.6). As described for installation (Section 8.7.1.1), the largest expected discharges of treated water for these activities is ~35,000 m^3 (double the inventory of the longest flowline)—this accounts for dewatering the full line volume at least once and a contingency for flushing a second time.

MEG

MEG may be discharged from maintenance and repair activities during operations. In the worst-case event of a flowline or full-bore rupture, MEG would be released during a major repair from leak testing, pigging, and pre-commissioning of the repaired flowline.

As described for treated water, a major repair would involve temporarily decommissioning the flowline, then flooding the flowline with treated water that will propel a pig towards the defect. This may result in discharges of treated water, sea water, residual gas condensate and MEG at the location of the defect.

Installing the replacement section would include leak testing and then dewatering and conditioning the flowline (Section 4.3.3.6). The worst-case discharge of MEG from flowline recommissioning is ~1,750 m^3 (Section 8.7.1.1).

MEG will also be released during inspections, as outlined under pigging fluids.

Residual gas condensate may be discharged in the unlikely event that a major repair is required; this would be a much smaller volume than the pipeline rupture scenario, which is assessed in Section 8.15.

Hydraulic control fluid

Operating the hydrocarbon system may result in discharges of hydraulic control fluid to the environment from valves located at the subsea electrohydraulic control systems and at production trees and manifolds (as described in Section 4.2). Each valve actuation is estimated to result in the loss of, on average, a few litres of hydraulic control fluid to the marine environment.

Hydraulic control fluid may also be released in the operations phase from leak testing during maintenance and repair activities, as described for treated water above.

Pigging fluids (treated water, gel, MEG, and/or nitrogen slugs)

Pigging may be used to internally inspect the flowline to ensure the integrity of infrastructure is maintained (Section 4.3.4.2). Pigging occurs from the DCs to the GFP tie-in point, then on to the GTP on Barrow Island.

Temporary pig launchers and receivers may use a combination of treated water, gel, MEG, and/or nitrogen slugs to complete pigging activities. A small amount of trapped hydrocarbon will be released from the end cap (Section 4.3.4.2).

The maximum volume of pigging fluids that may be discharged is ~4.5 m^3.

Marine growth removal fluids

Acid wash and chemicals may be used for removing marine biological growth and calcareous deposits during maintenance and repair activities. This will generally precede pigging or equipment change-out activities (Section 4.3.4.3). This type of cleaning will be done using water jetting from an ROV, generally with potable water or sea water. Structures with calcareous deposit accumulation may require acid washing or soaking (typically using <4.5 m^3 of water-soluble sulfamic acid or similar).

Discharges would not exceed those described for installation and commissioning (Section 8.7.1.1).

8.7.1.3 Decommissioning

When the Development fields are ready for decommissioning, the flowline contents will be flushed to remove hydrocarbons then decontaminated, if necessary. Options for decontaminating the equipment will be considered in more detail when the final decommissioning solution and end state is further defined and will include offshore and onshore decontamination options.

Fluids from flushing and cleaning activities will be assessed and either captured for onshore disposal or discharged with necessary approvals in place.

Sea water with residual flushing and cleaning contaminants

Each flowline may be filled with sea water following flushing and cleaning, which will be released to the marine environment before flowline decommissioning. The sea water may contain residual hydrocarbon, mercury, NORMs, surfactants, hydrochloric acid, or MEG. The volume of sea water that is likely to be released is determined by the flowline inventory, which is an estimated volume of 17,500 m^3 (based on the longest flowline).

8.7.2 Impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within a conservative 10 km radius adopted as the spatial extent (as per modelling summarised in Table 8-40) that may be impacted by subsea discharges:

- water quality
- fishes, including sharks and rays
- marine reptiles
- marine mammals
- commercial fisheries
- KEFs
- cultural heritage value: Traditional Owners.

Table 8-40 details the impact and risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to planned operational discharges within the conservative 10 km spatial extent.

Subsea operational discharges are positively buoyant, and upon release, the plume will dilute and disperse (Ref. 416). The discharges occur at the wells, DCs, and the GFP tie-in points, which are all located in waters ~150–1,400 m deep.

Therefore, impacts to sediment quality or benthic habitats and associated communities from planned operational subsea discharges are not expected, and are not evaluated further.

Table 8-40: Risk evaluation for Planned discharges—Subsea operations

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Planned subsea operational discharges may result in: • localised and temporary reduction in water quality	6	A localised and temporary reduction in water quality may result in: • Injury or mortality of marine fauna.	5	5	Very low (9)
		A localised and temporary reduction in water quality may result in: • Change to the functions, interests and activities of other marine users.	5	5	Very low (9)
		Planned subsea operational discharges within a KEF may result in: • Change to values and sensitivities of KEFs	5	5	Very low (9)

Impact and/or risk level summary					
		Planned subsea operational discharges may result in: • change to cultural heritage values	5	5	Very low (9)

Risk evaluation
Water quality
Localised and temporary reduction in water quality Planned operational subsea discharges include treated water, acid wash/chemicals for cleaning, hydraulic control fluid, conditioning chemicals, MEG and pigging fluids. These discharges are intermittent, non-continuous, and of short duration and may result in localised and temporary reduction in water quality during installation and commissioning, operations, and decommissioning phases of the Development. The worst-case discharge volumes are assessed for each discharge type. *Treated water* The highest volume discharge across installation, commissioning and operations phases is for treated water, from either dewatering before commissioning, or the unlikely event of a major repair of a flowline resulting from a flowline or bore rupture (~35,000 m^3). Treated water may contain a range of chemical additives such as biocide, oxygen scavenger, corrosion inhibitor, clear dye, and buffering solutions. Residual biocide in treated water has the potential to be acutely toxic to a range of marine biota associated with benthic habitats, including fish, molluscs, and echinoderms (Ref. 417). Dye, scale inhibitor and corrosion inhibitor are expected to be less toxic than the biocide (Ref. 418; Ref. 419). The biocides routinely used in the oil and gas industry are biodegradable and non-bioaccumulative (Ref. 420). In 2012, CAPL undertook pre-commissioning discharge modelling for the GFP, for the Gorgon and Jansz Feed Gas Pipelines (Ref. 86). These are 48″ (122 cm) diameter pipelines, and at ~65.5 km and ~134.5 km long, represented a maximum discharge volume of 120,000 m^3 and 220,000 m^3 respectively. In comparison, the Development flowlines are 24″ diameter, with the longest flowline (Chandon, 60 km) having an expected discharge of ~35,000 m^3. While specific modelling of treated water for the Development has not been undertaken, the 2012 modelling for GFP was for much larger volumes than predicted for the Development and has therefore been used as a conservative analogue to inform the impact assessment. The GFP modelling assumed a discharge duration of 133 and 244 hours at the Gorgon and Jansz-Io fields respectively, whereas the longest duration of release from Chandon will be much less. The modelled locations were at GFP infrastructure, within the Development OA, at similar water depths to the Development (i.e. >200 m). The depths for the Development range from ~150–1,400 m, therefore, the discharges are subject to similar subsea currents / oceanographic processes. The GFP modelling predicted that, in general, the plume will rise upwards immediately after release due to the plume momentum and pipe configuration, creating a turbulent mixing zone with the receiving waters (Ref. 86) Once the discharge water plume loses all its upward momentum, the ambient currents will further mix and disperse this wastewater. Instantaneous exposures below the predicted no-effect concentration (PNEC) for the representative biocide (Hydrosure) of 0.1 mg/L are predicted to occur up to 10 km from the release location. Using average ocean current speeds of 0.22 m/s it is expected to take <13 hours to return to below-impact thresholds (Ref. 86). CAPL also undertook whole effluent toxicity (WET) testing for inhibited seawater dosed with 500 ppm of Hydrosure O3670-R, which is biodegradable and non-bioaccumulative, and 50 ppm of dye for the Wheatstone project. This mix is considered a representative analogue for the Development. The results found that the no observed effect concentration (NOEC) for the inhibited seawater mix, for the protection of 99% and 95% of species, to be 0.06 ppm and 0.1 ppm respectively. The durations of exposures in the laboratory tests ranged from 48–96 hours, therefore a conservative approach has been adopted to establish an exposure duration for the species protection concentration based on the minim test duration of 48 hrs (Ref. 417). As the 0.06 mg/L 99% species protection concentration is less than half the NOEC value for any invertebrate species tested, the 0.1 mg/L associated with the 95% species protection criteria has been adopted.. As the volumes modelled for the Development (~35,000 m3) are significantly smaller than the GFP volumes, exposures at 0.1 mg/L are expected to be significantly smaller in extent and duration than the 10 km and 13 hour predicted effect area for the GFP modelled instantaneous threshold of 0.1 mg/L. Consequently, any reduction water quality is expected to be localised and temporary. *Nitrogen gas and methane*

Risk evaluation
As methane is highly soluble in water, it would dissolve quickly into the water column after release. The dissolved methane component would biodegrade whereas the gaseous methane will continue to rise to the sea surface and be transported away by surface winds (Ref. 255).
Following the 2012 gas leak from the Elgin platform in the North Sea, monitoring of water and sediment and fish health found no evidence of hydrocarbon contamination above background levels (Ref. 421, Ref. 422, Ref. 423). This study was in colder sea temperatures than the OA; however, generally as the temperature increases, the solubility of a gas decreases, meaning more gas will escape from solution. Due to the pressure difference between the gas and surrounding water, contamination of the water column as a result of methane release is expected to be minimal.
Nitrogen gas does not react with water and will dissolve. Marine environments naturally contain elementary nitrogen gas as a result of mixing with the atmosphere. There is no expected impact to water quality as a result of a release of nitrogen gas during commissioning.
Hydraulic control fluid
Evaluation is based on the worst-case largest discharge volume on the basis that the smaller discharges will dilute and disperse more rapidly upon release. These discharges are intermittent, non-continuous and of short duration, and as such, frequency of exposure is limited. Rapid dispersion of fluids is expected to occur due to small discharge volumes (e.g. up to 2.5 m^3 of control fluid), within open marine waters, which are typically influenced by large-scale ocean currents.
BP undertook fluid dispersion modelling for subsea releases of control fluids, which indicated the residence time or plume persistence (in similar water depths with a similar product) was estimated to be 18 minutes (Ref. 286). The spatial extent of these smaller discharges is expected to be limited to a small area in the water column around the source. Impacts from smaller discharges are not expected to exceed those outlined for the worst-case discharge.
MEG
Smaller discharges such as MEG (~1,750 m^3) will also be released (see Section 8.7.1 for the source of these fluids). Other discharges include pigging fluids during inspections (~4.5 m^3).
MEG is widely used by the oil and gas industry in wellheads and pipelines. It is rated as PLONOR (pose little or no risk) by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), is readily biodegradable, and has low potential for bioaccumulation (Ref. 424; Ref. 425). MEG is also completely miscible with water and would disperse quickly if released into the marine environment.
Marine growth removal fluids
The volumes of the chemicals used for acid washing will be relatively small (~4.5 m^3 per application depending on infrastructure); these chemicals will be applied directly to the infrastructure.
Sea water with residual flushing and cleaning contaminants
Following flushing and cleaning of flowlines at decommissioning, sea water with residual flushing and cleaning contaminants may be released. These fluids may include residual hydrocarbon, mercury, NORMs, surfactants, hydrochloric acid or MEG, and the maximum volume released would be ~17,500 m^3 (based on the longest flowline, Chandon). Residual scale (containing mercury and other contaminants) may build up on the inner wall of flowlines over their operational life. However, flushing and cleaning fluids themselves will not be discharged to sea; and only minimal residual levels of any internal contaminants would remain to potentially be included when the flowlines are flushed with seawater.
The other residual contaminants are assessed above; and any residual hydrocarbons in the discharge would be a lesser concentration than assessed in Section 8.15 for an unplanned release of condensate.
The largest volume of subsea operations discharges has been used to evaluate the maximum extent of potential impact, as any smaller discharge volumes will lie within the maximum impact extent evaluated. As the residence time of a plume is expected to be hours (not days), release volumes are low (Section 8.7.1), and releases are intermittent, discreet events at different locations, all planned subsea discharges are expected to have limited environmental impact.
The consequence level for planned subsea operational discharges to water quality has been evaluated as Incidental (6).
Marine Fauna
Injury or mortality to marine fauna
The planned release of subsea discharges has the potential to cause lethal or sub-lethal effects (through toxicity) to marine fauna including plankton, fish, marine reptiles, and marine mammals.
As described above, previous modelling was used to provide a conservative evaluation of the fate of discharges.

Risk evaluation
The largest planned subsea discharge for the Development is 35,000 m^3 of treated water during pre-commissioning of the longest flowline. Treated water contains chemical additives including biocide. Modelling of GFP pre-commissioning discharges predicted that instantaneous exposures below the PNEC (0.1 mg/L/0.1 ppm) for the representative biocide were predicted to occur up to 10 km from the release location (Ref. 86). The modelling predicted it will take <13 hours to return to below-impact thresholds. As previously stated, this modelling is based on a discharge volume of 220,000 m^3 and release duration of 133 hours, which is much larger than that for the Development (35,000 m^3). As described above, the Wheatstone WET testing (Ref. 417), set a conservative threshold for the appraisal of the potential toxicity impacts at no exceedance of 0.06 mg/L and 0.1 mg/L of Hydrosure over a 48 hour period: representing the 99% and 95% species protection criteria respectively. The 0.06 mg/L 99% species protection concentration is less than the half the NOEC value for any invertebrate species tested. Consequently, the 48 hour exposures of 0.1 mg/L associated with the 95% species protection criteria has been adopted. Given the discharge volume for the Development is significantly smaller than volume modelled for GFP (35,000 m^3 compared to 220,000 m^3), the 48 hour exposures of 0.1 mg/L associated with the 95% species protection criteria are expected to be significantly smaller in extent than the 10 km predicted effect area for the GFP modelled instantaneous threshold of 0.1 mg/L. Residual biocide in treated water has the potential to be acutely toxic to a range of marine biota associated with benthic habitats, including fish, molluscs, and echinoderms (Ref. 417). Dye, scale inhibitor and corrosion inhibitor are expected to be less toxic than the biocide (Ref. 418; Ref. 419). Modelling indicates that no exposures above MEG impact thresholds are expected and thus are not considered further. The values and sensitivities within the conservative 10 km spatial extent with the potential to be affected by injury or mortality to marine fauna include: • humpback whale BIA (foraging) • pygmy blue whale BIA (distribution and migration) • flatback turtle BIA (internesting buffer) and habitat critical • whale shark BIA (foraging) • wedge-tailed shearwater BIA (breeding) • fish communities (associated with the various KEFs). Early life stages of fish (embryo and larvae) and other plankton are the most susceptible to toxicity as they have limited mobility, thus are more likely to be exposed to toxic effects. Low nutrient levels within the OA indicates sparse populations of plankton species throughout the NWS (Ref. 104). Mortality rates for plankton are naturally high with distribution often patchy and linked to localised and seasonal productivity that produces sporadic bursts in phytoplankton and zooplankton populations (Ref. 104). Therefore, plankton populations are expected to recover quickly from any impacts of planned subsea discharges. The approved Conservation Advice for whale sharks (Ref. 30) states that the main threat to this species occurs outside Australian waters (from intentional and unintentional mortality from fishing); however, within Australian waters, habitat disruption from mineral exploration, production and transportation is listed as a threat. The recovery plans for marine turtles (Ref. 148) and the blue whale (Ref. 16) list acute chemical discharge from various pollutants as a threat to the species. Although the 10 km spatial extent overlaps the flatback turtle internesting buffer, Whittock (Ref. 151; Ref 150) defined unsuitable flatback turtle internesting habitat as waters >25 m deep and >27 km from the coast. Only the WTR and C&D fields, which are at depths >25 m deep and further than 27 km from the closest coast, have infrastructure within the internesting buffer. Therefore, it would be very unlikely that turtles would aggregate within the spatial extent during their internesting period, and only a small number of transient individuals are expected to be present. Marine mammals and reptiles are unlikely to be exposed to discharges released at the seabed for Chandon, G&E, Semele and the majority of C&D as these discharges will be released at water depths >1,000 m. As described by the GFP modelling of the largest discharge, the residence time of the plume (once the discharge has finished) is expected to be <13 hours. This duration is less than the 48 hour duration for acute toxicity impacts set by the Wheatstone WET testing. To be impacted, individuals would need to pass directly through any discharge plume almost immediately upon release and remain within the plume for at least 48 hours. As the plume is expected to dissipate in <13 hours, it is not expected that they would be exposed to concentrations above impact thresholds that would lead to toxic effects. The identified values and sensitivities are mobile and transient. The 10 km spatial extent was used as a conservative assessment for the Development, which, given the largest volume released (35,000 m^3), is expected to result in a much smaller predicted effect area (Ref. 86). Because there are significant differences in the modelled volumes compared to the volumes planned to be

Risk evaluation
released, the environment that may be affected by these discharges has been overestimated. This provides additional conservatism for the risk assessment and accounts for the different toxicity profiles from the smaller volume discharges, which would be expected to dilute more rapidly resulting in a spatial extent that is much smaller than presented. All species listed are highly mobile and are not expected to be affected by minor increases in toxicity and short-term turbidity increases. Therefore, the consequence of injury/mortality on marine fauna has been evaluated as Minor (5). Given subsea discharges will be localised and rapidly diluted, marine mammals and marine reptile and most fish species will be transitory in nature, the likelihood of injury/mortality to marine fauna has been evaluated as Remote (5). Overall, the risk of planned subsea operational discharges to marine fauna is Very Low (9).
Commercial fisheries
Change to the functions, interests and activities of other marine users Planned subsea discharges have the potential to result in a change to the functions, interests, and activities of commercial fisheries in these ways: • displacing fishing effort from areas affected by a planned release • damaging fish stocks as a result of mortality • inability to sell catch because of perceived or actual fish tainting or contamination. The 10 km spatial extent was used as a conservative assessment for the Development, which, given the largest volume released (35,000 m^3) is expected to result in a much smaller predicted effect area (Ref. 86). Because of the significant differences in the modelled volumes compared to the volumes planned to be released, the environment that may be affected from these discharges has been overestimated. This provides additional conservatism for the risk assessment and accounts for the different toxicity profiles from the smaller volume discharges, which would be expected to dilute more rapidly resulting in a spatial extent that is much smaller than presented. Only one State-managed fishery—the Mackerel Managed Fishery—recorded fishing effort in the OA from 2012–2021, as did 3 Commonwealth-managed fisheries (2010–2020). No additional Commonwealth- or State-managed fisheries reported activity within 10 km of the OA. There are no known important spawning areas identified that have the potential to be impacted. The residence time of the modelled plume for the GFP discharges was predicted to be ~13 hours— Based on the Wheatstone modelling, to be impacted, individuals would need to pass directly through any discharge plume almost immediately upon release and remain within the plume for and remain within the plume for at least 48 hours. As the plume is expected to dissipate in <13 hours, it is not expected that the mobile and transient life stages would be exposed to concentrations above impact thresholds for an extended time. Acute impacts may occur and would be limited to small numbers of juvenile fish, larvae, and planktonic organisms; these impacts are not expected to affect population viability or recruitment. Impacts from these discharges are not expected to manifest at a fish population viability level. Given impacts to commercial fisheries functions, interests and activities are expected to be temporary and localised, the consequence has been evaluated as Minor (5), and the likelihood of a change to the function, interests and activities of other marine users occurring as Remote (5). Overall, the risk of planned subsea operational discharges to commercial fisheries is Very Low (9).
KEFs
Change to values and sensitivities The planned release of subsea discharges has the potential to cause lethal or sub-lethal effects (through toxicity) to marine fauna, potentially resulting in a change to the values and sensitivities of KEFs. As assessed above, early life stages of fish (embryo and larvae) and other plankton are the most susceptible to toxicity as they have limited mobility, thus are more likely to be exposed to toxic effects. The Continental slope demersal fish communities KEF has values relating to fish that live and feed near the sea floor and is valued for its high biodiversity and endemism with a range of fish assemblages (Ref. 426). The 10 km spatial extent overlaps this KEF around the C&D flowline, C&D DC-3, WTR umbilical and one of the Gorgon tie-in points. The residence time of the modelled plume for the GFP discharges was predicted to be ~13 hours. Based on the Wheatstone modelling, to be impacted, individuals would need to remain within the plume for at least 48 hours. As the plume is expected to dissipate in <13 hours, it is not expected that mobile transient life stages

Risk evaluation
and species would be exposed to concentrations above impact thresholds for an extended time. Acute impacts may occur and would be limited to small numbers of juvenile fish, larvae, and planktonic organisms; these impacts are not expected to affect population viability or recruitment. Impacts from these discharges are not expected to manifest at a fish population viability level. Demersal fish are highly mobile and are not expected to be affected by minor increases in toxicity and short-term turbidity increases. Therefore, the consequence of injury/mortality of marine fauna values of the KEF has been evaluated as Minor (5). Given subsea discharges will be localised and rapidly diluted, and demersal fish species are transitory in nature, the likelihood of injury/mortality to marine fauna has been evaluated as Remote (5). Overall, the risk of planned subsea operational discharges to KEFs is Very Low (9).
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from planned release of subsea discharges includes indirect impacts to intangible Traditional Owner heritage from injury or mortality of marine fauna. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of marine fauna (Section 6.2.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural values may occur from the potential injury or mortality of marine fauna from planned release of subsea discharges. The consequence level for the potential for injury or mortality of marine fauna from planned subsea operational discharges was evaluated as Minor (5) from due to minor changes in water quality. As such, the consequence of changes to cultural heritage values from planned subsea operational discharges is also evaluated as Minor (5). Minor changes in water quality from planned subsea operational discharges will be localised and temporary as discharges will be rapidly diluted in open waters. Most marine fauna species in the OA will be transitory in nature which limits the potential exposure of marine fauna to in-water localised and temporary discharges. Therefore, the likelihood of the consequence occurring is evaluated as consistent with that of the above consequence ranking – i.e. the likelihood is assessed as Remote (5). The risk of planned subsea operational discharges to Traditional Owner cultural heritage values is Very Low (9).

8.7.3 Determination of acceptability

The acceptable level of impact and/or risk is a function of the magnitude of impact and/or residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-41 details the determination of acceptability for planned operational discharges.

Table 8-41: Determination of acceptability for Planned discharges—Subsea operations

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence level for Planned discharges—Subsea operations was evaluated as Minor (5). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the impact and risk evaluation for Planned discharges—Subsea operations. • Prevention measures for Planned discharges—Subsea operations are well regulated and managed in Australian waters. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="4"></td><td colspan="2">(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations</td></tr>
<tr><td colspan="2">The Development is consistent with principle of ESD (c) for this aspect as:
• The Development is committed to applying measures to prevent the impact and risk of Planned discharges—Subsea operations based on relevant environmental legislation and other requirements as listed below.
• The regulation and management of Planned discharges—Subsea operations in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
• The highest consequence level for Planned discharges—Subsea operations was evaluated as Minor (5).
• Any relevant stakeholder feedback in relation to planned discharges from subsea operations has been incorporated in the OPP and assessed in the external context acceptability criteria.
To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="4">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148)
Action Area A1 (maintain and improve efficacy of legal and management protection) relevant management actions:
• manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to their survival
• manage anthropogenic activities in BIAs Areas to ensure that biologically important behaviour can continue.
Management action A4: Minimise chemical and terrestrial discharge</td><td rowspan="2">EPBC management plan requirements to minimise chemical discharges and habitat degradation/ modification are addressed by adopting these control measures:
CM28: Fluids planned for discharge are subject to the hazardous materials selection process as per the CAPL Hazardous Materials Management Procedure (Ref. 415).
CM29: Chemicals planned for discharge will be selected and applied with the lowest practicable concentrations to provide technical effectiveness and reduce environmental impacts.
Therefore, the Development is not considered to be inconsistent with the EPBC management plans.</td></tr>
<tr><td>Approved Conservation Advice for Aipysurus apraefrontalis (Short-nosed Sea Snake) (Ref. 24)
Identifies habitat degradation / modification as a key threat.
Management action: Ensure there is no anthropogenic disturbance in areas where the short-nosed sea snake occurs, excluding necessary actions to manage the conservation of the species.</td></tr>
</table>

Determination of acceptability		
	Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 23) Identifies habitat degradation / modification as a key threat. Management action: Ensure there is no anthropogenic disturbance in areas where the leaf-scaled sea snake occurs, excluding necessary actions to manage the conservation of the species.	
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25) Management action 5C: Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks. Management action 5D: Implement measures to reduce adverse impacts of habitat degradation and/or modification.	
	Approved Conservation Advice for *Pristis pristis* (largetooth sawfish) (Ref. 27) Implement measures to reduce adverse impacts of habitat degradation and/or modification	
	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29) Review the level and spatial extent of protection measures at key aggregation sites to ensure appropriate levels of protection, and a consistent approach to the designation and implementation of protective measures, are applied. Use Biologically Important Areas (BIA) to help inform the development of appropriate conservation measures, including through the application of advice in the marine bioregional plans on the types of actions which are likely to have a significant impact on the species and updating such conservation measures as new information becomes available.	
	Conservation Advice *Rhincodon typus* Whale Shark (Ref. 30). Identifies habitat disruption as a threat. Management action: Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations (Ningaloo Reef, Christmas Island and the Coral Sea) and along the northward migration route that follows the northern WA coastline along the 200 m isobath (as set out in the Conservation Values Atlas [Ref. 138])	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16)	These EPBC management plans for species that may occur within the OA

Determination of acceptability		
	Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 17) Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 18) Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish) (Ref. 26) Approved Conservation Advice for *Milyeringa veritas* (Blind Gudgeon) (Ref. 33) Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 31).	identify habitat degradation / modification as a threat but do not have relevant actions.
Internal context	These CAPL procedures were identified as relevant for this aspect: • Hazardous Materials Management Procedure (Ref. 415)	
External context	CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.2.5 and 6.5.2). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM07** and **CM08**). No further feedback was received in relation to planned discharges—subsea operations from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	
Defined acceptable level	The consequence of Planned discharges—Subsea operations is inherently acceptable because the highest consequence level is Minor (5). Additionally, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan. The impact/risk evaluation does not identify scientific uncertainty against impacts/risks of Planned discharges—Subsea operations for each receptor. Chemical discharges, and habitat degradation/modification/disruption that could result from an impact to water quality have been identified as a relevant threat to protected matters under documents made or implemented under the EPBC Act; therefore, CAPL will define an acceptable level of impact that aligns with the objectives of these documents. Objectives of the relevant documents are shown below:	
	Plan and relevant objectives	**Demonstration of requirement**
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) <ins>Recovery objective</ins>: Minimise anthropogenic threats to allow for their conservation status to improve so that they can be removed from the EPBC Act threatened species list. <ins>Interim objective 4</ins>: Anthropogenic threats are demonstrably minimised.	CAPL considers that impacts of Planned discharges—Subsea operations to not be inconsistent with the relevant objectives of these EPBC management plans. By applying EPO11, impacts and risks to habitat degradation / modification/ disruption and chemical discharges from Planned discharges—Subsea operations will be managed at or below the defined acceptable level.
	Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148) <ins>Long-term recovery objective</ins>: Minimise anthropogenic threats to allow for the conservation status of marine turtles to	

Determination of acceptability		
	improve so that they can be removed from the EPBC Act threatened species list. Interim objective 3: Anthropogenic threats are demonstrably minimised.	
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25) Primary objective: To assist the recovery of sawfish and river sharks in Australian waters with a view to: • improving the population status leading to removal of the sawfish and river shark species from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder recovery in the near future or impact the conservation status of the species in the future. Specific objective: Objective 5: Reduce, and where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species	
	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29) Primary objective: To assist the recovery of the grey nurse shark in the wild, throughout its range in Australian waters, with a view to: • improving the population status, leading to future removal of the grey nurse shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the grey nurse shark in the near future or impact the conservation status of the species in the future. Specific objective: Objective 8: Continue to identify and protect habitat critical to the survival of the grey nurse shark and reduce the impact of threatening processes within these areas.	
	Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 31). Primary objective: To assist the recovery of the white shark in the wild, throughout its range in Australian waters, with a view to: • improving the population status, leading to future removal of the white shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the white shark in the near future or impact the conservation status of the species in the future.	

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="3"></td><td><u>Specific objective:</u>
Objective 7: Continue to identify and protect habitat critical to the survival of the white shark and minimise the impact of threatening processes within these areas</td><td></td></tr>
<tr><td>Conservation Advice Balaenoptera physalus Fin Whale (Ref. 17)
Conservation Advice Balaenoptera borealis Sei Whale (Ref. 18)
Approved Conservation Advice for Aipysurus apraefrontalis (Short-nosed Sea Snake) (Ref. 24)
Approved Conservation Advice on Aipysurus foliosquama (Leaf-scaled sea snake) (Ref. 23)
Approved Conservation Advice on Pristis clavate (Dwarf Sawfish) (Ref. 26)
Approved Conservation Advice for Pristis pristis (largetooth sawfish) (Ref. 27)
Approved Conservation Advice for Milyeringa veritas (Blind Gudgeon) (Ref. 33)
Conservation Advice Rhincodon typus Whale Shark (Ref. 30).</td><td>These EPBC management plans for species that may occur within the OA identify habitat degradation / modification/ disruption as a threat, but do not identify any relevant objectives.</td></tr>
<tr><td colspan="2">Therefore, CAPL has defined these acceptable levels of impact such that they are not inconsistent with these documents:
• management of impacts of the Development must not be inconsistent with the relevant EPBC management plans identified above
• no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery
• no adverse effect to an important or substantial area of habitat such that a significant impact on marine ecosystem functioning or integrity results
• no significant adverse impact to cultural heritage values attributed to the offshore marine area.
CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets these acceptable levels.</td></tr>
</table>

8.7.4 Environmental performance

Table 8-42 lists the EPOs defined for Planned discharges—Subsea operations and the adopted control measures to achieve the outcome.

Table 8-42: Environmental performance for Planned discharges—Subsea operations

EPO	Adopted control measure
EPO11: No impacts to benthic habitats or marine fauna outside the OA from planned subsea operations discharges during the Development activities.	**CM28**: Fluids planned for discharge are subject to the hazardous materials selection process as per the CAPL Hazardous Materials Management Procedure (Ref. 415). **CM29**: Chemicals planned for discharge will be selected and applied with the lowest practicable concentrations to provide technical effectiveness and reduce environmental impacts.

EPO	Adopted control measure
EPO03: No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.

8.8 Planned discharges—Drilling

8.8.1 Source

Drilling activities will result in planned discharges such as drilling cuttings, drilling fluids, additives, and cement. These materials are discharged to the marine environment at the sea surface or subsea.

The key discharge streams are discussed in further detail in Section 8.8.2 and are considered to represent the largest planned discharges associated with the Development's drilling activities. The full range of potential planned drilling discharge sources that may be released at different phases of the Development will be assessed and defined as the engineering design progresses in subsequent EPs.

Table 8-43 lists activities within each phase where planned drilling discharges occur in the OA.

Table 8-43: Phases and activities that generate Planned discharges—Drilling

Phase	Activity
Drilling	Drilling top- and bottom-holes Drilling fluids and cuttings handling Cementing operations Pressure-control equipment installation Completions installation Production tree installation Well clean-up and testing
Operations	Well intervention
Decommissioning	Well suspension and well P&A

8.8.1.1 Drilling

Drilling activities may take an estimated 24 months per field (~3 months to drill each well). The maximum number of wells per field is 8.

The drilling phase involves multiple activities (described in Section 4.3.2). During these activities, drilling cuttings and fluids, completion fluids, control fluids, solid additives and cement will be discharged to the marine environment. Depending on the activity, cuttings, fluids, or cements may be discharged at the surface or subsurface, with the potential for additional bulk discharges at the surface. Discharges may also vary in composition and will often be discharged as a mixture of drilling cuttings and fluids, completion fluids, control fluids or cement and additives.

Details of these discharges are outlined below.

Drilling fluids

Drilling fluids (sometimes called drilling mud) lubricate and cool the drill bit, help stabilise the strata, and carry rock cuttings to the surface. Drilling fluid also maintains hydrostatic pressure greater than formation pressure, preventing the influx of hydrocarbons from the formation into the wellbore–forming the primary well control barrier.

Drilling fluids are a mix of sea water, clay (or gel) and additives such as barite, chalk, and polymer and polyamine to control fluid loss, viscosity and provide further formation inhibition.

Drilling additives typically used include:

- sodium chloride
- potassium chloride
- bentonite (clay)
- cellulose polymers
- guar gum
- barite
- calcium carbonate.

During the initial stages of drilling a combination of sea water and high-viscosity gel sweeps are typically used as drilling fluid (described in Section 4.3.2.3).

Throughout the drilling program various fluids will be run through the closed circulation system including, but not limited to nonaqueous drilling fluid (NADF), water-based fluid (WBF), sea water and completion/suspension brine. When one fluid displaces another, they will mix. This NADF brine mixture may be discharged (Section 4.3.2.3 and Table 8-44).

Tanks used to store NADF will be emptied and cleaned after drilling is completed. NADF tank washing residue (<1% residual hydrocarbon) may be discharged to the marine environment. Table 8-44 lists estimates of fluid volumes.

Drilling cuttings

The break-up of solid seabed material during drilling activities generates drilling cuttings, which can vary in size from very coarse to very fine.

During drilling, cuttings and drilling fluids will be released directly to the seabed near the well site. Once the top-hole section is complete, the riser and BOP are installed, which provide a conduit back to the MODU and form a closed circulating system. Cuttings are then processed within the solids control equipment, with drilling fluids separated from the cuttings and recirculated back for further use (described in Section 4.3.2.3).

Although volumes of cuttings will depend on the final depth of each well, an indicative average cuttings volume of 440 m^3 for the top-hole section and 250 m^3 for the bottom-hole section (based on the volume of the previously drilled wells in these fields) is expected to be generated per well.

Indicative volumes of drilling fluids and cuttings discharged per well have been estimated based on historical data and well planning (Table 8-44).

Cementing

During drilling, cement is used to seal the space between the casing and the formation, and to permanently position the casing in place (described in Section 4.3.2.3).

Marine cement typically comprises of cement clinker, gypsum and ground granulated blast furnace slag.

Approximate volumes of cement discharges are:

- on liner cement jobs—occasionally small quantities (<10 m^3) of cement products and spacer (a WBF) may be circulated (discharged) out of the well from above the top of the liner
- cementing operations— up to 109 m^3 of cement discharged at the seabed
- equipment washing or flushing—small volumes of a cement/water mix may be released in surface waters (~10 m^3 per cement job) or if a mixed batch of cement spoils in the cement unit (up to 78 m^3).

Control fluids

Control fluids (hydraulic fluids) are required to operate pressure-control equipment such as the BOP. The BOP will be installed after the top-hole sections of the well have been completed; ~2.5 m^3 of water-based hydraulic control fluid will be released to the marine environment during function and pressure tests.

Small amounts of control fluid may also be discharged to the marine environment during production tree installation and valve functionality testing.

The control fluid, which is fully biodegradable, is typically diluted to ~3% using potable water.

As control fluid is also released during other subsea activities, it has been evaluated in Planned discharges-subsea operations (Section 8.7) and is not considered further here.

Completion fluids

Well completion fluids are required to ensure that the wellbores and casings are clear of solids, debris, and other contaminants. Completion fluids usually comprise a brine (often chlorides of calcium, potassium, or sodium) with additives that may include:

- biocide
- bromides
- hydrate inhibitor (methanol, MEG)
- oxygen scavenger
- surfactant.

Completion fluids may be discharged to the sea, with an expected volume of ~500 m^3 per well.

8.8.1.2 Operations

Throughout the life of the Development, well intervention activities, such as maintenance, repair and replacement of components will be required to maintain operational integrity. Maintenance and repair activities occur mainly within the wellbore and usually include well logging, well testing and flowback, and well workovers. Subsea discharges, which may occur during maintenance and repair activities, are not expected to be different to those discharges described above (Section 8.8.1.1) for drilling operations, but the volumes may slightly vary.

Discharged fluids during maintenance and repair activities include completion fluids (similar to during drilling).

8.8.1.3 Decommissioning

At the end of a producing well's life, it will be permanently plugged and abandoned (P&A) in alignment with relevant requirements. P&A procedures are designed to permanently isolate the well and mitigate the risk of a potential release of wellbore fluids to the marine environment by setting a series of plugs or suitable barriers within the wellbore. These plugs are tested to confirm their integrity. These activities may lead to discharges that are not dissimilar to fluids described for drilling (Section 8.8.1.1); however, the volumes will be significantly smaller and may include:

- treated sea water (with caustic soda or soda ash)
- completions fluids
- drilling fluids
- cement.

8.8.1.4 Discharge volumes

Table 8-44 lists indicative volumes of planned drilling discharges per well.

Table 8-44: Indicative volume of planned drilling discharges per well

Discharge type	Average volume per well (m^3)	Location	Timing
Drilling and completion fluids			
WBF and gel sweeps	1,500	Seabed	Drilling of top-hole sections
	500	Sea surface	Drilling of bottom-hole sections
NADF	220	Sea surface	Drilling of bottom-hole sections. Includes residue on cuttings, displacement interface and residue from tank washing.
Suspension/completion brine	500	Sea surface	Completions
Formation			
Cuttings	440	Seabed	Drilling of top-hole sections
	250	Sea surface	Drilling of bottom-hole sections
Cement			
Cement	109	Seabed	Drilling of top-hole sections
	10	Sea surface	Drilling of bottom-hole sections
Cement (unplanned)	78	Sea surface	(If cement job fails) Drilling of bottom-hole sections

8.8.2 Impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the OA that may be impacted by planned drilling discharges:

- water quality
- benthic habitats and associated communities
- fishes, including sharks and rays
- marine reptiles
- marine mammals
- KEFs
- cultural heritage value: Traditional Owners.

Although fish may potentially be impacted by drilling discharges, the area of influence is highly localised and is not expected to result in a change in the viability of the population of commercially important species. Only one State- and 3 Commonwealth-managed fisheries have recorded historical fishing effort in the OA. Therefore, impacts to commercial fisheries from planned drilling discharges are not expected, and are not evaluated further.

Table 8-45 details the impact and risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to planned drilling discharges in the OA.

Table 8-45: Risk evaluation for Planned discharges—Drilling

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
Planned drilling discharges may result in: • localised and temporary reduction in water quality	6	A localised and temporary reduction in water quality may result in: • injury or mortality of marine fauna.	5	4	Low (7)
Planned drilling discharges may result in: • localised and temporary reduction in sediment quality.	6	An alteration of marine habitat may result in: • injury or mortality of marine fauna.	5	3	Low (7)
Planned drilling discharges may result in: • alteration of benthic habitats and associated communities.	5	Planned drilling discharges within a KEF may result in: • change to values and sensitivities of KEFs	5	4	Low (8)
		Planned drilling discharges may result in: • change to cultural heritage values	5	3	Low (7)

Risk evaluation
Water quality
Localised and temporary reduction in water quality (turbidity) Planned drilling discharges (Table 8-44), which occur both at the seafloor (e.g. during drilling of the top-hole sections), and in surface waters, may result in localised and temporary reduction in water quality from increased turbidity during the drilling, operations, and decommissioning phases of the Development.

Risk evaluation
Drilling discharges at the seabed are expected to create a localised increase in turbidity immediately around the wellhead. Dispersion of the cuttings plume is influenced by two factors: fluid type (i.e. particle size) and ocean current speed (Ref. 427). Dispersion modelling by RPS APASA of near-seabed discharges of cuttings and fluids for the Barossa Development (located in the Bonaparte Basin) was conducted in waters ~200–370 m deep; the total seabed discharge volume was 1,643 m^3 (Ref. 419). Although this modelling was carried out at water depths representative of the shallower continental shelf portion of the OA (i.e. WTR, Semele), previous modelling of the seafloor currents within the OA indicated currents are typically in the range of >0 m/s to 0.2 m/s with an average current speed of 0.05 m/s to 0.1 m/s (Ref. 428; Ref. 429). These conditions are similar to the seafloor currents within the Barossa Development and therefore modelled distances provide a good measure of the order of magnitude over which an increase in turbidity could be predicted for seabed drilling discharges across the OA. The Barossa dispersion modelling predicted larger particulates would settle within 60 m of the release location, with smaller particulates expected to be carried further away (up to 3–4 km) due to slower settling velocities and settling as a very thin layer of sediment (Ref. 419). Although turbidity will be increased locally around the wellhead, in-water drilling cuttings, drilling fluids, and cement material are expected to settle and disperse rapidly (until cement hardens), resulting in short-term and highly localised increase in turbidity near the seabed. Surface discharges will cause the largest (spatial) changes to water quality given influence by surface currents and wind speeds. When cuttings are discharged to the ocean from surface, the larger particles, which represent ~90% of the mass of the cutting and associated mud solids, form a plume that settles quickly to seabed close to the release point (Ref. 430). Barossa dispersion modelling for near-surface water discharges of cuttings and fluids predicted larger particulates would settle close to the discharge location with smaller particulates settling over a larger area up to 1.2 km from the release location (Ref. 419). The average surface current speed within the OA ranges between 0.16 – 0.27 m/s which is analogous to the average surface current speeds for the Barossa, therefore, the modelled distances are considered applicable to the OA. WBF cuttings and adhered fluids typically disperse more widely and settle slower than NADF thus covering a wider seafloor area (Ref. 431). The area and depth of WBF cuttings settlement determines the detectability. A study by the IAOGP showed WBF cuttings discharged from a single well within waters deeper than 300 m could not be detected in sediment at any distance from the well (Ref. 431). Discharges of NADF from the surface settle rapidly (in clumps), under and downstream from the discharge source and may be patchy in distribution, covering a smaller area than WBF discharge plumes (Ref. 432; Ref. 433). Surface discharges of NADF cuttings within water depths <300–400 m are generally deposited within ~100–200 m downstream of the discharge source (Ref. 432; Ref. 434; Ref. 435). NADF cuttings discharged to deeper water are usually deposited to a horizontal distance of 500–1,000 m from the discharge site (Ref. 431; Ref. 433; Ref. 436). A study conducted in the NWS modelled (~70 km to 90 km east of most of the Development's proposed well locations) and surveyed the fate of drilling cuttings and fluids for 3 wells in ~300 m water depths, with a total discharge volume of 1,543 m^3 (Ref. 437). Proxy estimates of total suspended solids (TSS) were made using continuous turbidity measurements (Ref. 437). The study found sporadic and intermittent TSS concentrations (up to 10 mg/L) ~1,000 m from the discharge point lasting over a period of minutes for each discharge event. In context, during cyclones and storms TSS concentrations of tens or hundreds of mg/L over a few hours are common in tropical shallow-water reef environments (Ref. 438; Ref. 439). Planned discharge of cuttings and adhered fluids from the surface will occur intermittently during drilling. Neff states that although the total volumes of muds and cuttings discharged to the ocean during the drilling of a well are large, the impacts in the water column environment are minimal, because discharges of small amounts of materials are intermittent (Ref. 427). Hinwood et al. (Ref. 430) note that a drilling cuttings and fluids plume will dilute by a factor of at least 10 000 within 100 m of the discharge point. In addition, Neff (Ref. 427) indicates that within well-mixed ocean waters (similar to that of the OA), drilling cuttings and fluids will dilute by over 100-fold within 10 m of the discharge point. Using the 10,000 dilution factor, it is predicted that discharges of cuttings and adhered fluids will reach 100 mg/L within 100 m of the MODU within ~16 minutes, assuming a conservative 0.1 m/s current speed. Therefore, changes in water quality associated with increased turbidity are restricted to close to the discharge source. Discharges from the surface are expected to impact a larger area than that of subsea discharges; however, the volumes are much lower and drilling cuttings and adhered fluids will disperse rapidly within the offshore marine environment, resulting in a relatively small footprint of water quality change. A release of cement at the water surface may also contribute to turbidity in the water column. Small volumes of a cement/water mix may be released during equipment washing (~10 m^3 of residual cement per well) or if a mixed batch of cement spoils in the cement unit (up to 78 m^3 and predicted to be a rare event). Modelling by BP (Ref. 286) of cement discharges (~78 m^3 over a one-hour period) for wells in waters 70—530 m deep, suggested that within 2 hours of discharge, suspended solid concentrations ranged between 5–50 mg/L within the extent of the plume (~150 m horizontal and 10 m vertical). Four hours after discharge concentrations were <5 mg/L.

Risk evaluation
Given the intermittent nature of planned drilling discharge and the mixing potential for these discharges influenced by oceanic currents, turbidity impacts to water quality will be limited in duration and water quality is expected to rapidly recover following cessation of the discharges. **Localised and temporary reduction in water quality (toxicity)** Planned discharges of drilling cuttings, drilling fluids, solid additives, cement, control fluids and completion fluids may result in localised and temporary reduction in water quality through chemical toxicity and oxygen depletion during the drilling, operations, and decommissioning phases of the Development. The whole fluids and fluid components of the WBFs currently in use are ‘non-toxic’ or ‘almost nontoxic’ (Ref. 440). Similarly, many drilling fluid additives that are likely to be used, such as barite, bentonite, or guar gum, are listed as an “E” Category fluids under the Offshore Chemical Notification Scheme (OCNS) and considered to pose little or no risk to the environment (PLONOR). Given their inert nature, adverse impacts to water quality from additives to WBF are not predicted to occur. The risk of toxicity from discharges of cement additives (added to dry cement mix), control fluids and completion fluids are expected to be similar to or less toxic than that of drilling fluids and will be released in smaller volumes (~2.5–500 m^3 per well) (see Table 8-44). Rapid dilution of these drilling fluids, control fluids and completion fluids is expected based on dispersion predictions of drilling cuttings plume in the water column (Ref. 286; Ref. 419; Ref. 427; Ref. 437). Neff (Ref. 441) states that the lack of toxicity concentrations and low bioaccumulation potential of the drilling fluids means that the effects of the discharges are highly localised and are not expected to spread through the food web. Cement additives are only considered bioavailable before the cement hardens on the seabed. Terrens et al. (Ref. 442) suggest that once the cement has hardened, the chemical constituents are locked into the cement. CHARM Implementation Network (Ref. 443) also states that once cement has set it is essentially inert and not likely to have chronic toxicity effects. Before the cement hardens, toxic chemical levels from cement additives will also be subject to rapid dispersion and high dilution rates in the open ocean. Ambient water quality in the OA is expected to be high and typical of the offshore marine environment. In high-energy waters, any changes in water quality will be quickly dispersed and settle, resulting in localised impacts to water quality. Discharges of drilling cuttings, drilling fluids, solid additives, cement, control fluids and completion fluids will occur at both the surface and seabed but will occur for short periods (~3 months per well) in each field, with no planned concurrent drilling activities in the same field. This will allow water quality to quickly recover, with no long-term changes to ambient water quality expected. Given the mixing potential for these discharges influenced by oceanic currents, impacts to water quality will be limited in duration and water quality is expected to rapidly recover following cessation of the discharges. Given the potential for limited environmental impact (i.e. within close proximity to the discharge point), the consequence of planned drilling discharges causing localised and temporary reduction in water quality has been evaluated as Incidental (6).
Sediment quality
Localised and temporary reduction in sediment quality (toxicity) Changes in sediment quality may occur as a result of both subsea discharges and surface discharges. Contaminants may accumulate within benthic sediment as a result of chemical additives within drilling fluids and cement additives. Increased sedimentation as a result of cuttings material and cement deposition may alter the physical characteristics of the seabed sediment profile through changes in minerology, sediment structure, particle distribution, particle flow and chemical composition. The area of thickness for seabed deposition depends on a range of factors including: • fluid type adhered to cuttings (WBF or NADF) • amount of fluid retained on cuttings • particle size distribution of cuttings • amount of cement overspill • water depth • ocean current speed and direction at varying depths. Drilling cuttings, drilling fluids and cement discharged during drilling operations are expected to result in the greatest change in sediment quality. Drilling cuttings tend to clump together and settle rapidly, with thicker cuttings piles generally located downstream from the discharge. Cement overspill will harden and potentially smother and alter the benthic substrate permanently (discussed in benthic habitats and associated communities section below). Sediment deposition is expected to be highly localised around the well site (Ref. 427). Field studies summarised by IAOGP (Ref. 431) found that cuttings and adhered WBF discharged at the sea floor could be detected visually or through increases in barium concentrations within 10–150 m of the source, whereas

Risk evaluation
cuttings discharged near the surface accumulated on the sea floor at distances of ~0.1–1 km. Cuttings piles were generally <50 cm high. Surface discharges of smaller cuttings from the drilling facility will disperse more rapidly within the water column, resulting in a thinner layer near the well site. As described in water quality above, cuttings and adhered fluids typically disperse more slowly and cover a wider area when WBF are used rather than NADF (Ref. 431). The physical and chemical persistence of drilling cuttings and fluids within the sea floor sediment depends on the energy of the sea floor (i.e. currents) and the reactivity and biodegradation rate of drilling materials. Most minerals within drilling cuttings are stable and insoluble within water, and most organic chemicals in WBF and NADF are biodegradable (Ref. 431). Studies at 3 continental slope locations where drilling was undertaken in waters 37–119 m deep found that within a year, concentrations of barium from WBF and NADF discharges reduced by 2.4% to 80% respectively within 100 m of the discharge source (Ref. 431). Barite comprises a significant component of drilling fluid systems and therefore barium has been frequently used as a tracer of drilling fluid discharges (Ref. 444). The Jones et al. study near Rankin Bank (Ref. 445), suggests a zone of high impact is likely to be observed 50 – 75 m in all directions from drilling locations and elevated sediment barium concentrations of up to 3 g/kg may be detected at 50 m, decreasing to 1.2 g/kg and 0.75 g/kg at 100 m and 200 m respectively. Other studies including Ellis et al. (Ref. 444) indicate barium sediment concentrations may be slightly elevated (10s of mg/kg) up to 3,000 m from drilling locations before decreasing to background levels. There are no sediment quality guidelines for barium, however the drilling additive barite has a low solubility in seawater (Ref. 446), and has been referred to as practically inert from a toxicological perspective (Ref. 447) and remains on the Oslo and Paris (OSPAR) commission list of PLONOR substances. Barite and bentonite may contain some heavy metal concentrations. Most of the metals detected in drilling muds are present primarily as trace impurities in barite, bentonite clay, or the sedimentary rocks (drill cuttings) in the formations penetrated by the drill bit (Ref. 448). The metals of environmental concern (because of their potential toxicity and persistence) that may be present in some drilling mud barites include cadmium, chromium, copper, mercury, lead, and zinc. These metals are present in barite primarily as inorganic, insoluble sulphide minerals (Ref. 448) and have limited environmental mobility and low bioavailability (Ref. 448). The Environmental, Health, and Safety Guidelines Offshore Oil and Gas Development (Ref. 449) set stock barite limits of 1 mg/kg and 3 mg/kg for mercury and cadmium respectively. These values are representative of the total heavy metal concentrations in barite (both soluble and insoluble) and a study investigating barite solubility and the release of trace metals to the marine environment recorded that <1% of the mercury and 15% of the cadmium dissolved from the barite after one-week exposure in sea water (Ref. 450). Given the low concentrations of heavy metals including mercury and cadmium in stock barite, and due to the sparingly, low solubility of barite and metal sulphides in seawater, it is expected that environmental consequences associated with the presence of trace heavy metals in barite will be negligible. Cement discharges from overflow during drilling operations may affect the seabed within a 10-50 m radius around the well (an area of ~0.007 km^2 for an individual well). Background toxicity levels are expected to be minimal—once cement hardens, its chemical constituents are locked in (Ref. 442), with no potential for chronic exposure. There are no management plans, recovery plans or conservation advice related to sediment quality within the OA. Previous surveys within the OA found the sediment type ranged from soft bioturbated sediment to a combination of sand, silt and mud throughout deeper areas. Sediment quality within the OA is expected to be high and no important or substantial area of seabed is expected to be modified, destroyed, fragmented, isolated or disturbed. Given planned drilling discharges during the Development are expected to result in localised and temporary reduction in sediment quality, the consequence has been evaluated as Incidental (6).
Benthic habitats and associated communities
Alteration of benthic habitats and associated communities A change in marine habitat could occur as a result of planned drilling discharges causing localised alteration of the benthic substrate. Results of the benthic survey found a limited number of benthic infauna were observed in the sediment samples taken from potential DC sites. Benthic infauna were found primarily in deep-sea sediments (1,100–1,200 m) around proposed DCs Semele DC-1 and Semele DC-2, and shallower seabed (100–200 m) at WTR DC-1. The benthic infauna collected included marine worms, polychaete worms and molluscs (Ref. 105, Appendix A). These findings are consistent with previous seabed surveys in the NWS region (Ref. 110; Ref. 115; Ref. 116) whereby polychaetes and crustaceans are the dominant, albeit sparsely distributed, epibenthic and infaunal invertebrates of soft sediment habitats (Ref. 105, Appendix A). These habitat types

Risk evaluation
are widespread in the region and are not considered regionally significant due to their ubiquity and the sparseness of biota supported. Dispersion modelling of drilling cuttings and fluids was completed for various drilling campaigns (Ref. 419, Ref. 437; Ref. 451). Modelling results for the drilling campaign in the Northwest Transition (300 m water depth) predicted seabed deposition of 1 and 10 mm depth of drilling cuttings up to 1.24 km and 400 m, respectively, from the well location (Ref. 451). Similar localised deposition fields from cuttings discharges have been modelled and described previously (Ref. 419, Ref. 437). Meanwhile, cement overspill during drilling activities has the potential to permanently smother and alter the benthic substrate. The extent of overflow may be 10–50 m from each wellbore and is considered a localised impact. Given the localised alteration of the benthic substrate from drilling cuttings and fluids deposition and cement overspill (up to 1.24 km for drilling cuttings and fluids, and up to 50 m for cement overspill), marine habitats affected are limited to predominantly soft sediments with sparsely distributed, epibenthic and infaunal invertebrates which are highly represented throughout the region. Planned drilling discharges during the Development are expected to result in localised alteration of marine habitats of predominantly soft sediments with sparsely distributed, epibenthic and infaunal invertebrates highly represented throughout the region. The consequence of planned drilling discharges causing localised alteration of benthic habitats and associated communities has been evaluated as Minor (5).
Injury or mortality of marine fauna An alteration in marine habitat from planned drilling discharges has the potential for localised burial of benthic organisms / infauna. The planned release of drilling cuttings, drilling fluids, and cement has the potential to cause injury or mortality to benthic organisms, mainly by smothering. Hinwood et al. (Ref. 430) explain that the main environmental disturbance from discharging drilling cuttings and fluids is associated with smothering and burying sessile benthic and epibenthic fauna. A review of the findings of 75 studies relating to the discharge of synthetic-based muds, including NADF, concluded that, generally, benthic community disturbance is very localised and temporary (Ref. 452). The effects on soft-bottom communities from cuttings discharges are rarely seen outside 250–500 m radius of the discharge point (Ref. 453). This statement by Jensen et al. (Ref. 453) is substantiated by observations from a study after an NWS drilling campaign by Jones et al. (Ref. 437). Jones et al. (Ref. 437) found the loss of biota including soft corals, sponges, and hydroids in generally muddy seabed sediments to be within a 75 m radius of the well which was a result of seabed discharges from top-hole drilling. Within 200 m of the well, sponges and soft corals were found to be covered by sediment (Ref. 437). The localised burial of benthic organisms / infauna as observed by Jones et al. (Ref. 437) and Jensen et al. (Ref. 453) is also anticipated for the planned release of drilling cuttings, drilling fluids, and cement during the Development. Recovery of benthic organisms from the effects of smothering could take up to 2 years, based on <1 year for the majority of benthic habitats and communities to recover from seabed disturbance (Ref. 278; Section 8.1) and <1 year for ambient sediment quality to recover from planned discharges of drilling cuttings and fluids. This <2 year recovery timeframe for benthic organisms is considered short-term. Results of the benthic survey found a limited number of benthic infauna were observed in the sediment samples taken from potential DC sites and tie-in locations (14 sites altogether). The benthic infauna collected included marine worms, polychaete worms and molluscs (Ref. 105, Appendix A). These findings are consistent with previous seabed surveys in the NWS region (Ref. 110; Ref. 115; Ref. 116) whereby polychaetes and crustaceans are the dominant, albeit sparsely distributed, epibenthic and infaunal invertebrates of soft sediment habitats found highly represented in the region (Ref. 105, Appendix A). As described above, trace levels of heavy metals may be released to the marine environment from drilling fluid discharges, and consequently have the potential to become bioavailable to, and bioaccumulate within, benthic invertebrates. However, the impact is considered to be limited given the low solubility, limited concentrations and volumes of metals discharged. Given the duration of the activity, and the localised and short-term extent of exposure, injury, or mortality of benthic organisms as a result of planned drilling discharges has been evaluated as Minor (5). Sparsely distributed, epibenthic and infaunal invertebrates occur across the potential DC sites and tie-in locations; therefore, the likelihood of injury or mortality to marine fauna is assessed as Seldom (3). Overall, the risk of planned drilling discharges to benthic habitats and associated communities is Low (7).
KEFs
Change to values and sensitivities

Risk evaluation

Planned drilling discharges may result in changes to the values and sensitivities of KEFs through alteration of benthic habitats and associated communities or injury or mortality to marine fauna.

Three KEFs overlap some of the OA:

- Ancient coastline at 125 m depth contour KEF (Ancient coastline KEF)
- Exmouth Plateau KEF
- Continental slope demersal fish communities KEF.

The Ancient coastline and Exmouth Plateau KEFs both have benthic habitat values. The Chandon DC-1 and DC-2 are within the Exmouth Plateau KEF and WTR DC-1 is ~200 m away from the Ancient coastline KEF. Benthic habitat surveys within the Ancient coastline KEF showed that the benthic habitat comprises smooth seabed with bioturbation and with no epibenthic biota observed. Values associated with the Ancient coastline KEF were not detected within the OA benthic survey (Ref. 105, Appendix A). Benthic habitat surveys within the Exmouth Plateau KEF showed that the benthic habitat is dominated by irregular seabed with bioturbation, irregular seabed floor with bare substrates, and depressions on the sea floor of bare substrate (Ref. 105, Appendix A). Benthic habitats observed within the Exmouth Plateau are highly represented throughout the region.

The Continental slope demersal fish communities KEF has values relating to fish that live and feed near the sea floor and is valued for its high biodiversity and endemism with a range of fish assemblages (Ref. 426). C&D DC-3 is within this KEF and C&D DC-2 is ~1 km away. Benthic habitat surveys within the Continental slope demersal fish communities KEF showed that the benthic habitat mostly comprises irregular and smooth seabed with bare substrates and discrete depressions of bioturbated sediments (Ref. 105, Appendix A). These benthic habitats do not represent site-attached fish habitat and is consistent with observations of few benthic biota (Ref. 105, Appendix A). The fish species observed were predominantly pelagic and demersal species (Ref. 105, Appendix A), which are generally considered transient and highly mobile as they are adapted to living and moving through open water habitats (Ref. 283).

No other DCs are located within KEFs; however, as noted above WTR DC-1 is ~200 m from the Ancient coastline at 125 m depth contour KEF (Ancient coastline KEF) and WTR DC-2 is ~700 m from the KEF.

The planned release of drilling cuttings, drilling fluids, and cement has the potential to cause injury or mortality to benthic organisms mainly by smothering. Previous studies on benthic disturbance from discharges are outlined above and indicate localised and temporary impact.

As discussed above, dispersion modelling for previous drilling campaigns indicates localised impacts to benthic substrate from drilling cuttings and fluids deposition and cement overspill (up to 1.24 km for drilling cuttings and fluids, and up to 50 m for cement overspill) (Ref. 451).

Only 3 DCs are within the KEFs, meaning the extent of any potential impact is highly localised.

Observations from the benthic survey (Ref. 105, Appendix A) highlights KEF values with the potential to be impacted are limited to deep-sea benthic habitats, and pelagic and demersal fish species of the Continental slope demersal fish communities KEF. These habitats and biota are widespread and well represented in the region; and thus, the extent of any potential impact is relatively localised.

Injury or mortality of benthic marine fauna not of regional significance may occur from smothering or burial as a result of planned drilling discharges. Although the conditions to support recolonisation and recovery are present, drilling discharges will remain *in situ* for a long time; therefore, the impact to benthic habitat values of relevant KEFs was determined as Minor (5).

The benthic survey found the OA to predominantly contain soft sediments, sparsely distributed epibenthic and infaunal invertebrates highly represented throughout the region, and highly mobile pelagic and demersal fish species; therefore, the likelihood of planned drilling discharges leading to injury or mortality of marine fauna values of relevant KEFs is assessed as Seldom (3).

Overall, the risk of planned drilling discharges to KEFs is Low (7).

Marine Fauna

Injury or mortality of marine fauna

The planned release of drilling cuttings, drilling fluids and cement has the potential to cause injury or mortality to marine fauna including plankton, fish, marine reptiles, and marine mammals through toxicity.

The toxicity of widely used synthetic-based fluids (NADF) to zooplankton is considered low, with acute toxicity >10,000 ppm for NADF fluids and drilling fluids (Ref. 411). As discussed above, WBF is less toxic than NADF. Therefore, the impact threshold for NADF was used for this evaluation. Neff (Ref. 427) states that in well-mixed ocean waters (such as within the drilling area), drilling mud is diluted by more than 100-fold within 10 m of the discharge point, indicating that, following dilution, concentrations would be well below acute impact levels. This is further demonstrated by Melton et al. (Ref. 454) who used modelling to demonstrate that WBF and NADF cuttings and solids within the water column fall below the United States Environment Protection

Risk evaluation
Agency minimum 96-hour LC50 for drilling fluids within the first few metres of a surface discharge point. The surface current speed used to build the model was 0.17 m/s. Currents in the region are ~0.3–0.4 m/s; therefore, this assessment is considered suitable (Ref. 454). Various other studies support the understanding that only organisms very close to the discharge point will be exposed to chemical concentrations above toxicity thresholds (Ref. 409; Ref. 412; Ref. 413; Ref. 414; Ref. 416). However, a conservative impact area (at which chemical concentrations are expected to result in an impact) of 500 m was set. The OA overlaps these BIAs: • humpback whale BIA (migration) • pygmy blue whale BIA (distribution and migration) • flatback turtle (internesting buffer) • whale shark BIA (foraging) • fish communities (associated with the various KEFs). As discussed above, the Continental slope demersal fish communities KEF overlaps the OA and is valued for a diversity of fish assemblages. Drilling cuttings, drilling fluids and cement material released at the sea surface will be subject to rapid dilution and dispersion within the water column (as described above). Harm to marine fauna has not been demonstrated historically and is considered unlikely (Ref. 427). Neff (Ref. 441) also states that the lack of toxicity and low bioaccumulation potential of the drilling fluids in particular means that the effects of the discharges are highly localised and are not expected to spread through the food web. Marine fauna most sensitive to changes in water quality within 200 m of the discharge are species that are sedentary within the discharge plume and thus exposed for a prolonged period of time. Marine fauna found in the water column, such as fish, marine mammals, and marine reptiles, are expected to actively avoid discharge plumes and associated turbidity and toxicity within the water column and no site attached species are expected to occur given the absence of suitable habitat in these water depths. In addition, there are no known significant fish nursery and/or spawning grounds in the OA (Section 6.3.1). On review, the Conservation Management Plan for the Blue Whale, the Recovery Plan for Marine Turtles in Australia (Ref. 21) and the Conservation Advice Rhincodon typus Whale Shark (Ref. 30) do not list water quality as a key threat to the species. The relevant BIAs do not suggest sedentary behaviour to occur within the OA. Consequently, only transient individuals would have the potential to be exposed to these discharges. The only drilling within the flatback turtle internesting buffer is at the WTR DCs (150 m depth and >50 km from the coast). Whittock (Ref 150; Ref. 151) defined unsuitable flatback turtle internesting habitat as waters >25 m deep and >27 km from the coast. Therefore, it would be very unlikely that turtles would aggregate in the WTR DC area during their internesting period. Based on the nature of receptors, extent of exposure and duration of the activity, these discharges are expected to result in localised, short-term impacts to a small number of individuals, and as such the consequence has been evaluated as Minor (5). Given the drilling cuttings and fluid discharges will be localised and rapidly diluted, and fish, marine mammals and marine reptile species will be transitory, the likelihood of injury/mortality to marine fauna has been evaluated as Unlikely (4). Overall, the risk of planned drilling discharges to marine fauna is Low (8).
Cultural heritage value: Traditional Owners
Change to cultural heritage values No protected underwater cultural heritage sites or artefacts protected by the UCH Act have been identified within the OA (Section 6.5.2). At the time of writing, CAPL understands through consultation with the relevant Traditional Owner groups that there are no known artefacts or specific sites of cultural value associated with the seabed within the OA. Therefore, no impacts to tangible seabed-based cultural heritage (e.g. shipwrecks or archaeology) are expected; and no further evaluation has been undertaken. Potential changes to cultural heritage values from planned drilling discharges includes indirect impacts to intangible Traditional Owner heritage from injury or mortality of marine fauna. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of marine fauna (Section 6.2.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural values may occur from the potential injury or mortality of marine fauna from planned drilling discharges.

Risk evaluation
The consequence level for the potential injury or mortality of marine fauna from planned drilling discharges was evaluated as Minor (5) from an alteration in marine habitat. As such, the consequence of changes to cultural heritage values from planned drilling discharges is also evaluated as Minor (5). Marine habitats across the potential DC sites are known habitats for sparsely distributed, epibenthic and infaunal invertebrates. Based on the sparseness of biota supported at the potential DC sites; a significant adverse change to cultural heritage values is not predicted to occur. Therefore, the likelihood of the consequence occurring is assessed as Seldom (3). The risk of planned drilling discharges to Traditional Owner cultural heritage values is Low (7).

8.8.3 Determination of acceptability

The acceptable level of impact and risk is a function of the magnitude of impact and residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-46 details the determination of acceptability for planned drilling discharges.

Table 8-46: Determination of acceptability for Planned discharges—Drilling

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence level for planned drilling discharges was evaluated as Minor (5). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the impact and risk evaluation for planned drilling discharges. • Consideration of industry standard measures addresses the Minamata Convention requirement to implement the best available techniques and best environmental practices to control releases of drilling cuttings containing mercury. • Prevention measures for planned drilling discharges are well regulated and managed in Australian waters. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations
	The Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the impact and risk of planned drilling discharges based on relevant environmental legislation and other requirements as listed below. • The regulation and management of planned drilling discharges in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures. • The highest consequence level for planned drilling discharges was evaluated as Minor (5). • Any relevant stakeholder feedback in relation to planned drilling discharges has been incorporated in the OPP and assessed in the external context acceptability criteria. To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="2"></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="6">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address relevant requirements/actions within each of the listed legislative requirements considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Environmental, Health, and Safety Guidelines: Offshore Oil and Gas Development (Ref. 449)
Industry guidance for good drilling practices including:
• no overboard discharge of whole NADF
• chemical selection process
• cuttings requirements</td><td rowspan="2">Legislative requirements to manage planned drilling discharges are addressed by adopting these control measures:
CM28: Fluids planned for discharge are subject to the hazardous materials selection process as per CAPL's Hazardous Materials Management Procedure (Ref. 415).
CM30: Implement CAPL's Offshore Drilling Fluid Guidelines; key requirements include); of which key requirements include:
• restrict heavy metal concentrations in barite
• limit NADF concentrations on cuttings
• limit NADF content in tank wash discharge
• no overboard discharge of whole NADF.
CM31: Drilling and cementing procedures will be developed prior to activities commencing, including controls on quantity of cement mixed.</td></tr>
<tr><td>Minamata Convention
The use of best available techniques and best environmental practices to control releases from relevant sources.</td></tr>
<tr><td>Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148)
Action Area A1: (maintain and improve efficacy of legal and management protection) relevant management actions:
• manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to their survival
• manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue.
Management action A4: Minimise chemical and terrestrial discharge.</td><td rowspan="2">EPBC management plan requirements to minimise habitat degradation/ modification/ disruption are addressed by adopting these control measures:
CM01: Prior to drilling or installation, surveys will be conducted to verify that no emergent seabed features / obstacles are present. Where these features are identified, infrastructure location may be amended if practicable.
CM28: Fluids planned for discharge are subject to the hazardous materials selection process as per CAPL's Hazardous Materials Management Procedure (Ref. 415).
CM30: Implement CAPL's Offshore Drilling Fluid Guidelines; of which key requirements include:
• restrict heavy metal concentrations in barite</td></tr>
<tr><td>Approved Conservation Advice for Aipysurus apraefrontalis (Short-nosed Sea Snake) (Ref. 24)
Identifies habitat degradation / modification as a key threat.</td></tr>
</table>

Determination of acceptability		
	Management action: Ensure there is no anthropogenic disturbance in areas where the Short-nosed sea snake occurs, excluding necessary actions to manage the conservation of the species.	• limit NADF concentrations on cuttings • limit NADF content in tank wash discharge • no overboard discharge of whole NADF. **CM31**: Drilling and cementing procedures will be developed prior to activities commencing, including controls on quantity of cement mixed. Therefore, the Development is not considered to be inconsistent with the EPBC management plans
	Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 23) Identifies habitat degradation / modification as a key threat. Management action: Ensure there is no anthropogenic disturbance in areas where the Leaf-scaled sea snake occurs, excluding necessary actions to manage the conservation of the species.	
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25) Management action 5C: Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks. Management action 5D: Implement measures to reduce adverse impacts of habitat degradation and/or modification.	
	Approved Conservation Advice for *Pristis pristis* (largetooth sawfish) (Ref. 27) Implement measures to reduce adverse impacts of habitat degradation and/or modification	
	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29) Review the level and spatial extent of protection measures at key aggregation sites to ensure appropriate levels of protection, and a consistent approach to the designation and implementation of protective measures, are applied. Use Biologically Important Areas (BIA) to help inform the development of appropriate conservation measures, including through the application of advice in the marine bioregional plans on the types of actions which are likely to have a significant impact on the species and updating such conservation measures as new information becomes available.	
	Conservation Advice *Rhincodon typus* Whale Shark (Ref. 30). Identifies habitat disruption as a threat. Management action: Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations (Ningaloo Reef, Christmas Island and the Coral Sea) and along the northward migration route that follows the northern WA coastline along the 200 m	

Determination of acceptability		
	isobath (as set out in the Conservation Values Atlas [Ref. 138])	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 17) Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 18) Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish) (Ref. 26) Approved Conservation Advice for *Milyeringa veritas* (Blind Gudgeon) (Ref. 33) Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 31)	These EPBC management plans for species that may occur within the OA identify habitat degradation / modification as a threat, but do not identify any relevant actions.
Internal context	These CAPL procedures were identified as relevant for this aspect: • Hazardous Materials Management Procedure (Ref. 415) • Wells fluid field guidelines offshore (Ref. 455)	
External context	CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.2.5 and 6.5.2). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM07** and **CM08**). No further feedback was received in relation to planned drilling discharges from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	
Defined acceptable level	The consequence of planned drilling discharges is inherently acceptable because the highest consequence level is Minor (5). Additionally, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan. The impact/risk evaluation does not identify scientific uncertainty against impacts/risks of drilling discharges for each receptor. Although drilling discharges are not listed as a threat to protected matters under documents made or implemented under the EPBC Act, they can impact water quality, sediment quality and benthic habitats and communities, and thus modify the marine habitat for some species. Habitat degradation / modification / disruption and chemical discharges have been identified as a relevant threat to protected matters under documents made or implemented under the EPBC Act; therefore, CAPL will define an acceptable level of impact that aligns with the objectives of these documents. Objectives of the relevant documents are shown below:	
	Plan and relevant objectives	**Demonstration of requirement**
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) <u>Recovery objective</u>: Minimise anthropogenic threats to allow for their conservation status to improve so that they	CAPL considers the impacts of planned drilling discharges to not be inconsistent with the relevant objectives of these EPBC management plans.

Determination of acceptability		
	can be removed from the EPBC Act threatened species list. Interim objective 4: Anthropogenic threats are demonstrably minimised.	By applying EPO12, impacts and risks associated with habitat degradation / modification/ disruption and chemical discharges from planned drilling discharges will be managed at or below the defined acceptable level.
	Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148) Long-term recovery objective: Minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 3: Anthropogenic threats are demonstrably minimised.	
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25) Primary objective: To assist the recovery of sawfish and river sharks in Australian waters with a view to: • improving the population status leading to removal of the sawfish and river shark species from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder recovery in the near future or impact the conservation status of the species in the future. Specific objective: Objective 5: Reduce, and where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species	
	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29) Primary objective: To assist the recovery of the grey nurse shark in the wild, throughout its range in Australian waters, with a view to: • improving the population status, leading to future removal of the grey nurse shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the grey nurse shark in the near future or impact the conservation status of the species in the future. Specific objective: Objective 8: Continue to identify and protect habitat critical to the survival of the grey nurse shark and reduce the impact of threatening processes within these areas.	
	Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 31). Primary objective: To assist the recovery of the white shark in the wild, throughout its range in Australian waters, with a view to:	

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="3"></td><td>improving the population status, leading to future removal of the white shark from the threatened species list of the EPBC Act
ensuring that anthropogenic activities do not hinder the recovery of the white shark in the near future or impact the conservation status of the species in the future.
<u>Specific objective</u>:
Objective 7: Continue to identify and protect habitat critical to the survival of the white shark and minimise the impact of threatening processes within these areas</td><td></td></tr>
<tr><td>Conservation Advice Balaenoptera physalus Fin Whale (Ref. 17)
Conservation Advice Balaenoptera borealis Sei Whale (Ref. 18)
Approved Conservation Advice on Aipysurus foliosquama (Leaf-scaled sea snake) (Ref. 23)
Approved Conservation Advice for Aipysurus apraefrontalis (Short-nosed Sea Snake) (Ref. 24)
Approved Conservation Advice on Pristis clavate (Dwarf Sawfish) (Ref. 26)
Approved Conservation Advice for Pristis pristis (largetooth sawfish) (Ref. 27)
Approved Conservation Advice for Milyeringa veritas (Blind Gudgeon) (Ref. 33)
Conservation Advice Rhincodon typus Whale Shark (Ref. 30).</td><td>These EPBC management plans for species that may occur within the OA identify habitat degradation / modification/ disruption as a threat, but do not identify any relevant objectives.</td></tr>
<tr><td colspan="2">Therefore, CAPL has defined these acceptable levels of impact such that they are not inconsistent with these documents:
management of impacts of the Development must not be inconsistent with the relevant EPBC management plans identified above
no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery
no adverse effect to an important or substantial area of habitat such that a significant impact on marine ecosystem functioning or integrity results
no significant adverse impact to cultural heritage values attributed to the offshore marine area.
CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets these acceptable levels.</td></tr>
</table>

8.8.4 Environmental performance

Table 8-47 lists the EPO defined for planned drilling discharges and the adopted control measures to achieve the outcome.

Table 8-47: Environmental performance for Planned discharges—Drilling

EPO	Adopted control measure
EPO12: No impacts to benthic habitats or marine fauna outside the OA from planned drilling discharges during the Development activity.	**CM01:** Prior to drilling or installation, surveys will be conducted to verify that no emergent seabed features / obstacles are present. Where these features are identified, infrastructure location may be amended if practicable. **CM28:** Fluids planned for discharge are subject to the hazardous materials selection process as per CAPL's Hazardous Materials Management Procedure (Ref. 415). **CM30:** Implement CAPL's Offshore Drilling Fluid Guidelines; of which key requirements include: • restrict heavy metal concentrations in barite • limit NADF concentrations on cuttings • limit NADF content in tank wash discharge • no overboard discharge of whole NADF. **CM31**: Drilling and cementing procedures will be developed prior to activities commencing, including controls on quantity of cement mixed.

8.9 Physical presence—Other marine users

8.9.1 Source

After installation, subsea infrastructure will remain in the OA for the life of the Development. This infrastructure has the potential to interact with other marine users by disrupting commercial activities.

Additionally, the presence of the MODU and vessels in the OA has been identified as having the potential to result in interaction with other marine users.

The OA has a 5 km radius around the outermost expected position of subsea infrastructure.

Table 8-48 lists activities within each phase where interactions with other marine users may occur in the OA.

Table 8-48: Phases and activities that generate Physical presence—Other marine users

Phase	Activity
Installation and commissioning	Pre-lay works
Operations	Operation of the hydrocarbon system
Decommissioning	Other subsea structure decommissioning
Support activities	MODU operations Vessel operations

8.9.1.1 Installation and commissioning

An initiation anchor (deadman anchor) or suction pile will be deployed to fix the end of the flowline in place at the beginning of pipelay. The anchor or pile is installed up to 3,000 m behind the flowline or MEG pipeline and the initiation wire is laid out on the seabed to the end of the flowline or MEG pipeline. These anchors and wires are recovered from the seabed at the end of the pipelay process.

For any third-party infrastructure present in the OA before pre-lay activities occur at Chandon (i.e., the Vocus cable and the proposed Scarborough Trunkline), CAPL will work with the third-party to manage potential interactions.

8.9.1.2 Operations

The hydrocarbon infrastructure associated with this activity will be installed in the OA and will remain in place for the life of the Development. The OA provides a conservative 5 km buffer around the outermost extent of the infrastructure and activities; however, this is not an exclusion zone preventing other marine users from accessing the area.

The potential for interactions with other marine users is limited to where these users interact with the sea floor. As a result, only commercial fisheries that use trawl fishing methods were identified as having the potential to interact with the hydrocarbon infrastructure.

To protect a petroleum well, structure or any equipment in an offshore area, NOPSEMA can specify a petroleum safety zone (PSZ), which prohibits vessels from entering or being present in that specified area and up to within 500 m from it. A PSZ may be implemented for the infrastructure in the WTR field as this field is shallower (~150 m water depth) than the others.

The potential risks to trawling vessels from subsea infrastructure includes disrupting fishing efforts (because vessels must avoid the infrastructure) and damaging trawling gear that contacts the infrastructure.

If third-party infrastructure is installed in the OA during operations at Chandon (i.e., proposed Scarborough Trunkline), CAPL will work with the third-party to manage interactions.

8.9.1.3 Decommissioning

Some subsea structures, such as small, inert items like grout bags (Section 4.3.5.7), may remain in situ after decommissioning if all requirements are met. CAPL's decommissioning philosophy is described in Section 4.3.5.1.

8.9.1.4 Support activities (all phases)

The MODU will be present in the OA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well interventions). A safe navigation area (SNA) will be established around the MODU (or HWIU if used for decommissioning). This is a temporary area with a 500 m radius that excludes other marine users from the MODU for safety reasons.

An SNA is also likely to be implemented for PLV and large construction vessels. Any SNA will be in place for the duration of the relevant activities. A larger (2 km) cautionary zone may also be established.

Vessels are present in the OA during all phases of the Development. The highest number of vessels working concurrently across the OA is estimated at 5–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation may take as long as 15 months per field and while concurrent activities are possible during this time, they will be intermittent and would occur for only a small portion of the overall duration.

These vessels have the potential to disrupt other marine users, including commercial shipping, fishing vessels and other industries. For any third-party infrastructure (i.e., the Vocus cable and proposed Scarborough Trunkline) installed in the OA before activities begin at Chandon, CAPL will work with the third-party to manage potential interactions.

8.9.2 Impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the OA that may be impacted by interaction with other marine users:

- commercial fisheries
- petroleum activities
- commercial shipping.

Due to the distance offshore (~47 km at the closest point from the Montebello Islands, ~55 km at the closest point from Barrow Island and ~125 km from Onslow) and ~150–1 400 m water depths, tourism and recreation activities within the OA are expected to be unlikely. The OA does not overlap any designated Department of Defence areas. Therefore, these impacts are not expected and are not evaluated further.

Table 8-49 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to interaction with other marine users in the OA.

Table 8-49: Risk evaluation for Physical presence—Other marine users

Impact and/or risk level summary						
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	-	Unplanned interactions with commercial fisheries may result in: • Change to the functions, interests, and activities of other marine users.	6	3	Low (8)
		Unplanned interactions with petroleum activities and commercial shipping may result in: • Change to the functions, interests, and activities of other marine users.	6	3	Low (8)

Risk evaluation
Commercial fisheries

Change to the functions, interests and activities of other marine users

The loss of fishing grounds due to the presence of the SNA is limited to a small area (500 m radius) around specific vessels and the MODU during certain activities (e.g. drilling, pipelay). These activities are not long-term, with drilling taking ~3 months per well and installation taking ~15 months at its longest.

A 500 m PSZ may be established for safety purposes around certain infrastructure (e.g. the shallower WTR wells), which would be in place for the life of the Development.

A 2 km radius cautionary zone may also be established around the MODU and large construction vessels to ensure that fishing and third-party vessels are aware of the presence of vessels and infrastructure but does not necessarily exclude them from the area.

Commonwealth-managed Fisheries:

Several Commonwealth-managed fisheries have licences that overlap the OA and thus have the potential to be displaced from the OA. However, as identified in Section 6.3.1, only 3 Commonwealth-managed commercial fisheries recorded fishing effort within the OA from 2010–2020 (Ref. 239), based on the most recent data available. The permit and vessel details for these 3 fisheries are:

- North-West Slope Trawl Fishery—2020–2021 season: 6 permits with 4 active vessels.
- Western Deepwater Trawl—2020–2021 season: 11 permits with one active vessel.
- Western Tuna and Billfish Fishery—This is a pelagic longline and minor-line fishery, which may be impacted by the Development's support activities. In 2021 the WTBF had 94 fishing permits, but only 2 pelagic longline vessels were active during this season.

Fishing activity within the Commonwealth trawl fisheries is restricted to waters between the 200 m isobath and the outer boundary of the Australian Fishing Zone (Ref. 456, Ref. 457). Therefore, no trawl fishing is expected to occur around the WTR field, which is only ~150 m deep.

State-managed Fisheries:

As identified in Section 6.3.1.2, only the Mackerel Managed Fishery had fishing effort (2012–2021) that overlapped the OA. Fishing effort records obtained from DPIRD (Ref. 458) for State-managed commercial fisheries indicate that fishing effort within the OA varies each year, with <3 vessels active from 2012–2014 and 2016–2018.

Commercial fishing activity will be excluded from the SNAs (within 500 m of the MODU or large construction vessels) for temporary periods only, e.g. during specific activities such as drilling, P&A and pipelay. This SNA represents a very small portion of the managed fishery areas, and fishing effort within the OA has historically been low. This is considered an insignificant area in relation to the size of the fishing grounds across the NWS. In addition, prior notification through stakeholder consultation and the issuing of a notice to mariners will inform fishers of operations to minimise impacts on their activities.

Infrastructure will be installed on the seabed and remain throughout the life of the Development, resulting in potential interaction where users interact with either the seafloor or the water column where these structures exist. This infrastructure includes manifolds, wellheads and other infrastructure around tie-in and DC locations, plus production flowlines, MEG pipelines and umbilicals.

A 7-year field survey on sedimentation-induced burial of marine pipelines was undertaken in the NWS region, and indicated that subsea pipelines experienced significant lowering into the seabed due to sediment mobility

Risk evaluation
and scour, mostly within 2 years of pipelay (Ref. 279; Ref. 280). T Biological activity such as crustaceans and demersal fish tunnelling under equipment also contributed to embedment. The relatively low profile of flowlines (~24″ pipeline diameter) and structures (maximum height of ~13 m) means that partial burial of some objects will likely occur over time (depending on size). The presence of the subsea infrastructure and support activities is expected to have a low impact on Commonwealth or State commercial fishing operations (i.e. catch losses; equipment damage), therefore, CAPL has ranked the consequence to commercial fishing from unplanned interactions as Incidental (6). Offshore construction of the GFP began in 2010, and included drilling, installation, commissioning, and start-up activities, with operations beginning in 2016. The vessel fleet used for the construction phase of the GFP was very large. At the time of writing, no incidences of commercial fishing activities interacting with the infrastructure or with support activities has been communicated to CAPL since GFP construction began in 2010. The OA is located in areas of low commercial trawl fishing activity and overlaps only ~0.218 % of fishery management areas. Exclusion areas are small (500 m around some vessels and the MODU) and are temporary. If any permanent PSZs are implemented, they would also have a small spatial extent (500 m). Based on GFP experience, commercial fishing interaction with subsea infrastructure is expected to be limited. Therefore, CAPL has ranked the likelihood of unplanned interactions with commercial fishing as Unlikely (4). Overall, the risk of interaction with commercial fisheries is Low (8).
Petroleum activities
Change to the functions, interests and activities of other marine users The OA is in the Northern Carnarvon Basin which is one of Australia's premier hydrocarbon-producing provinces containing an established network of oil, condensate, and gas production infrastructure. The closest facility to the OA is Santos' John Brookes Platform, which is ~15 km from the OA. The OA for the Development has been defined to include the extent of all planned activities across multiple fields. An existing pipeline—the CAPL-operated Wheatstone trunkline—crosses the OA. Woodside plans to undertake appraisal drilling, decommissioning and survey activities in the neighbouring title WA-49-L from Quarter 3 2023, with potential for a later start in 2024 or 2025 (Ref. 258). The proposed Woodside OA and survey area for these activities will overlap with the Development's OA at WA-5-R. An existing cable—the Vocus-operated Highclere Cable—also crosses the OA. A new trunkline (the Scarborough Trunkline) has been proposed, which would cross the OA. CAPL will work with Woodside, Vocus and any other third-parties who may have future development plans in the vicinity of the OA, to safely manage any interactions. Because the OA does not prohibit access to other marine users, and any exclusion area will be restricted to 500 m PSZ for drilling and decommissioning activities, the physical presence of support vessels is not expected to cause significant impacts to other petroleum activities and the risks are considered limited. Therefore, CAPL has ranked the consequence of interaction with petroleum activities to be Incidental (6). The operation of support vessels is commonplace and well-practised nationally and internationally—the risks associated with interactions are well understood by the industry. Therefore, CAPL has ranked the likelihood of unplanned interactions with other petroleum activities as Seldom (3). Overall, the risk of interaction with petroleum activities is Low (8).
Commercial shipping
Change to the functions, interests and activities of other marine users The presence of support vessels and the MODU within the OA may disturb shipping activity in the region. Although the OA is predominantly outside major shipping fairways and commercial vessel traffic density, a portion of the OA near the proposed G&E pipeline overlaps part of the NWS shipping fairway system (Figure 6-33). The presence of the MODU and vessels within the OA is not expected to affect most commercial shipping operators; however, intermittent deviations may be required within the OA as the Development unfolds, in particular during drilling and decommissioning activities when an SNA is required around the MODU. SNAs are temporary and comprise a small radius (500 m) around the MODU; therefore, any deviations would be minor and thus have a negligible impact on travel times or fuel use of commercial shipping vessels. Because of the small overlap with the shipping fairway and the relative low-density shipping activity throughout the rest of the OA, the presence of support vessels for the Development is not expected to impact the functions, interests, or activities of commercial shipping. Therefore, CAPL has ranked the consequence of unplanned interaction with shipping activities as Incidental (6) and the likelihood as Seldom (3).

Risk evaluation
Overall, the risk of interaction with shipping activities is Low (8).

8.9.3 Determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-50 details the determination of acceptability for interaction with other marine users.

Table 8-50: Determination of acceptability for Physical presence—Other marine users

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence level for unplanned interaction with other marine users was evaluated as Incidental (6). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the risk evaluation for unplanned interaction with other marine users. • Offshore commercial vessel operations are commonplace and well-practised nationally and internationally. Prevention measures for unplanned interaction with other marine users are well regulated and managed in Australian waters. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations
	The Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the impact and risk of unplanned interaction with other marine users based on relevant environmental legislation and other requirements as listed below. • The regulation and management of interactions with other marine users in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures. • The highest consequence level for unplanned interaction with other marine users was evaluated as Incidental (6). • Any relevant stakeholder feedback in relation to unplanned interaction with other marine users has been incorporated in the OPP and assessed in the external context acceptability criteria. To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
	Feasible Development alternatives were considered, comparing environmental impacts and risks of each option. The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5). The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.

Determination of acceptability		
Relevant environmental legislation and other requirements	Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.	
	Requirement	**Demonstration of requirement**
	***Navigation Act 2012* (Cth), MARPOL and various Marine Orders** (as appropriate to vessel class) enacted under this Act. Regulates navigation and shipping including Safety of Life at Sea, and specific requirements for navigational lighting. Several Marine Orders enacted under this Act apply directly to offshore petroleum exploration and production activities	Legislative requirements to manage interaction with other marine users are addressed by adopting these control measures: **CM32:** Before commencing offshore activities, relevant agencies will be notified of activities, vessel movements, and requested exclusion zones, to enable them to generate radio navigation warnings and/or Notice to Mariners. **CM33**: Relevant parties will be advised of the commencement of key phases of activities and any exclusion zones and other relevant information as requested. **CM34:** MODUs and vessels will meet crew competency, navigation equipment, and radar requirements of the Chevron Marine Standard Non Tankers (Ref. 284). **CM35**: Consultation with relevant persons will be undertaken for all petroleum activities as part of EP development as per the OPGGS(E)R.
	Chapter 6, Part 6.6 of the OPGGS Act **Safety Zones and the Area to be Avoided NOPSEMA Guidance Note** (Ref. 459) For the protection of petroleum wells, structure and equipment, safety zones of up to 500 m can prohibit unauthorised vessels from entering or being present.	**CM33**: Relevant parties will be advised of the commencement of key phases of activities and any exclusion zones and other relevant information as requested.
	Offshore Petroleum Decommissioning Guideline (Ref. 76) Applies to all petroleum structures, equipment, wells, and property brought onto the area under the authority of a title granted under the OPGGS Act, during any stage of operations. Decommissioning activities are the responsibility of the registered holder of the title under which the activities take place.	**CM05:** Implement CAPL's Asset Retirement philosophy, which aligns with legislative requirements.
	Section 572 Maintenance and removal of property Policy (Ref. 81) States that: • all property is designed, installed and operated with the intention of being removed when it is no longer in use • when a field permanently ceases production, all remaining property is removed if it is not to be used in connection with the operations • a comparative assessment may be used in an EP as a method to	

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td>evaluate feasible alternatives to removing property
• when an evaluation of impacts and risks are required by the OPGGS(E)R, they must incorporate a holistic evaluation of the impacts and risks of the alternative arrangements (including those impacts and risks that may arise from removing or relocating property outside the title area) and consider community interest.</td><td></td></tr>
<tr><td>Internal context</td><td colspan="2">These CAPL procedures were identified as relevant for this aspect:
• Stakeholder engagement (Section 3)
• Maritime Safety Information
• Chevron Marine Standard Non Tankers (Ref. 284)
• Control of Work (CoW) Process</td></tr>
<tr><td>External context</td><td colspan="2">CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment.
No feedback was received in relation to interaction with other marine users from Phase 1 stakeholder consultation.</td></tr>
<tr><td rowspan="4">Defined acceptable level</td><td colspan="2">The consequence of interaction with other marine users is inherently acceptable because the highest consequence level is Incidental (6).
The risk evaluation does not identify scientific uncertainty against risks of physical presence for each receptor.
There are no relevant EPBC management plans for this aspect.</td></tr>
<tr><td>Plan and relevant objective</td><td>Demonstration of requirement</td></tr>
<tr><td>N/A</td><td>N/A</td></tr>
<tr><td colspan="2">Therefore, CAPL has defined these acceptable levels of impact:
• no substantial impact to the functions, interests and activities of other marine users.
CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets these acceptable levels.</td></tr>
</table>

8.9.4 Environmental performance

Table 8-51 lists the EPOs defined for unplanned interaction with other marine users and the adopted control measures to achieve the outcome.

Table 8-51: Environmental performance for Physical presence—Other marine users

EPO	Adopted control measure
EPO13: Reduce disruption to other marine users' activities within the OA to no greater than necessary.	**CM05:** Implement CAPL's Asset Retirement philosophy, which aligns with legislative requirements. **CM32:** Before commencing offshore activities, relevant agencies will be notified of activities, vessel movements, and requested exclusion zones, to enable them to generate radio navigation warnings and/or Notice to Mariners. **CM33**: Relevant parties will be advised of the commencement of key phases of activities and any exclusion zones and other relevant information as requested. **CM34:** MODUs and vessels will meet crew competency, navigation equipment, and radar requirements of the Chevron Marine Standard Non Tankers (Ref. 284). **CM35:** Consultation with relevant persons will be undertaken for all petroleum activities as part of EP development as per the OPGGS(E)R.

8.10 Physical presence—Marine fauna

8.10.1 Source

Vessel, helicopter and flowline flooding operations have the potential to result in unplanned interactions with marine fauna. Unplanned interactions include vessel strike (collision between marine fauna and a moving vessel), bird strike (collision between a bird and a helicopter) and marine fauna entrainment and impingement.

Water intake for flowline flooding operations during hydrotesting and pre-commissioning has the potential to entrain and impinge marine fauna. Entrainment is the unwanted passage of marine fauna through a water intake, which is generally caused by an absent or inadequate water intake screen. Impingement is the physical contact of marine fauna with such a barrier structure (screen) due to intake velocities that are too high to allow marine fauna to escape.

These unplanned interactions with marine fauna are considered credible threats to EPBC Act listed marine fauna during the Development.

Table 8-52 lists the activities within each phase that have the potential for unplanned interactions with marine fauna in the OA.

Table 8-52: Phases and activities that interact with Physical presence—Marine fauna

Phase	Activity
Installation and commissioning	Hydrotesting and pre-commissioning
Operations	Maintenance and repairs
Support activities	MODU operations Vessel operations Helicopter operations

8.10.1.1 Installation and commissioning

Marine fauna entrainment and impingement is possible during flowline flooding operations conducted for hydrotesting (FCGT, leak testing) and pre-commissioning activities during the installation and commissioning phase. Flowline reflooding operations conducted for major repair activities during the operations phase can also be a source of marine fauna entrainment and impingement.

FCGT activities require flowlines to be flooded with FCGT media to send gauge pigs from one end of the flowline to the other. FCGT media comprises sea water sourced from the marine environment, MEG and freshwater conditioning chemicals. Freshwater conditioning chemicals generally comprise oxygen scavengers, biocides, corrosion inhibitor, which are added to the sea water to prevent the risk of corrosion and microorganism growth in the flowlines. The flowlines remained filled with FCGT media for leak testing and pre-commissioning activities.

Sea water intake for flooding operations is expected to be a one-off activity per field, planned to occur during hydrotesting and pre-commissioning activities (these activities are estimated to take one month per field).

8.10.1.2 Operations

In the unlikely event major repairs are required for the flowlines, pipeline repair activities may require the flowlines to be dewatered and reflooded. Water for reflooding will again be sourced from the marine environment and freshwater conditioning chemicals added.

Pipeline repair reflooding operations may occur during the operations (for ~1 month). Leak testing of the repaired flowline may involve hydrotesting and pre-commissioning techniques to determine the flowline's structural integrity.

8.10.1.3 Support activities (all phases)

Vessel strike may occur during vessel movements within the OA. Vessels undertaking Development activities within the OA include support vessels, anchor-handling tugs, installation vessels and MODU.

Locations where there is a co-occurrence of high numbers of vessels occurring simultaneously in marine fauna aggregation areas are considered high-risk for vessel strike (Ref. 460). The highest number of vessels working concurrently across the OA is estimated to be 5–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation may take as long as 15 months per field (C&D field) and while concurrent activities are possible during this time, they will be intermittent and would occur for only a small portion of the overall duration.

The MODU will be present in the OA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well workovers). The MODU will move between fields but will spend most of the time at the DCs, where it will be stationary. The MODU has minimal movement capability and likely will require at least 2 support vessels to help move and position it. If the MODU is towed, the tow speed will be slow at ~2 knots.

The potential for bird strike from helicopter operations is limited to the drilling, installation, and decommissioning phases of the Development. Installation vessels and the MODU will be serviced by helicopters (estimated ~15-16 flights per week for the largest vessel; ~5 flights per week for the MODU).

8.10.2 Impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the OA that are susceptible to unplanned interactions with marine fauna:

- seabirds and shorebirds
- fishes, including sharks and rays
- marine reptiles
- marine mammals
- cultural heritage value: Traditional Owners.

Table 8-53 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to unplanned interactions with marine fauna in the OA.

Although fish may potentially be impacted by unplanned interactions with marine fauna (from vessel strike or entrainment/entrapment) (Table 8-53), it would only have individual impacts, and is not expected to result in a change in the viability of the population of commercially important species or demersal fish assemblages. Only one State- and 3 Commonwealth-managed fisheries have recorded historical fishing effort in the OA.

Therefore, impacts to commercial fisheries or a change in values and sensitivities of the fish assemblage values of the Continental slope demersal fish communities KEF from unplanned interactions with marine fauna are not expected, and are not evaluated further.

Table 8-53: Risk evaluation for Physical presence—Marine fauna

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	-	Unplanned interactions with birds may result in: • injury or mortality of marine fauna.	6	3	Low (8)
		Unplanned interactions with fishes, including sharks and rays may result in: • injury or mortality of marine fauna.	6	3	Low (8)
		Unplanned interactions with marine reptiles may result in: • injury or mortality of marine fauna.	6	3	Low (8)
		Unplanned interactions with marine mammals may result in: • injury or mortality of marine fauna.	6	3	Low (8)
		Injury or mortality of marine fauna may result in: • change to cultural heritage values.	6	3	Low (8)

Risk evaluation
Birds
Injury or mortality of marine fauna (aerial strike) Bird strikes may occur on the helidecks of the MODU and large installation vessels during helicopter passenger transfer/crew change operations. Locations where there is a co-occurrence of high number of helicopter flights in bird resting areas are considered high-risk areas for bird strike (Ref. 461). Helicopter transfer frequency may be ~15-16 times per week for a large vessel and ~5 flights per week on the MODU during the drilling, installation, and decommissioning phases. The OA does not overlap known bird resting BIAs. Despite the potential high number of helicopter flights in the OA during short-term Development phases (i.e. not operations), the absence of known bird resting BIAs in the OA will reduce the likelihood for bird strike. Unmanned offshore installations are found to attract large number of birds for use as a resting location (Ref. 461). Vessels in the OA may act as temporary resting locations for birds. The MODU and installation vessels used for the Development will be manned and their presence in the OA will be sporadic and temporary during the Development. Given the temporary presence and manned status of vessels equipped with helidecks in the OA, large numbers of resting birds are not expected—people are a deterrent for birds. Deaths recorded from instances of bird strike highlight the potential for injury and death to individual EPBC Act listed marine fauna. The OA contains EPBC Act listed bird species that may, or are known to, occur, and it overlaps the breeding BIA for the wedge-tailed shearwater. The Wildlife Conservation Plan for Seabirds (Ref. 35) identifies aircraft as a key threat; however, this plan focuses on aircraft flying close to onshore breeding colonies. If a bird strike occurred during the Development, injury and death to individual EPBC Act listed species would not decrease the population size (at a local or regional scale). As individual deaths are not expected to have a detrimental effect on the overall population; this event would result in a limited environmental impact (individual impacts). Therefore, unplanned interactions between helicopters and marine fauna was evaluated as having the potential to result in an Incidental (6) consequence. During the 3-year construction period for the ~200 km Gorgon Gas trunkline to Barrow Island, no incidents of bird strike were reported (Ref. 462). Since GFP operations began in 2016, no incidents of bird strike have

Risk evaluation
been reported (Ref. 207; Ref. 463; Ref. 464). Based on previous experience in the OA, CAPL considers the likelihood of the consequence occurring is Seldom (3). The risk ranking for unplanned interactions between helicopters and marine fauna for birds is Low (8).
Fishes, including sharks and rays
Injury or mortality of marine fauna (vessel strike) Vessels undertaking Development activities in the OA have the potential for unplanned vessel strike with large fish species that commonly dwell at or near surface waters. A review of EPBC Act listed fish species in the OA found the whale shark to be the only fish species susceptible to vessel strike, with the Conservation Advice Rhincodon typus Whale Shark (Ref. 30) identifying vessel disturbance as a key threat to the species. Whale sharks tagged off Western Australia (Ref. 170; Ref. 174) spend ~25% of their time <2 m from the surface and >40% of their time in the upper 15 m of the water column. The eastern edge of the OA (Figure 6-22) overlaps the whale shark foraging BIA in the deeper oceanic waters along the 200 m isobath, where seasonal migration of whale sharks occurs mainly between July to November (Ref. 30). However, as there are no known aggregation areas within the OA and given the seasonal and transient presence of the species, whale shark numbers are not expected be significant. Laist et al. (Ref. 465) identify that larger vessels with reduced manoeuvrability that move >10 knots may cause fatal or severe injuries from vessel strike, with the most severe injuries caused by vessels travelling >14 knots. Although the OA overlaps the whale shark foraging BIA, vessels will be slow-moving whilst implementing the activities associated with the Development, therefore vessel strike resulting in fauna death or severe injuries is not anticipated. If a vessel strike occurred during the Development, causing the injury and death of an individual whale shark, this is not expected to have a detrimental effect on the overall whale shark population, and would result in a limited environmental impact (individual impacts); thus, unplanned interactions between vessels and marine fauna is evaluated as having the potential to result in an Incidental (6) consequence. During the 3-year construction period for the ~200 km Gorgon Gas trunkline to Barrow Island, no incidents of vessel strike to fish, including whale sharks, were reported (Ref. 462). Since GFP operations began in 2016, no incidents of vessel strike have been reported (Ref. 207; Ref. 463; Ref. 464), and the National Ship Strike Database (Ref. 466) does not identify any previous incidents of whale shark strikes in the OA. The likelihood of the consequence occurring is Seldom (3). The risk ranking for unplanned interactions between vessels and fish is Low (8). **Injury or mortality of marine fauna (entrainment and impingement)** Flooding and reflooding flowlines with sea water in the OA has the potential for unplanned entrainment and impingement of juvenile fish, eggs, and larvae. Fish may be subject to impingement (fauna trapped against plant intake screens by force of the flowing water) and/or entrainment (fauna actively drawn into plant intake). A 40-year literature review on the impacts of entrainment and impingement of fish by Barnthouse (Ref. 467) found substantial evidence that impacts related to entrainment and impingement are generally small compared to natural mortality rates of susceptible life stages and impacts to populations from fishing. Water winning for hydrotesting would only be undertaken once for each field, during commissioning of flowlines, and if major repairs were required. Because the impact of entrainment and impingement of fish is insignificant relative to natural mortality, unplanned interactions between flooding and reflooding operations and marine fauna is evaluated as having the potential to result in an Incidental (6) consequence. There are no known significant fish nursery and/or spawning grounds in the OA, which reduces the potential for fish entrainment and impingement. The likelihood of the consequence occurring is Seldom (3). The risk ranking for unplanned interactions between flooding and reflooding operations and fish is Low (8).
Marine reptiles
Injury or mortality of marine fauna (vessel strike) Vessels undertaking Development activities in the OA have the potential for unplanned vessel strike with marine reptile species when these species surface to breathe. A review of EPBC Act listed marine reptile species in the OA found marine turtles to be susceptible to vessel strike. The OA overlaps the flatback turtle internesting buffer but does not overlap critical habitat or aggregation areas for sea snakes. Although the OA overlaps the flatback turtle internesting buffer, Whittock (Ref 150; Ref. 151) defined unsuitable flatback turtle internesting habitat as waters >25 m deep and >27 km from the coast. Only the WTR and C&D fields, which are at depths >25 m deep and further than 27 km from the closest coast, have infrastructure within the internesting buffer. Therefore, it would be very unlikely that turtles would aggregate in

Risk evaluation
the OA during their internesting period. Consequently, only a small number of transient marine turtles are expected to be present. Marine turtles are known to avoid vessels by rapidly diving; however, their ability to respond varies greatly depending on the speed of the vessel. Hazel et al. (Ref. 369) reported that the number of turtles that fled vessels decreased significantly as vessel speed increased. Slow vessel speeds combined with marine turtles vessel avoidance behaviours will reduce the likelihood of lethal collisions during internesting periods in the OA. Given the offshore location of the OA, only a small number of transient marine turtles are expected to be present. If a vessel strike occurred during the Development, injury, and death to individual EPBC Act listed species would not decrease population size (at a local or regional scale) and would result in a limited environmental impact (individual impacts). Therefore, unplanned interactions between vessels and marine reptiles is evaluated as having the potential to result in an Incidental (6) consequence. During the 3-year construction period for the GFP feed gas pipelines, extending ~200 km to Barrow Island, no incidents of vessel strike to marine reptiles were reported (Ref. 462). Since GFP operations began in 2016, no incidents of vessel strike have been reported (Ref. 207; Ref. 463; Ref. 464). Marine turtles are also not expected to be common as far offshore as the OA, reducing the probability of a vessel strike. The likelihood of the consequence occurring is Unlikely (4). The risk ranking for unplanned interactions between vessels and marine reptiles is Low (8). **Injury or mortality of marine fauna (entrainment and impingement)** Flooding and reflooding flowlines with sea water in the OA has the potential for unplanned entrainment and impingement of marine turtle hatchlings. Marine turtle hatchlings may be subject to impingement and entrainment because hatchlings are known to drift passively within ocean currents and are unlikely to out-swim the current generated by water intake for pipeline flooding (Ref. 468; Ref. 469). If entrainment and impingement of marine turtle hatchlings occurred during the Development, injury and death to individual EPBC Act listed species would not decrease population size (at a local or regional scaled) any more than would usually occur due to natural variation. Because the impact of entrainment and impingement to marine turtle hatchlings is insignificant relative to natural mortality, unplanned interactions between flooding and reflooding operations and marine fauna is evaluated as having the potential to result in an Incidental (6) consequence. As mentioned above, only a small number of transient marine turtles are expected to be present in the OA despite overlap with marine turtle internesting habitat critical—the OA is offshore (>55 km from Barrow Island at its closest point) and with increasing water depths (up to ~1,400 m). Marine turtles prefer the proximity of the coast and relatively shallow water depths during internesting periods, which reduces the potential for entrainment and impingement. The likelihood of the consequence occurring is Seldom (3). The risk ranking for unplanned interactions between flooding and reflooding operations and marine reptiles is Low (8).
Marine mammals
Injury or mortality of marine fauna (vessel strike) Vessels undertaking Development activities in the OA have the potential for unplanned vessel strike with marine mammals. A review of EPBC Act documents for listed marine mammal species in the OA found humpback whales and pygmy blue whales are susceptible to vessel strike because the OA overlaps their respective BIAs for migrating. The southern edge of the OA overlaps the humpback whale migration BIA where migration is predicted from June to October (Section 6.2.3.1.1). Satellite tracking and acoustic detection studies indicate that pygmy blue whales are likely to travel predominantly to the north-west of the OA in deeper waters, particularly on their southern migration (November to December), but also during the northern migration (April to August) (Section 6.2.3.1.2). Entrainment and entrapment in water intakes is only a risk for small marine fauna, and not credible for marine mammals. Hence it is not evaluated further. Cetaceans are naturally inquisitive marine mammals that are often attracted to offshore vessels and facilities. The reaction of whales to the approach of a vessel is quite variable. Some marine mammal species, such as humpback whales, can detect and change course to avoid a vessel (Ref. 470), some species remain motionless when near a vessel, while others are curious and often approach vessels that have stopped or are slow moving, although they generally do not approach, and sometimes avoid, faster-moving vessels (Ref. 465). As described above, severe or lethal injuries to marine fauna from vessel strike are more likely to occur with larger or faster vessels travelling >10 knots. For large whale populations, the probability of lethal injuries resulting from collisions decreased to <50% when vessels travelled at speeds ≤10 knots (Ref. 465). Stationary

Risk evaluation
or slow-moving vessels have an extremely low risk of colliding with marine mammals. While it is likely that greater numbers of individuals would be encountered during the short duration survey or installation activities, if these occur during migration periods, vessels undertaking these Development activities in the OA will move slowly. There have been few recorded instances of cetacean deaths in Australian waters. Mackay et al. (Ref. 471) report that four fatal and three non-fatal collisions with southern right whales were recorded in Australian waters between 1950 and 2006, with one fatal and one non-fatal collision reported between 2007 and 2014. The death of a Bryde's whale in Bass Strait in 1992 (Ref. 474) was also recorded, noting this data indicates deaths are more likely to be associated with container ships and fast ferries. Due to the stationary or slow speeds of vessels undertaking Development activities in the OA, the generally low number of vessels within the OA at any time, and as incidents have been demonstrated to be very rare, vessel strike resulting in death or severe injuries to marine mammals is not anticipated. If a vessel strike occurred during the Development, injury and death to individual EPBC Act listed species will not decrease population size (at a local or regional scale) and would result in a limited environmental impact (individual impacts). Therefore, unplanned interactions between vessels and marine fauna has been evaluated as having the potential to result in an Incidental (6) consequence. During the 3-year construction period for the ~200 km Gorgon Gas trunkline to Barrow Island, no incidents of vessel strike to marine mammals were reported (Ref. 462). Since GFP operations began in 2016, no incidents of vessel strike have been reported (Ref. 207; Ref. 463; Ref. 464), and the National Ship Strike Database (Ref. 472) does not identify any previous incidents of vessel strikes in the OA. The likelihood of the consequence occurring is Seldom (3). The risk ranking for unplanned interactions between vessels and marine mammals is Low (8).
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from unplanned interactions with marine fauna includes indirect impacts to intangible Traditional Owner heritage from injury or mortality of marine fauna. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of marine fauna (Section 6.2.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural values may occur from the potential injury or mortality of marine fauna from unplanned interactions. The consequence evaluations to these receptors are provided above; and the highest consequence level for unplanned interactions with marine fauna was evaluated as Incidental (6) from the potential for injury or mortality of marine fauna resulting from vessel or aerial strike; or impingement or entrainment. As such, the consequence of changes to cultural heritage values from unplanned interactions with marine fauna is also evaluated as Incidental (6). Given the limited environmental impact (individual impacts), and no incidents of vessel or helicopter strike on the Gorgon Gas Development to date; the likelihood of the consequence occurring is assessed as Seldom (3). The risk ranking for unplanned interactions with marine fauna to Traditional Owner cultural heritage values is Low (8).

8.10.3 Determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-54 details the determination of acceptability for interaction with marine fauna.

Table 8-54: Determination of acceptability for Physical presence—Marine fauna

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="6">Principles of ESD</td><td colspan="2">(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation</td></tr>
<tr><td colspan="2">The Development is consistent with principle of ESD (b) for this aspect as:
• The highest consequence level for unplanned interaction with marine fauna was evaluated as Incidental (6).
• The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the risk evaluation for unplanned interaction with marine fauna.
• Prevention measures for unplanned interaction with marine fauna are well regulated and managed in Australian waters.
To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td colspan="2">(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations</td></tr>
<tr><td colspan="2">The Development is consistent with principle of ESD (c) for this aspect as:
• The Development is committed to applying measures to prevent the impact and risk of unplanned interaction with marine fauna based on relevant environmental legislation and other requirements as listed below.
• The regulation and management of unplanned interaction with marine fauna in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.
• The highest consequence level for unplanned interaction with marine fauna was evaluated as Incidental (6).
• Any relevant stakeholder feedback in relation to unplanned interaction with marine fauna has been incorporated in the OPP and assessed in the external context acceptability criteria.
To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="2">Relevant environmental legislation and</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address relevant requirements/actions within each of the listed legislative requirements considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
</table>

Determination of acceptability		
other requirements	**EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans** The requirements to manage interactions between vessels and cetaceans are detailed in the EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans. These regulations describe strategies to ensure cetaceans are not harmed during offshore interactions with people.	Legislative requirements to manage vessel interactions with protected marine fauna are addressed by adopting these control measures: **CM22**: In accordance with EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans, vessels and helicopters will implement caution and no-approach zones, where practicable.
	Conservation Advice *Rhincodon typus* Whale Shark (Ref. 30) Identifies vessel disturbance as a key threat. Management action: Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations (Ningaloo Reef, Christmas Island and the Coral Sea) and along the northward migration route that follows the northern WA coastline along the 200 m isobath (as set out in the Conservation Values Atlas [Ref. 138]).	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) Management action A.4.2: Ensure all vessel strike incidents are reported in the National Ship Strike Database (Ref. 466) Management action A.4.3: Ensure the risk of vessel strikes on blue whales is considered when assessing actions that increase vessel traffic in areas where blue whales occur and, if required, implement appropriate mitigation measures	EPBC management plan requirements to manage vessel interactions with protected marine fauna are addressed by adopting these control measures: **CM22**: In accordance with EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans, vessels and helicopters will implement caution and no-approach zones, where practicable. Requirements to report vessel strike incidents are included in Section 10.4. **CM36**: Minimise entrainment of fauna during water intake, by use of intake screens and controlling intake velocity.
	Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 18) Identifies vessel collision as a key threat. Management action: Minimise vessel collisions: • ensure all vessel strike incidents are reported in the National Vessel Strike Database (Ref. 466)	
	Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 17) Identifies vessel collision as a key threat. Management action: Minimise vessel collisions: • ensure all vessel strike incidents are reported in the National Vessel Strike Database (Ref. 466)	
	National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Ref. 14) Objectives are to acquire data, determine risks of vessel strike, and identify mitigation measures, with the target audience being government agencies:	

Determination of acceptability		
	• ensure all vessel strike incidents are reported in the National Vessel Strike Database (Ref. 466) • adopt best-practice mitigation measures.	
	Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 31) Recovery Plan for Marine Turtles in Australia (Ref. 148) Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle) (Ref. 22) Wildlife Conservation Plan for Seabirds (Ref. 35) National Recovery Plan for Albatrosses and Petrels (Ref. 37)	These EPBC management plans for species that may occur within the OA identify unplanned interaction with marine fauna as a threat, but do not identify relevant actions.
Internal context	No CAPL procedures were identified as relevant for this aspect.	
External context	CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.2.5 and 6.5.2). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM07** and **CM08**). No further feedback was received in relation to unplanned interaction with marine fauna from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	
Defined acceptable level	The consequence of unplanned interaction with marine fauna is inherently acceptable because the highest consequence level is Incidental (6). Additionally, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan for values and sensitivities in the OA that identify unplanned interaction with marine fauna as a threat. The risk evaluation does not identify scientific uncertainty against risks of unplanned interaction with marine fauna for each receptor. However, given that unplanned interaction with marine fauna (fauna strike) is listed as a threat to protected matters under documents made or implemented under the EPBC Act, CAPL will define an acceptable level of impact that aligns with the objectives of these documents. Objectives of the relevant documents are shown below and were considered during the impact evaluation.	
	Plan and relevant objectives	**Demonstration of requirement**
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) Recovery objective: Minimise anthropogenic threats to allow for their conservation status to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 4: Anthropogenic threats are demonstrably minimised.	CAPL considers the impacts of unplanned interaction with marine fauna to not be inconsistent with the relevant objectives of these EPBC management plans. By applying EPO14, impacts and risks from unplanned interaction with marine

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="5"></td><td>National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Ref. 14)
Objective 3: Mitigation – reduce the likelihood and severity of megafauna vessel collision</td><td rowspan="2">fauna will be managed at or below the defined acceptable level.</td></tr>
<tr><td>Recovery Plan for Marine Turtles in Australia (Ref. 148)
Recovery objective: Minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list.
Interim objective 3: Anthropogenic threats are demonstrably minimised.</td></tr>
<tr><td>National Recovery Plan for Albatrosses and Petrels (Ref. 37)
Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced.</td><td></td></tr>
<tr><td>Conservation Advice Balaenoptera borealis Sei Whale (Ref. 18)
Conservation Advice Balaenoptera physalus Fin Whale (Ref. 17)
Conservation Advice Rhincodon typus Whale Shark (Ref. 30)
Approved Conservation Advice for Dermochelys coriacea (Leatherback Turtle) (Ref. 22)
Wildlife Conservation Plan for Seabirds (Ref. 35)</td><td>These EPBC management plans for species that may occur within the OA identify unplanned interaction with marine fauna as a threat, but do not identify any relevant objectives.</td></tr>
<tr><td colspan="2">Therefore, CAPL has defined these acceptable levels of impact such that they are not inconsistent with these documents:
• management of impacts of the Development must not be inconsistent with the relevant EPBC management plans identified above
• no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery
• no adverse effect to an important or substantial area of habitat such that a significant impact on marine ecosystem functioning or integrity results
• no displacement of marine turtles, or disruption of biologically important behaviours of marine turtles, from BIAs, important habitats, or habitat critical to the survival of a species
• no significant adverse impact to cultural heritage values attributed to the offshore marine area.
CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets these acceptable levels.</td></tr>
</table>

8.10.4 Environmental performance

Table 8-55 lists the EPO defined for unplanned interaction with marine fauna and the adopted control measures to achieve the outcome.

Table 8-55: Environmental performance for Physical presence—Marine fauna

EPO	Adopted control measure
EPO14: No injury or mortality to marine fauna within the OA from the physical presence of the Development	**CM22**: In accordance with EPBC Regulations 2000 – Part 8 Division 8.1 – Interacting with cetaceans, vessels and helicopters will implement caution and no-approach zones, where practicable. **CM36**: Minimise entrainment of fauna during water intake, by use of intake screens and controlling intake velocity.
EPO03: No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.

8.11 Introduction of invasive marine pests

8.11.1 Source

When new species are introduced into environments in which they do not occur naturally, they may be able to survive, reproduce and establish. Invasive marine pests (IMPs) are introduced species that become pests by outcompeting endemic marine species.

IMPs may be introduced to, and translocated within, Australian waters in various ways, including ballast water discharged from vessels and facilities, biofouling on hulls and inside internal seawater systems of vessels and facilities, as well as by ocean currents and attached to marine debris.

These stages are required to successfully introduce, establish, and spread IMPs (Ref. 473):

- colonise and establish on a vector (e.g. vessel, MODU, equipment) in a donor region (e.g. port, harbour, project site)
- survive on the vector during the voyage from the donor to the recipient region
- colonise the recipient region (e.g. by reproduction or dislodgement), then successfully establish a viable new local population.

Several pathways exist for potentially introducing, establishing, and spreading IMPs:

- vessel/MODU/equipment to marine habitat within the OA
- vessel to vessel; or vessel to MODU followed by spread to marine habitat within the OA
- subsequent spread from marine habitat within the OA to outside the OA.

To become established within the OA, IMPs need suitable habitat and conditions. Hard substrates such as rocks or subsea infrastructure in shallow waters (where photosynthesis can occur) are suitable habitats. Most activities associated with the Development occur in deep water with strong currents and soft sediment on the sea floor, conditions which are not considered suitable for IMP establishment.

The major vector pathways for introducing IMPs are described below.

Ballast water

Vessels may need to adjust their ballast to maintain stability, balance, and trim—they use ballast water to achieve this, either by taking in the surrounding water, or expelling it from the vessel. The water taken in may contains IMPs from all life stages, including adults, eggs, and larvae. This biota may then be discharged at the vessel's new location during ballast water exchange. The risk of species introduction is greatest when coastal water is taken up in one location and discharged at another with similar physical and environmental characteristics (Ref. 474).

Biofouling

Biofouling occurs when organisms attach and grow on the submerged parts of a vessel or MODU, like the hull, propellers, anchors, mooring lines, and niche areas. Immersible equipment and infrastructure such as subsea tieback systems (i.e. flowlines, umbilicals, spools, manifolds) may provide IMPs with submerged surfaces they can attach to (Ref. 474). Many structures can remain undisturbed for long periods (e.g. decades) before they are retrieved for decommissioning.

Table 8-56 lists the activities within each phase that have the potential for introducing IMPs in the OA.

Table 8-56: Phases and activities that have the potential for Introduction of IMP

Phase	Activity
Decommissioning	Other subsea structures decommissioning
Support activities	MODU operations Vessel operations

8.11.1.1 Decommissioning

When structures are retrieved to the deck during decommissioning, biofouling may become dislodged and fall to the seabed. Lifting points of structures may also be cleaned to remove marine growth, releasing organisms into the marine environment.

8.11.1.2 Support activities (all phases)

Any of the vessels or the MODU may enter the OA directly from international waters or come from domestic ports. If IMPs are introduced to the OA by one of these pathways, it is also possible that these support vessels moving between the facility and the coastal waters could act as a vector for spreading IMPs from the OA into port environments.

Vessels are the most important vector for transporting IMPs, mostly by biofouling (Ref. 476; Ref. 477, Ref. 478). It is estimated that 25% of Australia's established IMS was the result of ballast water exchange (Ref. 58).

The Australian Ballast Water Management Requirements (Ref. 58) set out the legislative obligations for managing ballast water, when operating within Australian seas to comply with the Commonwealth *Biosecurity Act 2015*. Key requirements are that ballast water exchange is conducted in an acceptable area, use of low risk ballast water and retention of any high-risk ballast water onboard the vessel. All vessels must have a Ballast Water Management Plan and Certificate. These requirements for ballast water exchange greatly reduces the risk introducing IMPs.

During the Development, vessels will transit between the OA and international and domestic ports. Each vessel has the potential to host IMPs if it is not managed appropriately. IMPs may translocate into the OA or from one vessel to another through ballast exchange or be dislodged or spawned from biofouling.

The time a vessel spends in a location (residence time) affects the likelihood of species attachment or uptake. The longer the residence time, the more likely the vessel will be colonised by biofouling species. The residence time can also affect the performance of some types of antifouling coatings (Ref. 474).

The Development does not have any permanent platforms or moored facilities. Of all the Development vessels or facilities, the MODU has the greatest risk of accumulating biofouling, as it will be stationary for the longest period while it drills multiple wells at a DC (~3 months per well, estimated ~24 months in total).

The MODU will be in the OA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well workovers). It will move between fields but will spend most of the time at the DCs.

Vessels are present in the OA during all phases of the Development. The highest number of vessels working concurrently across the OA is estimated at 5–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation may take as long as 15 months per field (C&D field) and while concurrent activities are possible during this time, they will be intermittent and would occur for only a small portion of the overall duration.

The National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry (Ref. 73) states that ROVs should not pose a threat of biofouling-mediated IMP transfers because they are routinely deployed (typically from a deck), retrieved, washed down, and maintained.

8.11.2 Impact and risk evaluation

The scoping exercise (Section 7.4) identified receptors within the OA that are susceptible to the introduction of IMPs, including:

- benthic habitats and associated communities
- KEFs
- cultural heritage value: Traditional Owners.

Table 8-57 evaluates and assigns levels of consequence and likelihood to determine the residual risk of introducing IMPs to each susceptible receptor.

Table 8-57: Risk evaluation for Introduction of IMPs

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	-	Introduction of an IMP to a benthic habitats and associated communities or KEF may result in: • Widespread, long-term displacement of, or competition with, endemic species.	3	6	Low (8)
		Introduction of an IMP to a KEF may result in:	3	6	Low (8)

Impact and/or risk level summary					
		• Change to values and sensitivities.			
		Introduction of an IMP may result in: • change to cultural heritage values.	3	6	Low (8)

Risk evaluation
Benthic habitats and associated communities

Displacement or competition with endemic species

IMPs are likely to have little or no natural competition or predators, thus potentially outcompeting endemic species for food or space, preying on endemic species, or changing the nature of the environment. It is estimated that Australia has >250 IMP species, and that approximately one in 6 introduced marine species becomes a pest (Ref. 479).

Risks to marine habitat from the introduction of IMPs depends on the successful reproduction and establishment of IMP populations, which leads to displacement of, or competition with, endemic species.

IMP colonisation requires a suitable habitat in which to establish, such as rocky and hard substrates or subsea infrastructure, especially that with pre-existing biofouling. (Ref. 480). Many IMP primarily occur in shallow areas within the photic zone (upper 200 m of ocean), with high nutrient levels. Therefore, soft sediment habitat, deep water areas below the photic zone and nutrient-poor oceanic waters are likely to limit establishment for a number of IMP species (Ref. 481).

Most of the benthic habitat in the OA is not considered suitable for establishing IMP habitat because water depths are mostly below the photic zone where photosynthesis does not occur, there are low nutrients and benthic cover is dominated by bare sediment (soft unconsolidated sand/mud) with sparsely distributed, epibenthic and infaunal invertebrates highly represented throughout the region (Ref. 400; Ref. 105, Appendix A). The WTR field, which has water depths of ~150 m, is the only section of the OA within the euphotic zone. The remaining G&E, Chandon, C&D and Semele fields contain natural dispersal barriers where IMP establishment is not considered a credible risk (Ref. 105, Appendix A, Ref. 278). Consequently, the risk evaluation for IMP focused on the WTR field, the worst-credible case, where photosynthesis is possible and hard substrates are anticipated.

The WTR flowline corridor runs mostly parallel to the Ancient coastline KEF. Benthic habitat within this KEF comprises hard substrate relative to surrounding areas of predominantly soft sediment (Ref. 482). Benthic habitat surveys of the OA area within the Ancient coastline KEF showed that the benthic habitat comprises smooth seabed with bioturbation and with no epibenthic biota observed. Values associated with the Ancient coastline KEF were not detected within the OA benthic survey (Ref. 105, Appendix A). WTR is located in an area with low topographic features and is unlikely to provide significant habitat to biota (Ref. 105, Appendix A).

WTR also contains natural dispersal barriers for IMPs, such as internal waves and enhanced vertical mixing of water layers (Ref. 482). The presence of soft sediments and water currents at WTR is expected to limit the successful reproduction and establishment of founder IMP populations in the OA.

Benthic habitat may serve as spawning sites for marine fauna and these habitats are at risk from IMPs through competition for resources and being subject to predation (Ref. 479). The OA contains mostly bare sediment (soft unconsolidated sand/mud) with no epibenthic biota observed. Of the 14 sites examined that comprise the proposed DCs and tie-in locations in the benthic survey, only one site (M1 – tie-in point) had very low percent cover of cnidarians over bioturbated sediments (Ref. 105, Appendix A). The presence of sparse benthic populations makes it difficult for IMPs to spread. Based on sparse benthic cover observations during the survey, IMP spawning and colonisation is not anticipated.

Successful IMP establishment also depends on distance from coastal habitats. Highly disturbed shallow-water and coastal marine environments (such as marinas) are more susceptible to colonisation than open-water environments, where the number of dilutions and the degree of dispersion is high (Ref. 480; Ref. 483; Ref. 484; Ref. 485). The Bureau of Rural Sciences (BRS) calculated the risk of IMP incursion along Australian coastlines decreases with distance from the shoreline. Modelling conducted by BRS (Ref. 486) estimates:

- 33% chance of colonisation at 3 nm
- 8% chance at 12 nm
- 2% chance at 24 nm.

The OA is ~27 nm from shore; therefore, there is a very low likelihood that any IMP incursion would become established in the OA based on the risk estimates by BRS (Ref. 486).

All subsea equipment will be installed new (i.e. not recycled) and will be ‘dry’ and will not be exposed to biofouling before installation – i.e. no large structures towed to site.

Risk evaluation
Once established, some IMPs can be difficult to eradicate (Ref. 487) and therefore there is the potential for a long-term change in habitat structure. If an IMP was introduced, and if it did colonise an area, there is the potential for that colony to spread outside the OA resulting in a widespread long-term impact, therefore resulting in a Major (3) consequence. Since IMP can be difficult or impossible to eradicate, once established, the main focus of managing IMP risks is to minimise the likelihood that incursions will occur in the first place. As the vessels associated with the Development will be operated and maintained in accordance with CAPL's Quarantine Procedure Marine Vessels (Ref. 74) and a vessel-specific biofouling management plan they should be able to effectively withstand large-scale settlement of marine organisms, including when vessels are exposed to locations of IMP infestation (Ref. 474). Given these control measures and the low likelihood of IMP incursion in the OA based on the BRS risk estimates (Ref. 474), the likelihood of introduced IMPs displacing or competing with endemic species is assessed as Rare (6). Overall, the risk of introducing IMPs to benthic habitats and associated communities and causing a change in the values and sensitivities of a KEF is Low (8).
KEFs
Changes to the values and sensitivities The introduction of IMPs may result in changes to the values and sensitivities of KEFs through displacement or competition with endemic species. Risks to KEFs from the introduction of IMPs depends on successful reproduction and establishment of IMP populations, leading to displacement of, or competition with, endemic species. The OA overlaps with 3 KEFs: Ancient coastline, Exmouth Plateau and Continental slope demersal fish communities. The Ancient coastline and Exmouth Plateau KEFs both have benthic habitat values and therefore have values that may be impacted by an IMP. Benthic habitat surveys of the OA area within the Exmouth Plateau KEF showed that the benthic habitat is dominated by irregular seabed with bioturbation, irregular seabed floor with bare substrates, and depressions on the sea floor of bare substrate. Within the Exmouth Plateau KEF, a large scarp with 3-dimensional hard structure (i.e. rock) crosses through the indicative Chandon flowline from east to west, likely providing biota with suitable habitat, although no biota were detected along the transect in this area. Although these substrates may provide a suitable habitat for IMP colonisation, strong internal tides, and seabed depth (~900–1,000 m) reduce the likelihood of IMPs becoming established. The Ancient coastline KEF is an underwater escarpment characterised by areas of hard substrate, which may provide sites for higher species diversity compared to the surrounding soft sediment. The benthic survey (Ref. 105, Appendix A) detected no ancient coastline features within the OA. Instead, the seabed where the OA overlaps with this KEF is smooth, with bioturbation and with no epibenthic biota observed. Although the seabed, at ~150 m, is not as deep as some areas of the OA, internal waves reduce the likelihood of IMPs becoming established. As for the benthic habitats assessed above, IMP introduction primarily occurs in shallow waters with high levels of slow-moving or stationary shipping traffic (e.g. ports), not in environments like the OA. IMP colonisation also often requires a suitable habitat in which to establish, such as rocky and hard substrates or subsea infrastructure. Once established, some IMPs can be difficult to eradicate (Ref. 487) and therefore there is the potential for a long-term change in habitat structure. If an IMP was introduced, and if it did colonise an area, there is the potential for that colony to spread outside the OA resulting in a widespread long-term impact to the values and sensitivities of a KEF, therefore resulting in a Major (3) consequence. As the benthic environment where the OA and KEFs overlap contains natural dispersal barriers unfavourable to IMP survival, the water depths of the OA and the requirement for vessels to implement CAPL's Quarantine Procedure Marine Vessels (Ref. 74) and a vessel-specific biofouling management plan , the likelihood of introduced IMPs displacing or competing with endemic species and causing a change in the values and sensitivities of a KEF is assessed as Rare (6). Overall, the risk of introducing IMPs to KEFs is Low (8).
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from the introduction of IMPs includes indirect impacts to intangible Traditional Owner heritage from alterations to benthic habitats and associated communities. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of benthic habitats and associated communities (Section 6.2.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural heritage

Risk evaluation
values may occur due to alterations to benthic habitats and associated communities from the introduction of IMPs. The highest consequence level for the introduction on an IMP was evaluated as Major (3), from the potential for widespread, long-term displacement of, or competition with, endemic species. As such, the consequence of changes to cultural heritage values from introduction of IMPs is also evaluated as Major (3). Given the benthic environment of the OA contains natural dispersal barriers unfavourable to IMP survival; a significant adverse change to cultural heritage values is not predicted to occur. Therefore, the likelihood of the consequence occurring is assessed as Rare (6). The risk of introducing IMPs to Traditional Owner cultural heritage values is Low (8).

8.11.3 Determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-58 details the determination of acceptability for introduction of IMPs.

Table 8-58: Determination of acceptability for Introduction of IMPs

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence level for introduction of IMPs was evaluated as Major (3). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the risk evaluation for introduction of IMPs. • Prevention measures for introduction of IMPs are well regulated and managed in Australian waters. Commercial vessel operations are commonplace and well-practised nationally and internationally. The control measures to manage the risks of IMP introduction are well defined via legislative requirements that are considered standard industry practice. These are well understood and implemented by the petroleum industry and CAPL. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations
	The Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the impact and risk of IMPs based on relevant environmental legislation and other requirements as listed below. • The regulation and management of IMPs in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures. • The highest consequence level for introduction of IMPs was evaluated as Major (3). • Any relevant stakeholder feedback in relation to introduction of IMPs has been incorporated in the OPP and assessed in the external context acceptability criteria. To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
	Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="7">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Biosecurity Act 2015 (Cth)
Vessels entering into the Australian territorial seas from outside Australian territory must complete pre-arrival reporting.</td><td rowspan="5">Legislative requirements to manage the introduction of IMPs are addressed by adopting these control measures:
CM37: MODUs and vessels will meet the relevant requirements of CAPL’s Quarantine Procedure Marine Vessels (Ref. 74).
CM38: Where required, MODUs and vessels will have a current antifouling system certification in accordance with Marine Order Part 98 (Anti-fouling systems) and Australian Biofouling Management Requirements (Ref. 58).
CM39: Ballast water exchanges will be managed in accordance with the Australian Ballast Water Management Requirements (Ref. 58).
CM40: Where required, MODUs and vessel pre-arrival information will be reported through the Maritime Arrivals Reporting System as per the Biosecurity Act 2015 (Cth).</td></tr>
<tr><td>Protection of the Sea (Harmful Anti-fouling Systems) Act 2006 (Cth)
Marine vessels greater than 400 gross tonnes with an antifouling coating are to maintain up-to-date international antifouling coating certification.</td></tr>
<tr><td>Australian Ballast Water Management Requirements (Ref. 58)
Details Australia’s commitment to the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Ballast Water Convention) (Ref. 488). International marine vessels must comply with these key requirements:
• non-discharge of ‘high-risk’ ballast water in Australian ports or waters
• full ballast exchange outside Australian territorial seas
• documentation of all ballast exchange activities.</td></tr>
<tr><td>Control and Management of Ships’ Biofouling to Minimize the Transfer of Invasive Aquatic Species (Biofouling Guidelines) 2011 (Ref. 70)
Internationally agreed guidance for operators to develop vessel-specific biofouling management plans.</td></tr>
<tr><td>National Biofouling Management Guidance for the Petroleum Production and Exploration Industry (Ref. 73)
Guides operators on:
• evaluating biofouling risk of types of structure/facilities</td></tr>
</table>

Determination of acceptability		
	• biofouling management and decommissioning.	
	Reducing marine pest biosecurity risks through good practice biofouling management (Ref. 79) Guides operators on: • biosecurity requirements relevant to offshore activities • coordinated good practice advice that is consistent with the expectations of all jurisdictions responsible for regulating biofouling management within the Australian marine environment • the industry's contribution to marine pest risk management consistent with Australia's MarinePestPlan 2018–2023 (Ref. 80).	
	Australian Biofouling Management Requirements (Ref. 58) Guides operators on biofouling management of vessels.	
	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 67)	These EPBC management plans for species that may occur within the OA identify invasive marine pests as a threat, but do not identify any relevant actions.
Internal context	These CAPL procedures were deemed relevant for this aspect: • Quarantine Procedure Marine Vessels (Ref. 74).	
External context	CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.2.5 and 6.5.2). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM07** and **CM08**). No further feedback was received in relation to introduction of IMPs from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	
Defined acceptable level	The consequence of introduction of IMPs is inherently acceptable because the highest consequence level is Major (3). Additionally, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan for values and sensitivities in the OA that identify IMP as a threat. The risk evaluation does not identify scientific uncertainty against risks of IMP introduction for each receptor. There are no relevant EPBC management plans for this aspect.	
	Plan and relevant objective	**Demonstration of requirement**
	N/A	N/A

Determination of acceptability	
	Therefore, CAPL has defined these acceptable levels of impact: • no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery • no adverse effect to an important or substantial area of habitat such that a significant impact on marine ecosystem functioning or integrity results • no significant adverse impact to cultural heritage values attributed to the offshore marine area. CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets these acceptable levels.

8.11.4 Environmental performance

Table 8-59 lists the EPO defined for the introduction of IMPs and the adopted control measures to achieve the outcome.

Table 8-59: Environmental performance for the Introduction of IMPs

EPO	Adopted control measure
EPO15: No introduction of invasive marine pests to the OA due to the Development activities.	**CM37:** MODUs and vessels will meet the relevant requirements of CAPL's Quarantine Procedure Marine Vessels (Ref. 74). **CM38:** Where required, MODUs and vessels will have a current antifouling system certification in accordance with Marine Order Part 98 (Anti-fouling systems) and Australian Biofouling Management Requirements (Ref. 58). **CM39:** Ballast water exchanges will be managed in accordance with the Australian Ballast Water Management Requirements (Ref. 58). **CM40:** Where required, MODUs and vessel pre-arrival information will be reported through the Maritime Arrivals Reporting System as per the *Biosecurity Act 2015* (Cth).
EPO03: No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.

8.12 Unplanned release—Solid objects

8.12.1 Source

Hazardous and non-hazardous waste stored on board facilities and vessels may be accidentally lost overboard. Solid materials that are lifted or handled during Development activities have the potential to be accidentally released overboard. Seabed disturbance can occur if the waste or solid material reaches the sea floor. There is also potential for a dropped object to cause a loss of containment (LOC) of hydrocarbons if the object damages a live pipeline; this event is assessed separately in Section 8.13.

Table 8-60 lists the activities within each phase where unplanned release of solid objects may occur in the OA.

Table 8-60: Phases and activities that generate Unplanned release—Solid objects

Phase	Activity
Installation and commissioning	Pre-lay works
	Installing subsea structures
Operations	Major repairs
Decommissioning	Flowline and MEG pipeline decommissioning
	Umbilical decommissioning
	Other subsea structures decommissioning
Support activities	MODU operations Vessel operations

8.12.1.1 Installation and commissioning

Infrastructure such as trees, manifolds, pipeline termination structures, PLETs/PLEMs, spools, jumpers, foundations, and pipeline stabilisation materials (e.g. concrete mattresses) may be lowered by crane to the seabed, and there is the potential for structures to be accidentally dropped during this installation process.

This equipment is typically made of steel or concrete and will sink onto the seabed. Although these items will be retrieved from the seabed, they may disturb the marine environment as a result of the release and when being retrieved.

The largest individual structure that will be installed is likely to be a slug catcher or overpressure protection system, which will be no more than ~2,100 m^2. This type of infrastructure will only be installed in the vicinity of the Jansz field. In other parts of the OA the largest infrastructure that will be installed is likely to be a manifold or pipeline termination structure with an estimated footprint of ~900 m^2.

8.12.1.2 Operations

Major repairs are a consequence of a significant infrastructure defect or failure. If major repairs are required, solid objects and equipment have the potential to be accidentally dropped during installation or retrieval.

These materials are likely to be non-buoyant and therefore are expected to sink through the water column and settle on the seabed in the OA.

8.12.1.3 Decommissioning

Multiple options for flowline and umbilical decommissioning are included in this OPP (as per Section 5). The methods with the highest risk of unplanned release of solid objects are assessed in this section.

The cut and lift flowline decommissioning method involves cutting the flowline into sections on the seabed, then using a crane to lift them onto a vessel. Cut sections of pipe have the potential to be accidentally released or dropped due to manual handling errors or as a consequence of inappropriately secured or unbalanced loads during lifts.

The recover and cut on deck method involves recovering the umbilicals from the seabed before cutting them into sections on the vessel deck. Cut sections may be released overboard as a result of handling or lifting errors.

These materials are non-buoyant and will sink through the water column and settle on the seabed in the OA.

8.12.1.4 Support activities (all phases)

Vessels are present in the OA during all phases of the Development. The MODU will be present in the OA during drilling and decommissioning phases and potentially during operations for well intervention.

Solid waste is handled and stored on board the MODU and vessels, before being transported to shore for disposal at licensed facilities. If waste is inappropriately handled or stored while offshore, it may be accidentally discharged to the marine environment. This accidental release of waste may be due to improper or unsuitable waste storage, human error, or failure of waste storage equipment. Accidental releases may be more likely in rough ocean conditions and high winds when items have the potential to roll or be blown off the deck if not appropriately stored or secured.

Solid waste may be considered hazardous due to toxic, reactive, corrosive, or ignitable properties. Hazardous waste includes:

- contaminated material (e.g. rags, oil filters, personal protective equipment)
- paint cans, printer cartridges, batteries, fluorescent tubes, aerosol cans.

Non-hazardous waste may still pose a threat to receptors (via ingestion, entangling or smothering) if released to the environment, and includes:

- plastics
- glass
- wood, paper, cardboard
- metal (e.g. cans, scrap steel, aluminium).

Solid objects and equipment, such as handheld tools, may also be released overboard due to manual handling errors.

All non-buoyant solid waste material or dropped objects are expected to remain in the OA as they will sink through the water column and settle on the seabed. Buoyant waste material lost overboard has the potential to be carried by ocean currents beyond the OA.

8.12.2 Impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the OA that may be impacted by an unplanned release of solid objects:

- water quality
- benthic habitats and associated communities
- seabirds and shorebirds
- fishes, including sharks and rays
- marine reptiles
- marine mammals
- KEFs
- cultural heritage value: Traditional Owners.

Although fish may potentially be impacted by an unplanned release of solid objects, the area of influence is highly localised and is not expected to result in a change in the viability of the population of commercially important species. Only one State- and 3 Commonwealth-managed fisheries have recorded historical fishing effort in the OA. Therefore, impacts to commercial fisheries from an unplanned release of solid objects is not expected; and are not evaluated further.

Table 8-61 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to an unplanned release of solid objects in the OA.

Table 8-61: Risk evaluation for Unplanned release—Solid objects

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	-	Unplanned release of solid objects in the marine environment may result in: • localised and temporary reduction in water quality.	6	5	Very low (10)
		Unplanned release of solid objects may interact with marine fauna to result in: • injury or mortality of marine fauna	6	5	Very low (10)
		Unplanned release of solid objects may result in: • alteration of benthic habitats and associated communities.	5	5	Very Low (9)
		Unplanned release of solid objects in a KEF may result in: • change to values and sensitivities.	5	5	Very Low (9)
		Unplanned release of solid objects may result in: • change to cultural heritage values.	5	5	Very Low (9)

Risk evaluation
Water quality
Localised and temporary reduction in water quality Unplanned loss of hazardous or non-hazardous solid waste from vessels and the MODU may have the potential to cause a localised and temporary reduction in water quality. The magnitude of water quality change depends on the nature of the waste. These losses usually comprise solid waste items such as oily rags and residue from paint cans lost overboard and therefore have relatively low levels of toxicity. Due to wave action and local ocean currents, minor releases of residual hazardous material from dropped objects will be rapidly mixed and diluted. Therefore, no long-term changes in water quality are expected. Unplanned release of solid objects offshore has occurred previously in the industry but a resulting impact to water quality is considered highly unlikely. Given the details above, the consequence of an unplanned release of a solid object causing a change in water quality has been evaluated as Incidental (6). CAPL considers the likelihood of the consequence occurring to be Remote (5). Overall, the risk of an unplanned release of solid objects to water quality is Very low (10).
Seabirds and shorebirds
Injury or mortality of marine fauna Unplanned release of non-hazardous waste may impact marine fauna via ingestion or entanglement. Between 1974 and 2008, 77 individuals (of various species) were reported to have been entangled in, or ingested, plastic debris within Australian waters according to a study commissioned by DEWHA. Records were dominated by humpback whales, marine turtles, Australian pelicans, and a range of cormorant species, with the sources of waste unknown (Ref. 489). The marine fauna most at risk from ingestion or entanglement is seabirds (Ref. 148, Ref. 490). Ingestion or entanglement has the potential to limit feeding or foraging behaviours and thus can result in marine fauna injury or mortality. Seabirds that feed at the surface and at the top of the water column are vulnerable to buoyant waste (e.g. plastics). There were 14 EPBC listed bird species identified in the PMST report for the OA, including 2 species listed as critically endangered—curlew sandpiper and eastern curlew—and 3 species listed as vulnerable—red-tailed tropicbird, southern giant petrel and Christmas Island white-tailed tropicbird. The southern giant petrel is the only threatened bird species that was identified as being sensitive to interactions with marine debris and listed in the EPBC PMST report (Ref. 123, Appendix B) for the OA. The OA overlaps a BIA for the wedge-tailed shearwater; however, there is no recovery plan for this species. Because of the distance of the Development activities from land (the closest infrastructure is ~60 km from Barrow Island and ~120 km from the mainland), any seabirds and shorebirds present within the OA are only expected to be transitory and incidental. Unplanned release of solid objects offshore has occurred previously in the industry but, impacts to seabirds and shorebirds would be to individuals, with no population or ecosystem impacts expected. Based on this information, CAPL assessed the consequence of an unplanned discharge of a solid object causing injury or mortality to seabirds and shorebirds as Incidental (6). CAPL considers the likelihood of the consequence occurring to be Remote (5). Overall, the risk of an unplanned release of solid objects to birds is Very low (10).
Marine reptiles, marine mammals and fishes, including sharks and rays
Injury or mortality of marine fauna Unplanned release of non-hazardous waste may impact marine fauna via ingestion or entanglement, with seabirds and marine reptiles most at risk (Ref. 148, Ref. 490). Ingestion or entanglement has the potential to limit feeding or foraging behaviours and thus can result in marine fauna injury or death. Plastics released into the marine environment degrade over time into microplastics, which can bioaccumulate within species, in particular in higher trophic levels. However, any unplanned release of plastic material from the Development would be infrequent and comprise small objects that could be lost overboard—these would contribute a negligible amount to the ubiquitous microplastics found in the marine environment. Although marine debris is identified as being of concern to marine reptile species under the Marine bioregional plan for the North-west Marine Region (Ref. 103), the risk documented in that plan is associated with 'land-sourced plastic garbage, fishing gear from recreational and commercial fishing abandoned into the sea, and ship-sourced, solid non-biodegradable floating materials disposed of at sea'. This type of waste is not associated with the activities described in this OPP and given the limited quantity of waste with the potential to

Risk evaluation
cause marine pollution that is expected to be generated from petroleum activities, it is expected that any impacts from marine pollution would result in limited impacts to individuals. Debris most likely to affect marine fauna through entanglement or ingestion in the open ocean comprises floating non-degradable debris, such as lost or discarded fishing gear (e.g. discarded nets, crab pots, synthetic ropes, floats, hooks, fishing line and wire trace). The values and sensitivities within the OA with the potential to be affected by injury or mortality include: • humpback whale BIA (foraging) • pygmy blue whale BIA (distribution and migration) • flatback turtle (internesting buffer) • whale shark BIA (foraging) • fish communities (associated with the various KEFs). Five species of turtle listed as Vulnerable (green, hawksbill and flatback) or Endangered (loggerhead and leatherback) are known or are likely to occur in the OA—all are identified as being sensitive to interactions with marine debris under the Threat Abatement Plan (Ref. 13) and Recovery Plan for Marine Turtles in Australia (Ref. 148). The Conservation Advice for the Whale Shark (Ref. 30) and the Conservation Management Plan for the Blue Whale (Ref. 16) also identify marine debris as a threat to the species. Marine debris ingested by marine reptiles may result in ecotoxicological effects, physical blockage, and internal injuries (Ref. 491). For marine turtles, this threat has been risk assessed as having either a moderate consequence (defined as ‘stock recovery stalls or reduces’) for Loggerheads or a minor consequence (defined as ‘individuals are affected but no effect at stock level’) for green, flatback, hawksbill and leatherback turtles (Ref. 148). Although the OA overlaps the flatback turtle internesting buffer, Whittock (Ref. 151; Ref 150) defined unsuitable flatback turtle internesting habitat as waters >25 m deep and >27 km from the coast. Only the WTR and C&D fields, which are at depths >25 m deep and further than 27 km the closest coast, have infrastructure within the internesting buffer. Therefore, it would be very unlikely that turtles would aggregate within the OA during their internesting period. Consequently, only a small number of transient marine turtles are expected to be present. Marine mammals, marine reptiles and fish may ingest buoyant wastes and microplastics. Studies show that ingestion of microplastics by fish is relatively common, with over a third of all fish examined in studies in European waters having microplastics within their gastrointestinal tract (Ref. 492). Unplanned release of solid objects offshore has occurred previously in the industry, but impacts to marine reptiles, marine mammals and fish are considered to be individual, with no population or ecosystem impacts expected. Based on the above the consequence of an unplanned release of a solid object causing injury or mortality to marine reptiles, marine mammals, and fish as Incidental (6), and the likelihood of the consequence occurring Remote (5). Overall, the risk of an unplanned release of solid objects to marine reptiles, marine mammals, and fishes, including sharks and rays is Very low (10).
Benthic habitats and associated communities
Alteration of benthic habitats and associated communities Unplanned release of solid objects from installation, operations, decommissioning and support activities may lead to large solid objects falling to the sea floor in the OA. The area of impact would correspond to the footprint of the particular object, with the benthic sediments and communities beneath the object subject to physical disturbance. The footprint of any released object would be significantly smaller than the total planned footprint of the Development. If any equipment is dropped, it is expected to settle on the seabed in or near the long-term disturbance area. A benthic survey was undertaken to support the Development, which suggests the sea floor of the OA is varied but typical of the area, containing predominantly soft sediments with sparsely distributed, epibenthic and infaunal invertebrates highly represented throughout the region (Ref. 105, Appendix A). Although areas along scarp habitats are more likely to support biota, the habitat types within the OA are ubiquitous, and include no unique or regionally significant marine habitats were (Ref. 105, Appendix A). The consequence to benthic habitats is considered to be highly localised and negligible. Unplanned release of solid objects offshore has occurred previously in the industry but is considered highly unlikely. Data compiled from a number of platforms in the United Kingdom and published in the OREDA-84 handbook gives dropped load frequency of 0.095 per year of crane service (Ref. 493). This suggests a dropped load from a crane is likely to happen once in ~10 years of crane service.

Risk evaluation
Dropping an object during major repairs is even more unlikely because major repairs have an extremely low probability of occurring. Given the above, the consequence of an unplanned release of solid objects causing alteration of benthic habitats and associated communities has been evaluated as Minor (5), and the likelihood of the consequence occurring to be Remote (5). Overall, the risk of an unplanned release of solid objects to benthic habitats and associated communities is Very Low (9).
KEFs
Change to values and sensitivities An unplanned release of solid objects event may result in changes to the values and sensitivities of KEFs through alteration of benthic habitats and associated communities or injury or mortality of marine fauna. Unplanned release of solid objects may lead to large solid objects falling to the sea floor in the OA. The area of impact would correspond to the footprint of the particular object, with the benthic sediments and communities beneath the object subject to physical disturbance. The footprint of any released object would be significantly smaller than the total planned footprint of the Development. The OA overlaps with 3 KEFs: Ancient coastline, Exmouth Plateau and Continental slope demersal fish communities. The Ancient coastline and Exmouth Plateau KEFs both have benthic habitat values. The only parts of the OA that overlap these KEFs are at or near the Chandon and WTR flowlines and DCs, and one of the Gorgon tie-in locations. The Chandon DCs and part of the Chandon flowline will occur within the Exmouth Plateau KEF. The OA extending from the WTR DC, WTR flowline and one of the Gorgon tie-in points overlaps the Ancient coastline KEF. Therefore, only activities at 2 of the 5 fields in the Development have the potential to impact these KEFs by dropped non-buoyant objects. In addition, the habitat types in these KEFs are widespread in the region. Although areas along scarp habitats are more likely to support biota, the habitat types in the OA are ubiquitous, and the benthic survey did not find any unique or regionally significant marine habitats (Ref. 105, Appendix A). Fish may ingest buoyant wastes and microplastics, which can bioaccumulate in higher trophic levels; and ingestion or entanglement can limit feeding, which could result in injury or mortality, and is assessed for marine fauna above. The Continental slope demersal fish communities KEF has values relating to fish that live and feed near the sea floor and is valued for its high biodiversity and endemism with a range of fish assemblages (Ref. 426). The Continental slope demersal fish communities KEF will overlap with the OA at the C&D flowline, C&D DC-3, WTR umbilical and one of the Gorgon tie-in points. While the OA overlaps 0.02–1% of 3 KEFs, the benthic survey (Ref. 105, Appendix A) highlights KEF values with the potential to be impacted by Development activities are limited to deep-sea benthic habitats and highly mobile pelagic and demersal fish species of the Continental slope demersal fish communities KEF. These habitats and biota are widespread and well represented throughout the region, and as such any potential impact is localised. Unplanned release of solid objects offshore has occurred previously in the industry, but is considered highly unlikely, and the footprint of a dropped object would constitute a very small proportion of the KEFs. The consequence to habitats within the KEFs is considered to be highly localised and negligible. impacts to marine reptiles, marine mammals, and fishes, including sharks and rays are considered to be individual, with no population or ecosystem impacts expected. Given the above the consequence of an unplanned release of a solid object causing a change in the values and sensitivities of a KEF as Minor (5), and the likelihood of the consequence Remote (5). Overall, the risk of an unplanned release of solid objects to KEFs is Very Low (9).
Cultural heritage value: Traditional Owners
Change to cultural heritage values No protected underwater cultural heritage sites or artefacts protected by the UCH Act have been identified within the OA (Section 6.5.2). At the time of writing, CAPL understands through consultation with the relevant Traditional Owner groups that there are no known artefacts or specific sites of cultural value associated with the seabed within the OA. Therefore, no impacts to tangible seabed-based cultural heritage (e.g. shipwrecks or archaeology) are expected; and no further evaluation has been undertaken. Potential changes to cultural heritage values from unplanned release of solid objects includes indirect impacts to intangible Traditional Owner heritage from alteration of benthic habitats and associated communities. Outcomes of Phase 1 stakeholder consultation highlights Traditional Owners are cultural custodians of NWMR Sea Country with obligations for the protection of benthic habitats and associated communities (Section 6.2.5.2.1). CAPL considers that indirect impacts to intangible Traditional Owners cultural heritage

Risk evaluation
values may occur due to alterations to benthic habitats and associated communities from unplanned release of solid objects. The consequence level for the alteration of benthic habitats and associated communities from unplanned release of solid objects was evaluated as Minor (5). As such, the consequence of changes to cultural heritage values from unplanned release of solid objects is also evaluated as Minor (5). Given the extremely small footprint of any dropped object; a significant adverse change to cultural heritage values is not predicted to occur. Therefore, the likelihood of the consequence occurring is assessed as Remote (5). The risk of an unplanned release of solid objects to Traditional Owner cultural heritage values is Very Low (9).

8.12.3 Determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-62 details the determination of acceptability for an unplanned release of solid objects.

Table 8-62: Determination of acceptability for Unplanned release—Solid objects

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence level for unplanned release of solid objects was evaluated as Minor (5). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the risk evaluation for the unplanned release of solid objects. • Prevention measures for unplanned release of solid objects are well regulated and managed in Australian waters. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations
	The Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the impact and risk of Unplanned release—Solid objects based on relevant environmental legislation and other requirements as listed below. • The regulation and management of unplanned releases of solid objects in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures. • The highest consequence level for unplanned release of solid objects was evaluated as Minor (5). • Any relevant stakeholder feedback in relation to unplanned release of solid objects has been incorporated in the OPP and assessed in the external context acceptability criteria. To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
	Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="6">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP will implement controls to address the relevant item / objective / action within each listed legislative requirement considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>AMSA Marine Order 95 (Marine Pollution Prevention – Garbage)
Sets out the requirements of the prevention of pollution of the environment for regulated Australian vessels, domestic commercial vessels, and Australian recreation vessels.

Navigation Act 2012 (Cth) – Chapter 4 (Prevention of Pollution)
Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment and gives effect to the requirements under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) in Australia</td><td>Legislative requirements to manage the unplanned release of solid objects are addressed by adopting these control measures:
CM41: MODUs and vessels will comply with the requirements of Marine Order 95 (MARPOL 73/78 Annex V) in relation to managing waste (garbage) offshore.
CM42: MODUs and vessels will have specific lifting plans in place for cranes before commencing lifting operations and transfers, to prevent dropped objects.
CM43: Any dropped objects will be retrieved if practicable.</td></tr>
<tr><td>Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148)
Management action A3. Reduce the impacts from marine debris:
Support the implementation of the EPBC Act Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (Ref. 13).</td><td rowspan="2">EPBC management plan requirements to reduce impacts from marine debris are addressed by adopting these control measures:
CM41: MODUs and vessels will comply with the requirements of Marine Order 95 (MARPOL 73/78 Annex V) in relation to managing waste (garbage) offshore.
CM42: MODUs and vessels will have specific lifting plans in place for cranes before commencing lifting operations and transfers, to prevent dropped objects.
CM43: Any dropped objects will be retrieved if practicable.
Therefore, the Development is not considered to be inconsistent with the EPBC management plan.</td></tr>
<tr><td>National recovery plan for threatened albatrosses and giant petrels 2011–2016 (Ref. 37)
Risk based response strategies for marine pollution incidents are developed.
Where appropriate monitoring of breeding colonies includes an assessment of marine debris, plastics, and marine pollution impacts</td></tr>
<tr><td>Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (Ref. 13)</td><td>These EPBC management plans for species that may occur within the OA identify marine</td></tr>
</table>

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td>Wildlife Conservation Plan for Seabirds (ref. 35)
Conservation Advice for the Abbott's Booby (Papasula abbotti) (Ref. 38)
Conservation Advice Rhincodon typus Whale Shark (Ref. 30).
Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16)
Approved Conservation Advice for Dermochelys coriacea (Leatherback Turtle) (Ref. 22)
Approved Conservation Advice for Pristis pristis (largetooth sawfish) (Ref. 27)
Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25)</td><td>debris as a threat, but do not identify any relevant actions.</td></tr>
<tr><td>Internal context</td><td colspan="2">These CAPL procedures were identified as relevant for this aspect:
ABU – Lifting and Rigging Control of Work Manual (Ref. 494)
Chevron Marine Standard Non Tankers (Ref. 284) (details the requirements for lifting and installing heavy equipment. Installation risk is minimised by ensuring lifting plans are in place for heavy and complicated lifts).</td></tr>
<tr><td>External context</td><td colspan="2">CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment.
During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.2.5 and 6.5.2).
Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (CM07 and CM08).
No further feedback was received in relation to unplanned release of solid objects from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.</td></tr>
<tr><td rowspan="3">Defined acceptable level</td><td colspan="2">The consequence of unplanned release of solid objects is inherently acceptable because the highest consequence level is Minor (5).
Additionally, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan.
The risk evaluation does not identify scientific uncertainty against risks of unplanned release of solid objects for each receptor.
However, given that marine debris is listed as a threat to protected matters under documents made or implemented under the EPBC Act, CAPL will define an acceptable level of impact that aligns with the objectives of these documents. Objectives of the relevant documents are shown below and were considered during the impact and risk evaluation.</td></tr>
<tr><td>Plan and relevant objective</td><td>Demonstration of requirement</td></tr>
<tr><td>Threat Abatement Plan for the Impacts of Marine Debris on the Vertebrate Wildlife of Australia's Coasts and Oceans (Ref. 13)
There are 4 relevant objectives:
<u>Objective 1</u>: Contribute to the long-term prevention of marine debris.</td><td>CAPL considers the impact and risk of unplanned release of solid objects to not be inconsistent with the relevant objectives of these EPBC management plans.
By applying EPO16, impacts and risks from marine debris from Unplanned release–</td></tr>
</table>

Determination of acceptability		
	Objective 2: Understand the scale of impacts from marine plastic and microplastic on key species, ecological communities and locations. Objective 3: Remove existing marine debris. Objective 4: Monitor the quantities, origins and hazardous chemical contaminants of marine debris and assess the effectiveness of management arrangements for reducing marine debris.	Solid objects will be managed at or below the defined acceptable level.
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) Recovery objective: Minimise anthropogenic threats to allow for their conservation status to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 4: Anthropogenic threats are demonstrably minimised.	
	Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148) Long-term recovery objective: Minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 3: Anthropogenic threats are demonstrably minimised.	
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25) Primary objective: To assist the recovery of sawfish and river sharks in Australian waters with a view to: • improving the population status leading to removal of the sawfish and river shark species from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder recovery in the near future or impact the conservation status of the species in the future. Specific objective: Objective 6: Reduce and, where possible, eliminate any adverse impacts of marine debris on sawfish and river hark species noting the linkages with the Threat Abatement Plan for the Impacts of Marine Debris on the Vertebrate Wildlife of Australia’s Coasts and Oceans (Ref. 13).	

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="3"></td><td>National recovery plan for threatened albatrosses and giant petrels 2011–2016 (Ref. 37)
<u>Overall objective</u>:
Ensure the long-term survival and recovery of albatross and giant petrel populations breeding and foraging in Australian jurisdiction by reducing or eliminating human-related threats at sea and on land.
<u>Specific objective 3</u>:
Quantify and reduce marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction.</td><td></td></tr>
<tr><td>Conservation Advice Rhincodon typus Whale Shark (Ref. 30)
Approved Conservation Advice for Dermochelys coriacea (Leatherback Turtle) (Ref. 22)
Approved Conservation Advice for Pristis pristis (largetooth sawfish) (Ref. 27)</td><td>These EPBC management plans for species that may occur within the OA identify marine debris as a threat, but do not identify any relevant objectives.</td></tr>
<tr><td colspan="2">Therefore, CAPL has defined these acceptable levels of impact such that they are not inconsistent with these documents:
no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery
no adverse effect to an important or substantial area of habitat such that a significant impact on marine ecosystem functioning or integrity results
no significant adverse impact to cultural heritage values attributed to the offshore marine area.
CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets these acceptable levels.</td></tr>
</table>

8.12.4 Environmental performance

Table 8-63 lists the EPO defined for the unplanned release of solid objects and the adopted control measures to achieve the outcome.

Table 8-63: Environmental performance for Unplanned release—Solid objects

EPO	Adopted control measure
EPO16: No uncontrolled release of solid objects to the environment during the Development activities. **EPO17:** No injury or mortality to marine fauna from an uncontrolled release of solid objects to the environment associated with the Development.	**CM41**: MODUs and vessels will comply with the requirements of Marine Order 95 (MARPOL 73/78 Annex V) in relation to managing waste (garbage) offshore. **CM42**: MODUs and vessels will have specific lifting plans in place for cranes before commencing lifting operations and transfers, to prevent dropped objects. **CM43**: Any dropped objects will be retrieved if practicable.
EPO02: No impacts to underwater cultural heritage from the Development activities. **EPO03:** No adverse change to First Nations cultural heritage values from the Development activities.	**CM06**: Prior to drilling or installation, studies, and surveys (as necessary) will be conducted to verify that no identifiable or reasonably detectable underwater cultural heritage (as defined in the *Underwater Cultural Heritage Act 2018* (Cth)) is present within areas of the seabed expected to be disturbed. Results will be incorporated into relevant subsequent EPs and, based on assessed risks, additional control measures may be adopted, or infrastructure locations may be amended if practicable. **CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development. **CM09**: A protocol to manage underwater cultural heritage will be developed, which will include a decision framework in the event of unexpected finds *in situ* during seabed-disturbing activities.

8.13 Unplanned release—Minor LOC

8.13.1 Source

The loss of containment (LOC) of minor volumes of hydrocarbons and chemicals may result in an unplanned release to the marine environment.

Table 8-64 lists activities within each phase where credible minor LOC scenarios may occur in the OA.

Note: Major unplanned release scenarios are not included in this section; they are assessed in:

- Unplanned release—Vessel collision (MDO): Section 8.14
- Unplanned release—Hydrocarbon system (condensate): Section 8.15.

Table 8-64: Phases and activities that may generate an Unplanned release—Minor LOC

Phase	Activity
Installation and commissioning	Installation of subsea structures Hydrotest and pre-commissioning
Operations	Maintenance and repairs
Support activities	MODU operations Vessel operations ROV operations

8.13.1.1 Installation and commissioning

A minor LOC of hydrocarbons and chemicals during this phase may result from:

- dropped objects (and interaction with the Development subsea infrastructure) resulting in a loss of various fluids including treated sea water, hydraulic fluids, or MEG
- hydrotesting and pre-commissioning activities, resulting in a loss of hydraulic fluid.

The various fluids that could be released include treated sea water, hydraulic fluids and MEG. Treated water may contain a range of commercial chemicals such as biocide, oxygen scavenger, corrosion inhibitor, clear dye, and buffering solutions. MEG is a category ‘E’ OCNS chemical with no substitution warning, is readily biodegradable and has a low potential for bioaccumulation.

During installation of subsea infrastructure, a minor LOC of hydraulic control fluid may occur. The maximum volume of hydraulic control fluid accidentally released is anticipated to be <100 L at the pipeline/GFP tie-in point for each field.

Failure of hydrotesting and pre-commissioning activities may result in a maximum 50 m^3 LOC of both MEG and treated water and <100 L of hydraulic control fluid.

The duration for the installation and commissioning phase for the Development is expected to be 12–15 months, per field.

8.13.1.2 Operations

During maintenance and minor repairs (and any associated testing), LOC of hydraulic control fluid may also occur. The maximum volume of hydraulic control fluid accidentally released is anticipated to be <100 L at the flowline/GFP tie-in point for each field.

The duration for the operations phase is expected to be 10–30 years, depending on the field.

8.13.1.3 Support activities (all phases)

Routine support operations include handling, using, and transferring hydrocarbons and chemicals, which may lead to these LOC events:

- poor use, handling and transfer of hydrocarbons and chemicals on board (deck spill)
- transferring hydrocarbons and chemicals between vessels and MODU
- hydraulic line failure from ROV.

The MODU will be present in the OA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well interventions). It will move between fields but will spend most of the time at the DCs.

Vessels are present in the OA during all phases of the Development. The highest number of vessels working concurrently across the OA is estimated at 5–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation may take as long as 15 months per field (C&D field) and while concurrent activities are possible during this time, they will be intermittent and would occur for only a small portion of the overall duration.

Deck spill

Various chemicals and hydrocarbons are used or stored on the deck of vessels and the MODU. Causes of a minor LOC can include mechanical integrity failures, poor process design, inadequate hazard analysis, unexpected or uncontrolled reactions, mishandling or human error. In most cases, a minor LOC on deck will be captured by a drainage system and diverted to a bilge tank or similar where it can be treated or transported to the mainland for safe disposal. If a minor LOC is not captured within a closed system (an unlikely event), it will likely be discharged to the marine environment.

The maximum volume expected is ~1 m^3 based on the loss of an entire intermediate bulk container (IBC) due to rupture while handling.

Bunkering / Bulk transfer

Bulk transfer of MDO and chemicals will be done throughout all phases, both between vessels and between supply vessels and the MODU. During bunkering, an accidental release of MDO to the marine environment may occur if there is partial or total failure of the bulk transfer hose or associated dry-break couplings.

The predicted maximum volume of MDO lost (50 m^3) is based on assuming failure of dry-break couplings and an assumed 200 m^3/h transfer rate (based on previous operations) for 15 minutes.

This volume is expected to be less than that released during vessel collision (~500 m^3), therefore modelling of a 50 m^3 release of MDO was not undertaken to support the impact assessment.

Drilling fluids, MEG and cement may also be released during bulk transfer. A single release of these materials is expected to be ~25 m^3.

ROV hydraulic hose

ROVs, which can operate hydraulic tools/equipment, may be used during all phases of the development. Hydraulic fluids are likely to be relatively non-toxic and water-based. Fluid volumes on the ROV units are limited (typically <50 L) with shutdown systems designed to limit the loss of fluid if a leak occurs in the hydraulic system.

8.13.2 Impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the OA that may be impacted by a minor LOC:

- water quality
- fishes, including sharks and rays
- marine reptiles
- marine mammals.

Table 8-65 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to a minor LOC in the OA.

Although fish may potentially be impacted by a minor LOC, the area of influence is highly localised and is not expected to result in a change in the viability of the population of commercially important species or demersal fish assemblages. Only one State- and 3 Commonwealth-managed fisheries have recorded historical fishing effort in the OA. The spatial extent of impact from a <0.05–50 m^3 LOC is an insignificant area compared to the size and scale of commercial fisheries, and is not expected to damage fish stocks, displace fishing effort, or result in the inability to sell catch due to perceived or actual fish tainting.

Therefore, impacts to commercial fisheries or a change in values and sensitivities of the fish assemblage values of the Continental slope demersal fish communities KEF from an unplanned minor LOC are not expected, and are not evaluated further.

Table 8-65: Risk evaluation for Unplanned release—Minor LOC

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A		Minor loss of containment may result in: • Localised and temporary reduction in water quality.	5	5	9 (Very low)
		Minor loss of containment may result in: • Injury or mortality of marine fauna.	5	5	9 (Very low)

Risk evaluation
Water quality
Localised and temporary reduction in water quality A minor LOC of hazardous substances has the potential to result in a localised and temporary reduction in water quality at the release location. The various fluids that could be released include treated sea water, MEG, hydraulic fluids, MDO, as well as various chemicals and hydrocarbons stored on the deck of vessels and the MODU. The worst-case credible scenario for MEG, treated water and MDO is 50 m^3.

Risk evaluation
Treated water may contain various commercial chemicals such as biocide, oxygen scavenger, corrosion inhibitor, clear dye, and buffering solutions. MEG is widely used by the oil and gas industry in wellheads and pipelines. It is rated as PLONOR by CEFAS and is readily biodegradable with low potential for bioaccumulation (Ref. 424, Ref. 425). MEG is also completely miscible with water and would disperse quickly if released into the marine environment. MDO is required to fuel the vessel's main engines, as well as power equipment on board, such as pumps, cranes, and generators. As a light hydrocarbon, MDO evaporates quickly and spreads rapidly in warm waters, indicating that a surface release would result in a temporary surface slick. Smaller quantities of other chemicals also have the potential to be released during support activities, including: • ~1 m^3 of wash chemicals, cleaning chemicals and solvents • <50 L of hydraulic fluid from machinery (hoses/ROV) • ~25 m^3 of drilling fluids (WBF/NADF), MEG and cement. Any impacts to surface and pelagic waters are expected to be less than those associated with planned discharges (Sections 8.6, 8.7 and 8.8) or unplanned larger spill events resulting from a vessel collision (Section 8.14) or a full-bore rupture of a flowline (Section 8.15). Due to the small volumes associated with an unplanned minor LOC (up to 50 m^3), impacts to water quality will be localised and temporary. Any hydrocarbons or chemicals released to the marine environment are expected to evaporate quickly or be mixed and diluted due to wave action and local currents. Therefore, the consequence of this scenario has been evaluated as Minor (5) because there is unlikely to be a lasting effect to the physical environment. With the implementation of relevant control measures including the implementation of Chevron's Marine Standard Non-Tankers as well as MARPOL requirements, the likelihood of a minor LOC arising during the Development that results in a Minor (5) consequence is assessed as Remote (5). Overall, the risk of Unplanned release—Minor LOC to water quality is Very low (9).
Marine fauna
Injury or mortality of marine fauna Impacts to ambient water quality are likely to be localised and temporary based upon the volumes associated with minor releases (typically <0.05 m^3 but up to 50 m^3) of: • chemicals (MEG, treated water, hydraulic fluid, drilling fluids, cement) • hydrocarbons (MDO). A change to ambient water quality could lead to short-term impacts on marine fauna, with chronic impacts not expected due to short exposure time and small volumes. Small volumes (up to 50 m^3) of hydrocarbons and chemicals released in a minor LOC event within the OA will be mixed and diluted rapidly by wave and current action. As a result, fauna would need to pass directly through the plume almost immediately upon release to be impacted. A minor LOC event would have a very localised effect on plankton in the water column within the plume. Low nutrient levels within the OA indicates sparse populations of plankton which is representative of the sparse populations of plankton species throughout the NWS (Ref. 104). Mortality rates for plankton are naturally high with distribution often patchy and linked to localised and seasonal productivity that produces sporadic bursts in phytoplankton and zooplankton populations (Ref. 104). Therefore, plankton populations are expected to recover quickly from any impacts of a minor LOC event. Fish, marine mammal and marine turtle species are also unlikely to be affected by a minor LOC because they are highly mobile and will move away from any temporary release of a hydrocarbon or chemical. The OA overlaps the following BIAs; however, impacts from a minor LOC are extremely unlikely as discharges will be rapidly mixed and diluted by natural processes. The values and sensitivities within the OA with the potential to be affected injury or mortality include: • humpback whale BIA (migration) • pygmy blue whale BIA (distribution and migration) • flatback turtle (habitat critical and internesting buffer) • whale shark BIA (foraging) • fish communities (associated with the various KEFs). The approved Conservation Advice for Whale Sharks (Ref. 30) states that the main threat to the species occurs outside Australian waters (from intentional and unintentional mortality from fishing). Within Australian waters, habitat disruption from mineral exploration, production and transportation is listed as a threat.

Risk evaluation
The recovery plans for marine turtles (Ref. 148) and the blue whale (Ref. 16) lists acute chemical discharge from various pollutants as a threat to the species. Although the OA overlaps the flatback turtle internesting buffer, Whittock (Ref 150; Ref. 151) defined unsuitable flatback turtle internesting habitat as waters >25 m deep and >27 km from the coast. Only the WTR and C&D fields, which are at depths >25 m deep and further than 27 km the closest coast, have infrastructure within the internesting buffer. Therefore, it would be very unlikely that turtles would aggregate within the OA during their internesting period and only transient individuals would be present. The small volumes combined with the dilution and dispersion that occurs from natural weathering processes such as ocean currents, indicates that the extent of exposure will be limited in area and duration. Given the highly mobile nature of the identified species, only pelagic fauna present in the immediate vicinity of the release would likely be at risk of impact; therefore, the only potential impact would occur to individuals, with no population impact expected. The potential consequence of an Unplanned release—Minor LOC of hazardous substances within the OA would be limited to the potential change to fauna behaviour (e.g. avoidance) within surface waters affected by the release. Any potential impact is expected to be short term and limited to a small number of individuals; therefore, the consequence has been evaluated as Minor (5). With the implementation of relevant control measures including the implementation of Chevron's Marine Standard Non-Tankers as well as MARPOL requirements and given the transient nature of values and sensitivities the likelihood of a minor LOC arising during the Development that results in a Minor (5) consequence is assessed as Remote (5). Overall, the risk of Unplanned release—Minor LOC to marine fauna is Very low (9).

8.13.3 Determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-66 details the determination of acceptability for an unplanned minor LOC.

Table 8-66: Determination of acceptability for Unplanned release—Minor LOC

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence level for an unplanned minor LOC was evaluated as Minor (5). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the risk evaluation for an unplanned minor LOC. • Prevention measures for an unplanned minor LOC are well regulated and managed in Australian waters. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted..
	(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations
	The Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the impact and risk of an unplanned minor LOC based on relevant environmental legislation and other requirements as listed below. • The regulation and management of loss of containment in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">The highest consequence level for an unplanned minor LOC was evaluated as Minor (5).
Any relevant stakeholder feedback in relation to unplanned minor LOC has been incorporated in the OPP and assessed in the external context acceptability criteria.
To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5).
The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td rowspan="5">Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address relevant requirements/actions within each of the listed legislative requirements considered relevant to this aspect.</td></tr>
<tr><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td>Protection of the Sea (Prevention of Pollution from Ships) Act 1983 – Section 26F (implements MARPOL Annex I).
Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution.
It also invokes certain requirements of the MARPOL Convention including those relating to discharge of noxious liquid substances, sewage, garbage and air pollution.
This Act requires ships >400 gross tonnes to have in place pollution emergency plans, and also provides for emergency discharges from ships.</td><td rowspan="4">Legislative requirements to manage Unplanned release–Minor LOC are addressed by adopting these control measures:
CM44: MODUs and vessels will meet the requirements of the Chevron Marine Standard Non Tankers (Ref. 284), including pre-mobilisation inspections of equipment, couplings, and secondary containment.
CM45: MODUs and vessels will have a bulk transfer procedure in place to prevent spills before commencing the activities.
CM42: The MODUs and vessels will have specific lifting plans in place for cranes before commencing lifting operations and transfers, to prevent dropped objects.
CM46: MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to having an approved Ship Oil Pollution Emergency Plan or equivalent in place.</td></tr>
<tr><td>Navigation Act 2012 – Chapter 4 (Prevention of Pollution).
Gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).</td></tr>
<tr><td>Guidelines for Offshore Marine Operations (Ref. 495)
The objective of this document is to provide guidance in the best practices that should be adopted to ensure the safety of personnel on board all vessels servicing and supporting offshore facilities, and to reduce the risks associated with such operations.

AMSA Marine Orders 91 and 94</td></tr>
</table>

Determination of acceptability		
	Sets out the requirements of the prevention of pollution of the environment for regulated Australian vessels, domestic commercial vessels, and Australian recreation vessels. Marine Order 91 (Marine Pollution Prevention – Oil) Marine Order 94 (Marine pollution prevention – packaged harmful substances)	
	Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148) Management action A1: Maintain and improve efficacy of legal and management protection: • Ensure spill risk strategies and response programs adequately include management for marine turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs.	EPBC management plan requirements to minimise habitat degradation / modification are addressed by adopting these control measures: **CM44:** MODUs and vessels will meet the requirements of the Chevron Marine Standard Non Tankers (Ref. 284), including pre-mobilisation inspections of equipment, couplings, and secondary containment. **CM45:** MODUs and vessels will have a bulk transfer procedure in place to prevent spills before commencing the activities. **CM42**: The MODUs and vessels will have specific lifting plans in place for cranes before commencing lifting operations and transfers, to prevent dropped objects. **CM46** MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to having an approved Ship Oil Pollution Emergency Plan or equivalent in place. Therefore, the Development is not considered to be inconsistent with the EPBC management plans.
	Conservation Management Plan for the Southern Right Whale (Ref. 19) Addressing infrastructure and coastal development impacts.	
	Draft National Recovery Plan for the Southern Right Whale (Ref. 20) Baseline surveys and monitoring undertaken during activity implementation are conducted in accordance with best practice standards and guidelines to ensure standardised datasets are obtained and suitable to inform environmental management decision making that can reduce the risk of threats to southern right whales.	
	Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Sea Snake) (Ref. 24) Identifies habitat degradation / modification as a key threat. Management action: Ensure there is no anthropogenic disturbance in areas where the short-nosed sea snake occurs, excluding necessary actions to manage the conservation of the species.	
	Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 23) Identifies habitat degradation / modification as a key threat. Management action: Ensure there is no anthropogenic disturbance in areas where the leaf-scaled sea snake occurs, excluding necessary actions to manage the conservation of the species.	

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="3"></td><td>Approved Conservation Advice for Pristis pristis (largetooth sawfish) (Ref. 27)
Implement measures to reduce adverse impacts of habitat degradation and/or modification</td><td rowspan="2"></td></tr>
<tr><td>Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25)
Management action 5C: Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.
Management action 5D: Implement measures to reduce adverse impacts of habitat degradation and/or modification.</td></tr>
<tr><td>Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16)
Conservation Advice Balaenoptera physalus Fin Whale (Ref. 17)
Conservation Advice Balaenoptera borealis Sei Whale (Ref. 18)
Approved Conservation Advice on Pristis clavate (Dwarf Sawfish) (Ref. 26)
Recovery Plan for the Grey Nurse Shark (Carcharias taurus) (Ref. 29)
Recovery Plan for the White Shark (Carcharodon carcharias) (Ref. 31)
Conservation Advice Rhincodon typus Whale Shark (Ref. 30).</td><td>These EPBC management plans for species that may occur within the OA identify habitat degradation / modification as a threat, but do not identify any relevant actions.</td></tr>
<tr><td>Internal context</td><td colspan="2">This CAPL environmental performance standard/procedure was deemed relevant for this aspect:
• Chevron Marine Standard Non Tankers (Ref. 284)</td></tr>
<tr><td>External context</td><td colspan="2">CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment.
No feedback was received in relation to an unplanned minor LOC from Phase 1 stakeholder consultation.</td></tr>
<tr><td>Defined acceptable level</td><td colspan="2">The consequence of an unplanned minor LOC is inherently acceptable because the highest consequence level is Minor (5).
Additionally, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan.
The risk evaluation does not identify scientific uncertainty against risks of loss of containment for each receptor.
Although minor LOC is not listed as a threat to protected matters under documents made or implemented under the EPBC Act, it can modify the marine habitat for some species.
Habitat degradation / modification has been identified as a threat to protected matters under documents made or implemented under the EPBC Act, CAPL will define an acceptable level of impact that aligns with the objectives of these documents. Objectives of the relevant documents are shown below—these were considered during the impact and risk evaluation.</td></tr>
</table>

Determination of acceptability		
	Plan and relevant objective	**Demonstration of requirement**
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) Recovery objective: Minimise anthropogenic threats to allow for their conservation status to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 4: Anthropogenic threats are demonstrably minimised.	CAPL considers the impacts of unplanned minor LOC to not be inconsistent with the relevant objectives of these EPBC management plans. By applying EPO18, impacts and risks to habitat degradation / modification from unplanned minor LOC will be managed at or below the defined acceptable level.
	Conservation Management Plan for the Southern Right Whale (Ref. 19) Long-term recovery objective: The population has increased in size to a level that the conservation status has improved, and the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria. Interim recovery objective 5: Anthropogenic threats are demonstrably minimised.	
	Draft Recovery Plan for the Southern Right Whale (Ref. 20) Long-term recovery objective: The population has increased in size to a level that the conservation status has improved, and the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria. Interim recovery objective 2: Anthropogenic threats are managed consistent with ecologically sustainable development principles and do not impede recovery of southern right whales	
	Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148) Long-term recovery objective: Minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 3: Anthropogenic threats are demonstrably minimised.	
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25) Primary Objective: To assist the recovery of sawfish and river sharks in Australian waters with a view to: • improving the population status leading to removal of the sawfish and river shark species from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder recovery in the near	

Determination of acceptability		
	future or impact the conservation status of the species in the future. Specific Objectives: Objective 5: Reduce, and where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species.	
	Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 31). Primary objective: To assist the recovery of the white shark in the wild, throughout its range in Australian waters, with a view to: • improving the population status, leading to future removal of the white shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the white shark in the near future or impact the conservation status of the species in the future. Specific objective: Objective 7: Continue to identify and protect habitat critical to the survival of the white shark and minimise the impact of threatening processes within these areas	
	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29) Primary Objective: To assist the recovery of the grey nurse shark in the wild, throughout its range in Australian waters, with a view to: • improving the population status, leading to future removal of the grey nurse shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the grey nurse shark in the near future or impact the conservation status of the species in the future. Specific Objectives: Objective 8: Continue to identify and protect habitat critical to the survival of the grey nurse shark and reduce the impact of threatening processes within these areas.	
	Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 17) Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 18) Conservation Advice *Rhincodon typus* Whale Shark (Ref. 30) Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Sea Snake) (Ref. 24)	These EPBC management plans for species that may occur within the OA identify habitat degradation / modification as a threat, but do not identify any relevant objectives.

Determination of acceptability		
	Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 23) Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish) (Ref. 26) Approved Conservation Advice for *Pristis pristis* (largetooth sawfish) (Ref. 27)	
	Therefore, CAPL has defined these acceptable levels of impact such that they are not inconsistent with these documents: • no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery • no adverse effect to an important or substantial area of habitat such that a significant impact on marine ecosystem functioning or integrity results CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets these acceptable levels.	

8.13.4 Environmental performance

Table 8-67 lists the EPO defined for an unplanned minor LOC and the adopted control measures to achieve the outcome.

Table 8-67: Environmental performance for Unplanned release—Minor LOC

EPO	Adopted control measure
EPO18: No unplanned release of hydrocarbons or chemicals to the marine environment during the Development activities.	**CM42**: The MODUs and vessels will have specific lifting plans in place for cranes before commencing lifting operations and transfers, to prevent dropped objects. **CM44:** MODUs and vessels will meet the requirements of the Chevron Marine Standard Non Tankers (Ref. 284), including pre-mobilisation inspections of equipment, couplings, and secondary containment. **CM45:** MODUs and vessels will have a bulk transfer procedure in place to prevent spills before commencing the activities. **CM46:** MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to having an approved Ship Oil Pollution Emergency Plan or equivalent in place

8.14 Unplanned release—Vessel collision (MDO)

8.14.1 Source

Vessels and the MODU will use marine diesel oil (MDO) as fuel.

A vessel collision event within the OA is considered a credible (but unlikely) unplanned event. A major marine spill because of vessel collision is only likely to occur under exceptional circumstances (e.g. loss of DP, navigational error, inclement weather conditions). Collision could potentially occur between Development vessels and/or the MODU or third-party vessels.

Given the location, water depths, and lack of submerged features within the OA, grounding is not considered credible, and is not considered further.

CAPL commissioned RPS to conduct stochastic spill modelling to predict the extent of hydrocarbon exposure associated with a vessel collision event.

The Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA for MDO modelling represent the outer area where hydrocarbons above impact concentration thresholds (Table 6-1 and Figure 6-2 respectively) may be present in the environment if a spill resulted from a vessel collision (refer to Figure 12.1 in Appendix C; Ref. 496 and Table 6-1 in Section 6.1 of this OPP).

Table 8-68 lists activities within each phase where a vessel collision resulting in a loss of MDO could occur in the OA.

Table 8-68: Phases and activities that generate Unplanned release—Vessel collision (MDO)

Phase	Activity
Support activities	MODU operations Vessel operations

8.14.1.1 Support activities

The MODU and various vessels will be present in the OA during the Development.

The MODU will be present in the OA during the drilling and decommissioning phases and potentially for shorter periods during the operations phase (for well interventions). Drilling of each well will take ~3 months.

An SNA will be established around the MODU (or HWIU if used for decommissioning). This is a temporary area that excludes other marine users from a 500 m radius around the MODU for safety purposes. An SNA is also likely to be requested for pipelay, construction and decommissioning vessels. Any SNA will only be in place for the duration of the relevant activities. A larger (2 km) cautionary zone may also be established.

Vessels are present in the OA during all phases of the Development. The highest number of vessels working concurrently across the OA is estimated at 5–10 vessels. This may occur when different phases or activities are occurring concurrently. For example, installation may take as long as 15 months per field (C&D field) and while concurrent activities are possible during this time, they will be intermittent and would occur for only a small portion of the overall duration.

A vessel collision between these vessels and/or the MODU, and/or third-party vessels may result in a hydrocarbon spill.

The calculation of discharge volume and timing aligns with the methodology recommended in AMSA's Technical Guidelines for Preparing Contingency Plans for Marine and Coastal Facilities (Ref. 497).

Based upon the types of vessels present in the OA during the Development, CAPL identified the credible worst-case scenario (as per AMSA guidelines; Ref. 497) as a surface release of 1,500 m^3 of MDO following a vessel collision.

8.14.2 Stochastic spill modelling

Stochastic modelling was performed using a 3-dimensional (3D) trajectory and fates model, Spill Impact Mapping Analysis Program (SIMAP) (Appendix C; Ref. 496). The SIMAP model calculates the transport, spread, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

Stochastic modelling was completed for 3 seasons, defined by the unique prevailing wind and general current conditions: summer (September to March), the transitional periods (April and August) and winter (May to July).

Because spills can occur during any set of wind and current conditions, modelling was conducted using a stochastic (random or non-deterministic) approach, which involved running 100 spill simulations per season for each scenario using random start times and the same release information (spill volume, duration, and composition of the oil). This ensured that each simulation was subject to different wind and current conditions and, in turn, movement and weathering of the hydrocarbon.

Stochastic modelling was conducted for a 1,500 m^3 surface release of MDO over 24 hours, which represents a loss of inventory from the largest fuel tank on a vessel or MODU as a result of a hypothetical vessel collision.

Stochastic modelling for a vessel collision was done for the WTR field because it is the closest field to shore and represents the worst-case spill location for hydrocarbon exposure to sensitive receptors (i.e. shoreline hydrocarbon exposure).

Table 8-69 summarises the model settings. Table 8-70 summarises the hydrocarbon properties for MDO. The modelled impact thresholds for social and ecological receptors are defined in Table 6-2.

Table 8-69: Vessel collision spill scenario model settings

Parameter	Details
Release location	WTR Well 5
Latitude	20.23666° S
Longitude	115.04357° E
Water Depth	150 m
Oil type	MDO
Simulation spill type	Surface
Simulation spill volume	1,500 m^3
Simulation spill duration	24 hours
Total simulation duration	60 days
Number of randomly selected spill simulation start times	100 per season (300 total)

Parameter	Details
Seasons modelled	Summer (September to March) Transitional (April and August) Winter (May to July)

Table 8-70: Physical properties and boiling point ranges for MDO

Characteristic	Value			
Density	829 kg/m^3 (at 25 °C)			
Dynamic viscosity	4 cP (at 25 °C)			
Pour point	−14 C			
API gravity	37.6 API			
Classification	Group II, light persistent oil			
Boiling point	**Volatile <180 °C**	**Semi-volatile 180–265 °C**	**Low volatility 265–380 °C**	**Residual >380 °C**
	6.0%	34.6%	54.4%	5.0%

8.14.2.1 Hydrocarbon Characteristics

MDO is a light persistent fuel oil used in the maritime industry (Table 8-70). The low viscosity (4 cP) indicates that this oil will spread quickly when released and will form a thin film on the sea surface, increasing the evaporation rate.

Generally, about 6.0% of the MDO mass should evaporate within the first 12 hours (boiling point <180 °C); a further 34.6% should evaporate within the first 24 hours (boiling point 180 °C–265 °C); and an additional 54.4% should evaporate over several days (boiling point 265 °C–380 °C). Approximately 5% (by mass) of MDO will not evaporate at atmospheric temperatures. These compounds will persist in the environment.

While MDO will typically remain on the water surface (where it is subject to evaporation), it is noted that some of the heavy components have a strong tendency to physically entrain into the upper water column in the presence of moderate winds (i.e., >12 knots) and breaking waves but can re-float to the surface if these energies abate.

8.14.2.2 Modelling outputs

Stochastic modelling outputs (Appendix C; Ref. 496) are summarised in Table 8-71, having regard to the particular values and sensitivities, as identified in Section 6.

The outputs of from the 300 simulations modelled for the 1,500 m^3 MDO release within the WTR are summarised below:

- The maximum distance from the release location to the low (≥1 g/m^2), moderate (≥10 g/m^2) and high (≥50 g/m^2) threshold for floating condensate was 167.0 northeast (summer), 59.6 km south-southwest(winter) and 17.6 km north-northeast (summer), respectively.
- Excluding the receptors that the release location resides within, the humpback whale - Migration BIA and Continental Slope Demersal Fish Communities KEF were the only receptors predicted to be exposed during all three seasons at the low and moderate floating oil thresholds. The probabilities of low and

moderate exposure at the humpback whale - Migration BIA ranged between 16–22% and 3–4%, whilst the probabilities of low and moderate exposure to the Continental Slope Demersal Fish Communities KEF ranged between 35–54% and 4–13%, respectively. The minimum times before exposure at the low threshold for the humpback whale - Migration BIA and Continental Slope Demersal Fish Communities KEF were 0.54 days (winter) and 0.38 days (transitional), respectively.

- The probability of accumulation on any shoreline at, or above, the low threshold (≥10 g/m2) was greatest during winter at 9%, while the minimum time before shoreline accumulation was 6.50 days and the maximum volume of oil ashore above the low threshold was 35.1 m^3. No high (≥1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.
- In the surface (0-10 m) depth layer, a total of 14, 12, and 14 BIAs were predicted to be exposed to dissolved hydrocarbons at, or above, the low threshold during summer, transitional and winter, respectively. Excluding the 4 BIAs, the highest probabilities of exposure for the low threshold during summer, transitional and winter were predicted as 6%, 6% and 14%, respectively for the humpback whale - Migration BIA.
- In the surface (0-10 m) depth layer, a total of 29 BIAs were predicted to be exposed at, or above, the low threshold during all 3 seasons. Excluding the 4 BIAs (that the release location resides within, the highest probabilities of exposure for the low threshold were predicted for the humpback whale - Migration during all seasons (42%, 59% and 71% for summer, transitional and winter, respectively).
- During all 3 seasons, 3 AMPs were predicted to be exposed at the low entrained hydrocarbon threshold, with the highest probabilities predicted at the Gascoyne AMP (21% summer, 22% transitional and 37% winter). Furthermore, during seasonal conditions the Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold.

Table 8-71: Vessel collision (MDO) stochastic modelling receptor exposure summary

Sensitivity	Name	Surface*		In-water (dissolved)*	In-water (entrained)*	Shoreline*	
		Hydrocarbon Social EMBA ≥1 g/m²	Hydrocarbon Ecological EMBA ≥10 g/m²	Hydrocarbon Social and Ecological EMBA ≥50 ppb	Hydrocarbon Social and Ecological EMBA ≥100 ppb	Hydrocarbon Social EMBA ≥10 g/m²	Hydrocarbon Ecological EMBA ≥100 g/m²
		(probability of exposure[58], minimum time to exposure)		(probability of exposure[58])	(probability of exposure[58])	(probability of exposure[58], minimum time to exposure, mean length of shoreline)	
AMP	Gascoyne	—	—	—	3–8%	—	—
	Montebello	1–4%, 1.96 days	—	0–1%	2–11%	—	—
	Ningaloo	—	—	—	2–6%	—	—
State protected areas	Barrow	—	—	—	—	0–2%, 10.63 days, 16.4 km	0–2% 12.42 days, 2.4 km
	Muiron	—	—	—	—	3–4%, 6.5 days, 6.7 km	0–1%, 12.92days, 1 km
KEF	Ancient coastline at 125 m depth contour[59]	100%, 0.04 days	100%, 0.04 days	25–35%	90–97%	—	—
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula		—	—	5–13%	—	—
	Commonwealth waters adjacent to Ningaloo Reef		—	—	2–6%	—	—
	Continental slope demersal fish communities	35–54%, 0.38 days	4–13%, 0.58 days	0–1%	36–44%	—	—

[58] *Ranges in values shown are due to the different results between seasons.*
[59] *The release location resides within the receptor boundaries.*

Sensitivity	Name	Surface*		In-water (dissolved)*	In-water (entrained)*	Shoreline*	
		Hydrocarbon Social EMBA ≥1 g/m²	**Hydrocarbon Ecological EMBA ≥10 g/m²**	**Hydrocarbon Social and Ecological EMBA ≥50 ppb**	**Hydrocarbon Social and Ecological EMBA ≥100 ppb**	**Hydrocarbon Social EMBA ≥10 g/m²**	**Hydrocarbon Ecological EMBA ≥100 g/m²**
		(probability of exposure[58], minimum time to exposure)		**(probability of exposure[58])**	**(probability of exposure[58])**	**(probability of exposure[58], minimum time to exposure, mean length of shoreline)**	
	Exmouth Plateau	0–1% 7.04 days	—	—	0–3%	—	—
World Heritage properties / National Heritage places	The Ningaloo Coast World Heritage Area	—	—	—		3–7%, 6. 5 days, 4.3 km	1–2%, 12.46 days, 3.8 km
Commonwealth Heritage properties	Ningaloo Marine Area – Commonwealth Waters *(inferred from Ningaloo IMCRA)*	—	—	—	3–8%	—	—

8.14.3 Impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA that may be impacted by hydrocarbon exposure as a result of a vessel collision event:

- water quality
- coastal habitats and associated communities: rocky coasts and sandy beaches
- coastal habitats and associated communities: intertidal mudflats, mangroves, seagrasses
- marine mammals
- marine reptiles
- fishes, including sharks and rays
- seabirds and shorebirds
- KEFs
- commercial fisheries
- tourism and recreation
- AMPs
- cultural heritage value: Ningaloo Coast
- cultural heritage value: Traditional Owners.

Based on the surface release of MDO and in-water hydrocarbon exposure is limited to the upper 10 m of the water column, benthic habitats and associated communities will not be exposed to MDO and will not be evaluated in this section.

The likelihood of an unplanned release of MDO from a vessel collision event was assessed using data from AMSA's Annual Report 2021–22 (Ref. 498) relating to serious pollution incidents from marine operations in Australia. For all marine operations within Australia, 2 serious marine pollution incidents have been reported in the last 4 years. Reportable unplanned releases of MDO from vessel collisions have been heard of within the industry but are not a common occurrence at the magnitude of a serious pollution event.

Based on industry data (Ref. 498), vessel collisions are considered rare. Most vessel collisions involve the loss of containment of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volume used in stochastic modelling (i.e. 1,500 m^3 surface release of MDO over 24 hours) is unlikely.

Offshore vessel operations are dictated by legislative requirements to prevent and manage unplanned releases from vessel collisions. The inherent legislative requirements ensure unplanned releases of MDO from vessel collisions as an uncommon occurrence, as backed by industry data.

Table 8-72 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible hydrocarbon exposure from a vessel collision event. The hydrocarbon environmental exposure thresholds used in this evaluation are detailed in Table 6-2.

Table 8-72: Risk evaluation for Unplanned release—Vessel collision (MDO) event

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	-	Unplanned release of MDO due to a vessel collision event may result in: • Change in water quality.	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • Change in sediment quality.	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • Alteration of coastal habitats and associated communities.	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • Injury or mortality of marine fauna	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • Change to the functions, interests and activities of other marine users	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • Change to values and sensitivities of Australian Marine Parks	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • Change to values and sensitivities of KEFs	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • Change to values and sensitivities of the Ningaloo Coast	5	5	Very Low (9)
		Unplanned release of MDO due to a vessel collision event may result in: • Change to cultural heritage values	5	5	Very Low (9)

Risk evaluation
Water quality
Change in water quality An unplanned release of MDO from a vessel collision may result in a reduction in water quality in offshore waters surrounding the release location. Impacts to water quality are likely to be localised and short-term based on the maximum potential volume released (1,500 m^3) and weathering properties of MDO. On release to the marine environment, MDO spreads quickly and evaporates rapidly in warm waters. Stochastic modelling of 300 simulated vessel collision events predicts potential hydrocarbon exposure at the low surface threshold to extend up to 167 km from the release location (Appendix C; Ref. 496). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 912 km^2 at the low threshold (1 g/m^2) and 256 km^2 at the moderate threshold (10 g/m^2) across the 60 day simulation. This predicted impact is very short in duration. At the low threshold (1 g/m^2), floating oil on the surface peaks at an area of ~105 km^2 on the third day following the release, but rapidly reduces to zero on day 4. At the moderate threshold (10 g/m^2) floating oil on the surface peaks at an area of ~30 km^2 on the first day following the release and returns to zero by day 3. By day 4 there was no predicted surface exposure above these thresholds. Surface and in-water hydrocarbons would be exposed to processes such as evaporation, dispersion, dilution, and physical and biological degradation, Within the localised area of exposure, rapid evaporation and

Risk evaluation
biological and photochemical degradation of MDO will lead to exposure being limited to short periods, with up to ~40% of the mass lost within the first 24 hours and ~95% of the mass lost over several days (Section 8.14.2.1) (Appendix C; Ref. 496). Approximately 5% of the mass will not evaporate and persist in the environment. This fraction will be subject to hydrodynamic forces and will decay over time. In the event of a vessel collision event, rapid evaporation, chemical degradation, and dispersion, as well as biological and photochemical degradation of MDO will ensure exposure is limited in areas impacted and duration. As such, only a small, localised area will be subject to potential changes in water quality over short-term durations. The consequence of a vessel collision event resulting in an MDO spill has been evaluated as Minor (5) because the change in water quality from hydrocarbon exposure may be short-term and localised. As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, and the safeguards in place, including enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision (MDO) event to water quality is Very Low (9).
Coastal habitats and associated communities: Rocky coasts and sandy beaches
Alteration of coastal habitats and associated communities Based on the maximum potential volume released (1,500 m^3) and weathering properties of MDO, an unplanned release of MDO from a vessel collision event may result in alterations to rocky coasts and sandy beaches resulting from shoreline accumulation of hydrocarbons. Stochastic modelling predicted a 2% probability of shoreline accumulation above the impact (moderate) threshold at Barrow Island and the Ningaloo Coast World Heritage Area and a 1% probability of contact along the Exmouth and Murion Island coastlines (Table 8-71). The deterministic run for the largest volume ashore and longest length of shoreline with accumulation above the moderate threshold predicted a peak of ~ 20 m^3 and a maximum length of ~10 km. There was no predicted accumulation ≥1,000 g/m^2 predicted to occur. As a result, hydrocarbon exposure to rocky coasts and sandy beaches from a vessel collision event is likely to be localised to a small number and sections of shorelines. Further, based on the natural biological and mechanical processes of shorelines and the rapid weathering of MDO, this localised impact is expected to be short term in duration. Rocky coasts and sandy beaches across the Pilbara range from soft sand beaches to exposed rocky shores (Ref. 499). Oil deposited on soft sandy beaches may penetrate the sand; however, natural processes (e.g. wave action) help disperse stranded oils and mix them into the water column, thus helping sandy beaches recover from light oiling (Ref. 500). Sun and wind can also help break down oil over time, reducing its toxicity and allowing it to be metabolised and degraded by microorganisms in the sand (Ref. 501). At exposed rocky shores, oil is typically helped offshore by reflecting waves—any oil deposited is rapidly removed by wave action. Hydrocarbons present on rocky shores are generally only there for a short period (Ref.500). Physical dispersion and microorganism degradation processes on shorelines limit changes in sediment quality from hydrocarbon exposure to a short-term period. Given these natural biological and mechanical processes, and the predicted localised area of impact, the consequence of a vessel collision event resulting in an MDO spill has been evaluated as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision (MDO) event to coastal habitats and communities: rocky coasts and sandy beaches is Very Low (9).
Coastal habitats and associated communities: intertidal mudflats, mangroves, seagrasses
Alteration of coastal habitats and associated communities Shoreline hydrocarbons can have smothering and toxic effects on intertidal mudflats, mangroves and seagrasses. Intertidal mudflats, which are typically sheltered and have a large surface area for oil absorption, can trap oil, potentially causing toxicity impacts to infauna. Intertidal mudflats are very sensitive to oil pollution because the oil enters lower layers of the mudflats where a lack of oxygen prevents it from decomposing (Ref. 502). Acute and chronic impacts to the health of mangrove communities can occur via pneumatophore smothering and exposure to the toxic volatile fraction of the hydrocarbons (Ref. 502). Intertidal seagrasses are vulnerable to smothering, which can lead to mortality if oil coats their flowers, leaves and stems (Ref. 503; Ref. 504).

Risk evaluation
Stochastic modelling showed that in-water (entrained) hydrocarbons were predicted to remain within the surface layers only. Therefore, exposure to benthic habitat in deeper waters are not predicted to occur. However, smothering of benthic habitat communities may occur if a surface slick occurs in the intertidal area. Stochastic modelling predicted that a 2% probability of shoreline accumulation above the ≥100 g/m^2 impact threshold may occur along the Barrow Island and the Ningaloo Coast World Heritage Area shorelines. No accumulation ≥1,000 g/m^2 was predicted to occur at any location. This higher threshold is typically associated with impacts to coastal vegetation communities. Observations by Lin and Mendelssohn (Ref. 99) demonstrated that loadings of >1,000 g/m^2 of oil would be required to impact plants significantly. Similar thresholds have been found in studies assessing oil impacts on mangroves (e.g. Grant et al. [Ref. 100], Suprayogi and Murray [Ref.101]). Based on these findings, and limited shorelines where accumulation is predicted above impact thresholds (Hydrocarbon Ecological EMBA), shoreline exposure to intertidal mudflats, mangroves and seagrasses are anticipated to result in localised sublethal effects. As such shoreline exposure to mangroves and intertidal mudflats is not discussed further. The deterministic model for the largest swept area of floating oil above 10 g/m^2 indicates that surface hydrocarbons concentrations ≥10 g/m^2 (i.e., impact threshold) are present for <3 days following the spill event, with a maximum area of coverage of ~30 km^2 occurring 24 hours after the spill commenced. Further, the deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km. These deterministic scenarios are considered most relevant for nearshore waters and subsequent impacts to seagrasses. Therefore, as the extent and duration of exposure to nearshore environments is expected to be limited, the potential for environmental impacts would also be limited. Based on an assessment of the predicted magnitude and duration of surface oil, and both instantaneous and time-integrated entrained oil, it is expected that only a small proportion of any seagrass would be exposed above the defined impact thresholds. Therefore, the potential impacts of oil to cause smothering was ranked as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision (MDO) event to coastal habitats and associated communities: intertidal mudflats, mangroves, seagrasses is Very Low (9).
Coastal habitats and associated communities: Intertidal and subtidal corals
Alteration of coastal habitats and associated communities Shoreline and entrained hydrocarbons can have smothering and toxic effects on intertidal and subtidal corals. Direct contact of hydrocarbons to coral can cause smothering, resulting in a decline in metabolic rate, and may cause varying degrees of tissue decomposition and death. A range of impacts may also result from toxicity, including partial mortality of colonies, reduced growth rates, bleaching, and reduced photosynthesis (Ref. 505; Ref. 506). Given the surface release of MDO in offshore waters and presence of in-water hydrocarbons is predicted in the surface layers (<10 m water depth) only, exposure to coral reefs in deeper water are not predicted occur and therefore are not mentioned further. However, smothering of benthic habitat communities may occur if a surface slick occurs in the intertidal area. A review of modelling predictions for shoreline oil across the Ningaloo Coast and Barrow and Montebello Islands were used as indicators for consequence evaluation. A review of shoreline hydrocarbons is considered most relevant for nearshore waters and subsequent impacts to nearshore intertidal and subtidal corals. Stochastic modelling predicted a <2% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island, and the Montebello Islands. Based on the modelling, coral habitats along the Ningaloo Coast and those on the western side of Montebello Islands in 0–10 m water depths have a low probability of impact. Review of shoreline hydrocarbons is considered most relevant for nearshore waters and subsequent impacts to nearshore intertidal and subtidal corals. The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km. This deterministic scenario is considered most relevant for nearshore waters and subsequent impacts to corals. Therefore, as the extent and duration of exposure to nearshore environments is expected to be limited the potential for environmental impacts would also be limited.

Risk evaluation
Based on an assessment of the predicted magnitude and duration of surface and shoreline oil, it is expected that only a small proportion of any coral habitat would be exposed above the defined impact thresholds over very short durations. Therefore, the potential impacts of oil to cause smothering was ranked as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision (MDO) event to coastal habitats and associated communities: intertidal and subtidal corals is Very Low (9).
Marine mammals
Injury or mortality of marine fauna Marine mammals can be exposed to oil externally (e.g. swimming through surface slick) or internally (e.g. swallowing oil, consuming oil-affected prey/vegetation, or inhaling volatile oil-related compounds) (Ref. 93). Direct contact with hydrocarbons may result in skin and eye irritation, burns to mucous membranes of eyes and mouth, and increased susceptibility to infection (Ref. 509). However, direct contact with surface hydrocarbons is considered to have little deleterious effect on marine mammals because their smooth skin surfaces are less likely to suffer from hydrocarbon adherence (Ref. 510). The physical impacts from ingested hydrocarbons with subsequent lethal or sublethal impacts are applicable. Depending upon the amount and composition of the ingested oil, the effects could range from acute, to subtle, to progressive organ damage. The susceptibility of marine mammals varies with feeding habits. Baleen whales are susceptible to ingesting oil in the water column and surface waters as they lunge feed at depth and also feed by skimming the surface (i.e. they are more susceptible to surface slicks). Toothed whales and dolphins may be susceptible to ingesting dissolved and entrained oil as they gulp feed at depth. Dugongs may also suffer from long-term chronic effects such as liver problems if they consume oil droplets or oil-affected sea grasses (Ref. 510). Marine mammals are vulnerable if they inhale volatile hydrocarbons when they surface within a hydrocarbon slick. For the short period that they persist, vapours from the spill are a significant risk to mammal health, with the potential to damage mucous membranes in eyes and airways, which will reduce the health and potential survivability of an animal. Inhaled volatile hydrocarbons are transferred rapidly to the bloodstream and may also accumulate in tissues (Ref. 509). The Hydrocarbon Ecological EMBA includes BIAs for marine mammals including: • humpback whale BIA (migration) • pygmy blue whale BIA (distribution, foraging) • southern right whale (reproduction, migration) • dugongs (breeding, calving, foraging, nursing). Cetacean species are considered most sensitive to surface hydrocarbon exposures, whereas dugongs are considered more sensitive to oil droplets and oil-affected seagrass as a result of entrained hydrocarbon exposure. Deterministic analyses for surface hydrocarbons for cetaceans and in-water entrained hydrocarbons for dugongs were used to understand the potential extent of exposure. Stochastic modelling of 300 simulated vessel collision events predicts a potential hydrocarbon exposure at the moderate (impact) threshold (10 g/m^2) to extend up to ~60 km the from the release location (Appendix C; Ref. 496). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 256 km^2 at the moderate threshold across the 60 day simulation. This predicted impact is very short in duration; floating oil on the surface peaks at an area of ~30 km^2 on the first day following the release and returns to zero by day 3. Compared to the total area encompassed by the humpback and pygmy blue whale BIAs, the predicted extent of surface exposure was predicted to be significantly <1% of either BIA. This information indicates that if an unplanned release of MDO from a vessel collision event occurred, it is unlikely to impact entire humpback and pygmy blue whale populations, resulting in only a localised impact. Dugongs undertaking breeding, calving, foraging, nursing behaviours in nearshore waters demonstrate high site fidelity to habitats required to facilitate these behaviours (Ref. 511). This high-site fidelity when undertaking critical behaviours increases their sensitivity to hydrocarbon exposures as they are less likely to be transient. Stochastic modelling predicted a 2% probability (winter) of the dugong BIA being contacted by entrained hydrocarbons in the 0-10 m layer and the high (impact) threshold. The deterministic model for the largest area of entrained hydrocarbons above 100 ppb indicates that entrained hydrocarbons were present across a maximum peak area of ~200 km^2, occurring 6 days after the spill. After 13 days there is no further predicted exposure to entrained hydrocarbons at this threshold. Using the dugong BIA area, modelling indicates that the extent of entrained exposure was predicted to be limited to ~2% of the entire BIA. As the extent and duration of exposure to nearshore environments is expected to be limited the potential for

Risk evaluation
significant environmental impacts would also be limited. However, it is acknowledged that behaviours in nearshore waters will result in increased sensitivity to hydrocarbon exposures as the species are not expected to be transient. As surface and in-water hydrocarbons would be exposed to processes such as dispersion, dilution, and physical and biological degradation, surface and in-water hydrocarbon exposure to marine mammals will be limited to a short-term period. As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to marine mammals is Very Low (9).
Marine reptiles
Injury or mortality of marine fauna Reptiles may be exposed to surface and shoreline hydrocarbons from an unplanned release of MDO from a vessel collision event. Reptiles can be exposed to oil externally (e.g. swimming through surface slick) or internally (e.g. swallowing oil, consuming oil-affected prey, or inhaling volatile oil-related compounds) (Ref. 512). Hydrocarbon exposure has the potential to cause injury or mortality to reptiles. Marine turtles are vulnerable to the effects of oil at all life stages—eggs, hatchlings, juveniles, and adults. Several aspects of turtle biology and behaviour place them at risk, including a lack of avoidance behaviour, indiscriminate feeding in convergence zones, and large pre-dive inhalations (Ref. 510). Oil effects on turtles can include impacts to skin, blood, digestive, and immune systems, and increased mortality due to oiling. Shoreline hydrocarbons can impact turtles coming ashore at nesting beaches. Eggs may also be exposed during incubation, potentially resulting in increased egg mortality and detrimental effects on hatchlings. Hatchlings may be particularly vulnerable to toxicity and smothering as they emerge from the nests and make their way over the intertidal area to the water (Ref. 512). Light oils, such as unweathered MDO, expose marine reptiles to volatile polycyclic aromatic hydrocarbons (PAHs) which may result in breathing, sight, or gastro-intestinal injuries (Ref. 148). The volatile PAHs' can penetrate the skin of sea snakes and carapace of marine turtles affecting respiration, salt gland function and blood chemistry (Ref. 148). These injuries to marine reptiles can result in decreased health, starvation, increased stranding, and decreased breeding condition (Ref. 148). Sudden high toxic contaminant load during pre-dive inhalations have caused instantaneous death to marine turtles and is to be expected with sea snakes (Shigenaka, 2021 cited in Ref. 513). The Hydrocarbon Ecological EMBA (Table 6-2; Figure 6-1) includes BIAs for flatback, loggerhead, green and hawksbill turtles, based on predicted shoreline hydrocarbons exposure at concentrations greater than the impact thresholds. The flatback turtle internesting BIA is predicted to be exposed to surface hydrocarbon concentrations greater than impact thresholds due to the fact that the receptor overlaps with the release location. The behaviours associated with these BIAs include aggregation, basking, foraging, internesting, mating, and nesting. The Ningaloo Coast, Barrow Island, the Montebello Islands and Muiron Islands are areas are identified as habitat critical to the survival of flatback, green and hawksbill turtles (Section 6.2.3.2). Nesting adult turtles and hatchlings may be exposed as they traverse the intertidal area, resulting in potential smothering and acute impacts to some hatchlings during that nesting season. As a result, a small proportion of any reptile population would be exposed above the defined impact thresholds, for a limited duration. Stochastic modelling predicted a <2% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island, and the Montebello Islands. The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km. Based on the rapid weathering of the MDO, the volatile PAHs which are known to cause breathing, sight, or gastro-intestinal injuries for marine reptiles would have weathered off out of the stranded oils, leaving mostly waxy residues that don't result in the same level of impacts. The deterministic model for the largest swept area of floating oil above 10 g/m^2 indicates that surface hydrocarbons concentrations ≥10 g/m^2 (i.e., impact threshold) are present for <3 days following the spill event, with a maximum area of coverage of ~30 km^2 occurring 24 hours after the spill commenced. Using the flatback turtle internesting BIA as an example, modelling indicates that the extent of surface exposures was predicted to be limited to <1% of the entire BIA. This information indicates that if a vessel spill event occurred during the nesting season, it is unlikely to impact entire local nesting populations, resulting only in a localised impact. The EPBC threatened short-nosed sea snake, and other EPBC marine listed sea snake species, may be present within the Hydrocarbon EMBAs. Oil pollution has been identified as a pressure 'of potential concern'

Risk evaluation
(Ref. 317) to sea snakes[60]. Sea snakes are susceptible to oil on the sea surface (Ref. 317; Ref. 514; Ref. 515). Being air breathers and obligate bottom feeders, oil may be either inhaled or ingested (Ref. 317; Ref. 516). As described above, surface oil exposure above impact thresholds is predicted to only be present for a short (<3 days) duration and over a relatively small (maximum ~30 km^2) area. Any exposure to benthic habitats is only predicted to occur within nearshore (<10 m water depth) areas. Using the shoreline exposure described above as indicative of oil presence in a nearshore environment, the duration and extent of exposure from a single spill event is predicted to be limited. Surface hydrocarbons would be exposed to processes such as dispersion, dilution, and physical and biological degradation; shoreline hydrocarbons on sandy beaches would be exposed to physical dispersion and microorganism degradation processes. These processes will limit in-water and shoreline hydrocarbon exposure to a short-term period. Based on an assessment of the predicted magnitude and duration of surface and shoreline hydrocarbons, it is expected that only a small proportion of any reptile population would be exposed above the defined impact thresholds, and only for a limited time. Given the localised, short-term impact to a small proportion of any marine reptile population the consequence of this scenario has been evaluated as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to marine reptiles is Very Low (9).
Fishes, including sharks and rays
Injury or mortality of marine fauna Fishes, including sharks and rays, may be exposed to surface and in-water hydrocarbons from an unplanned release of MDO from a vessel collision event. Although most fishes do not break the sea surface, some shark species (including whale sharks) feed in surface waters, so there is also the potential for surface hydrocarbons to be ingested. Potential effects include damage to the liver and lining of the stomach and intestine, and toxic effects on embryos (Ref. 505). Fishes are most vulnerable to oil during embryonic, larval, and juvenile life stages. However, very few studies have demonstrated increased mortality of fish as a result of oil spills (Ref. 506; Ref. 502; Ref. 518). Demersal fishes are not expected to be impacted because in-water hydrocarbons are only predicted in the surface layers (<10 m water depth). Pelagic free-swimming fishes and sharks are unlikely to suffer long-term damage from oil spill exposure because dissolved/entrained hydrocarbons are typically insufficient to cause harm (Ref. 83). Pelagic species are also generally highly mobile and thus are not likely to suffer extended exposure (e.g. >48–96 hours) at concentrations that would lead to chronic effects. Near the sea surface, fish can detect and avoid contact with surface slicks—fish mortalities are rare near hydrocarbon spills in open waters (Ref. 519). Fish exposed to dissolved hydrocarbons can eliminate the toxicants once they are in clean water; hence, individuals exposed to a spill are likely to recover (Ref. 496). Marine fauna with gill-based respiratory systems, including whale sharks, are expected to have higher sensitivity to exposures of entrained oil. The Hydrocarbon Ecological EMBA includes the whale shark foraging BIA. As these species are considered most sensitive to surface exposures, deterministic analyses were used to understand the potential extent of exposure. Stochastic modelling predicts a potential hydrocarbon exposure at the moderate (impact) threshold (10 g/m^2) to extend up to ~60 km from the release location (Appendix C; Ref. 496). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 256 km^2 at the moderate threshold across the 60 day simulation. This predicted impact is very short in duration; floating oil on the surface peaks at an area of ~30 km^2 on the first day following the release and returns to zero by day 3. Using the whale shark BIA as an example, modelling indicates that the extent of surface exposures was predicted to be limited to <1% of the entire BIA. Based on an assessment of the predicted magnitude and impact of surface hydrocarbons at levels above impact thresholds, it is expected that only a small proportion of any fish population would be exposed. Therefore, the consequence of this scenario has been evaluated as Minor (5) because of the localised, short-term impact to a small proportion of any fish population.

[60] *The pressure analysis distinguished between oil pollution from shipping ('of less concern') and oil rigs ('of potential concern') (Ref. 317). Although the aspect source for this risk assessment is a spill from a vessel, the higher pressure concern has been adopted*

Risk evaluation
As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to fishes, including sharks and rays is Very low (9).
Seabirds and shorebirds
Injury or mortality of marine fauna Seabirds that rest at the water's surface (e.g. shearwaters) or surface-plunging birds (e.g. terns, boobies) may be exposed to surface hydrocarbons from an unplanned release of MDO from a vessel collision event (Ref. 92; Ref. 410); shorebirds may be exposed to shoreline hydrocarbons. Damage to external tissues, including skin and eyes, can occur, along with internal tissue irritation in lungs and stomachs (Ref. 520). Acute and chronic toxic effects may result where the product is ingested as the bird attempts to preen its feathers (Ref. 520). The Hydrocarbon Ecological EMBA includes fairy Tern, lesser crested tern, roseate tern, wedge-tailed shearwater, and white-tailed tropicbird breeding BIAs (Appendix C; Ref. 496, Table 6-12). Wedge-tailed shearwaters breed in nesting burrows on many islands in the Exmouth Sub-basin and forage in pelagic waters 10–300 km off the west coast (Ref. 139). Breeding populations of roseate terns have been recorded at the Lowendal Islands (Ref. 189). Northern Australia white-tailed tropicbirds forage in warm waters and over long distances (up to 1,500 km from breeding sites) (Ref. 177). Roosting gulls and terns (including fairy terns and lesser crested terns) have been recorded along sandy parts of the Ningaloo Coast (Surman & Nicholson 2015 cited in Ref. 521). Barrow Island, Boodie Island, Ningaloo Coast (Exmouth), Middle Island and Muiron Islands are the only areas predicted to be exposed to shoreline hydrocarbon accumulations ≥100 g/m^2 (Hydrocarbon Ecological EMBA: shoreline ecological impact threshold). Stochastic modelling predicts a potential hydrocarbon exposure at the moderate (impact) threshold (10 g/m^2) to extend up to ~60 km from the release location (Appendix C; Ref. 496). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 256 km^2 at the moderate threshold across the 60 day simulation. This predicted impact is very short in duration; floating oil on the surface peaks at an area of ~30 km^2 on the first day following the release and returns to zero by day 3. The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km. A review of these areas against the total areas encompassed by fairy tern, lesser crested tern, roseate tern, wedge-tailed shearwater, and white-tailed tropicbird breeding BIAs, indicates that the extent of shoreline and surface exposures was predicted to be <1% of all breeding BIAs. This information indicates that if a spill from a vessel collision event occurred during seasonal roosting or breeding season, it is unlikely to impact entire local populations. Based on an assessment of the predicted magnitude and duration of surface and shoreline hydrocarbons, it is expected that only a small proportion of any seabird or shorebird population would be exposed above the defined impact thresholds, and only for a limited time. Given the localised, short-term impact to a small proportion of any seabird or shorebird population the consequence of this scenario has been evaluated as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to seabirds and shorebirds is Very Low (9).
KEFs
Change to values and sensitivities An unplanned release of MDO from a vessel collision event may result in changes to the values and sensitivities of KEFs. As per Section 6.2.6.1, there are a number of KEFs present in the Hydrocarbon Ecological EMBA. As identified in Section 6.2.6.1, the values of these KEFs include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, as well as identified BIAs for regionally significant marine fauna. The consequence evaluations for these values have been detailed separately.

Risk evaluation
Stochastic modelling (Appendix C; Ref. 496) predicts that entrained hydrocarbon exposure is limited to the upper water column (0–10 m), and therefore the hydrocarbon exposure is limited to values within the upper water column of these KEFs, and not the benthic habitat or values within the KEFs. For example, the Ancient Coastline at 125 m depth contour KEF resides within the release location, however the modelling did not predict any exposure to its benthic values. Given the consequences of all values that reside within these KEFs have been evaluated in other sections of this chapter, and due to no predicted impact of oil below the 10m depth contour, this aspect has not been evaluated further.
Commercial fisheries
Change to functions, interests and activities An unplanned release of MDO from a vessel collision event may result in changes to the functions, interests or activities of commercial fisheries within the Hydrocarbon Social EMBA. As identified in Section 6.3.1, several commercial fisheries have management areas and recent fishing effort recorded within the Hydrocarbon Social EMBA (Section 6.3.1). Commercial fishing may be impacted by exclusion zones associated with the unplanned release of MDO, and subsequent reduction in fishing effort. Exclusion zones may impede access to commercial fishing areas for a short time and nets and lines may become oiled. However, the impacts to commercial fishing from a public perception may be much more significant and longer term than the actual spill. Fishing areas may be temporarily closed for fishing because of the risks of the catch being tainted by hydrocarbons. Concentrations of petroleum contaminants in fish, crustacean and mollusc tissues could pose a significant potential for adverse human health effects, and until these products are cleared by health authorities, they could be restricted for sale and human consumption. Toxicity in adult fish has been reported in response to diesel exposure (Ref. 522; Ref. 523). Uptake of hydrocarbons has been demonstrated in bony fish after exposure to water-accommodated fraction of between 24 and 48 hours. Davis et al (Ref. 524) reported detectable tainting of fish flesh after a 24-hour exposure to marine fuel oil concentrations of 0.33 ppm and diesel concentrations of 0.25 ppm. Most studies, from laboratory trials or of fish collected after release events (including the *Hebei Spirit*, *Macondo*, and *Sea Empress* spills), find evidence of elimination of PAHs in fish, with tissues returning to reference levels within 2 months of exposure (Ref. 524; Ref. 525; Ref. 526; Ref. 527; Ref. 528; Ref. 529; Ref. 530). If there are impacts to fish stocks associated with impacts to the larval life phase of fish, there is the potential for reduced profits for commercial fisheries over a longer time, and potential for reduced fishing quotas or exclusion zones which could exclude fishing effort. The *Montara* spill of a light gas condensate (the most recent [2009] example of a large hydrocarbon spill in Australian waters) occurred over an area fished by the Northern Demersal Scalefish Managed Fishery (11 licences held by 7 operators), with goldband snapper, red emperor, saddletail snapper and yellow spotted rockcod being the key species fished (Ref. 531). As a precautionary measure, the then WA Department of Fisheries (now part of DPIRD) advised the commercial fishing fleet to avoid fishing in oil-affected waters. Testing of fish caught in areas of a visible slick (November 2009) found no detectable petroleum hydrocarbons in fish muscle samples, suggesting fish were safe for human consumption. Limited ill effects were only detected in a small number of individual fish (Ref. 531). No consistent effects of exposure on fish health could be detected within 2 weeks of the end of the well release. Follow-up sampling in areas affected by the spill during 2010 and 2011 (Ref. 531) found negligible ongoing environmental impacts from the spill. If an MDO spill occurred as the result of a vessel collision, a temporary fisheries closure may be put in place by DPIRD's Fisheries division (or voluntarily by the fishers themselves). MDO may foul the hulls of fishing vessels and associated equipment, such as gill nets. A temporary fisheries closure, combined with oil tainting of target species (actual or perceived), may lead to financial losses to fisheries and economic losses for individual licence holders. Fishery closures and the flow-on losses from the lack of income derived from these fisheries are likely to have short-term and localised socio-economic consequences, such as reduced employment (in fisheries service industries, such as tackle and bait supplies, fuel, marine mechanical services, accommodation etc.). A temporary fishing exclusion zone may be implemented by AFMA or DPIRD. For most fisheries described in Section 6.3.1, a precautionary exclusion from fishing grounds can be expected until water quality monitoring verifies the absence of residual hydrocarbons, thus providing confidence to consumers related to fish tainting. The minor loss of revenue for commercial fisheries in the Hydrocarbon Social EMBA has been evaluated as Minor (5) because the area of potential impact to fishes is localised (evaluation provided above), and the loss of revenue is short-term (based on temporary exclusion zones that may be implemented). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the

Risk evaluation
inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to commercial fisheries is Very low (9).
Tourism and recreation
Change to functions, interests and activities Tourist destinations in the Hydrocarbon Social EMBA may be exposed to shoreline, surface, and in-water hydrocarbons from an unplanned release of MDO from a vessel collision event. Hydrocarbon presence in these tourist destinations may reduce the visual amenity of the area, and, because these destinations offer exclusively nature-based tourism, potential environmental impacts to these places may also reduce visitor numbers. Several tourism destinations are within the Hydrocarbon Social EMBA, including Ningaloo Reef and Pilbara Inshore Islands Nature Reserves and other marine parks, management areas and reserves listed in Table 6-21, Table 6-22 and Table 6-23. Reduced visitor numbers may lead to a minor loss of revenue for tourist operators (e.g. charter fishing cancellations due to fishery closures). On release to the marine environment, MDO spreads quickly and evaporates rapidly in warm waters. Stochastic modelling of 300 simulated vessel collision events predicts potential hydrocarbon exposure at the low surface threshold to extend up to 167 km from the release location (Appendix C; Ref. 496).The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 912 km^2 at the low threshold (1 g/m^2) and 256 km^2 at the moderate threshold (10 g/m^2) across the 60 day simulation. This predicted impact is very short in duration. At the low threshold (1 g/m^2), floating oil on the surface peaks at an area of ~105 km^2 on the third day following the release, but rapidly reduces to zero on day 4. At the moderate threshold (10 g/m^2) floating oil on the surface peaks at an area of ~30 km^2 on the first day following the release and returns to zero by day 3. By day 4 there was no predicted surface exposure above these thresholds. Stochastic modelling predicted a <2% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island, and the Montebello Islands. The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km. Shoreline and surface hydrocarbons would be exposed to processes such as dispersion, dilution, and physical and biological degradation, which will ensure hydrocarbon exposure to tourist destinations is limited to a short-term period. Minor loss of revenue from reduced tourist numbers in the Hydrocarbon Social EMBA, has been evaluated as Minor (5) given the localised, short-term impact. As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to tourism and recreation is Very Low (9).
AMPs
Change to values and sensitivities An unplanned release of MDO from a vessel collision event may result in changes to the values and sensitivities of AMPs. Modelling predicts surface exposure ≥1 g/m^2 (4% probability) and entrained exposure ≥100 ppb (11% probability) within the Montebello Marine Park (Table 8-71). Modelling predicted a low probability (<37%) of entrained oil exposure at the low threshold (10 ppb) within the Abrolhos, Argo–Rowley Terrace, Carnarvon Canyon, Gascoyne, Montebello, Ningaloo, and Shark Bay Marine Parks (Ref. 496; Appendix C). No seabed hydrocarbon exposure was predicted, based on the surface release of MDO in deep offshore waters. As identified in Section 6.4.1, the natural values of the AMPs listed above include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, and BIAs for regionally significant marine fauna. Social and economic values of the listed AMPs include commercial fishing. The consequence evaluations to specific marine fauna and commercial fisheries are provided above. Based on the temporary and localised hydrocarbon exposure to marine fauna or commercial fish species above impact exposure thresholds, the potential risks of an unplanned release of MDO from a vessel collision event to the values and sensitivities of the listed AMPs has been evaluated as Minor (5).

Risk evaluation
As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to AMPs is Very Low (9).
Cultural heritage value: Ningaloo Coast
Change to values and sensitivities An unplanned release of MDO from a vessel collision event may result in changes to the values and sensitivities of heritage values of the Ningaloo Coast (a World Heritage property and listed under the National Heritage listing). Stochastic modelling predicted that a 2% probability of shoreline accumulation above the ≥100 g/m^2 impact threshold may occur along the Barrow Island and the Ningaloo Coast World Heritage Area shoreline. The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km (Table 8-71). As identified in Section 6.5.1, heritage values for the Ningaloo Coast include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, and BIAs for regionally significant marine fauna. The intertidal systems of the Ningaloo Coast World Heritage Area are also considered high-diversity habitats, which sustain the species listed under the EPBC Act and the resultant tourism in the area. The consequence evaluations to marine fauna, marine habitat and tourism and recreation are provided above. Based on the temporary and localised exposure of hydrocarbons along the Ningaloo Coast, the risks of an unplanned release of MDO from a vessel collision event to the values and sensitivities of the Ningaloo Coast has been ranked as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to the Ningaloo Coast is Very Low (9).
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from unplanned release of MDO from a vessel collision includes: • potential indirect impacts to intangible Traditional Owner heritage from injury or mortality of marine fauna • potential impacts to tangible Traditional Owner heritage from hydrocarbon exposure of protected First Nation sites or artefacts. As discussed in Section 6.5.2, at the time of writing this OPP, CAPL understands through consultation with Traditional Owners that there are no known artefacts or specific sites on the seabed within the EMBAs that have, or are associated with, cultural heritage values. As identified from literature and/or consultation (Section 6.2.5.2.1), Sea Country is a value for First Nations people. It is understood that the term 'Country' refers to more than just a geographical area, and includes values, places, resources, stories, and cultural obligations associated with that geographical area (Ref 532; Ref 533). Specific intangible values of Sea Country identified through consultation on other CAPL activities included Dreamtime stories and songlines. In particular, relevant persons have previously identified the existence of songlines that go through Barrow Island and offshore. The waters of the NWMR (and therefore the waters within the Hydrocarbon EMBAs) are acknowledged as potentially having some cultural and spiritual significance to First Nations as well as providing natural resources (Section 6.2.5.2.1). The Hydrocarbon EMBAs intersect with the coast of the North West Cape peninsula, along or adjacent to which, cultural heritage sites or artefacts are located. Stochastic modelling predicted that a 2% probability of shoreline accumulation above the ≥100 g/m^2 impact threshold may occur along the Barrow Island and the Ningaloo Coast World Heritage Area shoreline. The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~20 m^3 and a maximum length of ~10 km (Table 8-71). If shoreline contact occurs, it is expected that any impacts from this type of event would be localised, non-continuous and short term in duration. As such, given the volume, type of oil (marine fuel) and predicted weathering, no prolonged impact pathway to a change in access to Country is anticipated.

Risk evaluation
Based on the temporary and localised exposure of hydrocarbons along the Ningaloo Coast, the risks of potential changes to Traditional Owner cultural heritage values from an unplanned release of MDO from a vessel collision event has been ranked as Minor (5). As most vessel collisions involve the LOC of a forward tank, which are generally double-lined and smaller than other tanks, the loss of the maximum credible volumes used in this scenario is unlikely. Considering the inherent low likelihood of a collision occurring, the safeguards in place, and enactment of the OPEP, the potential likelihood of causing the consequences described in this section is assessed as Remote (5). Overall, the risk of Unplanned release—Vessel collision event (MDO) to Traditional Owner cultural heritage values is Very Low (9).

8.14.4 Determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context and legislative requirements.

Table 8-73 details the determination of acceptability for Unplanned release—Vessel collision (MDO).

Table 8-73: Determination of acceptability for Unplanned release—Vessel collision (MDO)

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest consequence level for unplanned release of MDO from vessel collision was evaluated as Moderate (4). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the risk evaluation for the unplanned release of MDO from a vessel collision. • Prevention measures for unplanned release of MDO from vessel collision are well regulated and managed in Australian waters. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations
	The Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the impact and risk of unplanned release of MDO from vessel collision based on relevant environmental legislation and other requirements as listed below. • The regulation and management of vessel collisions in Australian waters ensures the health, diversity and productivity of the environment is maintained for future generations through application of prevention measures. • The highest consequence level for unplanned release of MDO from vessel collision was evaluated as Moderate (4). • Any relevant stakeholder feedback in relation to unplanned release of MDO from vessel collision has been incorporated in the OPP and assessed in the external context acceptability criteria. To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
	Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.

Determination of acceptability		
	The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk (Section 5). The Development is consistent with principle of ESD (d) for this aspect by considering conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.	
Relevant environmental legislation and other requirements	Legislation and other requirements considered relevant for this aspect are listed below. The OPP identifies adopted control measures to address relevant requirements/actions within each of the listed legislative requirements considered relevant to this aspect.	
	Requirement	**Demonstration of requirement**
	OPGGS(E)R An Environmental Plan, including oil spill contingency and emergency response arrangements, must be place for any petroleum activity before commencing activities.	Legislative requirements to manage Unplanned release–Vessel collision (MDO) are addressed by adopting these control measures: **CM32**: Before commencing offshore activities, relevant agencies will be notified of activities, vessel movements, and requested exclusion zones, to enable them to generate radio navigation warnings and/or Notice to Mariners. **CM47**: In the event of a spill occurring, the accepted Oil Pollution Emergency Plan (OPEP) in subsequent EPs for the Development will be implemented. **CM48**: In the event of a spill occurring, the accepted Operational and Scientific Monitoring Plan (OSMP) in subsequent EPs for the Development will be implemented. **CM44**: MODUs and vessels will meet the requirements of the Chevron Marine Standard Non Tankers, including pre-mobilisation inspections of equipment, couplings, and secondary containment. **CM46**: MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to having an approved Ship Oil Pollution Emergency Plan or equivalent in place.
	***Protection of the Sea (Prevention of Pollution from Ships) Act 1983* – Section 26F (implements MARPOL Annex I).** Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution. It also invokes certain requirements of the MARPOL Convention including those relating to discharge of noxious liquid substances, sewage, garbage, and air pollution. This Act requires ships >400 gross tonnes to have in place pollution emergency plans, and also provides for emergency discharges from ships.	
	***Navigation Act 2012* – Chapter 4 (Prevention of Pollution).** Gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). Maintaining and disseminating navigational charts and publications, including providing safety-critical information to mariners via the Notice to Mariners system.	
	Guidelines for Offshore Marine Operations (Ref. 495) The objective of this document is to provide guidance in the best practices that should be adopted to ensure the safety of personnel on board all vessels servicing and supporting offshore facilities, and to reduce the risks associated with such operations.	
	AMSA Marine Orders 91 and 94	

Determination of acceptability		
	Sets out the requirements of the prevention of pollution of the environment for regulated Australian vessels, domestic commercial vessels, and Australian recreation vessels. Marine Order 91 (Marine Pollution Prevention – Oil) Marine Order 94 (Marine pollution prevention – packaged harmful substances)	
	Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148) Management action A1: Maintain and improve efficacy of legal and management protection: • Ensure spill risk strategies and response programs adequately include management for marine turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs.	EPBC management plan requirements to minimise habitat degradation / modification, including marine pollution, are addressed by adopting these control measures: **CM47:** In the event of a spill occurring, the accepted OPEP in subsequent EPs for the Development will be implemented. Assessment of spill risk strategies is within scope of the approved OPEP. **CM48:** In the event of a spill occurring, the accepted OSMP in subsequent EPs for the Development will be implemented. Response and recovery of habitats and marine fauna is within the scope of the approved OSMP. Therefore, the Development is not considered to be inconsistent with the EPBC management plans.
	Conservation Management Plan for the Southern Right Whale (Ref. 19) Addressing infrastructure and coastal development impacts.	
	Draft National Recovery Plan for the Southern Right Whale (Ref. 20) Baseline surveys and monitoring undertaken during activity implementation are conducted in accordance with best practice standards and guidelines to ensure standardised datasets are obtained and suitable to inform environmental management decision making that can reduce the risk of threats to southern right whales.	
	Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Sea Snake) (Ref. 24) Identifies habitat degradation / modification as a key threat. Management action: Ensure there is no anthropogenic disturbance in areas where the short-nosed sea snake occurs, excluding necessary actions to manage the conservation of the species.	
	Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 23) Identifies habitat degradation / modification as a key threat. Management action: Ensure there is no anthropogenic disturbance in areas where the leaf-scaled sea snake occurs, excluding necessary actions to manage the conservation of the species.	

Determination of acceptability		
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25) Management action 5C: Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks. Management action 5D: Implement measures to reduce adverse impacts of habitat degradation and/or modification.	
	Approved Conservation Advice for *Pristis pristis* (largetooth sawfish) (Ref. 27) Implement measures to reduce adverse impacts of habitat degradation and/or modification	
	National Recovery Plan for Albatrosses and Petrels (Ref. 37) Risk based response strategies for marine pollution incidents are developed. Where appropriate monitoring of breeding colonies includes an assessment of marine pollution impacts including the incidence of oiled birds at nest.	
	Wildlife Conservation Plan for Seabirds (Ref. 35) Enhance contingency plans to prevent and/or respond to environmental emergencies that have an impact on seabirds and their habitats.	
	Approved Conservation Advice for *Thalassarche cauta* (Shy Albatross) (Ref. 55) Where feasible, population monitoring programmes also monitor, in a standardised manner, the incidence of oiled birds at the nest, marine debris egestion / entanglement at the nests, and eggshell thinning	
	Conservation Advice for Sternula nereis nereis (Fairy Tern) (Ref. 40) Ensure appropriate oil spill contingency plans are in place for the subspecies' breeding sites that are vulnerable to oil spills.	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 17) Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 18) Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish) (Ref. 26) Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 31).	These EPBC management plans for species that may occur within the Hydrocarbon Social and Hydrocarbon Ecological EMBAs that identify habitat degradation / modification or acute pollution as a threat, but do not identify any relevant actions.

Determination of acceptability		
	Conservation Advice *Rhincodon typus* Whale Shark (Ref. 30). Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29) National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*) (Ref. 41) Conservation Advice *Calidris ferruginea* curlew sandpiper (Ref. 45) Conservation Advice *Numenius madagascariensis* eastern curlew (Ref. 46) Conservation Advice *Calidris canutus* Red knot (Ref. 52) Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper) (Ref. 54) Conservation Advice for *Limosa lapponica menzbieri* (Yakutian bar-tailed Godwit) (Ref. 51) Conservation Advice for *Charadrius leschenaultia* (Greater Sand Plover) (Ref. 47) Conservation Advice for *Tringa nebularia* (Common Greenshank) (Ref. 44) Conservation Advice for *Limnodromus semipalmatus* (Asian dowitcher) (Ref. 39) Wildlife Conservation Plan for Migratory Shorebirds (Ref. 67)	
	North-west Marine Parks Network Management Plan (Ref. 83) The Plan requires that 'actions required to respond to oil pollution incidents, including environmental monitoring and remediation, in connection with mining operations authorised under the OPGGS Act may be conducted in all zones. The Director should be notified in the event of an oil pollution incident that occurs within, or may impact upon, an Australian Marine Park and, so far as reasonably practicable, prior to a response action being taken within a marine park.'	Protected area requirements to respond to an Unplanned release–Vessel collision (MDO) event, including notifying, environmental monitoring, and remediation, authorised under the OPGGS Act are addressed by adopting these control measures: **CM47:** In the event of a spill occurring, the accepted OPEP in subsequent EPs for the Development will be implemented. **CM48:** In the event of a spill occurring, the accepted OSMP in subsequent EPs for the Development will be implemented.
Internal context	These CAPL environmental performance standard/procedure were deemed relevant for this aspect: • Chevron Marine Standard Non Tankers (Ref. 284).	
External context	CAPL has maintained long-term external stakeholder relationships for the GFP since initial engagement began during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation, where relevant, as part of the Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.2.5 and 6.5.2).	

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (CM07 and CM08).
No further feedback was received in relation to Unplanned release–Vessel collision (MDO) from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.</td></tr>
<tr><td rowspan="5">Defined acceptable level</td><td colspan="2">The residual risks of an unplanned release of MDO from vessel collision are inherently acceptable because the highest residual risk ranking is Moderate (4).
Additionally, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan.
The risk evaluation does not identify scientific uncertainty against risks of unplanned release of MDO from vessel collision for each receptor.
Although unplanned release of MDO from vessel collision is not listed as a threat to protected matters under documents made or implemented under the EPBC Act, it can modify the marine habitat for some species.
Because habitat degradation / modification has been identified as a threat to protected matters under documents made or implemented under the EPBC Act, CAPL will define an acceptable level of impact that aligns with the objectives of these documents. Objectives of the relevant documents are shown below: and were considered during the impact and risk evaluation.</td></tr>
<tr><td>Plan and relevant objective</td><td>Demonstration of requirement</td></tr>
<tr><td>Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16)
Recovery objective: Minimise anthropogenic threats to allow for their conservation status to improve so that they can be removed from the EPBC Act threatened species list.
Interim objective 4: Anthropogenic threats are demonstrably minimised.</td><td rowspan="3">CAPL considers the impacts of unplanned release of MDO to not be inconsistent with the relevant objectives of these EPBC management plans.
By applying EPO19, impacts and risks to habitat degradation / modification, including marine pollution, from Unplanned release of MDO will be managed at or below the defined acceptable level.</td></tr>
<tr><td>Conservation Management Plan for the Southern Right Whale (Ref. 19)
Long-term recovery objective:
The population has increased in size to a level that the conservation status has improved, and the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria.
Interim recovery objective 5:
Anthropogenic threats are demonstrably minimised.</td></tr>
<tr><td>Draft Recovery Plan for the Southern Right Whale (Ref. 20)
Long-term recovery objective:
The population has increased in size to a level that the conservation status has improved, and the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria.
Interim recovery objective 2:
Anthropogenic threats are managed consistent with ecologically sustainable development principles and do not impede recovery of southern right whales</td></tr>
</table>

Determination of acceptability		
	Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148) Long-term recovery objective: Minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 3: Anthropogenic threats are demonstrably minimised.	
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25) Primary objective: To assist the recovery of sawfish and river sharks in Australian waters with a view to: • improving the population status leading to removal of the sawfish and river shark species from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder recovery in the near future or impact the conservation status of the species in the future. Specific objectives: Objective 5: Reduce, and where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species.	
	Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 31). Primary objective: To assist the recovery of the white shark in the wild, throughout its range in Australian waters, with a view to: • improving the population status, leading to future removal of the white shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the white shark in the near future or impact the conservation status of the species in the future. Specific objective: Objective 7: Continue to identify and protect habitat critical to the survival of the white shark and minimise the impact of threatening processes within these areas.	
	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29) Primary objective: To assist the recovery of the grey nurse shark in the wild, throughout its range in Australian waters, with a view to: • improving the population status, leading to future removal of the grey	

Determination of acceptability		
	nurse shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the grey nurse shark in the near future or impact the conservation status of the species in the future. Specific objectives: Objective 8: Continue to identify and protect habitat critical to the survival of the grey nurse shark and reduce the impact of threatening processes within these areas.	
	National Recovery Plan for Albatrosses and Petrels (Ref. 37) Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced.	
	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 67) Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	
	Wildlife Conservation Plan for Seabirds (Ref. 37) Seabirds and their habitats are identified, protected, and managed in Australia.	
	Approved Conservation Advice for *Thalassarche cauta* (Shy Albatross) (Ref. 55) Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced.	
	Conservation Advice *Numenius madagascariensis* eastern curlew (Ref. 46) Minimise further loss of habitat critical to the survival of far eastern curlew throughout Australia.	
	Conservation Advice *Calidris canutus* (Red knot) (Ref. 52) Minimise further loss of habitat critical to the survival of red knot throughout Australia	
	Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper) (Ref. 52) Minimise further loss of habitat critical to the survival of the sharp-tailed sandpiper throughout Australia.	
	Conservation Advice for *Limosa lapponica menzbieri* (Yakutian bar-tailed Godwit) (Ref. 51)	

Determination of acceptability		
	Minimise further loss of habitat critical to the survival of Yakutian bar-tailed godwit throughout Australia	
	Conservation Advice for *Charadrius leschenaultia* (Greater Sand Plover) (Ref. 47) Minimise further loss of habitat critical to the survival of greater sand plover throughout Australia.	
	Conservation Advice for *Tringa nebularia* (Common Greenshank) (Ref. 44) Minimise further loss of habitat critical to the survival of common greenshank throughout Australia.	
	Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 17) Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 18) Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Sea Snake) (Ref. 24) Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 23) Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish) (Ref. 26) Conservation Advice *Rhincodon typus* Whale Shark (Ref. 30) National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*) (Ref. 41) Conservation Advice *Calidris ferruginea* curlew sandpiper (Ref. 45) Conservation Advice for Sternula nereis nereis (Fairy Tern) (Ref. 40) Conservation Advice for *Limnodromus semipalmatus* (Asian dowitcher) (Ref. 39)	These EPBC management plans for species that may occur within the Hydrocarbon Social and Hydrocarbon Ecological EMBAs that identify habitat degradation / modification or acute pollution as a threat, but do not identify any relevant objectives.
	North-west Marine Parks Network Management Plan 2018 <u>Specific objectives</u>: • the protection and conservation of biodiversity and other natural, cultural and heritage values of marine parks in the North-west Network • ecologically sustainable use and enjoyment of the natural resources within marine parks in the North-west Network, where this is consistent with objective (a).	CAPL considers the impacts of Unplanned release—Vessel collision (MDO) to not be inconsistent with the relevant objectives of these EPBC management plans. By applying EPO19, impacts and risks to the protection and conservation of biodiversity and other natural, cultural and heritage values of marine parks in the North-west Network from Unplanned release—Vessel collision (MDO) will be managed at or below the defined acceptable level.
	Therefore, CAPL has defined this acceptable level of impact such that it is not inconsistent with these documents: • no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery	

Determination of acceptability	
	• no adverse effect to an important or substantial area of habitat such that a significant impact on marine ecosystem functioning or integrity results • no adverse effect on AMPs, State Protected Areas and World Heritage Areas such that it prevents the long-term protection and conservation of the identified values or natural resources of the area • no significant adverse impact to cultural heritage values attributed to the offshore marine area • no substantial impact to functions, interests and activities of other marine users. CAPL considers that the Development, with the adopted control measures as described for this aspect in place, meets this acceptable level.

8.14.5 Environmental performance

Table 8-74 lists the EPO defined for unplanned release of MDO from vessel collision and the adopted control measures to achieve the outcome.

Table 8-74: Environmental performance for Unplanned release—Vessel collision (MDO)

EPO	Adopted control measure
EPO19: No unplanned release of hydrocarbons to the environment from vessel collision during Development activities.	**CM32**: Before commencing offshore activities, relevant agencies will be notified of activities, vessel movements, and requested exclusion zones, to enable them to generate radio navigation warnings and/or Notice to Mariners. **CM44**: MODUs and vessels will meet the requirements of the Chevron Marine Standard Non Tankers, including pre-mobilisation inspections of equipment, couplings, and secondary containment. **CM46**: MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to having an approved Ship Oil Pollution Emergency Plan or equivalent in place. **CM47**: In the event of a spill occurring, the accepted Oil Pollution Emergency Plan (OPEP) in subsequent EPs for the Development will be implemented. **CM48**: In the event of a spill occurring, the accepted Operational and Scientific Monitoring Plan (OSMP) in subsequent EPs for the Development will be implemented.
EPO03: No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.

8.15 Unplanned release—Hydrocarbon system (condensate)

8.15.1 Source

The Development introduces the potential for an unplanned release of gas and condensate into the environment. An evaluation of all spill scenarios associated with the hydrocarbon system was completed and the following event scenarios identified:

- loss of well integrity
- loss of effective well control
- minor defect in flowline
- major defect in flowline.

The loss of effective well control (LOWC) event presents the worst-case credible unplanned release from the hydrocarbon system (condensate) scenario under this OPP and has been used as the basis for the risk assessment.

Note that minor unplanned release scenarios are not included in this section. These scenarios are assessed in:

- Unplanned release-Minor Loss of containment—Section 8.13.

CAPL commissioned RPS to conduct stochastic spill modelling (stochastic modelling) of LOWC events in all fields to predict the extent of hydrocarbon exposure to inform the definitions of the Hydrocarbon Ecological EMBA and the Hydrocarbon Social EMBA. The Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA considers hydrocarbon exposure from both LOWC and vessel collision events resulting in unplanned release of hydrocarbons.

The Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA represent the outer area where hydrocarbons above impact concentration thresholds (Table 6-1) may be present in the environment in the event of an unplanned release of condensate (refer to Figure 6-1 and Figure 6-2 respectively; Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537 and Table 6-1).

Table 8-75 identifies activities within each phase where an unplanned release of condensate could occur from the hydrocarbon system in the OA.

Table 8-75: Phases and activities that generate Unplanned release—Hydrocarbon system (condensate)

Phase	Activity
Drilling	Drilling top and bottom holes Pressure control equipment—installation and testing Completions
Installation and commissioning	Installation of flowlines, MEG pipelines and PLETs/PLEMs Installation of subsea infrastructure
Operations	Operation of the hydrocarbon system Well intervention
Decommissioning	Flush and clean Well suspension and P&A

8.15.1.1 Drilling

Drilling of subsea wells introduces the potential for an unplanned release of gas and condensate. CAPL categorise well control into two categories:

- loss of well integrity—where integrity of the well has been compromised, but the well remains under control
- loss of effective well control—where control of the well has been lost (which would require a Level 3 well control emergence response).

Well control events are credible risks during the drilling phase and have the potential to occur by:

- dropped objects onto the well envelope
- mechanical failure
- corrosion
- loss of effective well control
- loss of station keeping
- operating error.

Well operation management plans (WOMPs) will be developed for the wells detailing risk controls (e.g. casing and formation integrity testing, well control system standards) to mitigate well control events during the drilling phase of the Development.

Based upon the feasible risks identified during the Development's drilling phase, a loss of effective well control was deemed to present the worst-case credible spill scenario and has been used as the basis for the following risk assessment.

8.15.1.2 Installation and commissioning

Loss of well integrity events during this phase may result from:

- dropped objects onto the well envelope (potential damage to wellhead).

Lifting of flowlines and subsea structures for installation activities near DCs introduces the risk of dropped objects onto the wellhead resulting in a loss of well integrity event.

8.15.1.3 Operations

Defects in flowlines during the operations phase may result from:

- third-party interference (potential damage to flowline)
- materials fatigue (including corrosion leading to loss of flowline integrity).

CAPL categorises defects in flowlines into two categories:

- minor defect in flowline—defects of up to 25 mm is indicative of the largest defect that can be fixed using pipe clamps; therefore, defects of this size are considered as minor defect events.
- major defect in flowline—full-bore rupture is considered the worst-case major defect event.

Studies undertaken for the Gorgon and Jansz pipelines (Ref. 519) indicate that a minor defect could lead to a loss of ~574 m^3 for a two week un-isolated leak. A major defect on the Gorgon and Jansz pipelines (Ref. 519) could lead to a loss of between ~276 m^3 and ~529 m^3. The Gorgon and Jansz pipelines are 48″ in diameter as compared to the 24″ flowlines planned for the Development. Accordingly, the losses from a major or minor defect for the Development flowlines are not expected to exceed these values.

8.15.1.4 Decommissioning

Decommissioning of subsea wells introduces the potential for well control events as described in Section 8.15.1.1.

8.15.2 Spill modelling

The loss of effective well control (LOWC) event presents the worst-case credible unplanned release from the hydrocarbon system (condensate) scenario under this OPP. Other unplanned release from the hydrocarbon system (condensate) scenarios have potential release volumes significantly smaller in comparison to LOWC spill volumes. As a result, LOWC events at each field in the Development has been modelled to predict the extent of potential hydrocarbon exposure to inform the risk assessment.

Stochastic modelling for LOWC was performed using two models: OILMAP-DEEP was used to simulate the nearfield multiphase plume rise dynamics from the subsea release, and a three-dimensional oil spill model (SIMAP) was used to simulate the drift, spread, weathering and fate of the spilled oil (Ref. 538). Modelling was conducted using a stochastic approach, where multiple simulations (using the same spill parameters) were conducted, but under varying meteorological and oceanographic conditions. For further details on SIMAP and the stochastic modelling method refer to Section 8.14.1 and Appendix C for full modelling reports for all fields.

A LOWC scenario evaluation was undertaken to determine all possible LOWC events for the Development. Based on the scope of the Development, CAPL identified 5 possible LOWC event scenarios to represent all fields, drilling locations and hydrocarbon types within the Development. The 5 LOWC event scenarios were defined based on hydrocarbon types expected to be extracted from the 7 fields:

- WTR scenario: WTR field predicted to contain WTR condensate
- G&E scenario: combined Geryon and Eurytion fields predicted to contain similar condensate, represented by Geryon condensate
- C&D scenario: combined C&D fields predicted to contain similar condensate represented by Chrysaor condensate
- Semele scenario: Semele field predicted to contain Semele condensate*
- Chandon scenario: Chandon field predicted to contain Chandon condensate.

*The Semele field is a prospect at this time and as a result, no composition data is available. The field is contained within retention lease permits WA-14-R and WA-15-R, which also cover the C&D fields. All Semele values presented this this section are interpretations from analogues, not data.

Response Time Models (RTMs) indicate that it is reasonable to expect that all LOWC scenarios could be killed within ~13 weeks (90 days). The RTMs take into account the preparation, assessment, and approval of the Safety Case revisions for the relief well rig and support vessels. Further details on the RTM are provided in the Source Control Emergency Response Plan (SCERP) (Ref. 539).

Stochastic modelling was conducted for each field for a subsea release of condensate over 90 days representing the worst-case LOWC events:

- WTR scenario: A 684 m^3/day subsea release totalling 61,555 m^3 (Ref. 496)
- G&E scenario: A 557 m^3/day subsea release totalling 50,165 m^3 (Ref. 534)
- C&D scenario: A 208 m^3/day subsea release totalling 18,715 m^3 (Ref. 535)
- Semele scenario: A 388 m^3/day subsea release totalling 34,927 m^3 (Ref. 536)
- Chandon scenario: A 829 m^3/day subsea release totalling 74,604 m^3 (Ref. 537).

A total of 300 simulations were modelled per LOWC scenario. Including the 300 simulations modelled for the vessel collision scenario, the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBAs are defined as the combined hydrocarbon exposure spatial extent of 1800 simulations.

Table 8-76 summarises the model settings. Table 8-77 and Table 8-78 summarise the hydrocarbon properties for each field. Table 6-2 describes the modelled impact thresholds for social and ecological receptors.

Table 8-76: Subsea release scenario model settings

Parameter	Details				
	WTR	G&E	C&D	Semele	Chandon
Latitude	20.23666° S	19.94487º S	20.23988º S	19.99726° S	19.56712° S
Longitude	115.04357° E	114.89167º E	114.87716º E	114.94312° E	114.12603° E
Water Depth	150 m	410 m	800 m	800 m	1 100 m
Oil type	WTR condensate	Geryon condensate	Chrysaor Condensate	Semele condensate	Chandon condensate
Simulation spill volume	61,555 m^3	50,165 m^3	18,715 m^3	34,927 m^3	74,604 m^3
Simulation spill type	Subsea				
Simulation spill duration	90 days				
Total simulation duration	104 days				
Number of randomly selected spill simulation start times	100 per season (300 total)				
Seasons modelled	Summer (September to the following March) Transitional (April and August) Winter (May to July)				

Table 8-77: Physical properties for hydrocarbons of each field

Characteristic	WTR	G&E	C&D	Semele	Chandon
Density	817 (at 15°C)	810.0 (at 15°C)	824 (at 15°C)	816 (at 15°C)	789 (at 15°C)
Dynamic viscosity	5.9 (at 15°C)	5.2 (at 15°C)	5.6 (at 15°C)	6.7 (at 15°C)	2.6 (at 15°C)
Pour point	0	−20	−9	−9	−20
API gravity	41.2	42.67	40.20	41.9	47.8
Classification	Group II (Light-persistent)	Group II (Light-persistent)	Group II (Light-persistent)	Group I (Non-persistent)	Group I (Non-persistent)

Table 8-78: Boiling point ranges for hydrocarbons of each field

Field	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	**<180 C4 to C10**	**180-265 C11 to C15**	**265-380 C16 to C20**	**>380 >C20**
WTR	% of total	31.1	29.9	19.4	19.6
	% of aromatics	3.2	0.0	0.0	0.0
G&E	% of tot	31.5	27.1	31.7	9.7
	% of aromatics	2.9	0	0	0
C&D	% of total	23.8	33.0	32.9	10.3
	% of aromatics	3.0	0	0	0
Semele	% of total	33.0	32.5	27.9	6.5
	% of aromatics	3.9	0	0	0
Chandon	% of total	45.9	26.3	22.4	5.4
	% of aromatics	2.5	0	0	0

8.15.2.1 Hydrocarbon Characteristics

All field condensate properties (Table 8-77 and Table 8-78) are either light-persistent or non-persistent hydrocarbons with low viscosity levels. These condensates will spread quickly when released and form a thin film on the sea surface, increasing the evaporation rate.

Generally, approximately 23 - 46% of the mass of the condensates should evaporate within the first 12 hours (boiling point <180°C); a further ~27 - 33% should evaporate within the first 24 hours (boiling point 180°C–265°C); and an additional ~19 - 33% should evaporate over several days (boiling point 265°C–380°C). Approximately 5 - 20% (by mass) of condensates will not evaporate at atmospheric temperatures. These compounds will persist in the environment. Boiling point ranges for hydrocarbons of each field are summarised in Table 8-78 and further information on fate and weathering of the products can be found in the individual modelling reports (Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537).

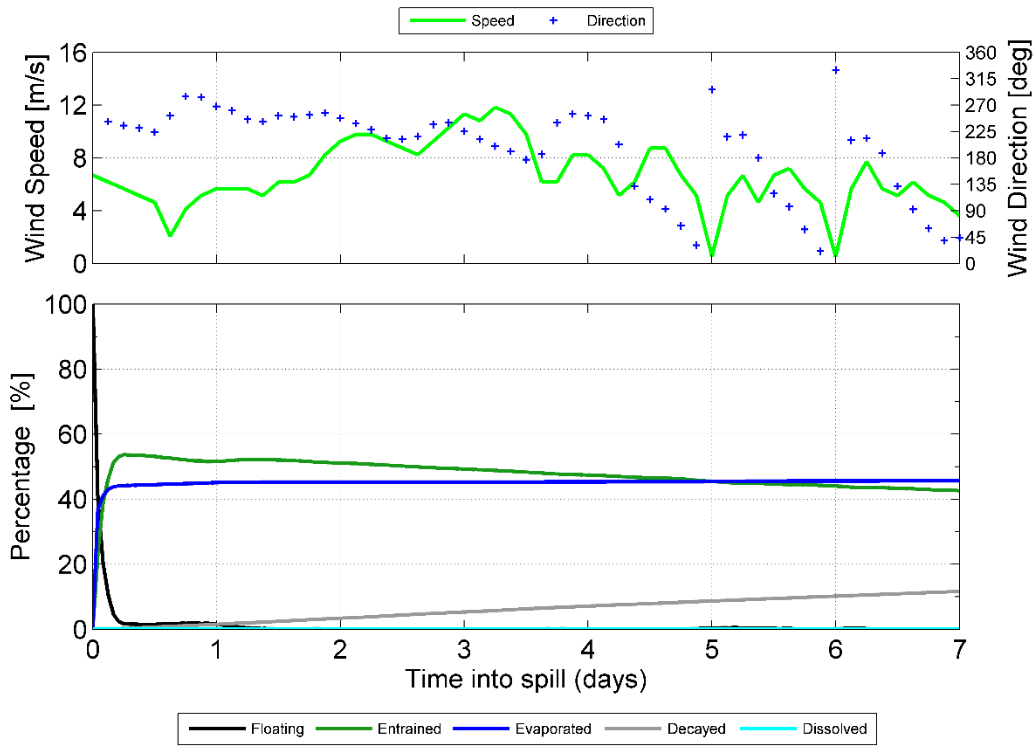

Figure 8-23: Proportional mass balance plot representing the weathering of WTR condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27 °C water temperature

8.15.2.2 Modelling outputs

Stochastic modelling outputs for the 1500 LOWC simulations are summarised in Table 8-76 having regard to the particular values and sensitivities, as identified in Section 4.

Table 8-76 shows the predicted maximum probability and minimum time to exposure for the listed particular values and sensitivities. The maximum probability or minimum time values are assigned superscript text to identify which scenario/field it was derived from. If a scenario predicts exposure to a particular value or sensitivity at or below the maximum values cited, the field is mentioned below the values.

The outcomes of stochastic modelling for each scenario were compared, and the WTR scenario was identified as the clear worst-case scenario. Table 8-79 shows all values and sensitivities with the potential for hydrocarbon exposure is predicted from the WTR scenario, with the exception of Exmouth Plateau KEF for the Hydrocarbon Ecological EMBA.

For the worst-case WTR LOWC scenario:

- The maximum distance from the release location to the ≥1 g/m^2 visible impact threshold was ~252 km west-southwest (summer), and ~46 km north-northwest (transitional) for the ≥10 g/m^2 impact threshold.
- The probability of contact to any shoreline at ≥10 g/m^2 was greatest during summer at 59%, while the minimum time before shoreline accumulation was ~7 days and the maximum volume of oil ashore above the low threshold was 128 m^3 across Barrow Island and Montebello Islands. No high (≥1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.
- Dissolved oil at ≥50 ppb impact thresholds was predicted to occur; however, remained in the surface layer (<10 m water depth) only. The maximum instantaneous dissolved oil concentration was 56 ppb in the offshore area. No high threshold (≥400 ppb) dissolved oil concentrations were predicted in the modelling results.
- Entrained oil at ≥10 ppb and ≥100 ppb impact thresholds was predicted to occur. The maximum instantaneous entrained oil concentration was 3,989 ppb in the offshore area.

Full stochastic modelling results for the WTR LOWC event and other fields are provided in Appendix C.

Table 8-79: Hydrocarbon system stochastic modelling receptor exposure summary

Sensitivity	Name	Surface		In-water (dissolved)	In-water (entrained)	Shoreline	
		Hydrocarbon Social EMBA ≥1 g/m²	Hydrocarbon Ecological EMBA ≥10 g/m²	Hydrocarbon Social and Ecological EMBA ≥50 ppb	Hydrocarbon Social and Ecological EMBA ≥100 ppb	Hydrocarbon Social EMBA ≥10 g/m²	Hydrocarbon Ecological EMBA ≥100 g/m²
		(probability of exposure[61], minimum time to exposure, field source of exposure)[62]		(probability of exposure[61], field source of exposure)[62]	(probability of exposure[61], field source of exposure)[62]	(probability of exposure[61], minimum time to exposure, maximum length of shoreline, field source of exposure)[62]	
AMP	Gascoyne	—	—	—	0–45%WTR (Chandon, C&D, G&E, WTR)	—	—
	Montebello	0–77%, 1.21 days WTR (C&D, WTR)	—	—	0–78%WTR (C&D, G&E, WTR)	—	—
	Ningaloo	—	—	—	0–39%WTR (WTR)	—	—
	Shark Bay	—	—	—	0–2%WTR (WTR)	—	—
State protected areas	Barrow	—	—	—	—	0–26%, 7.63 days WTR, 20.1 km WTR (C&D, G&E, Semele, WTR)	0–15%, 8.5 days WTR, 8.3 km WTR (WTR)
	Montebello	—	—	—	—	0–36%, 6.5 days WTR, 16.6 km WTR (C&D, G&E, Semele, WTR)	0–15%, 8.5 days WTR, 3.3 km WTR (WTR)

[61] *Ranges in values shown are due to the different results between seasons.*

[62] *The maximum probability or minimum time values are assigned superscript text to identify which scenario/field it was derived from. If a scenario predicts exposure to a particular value or sensitivity at or below the maximum values cited, the field is mentioned below the values.*

Sensitivity	Name	Surface		In-water (dissolved)	In-water (entrained)	Shoreline	
		Hydrocarbon Social EMBA ≥1 g/m^2	Hydrocarbon Ecological EMBA ≥10 g/m^2	Hydrocarbon Social and Ecological EMBA ≥50 ppb	Hydrocarbon Social and Ecological EMBA ≥100 ppb	Hydrocarbon Social EMBA ≥10 g/m^2	Hydrocarbon Ecological EMBA ≥100 g/m^2
		(probability of exposure[61], minimum time to exposure, field source of exposure)[62]		(probability of exposure[61], field source of exposure)[62]	(probability of exposure[61], field source of exposure)[62]	(probability of exposure[61], minimum time to exposure, maximum length of shoreline, field source of exposure)[62]	
	Muiron	—	—	—	—	0–29%, 9 days [WTR], 4.1 km [WTR] (C&D, G&E, Semele, WTR)	—
KEF	Ancient coastline at 125 m depth contour	0–100%, 0.3 day [WTR] (C&D, G&E, Semele, WTR)	—	—	0–100%[WTR] (C&D, G&E, Semele, WTR)	—	—
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	—	—	—	0–53%[WTR] (WTR, G&E)	—	—
	Commonwealth waters adjacent to Ningaloo Reef	—	—	—	0–39%[WTR] (WTR)	—	—
	Continental slope demersal fish communities	0–100%, 0.46 days[WTR] (C&D, G&E, Semele, WTR)	0–99%, <0.46 days[C&D] (C&D, WTR)	—	0–100%[WTR] (Chandon, C&D, G&E, Semele, WTR)	—	—
	Exmouth Plateau	0–100%, 0.5 days[Chandon] (Chandon)	0–37%, 1.21 days[Chandon] (Chandon)	—	0–100%[Chandon] (Chandon, G&E, WTR)	—	—
	Glomar Shoals	—	—	—	0–7%[WTR] (WTR)	—	—

Sensitivity	Name	Surface		In-water (dissolved)	In-water (entrained)	Shoreline	
		Hydrocarbon Social EMBA ≥1 g/m²	**Hydrocarbon Ecological EMBA ≥10 g/m²**	**Hydrocarbon Social and Ecological EMBA ≥50 ppb**	**Hydrocarbon Social and Ecological EMBA ≥100 ppb**	**Hydrocarbon Social EMBA ≥10 g/m²**	**Hydrocarbon Ecological EMBA ≥100 g/m²**
		(probability of exposure[61], minimum time to exposure, field source of exposure)[62]		**(probability of exposure[61], field source of exposure)[62]**	**(probability of exposure[61], field source of exposure)[62]**	**(probability of exposure[61], minimum time to exposure, maximum length of shoreline, field source of exposure)[62]**	
World Heritage Properties / National Heritage Places	Ningaloo Coast World Heritage Area	—	—	—		0–35%, 7.75 days [WTR], 14.1 km [WTR] (C&D, G&E, WTR)	0–6%, 10.54 days [WTR], 2.4 km [WTR] (WTR)
Commonwealth Heritage Properties	Ningaloo Marine Area – Commonwealth *(inferred from Ningaloo IMCRA)*	0–1%, 10.38 days[WTR] (WTR)	—	—	0–41%[WTR] (WTR)	—	—

Deterministic analysis of stochastic modelling outputs for each scenario was conducted to determine the largest area exposed by hydrocarbons at impact thresholds for single worst-case simulations. The deterministic analysis provides context of the potential area affected during a single LOWC event as opposed to stochastic modelling, which shows all potential areas affected based on 1500 LOWC simulation run.

The outcomes of deterministic analyses for each scenario were compared, and the WTR scenario was identified as the clear worst-case scenario.

As such the worst-case deterministic outputs for the WTR scenario will be used in conjunction with the stochastic modelling outputs to inform the following impact and risk evaluation.

8.15.3 Impact and risk evaluation

The scoping exercise (Section 7.4) identified the receptors within the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA that may be impacted by hydrocarbon exposure as a result of an unplanned release of condensate from the hydrocarbon system:

- water quality
- coastal communities and habitats: rocky coasts and sandy beaches
- coastal communities and habitats: intertidal and subtidal corals
- coastal communities and habitats: intertidal mudflats, mangroves, seagrasses
- marine mammals
- reptiles
- fishes, including sharks and rays
- seabirds and shorebirds
- KEFs
- commercial fisheries
- commercial shipping
- petroleum activities
- defence
- tourism and recreation
- AMPs
- cultural heritage value: Ningaloo coast
- cultural heritage value: Traditional Owners.

In-water hydrocarbon exposure above impact thresholds (Hydrocarbon Ecological EMBA) is limited to the upper 30 m of the water column in the offshore area i.e. offshore benthic habitats and associated communities are not predicted to be exposed to in-water hydrocarbons as a result of LOWC. As a result, offshore benthic marine communities and habitats and benthic sediment quality in deeper waters are not expected to be exposed to hydrocarbons during a LOWC event (Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537).

Therefore, impacts to benthic sediment quality and benthic habitats and communities from an unplanned release of condensate are not expected and will not be evaluated further.

The likelihood of a LOWC event was assessed using blowout frequencies data (Ref. 540). The frequency of blowouts from normal development wells is estimated to be 6.0 x 10^{-5} per development well. The occurrence of the Montara blowout in 2009 is evidence that a LOWC event from a development well has occurred in Australian waters (Ref. 541).

Offshore drilling operations are dictated by legislative requirements to prevent and manage LOWC events. The inherent legislative requirements ensure unplanned release of hydrocarbons from a hydrocarbon system as an uncommon occurrence, as backed by industry data.

Table 8-80 details the risk evaluation and the level of consequence, likelihood and risks to receptors found to be susceptible to an unplanned release of hydrocarbons in the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA. The hydrocarbon environmental exposure thresholds used in this evaluation are detailed in Table 6-2.

Table 8-80: Risk evaluation for Unplanned release—Hydrocarbon system

Impact and/or risk level summary					
Impacts	**C**	**Risks**	**C**	**L**	**RR**
N/A	-	Unplanned release of condensate from the hydrocarbon system may result in: • Change in water quality	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • Change in sediment quality	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • Alteration of coastal habitats and associated communities	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • Injury or mortality of marine fauna	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • Change to values and sensitivities of KEFs	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • Change to the functions, interests and activities of other marine users	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • Change to values and sensitivities of Australian Marine Parks	5	5	Very Low (9)
		Unplanned release of condensate from the hydrocarbon system may result in: • Change to values and sensitivities of the Ningaloo Coast	5	5	Very Low (9)

Impact and/or risk level summary					
		Unplanned release of condensate from the hydrocarbon system may result in: • Change to cultural heritage values.	5	5	Very Low (9)

Risk evaluation
Water quality
Change in water quality Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 496). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 3,033 km^2 at the low threshold (1 g/m^2) and 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. Within this worst-case modelled run, there are several (seven) periods where floating oil peaks then rapidly declines over the 104 day simulation. For example, the largest swept area of floating oil above 10 g/m^2 predicts a peak impacted area of ~220 km^2 at the low threshold (1 g/m^2) on day 9, which was reduced to ~15 km^2 by day 11. This rapid increase and decrease in area is driven by high rates of spreading and evaporation; and would likely result in impacts to water quality being limited to these short duration spikes. As such, the impact to surface water quality would be expected to be short-term and localised. The WTR scenario is a subsurface release, and based on the physical composition of the condensate, water quality may also be impacted through the presence of entrained hydrocarbons. These impacts may include increased toxicity and reduced oxygen exchange, and result in bioaccumulation in marine organisms. The deterministic run for the largest area of entrained hydrocarbons above 100 ppb predicts a total impacted area of 45,223 km^2 across the 104 day simulation. During this simulation, the peak area impacted at any one time is ~1,250 km^2. Without any response options applied, entrained condensate may remain suspended in the water column, and naturally degrade and disperse. As a result, hydrocarbon exposure within the water column from a LOWC event is likely to be localised and have short-term changes to water quality. In the event of a LOWC event, rapid evaporation, chemical degradation, and dispersion, as well as biological and photochemical degradation of condensate will ensure exposure is limited in areas impacted and duration (Ref. 496). As such, the consequence of an Unplanned release—Hydrocarbon systems (condensate) event has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to water quality is Very Low (9).
Coastal habitats and associated communities: Rocky coasts and sandy beaches
Alteration of coastal habitats and associated communities Rocky coasts and sandy beaches across the Pilbara range from soft sand beaches to exposed rocky shores (Ref. 499). Oil deposited on soft sandy beaches may penetrate the sand; however, natural processes (e.g. wave action) help disperse stranded oils and mix them into the water column, thus helping sandy beaches recover from light oiling (Ref. 500). Sun and wind can also help break down oil over time, reducing its toxicity and allowing it to be metabolised and degraded by microorganisms in the sand (Ref. 501). At exposed rocky shores, oil is typically helped offshore by reflecting waves—any oil deposited is rapidly removed by wave action. Hydrocarbons present on rocky shores are generally only there for a short period (Ref. 500). Physical dispersion and microorganism degradation processes on shorelines limit changes in sediment quality from hydrocarbon exposure to a short-term period. Stochastic modelling predicted the greatest probability of shoreline contact above the moderate threshold (10 g/m^2) to be 15% (Barrow Island), followed by a 13% probability of contact along the shorelines of the Montebello Islands. Further, the modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold) (Section 8.15.2.2). There was no predicted accumulation ≥1,000 g/m^2 predicted to occur. The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537). As a

Risk evaluation
result, hydrocarbon exposure to rocky coasts and sandy beaches from a LOWC event is likely to be localised to a small number and sections of shorelines. Further, based on the natural biological and mechanical processes of shorelines and the rapid weathering of condensate, this localised impact is expected to be short term in duration. As such, the consequence of an Unplanned release—Hydrocarbon systems (condensate) event has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to coastal communities and habitats: rocky coasts and sandy beaches is Very Low (9).
Coastal communities and habitats: intertidal and subtidal corals
Alteration of marine habitats Shoreline and entrained hydrocarbons can have smothering and toxic effects on intertidal and subtidal corals. Direct contact of hydrocarbons to coral can cause smothering, resulting in a decline in metabolic rate, and may cause varying degrees of tissue decomposition and death. A range of impacts may also result from toxicity, including partial mortality of colonies, reduced growth rates, bleaching, and reduced photosynthesis (Ref. 505; Ref. 506). Stochastic modelling predicted that following the LOWC event the presence of in-water hydrocarbons above impact levels is predicted in the surface layers (<10 m water depth) only. As such, exposure to coral reefs in deeper water are not predicted occur and therefore are not mentioned further. However, smothering of benthic habitat communities may occur if a surface slick occurs in the shallower subtidal and intertidal area. Review of modelling predictions for oil ashore from the WTR LOWC scenario was used as indicators for consequence evaluation. Stochastic modelling predicted the greatest probability of shoreline contact above the moderate threshold (10 g/m^2) to be 15% (Barrow Island), followed by a 13% probability of contact along the shorelines of the Montebello Islands. Further, the modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537). This modelling is considered most relevant for nearshore waters and subsequent impacts to subtidal and intertidal corals. Based on the majority of oil becoming stranded onshore and way from subtidal and intertidal corals, and the rapid weathering of condensate, this localised impact is expected to be short term in duration. Therefore, as the extent and duration of exposure to subtidal and intertidal corals in nearshore environments is expected to be limited the potential for environmental impacts would also be limited. As a result, hydrocarbon exposure to subtidal and intertidal corals from a LOWC event is likely to be localised to a small number and sections of shorelines over short term durations. As such, the consequence has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to coastal communities and habitats: intertidal and subtidal corals is Very Low (9).
Coastal communities and habitats: intertidal mudflats, mangroves, seagrasses
Alteration of marine habitats Shoreline hydrocarbons can have smothering and toxic effects on intertidal mudflats, mangroves, and seagrasses. Intertidal mudflats, which are typically sheltered and have a large surface area for oil absorption, can trap oil, potentially causing toxicity impacts to infauna. Intertidal mudflats are very sensitive to oil pollution because the oil enters lower layers of the mudflats where a lack of oxygen prevents it from decomposing (Ref. 502). Acute and chronic impacts to the health of mangrove communities can occur via pneumatophore smothering and exposure to the toxic volatile fraction of the hydrocarbons (Ref. 502). Intertidal seagrasses are vulnerable to smothering, which can lead to mortality if oil coats their flowers, leaves and stems (Ref. 503; Ref. 504). Stochastic modelling of 300 simulated LOWC events predicted the greatest probability of shoreline contact above the moderate threshold (10g/m^2) to be 15% (Barrow Island), followed by a 13% probability of contact along the shorelines of the Montebello Islands. No accumulation ≥1,000 g/m^2 was predicted to occur at any

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location. This higher threshold is typically associated with impacts to coastal vegetation communities. Observations by Lin and Mendelssohn (Ref. 99) demonstrated that loadings of >1,000 g/m^2 of oil would be required to impact plants significantly. Similar thresholds have been found in studies assessing oil impacts on mangroves (e.g. Grant et al. [Ref. 100], Suprayogi and Murray [Ref. 101]). Based on these findings, and limited shorelines where accumulation is predicted above impact thresholds (Hydrocarbon Ecological EMBA), shoreline exposure to intertidal mudflats, mangroves and seagrasses are anticipated to result in localised sublethal effects. As such shoreline exposure to mangroves and intertidal mudflats is not discussed further. Stochastic modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537). This modelling is considered most relevant for nearshore waters and subsequent impacts to seagrasses. Based on the majority of oil becoming stranded onshore and away from subtidal seagrasses, and the rapid weathering of condensate, this localised impact is expected to be short term in duration. Therefore, as the extent and duration of exposure to seagrasses in nearshore environments is expected to be limited the potential for environmental impacts would also be limited. As a result, hydrocarbon exposure to intertidal mudflats, mangroves, seagrasses from a LOWC event is likely to be localised to a small number and sections of shorelines over short term durations. As such, the consequence of an Unplanned release—Hydrocarbon systems (condensate) event has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of an Unplanned release—Hydrocarbon systems (condensate) event to coastal habitats and associated communities: intertidal mudflats, mangroves, seagrasses is Very Low (9).
Marine mammals
Injury or mortality of marine fauna Marine mammals can be exposed to oil externally (e.g. swimming through surface slick) or internally (e.g. swallowing the oil, consuming oil-affected prey/vegetation, or inhaling of volatile oil related compounds) (Ref. 93). Direct contact with hydrocarbons may result in skin and eye irritation, burns to mucous membranes of eyes and mouth, and increased susceptibility to infection (Ref. 509). However, direct contact with surface hydrocarbons is considered to have little deleterious effect on marine mammals, given smooth skin surfaces are less likely to suffer from hydrocarbon adherence (Ref. 510). The physical impacts from ingested hydrocarbons with subsequent lethal or sublethal impacts are applicable. Depending upon the amount and composition of the ingested oil, the effects could range from acute, to subtle, to progressive organ damage. the susceptibility of marine mammals varies with feeding habits. Baleen whales are not particularly susceptible to ingestion of oil in the water column as they feed by skimming the surface (i.e. they are more susceptible to surface slicks). Toothed whales and dolphins may be susceptible to ingestion of dissolved and entrained oil as they gulp feed at depth. Dugongs may also suffer from long-term chronic effects such as liver problems if they consume oil droplets or oil-affected sea grasses (Ref. 510). Marine mammals are vulnerable if they inhale volatiles when they surface within a hydrocarbon slick. For the short period that they persist, vapours from the spill are a significant risk to mammal health, with the potential to damage mucous membranes of the airways and the eyes, which will reduce the health and potential survivability of an animal. Inhaled volatile hydrocarbons are transferred rapidly to the bloodstream and may also accumulate in tissues (Ref. 93). The Hydrocarbon Ecological EMBA includes the presence of BIAs for marine mammals including: • humpback whale BIA (migration) • pygmy blue whale BIA (distribution, foraging) • southern right whale BIA (reproduction, migration) • dugongs (breeding, calving, foraging, nursing). Cetacean species are considered most sensitive to surface hydrocarbon exposures, whereas dugongs are considered more sensitive to oil-droplets and oil-affected seagrass as a result of entrained hydrocarbon exposure. Deterministic analyses for surface hydrocarbons for cetaceans and in-water entrained hydrocarbons for dugongs were utilised to understand the potential extent of exposure. Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating

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condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 496). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. During this simulation, the deterministic analysis predicts that on most days the floating oil impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. These small areas are due to high rates of spreading and evaporation; and would likely result in impacts to surface receptors being limited to these short duration spikes. Compared to the total area encompassed by the humpback and pygmy blue whale BIAs, the predicted extent of surface exposure is predicted to be significantly <1% of either BIA. This information indicates that if an unplanned LOWC event occurred, it is unlikely to impact entire humpback and pygmy blue whale populations, resulting in only a localised impact. As such, the impact to surface water quality would be expected to be short-term and localised. Dugongs undertaking breeding, calving, foraging, nursing behaviours in nearshore waters have shown high site fidelity to habitats required to facilitate these behaviours (Ref. 511). This high-site fidelity when undertaking critical behaviours increases their sensitivity to hydrocarbon exposures as they are less likely to be transient. Stochastic modelling predicted a 34% probability of the dugong BIA being contacted by entrained hydrocarbons in the 0-10 m layer and the high (impact) threshold. The deterministic run for the largest area of entrained hydrocarbons above 100 ppb within the dugong BIA predicts the cumulative swept area above 100 ppb to be ~800 km^2 and the peak (largest area impacted at any one time) to be ~100 km^2. Using the dugong BIA area, modelling indicates that the extent of entrained exposure was predicted to be limited to ~7% of the entire BIA. In the event of a LOWC event, rapid evaporation, chemical degradation, and dispersion, as well as biological and photochemical degradation of condensate will ensure exposure to dugongs is limited in areas impacted and duration. Based on an assessment of the predicted magnitude of surface and in-water hydrocarbons at levels above impact thresholds, it is expected that there is potential for short-term and localised impact to marine mammals. Given the localised, short-term impact to a marine mammal population the consequence has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to marine mammals is Very Low (9).
Marine Reptiles
Injury or mortality of marine fauna Reptiles may be exposed to surface and shoreline hydrocarbons from an unplanned release of condensate from a LOWC event. Reptiles can be exposed to oil externally (e.g. swimming through surface slick) or internally (e.g. swallowing the oil, consuming oil-affected prey, or inhaling of volatile oil related compounds) (Ref. 512). Hydrocarbon exposure has the potential to cause injury or mortality to reptiles. Marine turtles are vulnerable to the effects of oil at all life stages: eggs, hatchlings, juveniles, and adults. Several aspects of turtle biology and behaviour place them at risk, including a lack of avoidance behaviour, indiscriminate feeding in convergence zones, and large pre-dive inhalations (Ref. 510). Oil effects on turtles can include impacts to the skin, blood, digestive, and immune systems, and increased mortality due to oiling. Shoreline hydrocarbons can impact turtles coming ashore at nesting beaches. Eggs may also be exposed during incubation, potentially resulting in increased egg mortality and detrimental effects on hatchlings. Hatchlings may be particularly vulnerable to toxicity and smothering as they emerge from the nests and make their way over the intertidal area to the water (Ref. 512). Light oils, such as unweathered condensate, expose marine reptiles to volatile polycyclic aromatic hydrocarbons (PAHs) which may result in breathing, sight, or gastro-intestinal injuries (Ref. 148). The volatile PAHs' can penetrate the skin of sea snakes and carapace of marine turtles affecting respiration, salt gland function and blood chemistry (Ref. 148). These injuries to marine reptiles can result in decreased health, starvation, increased stranding, and decreased breeding condition (Ref. 148). Sudden high toxic contaminant load during pre-dive inhalations have caused instantaneous death to marine turtles and is to be expected with sea snakes (Shigenaka, 2021 cited in Ref. 513). The Hydrocarbon Ecological EMBA includes BIAs for flatback, loggerhead, green and hawksbill turtles, based on predicted shoreline hydrocarbons exposure at concentrations greater than the impact thresholds. The flatback turtle internesting BIA is predicted to be exposed to surface hydrocarbon concentrations greater than impact thresholds due to the fact that the receptor overlaps with the release location. The behaviours associated with these BIAs include aggregation, basking, foraging, internesting, mating, and nesting. The Hydrocarbon Ecological EMBA does not overlap sea snake BIAs.

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Table 6-7 lists key nesting areas in the Hydrocarbon Ecological EMBA predicted to be exposed to shoreline hydrocarbons concentrations greater than the impact thresholds. These areas are identified as habitat critical to the survival of flatback, green, hawksbill and loggerhead turtles (Section 6.2.3.2). As such nesting adult turtles and hatchlings may be exposed as they traverse the intertidal area, resulting in potential smothering and acute impacts to some hatchlings during that nesting season. As a result, a small proportion of any reptile population would be exposed above the defined impact thresholds, for a limited duration. Stochastic modelling predicted a <15% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island, and the Montebello Islands. Stochastic modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537). The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~90 m^3 and a maximum length of ~30 km. This deterministic run also indicates that oil does not start accumulating on the shoreline (at any threshold) until ~day 65. Based on the rapid weathering of the condensate, volatile PAHs which are known to cause breathing, sight, or gastro-intestinal injuries for marine reptiles would have weathered off out of the stranded oils, leaving mostly waxy residues that don't result in the same level of impacts. Further, the deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. During this simulation, the deterministic analysis predicts that on most days the floating oil impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. These small areas are due to high rates of spreading and evaporation; and would likely result in impacts to surface receptors being limited to these short duration spikes. Using the flatback turtle internesting BIA as an example, modelling indicates that the extent of surface exposures was predicted to be limited to <1% of the entire BIA over limited timeframes. This information indicates that if a LOWC event occurred during the nesting season, it is unlikely to impact entire local nesting populations. The EPBC threatened short-nosed sea snake, and other EPBC marine listed sea snake species, may be present within the Hydrocarbon EMBAs. Oil pollution has been identified as a pressure 'of potential concern' (Ref. 317) to sea snakes[63]. Sea snakes are susceptible to oil on the sea surface (Ref. 317; Ref. 514; Ref. 515). Being air breathers and obligate bottom feeders, oil may be either inhaled or ingested (Ref. 317; Ref. 516). As described above, surface oil exposure above impact thresholds is predicted to only be present for a short duration and over localised areas. Any exposure to benthic habitats is only predicted to occur within nearshore (<10 m water depth) areas. Using the shoreline exposure described above as indicative of oil presence in a nearshore environment, the duration and extent of exposure from a single spill event is predicted to be limited. Based on an assessment of the predicted magnitude and duration of surface and shoreline hydrocarbons, it is expected that only a small proportion of any reptile population would be exposed above the defined impact thresholds over a short-term period. Given the localised, short-term impact to a small proportion of any reptile population the consequence of this scenario has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to marine reptiles is Very Low (9).
Fishes, including sharks and rays
Injury or mortality of marine fauna Fishes, including sharks and rays, may be exposed to surface and in-water hydrocarbons from an unplanned release of condensate from a LOWC event. Although most fishes do not break the sea surface, some shark species (including whale sharks) feed in surface waters, so there is also the potential for surface hydrocarbons to be ingested. Potential effects include damage to the liver and lining of the stomach and intestine, and toxic effects on embryos (Ref. 505). Fishes are most vulnerable to oil during embryonic, larval and juvenile life stages.

[63] *The pressure analysis distinguished between oil pollution from shipping ('of less concern') and oil rigs ('of potential concern') (Ref. 317). Although the aspect source for this risk assessment is a spill from a vessel, the higher pressure concern has been adopted.*

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However, very few studies have demonstrated increased mortality of fish as a result of oil spills (Ref. 502; Ref. 506; Ref. 518). Demersal fishes are not expected to be impacted given the presence of in-water hydrocarbons is predicted in the surface layers (<30 m water depth) only, outside of the plume cone at the subsea release location. Pelagic free-swimming fishes and sharks are unlikely to suffer long-term damage from oil spill exposure because dissolved/entrained hydrocarbons are typically insufficient to cause harm (Ref. 83). Pelagic species are also generally highly mobile and as such are not likely to suffer extended exposure (e.g. >48–96 hours) at concentrations that would lead to chronic effects due to their patterns of movement. Near the sea surface, fish can detect and avoid contact with surface slicks meaning fish mortalities rarely occur in the event of a hydrocarbon spill in open waters (Ref. 519). Fish that have been exposed to dissolved hydrocarbons can eliminate the toxicants once placed in clean water; hence, individuals exposed to a spill are likely to recover (Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537). Marine fauna with gill-based respiratory systems, including whale sharks, are expected to have higher sensitivity to exposures of entrained oil. The Hydrocarbon Ecological EMBA includes the presence of whale shark foraging BIA. As these species are considered most sensitive to surface exposures, stochastic and deterministic analyses were utilised to understand the potential extent of exposure. Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 496). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. During this simulation, the deterministic analysis predicts that on most days the floating oil impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. These small areas are due to high rates of spreading and evaporation; and would likely result in impacts to surface receptors being limited to these short duration spikes. Using the whale shark BIA as an example, modelling indicates that the extent of surface exposures was predicted to be limited to <1% of the entire BIA. Based on an assessment of the predicted magnitude of surface hydrocarbons at levels above impact thresholds, it is expected that only a small proportion of any fish population would be exposed above the defined impact thresholds. Therefore, the consequence of this scenario has been evaluated as Minor (5) given the localised, short-term impact to a small proportion of any fish population. The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to fishes, including sharks and rays is Very Low (9). **Injury or mortality of marine fauna (fish eggs and larvae)** Plankton may be exposed to surface and in-water hydrocarbons from an unplanned release of condensate from a LOWC event. Plankton can be exposed to hydrocarbons through ingestion, inhalation, and dermal contact (Ref. 543). Plankton is a collective term for all marine organisms that are unable to swim against a current. This group is diverse and includes zooplankton (animals) such as fish eggs and larvae. Zooplankton are typically sensitive to oil (Ref. 544). Exposure of zooplankton to surface and in-water hydrocarbons can cause immediate mortality or declines in reproduction (Ref. 544). Lethal and sublethal effects on zooplankton include narcosis, alterations in feeding, development, and reproduction (Ref. 545). As a result, plankton within the Hydrocarbon Ecological EMBA are potentially susceptible to injury or mortality. Low nutrient levels within the Hydrocarbon Ecological EMBA indicates sparse populations of plankton species as represented throughout the NWS (Ref. 104). Mortality rates for plankton are naturally high with distribution often patchy and linked to localised and seasonal productivity that produces sporadic bursts in phytoplankton and zooplankton populations (Ref. 104). Plankton populations have evolved to respond to environmental perturbations by copious production within short generation times (Ref. 546). Plankton have rapid recovery and growth rates (Ref. 547; Ref. 548). Once background water quality conditions have re-established post well kill, the plankton community may recover within weeks to months (Ref. 546). An assessment of surface and in-water hydrocarbon modelling is considered most relevant of this receptor. Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 496). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. During this

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simulation, the deterministic analysis predicts that on most days the floating oil impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. These small areas are due to high rates of spreading and evaporation; and would likely result in impacts to surface receptors being limited to these short duration spikes. The deterministic run for the largest area of entrained hydrocarbons above 100 ppb predicts a total impacted area of 45,223 km^2 across the 104 day simulation. During this simulation, the peak area impacted at any one time is ~1,250 km^2. Without any response options applied, entrained condensate may remain suspended in the water column, and naturally degrade and disperse. As a result, hydrocarbon exposure within the water column from a LOWC event is likely to be localised and have short-term changes to water quality. Based on an assessment of the predicted magnitude and duration of surface and in-water hydrocarbons, it is expected that sparse plankton populations would be exposed above the defined impact thresholds over a short-term period. In addition, recovery of plankton populations is expected over a short-term period. Therefore, the consequence of this scenario has been evaluated as Minor (5) given the localised, short-term impact to sparse populations of plankton. The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to plankton is Very Low (9).
Seabirds and shorebirds
Injury or mortality of marine fauna Seabirds that rest at the water's surface (e.g. shearwaters) or surface-plunging birds (e.g. terns, boobies) may be exposed to surface hydrocarbons from an unplanned release of condensate from a LOWC event (Ref. 92; Ref. 510). Whereas shorebirds may be exposed to shoreline hydrocarbons from an unplanned release of condensate from a LOWC event. Damage to external tissues, including skin and eyes, can occur, along with internal tissue irritation in lungs and stomachs (Ref. 520). Acute and chronic toxic effects may result where the product is ingested as the bird attempts to preen its feathers (Ref. 520). The Hydrocarbon Ecological EMBA includes the presence of breeding BIAs for seabirds and shorebirds including: • fairy tern • lesser crested tern • roseate tern • wedge-tailed shearwater • white-tailed tropicbird. Roosting gulls and terms along sandy parts of the Ningaloo coast have been recorded including fairy terns, lesser crested terns, (Surman & Nicholson 2015 cited in Ref. 521). Breeding population of roseate terns have been recorded at the Lowendal Islands (Ref. 189). Wedge-tailed shearwaters breed on many of the islands in the Exmouth Sub-basin and are known to depart and return to nesting burrow to forage in pelagic waters 10–300 km off the west coast (Ref. 139). Northern Australia white-tailed tropicbird forages in warm waters and over long distances, moving up to 1,500 km from breeding sites (Ref. 177). Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 496). With the exception of the wedge-tailed shearwater BIA, in which the release location resides, there were no other BIAs impacted at or above the moderate threshold. Further, the deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. During this simulation, the deterministic analysis predicts that on most days the floating oil impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. These small areas are due to high rates of spreading and evaporation; and would likely result in impacts to surface receptors being limited to these short duration spikes. Based on the size of the fairy tern, lesser crested tern, roseate tern, wedge-tailed shearwater, and white-tailed tropicbird breeding BIAs, the modelling indicates that the extent of surface exposures was predicted to be limited to <1% of all breeding BIAs. Birds can also be impacted by oil stranded on shorelines. Stochastic modelling predicted a <15% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island and the Montebello Islands. Stochastic modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km

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or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537). The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~ 90 m^3 and a maximum length of ~30 km. This deterministic run also indicates that oil does not start accumulating on the shoreline (at any threshold) until ~day 65. Based on the rapid weather of the condensate, the volatile PAHs which are known to breathing, sight, or gastro-intestinal injuries for marine reptiles would have weathered off leaving mostly waxy residues that don't result in the same level of impacts. Based on an assessment of the predicted magnitude and duration of surface and shoreline hydrocarbons, it is expected that only a small, localised proportion of any seabird or shorebird population would be exposed above the defined impact thresholds over a short-term period. Given the localised, short-term impact to a small proportion of any seabird or shorebird population the consequence of this scenario has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to seabirds and shorebirds is Very Low (9).
KEFs
Change to values and sensitivities Section 6.2.6.1 lists the KEFs present in the Hydrocarbon Social EMBA. Stochastic modelling (Appendix C; Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537) predicts entrained hydrocarbon exposure at the high (impact) threshold is limited to the upper water column (0–30 m). Given this extent of hydrocarbon exposure within the water column, potential impacts are limited to values within these KEFs: • Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula • Commonwealth waters adjacent to Ningaloo Reef As identified in Section 6.2.6.1, the values of these KEFs include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, as well as identified BIAs for regionally significant marine fauna. The consequence evaluations to marine fauna and commercial fisheries are provided above. The following KEFs, whilst also present in the Hydrocarbon Social EMBA; have values that relate to benthic habitats or demersal fish, and therefore hydrocarbon exposure is not feasible for an unplanned LOWC event in offshore waters: • Glomar shoals KEF contains a submerged littoral feature found in water depths of 33–77 m (Ref. 110) • Ancient coastline at 125 m depth contour and Exmouth Plateau KEFs have benthic habitat values • Continental slope demersal fish communities KEF has values relating to fishes that live and feed near the sea floor. Based on the modelling, the predicted area of entrained oil above the high threshold is mostly limited to the upper 10m of the water column. As such, any impact would be localised to the upper layers of the KEFs and not impact any values and sensitivities that exist below this surface layer. Given the localised and short-term, hydrocarbon exposure to marine fauna or commercial fish species above impact exposure thresholds, the risks of a LOWC event to the values and sensitivities of the listed KEFs has been evaluated as Minor (5). The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to KEFs is Very Low (9).
Commercial fisheries
Change to the functions, interests and activities An unplanned release of condensate from a LOWC event may result in changes to the functions, interests, or activities of commercial fisheries within the Hydrocarbon Ecological EMBA and the Hydrocarbon Social EMBA. Commercial fishing has the potential to be impacted through exclusion zones associated with the unplanned release of condensate from a LOWC event, and subsequent reduction in fishing effort. Exposure of commercially targeted marine species to in-water hydrocarbons can have economic impacts to the industry. Exclusion zones may impede access to commercial fishing areas, for a short period of time, and nets and lines may become oiled. Actual or potential contamination of seafood can affect commercial fisheries and can

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impact seafood markets long after any actual risk to seafood from a spill has subsided (Ref. 549). Such that, the impacts to commercial fishing from a public perception may be much more significant and longer term than the actual spill. As identified in Section 6.3.4, several commercial fisheries have management areas and recent fishing effort recorded within the Hydrocarbon Social EMBA. Active commercial fisheries operating in the Hydrocarbon Ecological EMBA only include the following state managed fisheries: • Mackerel Managed Fishery • Nickol Bay Prawn Managed Fishery • Onslow Prawn Managed Fishery • Pilbara Line Fishery (Condition) • Pilbara Trap Managed Fishery • West Australian Sea Cucumber (Beche-De-Mer) Fishery • West Coast Deep Sea Crustacean Fishery. Concentrations of petroleum contaminants in fish and crustacean and mollusc tissues could pose a significant potential for adverse human health effects, and until these products cleared by the health authorities, they could be restricted for sale and human consumption. Uptake of hydrocarbons has been demonstrated in bony fish after exposure to water-accommodated fraction (WAF) of between 24 and 48 hours. Davis et al (Ref. 524) reported detectable tainting of fish flesh after a 24 hour exposure to marine fuel oil concentrations of 0.33 ppm and diesel concentrations of 0.25 ppm. Most studies, either from laboratory trials or of fish collected after release events (including the Hebei Spirit, Macondo, and Sea Empress spills) find evidence of elimination of PAHs in fish tissues returning to reference levels within two months of exposure (Ref. 524; Ref. 525; Ref. 526; Ref. 527; Ref. 528; Ref. 529; Ref. 530). The Montara spill of a light gas condensate, (as the most recent [2009] example of a large hydrocarbon spill in Australian waters) occurred over an area fished by the Northern Demersal Scalefish Managed Fishery (with 11 licences held by 7 operators), with goldband snapper, red emperor, saddletail snapper and yellow spotted rockcod being the key species fished (Ref. 531). As a precautionary measure, the WA Department of Fisheries advised the commercial fishing fleet to avoid fishing in oil-affected waters. Testing of fish caught in areas of a visible slick (November 2009) found that there were no detectable petroleum hydrocarbons in fish muscle samples, suggesting fish were safe for human consumption. Limited ill effects were detected in a small number of individual fish only (Ref. 531). No consistent effects of exposure on fish health could be detected within two weeks following the end of the well release. Follow up sampling in areas affected by the spill during 2010 and 2011 (Ref. 531) found negligible ongoing environmental impacts from the spill. Any acute impacts to commercially targeted marine species are expected to be limited to small numbers of juvenile fish, eggs and larvae (refer to plankton evaluation in Fishes, including sharks and rays section above), which are not expected to affect population viability or recruitment. Impacts from in-water hydrocarbon exposure are unlikely to manifest at a fish population viability level (refer to Fishes, including sharks and rays section above). In an unplanned release of condensate from a LOWC event, any exclusion zone established would be limited to the safety exclusion zone around the vicinity of the release point, and due to the rapid weathering of hydrocarbons would only be in place whilst well-kill activities are enacted, therefore physical displacement to vessels is unlikely to be a significant impact. However commercial fishers themselves may voluntarily implement an exclusion zone until water quality monitoring verifies the absence of residual hydrocarbons, as such providing confidence to consumers in fisheries tainting. Residual condensate may foul the hulls of fishing vessels and associated equipment, such as gill nets. A temporary fisheries closure, combined with oil tainting of target species (actual or perceived), may lead to financial losses to fisheries and economic losses for individual licence holders. Fishery closures and the flow on losses from the lack of income derived from these fisheries are likely to have short-term socio-economic consequences, such as reduced employment (in fisheries service industries, such as tackle and bait supplies, fuel, marine mechanical services, accommodation and so forth). Minor loss of revenue for commercial fisheries in the Hydrocarbon Social EMBA and acute impacts juvenile fish, eggs and larvae of commercially targeted marine species in the Hydrocarbon Ecological EMBA has been evaluated as Minor (5) because the area of potential impact to fishes is localised, and minor-loss of revenue and juvenile fish, eggs and larvae is short-term. The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5).

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Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) event to commercial fisheries is Very Low (9).
Commercial shipping
Change to the functions, interests and activities An unplanned release of condensate from a LOWC event may result in changes to the functions, interests or activities of commercial shipping within the Hydrocarbon Social EMBA. Commercial shipping has the potential to be impacted through exclusion zones associated with the unplanned release of condensate from a LOWC event. Exclusion zones may impede access to areas, for a short-term period. Any exclusion zone established would be limited to the safety exclusion zone around the vicinity of the release point, and due to the rapid weathering of hydrocarbons would only be in place whilst well-kill activities are enacted, therefore physical displacement to vessels is unlikely to be a significant impact. As a result, physical displacement of commercial vessels will be limited to a localised area. Impeding access to commercial shipping in the Hydrocarbon Social EMBA has been evaluated as Minor (5) because of the localised, short-term impact. The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to commercial shipping is Very low (9).
Petroleum activities
Change to the functions, interests and activities An unplanned release of condensate from a LOWC event may result in changes to the functions, interests, or activities of petroleum activities within the Hydrocarbon Social EMBA. Following the Deepwater Horizon incident in the Gulf of Mexico in 2011, the US Government placed a moratorium on new drilling permits, and other regulatory actions. The number of rigs drilling for oil dropped for a period and recovered slowly. However, by 2016, oil production in the Gulf of Mexico hit a record high (Ref. 550). Based on the slow recovery rate of regulatory actions in the Gulf of Mexico following the Deepwater Horizon incident, it is assumed that petroleum activities within the Northern Carnarvon Basin will also have a slow recovery following a moratorium on petroleum activities. Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 496). Petroleum operators within this area include: • Santos Ltd. John Brooks Platform • Santos Ltd. Armada Claire Platform • Woodside energy Ltd. Balnaves Development (undergoing decommissioning 2021) • Santos Ltd. Greater East Spar Development. The potential placement of a moratorium on these petroleum activities is considered a localised area considering the numerous active oil, condensate, and gas facilities in the Northern Carnarvon Basin. The moratorium established would likely be limited to the safety exclusion zone around the vicinity of the release point, and due to the rapid weathering of hydrocarbons would only be in place whilst well-kill activities are enacted. The duration of the potential moratorium is considered short-term. Change to the functions of petroleum activities in the Hydrocarbon Social EMBA has been evaluated as Minor (5) because of the localised, short-term impact. The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to petroleum activities is Very low (9).

Risk evaluation
Defence
Change to the functions, interests and activities An unplanned release of condensate from a LOWC event may result in changes to the functions, interests or activities of Defence activities within the Hydrocarbon Social EMBA. Defence practice and training areas in the Hydrocarbon Social EMBA include: • Defence—Exmouth VLF transmitter station • Defence—Exmouth admin and HF transmitting • Defence—Learmonth radar site, Vlamingh Head • Defence—Learmonth air weapons range. The Learmonth RAAF base extend offshore as a designated maritime firing practices and exercise area. In-water hydrocarbon exposure is not expected to adversely impact the use of these areas. Any exclusion zone established would be limited to the safety exclusion zone around the vicinity of the release point, and due to the rapid weathering of hydrocarbons would only be in place whilst well-kill activities are enacted, therefore physical displacement to Defence activities is unlikely to be a significant impact. A LOWC event duration is anticipated to be 90 days until well kill. Post well kill, remaining surface hydrocarbons would be exposed to processes such as dispersion, dilution, physical and biological degradation. These processes will ensure surface hydrocarbon exposure is limited to several weeks post well kill. As a result, change to the functions of Defence activities in the Hydrocarbon Social EMBA has been evaluated as Minor (5) because of the localised, short-term impact. The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5×10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to Defence activities is Very low (9).
Tourism and recreation
Change to the functions, interests and activities Tourist destinations present in the Hydrocarbon Social EMBA may be exposed to shoreline, surface and in-water hydrocarbons from an unplanned release of condensate from a LOWC event. The presence of hydrocarbons in these tourist destinations may reduce the visual amenity in the area; and given these destinations are exclusively nature-based tourism, potential environmental impacts to these places may also reduce tourism visitation numbers. A number of tourism destinations occur within the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA, including: • Great Sandy Islands • Montebello Islands • Passage Islands • Cape Range National Park • Ningaloo Coast • Point Cloates / Ningaloo Station area • Dampier Archipelago islands. The reduction of tourist visitation numbers may lead to a minor loss of revenue for tourist operators (e.g. charter fishing cancellations due to fishery closures). Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 496). Based on the distance between the tourism receptors listed above, it is not possible that all locations would be impacted from a single event, and any impacts to be localised at the particular location. Stochastic modelling predicted a <15% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island, and the Montebello Islands. Stochastic modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and

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Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and volume ashore when compared with the other LOWC scenarios modelled. (Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537). The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~90 m^3 and a maximum length of ~30 km. This deterministic run also indicates that oil does not start accumulating on the shoreline (at any threshold) until ~day 65. Shoreline, surface, and in-water hydrocarbons would be exposed to processes such as dispersion, dilution, physical and biological degradation. These processes will ensure hydrocarbon exposure to tourist destinations is limited to a short-term period. Minor loss of revenue from reduction of tourist visitation numbers in the Hydrocarbon Social EMBA, has been evaluated as Minor (5) because of the localised, short-term impact. The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to tourism and recreation is Low (8).
AMPs
Change to values and sensitivities An unplanned release of condensate from a LOWC event may result in change to values and sensitivities of AMPs. As detailed in Table 8-79, the Hydrocarbon Ecological EMBA and Hydrocarbon Social EMBA overlap the following AMPs: • Gascoyne • Montebello • Ningaloo • Shark Bay Stochastic modelling predicts a 13% probability of surface condensate exposure to the Montebello AMP. No other AMPs were predicted to be contacted by surface hydrocarbons at any threshold. Values and receptors of AMPs within the water column may also be impacted. At the moderate threshold, modelling predicted 2% (summer) probability of dissolved oil exposure within the Gascoyne Marine Park, 3% (winter) probability within the Montebello Islands Marine Park, and a 1% (transitional) probability within the Ningaloo Marine Park. With respect to entrained hydrocarbons, the modelling predicted a probability of contact at the high threshold (100 ppb) of 45% (transitional) for the Gascoyne Marine Park, 78% (transitional) for the Montebello Islands Marine Park, 39% (winter) for Ningaloo Marine Park and 2% (summer) for the Shark Bay Marine Park. As identified in Section 6.4.1, the natural values of the above listed AMPs include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, as well as any identified BIAs for regionally significant marine fauna. Social and economic values of the listed AMPs include commercial fishing. The consequence evaluations to specific marine fauna and commercial fisheries are provided above. Given the temporary and localised hydrocarbon exposure to marine fauna or commercial fish species above impact exposure thresholds the potential risks of an unplanned release of condensate from a LOWC event to the values and sensitivities of the listed AMPs has been ranked as Minor (5). The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to AMPs is Very Low (9).
Cultural heritage value: Ningaloo Coast
Change to values and sensitivities An unplanned release of condensate from a LOWC event may result in change to values and sensitivities of heritage values of the Ningaloo Coast, which is considered a World Heritage property, and listed under the National Heritage listing.

Risk evaluation
Stochastic modelling for LOWC events in all fields predicted a 6% probability of shoreline contact at the impact threshold (100 g/m^2). The largest volume of oil ashore along the Ningaloo Coast was 30 m^3 (Ref. 496) and the maximum length of shoreline exposed above the impact threshold along the Ningaloo Coast was predicted to be ~6 km (Ref. 496). As a result, hydrocarbon exposure to shoreline sediments from a LOWC event is expected to be localised along the coastline, which extends more than 300 km. As identified in Section 6.5.1, heritage values for the Ningaloo Coast include species listed as threatened, migratory, marine, or cetacean under the EPBC Act, as well as any identified BIAs for regionally significant marine fauna. The intertidal systems of the Ningaloo Coast World Heritage Area are also considered high diversity habitats that sustains the presence of species listed under the EPBC Act and resultant tourism in the area. The consequence evaluations to marine fauna, marine habitat and tourism and recreation are provided above. Given the temporary and localised hydrocarbon exposure along the Ningaloo Coast, the risks of an unplanned release of condensate from a LOWC event to the values and sensitivities of the Ningaloo Coast has been ranked as Minor (5). The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to the Ningaloo Coast is Very Low (9).
Cultural heritage value: Traditional Owners
Change to cultural heritage values Potential changes to cultural heritage values from unplanned release of condensate from a LOWC event includes: • potential indirect impacts to intangible Traditional Owner heritage from injury or mortality of marine fauna • potential impacts to tangible Traditional Owner heritage from hydrocarbon exposure of protected First Nation sites or artefacts As discussed in Section 6.5.2, at the time of writing this OPP, CAPL understands through consultation with Traditional Owners that there are no artefacts or specific sites on the seabed within the EMBAs that have, or are associated with, cultural heritage values. As identified from literature and/or consultation (Section 6.2.5.2.1), Sea Country is a value for First Nations people. It is understood that the term ‘Country’ refers to more than just a geographical area, and includes values, places, resources, stories, and cultural obligations associated with that geographical area (Ref 532; Ref 533). Specific intangible values of Sea Country identified through consultation on other CAPL activities included Dreamtime stories and songlines. In particular, relevant persons have previously identified the existence of songlines that go through Barrow Island and offshore. The waters of the NWMR (and therefore the waters within the Hydrocarbon EMBAs) are acknowledged as potentially having some cultural and spiritual significance to First Nations as well as providing natural resources (Section 6.2.5.2.1). The Hydrocarbon EMBAs intersect with the coast of the North West Cape peninsula, along or adjacent to which, cultural heritage sites or artefacts are located. Condensate on surface waters undergoes rapid spreading and evaporative loss in warm waters. Stochastic modelling of 300 simulated LOWC events predicts the maximum distance from the release location for floating condensate exposure to the low (≥1 g/m^2) and moderate (≥10 g/m^2) thresholds was ~252 km and ~46 km respectively (Ref. 496). The deterministic run for the largest swept area of floating oil above 10 g/m^2 predicts a total impacted area of 3,033 km^2 at the low threshold (1 g/m^2) and 485 km^2 at the moderate threshold (10 g/m^2) across the 104 day simulation. Within this worst case modelled run, there are several (seven) periods where floating oil peaks then rapidly declines over the 104 day simulation. For example, the deterministic run for the largest swept area of floating oil predicts a peak impacted area of ~220 km^2 at the low threshold (1 g/m^2) on day 9, which was reduced to ~15 km^2 by day 11. The low threshold represents presence of oil. Any ecological impact is not predicted to occur until oil gets above the moderate threshold. Using the same deterministic run, the analysis predicts that on most days the floating oil at the impact threshold impacts <5 km^2, and at no point over the 104 days does the floating oil impact more than ~15 km^2. As such, potential impacts would be expected to be short-term and localised. Stochastic modelling predicted a <15% probability of contact at the impact threshold across shorelines of the Ningaloo Coast, Barrow Island, and the Montebello Islands. Stochastic modelling predicted the maximum volume of shoreline hydrocarbons to be 128 m^3 across all shoreline receptors in the Hydrocarbon Social and Ecological EMBAs and potentially impacting up to 38 km or shoreline (at the moderate threshold). (Section 8.15.2.2). The WTR LOWC scenario represents the worst case predicted probability of contact and

Risk evaluation
volume ashore when compared with the other LOWC scenarios modelled. (Ref. 496; Ref. 534; Ref. 535; Ref. 536; Ref. 537). The deterministic run for the largest volume ashore and longest length of shoreline with accumulation of shoreline hydrocarbons above the moderate threshold predicted a peak of ~90 m^3 and a maximum length of ~30 km. This deterministic run also indicates that oil does not start accumulating on the shoreline (at any threshold) until ~day 65. Given the volume, type of oil (condensate) and predicted weathering, no prolonged impact pathway to a change in access to Country is anticipated. Based on the temporary and localised, exposure of hydrocarbons, the risks of potential changes to Traditional Owner cultural heritage values from an unplanned release of condensate from a LOWC event has been ranked as Moderate (4). The blowout frequencies data from IOGP (Ref. 542) was used to evaluate the likelihood of a LOWC scenario (blowout of an appraisal well), which was determined to be equivalent to 1.5 x 10^{-4} per drilled well. Due to the low probability of a LOWC event, and the control measures in place, the likelihood of the worst-case environmental consequence occurring as described above was assessed as Remote (5). Overall, the risk of Unplanned release—Hydrocarbon systems (condensate) to Traditional Owner cultural heritage values is Very Low (9).

8.15.4 Determination of acceptability

The acceptable level of risk is a function of the magnitude of residual risk, principles of ESD, internal and external context, and legislative requirements.

Table 8-81 details the determination of acceptability for Unplanned release—Hydrocarbon system (condensate).

Table 8-81: Determination of acceptability for Unplanned release—Hydrocarbon system (condensate)

Determination of acceptability	
Principles of ESD	**(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation**
	The Development is consistent with principle of ESD (b) for this aspect as: • The highest residual risk level for unplanned release of condensate from the hydrocarbon system was evaluated as Moderate (4). • The detailed literature review highlighting consensus of findings and effectiveness of prevention measures provides scientific certainty for the risk evaluation of unplanned release of condensate from the hydrocarbon system. • Prevention measures for unplanned release of condensate from the hydrocarbon system are well regulated and managed in Australian waters. To manage impacts and risks to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.
	(c) the principle of inter-generational equity – that the present generation should ensure that the health, diversity, and productivity of the environment is maintained or enhanced for the benefit of future generations
	The Development is consistent with principle of ESD (c) for this aspect as: • The Development is committed to applying measures to prevent the impact and risk of unplanned release of condensate from the hydrocarbon system based on relevant environmental legislation and other requirements as listed below. • The regulation and management of unplanned releases of hydrocarbons in Australian waters ensures health, diversity and productivity of the environment is maintained for future generations through application of prevention measures.

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td></td><td colspan="2">

- The highest residual risk level for unplanned release of condensate from the hydrocarbon system was evaluated as Moderate (4).
- Any relevant stakeholder feedback in relation to unplanned release of condensate from the hydrocarbon system has been incorporated in the OPP and assessed in the external context acceptability criteria.

To manage impacts to affected receptors, to at or below the defined acceptable levels, the controls detailed below will be adopted.</td></tr>
<tr><td></td><td colspan="2">(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making</td></tr>
<tr><td></td><td colspan="2">Feasible Development alternatives were considered, comparing environmental impacts and risks of each option.
The alternatives analysis highlights that the selected Development concept has the least environmental impact and risk to the environment (Section 5).
The Development is consistent with principle of ESD (d) for this aspect through the consideration of conservation of biological diversity and ecological integrity during the alternatives analysis as detailed in Section 5.</td></tr>
<tr><td>Relevant environmental legislation and other requirements</td><td colspan="2">Legislation and other requirements considered relevant for this aspect are listed below. The OPP will implement controls to address relevant item/objective/action within each of the listed legislative requirements considered relevant to this aspect.</td></tr>
<tr><td></td><td>Requirement</td><td>Demonstration of requirement</td></tr>
<tr><td></td><td>OPPGS(E)R
An Environmental Plan, including oil spill contingency and emergency response arrangements, must be place for any petroleum activity prior to activities commencing.</td><td>Legislative requirements to develop EPs, Safety Cases, and associated documents (e.g. Oil Pollution Emergency Plans (OPEPs), WOMPs) are addressed by adoption of the following control measures:
CM47: In the event of a spill occurring, the accepted OPEP in subsequent EPs for the Development will be implemented.
CM48: In the event of a spill occurring, the accepted OSMP in subsequent EPs for the Development will be implemented.
CM49: NOPSEMA-accepted Well Operations Management Plan in place for all wells, in accordance with the OPGGS Act requirements.
CM50: NOPSEMA-accepted Safety Case in place for all relevant facilities, in accordance with the OPGGS Act requirements.</td></tr>
<tr><td></td><td>Navigation Act 2012 – Chapter 4 (Prevention of Pollution).
Gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).
Maintaining and disseminating navigational charts and publications, including providing safety-critical</td><td>CM32: Before commencing offshore activities, relevant agencies will be notified of activities, vessel movements, and requested exclusion zones, to enable them to generate radio navigation warnings and/or Notice to Mariners.
CM44: MODUs and vessels will meet the requirements of the Chevron Marine Standard Non Tankers, including pre-mobilisation inspections of equipment,</td></tr>
</table>

Determination of acceptability		
	information to mariners via the Notice to Mariners system.	couplings, and secondary containment.
	Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148) Management action A1: Maintain and improve efficacy of legal and management protection: • Ensure spill risk strategies and response programs adequately include management for marine turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs.	EPBC management plan requirements to minimise habitat degradation / modification, including marine pollution, are addressed by adoption of the following control measures: **CM47:** In the event of a spill occurring, the accepted OPEP in subsequent EPs for the Development will be implemented. Assessment of spill risk strategies is within scope of the approved OPEP. **CM48:** In the event of a spill occurring, the accepted OSMP in subsequent EPs for the Development will be implemented. Response and recovery of habitats and marine fauna is within the scope of the approved OSMP. Therefore, the Development is not considered to be inconsistent with the EPBC management plans.
	Conservation Management Plan for the Southern Right Whale (Ref. 19) Addressing infrastructure and coastal development impacts.	
	Draft National Recovery Plan for the Southern Right Whale (Ref. 20) Baseline surveys and monitoring undertaken during activity implementation are conducted in accordance with best practice standards and guidelines to ensure standardised datasets are obtained and suitable to inform environmental management decision making that can reduce the risk of threats to southern right whales.	
	Approved Conservation Advice for Aipysurus apraefrontalis (Short-nosed Sea Snake) (Ref. 24) Identifies habitat degradation / modification as a key threat. Management action: Ensure there is no anthropogenic disturbance in areas where the short-nosed sea snake occurs, excluding necessary actions to manage the conservation of the species.	
	Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 23) Identifies habitat degradation / modification as a key threat. Management action: Ensure there is no anthropogenic disturbance in areas where the Leaf-scaled sea snake occurs, excluding necessary actions to manage the conservation of the species.	
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25)	

Determination of acceptability		
	Management action 5C: Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks. Management action 5D: Implement measures to reduce adverse impacts of habitat degradation and / or modification.	
	Approved Conservation Advice for *Pristis pristis* (largetooth sawfish) (Ref. 27) Implement measures to reduce adverse impacts of habitat degradation and/or modification	
	National Recovery Plan for Albatrosses and Petrels (Ref. 37) Risk based response strategies for marine pollution incidents are developed. Where appropriate monitoring of breeding colonies includes an assessment of marine pollution impacts including the incidence of oiled birds at nest.	
	Wildlife Conservation Plan for Seabirds (Ref. 35) Enhance contingency plans to prevent and/or respond to environmental emergencies that have an impact on seabirds and their habitats.	
	Approved Conservation Advice for *Thalassarche cauta* (Shy Albatross) (Ref. 55) Where feasible, population monitoring programmes also monitor, in a standardised manner, the incidence of oiled birds at the nest, marine debris egestion / entanglement at the nests, and eggshell thinning	
	Conservation Advice for Sternula nereis nereis (Fairy Tern) (Ref. 40) Ensure appropriate oil spill contingency plans are in place for the subspecies' breeding sites that are vulnerable to oil spills.	
	Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16) Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 17) Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 18) Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish) (Ref. 26) Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29)	These EPBC management plans for species that may occur within the Hydrocarbon Social or Hydrocarbon Ecological EMBAs that identify habitat degradation / modification or acute pollution as a threat; but do not identify any relevant actions.

Determination of acceptability		
	Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 31). Conservation Advice *Rhincodon typus* Whale Shark (Ref. 30). National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*) (Ref. 41) Conservation Advice *Calidris ferruginea* curlew sandpiper (Ref. 45) Conservation Advice *Numenius madagascariensis* eastern curlew (Ref. 46) Conservation Advice *Calidris canutus* Red knot (Ref. 52) Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper) (Ref. 54) Conservation Advice for *Limosa lapponica menzbieri* (Yakutian bar-tailed Godwit) (Ref. 51) Conservation Advice for *Charadrius leschenaultia* (Greater Sand Plover) (Ref. 47) Conservation Advice for *Tringa nebularia* (Common Greenshank) (Ref. 44) Conservation Advice for *Limnodromus semipalmatus* (Asian dowitcher) (Ref. 39) Wildlife Conservation Plan for Migratory Shorebirds (Ref. 67)	
	North-west Marine Parks Network Management Plan The Plan requires that "[a]ctions required to respond to oil pollution incidents, including environmental monitoring and remediation, in connection with mining operations authorised under the OPGGS Act may be conducted in all zones. The Director should be notified in the event of an oil pollution incident that occurs within, or may impact upon, an Australian Marine Park and, so far as reasonably practicable, prior to a response action being taken within a marine park."	Protected area requirements to respond to an Unplanned release—Hydrocarbon system (condensate), including notifying, environmental monitoring, and remediation, authorised under the OPGGS Act are addressed by adoption of the following control measures: **CM47:** In the event of a spill occurring, the accepted OPEP in subsequent EPs for the Development will be implemented. **CM48:** In the event of a spill occurring, the accepted OSMP in subsequent EPs for the Development will be implemented.
	Management Plan for the Montebello/Barrow Islands Marine Conservation Reserves The plan requires that: • "there are appropriate predictive models and specific management plans (given location and weather conditions) for oil spills to assist the State Committee for Combating Oil Pollution in managing any pollution event that occurs" against the water quality KPI.	

Determination of acceptability		
	• "Ensure the State Committee for Combating Oil Pollution has access to data relevant to the management of oil spills" against the coral reef communities KPI	
	Nyinggulu (Ningaloo) Coastal Reserves: Red Bluff to Winderabandi joint management plan 101 The plan requires that: • "Implement the regional response plan for wildlife affected by shipping and boating pollution, such as oil spills in line with national and state plans"	Protected area requirements to respond to an Unplanned release—Hydrocarbon system (condensate), including notifying, environmental monitoring and remediation, in accordance with National Plan for maritime environmental emergencies (Ref. 551), State hazard plan for maritime environmental emergencies (Ref. 552) and Western Australian oiled wildlife response plan (Ref. 553) are addressed by adoption of the following control measures: **CM47:** In the event of a spill occurring, the accepted OPEP in subsequent EPs for the Development will be implemented. **CM48:** In the event of a spill occurring, the accepted OSMP in subsequent EPs for the Development will be implemented.
	Management Plan Jurabi and Bundegi Coastal Parks, and Muiron Islands The plan generally states: • "Minimise adverse impact on flora and fauna from management actions or visitor activities."	
Internal context	These CAPL environmental performance standard/procedure was deemed relevant for this aspect: • Chevron Marine Standard Non Tankers (Ref. 284).	
External context	CAPL has maintained long-term external stakeholder relationships for the GFP since the inception of engagement during the environmental approval process in 2009. Existing and new stakeholders for the proposed Development were targeted for consultation where relevant as part of the Stage 1 assessment. During ongoing stakeholder consultation, feedback on the potential presence of Traditional Owners underwater cultural heritage sites within offshore Australian waters was received. CAPL provided a response that confirmed that a desktop assessment for underwater cultural heritage has been undertaken which included consultation with Traditional Owners to identify presence of underwater cultural heritage artefacts within the EMBA (see Sections 6.2.5 and 6.5.2). Further, CAPL has also since included adaptive management control measures for underwater cultural heritage sites/artefacts in the OPP (**CM07** and **CM08**). No further feedback was received in relation to unplanned release of condensate from the hydrocarbon system from Phase 1 stakeholder consultation. Ongoing consultation will be undertaken as per Section 3.	
Defined acceptable level	The consequence of unplanned release of condensate from the hydrocarbon system is inherently acceptable as the highest consequence level is Moderate (4). In addition, the potential impacts and risks evaluated for this aspect are not inconsistent with any relevant recovery or conservation management plan, conservation advice, or bioregional plan. The risk evaluation does not identify scientific uncertainty against risks of unplanned release of condensate from the hydrocarbon system for each receptor.	

<table>
<tr><th colspan="3">Determination of acceptability</th></tr>
<tr><td rowspan="6"></td><td colspan="2">Although unplanned release of condensate from the hydrocarbon system is not listed as a threat to protected matters under documents made or implemented under the EPBC Act, it can modify the marine habitat for some species.
Habitat degradation / modification has been identified as a threat to protected matters under documents made or implemented under the EPBC Act, CAPL will define an acceptable level of impact that aligns with the objectives of these documents. Objectives of the relevant documents are shown below: and were considered during the impact and risk evaluation.</td></tr>
<tr><td>Plan and Relevant Objective</td><td>Demonstration of Requirement</td></tr>
<tr><td>Conservation Management Plan for the Blue Whale 2015–2025 (Ref. 16)
Recovery objective: Minimise anthropogenic threats to allow for their conservation status to improve so that they can be removed from the EPBC Act threatened species list.
Interim objective 4 Anthropogenic threats are demonstrably minimised.</td><td rowspan="4">CAPL considers the impacts of Unplanned release—Hydrocarbon system (condensate) to not be inconsistent with the relevant objectives of these EPBC management plans.
By applying EPO20, impacts and risks to habitat degradation / modification, including marine pollution, from Unplanned release—Hydrocarbon system (condensate) will be managed at or below the defined acceptable level.</td></tr>
<tr><td>Conservation Management Plan for the Southern Right Whale (Ref. 19)
Long-term recovery objective:
The population has increased in size to a level that the conservation status has improved, and the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria.
Interim recovery objective 5:
Anthropogenic threats are demonstrably minimised.</td></tr>
<tr><td>Draft National Recovery Plan for the Southern Right Whale (Ref. 20)
Long-term recovery objective:
The population has increased in size to a level that the conservation status has improved, and the species no longer qualifies for listing as threatened under any of the EPBC Act listing criteria.
Interim recovery objective 2:
Anthropogenic threats are managed consistent with ecologically sustainable development principles and do not impede recovery of southern right whales</td></tr>
<tr><td>Recovery plan for marine turtles in Australia 2017–2027 (Ref. 148)
Long-term recovery objective: Minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list.
Interim objective 3: Anthropogenic threats are demonstrably minimised.</td></tr>
</table>

Determination of acceptability		
	Sawfish and River Sharks Multispecies Recovery Plan (Ref. 25) Primary Objective: To assist the recovery of sawfish and river sharks in Australian waters with a view to: • improving the population status leading to the removal of the sawfish and river shark species from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder recovery in the near future, or impact on the conservation status of the species in the future. Specific Objectives: • Objective 5: Reduce, and where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species.	
	Recovery Plan for the White Shark (*Carcharodon carcharias*) (Ref. 31). Primary objective: To assist the recovery of the white shark in the wild, throughout its range in Australian waters, with a view to: • improving the population status, leading to future removal of the white shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the white shark in the near future or impact the conservation status of the species in the future. Specific objective: Objective 7: Continue to identify and protect habitat critical to the survival of the white shark and minimise the impact of threatening processes within these areas	
	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (Ref. 29) Primary Objective: To assist the recovery of the grey nurse shark in the wild, throughout its range in Australian waters, with a view to: • improving the population status, leading to future removal of the grey nurse shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the grey nurse shark in	

Determination of acceptability		
	the near future, or impact on the conservation status of the species in the future. Specific Objectives: • Objective 8: Continue to identify and protect habitat critical to the survival of the grey nurse shark and reduce the impact of threatening processes within these areas.	
	National Recovery Plan for Albatrosses and Petrels (Ref. 37) Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced.	
	Wildlife Conservation Plan for Migratory Shorebirds (Ref. 67) Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	
	Wildlife Conservation Plan for Seabirds (Ref. 35) Seabirds and their habitats are identified, protected and managed in Australia.	
	Approved Conservation Advice for *Thalassarche cauta* (Shy Albatross) (Ref. 55) Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced.	
	Conservation Advice *Numenius madagascariensis* eastern curlew (Ref. 46) Minimise further loss of habitat critical to the survival of far eastern curlew throughout Australia.	
	Conservation Advice *Calidris canutus* Red knot (Ref. 52) Minimise further loss of habitat critical to the survival of red knot throughout Australia	
	Conservation Advice for *Calidris acuminata* (Sharp-tailed Sandpiper) (Ref. 54) Minimise further loss of habitat critical to the survival of the sharp-tailed sandpiper throughout Australia.	
	Conservation Advice for *Limosa lapponica menzbieri* (Yakutian bar-tailed Godwit) (Ref. 51)	

Determination of acceptability		
	Minimise further loss of habitat critical to the survival of Yakutian bar-tailed godwit throughout Australia	
	Conservation Advice for *Charadrius leschenaultia* (Greater Sand Plover) (Ref. 47) Minimise further loss of habitat critical to the survival of greater sand plover throughout Australia.	
	Conservation Advice for *Tringa nebularia* (Common Greenshank) (Ref. 44) Minimise further loss of habitat critical to the survival of common greenshank throughout Australia.	
	Conservation Advice *Balaenoptera physalus* Fin Whale (Ref. 17) Conservation Advice *Balaenoptera borealis* Sei Whale (Ref. 18) Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Sea Snake) (Ref. 24) Approved Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled sea snake) (Ref. 23) Approved Conservation Advice on *Pristis clavate* (Dwarf Sawfish) (Ref. 26) Approved Conservation Advice for *Pristis pristis* (largetooth sawfish) (Ref. 27) Conservation Advice *Rhincodon typus* Whale Shark (Ref. 30) National Recovery Plan for the Australian Fairy Tern (*Sternula nereis nereis*) (Ref. 41) Conservation Advice *Calidris ferruginea* curlew sandpiper (Ref. 45) Conservation Advice for Sternula nereis nereis (Fairy Tern) (Ref. 40) Conservation Advice for *Limnodromus semipalmatus* (Asian dowitcher) (Ref. 39)	These EPBC management plans for species that may occur within the Hydrocarbon Social or Hydrocarbon Ecological EMBAs that identify habitat degradation / modification or acute pollution as a threat; but do not identify any relevant objectives.
	North-west Marine Parks Network Management Plan 2018 <u>Specific Objectives:</u> • the protection and conservation of biodiversity and other natural, cultural and heritage values of marine parks in the North-west Network • ecologically sustainable use and enjoyment of the natural resources within marine parks in the North Network, where this is consistent with objective (a).	CAPL considers the impacts of Unplanned release—Hydrocarbon system (condensate) to not be inconsistent with the relevant objectives of these EPBC management plans. By applying EPO20, impacts and risks to the protection and conservation of biodiversity and other natural, cultural and heritage values of marine parks in the North-west Network from Unplanned release—Hydrocarbon system (condensate) will be

Determination of acceptability		
		managed at or below the defined acceptable level.
	Management Plan for the Montebello/Barrow Islands Marine Conservation Reserves <u>Specific Objectives:</u> • To ensure coral reef communities are not significantly impacted by accidental spillage of petroleum products or physical disturbance from development activities.	CAPL considers the impacts of Unplanned release—Hydrocarbon system (condensate) to not be inconsistent with the relevant objectives of this management plans. By applying EPO20, impacts and risks to the protection and conservation of biodiversity and other natural, cultural and heritage values of these conservation plans from Unplanned release—Hydrocarbon system (condensate) will be managed at or below the defined acceptable level.
	Nyinggulu (Ningaloo) Coastal Reserves: Red Bluff to Winderabandi joint management plan 101 <u>Specific Objectives:</u> • Management objective: Activities are appropriately managed to reduce pollution impacts on the key values of the planning area and adjacent marine areas	
	MANAGEMENT PLAN Jurabi and Bundegi Coastal Parks, and Muiron Islands <u>Specific Objectives:</u> • The objective is to protect and conserve flora and fauna with emphasis on species and communities of special value or significance.	This management plan provides a general objective to protect flora and fauna; but does not identify any relevant objectives.
	Therefore, CAPL has defined the following acceptable level of impact such that it is not inconsistent with these documents: • no significant impacts as a result of the Development to EPBC Act listed threatened or migratory species, or species habitat, such that it prevents their long-term recovery • No adverse effect to an important or substantial area of habitat such that a significant impact on marine ecosystem functioning or integrity results • No adverse effect on AMPs, State Protected Areas and World Heritage Areas such that it prevents the long-term protection and conservation of the identified values or natural resources of the area • no significant adverse impact to cultural heritage values attributed to the offshore marine area • no substantial impact to functions, interests, and activities of other marine users. CAPL considers that the Development, with the control measures as described for this aspect in place, meet this acceptable level.	

8.15.5 Environmental performance

Table 8-82 provides the EPO/s defined for Unplanned release—Hydrocarbon system and the adopted control measures to achieve the outcome.

Table 8-82: Environmental performance for Unplanned release—Hydrocarbon system (condensate)

Environmental performance outcome	Adopted control measure
EPO20: No unplanned release of condensate to the environment from the hydrocarbon system during Development activities.	**CM32**: Before commencing offshore activities, relevant agencies will be notified of activities, vessel movements, and requested exclusion zones, to enable them to generate radio navigation warnings and/or Notice to Mariners. **CM44**: MODUs and vessels will meet the requirements of the Chevron Marine Standard Non Tankers, including pre-mobilisation inspections of equipment, couplings, and secondary containment. **CM46:** MODUs and vessels will comply with the requirements of Marine Order 91 (MARPOL 73/78 Annex I) in relation to having an approved Ship Oil Pollution Emergency Plan or equivalent in place. **CM47**: In the event of a spill occurring, the accepted OPEP in subsequent EPs for the Development will be implemented. **CM48**: In the event of a spill occurring, the accepted OSMP in subsequent EPs for the Development will be implemented. **CM49:** NOPSEMA-accepted Well Operations Management Plan (WOMP) in place for all wells, in accordance with the OPGGS Act requirements. **CM50:** NOPSEMA-accepted Safety Case in place for all relevant facilities, in accordance with the OPGGS Act requirements.
EPO03: No adverse change to First Nations cultural heritage values from the Development activities.	**CM07:** Implement CAPL's ongoing consultation with Traditional Owners and/or representative bodies in accordance with Section 3. **CM08**: If new information is obtained during ongoing consultation with regards to the presence of, or potential for, Traditional Owners underwater cultural heritage, this will be incorporated into subsequent EPs for the petroleum activities associated with this Development.

9 Cumulative impact assessment

Cumulative impacts are a result of incremental, sustained, and combined effects of human action and natural variations over time and can be both positive and negative. They can be caused by the compounding effects of a single project or multiple projects in an area, and by the accumulation of effects from past, current and future activities as they arise (Ref. 554; Ref. 555).

Cumulative impacts and risks of the project may include:

- additive effects of activities within the same project
- additive effects from other activities within the region or potentially affecting the same environmental receptors
- long-term cumulative effects of a project lasting many years or decades (Ref. 11).

The assessment of cumulative impacts at the strategic level and site-specific level (or project-level) is termed cumulative impact assessment (CIA).

Cumulative impacts may arise from causes such as (Ref. 556):

- space crowding—occurs when a system is disturbed by several similar activities, or by different activities producing a similar effect, in an area too small to assimilate the combined impacts.
- time crowding—occurs when impacts are so close in time that the impact of one action are not dissipated before the next occurs.
- interactive effects—interactive effects can be additive or synergistic, reflecting the interactive nature of ecosystems. Additive is the simple linear addition of one impact on another, whereas synergistic is when 2 or more agents combine to cause an impact greater than the sum of their individual impacts. Antagonistic effects can also occur, where the combined impact of more than one agent is less than the sum of the individual impacts.
- indirect effects—arising as a result of the direct effect and include the impacts of activities facilitated by a project, including reasonably foreseeable impacts from downstream users.

9.1 Cumulative impact assessment methodology

There is no specific guidance on CIA provided by NOPSEMA or the federal government for the OPGGS Act or EPBC Act assessment regimes. Other relevant guidance has been used to inform the CIA methodology for this OPP, including:

- NSW CIA Guidelines for State significant projects (Ref. 554)
- UK Advice Note Seventeen: Cumulative effects assessment relevant to nationally significant infrastructure projects (Ref. 555).

The key principles of CIA are:

- setting the assessment boundaries
- identification of relevant existing and future projects and activities that may have a cumulative impact
- assessing the nature and scale of the cumulative impacts on the values and sensitivities.

The CIA only considers the impacts from planned aspects during the Development. Given the low likelihood of unplanned events (e.g. unplanned releases) occurring during the Development and other relevant projects/activities, impacts from unplanned events have not been considered in the assessment of cumulative impacts.

The methodology for undertaking cumulative impact assessment follows the same steps as those used for the environmental impact and risk assessment, described in Section 7.

9.1.1 Scoping the assessment

The level of assessment within CIA should be proportionate to the nature and scale, and potential significance of the cumulative impacts of the Development, combined with the impacts of other relevant projects/activities (Ref. 557). The NSW Department of Planning and Environment (Ref. 554) states that CIA is to focus on the key matters that could be materially affected by the cumulative impacts of the project and other relevant future projects—not on every conceivable cumulative impact on every matter.

For the Development, a matter may be considered a key matter because of the potential for cumulative impact on key values and sensitivities as described in Section 7.

DPE (Ref. 554) also states that the CIA only focuses on the key matters that are within the immediate geographical area of influence of a project (i.e. within proximity to the project site) and within the relevant strategic context.

9.1.1.1 Set the assessment boundaries

Two types of boundaries are required for the assessment of cumulative impacts:

- spatial (i.e. how far)
- temporal (i.e. how long into the past or future).

Spatial boundary

The spatial boundary selected for the CIA will vary depending on the specific characteristics of the assessment matter and the nature and scale of the potential impacts on the matter resulting from the project with other relevant projects/activities.

For example, the study area selected for the cumulative impact assessment on biodiversity may be based on the range and distribution of the listed threatened species within the relevant bioregion, and only focus on those species that are at risk of serious or irreversible harm due to the cumulative impacts of the project with other relevant projects/activities (Ref. 554).

The spatial boundary is designed to capture all possible planned aspect interactions (i.e. spatial extent for each aspect described in Sections 8.1 to 8.8).

While the spatial boundary chosen for each matter must be broad enough to capture all relevant cumulative impacts, it should not be unnecessarily large or include areas where the cumulative impacts are likely to be negligible relative to the baseline condition of the relevant matter (Ref. 554).

The largest potential impact area for any planned aspect of the Development is associated with a change in ambient light caused by emissions during short-term flaring activities, for which a conservative spatial extent of ~42.4 km was adopted

(Section 8.4). The next largest potential impact area was associated with a change in fauna behaviour which may be caused by underwater sound emissions during pipelay, for which a conservative spatial extent of 18.26 km was adopted (Section 8.5).

Overall, in order to be conservative, a spatial extent of ~50 km has been used for the purposes of identifying existing and future projects and activities which may have effects that overlap with those of the Development and result in potential cumulative impacts. Fisheries which are within this spatial extent are shown in Figure 6-29, Figure 6-30 and Figure 6-31. Petroleum activities within the ~50 km spatial extent are shown in Figure 9-1.

Depending on the nature and scale of potential cumulative impacts, larger spatial extents were considered for highly migratory species where the area covered by migratory routes may overlap other relevant projects/activities outside of the ~50 km spatial extent.

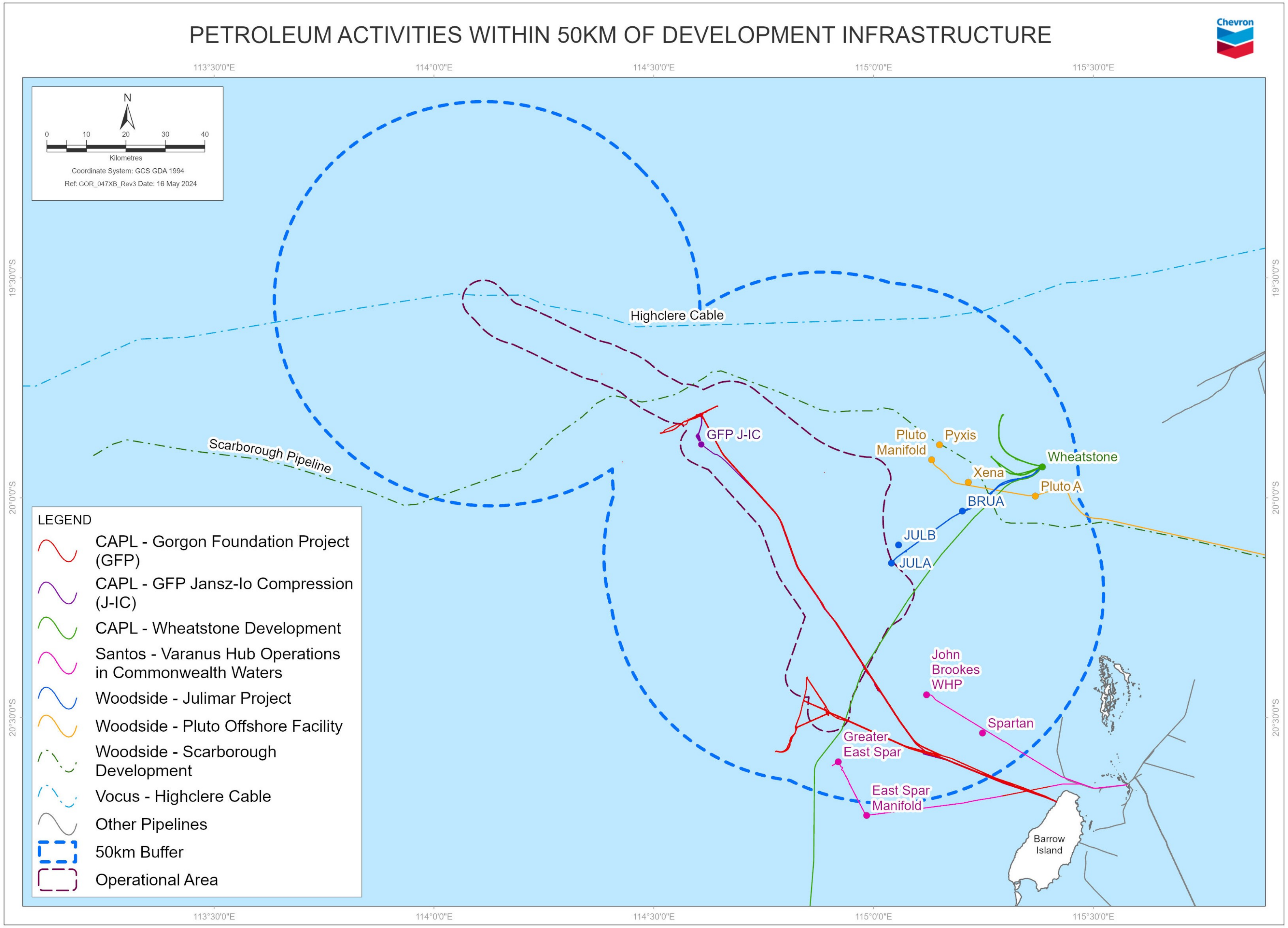

Figure 9-1: Petroleum activities within 50 km of Development Infrastructure

Temporal boundary

The spatial boundary selected for the CIA considers the complete duration of the Development, an additional ~2 years for decommissioning and an additional ~2 years post-decommissioning to allow for receptor recovery to pre-disturbance conditions, based on the following recovery timeframes:

- <1 year for the majority of benthic habitats and communities to recover from seabed disturbance (Ref. 278; Section 8.1)
- <1 year for ambient sediment quality to recover from planned discharges of drilling cuttings and fluids. Although cement discharges can cause a more permanent change to the sediment, due to the very localised nature (<50 m) of the area affected, this has not been evaluated further.
- ~2 years following installation for the majority of pipeline burial to occur, due to sedimentation, scour and biological activity contributing to embedment (Ref. 279; Section 8.1)—if any objects are assessed as acceptable and ALARP to leave in situ on the seabed.

Therefore, the temporal end date selected for the CIA has been conservatively set as 2074. This temporal boundary considers the end of Development life notionally as ~2070 and includes 2 years for decommissioning and 2 years post-decommissioning for receptor recovery. The duration of decommissioning activities has been estimated for the purpose of the CIA and the actual duration may be different.

9.1.1.2 Identification of third-party activities

CAPL has identified third-party activities that are known to occur, or are reasonably expected to occur, in the spatial boundary during the temporal extent of the Development based on the information available to CAPL during the preparation of this OPP.

Note for the purpose of this CIA, the GFP and any other CAPL activities not covered by this OPP are considered a third-party activity.

Methods used to identify third-party activities included:

- stakeholder consultation undertaken for this OPP, and CAPL's other EPs and activities in the NWS
- review of regulatory submission websites, including for submissions under the EPBC Act and the OPGGS Act
- public announcements of future projects, in media and industry publications
- review of publicly available data (e.g. AMSA's craft tracking system, fisheries reports)
- predicting future activities that may reasonably occur based on CAPL's knowledge of the known resources and existing uses in the region.
- CAPL has made a reasonable effort to identify credible third-party activities but acknowledges that there is the potential for future activities to occur within the spatial boundary that may not be considered as they are unknown or due to the inherent uncertainty of the future—and the long temporal boundary with the end date of 2074.

The activity-specific EPs that will be prepared subsequent to this OPP will provide an opportunity to undertake additional cumulative impact assessments that consider activities known to, or reasonably expected to, occur in the future that are identified at a later date.

CAPL has defined third-party projects that are certain or reasonably foreseeable as:

- Certain:
  - relevant approval document accepted by regulator (e.g. EP, EPBC Act referral)
  - data shows relevant activities occurring at time of writing (e.g. commercial shipping data, active commercial fishing data and licences)
- Reasonably foreseeable:
  - relevant approval document under assessment by regulator (e.g. EP or referral under assessment)
  - fishing licence even if no active fishing has occurred in last ~10 years
  - publicly announced project (e.g. another titleholder has announced future petroleum activity, e.g. exploration drilling, seismic survey).

Following the methodology above, CAPL has identified third-party activities that may result in a cumulative impact with the Development. Table 9-1 provides a summary and evaluation of whether activities are relevant for CIA and are carried through into the assessment.

For third-party activities to be carried through to the cumulative assessment, both the spatial and temporal boundary of the third-party activity must have the potential to overlap that of the Development. Some of the petroleum activities described in Table 9-1 may not overlap in temporal scale, however, they have been carried through to the assessment in the event changes in timing result in an overlap.

Different aspects of the activity will have different spatial and temporal EMBAs, for example light emissions have a different footprint and impact duration to seabed disturbance. This is taken into account in the identification of aspect overlap in Table 9-1.

Table 9-1: Identification of third-party activities within the spatial boundary

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
Commercial fisheries					
North-west Slope Trawl Fishery (Ref. 456)	• Bottom (or demersal) trawl method used by fishery operators to target deep-water prawn and scampi typically at depths of 350–600 m. • Data shows only one reporting grid overlaps the OA in 2010–2014 and 2016–2019. In 2015 and 2020 the OA overlapped 2 reporting grids. Twelve reporting grids overlap for the OA + 50 km from 2020–2011 to 2019–2020. • Intensity data for 2020 shows no overlap with OA or OA plus 50 km. All other reporting periods had <5 vessels operating and therefore data is considered confidential. • 12 month fishing season commenced 1 July each year	Active	Yes 12 month fishing season presents a potential temporal overlap with Development activity timings.	Yes. The North-west Slope Trawl Fishery may actively fish within the OA and surrounds which presents a potential spatial overlap.	Aspects related to vessel operations: • light emissions • underwater sound emissions • seabed disturbance • physical presence • planned discharges – vessels.
Western Deepwater Trawl Fishery (Ref. 457)	• Demersal trawl method used by fishery operators to target more than 50 species in waters seaward of the 200 m isobath. • Only one reporting grid overlaps the OA and OA plus 50 km (2018 season). • No intensity data available as all reporting periods had less than 5 vessels operating and therefore data is considered confidential. • 12 month fishing season commenced 1 July each year	Active	Yes. 12 month fishing season presents a potential temporal overlap with Development activity timings.	Yes. The Western Deepwater Trawl Fishery may actively fish within the OA and surrounds which presents a potential spatial overlap.	Aspects related to vessel operations: • light emissions • underwater sound emissions • seabed disturbance • physical presence • planned discharges – vessels.
Western Tuna and Billfish Fishery (Ref. 239)	• Pelagic longline and low levels of minor-line fishing used by fishery operators to target species including bigeye tuna, yellowfin tuna, broadbill swordfish and striped marlin. • Two reporting grids overlap the OA and 4 overlap the OA plus 50 km (2013 season).	Active	Yes. 12 month fishing season presents a potential temporal overlap with Development activity timings.	Yes. The Western Tuna and Billfish Fishery may actively fish within the OA and surrounds which presents a	Aspects related to vessel operations: • light emissions • underwater sound emissions • physical presence

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
	• No intensity data available as all reporting periods had less than 5 vessels operating and therefore data considered confidential. • 12 month fishing season commenced 1 July each year			potential spatial overlap.	• planned discharges – vessels.
Petroleum activities					
CAPL – Gorgon Foundation Project (GFP) (Ref. 8)	• Commissioning and start-up activities occurred in 2015 and operations are expected to continue for the nominal operational design life of 50 years. • The Development ties into the GFP and is within the OA. • Similar activities to the Development operations phase.	Ongoing	Yes Operational life of the GFP overlaps with the Development activity timings	Yes. The Development ties into the GFP and there is spatial overlap between the GFP footprint and the Development OA.	Aspects related to vessels associated with the GFP: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions. Aspects related to infrastructure operations: • physical presence • underwater sound emissions • planned subsea discharges (from IMR activities and operational planned subsea releases).
CAPL—GFP Jansz-Io Compression (J-IC) installation and pre-commissioning (Ref. 558)	• J-IC will involve the construction and installation of a floating Field Control Station (FCS), ~6,500 tonnes of subsea compression infrastructure and a 135 km submarine power cable linked to Barrow Island (Ref. 559).	Proposed	No. J-IC installation and pre-commissioning is expected to be completed before	Yes. J-IC installation and pre-commissioning is expected to be completed before	Although there is predicted overlap in spatial extent of third-party aspects with the Development OA, there is no temporal overlap

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
	• J-IC installation is scheduled to occur from mid-2024 to mid-2026 (Ref. 254) and is expected to be operational before the Development commences.		the Development commences and therefore does not present temporal overlap with Development activity timings.	the Development commences however there is spatial overlap with the Development OA.	therefore cumulative impacts are not expected.
CAPL – GFP J-IC operations	• J-IC will involve the operation of subsea compression infrastructure and a 135 km submarine power cable linked to Barrow Island (Ref. 559). • Operation of J-IC is scheduled to occur from mid-2026. • Preliminary results from the most recent acoustic models indicate the following: ○ exposure to received levels above marine mammal effect criteria thresholds for auditory impairment or injury (TTS and PTS (SEL_{24})), are not anticipated to occur. ○ the predicted ensonified area above the effect criteria for behavioural response for marine mammals occurs in the lower parts of the water column but does not extend into the upper water column.	Proposed	Yes. J-IC is expected to be operational during the Development and therefore presents a potential temporal overlap with Development activity timings.	Yes. J-IC is expected to be operational during the Development and therefore presents a potential spatial overlap with Development activities.	Aspects related to vessels associated with the GFP J-IC: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions. Aspects related to infrastructure operations: • physical presence • underwater sound emissions • planned subsea discharges (from IMR activities and operational planned subsea releases).
Woodside – Scarborough	• Development of Scarborough will include the installation of a floating production unit with 8 wells drilled in the initial phase and thirteen wells drilled over the life of the	Proposed	Yes. The earliest installation will	Yes. Spatial overlap is limited to the	Depending on the timeframes for trunkline / flowline installation,

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
Development (Ref. 255)	Scarborough field, with all wells tied back to a semi-submersible floating production unit (FPU) moored in 950 m of water close to the Scarborough field (Ref. 560). • The proposed Scarborough and North Scarborough fields are located in permits WA-61-L and WA-62-L. Wells may also be drilled and tied back to the FPU from the Thebe and Jupiter fields. • The FPU is ~95 km from the OA, with a 32″ trunkline running ~430 km from the FPU to Pluto LNG on the Burrup Peninsula. The proposed trunkline route crosses the Chandon flowline. • According to the Scarborough Seabed Intervention and Trunkline Installation EP (Ref. 256). activities were planned to commence in Q4 2023, depending on weather. The activities that may be underway concurrently with the Development from 2024 are: – trunkline installation – dry pre-commissioning / wet pre-commissioning – post-lay survey – rock installation – trenching and dredging is only proposed for water depths <40 m, so will not be undertaken in the OA. • Following this EP, it is assumed the next phases would be commissioning, operations for ~30 years; followed by decommissioning. • Decommissioning is expected in 2055.		commence is Q4 2023. The installation phase may be complete before the Development commences (planned for 2024). However, the operations phase may be underway.	proposed trunkline crossing the Chandon flowline. Hence, interacting aspects are limited to those associated with flowline / trunkline installation and operations.	installation of the Scarborough Development trunkline could generate the following aspects: • seabed disturbance Aspects related to IMR vessels associated with the Scarborough Development • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions. Aspects related to IMR vessels associated with the Scarborough Development: • physical presence (of infrastructure).
Woodside – Julimar Development Project (Ref. 257)	• Operation of the Julimar field production system and Julimar Phase 2 includes inspection, monitoring, maintenance, and repair during operations. • Infrastructure includes wells (up to 14 plus an additional 5 from Phase 2), production trees, 3 production manifolds, 3 x 22 km 18-inch flowlines/pipelines, umbilicals and	Ongoing	Yes. Operations are ongoing and will continue throughout the	Yes. Small spatial overlap at the edge of the OA with operational	Aspects related to vessels associated with IMR activities: • physical presence • planned discharges - vessels

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
	associated subsea structures (production status as of 2021) (Ref. 257). • Commenced production in 2016 with a field life of 25 years and operates 24 hours a day, every day of the year. • Located within licence areas WA-49-L, WA-26-PL and WA-29-PL. Vessel based operations may be undertaken within WA-356-P and WA-34-L. • The western edge of WA-49-L overlaps the OA with several production wells and associated subsea infrastructure within the OA. The wells are linked to the JULA manifold with the flowlines and umbilicals connected to the Wheatstone Platform, in a north-easterly direction away from the OA.		life of the Development.	subsea infrastructure.	• light emissions • atmospheric emissions underwater sound emissions. Aspects related to infrastructure operations: • planned subsea discharges • physical presence
Woodside – Julimar Development Phase 3 (JDP3) Drilling and Subsea Installation (Ref. 258)	• Activities to be undertaken in Petroleum Title WA-49-L include drilling of up to five wells, subsea installation, pre-commissioning, and cold commissioning activities up to the point of hydrocarbon introduction. • Activities are planned to commence in Q3 2024 and will take ~60 days per well. Subsea installation activities are planned to commence Q1 2025 and are likely to take 60 days, with production targeted for the second half of 2025. There is contingency for two campaigns, resulting in production from the second campaign wells in 2026 or 2027. • The western edge of WA-49-L overlaps the OA with 2 of the 4 proposed wells and relevant infrastructure (i.e., EHU, pipeline) within the OA. The wells are proposed to be connected back to the JULA (or new JULB) manifold which will tie into the existing in-line tee (ILT) assembly connected to the Wheatstone Platform, in a north-easterly direction away from the OA. • Flaring is included as a contingency activity.	Proposed	Assumed yes. EP under assessment at time of writing.	Yes Two of the proposed wells and associated infrastructure are within the OA.	Aspects related to vessels and MODU(s) associated with JDP3 drilling and subsea installation activities: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions. Aspects related to activities associated with the JDP3 drilling and subsea installation: • planned drilling discharges • seabed disturbance

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
	• Start-up and operations of the JDP3 production system will be subject to a future revision of the Julimar Operations EP. • At the time of writing, the EP is under assessment.				• light emissions (from flaring).
	•				
Santos – Varanus Island Hub Operations in Commonwealth waters (Ref. 259)	• Consists of the John Brookes, Spartan, and Greater East Spar (GES) gas fields which export well fluids from the production wells to the processing facilities on Varanus Island. • Infrastructure includes WHPs, wells, umbilicals, and flowlines for all fields. • Infrastructure within 25 km of the OA include: – the closest topsides facility to the OA is the John Brookes WHP (~15 km), normally unmanned. Exports gas from 4 wells via an 18″ pipeline to Varanus Island. There is no flare on the platform. – Spar- 2 XT, GES PLEM and GES SCS and Halyard-1 XT~8 km from OA. The Halyard electro- hydraulic umbilical runs from the GES PLEM to the John Brookes platform (~7 km from the OA at its closest point). GES field life is currently estimated to be until at least 2032. – East Spar manifold and PLEM ~22 km from OA. The East Spar to Varanus Island pipeline runs from this point to the Varanus Island Hub ~68 km from the OA. The East Spar pipeline crosses GFP Feed Gas Pipelines, umbilicals, MEG and utility pipelines. This pipeline is fit to operate until 2026; and it is assumed it will begin to be decommissioned after that. • There is no topsides infrastructure associated with the Halyard, Spar and East Spar fields.	Ongoing	Yes Operations are currently ongoing however decommissioning is anticipated to occur throughout the life of the Development.	Yes. Overlap in spatial extent is limited to the Varanus Island Hub which may overlap with the Development underwater sound extent.	Aspects related to Varanus Island Hub activities: • underwater sound emissions Aspects related to Varanus Island Hub IMR vessels: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions.

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
Woodside – Pluto Offshore Facility (Ref. 260)	• The Pluto offshore facility has been in production since 2012. • The Pluto offshore facility currently produces gas and condensate from the Pluto and Xena gas fields which is transported via a 36 inch 180 km trunk line to the onshore Pluto Gas Plant for processing and export to customers. • The platform has a relatively small quantity of gas that is required to be continuously flared. • The Pluto platform is not-normally manned, is more than 211 m tall and stands in a water depth of 85 m. • Drilling and subsea installation activities at Pyxis (WA-34-L) commenced in March 2024 with an estimated duration of 50 days therefore will not overlap with the Development. However, well intervention or workover activities may be undertaken at any time during the EP in-force period, which is until 30 Nov 2025 (Ref. 561) • End of life of the Pluto, Xena and Pyxis fields is un-known, however is not expected during the life of the approved EP (until 2024). • ~28 km from OA.	Ongoing	Yes. Operations are ongoing and are expected to continue throughout the life of the Development.	Yes The Pluto underwater sound and light (during flaring) extents from Pluto operations may overlap with those of the Development.	Aspects related to Pluto operations activities: • underwater sound emissions • Light emissions (during flaring). Aspects related to Pluto IMR vessels: • physical presence • planned discharges - vessels • light emissions • atmospheric emissions • underwater sound emissions.
CAPL – Wheatstone Development (Ref. 261)	• The Wheatstone offshore facilities gather and partially process gas and associated condensate from the Wheatstone, and Iago fields and delivers it onshore via trunkline for further processing. The platform also receives fluids from the Julimar Development Project (described above). • The platform is~29 km east of the OA (WA-3-IL), in water depth of 71 m deep and is ~213 m tall. • The platform has a flare system that includes a small, constantly lit low pressure flare, with the high pressure flare used for upset conditions only (non-continuous and infrequent use). The flare tip is ~150 m above sea level.	Ongoing	Yes. Operations are ongoing and will continue throughout the life of the Development.	Yes. Part of the Wheatstone trunkline runs along the south-eastern border of the OA, therefore IMR activities may overlap with those of the Development.	Aspects related to Wheatstone IMR vessels: • physical presence of the vessel(s) • planned discharges • light emissions • atmospheric emissions • underwater sound. Other aspects generated during operations include:

Third-party Activity	Overview of key characteristics	Status	Overlap in temporal extent	Overlap in the spatial extent	Third-party aspects with potential spatial or temporal overlap with the Development
	• The trunkline is ~221 km long and ~44 inches in diameter, part of the trunkline is within the OA running along the south-eastern border. • Indicative duration is for operations until 2046, with operations 24 hours a day every day and IMR activities when required.				• Light emissions (from flaring)
Vocus – Highclere Cable	• Vocus operate a fibre optic cable which connects the existing North West Cable System and Australia Singapore Cable. Also called the Darwin-Jakarta-Singapore cable. • The cable crosses the OA ~2.2 km from Chandon infrastructure.	Ongoing	Yes. Operation is ongoing and will continue throughout the life of the Development.	Yes. Part of the cable intersects with the northern tip of the Development OA.	Aspects related to operation of the Highclere Cable: • physical presence of the cable.
Commercial Shipping					
Shipping fairways	Vessel traffic data from AMSA shows that a portion of the OA within the vicinity of the G&E to Jansz flowline overlaps part of the NWS shipping fairway system (Section 6.3.4).	Ongoing	Yes. Shipping operations are ongoing and will continue throughout the life of the Development.	Yes. NWS shipping fairway system runs through the OA (~23 km).	Aspects related to Commercial shipping vessels: • physical presence of the vessel(s) • light emissions • noise emissions • planned discharges • atmospheric emissions.

9.1.2 Identification of values and sensitivities

A detailed description of the values and sensitivities of the existing environment is provided in Section 6. Based on the spatial and temporal boundaries established, this description is sufficient to support the assessment of cumulative impacts.

9.1.3 Identification of interactions

To identify where aspects may result in cumulative impacts to values and sensitivities, the potential interactions have been considered in 2 ways:

- could values and sensitivities be impacted by multiple aspects as a result of the Development?
- could values and sensitivities be impacted by the same or multiple aspects as a result of the Development in combination with the third-party activities (Table 9-2) within the relevant spatial and temporal boundary?

Table 9-2 identifies the interactions of aspects generated by the Development and by third-party activities with values and sensitivities. Note that as the largest spatial extent does not overlap any coastal areas, land-based values and sensitivities are not included.

Table 9-2: Values and sensitivities that may be subject to cumulative impacts

Values and Sensitivities	Aspects which may result in impacts to values and sensitivities									Will multiple aspects occur as a result of the Development?	Will aspects occur as a result of Third-Party Activities?			Are Cumulative Impacts possible? (Section reference to evaluation below)
	Seabed disturbance	Air emissions	Greenhouse gas emissions	Light emissions	Underwater sound	Planned discharges—MODU and vessels	Planned discharges—Subsea operations	Planned discharges—Drilling	Physical presence—Other marine		Commercial fishing	Commercial Shipping	Petroleum industry	
Ecosystems and their constituent parts														
Water quality	✓					✓	✓	✓		Yes	✓	✓	✓	Yes (9.2.1)
Sediment quality								✓		No			✓	Yes (9.2.2)
Air quality		✓								No	✓	✓	✓	Yes (9.2.3)
Climate			✓							No	✓	✓	✓	Yes (9.2.4)
Ambient light				✓						No	✓	✓	✓	Yes (9.2.5)
Ambient noise					✓					No	✓	✓	✓	Yes (9.2.6)
Benthic habitats and associated communities	✓							✓		Yes			✓	Yes (9.2.7)
Seabird and shorebirds				✓		✓				Yes	✓	✓	✓	Yes (9.2.8)
Fish	✓			✓	✓	✓	✓	✓		Yes	✓	✓	✓	Yes (9.2.9)

Values and Sensitivities	Aspects which may result in impacts to values and sensitivities									Will multiple aspects occur as a result of the Development?	Will aspects occur as a result of Third-Party Activities?			Are Cumulative Impacts possible? (Section reference to evaluation below)
	Seabed disturbance	Air emissions	Greenhouse gas emissions	Light emissions	Underwater sound	Planned discharges—MODU and vessels	Planned discharges—Subsea operations	Planned discharges—Drilling	Physical presence—Other marine		Commercial fishing	Commercial Shipping	Petroleum industry	
Marine reptiles				✓	✓	✓	✓	✓		Yes	✓	✓	✓	Yes (9.2.10)
Marine mammals					✓	✓	✓	✓		Yes	✓	✓	✓	Yes (9.2.11)
Heritage	✓			✓	✓		✓	✓		Yes	✓	✓	✓	Yes (9.2.12)
Commonwealth marine area (KEFs)	✓							✓		Yes			✓	Yes (9.2.13)
Natural and physical resources														
Commercial fisheries							✓		✓	Yes	N/A			Yes (9.2.14)
Recreational fisheries										No				No
Traditional fisheries										No				No
Commercial shipping									✓	No		N/A		No
Petroleum activities									✓	No			N/A	No
Tourism and recreation										No				No

Values and Sensitivities	Aspects which may result in impacts to values and sensitivities									Will multiple aspects occur as a result of the Development?	Will aspects occur as a result of Third-Party Activities?			Are Cumulative Impacts possible? (Section reference to evaluation below)
	Seabed disturbance	Air emissions	Greenhouse gas emissions	Light emissions	Underwater sound	Planned discharges—MODU and vessels	Planned discharges—Subsea operations	Planned discharges—Drilling	Physical presence—Other marine		Commercial fishing	Commercial Shipping	Petroleum industry	
Other maritime industries										No				No
Qualities														
AMPs										No				No

9.1.4 Assessment of cumulative impact

Once potential cumulative impacts have been identified, the methodology for undertaking CIA follows the same overarching process and criteria as those used for the environmental impact and risk assessment, described in Section 6, with additional consideration of how impact pathways may interact and whether this may result in a higher consequence/likelihood than was assessed for the individual Development aspect (Section 8). The overarching steps are:

- evaluation of cumulative impacts from the Development i.e. where multiple aspects have potential to impact a value/ sensitivity,
- evaluation of cumulative impacts from third-party activities combined with the Development,
- and consideration of any change to consequence/likelihood level as a result of cumulative effects,
- where a change in the consequence/ risk level has occurred and where the Development is a material contributor to the cumulative impact, demonstration of acceptability and evaluation of whether the existing EPO/s and adopted control measures associated with the Development, for that receptor, are sufficient to manage cumulative impacts to acceptable levels; and if not, identify additional performance objectives or control measures.

9.2 Cumulative impact assessment

For all environmental values and sensitivities identified in Table 9-2 as potentially being affected by cumulative impacts, an evaluation of potential cumulative impacts has been undertaken in the subsections below. Where further evaluation indicated that a cumulative impact was considered credible, the aspect was carried through to the acceptability assessment. Note that only relevant phases e.g. drilling, operations etc. of third party activities identified in Table 9-1 have been carried through to the evaluation.

9.2.1 Water quality

Table 9-3 provides the CIA and demonstration of acceptability for water quality.

Table 9-3: CIA and demonstration of acceptability—Water quality

Cumulative impact evaluation
Cumulative impact from the Development
The following Development aspects have the potential to result in a localised and temporary reduction in water quality: • seabed disturbance (evaluated in Section 8.1) • planned discharges–MODU and vessels (evaluated in Section 8.6) • planned discharges–subsea operations (evaluated in Section 8.7) • planned discharges–drilling (evaluated in Section 8.8). The impact of each aspect to water quality was evaluated individually and the highest consequence ranking assigned was Incidental (6). This evaluation is based on the small scale discharges planned, the low level of toxicity of planned discharges and the rapid return to ambient conditions due to the well-mixed offshore environment within the OA. The largest spatial and temporal extent of planned changes that would result in the localised and temporary reduction in water quality from the Development will occur during FCGT activities. Modelling of much larger GFP pre-commissioning discharges predicted a change in water quality to occur up to 10 km from the release location, however concentrations would return to background water quality within less than 13 hours

Cumulative impact evaluation
(Section 8.7). The largest planned discharge for the Development is expected to be ~15% of the modelled GFP discharge. The extent of other planned discharges from vessel / MODU operations and during drilling and installation phases will be more localised. It is likely that some planned discharges from the Development may occur concurrently e.g. planned discharges from the MODU may occur at the same time as planned drilling discharges. As each of these impacts are localised and temporary and given the high levels of dispersion in the marine environment, the effect on water quality of exposure to multiple aspects at the same time during the Development does not materially change the worst-case level of impact assessed for any individual aspect, with the overall cumulative impact consequence ranked as Incidental (6).
Cumulative impacts from the Development and third-party industries
Aspects from third party activities in the region, when combined with the Development's aspects, may result in cumulative impacts to water quality. These third parties (and potential aspects) include (refer to Table 9-1 for scoping): • Vessel operations – commercial fishing vessel, commercial shipping, and petroleum industry vessels will result in comparable volumes and frequencies of vessel discharges to those assessed in Section 8.6. • Petroleum activities which could result in changes to water quality: – CAPL – GFP – CAPL – GFP J-IC operations – Woodside – Scarborough Development – Woodside – Julimar Development Project – Woodside – JDP3 Drilling and Subsea Installation Third-party-generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, with no additional impact pathways. The consequence of impacts from third parties in isolation are predicted to be short-term and localised, and therefore evaluated as Incidental (6). The spatial and temporal extent of both the Development and third-party aspects is such that overlap in impacts is unlikely. Impact durations are sufficiently short-term, and the receiving environment is sufficiently robust, in that any changes to water quality resulting from cumulative sources will be fully recoverable, with impacts restricted to short-term and localised changes. Subsequently, the worst-case consequence of any cumulative impacts to water quality are not expected to have a consequence above that already assessed as the worst-credible impact to water quality from any individual aspect of the Development (Incidental (6)).
Demonstration of acceptability
The evaluation of potential cumulative impacts to water quality from the Development and third-party activities indicates that potential cumulative impacts are no greater than those already assessed for the Development in isolation. Consequently, potential cumulative impacts to water quality are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact for water quality.

9.2.2 Sediment quality

Third-party activities in the region may cause aspects which, when combined with the aspects generated by the Development, may result in the following impacts to sediment quality:

- localised and temporary reduction in sediment quality, from planned discharges during drilling (Section 8.8).

The largest spatial extent of a change in sediment quality for the Development is for drilling cuttings discharged at the sea surface. A study by IAOGP (Ref. 431) found that cuttings discharged at surface accumulated on the seafloor at distances of ~0.1–1 km, depending on water depth (Ref. 431).

Cement discharges from overflow during drilling operations may affect the seabed within a 10-50 m radius around the well (<0.007 km^2 per well).

Similar to the Development, it is assumed that third-party activities that cause a reduction in sediment quality would be planned discharges that accumulate at the seabed—most likely drilling discharges.

The largest spatial extent of a reduction in sediment quality is <1 km from each well location. While there are third-party petroleum pipelines and wells within the OA, there are no third-party wells or proposed drilling within <1 km of the expected Development well locations. Furthermore, third-party drilling activities could not be undertaken within CAPL held permits (Figure 1-1).

In summary, sediments in the OA are representative of the wider NWS region, there is no overlap of spatial extents of the Development and third party petroleum activities, and the small footprint of impacts to sediment quality from the Development will not result in a change to the overall health of sediment quality in the region. Therefore, cumulative impact to sediment quality from the Development and Third-party activities are not expected.

9.2.3 Air quality

Third-party activities in the region may cause aspects which, when combined with the aspects generated by the Development, may result in the following impacts to air quality:

- localised and temporary reduction in air quality (Section 8.2).

A localised and temporary reduction in air quality may result from the burning of MDO on vessels, helicopters and the MODU, ODS release, and flaring of reservoir fluids during well clean-up and flowback, and well intervention. If flaring is required, it will only occur from one well at a time and may take ~1 day to complete.

Air emissions by third-party activities are expected to be similar to the scale described above for the Development.

Wind conditions experienced in the open, offshore marine environment of the OA, located more than 115 km from the Pilbara coast, are generally expected to rapidly disperse air emissions temporarily generated during the Development. Air quality is expected to return to baseline levels after air emissions cease.

Therefore, cumulative impacts to air quality from the Development and third-party activities are not expected.

9.2.4 Greenhouse gas emissions

The detailed impact assessment provided in Section 8.3 includes the assessment of cumulative impacts of GHG emissions resulting from anthropogenic and natural emissions from a range of sources.

9.2.5 Ambient light

Third-party activities in the region may cause aspects which, when combined with the aspects generated by the Development, may result in the following impacts to ambient light:

- localised and temporary change in ambient light (Section 8.4).

Navigational and operational lighting generated by the Development will result in highly localised impacts which are not expected to affect ambient light conditions outside of the maximum spatial extent of 1.4 km (Section 8.4.1). Light emissions by third-party activities are expected to be similar to the Development.

Flaring during drilling and well intervention as part of the Development will result in a larger spatial footprint for light impacts (conservatively assessed as 42.4 km, Section 8.4), however this is short-term (~1 day per well) and not expected to intersect with any other permanent light sources within the wider area (i.e. coastal settlements or islands).

Ambient light conditions will return to natural levels immediately following cessation of Development and third-party activities.

Therefore, cumulative impacts to ambient light from the Development and third-party activities is not expected.

9.2.6 Ambient underwater sound

Third-party activities in the region may cause aspects which, when combined with the aspects generated by the Development, may result in the following impacts to ambient sound:

- localised and temporary change in ambient underwater sound (Section 8.5).

Underwater sound generated by the Development will result in localised impacts which may affect receptors out to a maximum horizontal distance of 18.26 km from the loudest modelled source (refer to Section 8.5.2 for details). Underwater sound emissions by third-party activities are expected to exhibit similar spatial and temporal changes to ambient underwater sound levels as those introduced by the Development, with the exception of J-IC SCSt operations. Given the location of the SCSt in deep water (~1,345 m), the deep ocean sound channel (centre estimated at ~800–1,000 m water depth at J-IC location) has the most significant effect on propagation of subsea sound emissions from the SCSt. Upward travelling energy away from the SCSt is refracted downward, and energy reflected from the seabed is also refracted back downward, which results in most of the acoustic energy occurring in the lower water column and less acoustic energy propagating into the upper water column (Ref. 558).

With the exception of J-IC SCSt, underwater sound conditions will return to ambient levels immediately following cessation of Development and third-party activities.

Taking the above into consideration, cumulative impact to ambient underwater sound from the Development and third-party activities is not expected.

9.2.7 Benthic habitats and associated communities

Table 9-4 provides the CIA and demonstration of acceptability for benthic habitats and associated communities.

Table 9-4: CIA and demonstration of acceptability—benthic habitats and associated communities

Cumulative impact evaluation
Cumulative impact from the Development
The following Development aspects have the potential to result in alteration of benthic habitat and/ or the risk of injury and mortality to benthic communities: • seabed disturbance (evaluated in Section 8.1) • planned discharges–drilling (evaluated in Section 8.8). The impact of alteration of benthic habitat for each aspect was evaluated individually and the highest impact consequence ranking assigned was Moderate (4). The risk of an alteration of benthic habitat resulting in injury and mortality to benthic communities for each aspect was also evaluated individually and the highest risk ranking assigned was Low (8). These rankings were assigned given benthic habitats and associated communities affected by the Development are mostly soft sediment habitats with sparse distribution of fauna and highly represented through the NWMR (Ref. 103, Ref, 104). The OA overlaps 2 KEFs which are associated with benthic values (Exmouth Plateau and Ancient coastline at 125 m depth contour KEF) (Section 6.2.6.1). A benthic survey of the OA found that the benthic environment is characteristic of the North Carnarvon Basin and the NWS region (Ref. 105, Appendix A). Cumulative impacts pathways to benthic habitats and associated communities from the Development include the combination of seabed disturbance and drilling discharges affecting the same small area of benthic habitat or associated species, and these same effects on multiple small areas of benthic habitat and associated species across multiple small areas as a result of the Development activities (e.g. multiple drill centres). Any potential cumulative impacts to soft sediment benthic habitat and risks to related to associated benthic epifauna and infauna, from the Development are restricted to the OA, where benthic survey results show that there is a mixture of flat bare substrates, and isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Ref. 110; Ref. 253; Ref. 105, Appendix A). An EPBC PMST report (Ref. 123, Appendix B) did not identify any epifaunal of infaunal threatened or migratory species, or any TECs within the OA. Following decommissioning of the Development, benthic communities impacted in the OA are expected to recover, given soft sediment benthic habitats have underlying conditions that support recolonisation and recovery (Ref. 278). The above listed aspects of the Development may present a localised cumulative impact and risk to benthic habitats and associated communities that have are highly represented in the region. Given this, and that following decommissioning, soft sediment benthic habitats and associated communities impacts are expected to recover, the effect on benthic habitats and associated communities of exposure to multiple aspects at the same time during the Development does not materially change the worst-case level of impact or risk. Consequently, the overall cumulative impact / risk assessment is ranked as Moderate (4) / Low (8) respectively.
Cumulative impact from the Development and third-party activities
Aspects from third-party activities in the region, when combined with the Development's aspects, may result in cumulative impacts or risk to benthic habitats and associated communities. These third parties (and potential aspects) include (refer to Table 9-1 for scoping): • Commercial fisheries – trawling activity could result in alteration of benthic habitats and injury or mortality of benthic communities. • Petroleum activities which could result in seabed disturbance (and subsequent impacts to benthic habitats and associated communities): – CAPL – GFP – CAPL – GFP J-IC operations – Woodside – Scarborough Development – Woodside – Julimar Development Project – Woodside – JDP3 Drilling and Subsea Installation – Vocus – Highclere cable.

Cumulative impact evaluation
Third-party generated aspects are evaluated to be of a similar nature and scale impact / risk to those predicted from the Development, and in isolation are therefore evaluated as Incidental (6) / Low (8) respectively. However, commercial Commonwealth fisheries, specifically fisheries which use trawling gear such as the North-west Slope Trawl Fishery (NWSTF) and the Western Deepwater Trawl Fishery (WDTF) introduce an additional impact pathway. The benthic communities within the OA and the wider area, consist of sparsely distributed, epibenthic and infaunal invertebrates located in soft sediment benthic habitats. These communities have been previously disturbed by the placement of seabed infrastructure by prior petroleum activities (refer to Table 9-1 for project specific details), and ongoing trawling activities by commercial fisheries. The Development and other third-party activities will lead to an increase into the existing loss of these benthic communities. However, this is still considered a localised impact given the NWMR, which covers ~1.07 million km^2, is dominated by soft sediment benthic habitats and associated communities (Ref. 103; Ref. 104). Given the benthic habitat and associated communities represented in the OA and relevant third-party project area: • do not contain particular values and sensitivities (Ref. 105, Appendix A) • are well represented in the NWMR region, and • have underlying conditions that support recolonisation and recovery (Ref. 278). the consequence of further alteration of benthic habitat and injury or mortality to benthic communities from the Development and third-party activities is considered a limited environmental impact and therefore an Incidental (6) consequence. Given the sparse distribution of benthic communities found in the OA and, as they are highly represented throughout the NWMR the likelihood that the Development and third-party activities will result in the loss of benthic communities was assessed as Occasional (2). Recognising the Incidental (6) consequence of further minor and localised alteration and loss of benthic habitats and associated communities and the Occasional (2) likelihood that the consequence may occur during the Development and third-party activities; potential cumulative risks to benthic habitats and associated communities does not materially change the worst-case level of risk (i.e. cumulative risk of Low (7) compared to worst-case individual aspect risk of Low (8)), if evaluated considering the Development and third-party activities.
Demonstration of acceptability
The evaluation of potential cumulative impacts and risks to benthic habitats and associated communities from the Development and third-party activities indicates that potential cumulative impacts or risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative impacts and risks to benthic habitats and associated communities demonstrates that: • cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts or risks to benthic habitats and associated communities has been received. Consequently, potential cumulative impacts and risks to benthic habitats and associated communities are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact and risk to benthic habitats and associated communities.

9.2.8 Seabirds and shorebirds

Table 9-5 provides the CIA and demonstration of acceptability for seabirds and shorebirds.

Table 9-5: CIA and demonstration of acceptability—Seabirds and shorebirds

Cumulative impact evaluation
Cumulative impact from the Development

The Development in isolation introduces the following risks to seabirds and shorebirds:
• change to behaviour, from
  – light emissions (evaluated in Section 8.4)
• change in predator/prey dynamics, from
  – planned discharges–MODU and Vessels (evaluated in Section 8.6)
The particular values and sensitivities identified for seabirds and shorebirds in the OA is the Wedge-tailed Shearwater BIA (breeding) (Section 6.2.3.4).
As discussed in Sections 8.4 and 8.6, minor changes to normal foraging behaviours for seabirds and shorebirds as a result of both light emissions and planned discharges from the MODU and vessels will be limited to the OA and affect only individuals. Assessment of the change in predator / prey dynamics resulting from planned discharges from the MODU and vessels concludes that changes in primary production will be localised and temporary, and subsequent indirect impacts to other marine fauna are not expected (Section 8.6).
The risk of each aspect to seabirds and shorebirds was evaluated individually and the highest risk ranking assigned was Very Low (10). This evaluation is based on the temporary nature of the risks, the absence of overlap with breeding islands, and that the OA and surrounds provides open water habitat for seabirds and shorebirds that are highly represented throughout the NWS region (Sections 8.4.2 and 8.6.2).
Cumulative impact pathways to seabirds and shorebirds from the Development may occur if there is:
• an intersection of impact/ risk footprints from multiple aspects, and/ or
• a concurrent occurrence of multiple impacts/ risks on the same footprint.
When considered in combination, risks from the Development may result in changes in predatory / prey dynamics whilst also potentially causing disruption of critical behaviours i.e. to the wedge-tailed shearwater. Wedge-tailed shearwater are known to breed on islands off Barrow Island (Mushroom, Double and Boodie islands) and the Montebello Islands. Since there are no roosting or nesting habitats within the OA as it is located entirely offshore, foraging is the only critical behaviour likely to occur in the marine waters, particularly where adjacent to breeding locations, such as waters close to Barrow Island. Known to use a bimodal foraging strategy during nesting the wedge-tailed shearwater forage both relatively close to breeding islands or over the larger area (from the Cape Range Canyon to the Indonesian Archipelago), depending on prey availability (Ref. 178).
Procellariiformes (i.e. shearwaters) may also forage at night on bioluminescent prey, and therefore are attracted to light of any kind (Ref. 324; Ref. 323). As evaluated in Section 8.4.2, minor changes to normal foraging behaviours for seabirds and shorebirds is expected to be spatially restricted to the immediate vicinity of the OA and affect only individuals (rather than populations) due to the absence of seabird aggregation areas in the spatial extents.
While planned discharges of sewage and macerated wastes from vessels and the MODU may attract foraging seabirds and shorebirds, effects on environmental receptors along the food chain are not expected beyond the immediate vicinity of the temporary discharges (Ref. 403) (Section 8.6).
While the Development may lead to minor, temporary and localised cumulative impacts to foraging seabirds and shorebirds, the effect on seabirds and shorebirds of exposure to multiple aspects at the same time during the development does not materially change the worst-case level of risk. Consequently, the overall cumulative risk assessment is ranked as Very Low (10).

Cumulative impact from the Development and third-party activities
Aspects from third-party activities in the region, when combined with the Development's aspects, may result in cumulative impacts to seabirds and shorebirds. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping): • Vessel operations – commercial fishing vessels, commercial shipping, and petroleum industry vessels will result in comparable sources of light emissions to those assessed in Section 8.4 and comparable source of planned marine discharges as assessed in Section 8.6.

Cumulative impact evaluation
• Petroleum activities undertaking flaring which will result in light emissions: – Woodside – Julimar Development Project – Woodside – JDP3 Drilling and Subsea Installation – Woodside – Pluto Offshore Facility – CAPL – Wheatstone Development Third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Very Low (10). Several of the petroleum activities identified (Wheatstone Development, Pluto Offshore Facility) undertake intermittent or continuous flaring, which will generate light emissions over a larger spatial extent (maximum of 42.4 km used as a reference case, Section 8.4.1). Therefore, third-party activities will not introduce any new risk or impact pathways to seabirds or shorebirds within the OA, however the number of sources of risk will increase. Under existing conditions, seabirds and shorebirds are expected to be attracted to vessels servicing the commercial fishing, shipping, and petroleum industries. The cumulative risk of further attracting seabirds and shorebirds as a result of the Development and third-party activities is not considered a disruption of behaviours, given the OA and project areas for third-party activities do not overlap nesting habitats for seabirds or shorebirds (Section 8.4, Section 8.6, Ref. 257). The cumulative risks to seabirds and shorebirds are expected to be limited to minor, localised and temporary changes to predator/prey dynamics and behaviours (i.e. temporary attraction behaviours). The consequence of further minor, localised and temporary changes to predator/prey dynamics and behaviours to seabirds and shorebirds is considered Incidental (6) owing to the following characteristics of the OA and third-party project areas: • absence of aggregation areas • absence of seabirds and shorebirds nesting habitats within the 42.4 km spatial extent adopted for flaring. The spatial and temporal extent of both Development and third-party aspects is such that overlap in impacts/ risks is unlikely. The likelihood of minor, localised and temporary changes in predator/prey dynamics and behaviours to seabirds and shorebirds from the Development and third-party activities is considered Remote (5) given: • existing presence of vessel operations in the region from commercial shipping and fishing industries • the Development will be completed in a phased approach where the aspect sources (i.e. presence of vessels) in the OA will not be continuous, and will vary per phase • for the Development, following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea. In the operations phase, the source of the above listed aspects is reduced to the intermittent, short-term presence of an IMR vessel in the OA such that illuminated areas, ensonified areas and discharge plumes in the OA are limited to a single vessel (i.e. source). • Woodside JDP3 Drilling and Subsea Installation activities are likely to commence Q3 2024 over multiple campaigns and with contingency campaigns in 2026 and 2027. Given the Incidental (6) consequence of causing further minor, localised and temporary changes in predator/prey dynamics and behaviours to seabirds and shorebirds and the Remote (5) likelihood that the consequence may occur during simultaneous Development and third-party activities; the potential cumulative impacts to seabirds and shorebirds does not materially change the worst-case level of risk (Very Low (10)) assessed for any individual aspect.
Demonstration of acceptability
The evaluation of potential cumulative risks to seabirds and shorebirds from the Development and third-party activities indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative risks to seabirds and shorebirds determines that: • cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD • significant impacts to species listed as threatened or migratory under the EPBC Act are not predicted to occur. Areas of importance, such as onshore nesting habitats will not be impacted • the potential impact and risk to seabirds and shorebirds is inherently acceptable with the highest residual risk ranking of Very Low (10) • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8

Cumulative impact evaluation
• no stakeholder feedback related to cumulative impacts or risks to seabirds and shorebirds has been received. Consequently, potential cumulative impacts and risks to seabirds and shorebirds are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact for seabirds and shorebirds.

9.2.9 Fishes, including sharks and rays

Table 9-6 provides the CIA and demonstration of acceptability for fishes.

Table 9-6: CIA and demonstration of acceptability—Fishes, including sharks and rays

Cumulative impact evaluation
Cumulative impact from the Development
The Development in isolation introduces the following risks to fishes (including sharks and rays): • change to behaviour, from: – light emissions (evaluated in Section 8.4) – underwater sound (evaluated in Section 8.5) • change in predator/prey dynamics, from: – planned discharges–MODU and vessels (evaluated in Section 8.6) • injury or mortality of marine fauna, from: – seabed disturbance (evaluated in Section 8.1) – planned discharges–subsea operations (evaluated in Section 8.7) – planned discharges–drilling (evaluated in Section 8.8). The particular values and sensitivities for fishes, including sharks and rays, in the OA and surrounds includes: • whale shark BIA (foraging) • fish communities (associated with the various KEFs). The risk of each aspect to fishes, including sharks and rays, was evaluated individually and the highest risk ranking assigned was Low (7). These evaluations (Section 8) are based on the risk footprint being limited to the OA, where fishes are likely to be highly mobile and transient, and no biological cost to populations due to the localised nature of any consequences. Cumulative impact pathways to fishes from the Development may occur if there is: • an intersection of impact/ risk footprints from multiple aspects, and/ or • a concurrent occurrence of multiple impacts/ risks on the same footprint. Transient and highly-mobile fishes may display cumulative behavioural changes by being attracted to illuminated areas and/or avoiding multiple ensonified areas and discharge plumes. Multiple sources of illuminated areas, ensonified areas and discharge plumes may be present in the OA during the temporary drilling, installation, and commissioning phases. During the operations phase, all infrastructure will be subsea and the source of illuminated areas, ensonified areas and discharge plumes is reduced to the low-frequency, short-term presence of an IMR vessel. Noise from the operation of subsea infrastructure is expected to be negligible as outlined in Section 8.5.1. The localised and temporary nature of the aspects may lead to temporary and localised cumulative impacts to transient and highly-mobile fishes, including sharks and rays. Given this, the effect on fishes, including sharks and rays, of exposure to multiple aspects at the same time during the Development does not materially change the worst-case level of impact or risk. Consequently, the overall cumulative risk assessment is ranked as Low (7).

Cumulative impact evaluation
Cumulative impact from the Development and third-party activities

Aspects from third-party activities in the region, when combined with the Development's aspects, may result in cumulative impacts or risks to fishes, including sharks and rays. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping):
• Vessel operations – commercial fishing vessels, commercial shipping, and petroleum industry vessels will result in comparable volumes and frequencies of vessel discharges to those assessed in Section 8.6, and comparable emissions to those discussed in Section 8.4 (light) and Section 8.5 (noise).
• Petroleum activities undertaking construction or drilling, which could result in seabed disturbance and planned discharges-subsea or drilling (and subsequent impacts to fishes):
  – CAPL – GFP
  – CAPL – GFP J-IC operations
  – Woodside – Scarborough Development
  – Woodside – Julimar Development Project
  – Woodside – JDP3 Drilling and Subsea Installation.
With the exception of J-IC operations, third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Low (7). There are no additional impact pathways.
Under existing conditions, transient and highly-mobile fishes are expected to avoid or be attracted to vessels servicing the commercial fishing, shipping and petroleum industries. The Development and third-party activities will introduce additional sources of aspects, which in turn adds additional illuminated areas attracting prey and subsequently feeding fishes, and ensonified areas and discharge plumes that may elicit active avoidance behaviours in fishes.
The cumulative risks of change in predator/prey dynamics to transient and highly-mobile fishes is considered an incidental consequence that will not result in population level impacts. Population level consequences is only anticipated when marine fauna abandon and avoid critical foraging and breeding habitats essential for life-cycle requirements (Ref. 75).
The cumulative risks to fishes, including sharks and rays, are expected to be limited to minor, localised and temporary changes to predator/prey dynamics and behaviours. The consequence of further minor, localised and temporary changes to predator/prey dynamics and behaviours to fishes, including sharks and rays is considered Incidental (6) owing to the following characteristics of the OA and third-party project areas:
• absence of aggregation areas
• presence of transient and highly-mobile pelagic and benthopelagic fishes
• absence of suitable fish habitat for high-site fidelity.
The spatial and temporal extent of both Development and third-party aspects is such that overlap in impacts is unlikely. The likelihood of minor, localised and temporary changes in predator/prey dynamics and behaviour to fishes, including sharks and rays from the Development and third-party activities is considered Occasional (2) given:
• continuous presence of vessel operations in the region from commercial shipping and fishing industries.
• the Development will be completed in a phased approach where the aspect sources (i.e. presence of vessels) in the OA will not be continuous and will vary per phase.
• for the Development, following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea. In the operations phase, the source of the above listed aspects is reduced to the intermittent, short-term presence of an IMR vessel in the OA such that illuminated areas, ensonified areas and discharge plumes in the OA is limited to a single vessel (i.e. source).
• Woodside's Julimar Drilling activities is likely to commence and be completed in 2024. Consideration of activity in 2025 is based on planned contingency.
Recognising the Incidental (6) consequence of causing further minor, localised and temporary changes in predator/prey dynamics and behaviours to fishes, including sharks and rays and the Occasional (2) likelihood that the consequence may occur during simultaneous Development and third-party activities; the potential cumulative impacts to fishes, including sharks and rays does not materially change the worst-case level of risk (Low (7)) assessed for any individual aspect, if evaluated considering the Development and third-party activities.

Cumulative impact evaluation
Demonstration of acceptability
The evaluation of potential cumulative risks to fishes, including sharks and rays, from the Development and third-party activities indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative risks to fishes, including sharks and rays, determines that: • cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD • significant impacts to species listed as threatened or migratory under the EPBC Act are not predicted to occur • the potential impact and risk to fishes, including sharks and rays, is inherently acceptable with the highest residual risk ranking of Low (7) • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts or risks to fishes, including sharks and rays, has been received. Subsequently, potential cumulative impacts and risks to fishes, including sharks and rays, are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact for fishes, including sharks and rays.

9.2.10 Marine reptiles

Table 9-7 provides the CIA and demonstration of acceptability for marine reptiles.

Table 9-7:CIA and demonstration of acceptability—Marine reptiles

Cumulative impact evaluation
Cumulative impact from the Development
The Development in isolation introduces the following risks to marine reptiles: • change to behaviour, from: – light emissions (evaluated in Section 8.4) – underwater sound (evaluated in Section 8.5) • change in predator/prey dynamics, from: – light emissions (evaluated in Section 8.4) – planned discharges–MODU and vessels (evaluated in Section 8.6) • injury or mortality of marine fauna, from: – planned discharges–subsea operations (evaluated in Section 8.7) – planned discharges–drilling (evaluated in Section 8.8). The particular values and sensitivities identified for marine reptiles in the OA and surrounds (42.4 km spatial extent adopted for flaring) are: • flatback turtle BIA (internesting buffer) and habitat critical • loggerhead turtle BIA (internesting buffer) and habitat critical • green turtle BIAs (foraging, internesting buffer) and habitat critical. The risk of each aspect to marine reptiles was evaluated individually and the highest risk ranking assigned was Low (7). This evaluation is based on the OA and surrounds being located in remote offshore waters with increasing water depths and marine turtles prefer habitats in proximity to the coast with relatively shallow depths (Ref. 143). As such it would be very unlikely that turtles would be aggregating within the area and only a small number of transient marine turtles are expected to be present.

Cumulative impact evaluation
Cumulative impacts pathways to marine reptiles from the Development may occur if there is: • an intersection of impact/ risk footprints from multiple aspects, and/ or • a concurrent occurrence of multiple impacts/ risks on the same footprint. Individual risk evaluations are all based on the localised nature of any consequences, concluding that the risk footprint is limited to the OA, where marine reptiles are likely to be highly mobile and transient. The only risk footprint which extends beyond the OA is light emissions from flaring (42.4 km spatial extent). The cumulative risk of injury or mortality to marine reptiles is limited to the exposure of a small number of transient marine turtles to planned subsea discharge and drilling discharge plumes. Due to rapid mixing and dispersal in the open ocean environment, these plumes are only likely to result in localised, low concentrations of toxicants (e.g. chemical additives such as biocide). Toxicity impacts to marine reptiles have only been observed from long-term exposure to persistent pollutants resistant to environmental degradation (Ref. 562). The presence of discharges from subsea and drilling operations in the marine environment are expected to be localised and temporary, where rapid dilution and low bioaccumulation potential of these discharges are expected based on dispersion predictions. As a result, it would be highly unlikely for marine reptiles to be adversely affected by the temporary exposure of toxicants due to the short-term exposure and dispersion. Discharge plumes will only cause cumulative risk of injury or mortality if the plume acts as a barrier to critical foraging and breeding habitats essential for life-cycle requirements (Ref. 75), which is not predicted. Although the OA overlaps the spatial extent of habitat critical to the survival of Flatback Turtles, due to the distance offshore and increasing water depths within the Development (~150–1,400 m) only on rare occurrences would flatback turtles be undertaking internesting behaviours within the OA. Multiple sources of illuminated areas and ensonified areas will be present during the temporary drilling, installation and commissioning phases and will reduce to a single source during routine operations phase. The cumulative risk of disruption of behaviours to marine reptiles is expected to be limited to incidental attraction or avoidance behaviours from light emissions and underwater sound. The cumulative risk of attracting or repelling marine reptiles from the OA is unlikely to disrupt marine turtle critical behaviours, given the conservative 42.4 km spatial extent of the light emissions adopted for flaring does not overlap marine turtle nesting habitats and only a small number of transient marine turtles are likely to display cumulative behavioural changes by being attracted to or avoiding multiple illuminated areas and/or avoiding multiple ensonified areas. Recognising the above listed aspects may be present simultaneously and temporarily in the OA over the course of the Development, this may lead to temporary and localised cumulative impacts to a small number of marine reptiles. CAPL has determined that the effect on marine reptiles of exposure to multiple aspects at the same time during the development does not materially change the worst-case level of impact or risk. Consequently, the overall cumulative risk assessment is ranked as Low (7).
Cumulative impact from the Development and third-party activities
Aspects from third-parties undertaking activities in the region, when combined with the Development’s aspects, may result in cumulative impacts to marine reptiles. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping): • Vessel operations – commercial fishing vessel, commercial shipping, and petroleum industry vessels will result in comparable volumes and frequencies of vessel discharges to those assessed in Section 8.6, and comparable emissions to those discussed in Section 8.4 (light) and Section 8.5 (sound). • Petroleum activities undertaking construction or drilling, which could result in planned discharges-subsea or drilling (and subsequent impacts to fishes): – CAPL – GFP – CAPL – GFP J-IC operations – Woodside – Scarborough Development – Woodside – Julimar Development Project – Woodside – JDP3 Drilling and Subsea Installation. Underwater sound emissions by third-party activities are expected to exhibit similar spatial and temporal changes to ambient underwater sound levels as those introduced by the Development, with the exception of J-IC SCSt operations. As outlined Section 9.2.6, upward travelling energy away from the SCSt is refracted downward, and energy reflected from the seabed is also refracted back downward, which results in most of the acoustic energy occurring in the lower water column and less acoustic energy propagating into the upper water column (Ref. 558). With the exception of J-IC SCSt, underwater sound conditions will return to ambient levels immediately following cessation of Development and third-party activities. Taking the above into consideration third-party generated aspects are evaluated as Low (7). There are no additional impact pathways.

Cumulative impact evaluation
Under existing conditions, a small number of transient marine turtles are expected to avoid or be attracted to vessels servicing the commercial fishing, shipping, and petroleum industries. The Development and third-party activities will introduce additional sources for the aspects listed, which in turn adds additional illuminated areas attracting marine turtles, and ensonified areas and discharge plumes that may elicit active avoidance behaviours in marine reptiles. The cumulative risk of attracting or repelling marine reptiles as a result of the Development and third-party activities is not considered a disruption of critical behaviours, given the OA and project areas for third-party activities do not overlap marine turtle nesting habitats (Section 8, Ref. 258). The cumulative risks of minor, localised and temporary changes to predator/prey dynamics and behaviours (i.e. temporary attraction and avoidance behaviours) to a small number of transient marine turtles is considered an incidental consequence that will not result in population level impacts. Population level consequences are only anticipated when marine fauna abandon and avoid critical foraging and breeding habitats essential for life-cycle requirements (Ref. 75). Particular values and sensitivities to marine reptiles in the OA and 42.4 km spatial extent adopted for flaring are limited to offshore inter-nesting behaviours for marine turtles and does not include marine turtle nesting habitats. The cumulative risks to marine reptiles are expected to be limited to minor, localised and temporary changes to predator/prey dynamics and behaviours (i.e. temporary attraction and avoidance behaviours). The consequence of further minor, localised and temporary changes in behaviours to marine reptiles is considered Incidental (6) owing to the following characteristics of the OA and third-party project areas: • absence of aggregation areas • presence of a small number of transient marine turtles • absence of marine turtle nesting habitats within the 42.4 km spatial extent adopted for flaring. The spatial and temporal extent of both Development and third-party aspects is such that overlap in impacts is unlikely. The likelihood of minor, localised and temporary changes in predator/prey dynamics and behaviours to marine reptiles from the Development and third-party activities is considered Occasional (2) given: • there will be continuous presence of vessel operations in the region from commercial shipping and fishing industries. • the Development will be completed in a phased approach where the aspect sources (i.e. presence of vessels) in the OA will not be continuous and will vary per phase. • for the Development, following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea. In the operations phase, the source of the above listed aspects is reduced to the intermittent, short-term presence of an IMR vessel in the OA such that illuminated areas, ensonified areas and discharge plumes in the OA is limited to a single vessel (i.e. source). • Woodside JDP3 Drilling and Subsea Installation activities are likely to commence Q3 2024 over multiple campaigns and with contingency campaigns in 2026 and 2027. • Preliminary estimates of J-IC SCSt Operations worst-case sound emissions (i.e. when operating under maximum compressor power) indicate the broadband source levels are of a similar magnitude to the cable lay vessels associated with J-IC installation activities. Given the location of the J-IC SCSt in deep water (~1,345 m), the deep ocean sound channel (centre estimated at ~800–1,000 m water depth at J-IC location) has the most significant effect on propagation of subsea sound emissions from the SCSt. Upward travelling energy away from the SCSt is refracted downward, and energy reflected from the seabed is also refracted back downward, which results in a large amount of acoustic energy occurring in the lower water column and less acoustic energy propagating into the upper water column. Preliminary acoustic modelling of J-IC SCSt Operations indicates that exposure to received levels above marine turtle effect criteria thresholds for the onset of TTS or PTS (SEL_{24}) are not anticipated to occur, and, as the acoustic energy will predominately occur within the lower part of the water column, there is only a low relative risk of acoustic sound from the SCSt resulting in any behavioural changes to transient marine turtles within the surface waters. Given the Incidental (6) consequence of causing further minor, localised and temporary changes in behaviours of marine reptiles and the Occasional (2) likelihood that the consequence may occur during simultaneous Development and third-party activities, potential cumulative impacts to marine reptiles does not materially change the worst-case level of risk (Low (7)) assessed for any individual aspect.
Demonstration of acceptability
The evaluation of potential cumulative risks to marine reptiles from the Development and third-party activities indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative risks to marine reptiles determines that:

Cumulative impact evaluation
• cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD • significant impacts to species listed as threatened or migratory under the EPBC Act are not predicted to occur. Areas of importance, such as onshore nesting habitats will not be impacted • the potential impact and risk to marine reptiles is inherently acceptable with the highest residual risk ranking of Low (7) • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts or risks to marine reptiles has been received. Consequently, potential cumulative impacts and risks to marine reptiles are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact for marine reptiles.

9.2.11 Marine mammals

Table 9-8 provides the CIA and demonstration of acceptability for marine mammals.

Table 9-8: CIA and demonstration of acceptability—Marine mammals

Cumulative impact evaluation
Cumulative impact from the Development

The Development in isolation introduces the following risks to marine mammals:
• change to behaviours, from:
  – underwater sound (evaluated in Section 8.5)
• change in predator/prey dynamics, from:
  – planned discharges–MODU and vessels (evaluated in Section 8.6)
• injury or mortality of marine fauna, from:
  – planned discharges–subsea operations (evaluated in Section 8.7)
  – planned discharges–drilling (evaluated in Section 8.8).
The risk of each aspect was evaluated individually against marine mammals, with the highest residual risk ranking of Low (7). The individual Low (7) risk rankings were generally assigned given the OA and surrounds (i.e. modelled ensonified areas and discharge plumes) provides open water habitat for migrating humpback and pygmy blue whales (Sections 8.5; 8.6; 8.7 and 8.8).
The particular values and sensitivities for marine mammals in the OA and surrounds includes:
• humpback whale BIA (migration)
• pygmy blue whale BIA (distribution and migration).
The presence of humpback and pygmy blue whale migration BIAs in the OA and surrounds infers the potential for the presence of these whales during peak migration periods (Section 6.2.3.1). There currently is no evidence of high-site fidelity for other marine mammals within the OA and surrounds (i.e. ensonified areas and discharge plumes do not contain known marine mammal breeding, calving and foraging grounds). As a result, other marine mammals are expected to be highly-mobile and transit within the OA (Section 6.2.3.1).
Cumulative impact pathways to marine mammals from the Development include overlap in impact footprint from each risk due to multiple aspects, and from overlap of multiple risks on the same footprint. Individual risk evaluations are all based on the localised nature of any consequences, where humpback and pygmy blue whales may be seasonally present within the OA; and other marine mammals are expected to be transient.
The cumulative risk of injury or mortality to marine mammals is limited to the exposure of transient and highly-mobile individuals to toxicants (chemical additives such as biocide) in discharge plumes resulting from planned subsea discharges and drilling discharges. Marine mammals breathe air and would be able to swim

Cumulative impact evaluation
past the discharge plume and not be adversely affected by the temporary exposure of toxicants due to their thick epidermal layer (Ref. 563; Ref. 564). Discharge plumes will only cause cumulative risk of injury or mortality if the plume acts as a barrier to known marine mammal breeding, calving and significant foraging grounds. Population level consequences such as changes in growth, reproduction and survival of marine mammals have only been observed when marine mammals abandon and avoid foraging and breeding critical habitats (Ref. 565; Ref. 129). Within ~50 km of the Development, particular values and sensitivities for marine mammals are limited to known migration and inferred foraging behaviours and does not include critical foraging and breeding habitats essential for life-cycle requirements. Marine mammals are expected to swim through discharge plumes to avoid the area, with no cumulative risk of injury or mortality. Planned MODU and vessel discharges may temporarily increase primary productivity and the presence of prey may attract marine mammals into the OA, resulting in the cumulative risk of change in predatory/prey dynamics. Routine vessel discharge plumes will dissipate rapidly in open water environments represented in the OA; however it is recognized that the Development will introduce multiple sources of routine vessel discharges over a long period of time. The highest number of vessels working concurrently at discrete locations across the OA is estimated to range between 5 and 10 vessels. This may occur when different phases or activities are occurring concurrently, but this will be intermittent. Following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea and the source of the above listed aspects will be from the low-frequency, short-term presence of an IMR vessel in the OA during the operations phase. Therefore, discharge plumes in the OA during operations phase is limited to a single vessel (i.e. source). The presence of vessels in the OA during the Development may introduce another temporary feeding area for passing marine mammals, which is not considered outside of normal behaviour given migrating marine mammals are known to opportunistically feed along their migration routes (Ref. 127; Ref. 566). Migrating marine mammals may elicit behavioural responses such as actively avoiding multiple sources of planned discharges and underwater sound; however, it is not expected that this would result in displacement from their migratory corridor. Discharge plumes may alter normal marine mammal behaviours, but these minor movements will be too small to be meaningfully measured or detected (NOAA 2023). Marine mammals are expected to swim through discharge plumes to avoid the area, rather than change direction in swimming. Conversely, marine mammals are known to actively avoid ensonified areas generated by vessels, such that marine mammals may increase swim speed and dive frequency to avoid the underwater sound source (Ref. 370; Ref. 372; Section 8.5). Multiple sources of ensonified areas and discharge plumes will be present in the OA during the temporary drilling, installation and commissioning phases and will reduce to a single source during routine operations phase. Review of modelling predictions for low-frequency cetaceans found the conservative area for behavioural response to low-frequency cetaceans to be 18.26 km from the source (i.e. maximum horizontal distance predicted for pipelay operations with multiple vessels). Within the 18.26 km radius around the expected position of subsea infrastructure, where these activities will occur, migration BIAs were identified for the pygmy blue and humpback whales and inferred foraging areas for the pygmy blue whale. No other BIAs and associated important behaviours for low-frequency cetaceans were identified (refer to Section 6.2.3.1). The potential energetic cost of avoiding activities associated with the Development is likely to be small in the context of the greater migratory movements of humpback and pygmy blue whales migrating through the area. Recognising the above listed aspects may be present simultaneously and temporarily in the OA over the course of the Development, this may lead to temporary and localised cumulative impacts to transient and highly-mobile marine mammals. The effect on marine mammals of exposure to multiple aspects at the same time during the development does not materially change the worst-case level of impact or risk. Subsequently, the overall cumulative risk assessment is ranked as Low (7).
Cumulative impact from the Development and third-party activities

Aspects from third-parties undertaking activities in the region, when combined with the Development's aspects, may result in cumulative impacts or risks to marine mammals. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping):
• Vessel operations – commercial fishing vessel, commercial shipping, and petroleum industry vessels will result in comparable volumes and frequencies of vessel discharges to those assessed in Section 8.6, and comparable noise emissions to those discussed in Section 8.5 (noise).
• Petroleum activities undertaking operations, construction, or drilling, which could result in planned discharges-subsea or drilling or underwater noise emissions (and subsequent impacts to marine mammals):
  – CAPL – GFP
  – CAPL – GFP J-IC operations

Cumulative impact evaluation
– Woodside – Scarborough Development – Woodside – Julimar Development Project – Woodside – JDP3 Drilling and Subsea Installation. Underwater sound emissions by third-party activities are expected to exhibit similar spatial and temporal changes to ambient underwater sound levels as those introduced by the Development, with the exception of J-IC SCSt operations. As outlined Section 9.2.6, upward travelling energy away from the SCSt is refracted downward, and energy reflected from the seabed is also refracted back downward, which results in most of the acoustic energy occurring in the lower water column and less acoustic energy propagating into the upper water column (Ref. 558 Appendix F). With the exception of J-IC SCSt, underwater sound conditions will return to ambient levels immediately following cessation of Development and third-party activities. Taking the above into consideration, third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Low (7). There are no additional impact pathways. It is possible that cumulative risks to marine mammals from the Development and third-party activities may occur if these activities coincide with peak migration periods for migrating humpback and pygmy blue whales across the OA and surrounds (Section 6.2.3.1). Review of the Listing Advice for the humpback whale (Ref. 126) and Conservation Management Plan for the Blue Whale (Ref. 16) identifies noise interference (underwater sound) and habitat modification from acute and chronic chemical discharges (planned discharges) as threats to humpback and pygmy blue whale populations. The following assessment will focus on migrating humpback and pygmy blue whales to evaluate worst-case potential cumulative risk to marine mammals, given migration BIAs for these species overlap the OA and third-party project areas. It is noted that other marine mammal species may be present in the OA, however with no known high-fidelity habitats in the OA (i.e. BIAs or habitats critical to the survival of the species), other marine mammals in the OA are expected to be highly-mobile and transient (Section 6.2.3.1). Under pre-existing conditions, transient and highly-mobile marine mammals are expected to avoid or be attracted to vessels servicing the commercial fishing, shipping and petroleum industries (Ref. 370; Ref. 372;; Sections 8.5; 8.6; 8.7 and 8.8). The Development and third-party activities will introduce additional sources for the aspects listed, which in turn adds additional ensonified areas and discharge plumes that may prompt active avoidance behaviours to marine mammals, at no significant change to pre-existing levels. The cumulative risks of minor, localised and temporary changes to predator/prey dynamics and behaviours (i.e. temporary avoidance behaviours) to transient and highly-mobile marine mammals is considered an incidental consequence that will not result in population level impacts. Population level consequences are only anticipated when marine fauna abandon and avoid critical foraging and breeding habitats essential for life-cycle requirements (Ref. 75). The cumulative risks to marine mammals are expected to be limited to minor, localised and temporary changes to predator/prey dynamics and behaviour (i.e. opportunistic feeding during migration and avoidance behaviours). The consequence of further minor, localised and temporary changes to predator/prey dynamics and behaviours to marine mammals is based on the following characteristics of the OA and surrounds: • absence of aggregating marine mammals outside of peak migration periods • presence of predominantly relatively fast, directed travelling (high move persistence) migrating pygmy blue whales (Ref. 136) • absence of breeding habitats • the population of migrating humpback whales has continued to increase in recent years. The spatial and temporal extent of both Development and third-party aspects is such that overlap in impacts is unlikely. The likelihood of minor, localised and temporary changes in predator/prey dynamics and behaviours to marine mammals from the Development and third-party activities is considered Occasional (2) given: • continuous presence of vessel operations in the region from commercial shipping and fishing industries. • the Development will be completed in a phased approach where the aspect sources (i.e. presence of vessels) in the OA will not be continuous and will vary per phase. • for the Development, following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea and the source of the above listed aspects is reduced to the low-frequency, short-term presence of an IMR vessel in the OA for the operations phase. Therefore, illuminated areas, ensonified areas and discharge plumes in the OA are limited to a single vessel (i.e. source). • Woodside's Julimar Drilling activities is likely to commence and be completed in 2024. Consideration of activity in 2025 is based on planned contingency.

Cumulative impact evaluation
Recognising the Incidental (6) consequence of causing further minor, localised and temporary changes in predator/prey dynamics and behaviours to marine mammals and the Occasional (2) likelihood that the consequence may occur during simultaneous Development and third-party activities; potential cumulative impacts to marine mammals does not materially change the worst-case level of risk (Low (7) assessed for any individual aspect, if evaluated considering the Development and third-party activities. Recognising the incidental consequence of increase in avoidance behaviours to marine mammals and the occasional likelihood that a marine mammal would be exposed to the short-term presence of any of the above listed aspects from multiple third-party activities, the cumulative risk of the Development and third-party activities is considered Low (7).
Demonstration of acceptability
The evaluation of potential cumulative risks to marine mammals from the Development and third-party activities indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative risks to marine mammals determines that: • cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD • significant impacts to species listed as threatened or migratory under the EPBC Act are not predicted to occur • impacts to marine mammals from the Development and third-party activities are not inconsistent with the relevant objectives of any recovery or conservation management plan, conservation advice, or bioregional plan • the potential impact and risk to marine mammals is inherently acceptable with the highest residual risk ranking of Low (7) • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts or risks to marine mammals has been received. Consequently, potential cumulative impacts and risks to marine mammals are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact for marine mammals; with the addition of the below adopted control measure: • **CM51**: CAPL will re-evaluate the cumulative impact assessment based on studies conducted for J-IC to manage scientific uncertainty against all potential cumulative impacts.

9.2.12 Cultural heritage values

Table 9-9 provides the CIA and demonstration of acceptability for cultural heritage value: Traditional Owners.

Table 9-9: CIA and demonstration of acceptability–Cultural heritage value: Traditional Owners

Cumulative impact evaluation
Cumulative impact from the Development
The following Development aspects have the potential to result in changes to Traditional Owner cultural heritage values: • seabed disturbance (evaluated in Section 8.1) • light emissions (evaluated in Section 8.4) • underwater sound (evaluated in Section 8.5) • planned discharges–subsea operations (evaluated in Section 8.7) • planned discharges–drilling (evaluated in Section 8.8).

Cumulative impact evaluation
The risk of change to cultural heritage values for each aspect was evaluated individually and the highest risk ranking assigned was Low (7) based on: • the OA and surrounds not containing known artefacts or specific sites of cultural value associated with the seabed (Section 6.5.2), and • potential risks being limited to indirect impacts to intangible Traditional Owner heritage i.e. obligations for the protection of Sea Country including marine fauna and benthic habitats and associated communities. The assigned ranking considering indirect impacts to intangible Traditional Owner heritage was Low (7) given: – potential disruption of behaviours for marine mega fauna will be localised and temporary – potential injury and death to epibenthic and infaunal invertebrates will be localised – alteration of benthic habitats and associated communities will be localised. – no threatened or migratory epifaunal or infaunal species, or TECs were identified within the OA – benthic survey results show a mixture of soft sediment habitat and isolated areas of higher structural complexity, typical of the Northern Carnarvon Basin (Ref. 110; Ref. 253; Ref. 105, Appendix A) Given the above, the cumulative risk these aspects may present to cultural heritage values for Traditional Owners is localised. Consequently, Consequently, exposure to multiple aspects at the same time during the Development does not materially change the worst-case level of impact or risk and the overall cumulative risk assessment is ranked as Low (7).
Cumulative impact from the Development and third-party activities
Aspects from third-parties undertaking activities in the region, when combined with the Development's aspects, may result in cumulative risks to cultural heritage values for Traditional Owners. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping): • Vessel operations – commercial fishing vessel, commercial shipping, and petroleum industry vessels will result in comparable sources of light emissions (Section 8.4), underwater sound (Section 8.5) and planned marine discharges (Section 8.6). • Commercial fisheries – trawling activity could result in alteration of benthic habitats and associated communities. • Petroleum activities which could result in seabed disturbance (and subsequent impacts to benthic habitats and associated communities), generate light emissions, underwater sound, planned subsea and drilling discharges: – CAPL – GFP – CAPL – GFP J-IC operations – Woodside – Scarborough Development – Woodside – Julimar Development Project – Woodside – JDP3 Drilling and Subsea Installation. Third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Low (7). However commercial Commonwealth fisheries, specifically from fisheries which use trawling gear such as the North-west Slope Trawl Fishery (NWSTF) and the Western Deepwater Trawl Fishery (WDTF), introduces an additional impact pathway for alteration of benthic habitats and associated communities. The benthic communities within the OA and the wider area, consist of sparsely distributed, epibenthic and infaunal invertebrates located in soft sediment benthic habitats. These communities have been previously disturbed by the placement of seabed infrastructure by prior petroleum activities (refer to Table 9-1 for project specific details) and ongoing trawling activities by commercial fisheries. The Development and other third-party activities will lead to an increase in the alteration of benthic habitats and associated communities. However, this contribution is still considered a localised impact given the NWMR which covers ~1.07 million km^2 is dominated by soft sediment benthic habitats and associated communities (Ref. 103, Ref. 104). The consequence of further alteration of benthic habitats and associated communities from the Development and third-party activities is considered a limited environmental impact, and therefore an Incidental (6) consequence of change to cultural heritage values for Traditional Owners. Given the sparse distribution of benthic communities found in the OA and, as they are highly represented throughout the NWMR the likelihood that the Development and third-party activities will result in alteration of benthic habitats and associated communities and therefore change to cultural heritage values for Traditional Owners was assessed as Occasional (2). Recognising the Incidental (6) consequence of further minor and localised change to cultural heritage values for Traditional Owners and the Occasional (2) likelihood that the consequence may occur during the

Cumulative impact evaluation
Development and third-party activities, potential cumulative risk of change to cultural heritage values for Traditional Owners does not materially change the worst-case level of risk (i.e. Low (7)), if evaluated considering the Development and third-party activities.
Demonstration of acceptability
The evaluation of potential cumulative risks to cultural heritage values for Traditional Owners from the Development and third-party activities indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative risks to change to cultural heritage values for Traditional Owners demonstrates that: • cumulative risks do not introduce additional sources or pathways which could contravene the principles of ESD • risks to cultural heritage values for Traditional Owners from the Development and third-party activities are not inconsistent with the relevant objectives of any bioregional plan • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no further feedback was received in relation to seabed disturbance from Phase 1 stakeholder consultation. Consequently, potential cumulative risks to cultural heritage values for Traditional Owners are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact and risk to cultural heritage values for Traditional Owners.

9.2.13 KEFs

Table 9-10 provides the CIA and demonstration of acceptability for KEFs.

Table 9-10: CIA and demonstration of acceptability–KEFs

Cumulative impact evaluation
Cumulative impact from the Development

The Development in isolation introduces the following risks to KEFs:
• Changes to values and sensitivities, from:
  – seabed disturbance (evaluated in Section 8.1)
  – planned discharges–subsea operations (evaluated in Section 8.7)
  – planned discharges–drilling (evaluated in Section 8.8).
The particular values and sensitivities for KEFs in the OA and surrounds are:
• Benthic habitat values; the Ancient coastline at 125 m depth contour KEF (Ancient coastline KEF) and the Exmouth Plateau KEF.
• Demersal fish assemblage values; Continental slope demersal fish communities KEF
The impact of alteration of benthic habitat for each aspect was evaluated individually and the highest impact consequence ranking assigned was Moderate (4). The risk of injury and mortality to benthic communities for each aspect was also evaluated individually and the highest risk ranking assigned was Low (8). These rankings were assigned given the localised nature of consequences and because benthic habitats and associated communities affected by the Development are highly represented through the NWS region. In addition, following decommissioning of the Development, benthic communities impacted in the OA are expected to recover, given soft sediment benthic habitats have underlying conditions that support recolonisation and recovery (Ref. 278).
Cumulative impacts pathways to KEFs with benthic habitat values from the Development may occur if there is:
• an intersection of impact/ risk footprints from multiple aspects, and/ or
• a concurrent occurrence of multiple impacts/ risks on the same footprint.

Cumulative impact evaluation
Despite the OA overlapping 3 KEFs, observations from the benthic survey (Ref. 105, Appendix A) highlights KEF values with the potential to be impacted are limited to deep-sea benthic habitats and demersal fish species that are widespread and well represented in the region. Benthic survey results show that within the OA there is a mixture of relatively homogenous, soft sediment habitat with sparse fauna and isolated areas of higher structural complexity, typical of the Northern Carnarvon Basin (Ref. 110; Ref. 112; Ref. 105, Appendix A). Endemic values associated with these KEFs were not detected within the OA benthic survey (Ref. 105, Appendix A). The extent of any potential impact is relatively localised, with the OA only covering from between 0.02–1% of these 3 KEFs. The cumulative risk of injury and mortality to benthic communities will be restricted to mortality within the subsea infrastructure footprint and the potential for injury to a minor area from planned discharges–drilling. The sparsely distributed, epibenthic and infaunal invertebrates in the OA are well represented in the region and there are no epifaunal or infaunal threatened or migratory species, or TECs within the OA (Ref. 123, Appendix B). Consequently, the area of benthic communities affected by both seabed disturbance and planned discharges–drilling is representative of a negligible impact on a regional scale. The Continental slope demersal fish communities KEF has values relating to fish that live and feed near the sea floor. The Continental slope demersal fish communities KEF will overlap with the OA at the C&D flowline, C&D DC-3, WTR umbilical and one of the Gorgon tie-in points. Where the OA crosses with the Continental slope demersal fish communities KEF, benthic habitat mostly comprises irregular and smooth seabed with bare substrates and discrete depressions of bioturbated sediments (Ref. 105, Appendix A). These benthic habitats do not represent site-attached fish habitat and is consistent with observations of few benthic biota (Ref. 105, Appendix A). The fish species observed were predominantly pelagic and demersal species (Ref. 105, Appendix A), which are generally considered transient and highly mobile as they are adapted to living and moving through open water habitats (Ref. 283). The benthic survey found that topographically complex scarps where the OA crosses the Continental slope demersal fish communities KEF hosts typical deep-sea benthic biota. For fish assemblages, a total of 468 fish belonging to 25 taxa have been recorded within the Continental slope demersal fish communities KEF area, with the fish assemblage dominated by Trevallies (Carangidae) with 4 species from 3 genera accounting for 256 of the individuals observed (Ref. 105, Appendix A). There was no statistically significant difference between the mean number of fish taxa within the Continental slope demersal fish communities KEF and the other KEFs in the OA. The fish species observed were predominantly benthic and demersal species (Ref. 105, Appendix A) , which are generally considered transient and highly mobile as they are adapted to living and moving through open water habitats (Ref. 283). The cumulative risk of injury and mortality to fish taxa affected by both seabed disturbance and planned discharges–drilling will not pose a significant risk to demersal fish assemblage values due to the localised (potential OA overlap of 0.02–1% of these 3 KEFs) and temporary extent of potential impact as well as the highly mobile and transient nature of the demersal species. The potential cumulative impacts or risks to KEFs, with values that are highly represented in the region, from the above listed aspects will be localised, and following decommissioning soft sediment benthic habitats and associated communities impacts are expected to recover. Therefore, the effect on KEFs of exposure to multiple aspects at the same time during the development does not materially change the worst-case impact or risk level of Moderate (4) / Low (8) respectively.
Cumulative impact from the Development and third-party activities

Aspects from third-parties undertaking activities in the region, when combined with the Development's aspects, may result in cumulative impacts or risks to KEFs. These third-parties (and potential aspects) include (refer to Table 9-1 for scoping):
• Commercial fisheries – trawling activity could result in alteration of benthic habitats and injury or mortality of benthic communities.
• Petroleum activities which could result in seabed disturbance (and subsequent impacts to benthic habitats and associated communities)
  – CAPL – GFP J-IC operations
  – Woodside – Julimar Development Project
  – Woodside – JDP3 Drilling and Subsea Installation.
Third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Incidental (6) / Low (8) respectively. However commercial Commonwealth fisheries, specifically from fisheries which use trawling gear such as the North-west Slope Trawl Fishery (NWSTF) and the Western Deepwater Trawl Fishery (WDTF), introduces an additional impact pathway.

Cumulative impact evaluation
The benthic communities within the OA and the wider area, consist of sparsely distributed, epibenthic and infaunal invertebrates located in soft sediment benthic habitats. These communities have been previously disturbed by the placement of seabed infrastructure from previous petroleum activities (refer to Table 9-1 for project specific details) and trawling activities from commercial fisheries. The Development and other third-party activities may contribute to the existing loss of these benthic communities. However, this is still considered a localised impact given the NWMR which covers ~1.07 million km^2 is dominated by soft sediment benthic habitats and associated communities (Ref. 103; Ref. 104). The consequence of further alteration of benthic habitat and injury or mortality to benthic communities from the Development and third-party activities is considered a limited environmental impact, and therefore an Incidental (6) consequence owing to the following characteristics of benthic habitat and associated communities represented in the OA and relevant third-party project area: • values associated with the Ancient coastline KEF and Exmouth Plateau KEF were not detected within the OA benthic survey (Ref. 105, Appendix A) • values associated with the Continental slope demersal fish communities KEF detected in the OA are typical deep-sea benthic biota • epibenthic and infaunal invertebrates located in soft sediment benthic habitats in the OA are well represented in the NWS region • soft sediment benthic habitats have underlying conditions that support recolonisation and recovery (Ref. 278). The sparse distribution of benthic communities found in the OA and throughout the NWS region gives the Occasional (2) likelihood that the Development and third-party activities will result in the injury or mortality of benthic communities. Recognising the Incidental (6) consequence of further minor and localised alteration and loss of benthic habitats and associated communities and the Occasional (2) likelihood that the consequence may occur during the Development and third-party activities, potential cumulative risks to KEFs does not materially change the worst-case level of risk (i.e. Low (7)), if evaluated considering the Development and third-party activities.
Demonstration of acceptability
The evaluation of potential cumulative impacts and risks to KEFs from the Development and third-party activities indicates that potential cumulative impacts or risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative impacts and risks to KEFs determines that: • cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD • impacts and risks to KEFs from the Development and third-party activities are not inconsistent with the relevant objectives of any bioregional plan • no additional legislative or other requirements have been identified, other than those presented in Section 8 • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts or risks to KEFs has been received. Subsequently, potential cumulative impacts and risks to KEFs are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact and risk to KEFs.

9.2.14 Commercial fisheries

Table 9-11 provides the CIA and demonstration of acceptability for commercial fisheries.

Table 9-11: CIA and demonstration of acceptability—Commercial fisheries

Cumulative impact evaluation
Cumulative impact from the Development
The following Development aspects have the potential to result in a change to the functions, interests and activities of other marine users: • planned discharges-subsea (evaluated in Section 8.7) • physical presence—Other marine users (evaluated in Section 8.9) The risk of each aspect to commercial fisheries was evaluated individually and the highest risk ranking assigned was Low (8). This evaluation is based on the low level of commercial fishing within the OA and the small and temporary nature of the risk footprint. Cumulative impact pathways to commercial fisheries from the Development may occur if there is overlap of multiple impacts / risks on the same footprint. Given the localised and temporary nature of the discharges impacts on fish populations are not expected to manifest at a fish population level, and therefore the risks of changes in fish stocks to fisheries are assessed as Very Low (9) (Section 9.2.1). The cumulative effect of a small exclusion area during the Development, combined with a very low risk of changes to fish stocks impacting catch rates, does not materially increase the worst-case level of risk determined for the Development. Consequently, the overall cumulative risk assessment is ranked as Low (8).
Cumulative impact from the Development and third-party activities
Aspects from third-party activities in the region, when combined with the Development's aspects, may result in cumulative impacts or risk to commercial fisheries. These third parties (and potential aspects) include (refer to Table 9-1 for scoping): • Vessel operations – commercial fishing vessel, commercial shipping, and petroleum industry vessels will result in comparable volumes and frequencies of vessel discharges to those assessed in Section 8.6, and comparable emissions to those discussed in Section 8.4 (light) and Section 8.5 (noise). • Petroleum activities that will implement exclusion zones comparable to those assessed in Section 8.9 (physical presence – other marine users) and are undertaking construction or drilling, which could result in seabed disturbance and planned discharges-subsea or drilling (and subsequent impacts to commercial fishes): – CAPL – GFP – CAPL – GFP J-IC operations – Woodside – Julimar Development Project – Woodside – JDP3 Drilling and Subsea Installation Underwater sound emissions by third-party activities are expected to exhibit similar spatial and temporal changes to ambient underwater sound levels as those introduced by the Development, with the exception of J-IC SCSt operations. As outlined Section 9.2.6, upward travelling energy away from the SCSt is refracted downward, and energy reflected from the seabed is also refracted back downward, which results in most of the acoustic energy occurring in the lower water column and less acoustic energy propagating into the upper water column (Ref. 558). With the exception of J-IC SCSt, underwater sound conditions will return to ambient levels immediately following cessation of Development and third-party activities. Taking the above into consideration, third-party generated aspects are evaluated to be of a similar nature and scale to those predicted from the Development, and in isolation are therefore evaluated as Low (7). The interaction of the Development and third-party activities may introduce: • additional illuminated areas attracting prey and subsequently feeding fishes • exclusion zones for other marine users • ensonified areas • discharge plumes that may elicit active attraction or avoidance behaviours in commercial fishes. The cumulative risk of attracting or repelling commercial fishes, and restricted access at exclusion zones is considered an Incidental (6) consequence to commercial fishers owing to the following characteristics of the OA and third-party project areas:

Cumulative impact evaluation
• loss of fishing grounds will be temporary and limited to SNAs, a small area of typically a 500 m radius around specific vessels and MODUs during certain activities • exclusion will be temporary and short-term, affecting a limited proportion of a large fishery management area where fishing effort is currently low • although third-party activities in combination with the Development will result in an overall increase in the total exclusion area, there will be no overlap in spatial extent of exclusion areas and limited temporal overlap • presence of transient and highly-mobile pelagic and demersal fishes. The spatial and temporal extent of both Development and third-party aspects is such that overlap in impacts is unlikely. The likelihood of unplanned interactions resulting in change to the functions, interests and activities of other marine users including commercial fisheries from the Development and third-party activities is considered Unlikely (4) given: • the Development will be completed in a phased approach where the aspect sources (i.e. presence of vessels) in the OA will not be continuous. • no incidences of commercial fishing activities interacting with the infrastructure or with support activities has been communicated to CAPL since GFP construction began in 2010. • for the Development, following drilling, installation and commissioning phases, all infrastructure remaining for operations will be subsea. In operations phase, the source of the above listed aspects is reduced to the low-frequency, short-term presence of an IMR vessel in the OA such that illuminated areas, ensonified areas and discharge plumes in the OA is limited to a single vessel (i.e. source). • Woodside JDP3 Drilling and Subsea Installation activities are likely to commence Q3 2024 over multiple campaigns with contingency campaigns in 2026 and 2027. These are discrete campaigns that are not continuous. • J-IC operations of J-IC SCSt introduces ensonified fields in the lower parts of the water column surrounding J-IC SCSt, compared to ensonified fields in the upper water column generated by other third-party vessels. Given the consequence of change to the functions, interests and activities of other marine users including commercial fisheries is ranked as Incidental (6) and the likelihood that the consequence may occur during simultaneous Development and third-party activities is Unlikely (4) ; the potential cumulative impacts to commercial fisheries does not materially change the worst-case level of risk (Low (7)) assessed for any individual aspect.
Demonstration of acceptability
The evaluation of potential cumulative risks to commercial fisheries from the Development indicates that potential cumulative risks are no greater than those already assessed for the Development in isolation. The evaluation of cumulative risks to commercial fisheries determines that: • cumulative impacts and risks do not introduce additional sources or pathways which could contravene the principles of ESD. • no additional legislative or other requirements have been identified, other than those presented in Section 8. • no additional CAPL procedures have been identified, other than those presented in Section 8 • no stakeholder feedback related to cumulative impacts or risks to commercial fisheries has been received. Consequently, potential cumulative impacts and risks to commercial fisheries are deemed acceptable, based on the acceptability justifications provided in the relevant sections of the impact assessment presented in Section 8.
Are identified EPO/s and adopted control measures appropriate?
CAPL considers that the EPOs and adopted control measures in place for the Development meet the acceptable level of impact and risk to commercial fisheries.

10 Implementation strategy

CAPL will carry out the Development in accordance with this OPP and all subsequent related EPs. The implementation strategy identifies the systems, practices, and procedures used to ensure this occurs, with particular focus on managing the environmental impacts and risks of the activities and emergency preparedness. The implementation strategy will help achieve the EPOs (detailed in Section 8), as per the requirements of Regulation 5A of the OPGGS(E)R.

10.1 Operational Excellence Management System

CAPL's operations are managed in accordance with Chevron Corporation's Operational Excellence Management System (OEMS), which is a comprehensive management framework that supports the corporate commitment to protect the safety and health of people and the environment. The OEMS aligns with ISO 14001:2015 Environmental Management Systems – Requirements with Guidance for Use (Ref. 567) and meets the requirements of the OPGGS(E)R.

Operational excellence (OE) systematically manages workforce safety and health, process safety, reliability, and integrity, environment, efficiency, security, and stakeholders to meet the OE objectives and ensure safe operations of CAPL facilities and projects. The OEMS comprises these key components (Figure 10-1):

- **leadership and OE culture**—through the OEMS, CAPL leaders engage employees and contractors to build and sustain the OE culture and deliver OE performance
- **management system cycle**—by applying this cycle, CAPL leaders make risk-based and data-driven decisions, prioritise activities, and direct improvements
- **focus areas and OE expectations** (including common expectations)
  - focus areas are categories of OE risks and include workforce safety and health, process safety, reliability and integrity, environment, efficiency, security, and stakeholder engagement
  - OE expectations guide the design, management, and assurance of the presence and effectiveness of safeguards.

The OEMS outlines the process for identifying, establishing, and maintaining safeguards and assures that they are in place, functioning as intended, and are in accordance with legal and OE requirements. The risk management process (Figure 10-1) assesses and identifies safeguards (hardware and human actions designed to directly prevent or mitigate an incident or impact associated with the project), personnel, and the environment. The assurance process (Figure 10-1) verifies and validates that the safeguards are in place and functioning as intended.

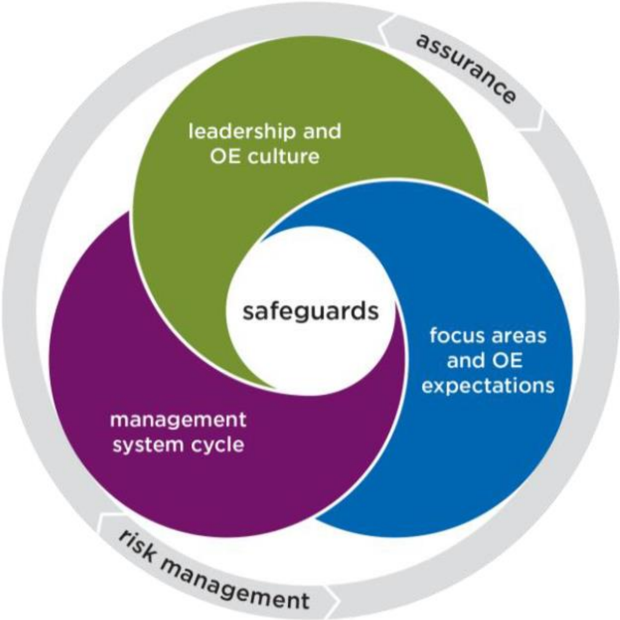

Figure 10-1: Overview of Chevron Corporation's OEMS

10.2 Leadership and OE culture

CAPL leaders demonstrate and are accountable for the consistent and rigorous application of the OEMS to drive performance and manage risks. The actions and visibility of leaders reinforce CAPL's commitment to place the highest priority on the safety and health of its workforce, and on protecting communities, the environment, and the integrity and reliability of its assets.

10.2.1 Roles and accountability

CAPL leaders have overall accountability for implementing the OEMS.

10.2.1.1 Training and competency

Personnel who hold responsibilities relating to implementing this OPP or subsequent EPs are hired by CAPL based on their particular qualifications, experience, and competency.

All external contractor personnel involved with the Development will hold qualifications or training certification relevant to their role, which will be confirmed through the contractor selection process, audits and review processes.

All personnel (including contractors) working on or in connection with the Development are required to attend inductions, relevant to their role, where they will be made aware of their responsibilities.

10.3 Focus areas and OE expectations

The OE expectations are organised into 6 focus areas (Figure 10-2), which provide guidance to design, operate, maintain, improve, and assure the presence and effectiveness of safeguards. Common expectations also apply—these support the OE expectations and focus areas (Figure 10-2).

Figure 10-2: Focus areas and common expectations

Table 10-1 lists the focus areas and common expectations, and related key processes relevant to this Development. Each focus area and common expectation is described in further detail in the following subsections.

Table 10-1: Relevant focus areas and common expectations

Focus area / common expectation	Key processes
Focus area	
Workplace safety and health	• Control of Work Process (Ref. 494) • Chevron Marine Standard Non Tankers (Ref. 284) • ABU Hazardous Materials Management Procedure: ABU Standardised OE Procedure (Ref. 415)
Process safety, reliability and integrity	• OE Information Management: ABU Standardised OE Process (Ref. 568) • Management of Change for Facilities and Operations: ABU Standardised OE Process (Ref. 569) • ABU Surface Equipment Reliability & Integrity Process (SERIP) Base Business Standardized OE Process (Ref. 570)
Environment	• Environment Risk Management Process (Ref. 571) • Environment Risk Assessment and Management Procedure (Ref. 572) • Quarantine Procedure Marine Vessels. ABU Standardised OE Process (Ref. 74)
Stakeholders	• Stakeholder Engagement and Issues Management: ABU Standardised OE Process (Ref. 82)
Common expectation	
Risk management	• ABU OE Risk Management Process (Ref. 274)
Assurance	• OE Assurance Corporate Process (Ref. 573) • OE Data Reporting Standard (Ref. 575)
Incident investigation and reporting	• OE Corporate Standard Incident Investigation (Ref. 576) • Incident Investigation and Reporting (II&R) Execution Manual (Ref. 577)
Emergency management	• Emergency Management OE Process (Ref. 578)

10.3.1 Workplace safety and health

10.3.1.1 Control of work

The Control of Work (CoW) expectation is to assess workplace safety and health hazards and manage the risks associated with carrying out and controlling work performed by CAPL employees and their business partners. The CoW process (Ref. 494) and supporting work authorisation, ensures activities are assessed and undertaken in a safe and consistent manner.

10.3.1.2 Marine

The Chevron Marine Standard Non Tankers (Ref. 284) identifies the requirements and activities necessary to deliver safe, reliable, and efficient third-party marine operations. This process describes key roles and responsibilities for managing marine safety and establishes measurement and verification activities designed to promote a process of continual improvement.

The Chevron Marine Standard Non Tankers applies to all marine vessels, emergency response, and all other (non-bulk petroleum) vessels chartered, owned, or operated by CAPL. The process also applies to vessels contracted by an affiliate or contractor that provide marine support or marine services to CAPL.

10.3.1.3 Hazardous materials

CAPL’s Hazardous Materials Management Procedure (Ref. 415) outlines the process for HSE assessment and approval of hazardous materials. Hazardous materials include those classified as hazardous substances or dangerous goods.

The Hazardous Materials Management Procedure is designed to:

- assess hazardous materials requested for procurement for their HSE risks
- ensure that appropriate controls are identified for using procured hazardous materials and that these controls are communicated to the requestors of the materials and end users at locations within CAPL’s operations
- ensure no product includes CAPL-prohibited ingredients
- ensure substitutes were considered if a product contains CAPL-restricted ingredients.

10.3.2 Process safety, reliability and integrity

10.3.2.1 OE information management

Under the OEMS, compliance records to demonstrate environmental performance will be retained.

The OE Information Management Process (Ref. 466) explains how critical information related to environment, workforce safety and health, process safety, reliability and integrity, efficiency, and security is to be identified, developed, assessed, and maintained so that the workforce has access to, and is using, the most current OE information.

10.3.2.2 Management of change

Management of change expectations are to manage proposed changes to design, equipment, operations and products before they are implemented. In conjunction with the Risk Management Process (Section 10.3.5), the Management of Change for Facilities and Operations Process (Ref. 569) is followed to document and assess the impact of changes to activities described in this OPP.

These changes will be addressed to determine if there is potential for any new or increased environmental impact or risk not already provided for in this OPP. In the EP phase, the trigger for resubmission of an EP will be evaluated against the requirements of Regulation 17 of the OPGGS(E)R.

10.3.2.3 Surface Equipment Reliability & Integrity Process

The ABU Surface Equipment Reliability & Integrity Process (SERIP) (Ref. 570) sets the expectations for CAPL's Asset Integrity Program to verify that equipment, components, and systems perform their required functions across their full asset lifecycle and provides guidance in alignment with the Chevron Tenets of Operation and the company's commitment to OE to achieve integrity and reliability excellence in our operations.

This process includes principles of continuous improvement with the intent of assisting operating facilities in achieving best-in-class performance within the industry over time. SERIP supports the following OEMS OE Objectives:

- eliminate fatalities, serious injuries, and illnesses
- eliminate high-consequence process safety incidents
- operate with industry-leading reliability.

At the time of writing, Chevron had begun the process to transition from SERIP to Facilities Integrity and Reliability Management (FIRM). This transition is expected to be completed by the end of 2024.

10.3.3 Environment

The environment focus area provides a framework for CAPL to protect the environment using a risk-based approach that addresses potential environmental impacts.

10.3.3.1 Environment risk management process

The Environment Risk Management Process (Ref. 572) provides a framework for CAPL to identify, assess, mitigate, and manage environmental risks, including environment-related community health and social risks, across the life cycle of CAPL assets.

The objectives of the process are to:

- establish standardized methodologies for the data-driven assessment and management of environmental risks
- identify environmental safeguards and mitigation measures, and support prioritization of their verification
- support assurance activities for environmental safeguards and mitigation measures
- maintain environmental information associated with the evaluation of environmental risks
- utilize the Management System Cycle process to identify improvement opportunities for Environment Risk Management Process.

10.3.3.2 Quarantine

The Quarantine Procedure Marine Vessels (Ref. 74) defines the procedure for marine vessels intending to undertake activities in offshore title areas. It provides information about quarantine compliance, including biofouling and ballast water requirements, to CAPL, contractors, and others associated with marine vessels.

10.3.4 Stakeholders

The Stakeholder Engagement and Issues Management Process (Ref. 82) details an integrated approach for engaging stakeholders and managing external stakeholder issues. This process describes key roles and responsibilities for stakeholder engagement, establishes measurement and verification activities designed to monitor the effectiveness of the stakeholder engagement process and to promote continual improvement. Section 3 describes the process undertaken for appropriate consultation with relevant authorities, interested persons or organisations. CAPL will continue to engage with relevant stakeholders as described in Section 3.

10.3.5 Risk management

The Risk Management Process (Ref. 274) assesses and identifies safeguards (hardware and human actions designed to directly prevent or mitigate an incident or event). This process is designed to be consistent with the environmental risk management requirements of ISO 14001 Environmental Management System (Ref. 567) and ISO 31000:2018 Risk management – Principles and guidelines (Ref. 271).

10.3.6 Assurance

Within the OEMS, assurance is a common expectation that supports the OE objective of each focus area. The Assurance Process (Ref. 573) enables CAPL to assure that safeguards are established and functioning; it details:

- a framework for managing verification activities that assure that CAPL complies with applicable legal and OEMS requirements
- a process to identify, report and resolve noncompliance
- the minimum qualifications and organisational capability to carry out this process.

The Assurance Plan (Ref. 574) documents CAPL's integrated assurance system and associated assurance activities by focus area. This plan is reviewed and approved annually and includes:

- a list of OE assurance priorities based on risk
- a schedule of assurance activities to evaluate safeguards and verifications (e.g. reviews, audits, and assurance programs)
- reference to project and asset assurance plans that outline asset-specific assurance activities and risk-based frequency (i.e. field inspection programs, audits, compliance reviews, performance reviews).

Assurance activities focus on infield activities and administrative processes (depending on the activities being undertaken), and assurance priorities (which are based on risk) and demonstrate that EPOs have been met and the activity implemented in accordance with this implementation strategy. A record of all assurance activities undertaken, and the outcomes, are maintained and actions are tracked until closure.

10.3.7 Incident investigation and reporting

The Incident Investigation and Reporting (II&R) Execution Manual (Ref. 577) defines the requirements to report, classify, record, and investigate incidents and near misses, including but not limited to injury, occupational illness, environmental impact, reliability, business disruption, and community concern. This includes the reporting to applicable regulators.

Events that meet the required criteria are recorded in the CAPL incident management system (IMS), which also contains records of associated investigation results. The lessons learned from selected investigations are shared to reduce the likelihood of future comparable events.

Specific incident reporting requirements for this OPP are detailed in Section 10.4.2.

10.3.8 Emergency management

The emergency management arrangements outline a systematic approach for preventing, planning, responding to, and recovering from emergency events and are intended to provide a standardised corporate management and response structure that details emergency management documentation, emergency response organisation (ERO), facilities and equipment, and training and exercises.

The ERO provides a standardised management and response structure for any emergency. Personnel filling roles within this structure may include full-time professionals, but most will be part-time volunteers drawn from across the workforce.

The system used to organise CAPL's emergency management teams is based on the Incident Command System and provides a standardised approach to the coordination of an emergency response across all hazards, including oil spill response. This program is compatible with the Australasian Inter-service Incident Management System (AIIMS) and the National Plan for Maritime Environmental Emergencies (National Plan; Ref. 551) and is consistent with the core aspects presented in the IMO-equivalent courses.

Any subsequent EPs are required to include an Oil Pollution Emergency Plan (OPEP) as per Regulation 14(8) of the OPGGS(E)R.

The Emergency Management Process (Ref. 578) is CAPL's system for managing emergencies. The process ensures CAPL is prepared to respond immediately and effectively to all emergencies involving contractor- or CAPL-owned or -operated assets as defined in their scope of work.

The emergency management process comprises these key elements.

- emergency scenarios, including worst-case, are identified; these scenarios are based on the findings from risk assessments of significant safety, health and environmental hazards and other sources (e.g. historical incidents)
- response plans are developed and maintained to address emergency scenarios

- a reliability program is in place for inspection, testing and preventive maintenance of critical emergency response equipment and systems supporting emergency response plans
- an IMS is in place that is capable of immediately and effectively managing all emergencies
- a training and exercise program, including minimum training and exercise requirements, is developed to establish and maintain emergency response capability
- a crisis management plan is developed to address potential crisis or significant event
- business continuity plans are developed in conformance with the Business Continuity Planning Corporate OE Process (Ref. 579).

The emergency management process and the OPEP prioritise the safety of all personnel and subsequently the protection of the environment and property. All employees, contractors and visitors are required to comply with the emergency management process and OPEP throughout the life of the Development.

10.4 Environmental monitoring and reporting

10.4.1 Environmental monitoring

Monitoring will be undertaken to demonstrate that CAPL complies with regulatory requirements specified in the OPP and subsequent EPs. The goals of monitoring activities are to:

- monitor discharges and emissions
- identify changes to the environment as a result of Development activities
- provide continuous review of procedures and activities.

Monitoring programs will be described in detail in subsequent EPs. The OSMP will be included with subsequent EPs and will describe a program of monitoring to determine the extent, severity, and persistence of environmental impacts from emergency conditions and emergency response activities undertaken by CAPL.

10.4.2 Incident reporting

Regulation 26A (4) of the OPGGS(E)R requires the reporting of incidents in subsequent EPs.

A reportable incident, as defined under the OPGGS(E)R is an incident relating to the activity that

> ‘has caused, or has the potential to cause, moderate to significant environmental damage.’

NOPSEMA will be notified of all reportable incidents as per Regulations 26, 26A and 26AA.

Environmental incident reporting requirements are covered in the II&R Execution Manual (Ref. 577) outlined in Section 10.3.7.

Other reporting requirements are shown in Table 10-2.

Table 10-2: Other incident reporting requirements

Reporting requirement	Reporting to	Timing
An oil/gas pollution incident that occurs within a marine park or is likely to impact on a marine park. The notification should include: • titleholder details • time and location of the incident (including name of marine park likely to be affected) • proposed response arrangements as per the OPEP (e.g. dispersant, containment, etc.) • confirmation of providing access to relevant monitoring and evaluation reports when available • contact details for the response coordinator.	DNP (24-hour) Marine Compliance Duty Officer Phone: 0419 293 465.	As soon as practicable
Death or injury to individual(s) from an EPBC Act Listed Species as a result of the petroleum activities	Report injury to or mortality of EPBC Act Listed Threatened or Migratory species to DCCEEW or equivalent: • Phone: +61 2 6274 1111 • Email: EPBC.Permits@environment.gov.au	Within 7 business days of observation
Vessel collision with marine megafauna	DCCEEW: • https://data.marinemammals.gov.au/report/shipstrike	As soon as practicable
Presence of any suspected IMP or disease	DPIRD: • Email: biosecurity@fish.wa.gov.au • Phone: FishWatch 24-hour hotline: 1800 815 507	Within 24 hours of confirmation

10.4.3 Routine environmental reporting

Regulation 26C of the OPGGS(E)R requires environmental performance reporting for activities described in subsequent EPs, including recordable incidents. These are summarised in Table 10-3.

Table 10-3: Routine external reporting requirements

Reporting requirement	Description	Reporting to	Timing
Environmental performance	A report detailing environmental performance of the activity detailed in an EP	NOPSEMA submissions@nopsema.gov.au Phone: +61 8 6461 7090	Annually
Recordable incident	Report includes details of recordable incidents (if any) that have occurred during the petroleum activity for the previous month		Monthly

10.5 Implementing requirements of the OPP in subsequent EPs

NOPSEMA's Offshore Project Proposal Content Requirements (Ref. 11) states that EPOs must be consistent with the principles of ESD and demonstrate that the environmental impacts and risks of the project will be managed to an acceptable level.

Control measures detail how EPOs will be achieved and are provided in subsequent EPs. EPs must have EPSs set with appropriate measurement criteria to monitor the performance of the control measures and determine whether the EPOs and EPSs have been met during the activity.

The impact and risk assessments in this OPP are based on conservative assumptions of Development activities, as understood at the time of writing. Evaluations in subsequent EPs will revalidate levels of impact and risk and acceptability, as needed.

This implementation strategy will have further detail added in subsequent EPs. The strategy will ensure control measures are effective in reducing the environmental impacts and risks of the activity to ALARP and acceptable levels, and that EPOs and EPSs are continually met.

11 Acronyms, abbreviations and definitions

Table 11-1 defines the acronyms, abbreviations and terminology used in this document.

Table 11-1: Acronyms and abbreviations

Acronym / abbreviation	Definition
~	Approximately
″	Inch
<	Less / fewer than
>	Greater / more than
≥	Greater / more than or equal to
µg	Microgram
µm	Micrometre. 1 µm = 10^{-6} metre = 0.000001 metre or one millionth of a metre.
µPa	Micropascal
3D	Three-dimensional
AASM	Airgun Array Source Model
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABU	Australian Business Unit
ACHIS	Aboriginal Cultural Heritage Inquiry System
ADD	Acoustic deterrent devices
AFMA	Australian Fisheries Management Authority
AHO	Australian Hydrographic Office
AIIMS	Australasian Inter-service Incident Management System
AIMS	Australian Institute of Marine Science
ALARP	As low as reasonably practicable
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
ANSI	American National Standards Institute
ANZG	Australian and New Zealand Guidelines
API	American Petroleum Institute
AR6	Sixth Assessment Report (AR6) of the United Nations Intergovernmental Panel on Climate Change (IPCC)
AS	Australian Standard
AUSCOAST	Australian Coastal (weather warning)
AUV	Autonomous underwater vehicle
barg	Bar gauge
BC Act	Western Australian *Biodiversity Conservation Act 2016*
BIA	Biologically important area
boe	Barrel of oil equivalent
BOP	Blowout preventer

Acronym / abbreviation	Definition
BRS	Commonwealth Bureau of Rural Sciences
BTEX	Benzene, toluene, ethylbenzene, and xylene
C&D	Chrysaor and Dionysus
CALM Act	Western Australian *Conservation and Land Management Act 1984*
CAMBA	China Australia Migratory Birds Agreement
CAPEX	Capital expenditure
CAPL	Chevron Australia Pty Ltd
CCS	Carbon capture and storage
CDU	Controls Distribution Unit. For the distribution of hydraulics, electrical power, chemicals and communications; refers to new units in the backfill fields that will be termination points for the umbilicals from the FCS or existing subsea infrastructure and where the umbilicals split to link components such as production manifolds.
CEFAS	Centre for Environment, Fisheries and Aquaculture Science (UK)
CER	Clean Energy Regulator
CH_4	Methane
CIA	Cumulative impact assessment
cm	Centimetre
CM	Control measure
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
CoW	Control of Work
cP	Centipoise
CPT	Cone penetration test
Critical behaviour	Critical life functions, such as reproduction, feeding, migration or resting, of protected marine species within BIAs. Also referred to as biologically important behaviours.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Cth	Commonwealth of Australia (Australian Government)
DAFF	Department of Agriculture, Fisheries and Forestry
DAWE	Former Commonwealth Department of Agriculture, Water and the Environment (now DCCEEW)
dB	decibel
DBCA	Department of Biodiversity, Conservation and Attractions (WA)
DC	Drill Centre. Refers to a central location from which several subsea wells are drilled. Some fields have more than one DC.
DCCEEW	Department of Climate Change, Energy, the Environment and Water (Cth)
DGV	Default guideline value
DISER	Department of Industry, Science, Energy and Resources (Cth) (now DISR)
DISR	Department of Industry, Science and Resources (Cth)

Acronym / abbreviation	Definition
DMIRS	Department of Mines, Industry Regulation and Safety (WA)
DNP	Director of National Parks
DoT	Department of Transport (WA)
DP	Dynamic positioning
DPE	Department of Planning and Environment (NSW)
DPIRD	Department of Primary Industries and Regional Development (WA)
DWER	Department of Water and Environmental Regulation (WA)
DWS	Diamond wire saw
e.g.	For example
EEZ	Exclusive economic zone
EFL	Electrical flying lead
EIS	Environmental Impact Statement
EJ	Exajoule
EMBA	Environment that may be affected
eNGO	Environmental nongovernmental organisations
EP	Environment Plan
EP Act	Western Australian *Environmental Protection Act 1986*
EPBC 2003/1294	Gorgon Gas Development/Barrow Island
EPBC 2005/2184	Jansz Feed Gas Pipeline
EPBC 2008/4178	Gorgon Gas Development Revised
EPBC 2011/5942	Gorgon Fourth Train Expansion
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EPO	Environmental performance outcome
EPRS	Emergency pipeline repair system
EPS	Environmental performance standard
ERMP	Environmental Review and Management Programme
ERO	Emergency Response Organisation
ESD	Ecologically sustainable development
FCGT	Flood, clean, gauge and testing
FCS	Field control station
Feed Gas Pipeline	Pipeline system from the Gorgon and Jansz–Io gas wells to the Gas Treatment Plant
FIRM	Facilities Integrity and Reliability Management
Flowline	For the transport of production fluids; refers to new Backfill Fields Development infrastructure, connecting DCs/production manifolds to production pipelines.
FMT	Flow Management Tool
FPSO	Floating production storage and offloading
FTU	Formazin Turbidity Unit

Acronym / abbreviation	Definition
G&E	Geryon and Eurytion
g/m^2	Grams per square metre
GDA	Geocentric Datum of Australia
GES	Greater East Spar
GFP	Gorgon Foundation Project
GHG	Greenhouse gas
GHGMP	Greenhouse Gas Management Plan
GS2	Gorgon Stage 2
Gt	Gigatonne
GT	Gross tonnage
GTP	Gas treatment plant
GW	Gigawatt
h	Hour
ha	Hectare
HFL	Hydraulic flying lead
Hg	Mercury
HIRA	Hazard identification and risk assessment
HSE	Health, safety, and environment
HWM	High water mark
Hz	Hertz
i.e.	That is
IAOGP	International Association of Oil and Gas Producers
IBC	Intermediate bulk container
IBRA	Interim Biogeographic Regionalisation of Australia
IEA	International Energy Agency
IEE	International energy efficiency
II&R	Incident investigation and reporting
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
IMO	International Maritime Organization
IMP	Invasive marine pest
IMR	Inspection, maintenance and repair
IMS	Incident management system
in	inch
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
JAMBA	Japan Australia Migratory Birds Agreement
J-IC	Jansz–Io Compression

Acronym / abbreviation	Definition
Jumpers and spools	For the transport of production fluids; for example, connecting production wells to production manifolds.
KEF	Key ecological feature
kg	Kilogram
kHz	Kilohertz
km	Kilometre
kV	Kilovolt
L	Litre
LC50	Lethal concentration with the potential to result in a 50% mortality of a sample population
LGM	Last glacial maximum
LNG	Liquefied natural gas
LOC	Loss of containment
LOWC	Loss of well control
lux	A standard for measuring light; equal to the amount of visible light per square metre incident on a surface. 1 lux = 1 lumen/square metre
m	Metre
m^3	For liquids: Cubic metres For gases: Standard cubic metres (Sm^3) measured at 0 barg
MAOP	Maximum allowable operating pressure
MARPOL	The International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978; also known as MARPOL 73/78.
MASS	Marine Autonomous Surface Ship
MBES	Multibeam echo sounder
MDO	Marine diesel oil
MEG	Monoethylene glycol
MEG pipeline	For the transport of MEG and other chemicals to the production system; may be used for the utility service.
MFE	Mass flow excavation
mg	Milligram
MGO	Marine gas oil
mm	Millimetre
MM	Million
MMscf/d	Million standard cubic feet per day (of gas). 1 MMscf/d = 1180 Sm^3/h (standard cubic metres per hour)
MNES	Matters of national environmental significance
MODU	Mobile offshore drilling unit
MOPU	Mobile operational production unit
MoU	Memorandum of Understanding
MPTS	Midline pipeline termination structure

Acronym / abbreviation	Definition
MS 1002	Ministerial Statement 1002 – Gorgon Gas Development Fourth Train Expansion Proposal
MS 1198	Ministerial Statement 1198 – Gorgon Gas Development Revised and Expanded Proposal
MS 748	Ministerial Statement 748 –Gorgon Gas Development Barrow Island Nature Reserve
MS 1136	Ministerial Statement 1136 – Gorgon Gas Development Revised and Expanded Proposal Barrow Island Nature Reserve
MS 769	Ministerial Statement 769 – Jansz Feed Gas Pipeline – Barrow Island Nature Reserve
MS 800	Ministerial Statement 800 – Gorgon Gas Development Revised and Expanded Proposal Barrow Island Nature Reserve
MS 865	Ministerial Statement 865 – Gorgon Gas Development Revised and Expanded Proposal Barrow Island Nature Reserve
MS 965	Ministerial Statement 965 – Gorgon Gas Development – Barrow Island
Mt	Million tonnes
Mtpa	Million tonnes per annum
N/A	Not applicable
NADF	Nonaqueous drilling fluids
NCVA	National conservation values atlas
NDC	Nationally determined contribution
NEPM	National Environmental Protection Measure
NGER Act	Commonwealth *National Greenhouse and Energy Reporting Act 2007*
NIS	Non-indigenous species
nm	Nautical mile
NMVOC	Non-methane volatile organic compound
NNM	Not normally manned
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOPSEMA	National Offshore Petroleum Safety and Environment Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
NORM	Naturally occurring radioactive material
NO_x	Nitrous oxides
NTGAC	Nganhurra Thanardi Garrbu Aboriginal Corporation
NWMR	North-west Marine Region
NWS	North West Shelf (of Western Australia)
NWSTF	North West Slope Trawl Fishery
NZS	New Zealand Standard
O_3	Ozone
OA	Operational area

Acronym / abbreviation	Definition
OCNS	Offshore Chemical Notification Scheme
OCV	Offshore construction vessel
ODS	Ozone-depleting substance
OE	Operational Excellence
OEMS	Operational Excellence Management System
OHS	Occupational health and safety
OPEP	Oil Pollution Emergency Plan
OPGGS Act	Commonwealth *Offshore Petroleum and Greenhouse Gas Storage Act 2006*
OPGGS(E)R	Commonwealth *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009*
OPP	Offshore Project Proposal
OSMP	Operational and Scientific Monitoring Plan
OSV	Offshore support vessel
P&A	Plug and abandonment
PAH	Polycyclic aromatic hydrocarbon
PCPT	Piezocone penetration test
PER	Public environmental review
Pipeline termination structure	For the commingling of production fluids; may refer to existing GFP infrastructure or a new pipeline termination structure in the backfill fields
PLEM	Pipeline end manifold
PLET	Pipeline end termination
PLONOR	Pose little or no risk
PLV	Pipelay vessel
PM	Particulate matter
$PM_{2.5}$	Particulate matter with a diameter of 2.5 micrometres or less
PNEC	Predicted no-effect concentration
POB	Personnel on board
ppb	Parts per billion
ppm	Parts per million
Production pipeline	For the transport of production fluids; refers to the existing Jansz and Gorgon Feed Gas Pipelines associated with the GFP.
PSZ	Petroleum safety zone
PTS	Permanent threshold shift
RNTBC	Registered Native Title Body Corporate
ROKAMBA	Republic of Korea Migratory Birds Agreement
ROV	Remotely operated vehicle
RTM	Response Time Model
SCSt	Subsea compression station
SIMAP	Spill Impact Mapping and Analysis Program

Acronym / abbreviation	Definition
SNA	Safe navigation area
SO	Sulfur monoxide
SO_2	Sulfur oxides
SO_3	Sulfur trioxide
SoE	State of the Environment
SOPEP	Ship Oil Pollution Emergency Plan
SPL	Sound pressure levels
SSPLR	Subsea pig launcher receiver
SSS	Side-scan sonar
STFL	Steel tube flying lead
t	Tonne
TEC	Threatened ecological community
TJ	Terajoules
TLP	Tension-leg platform
TSS	Total suspended solids
TTS	Temporary threshold shift
UCH	Underwater cultural heritage
UCH Act	*Underwater Cultural Heritage Act 2018* (Cth)
Umbilical	For the transfer of electricity; electrohydraulic umbilicals incorporate hydraulic power, electric power and a fibre-optic control link.
UN SDG	United Nations Sustainable Development Goal
UNFCCC	United Nations Framework Convention on Climate Change
UXO	Unexploded ordnance
VSP	Vertical seismic profiling
WA	Western Australia
WAFIC	Western Australian Fishing Industry Council Inc
WBF	Water-based fluid
WDTF	Western Deep Trawl Fishery
WOMP	Well operations management plan
WTBF	Western Tuna and Billfish Fishery
WTR	West Tryal Rocks

12 References

Table 12-1 lists documentation directly referenced in this document or recommended as a source of background information.

Table 12-1: References

Ref. No.	Description	Document ID
1.	Chevron Australia. 2005. *Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Gorgon Gas Development*. Chevron Australia, Perth, Western Australia. Available from: https://australia.chevron.com/-/media/australia/our-businesses/documents/Draft-EIS-ERMP_full-report.pdf	
2.	Chevron Australia. 2008. *Gorgon Gas Development Revised and Expanded Proposal Public Environmental Review*. Chevron Australia, Perth, Western Australia.	
3.	Mobil Australia Resources Limited. 2005. *Referral of a Proposal to the Environmental Protection Authority under Section 38(1) of the Environmental Protection Act – Jansz Feed Gas Pipeline*. 7 February 2005, Mobil Australia, Perth, Western Australia.	
4.	Mobil Exploration and Producing Australia Pty Ltd. 2006. *Referral of Proposed Action – Jansz Feed Gas Pipeline*. [Referral under EPBC Act to Department of Environment, Water, Heritage and the Arts]. 17 June 2005, Mobil Australia, Perth, Western Australia.	
5.	Chevron Australia. 2014. *Gorgon Gas Development Fourth Train Expansion Proposal Public Environmental Review / Draft Environmental Impact Statement*. Chevron Australia, Perth, Western Australia.	
6.	Chevron Australia. 2013. *Gorgon Gas Development and Jansz Feed Gas Pipeline: Offshore Feed Gas Pipeline Installation Management Plan*. Chevron Australia, Perth, Western Australia. [Accepted by NOPSEMA on 27 September 2013].	G1-NT-PLNX0000298
7.	Chevron Australia. 2020. *Gorgon Gas Development: Pipeline and Subsea Infrastructure Installation and Pre-commissioning Environment Plan*. Chevron Australia, Perth, Western Australia. [Accepted by NOPSEMA on 10 November 2020]	GOR-COP-02908
8.	Chevron Australia. 2021. *Gorgon and Jansz Feed Gas Pipeline and Wells Operations (Commonwealth waters) Environment Plan*. Chevron Australia, Perth, Western Australia. [Accepted by NOPSEMA on 21 April 2021].	GOR-COP-0902
9.	Chevron Australia. 2018. *Gorgon and Jansz–Io Drilling, Completions and Well Maintenance Program: Environment Plan*. Chevron Australia, Perth, Western Australia. [Accepted by NOPSEMA on 19 December 2018].	ABU140800133
10.	Chevron Australia. 2020. *Gorgon Operations: Gorgon and Jansz Feed Gas Pipeline Operations Environment Plan (State)*. Chevron Australia, Perth, Western Australia. [Accepted by DMIRS on 13 November 2020].	GOR-COP-0901
11.	NOPSEMA. 2020. *Offshore project proposal content requirements*. Guidance Note. National Offshore Petroleum Safety and Environmental Management Authority, Perth, Western Australia. Available from: https://www.nopsema.gov.au/sites/default/files/documents/2021-03/A473026.pdf [Accessed: August 2023].	N-04790-GN1663 A473026
12.	NOPSEMA. 2020. *Offshore project proposal assessment*. Policy. National Offshore Petroleum Safety and Environmental Management Authority, Perth, Western Australia. Available from: https://www.nopsema.gov.au/sites/default/files/documents/2021-03/A469720.pdf [Accessed: August 2023].	N-04790-PL1650 A469720

Ref. No.	Description	Document ID
13.	DoE. 2018. *Threat Abatement Plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans.* Department of the Environment, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/tap-marine-debris-2018.pdf [Accessed September 2023].	
14.	Commonwealth of Australia. 2017. *National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna.* Department of the Environment and Energy, Commonwealth of Australia. Available from: https://www.dcceew.gov.au/sites/default/files/documents/vessel-strike-strategy.pdf [Accessed: August 2022].	
15.	DoE. 2017. *National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna 2017*. Department of the Environment, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/vessel-strike-strategy.pdf [Accessed: September 2023].	
16.	DoE. 2015. *Conservation Management Plan for the Blue Whale (2015-2025), A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999.* Department of the Environment, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/blue-whale-conservation-management-plan.pdf [Accessed May 2023].	
17.	TSSC. 2015. *Conservation Advice Balaenoptera physalus fin whale.* Threatened Species Scientific Committee. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/37-conservation-advice-01102015.pdf [Accessed: September 2023].	
18.	TSSC. 2015. *Conservation Advice Balaenoptera borealis sei whale.* Threatened Species Scientific Committee. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/34-conservation-advice-01102015.pdf [Accessed: September 2023].	
19.	DSEWPaC. 2012. *Conservation Management Plan for the Southern Right Whale. A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 2011-2021*. Department of Sustainability, Environment, Water, Population and Communities, Canberra, ACT. Available from: http://www.environment.gov.au/resource/conservation-management-plan-southern-right-whale-recovery-plan-under-environment [Accessed October 2023]	
20.	DCCEEW. 2022. *Draft National Recovery Plan for the Southern Right Whale*. Department of Climate Change, Energy, the Environment and Water, Canberra, ACT. Available from: https://www.dcceew.gov.au/sites/default/files/documents/draft-national-recovery-plan-southern-right-whale.pdf [Accessed October 2023]	
21.	Commonwealth of Australia. 2017. *Recovery Plan for Marine Turtles in Australia, 2017-2027*. Department of the Environment and Energy, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/recovery-plan-marine-turtles-2017.pdf [Accessed January 2023].	
22.	DoE. 2008. *Conservation advice for Dermochelys coriacea (Leatherback Turtle).* Department of the Environment, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/biodiversity/threatened/species/pubs/1768-conservation-advice.pdf [Accessed September 2023].	
23.	DSEWPaC. 2011. *Approved Conservation Advice for Aipysurus foliosquama (Leaf-scaled Sea Snake).* Department of Sustainability, Environment, Water,	

Ref. No.	Description	Document ID
	Population and Communities. Threatened Species Scientific Committee. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/1118-conservation-advice.pdf. [Accessed March 2024].	
24.	DSEWPaC. 2011. *Approved Conservation Advice for Aipysurus apraefrontalis (Short-nosed Sea Snake)*. Department of Sustainability, Environment, Water, Population and Communities. Threatened Species Scientific Committee. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/1115-conservation-advice.pdf [Accessed September 2023].	
25.	DoE. 2015. *Sawfish and River Sharks Multispecies Recovery Plan.* Department of the Environment, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/environment/biodiversity/threatened/publications/recovery/sawfish-river-sharks-multispecies-recovery-plan [Accessed: September 2023].	
26.	DEWHA. 2009. *Approved Conservation Advice on Pristis clavate (Dwarf Sawfish).* Department of the Environment, Water, Heritage and the Arts, Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/68447-conservation-advice.pdf [Accessed: September 2023].	
27.	DoE. 2014. *Approved Conservation Advice for Pristis pristis (largetooth sawfish).* Department of the Environment, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/60756-conservation-advice.pdf [Accessed: September 2023].	
28.	DEWHA. 2008. *Approved Conservation Advice for Green Sawfish*. Department of the Environment, Water, Heritage and the Arts, Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/68442-conservation-advice.pdf [Accessed: September 2023].	
29.	DoE. 2014. *Recovery Plan for the Grey Nurse Shark (Carcharias taurus).* Department of the Environment, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/environment/biodiversity/threatened/recovery-plans/recovery-plan-grey-nurse-shark-carcharias-taurus-2014 [Accessed: September 2023].	
30.	TSSC. 2015. *Conservation Advice Rhincodon typus Whale shark.* Threatened Species Scientific Committee, Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/66680-conservation-advice-01102015.pdf [Accessed: April 2022]	
31.	DSEWPaC. 2013. *Recovery Plan for the White Shark (Carcharodon carcharias).* Department of Sustainability, Environment, Water, Population and Communities, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/white-shark.pdf [Accessed: September 2023].	
32.	DEWHA. 2008. *Approved Conservation Advice for Ophisternon candidum (Blind Cave Eel).* Department of Environment, Water, Heritage and the Arts. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/66678-conservation-advice.pdf. [Accessed March 2024].	
33.	DEWHA. 2008. *Approved Conservation Advice for Milyeringa veritas (Blind Gudgeon).* Department of Environment, Water, Heritage and the Arts. Australian Government, Canberra, Australian Capital Territory. Available from:	

Ref. No.	Description	Document ID
	http://www.environment.gov.au/biodiversity/threatened/species/pubs/66676-conservation-advice.pdf [Accessed March 2024].	
34.	DCCEEW. 2023. *National Light Pollution Guidelines for Wildlife*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/national-light-pollution-guidelines-wildlife.pdf [Accessed: August 2023].	
35.	DAWE. 2020. *Wildlife Conservation Plan for Seabirds, Commonwealth of Australia 2020*. Department of Agriculture, Water and the Environment, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/wildlife-conservation-plan-for-seabirds.pdf [Accessed: September 2023].	
36.	DoE. 2015. *Wildlife Conservation Plan for Migratory Shorebirds*. Department of the Environment, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/widlife-conservation-plan-migratory-shorebirds.pdf [Accessed March 2023].	
37.	DCCEEW. 2022. *National Recovery Plan for albatrosses and petrels (2022)*. Department of Climate Change, Energy, the Environment and Water, Canberra, ACT. Available from: https://www.dcceew.gov.au/sites/default/files/documents/national-recovery-plan-albatrosses-and-petrels-2022.pdf	
38.	TSSC. 2020. *Conservation Advice for the Abbott's Booby - Papasula abbotti.* Threatened Species Scientific Committee. Department of Agriculture, Water and the Environment, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/59297-conservation-advice-19102020.pdf [Accessed March 2024].	
39.	DCCEEW. 2024. *Conservation Advice for Limnodromus semipalmatus (Asian dowitcher*). Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/843-conservation-advice-05012024.pdf. [Accessed March 2024].	
40.	DSEWPaC. 2011. *Approved Conservation Advice for Sternula nereis nereis (Fairy Tern)*. Department of Sustainability, Environment, Water, Population and Communities. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/82950-conservation-advice.pdf. [Accessed March 2024].	
41.	DAWE. 2020. *National Recovery Plan for the Australian Fairy Tern (Sternula nereis nereis).* Department of Agriculture, Water and the Environment, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/environment/biodiversity/threatened/publications/recovery/fairy-tern-2022 [Accessed September 2023].	
42.	DSEWPaC. 2013. *Approved Conservation Advice for Rostratula australis (Australian painted snipe).* Department of Sustainability, Environment, Water, Population and Communities. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/77037-conservation-advice.pdf. [Accessed March 2024].	
43.	DoE. 2014. *Conservation Advice Phaethon lepturus fulvus white-tailed tropicbird (Christmas Island).* Department of the Environment. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/26021-conservation-advice.pdf. [Accessed March 2024].	

Ref. No.	Description	Document ID
44.	DCCEEW. 2024. *Conservation Advice for Tringa nebularia (common greenshank).* Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/832-conservation-advice-05012024.pdf. [Accessed March 2024].	
45.	DCCEEW. 2023. *Conservation Advice Calidris ferruginea (curlew sandpiper).* Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/856-conservation-advice-18122023.pdf. [Accessed March 2024].	
46.	DCCEEW. 2023. *Conservation Advice Numenius madagascariensis (far eastern curlew).* Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/847-conservation-advice-18122023.pdf. [Accessed March 2024].	
47.	DCCEEW. 2023. *Conservation Advice for Charadrius leschenaultii (greater sand plover)*. Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/877-conservation-advice-18122023.pdf. [Accessed March 2024].	
48.	DCCEEW. 2020. *Conservation Advice Falco hypoleucos Grey Falcon.* Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/929-conservation-advice-09072020.pdf. [Accessed March 2024]	
49.	TSSC. 2016. *Conservation Advice Pezoporus occidentalis night parrot.* Threatened Species Scientific Committee. Department of Agriculture, Water and the Environment, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/59350-conservation-advice-15072016.pdf. [Accessed March 2024].	
50.	DCCEEW.2024. Conservation Advice for Limosa lapponica menzbieri (Yakutian bar-tailed Godwit). Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/86432-conservation-advice-05012024.pdf. [Accessed March 2024].	
51.	DCCEEW. 2023. *Conservation Advice for Erythrotriorchis radiatus (red goshawk).* Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/942-conservation-advice-31032023.pdf. [Accessed March 2024].	
52.	DCCEEW. 2024. *Conservation Advice Calidris canutus (Red knot)*. Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/855-conservation-advice-05012024.pdf. [Accessed March 2024].	
53.	DCCEEW. 2023. *Conservation Advice for Phaethon rubricauda westralis (Indian Ocean red-tailed tropicbird).* Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/91824-conservation-advice-21122023.pdf. [Accessed March 2024].	

Ref. No.	Description	Document ID
54.	DCCEEW. 2024. *Conservation Advice for Calidris acuminata (sharp-tailed sandpiper).* Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/874-conservation-advice-05012024.pdf. [Accessed March 2024].	
55.	TSSC. 2020. *Conservation Advice Thalassarche cauta Shy Albatross.* Threatened Species Scientific Committee. Department of Agriculture, Water and the Environment, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/89224-conservation-advice-03072020.pdf. [Accessed March 2024].	
56.	TSSC. 2015. *Conservation Advice Pterodroma Mollis soft-plumaged petrel.* Threatened Species Scientific Committee. Department of Agriculture, Water and the Environment, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/1036-conservation-advice-01102015.pdf. [Accessed March 2024].	
57.	DEWHA. 2008. *Approved Conservation Advice for Malurus leucopterus edouardi (White-winged Fairy-wren (Barrow Island))*. Department of Environment, Water, Heritage and the Arts. Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/26194-conservation-advice.pdf. [Accessed March 2024].	
58.	DAWE. 2020. *Australian Ballast Water Management Requirements*. Version 8. Department of Agriculture, Water and the Environment, Canberra, Australian Capital Territory. Available from: https://www.agriculture.gov.au/sites/default/files/documents/australian-ballast-water-management-requirements.pdf [Accessed: March 2021].	
59.	DAWE. 2023. *Australian biofouling management requirements.* Version 2. Department of Agriculture, Water and the Environment, Canberra, Australian Capital Territory. Available from: https://www.agriculture.gov.au/sites/default/files/documents/Australian-biofouling-management-requirements.pdf [Accessed: February 2024]	
60.	DOEE. 2017. *Australian National Guidelines for Whale and Dolphin Watching 2017*. Department of the Environment and Energy, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/aust-national-guidelines-whale-dolphin-watching-2017.pdf [Accessed: August 2022].	
61.	DCCEEW. 2022. *Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2022*. Available from: https://www.dcceew.gov.au/sites/default/files/documents/nggi-quarterly-update-sept-2022.pdf [Accessed: May 2023].	
62.	NOPSEMA. 2020. *Acoustic impact evaluation and management*. Information Paper. National Offshore Petroleum Safety and Environmental Management Authority, Perth, Western Australia. Available from: https://www.nopsema.gov.au/sites/default/files/documents/2021-03/A625748.pdf	N-04750-IP1765 A625748
63.	API. 2021. *Compendium of greenhouse gas emissions methodologies for the natural gas and oil industry*. American Petroleum Institute, Washington, USA.	
64.	DoA. 2015. *Antifouling and in-water cleaning guidelines*. Department of Agriculture. Available from: http://www.agriculture.gov.au/biosecurity/avm/vessels/biofouling/anti-fouling-and-inwater-cleaning-guidelines [Accessed: August 2023].	
65.	ANZG. 2018. *Australian and New Zealand guidelines for fresh and marine water quality*. Australian and New Zealand Governments and Australian state	

Ref. No.	Description	Document ID
	and territory governments. Canberra, Australian Capital Territory. Available from: https://www.waterquality.gov.au/anz-guidelines [Accessed: August 2023].	
66.	Chevron Australia. 2023. *Gorgon Gas Treatment Plant Greenhouse Gas Management Plan*. Chevron Australia, Perth, Australia.	GOR-COP-03025
67.	DoE. 2015. *Wildlife Conservation Plan for Migratory Shorebirds*. Department of the Environment, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/widlife-conservation-plan-migratory-shorebirds.pdf [Accessed March 2023].	
68.	DCCEEW 2023. *Guidelines for working in the near and offshore environment to protect Underwater Cultural Heritage*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://consult.dcceew.gov.au/draft-guidelines-to-protect-uc-heritage [Accessed: August 2023].	
69.	GMI. 2020. *Identifying and Evaluating Opportunities for Greenhouse Gas Mitigation & Operational Efficiency Improvement at Oil and Gas Facilities*. Global Methane Initiative, USA. Available from: https://www.ccacoalition.org/en/resources/identifying-and-evaluating-opportunities-greenhouse-gas-mitigation-operational-efficiency [Accessed: August 2023]	
70.	IMO. 2011. *Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species*. International Maritime Organization, London, United Kingdom.	
71.	International Organisation for Standardisation 2018. *ISO 50001:2018 Energy management systems – Requirements with guidance for use*.	
72.	DoE 2013. *Significant impact guidelines 1.1 – Matters of National Environmental Significance.* Environment Protection and Biodiversity Conservation Act 1999, Department of the Environment, Australian Government, Canberra, Australian Capital Territory. Available from https://www.dcceew.gov.au/environment/epbc/publications/significant-impact-guidelines-11-matters-national-environmental-significance [Accessed July 2022]	
73.	Marine Pest Sectoral Committee. 2018. *National biofouling management guidelines for the petroleum production and exploration industry.* Department of Agriculture and Water Resources, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.marinepests.gov.au/sites/default/files/Documents/petroleum-exploration-biofouling-guidelines.pdf [Accessed March 2023].	
74.	Chevron Australia. 2020. *Quarantine Procedure Marine Vessels. ABU Standardised OE Process.* Chevron Australia, Perth, Western Australia	OE-07.08.1010
75.	DCCEEW. 2023. *National Light Pollution Guidelines for Wildlife*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/national-light-pollution-guidelines-wildlife.pdf [Accessed: August 2023].	
76.	DISR. 2022. *Guideline: Offshore Petroleum Decommissioning*. Department of Industry, Science and Resources, Canberra, Australian Capital Territory. Available from: https://www.nopta.gov.au/_documents/guidelines/decommissioning-guideline.pdf [Accessed: August 2023].	
77.	NOPSEMA. 2023. *Petroleum activities and Australian Marine Parks: A guidance note to support environmental protection and effective consultation*. NOPSEMA/Department of National Parks, Canberra, Australian Capital Territory. Available from: https://www.nopsema.gov.au/sites/default/files/documents/Guidance%20note	

Ref. No.	Description	Document ID
	%20-%20Petroleum%20Activities%20and%20Australian%20Marine%20Parks.pdf [Accessed: August 2023].	
78.	NOPSEMA. 2021. *Planning for proactive decommissioning*. Information Paper. National Offshore Petroleum Safety and Environmental Management Authority, Perth, Western Australia. Available from: https://www.nopsema.gov.au/sites/default/files/documents/2021-12/A816565.pdf [Accessed: August 2023].	N-00500-IP2002 A816565
79.	NOPSEMA. 2020. *Reducing marine pest biosecurity risks through good practice biofouling management*. Information Paper. National Offshore Petroleum Safety and Environmental Management Authority, Perth, Western Australia. Available from: https://www.nopsema.gov.au/assets/Environment-resources/A715054.pdf [Accessed: August 2023].	
80.	Commonwealth of Australia. 2018. *Marine Pest Plan 2018-2023: National Strategic Plan for Marine Pest Biosecurity (2018-2023)*. Department of Agriculture and Water Resources, Canberra, Australian Capital Territory. Available from: https://www.marinepests.gov.au/sites/default/files/Documents/marine-pest-plan-2018-2023.pdf [Accessed: August 2023].	
81.	NOPSEMA. 2022. *Policy: Section 572 Maintenance and removal or property*. National Offshore Petroleum Safety and Environmental Management Authority, Perth, Western Australia. Available from: https://www.nopsema.gov.au/sites/default/files/documents/N-00500-PL1903%20-%20S572%20Maintenance%20and%20Removal%20of%20property%20%28A720369%29.pdf [Accessed: February 2023].	N-00500-PL1903
82.	Chevron Australia. 2021. *Stakeholder Engagement and Issues Management Process: ABU Standardised OE Process*. Chevron Australia, Perth, Western Australia.	OE-10.00.01
83.	DNP. 2018. *North-west Marine Parks Network Management Plan 2018.* Director of National Parks. Canberra, Australian Capital Territory. Available from: https://parksaustralia.gov.au/marine/pub/plans/north-west-management-plan-2018.pdf [Accessed: September 2023].	
84.	CMACS. 2003. A baseline assessment of electromagnetic fields generated by offshore wind farm cables. COWRIE Report EMF - 01-200266.	
85.	DCCEEW. EPBC Act Policy Statement - Staged Developments - Split referrals: Section 74A of the EPBC Act. Available from: https://www.dcceew.gov.au/environment/epbc/publications/epbc-act-policy-statement-staged-developments-split-referrals-section-74a-epbc-act [Accessed: March 2024].	
86.	Asia–Pacific Applied Science Associates. 2012. *Hydrotest Discharge Water Simulation Study.* Unpublished report prepared for Gorgon Upstream Joint Venture, Perth, Western Australia.	
87.	NOPSEMA. 2019. *Environmental Bulletin: Oil spill modelling.* National Offshore Petroleum Safety and Environmental Management Authority, Perth, Western Australia. Available from: https://www.nopsema.gov.au/sites/default/files/documents/2021-04/A652993.pdf [Accessed: May 2023].	
88.	Bonn Agreement. 2016. *Bonn Agreement Aerial Operations Handbook.* Bonn Agreement, London, United Kingdom. Available from: https://www.bonnagreement.org/site/assets/files/1081/aerial_operations_handbook.pdf [Accessed: May 2023].	
89.	French, D., Reed, M., Jayko, K., Feng, S., Rines, H., Pavignano, S.1996. *The CERCLA Type A Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME),* Technical Documentation, Vol. I –	

Ref. No.	Description	Document ID
	Model Description, Final Report. Office of Environmental Policy and Compliance, United States Department of the Interior. Washington, United States of America.	
90.	French McCay, D.P. 2009. State-of-the-art and research needs for oil spill impact assessment modelling. In: *Proceedings of 32nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*, 601–653. Ottawa, Ontario, Canada.	
91.	Engelhardt, F. 1983. Petroleum effects on marine mammals. *Aquatic Toxicology*, 4, 199–217.	
92.	Clark R. 1984. Impacts of oil pollution on seabirds. *Environmental Pollution Series: Ecology and Biology*, 33, 1–22.	
93.	Geraci, J.R. and St. Aubin, D.J. 1988. *Synthesis of Effects of Oil on Marine Mammals*. Report to U.S. Department of the Interior, Minerals Management Service, Atlantic OCS Region, OCS Study. Ventura, California.	
94.	Jenssen, B.M. 1994. Effects of Oil Pollution, Chemically Treated Oil, and Cleaning on the Thermal Balance of Birds. *Environmental Pollution*, 86(2), 207–215	
95.	Carls, M.G., Holland, L., Larsen, M., Collier, T.K., Scholz, N.L. and Incardona, J.P. 2008. Fish embryos are damaged by dissolved PAHs, not oil particles. *Aquatic Toxicology*, 88(2), 121-127.	
96.	Nordtug, T., Olsen, A.J., Altin, D., Overrein, I., Storøy, W., Hansen, B.H. and De Laender, F. 2011. Oil droplets do not affect assimilation and survival probability of first feeding larvae of North-East Arctic cod. *Science of the Total Environment*, 412, 148-153.	
97.	Redman, A.D. 2015. Role of entrained droplet oil on the bioavailability of petroleum substances in aqueous exposures. *Marine Pollution Bulletin*, 97(1-2), 342–348.	
98.	French-McCay D. 2018. *Aquatic Toxicity Thresholds for Oil Spill Risk Assessments*. RPS Ocean Science, Rhode Island.	
99.	Lin, Q. and Mendelssohn, I.A. 1996. A comparative investigation of the effect of South Louisiana crude oil on the vegetation of freshwater, brackish, and salt marshes. *Marine Pollution Bulletin*, 32, 202–209.	
100.	Grant, D.L., Clarke, P.J. and Allaway, W.G. 1993. The response of grey mangrove (Avicennia marina (Forsk.) Vierh) seedlings to spills of crude oil. *The Journal of Experimental Marine Biological Ecology*, 171(2), 273–295.	
101.	Suprayogi, B. and Murray, F. 1999. A field experiment of the physical and chemical effects of two oils on mangroves. *Environmental and Experimental Botany*, 42(3), 221–229.	
102.	EPA. 2016. *Technical Guidance: Protection of Benthic Communities and Habitats*. Environmental Protection Authority, Government of Western Australia. Available from: https://www.epa.wa.gov.au/policies-guidance/technical-guidance-protection-benthic-communities-and-habitats [Accessed: August 2023].	
103.	DSEWPC. 2012. *Marine bioregional plan for the North-west Marine Region* Department of Sustainability, Environment, Water, Population and Communities, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/env/pages/1670366b-988b-4201-94a1-1f29175a4d65/files/north-west-marine-plan.pdf [Accessed: August 2023].	
104.	DEWHA. 2008. *The North-west Marine Bioregional Plan: Bioregional Profile. Parks Australia*. Department of the Environment, Water, Heritage and the Arts, Australian Government, Canberra, Australian Capital Territory. Available from:	

Ref. No.	Description	Document ID
	https://parksaustralia.gov.au/marine/pub/scientific-publications/archive/north-west-bioregional-plan.pdf [Accessed: August 2023].	
105.	Advisian. 2022. *Gorgon Backfill Fields Benthic Survey 2022—Survey Report*. Advisian Pty Ltd, Perth, Western Australia. [Attached as Appendix A to this OPP]	
106.	Baker, C., Potter, A., Tran, M., Heap, A. 2008. *Sedimentology and Geomorphology of the North West Marine Region of Australia*. Geoscience Australia. Canberra, Australian Capital Territory.	
107.	Brewer, DT., Lyne, V., Skewes, T.D. and Rothlisberg, P. 2007. *Trophic systems of the North West Marine Region.* Report to the Australian Government Department of the Environment and Water Resources, CSIRO, Cleveland.	
108.	CSIRO. 2015. *Marine Benthic Substrate Database – CAMRIS – Marsed* Version 1. CSIRO. Data Collection. Available from: https://doi.org/10.4225/08/551485612CDEE [Accessed: August 2023].	
109.	DEH. 2006. *A Guide to the Integrated Marine and Coastal Regionalisation of Australia – IMCRA* Version 4.0. Department of the Environment and Energy and Heritage, Australian Government.	
110.	Falkner, I., Whiteway, T., Przeslawski, R., Heap, A.D. 2009. *Review of ten key ecological features (KEFs) in the North-west Marine Region*. Record 2009/13. Geoscience Australia, Canberra, Australian Capital Territory.	
111.	Commonwealth of Australia. 2007. *A Characterisation of the Marine Environment of the North-west Marine Region.* A summary of an expert workshop convened in Perth, Western Australia. Available from: https://parksaustralia.gov.au/marine/pub/scientific-publications/archive/nw-characterisation.pdf [Accessed: March 2023].	
112.	Geoscience Australia. 2022. *Regional Geology of the Northern Carnarvon Basin*. Report by Geoscience Australia, Australian Government.	
113.	Chevron Australia. 2019. *Jansz Io Compression Benthic Video Footage Review*. Chevron Australia, Perth, Australia.	G7-NT-REPX0000239
114.	Currey-Randall, L.M., Galaiduk, R., Stowar, M., Vaughan, B.I., Miller, K.J. 2021. Mesophotic fish communities of the ancient coastline in Western Australia. *PloS ONE*, 16(4), e0250427.	
115.	Advisian. 2019. *Scarborough Offshore Benthic Marine Habitat Assessment.* Prepared for Woodside Energy Limited by Advisian, Report No. -EN-REP-0001, Perth, Western Australia, February 2019.	
116.	Heyward, A., Rees, M., Wolff, C., Smith, L. 2001. *Exploration of Biodiversity – Data Report on Benthic Habitats and Biological Collections from an Initial Benthic Survey Conducted in the Region of WA-271-P*, Draft Report prepared for Woodside Energy Limited by AIMS.	
117.	Gage, J.D. 1996. Why are there so many species in deep water sediments? *Journal of Experimental Marine Biology and Ecology* 200: pp257–286.	
118.	AIMS. 2014. *Rankin Bank and Glomar Shoals Environmental Survey 2013, Western Australia (WEL).* Australian Institute of Marine Science. Available from: https://apps.aims.gov.au/metadata/view/5dc0829a-c166-4798-96a9-e5e5f16b922a [Accessed: August 2023].	
119.	Abdul Wahab, M.A., Radford, B., Cappo, M. et al. 2018. Biodiversity and spatial patterns of benthic habitat and associated demersal fish communities at two tropical submerged reef ecosystems. *Coral Reefs,* 37, 327–343.	
120.	Sharplies, C., Mount, R., Pedersen, R., Lacey, M., Newton, J., Jaskierniak, D., and Wallace, L. 2009. *The Australian Coastal Smartline Geomorphic and*	

Ref. No.	Description	Document ID
	Stability Map Version 1. Prepared by University of Tasmania, for Geoscience Australia and Department of Climate Change, Australian Government.	
121.	Butler, C., Lucieer, V., Walsh, P., Flukes, E., Johnson, C. 2017. *Seamap Australia [Version 1.0] the development of a national benthic marine classification scheme for the Australian continental shelf.* ISBN: 978-1-925646-61-0.	
122.	DEC. 2007. *Management Plan for the Montebello/Barrow Islands Marine Conservation Reserves 2007-2017*. Management Plan No 55. Department of Environment and Conservation, Western Australian Government, Perth.	
123.	DCCEEW. 2022. *Protected Matters Search Tool*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/epbc/protected-matters-search-tool [Accessed: May 2023].	
124.	Chevron Australia. 2019. *Jansz-Io Soundscape Monitoring_ Marine fauna acoustic detections 1 Jan to 31 Dec 2019*. Chevron Australia, Perth, Australia.	ABU220200056
125.	DISER. 2022. *Conservation Advice: Megaptera novaeangliae humpback whale.* Threatened Species Scientific Committee, Australian Government, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/38-listing-advice-26022022.pdf [Accessed May 2023].	
126.	Jenner, K., Jenner, M., McCabe, K., 2001. Geographical and temporal movements of humpback whales in Western Australian waters. *APPEA Journal* 41, 692–707.	
127.	TSSC. 2015. *Conservation Advice: Megaptera novaeangliae humpback whale.* Threatened Species Scientific Committee, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/biodiversity/threatened/species/pubs/38-conservation-advice-10102015.pdf [Accessed May 2023].	
128.	Irvine, L.G., Thums, M., Hanson, C.E., McMahon, C.R. and Hindell, M.A. 2018. ‘Evidence for a widely expanded humpback whale calving range along the Western Australian coast’. *Marine Mammal Science*, 34(2), 294-310.	
129.	Double, M. C., Andrews-Goff, V., Jenner, K. C. S., Jenner, M-N., Laverick, S. M., et al. 2014. Migratory Movements of Pygmy Blue Whales (Balaenoptera musculus brevicauda) between Australia and Indonesia as Revealed by Satellite Telemetry. *PLoS ONE,* 9(4), e93578.	
130.	Gavrilov A. N., McCauley R. D., Paskos G. and Alexey G. 2018. Southbound migration corridor of Pygmy Blue Whales off the northwest coast of Australia based on data from ocean bottom seismographs. *The Journal of the Acoustical Society of America,* 144, EL281–EL285.	
131.	Double, M.C. Jenner, K.C.S., Jenner, M-N., Ball, I., Laverick, S. and Gales, N., 2012. *Satellite tracking of pygmy blue whales (Balaenoptera musculus brevicauda) off Western Australia. Final Report – May 2012*. Australian Marine Mammal Centre.	
132.	Gales, N., Double, M. C., Robinson, S., Jenner, C., Jenner, M, King, E. & Paton, D. 2010. *Satellite tracking of Australian humpback (Megaptera novaeangliae) and Pygmy Blue Whales (Balaenoptera musculus brevicauda).* 62nd Scientific Committee of the International Whaling Commission (IWC62). Available from: https://www.marinemammals.gov.au/site/assets/files/1080/sc-62-sh21.pdf [Accessed: August 2023].	
133.	Branch, T. A., Matsuoka, K. and Miyashita, T. 2004. Evidence for increases in Antarctic blue whales based on Bayesian modelling. *Marine Mammal Science* 20(4), 726-754.	

Ref. No.	Description	Document ID
134.	Kahn, B., 2007. Blue whales of the Savu Sea, Indonesia. In: *Biannual Marine Mammal Conference –- Blue Whale Workshop*. Cape Town, South Africa. 28 Nov –- 3 Dec 2007	
135.	McCauley R.D. and Jenner C. 2010. *Migratory patterns and estimated population size of pygmy blue whales (Balaenoptera musculus brevicauda) traversing the Western Australian coast based on passive acoustics*. Paper SC/62/SH26 presented to the IWC Scientific Committee.	
136.	Thums, M., Ferreira, L.C., Jenner, C., Jenner, M., Harris, D., Davenport, A., Andrews-Goff, V., Double, M., Moller, L., Attard, C.R.M., Bilgmann, K., Thomson, P.G., and McCauley, R. 2022. Pygmy blue whale movement, distribution and important areas in the Eastern Indian Ocean. *Global Ecology and Conservation*, 35, e02054.	
137.	Gill, P.C., Morrice, M.G., Page, B., Pirzl, R., Levings, A.H., Coyne, M. 2011. Blue whale habitat selection and within-season distribution in a regional upwelling system off southern Australia. *Marine Ecology Progress Series*, 421, 243–263.	
138.	DCCEEW. [n.d.]. *Australian Marine Spatial Information System.* Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: AMSIS - Advanced Map View (arcgis.com) [Accessed: July 2024].	
139.	DoE. 2023. Species Profile and Threats Database: *Dugong dugon - Dugong*. Department of the Environment, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=28 [Accessed December 2023].	
140.	DCCEEW. 2024. Dugongs. Department of Climate Change, Energy, the Environment and Water. Available from: https://www.dcceew.gov.au/environment/marine/marine-species/dugongs [Accessed March 2024].	
141.	DOE. 2023. *Natator depressus in Species Profile and Threats Database.* Department of the Environment, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/sprat [Accessed: August 2023].	
142.	Pendoley, K. L., Schofield, G., Whittock, P. A., Ierodiaconou, D., Hays, G. C. 2014. Protected species use of a coastal marine migratory corridor connecting marine protected areas. *Marine Biology*, 161, 1455–1466	
143.	Chatto, R., Baker, B. 2008. *The distribution and status of marine turtle nesting in the Northern Territory.* Technical Report 77. Parks and Wildlife Service. Department of Natural Resources, Environment, The Arts and Sport, Northern Territory. Available from: https://depws.nt.gov.au/__data/assets/pdf_file/0006/279915/marine_turtle_nesting.pdf [Accessed: August 2023].	
144.	Hodge, W., Limpus, C.J. and Smissen, P. 2007. *Queensland turtle conservation project: Hummock Hill Island Nesting Turtle Study December 2006*. Conservation Technical and Data Report. Volume 2006 Number 9. ISSN 1449-194X. Environmental Protection Agency, Queensland.	
145.	Pendoley, K.L. 2005. *Sea turtles and the environmental management of industrial activities in north-west Western Australia*. Ph.D. Thesis. PhD Thesis, Murdoch University: Perth.	
146.	Pendoley, K., Bell, C., McCracken, R., Ball, K., Sherborne, J., Oates, J., Becker, P., Vitenbergs, A. and Whittock, P. 2014. *Reproductive biology of the Flatback Turtle Natator depressus in Western Australia*. Endangered Species Research, 23: 115–123	

Ref. No.	Description	Document ID
147.	Pendoley Environmental. 2010. *Barrow Island Marine Turtle Track Census Monitoring 2004/05–2009/2010.* Unpublished report for Chevron Australia, Perth, Western Australia.	
148.	Commonwealth of Australia. 2017. Re*covery Plan for Marine Turtles in Australia, 2017-2027*. Department of the Environment and Energy, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/recovery-plan-marine-turtles-2017.pdf [Accessed January 2023].	
149.	Whittock, P., Pendoley, K., Hamann, M. 2014. Inter-nesting distribution of Flatback Turtles Natator depressus and industrial development in Western Australia. *Endangered Species Research* 26, 25–38.	
150.	Whittock, P., Pendoley, K., Hamann, M. 2016 Using habitat suitability models in an industrial setting: the case for internesting flatback turtles. *Ecosphere 7*, 11, e01551. 10.1002/ecs2.1551	
151.	Whittock, P. A., Pendoley, K. L., and Hamann, M. 2016. Using habitat suitability models in an industrial setting: the case for internesting flatback turtles. *Ecosphere* 7(11), e01551.	
152.	Dobbs, K. 2007. Marine turtle and dugong habitats in the Great Barrier Reef Marine Park used to implement biophysical operational principles for the Representative Areas Program. Great Barrier Reer Marine Parks Authority, Australian Government.	
153.	Guinea, M., Sperling J.B., and Whiting S.D. 2006. *Flatback sea turtle inter-nesting habitat in Fog Bay Northern Territory, Australia.* In Proceedings of the 23rd Annual Sea Turtle Symposium on Sea Turtle Biology and Conservation 2003 Kuala Lumpur. 2006. Kuala Lumpur, Malaysia.	
154.	Pendoley Environmental. 2010. Proposed Outer Harbour Development Port Hedland: Satellite Tracking of Flatback Turtles from Cemetery Beach 200–/2010 - Internesting Habitat. Report prepared by Pendoley Environmental Pty Ltd for SKM/BHP Billiton Iron Ore.	
155.	Seminoff, J.A., Allen, C.D., Balazs, G.H., Dutton, P.H., Eguchi, T., Haas, H.L., Hargrove, S.A., MP, J., Klemm, D.L., Lauritsen, A.M., MacPherson, S.L., Opay, P., Possardt, E.E., Pultz, S.L., Seney, E.E., Van Houtan, R.S and Waples, R.S. 2015. Status Review of the Green Turtle (Chelonia mydas) under the U.S. Endangered Species Act. NOAANMFS-SWFSC-539. pp 571.	
156.	Bjorndal, K.A. 1997. Foraging Ecology and Nutrition in Sea Turtles. In: P.L. Lutz and J.A. Musick (eds) The Biology of Sea Turtles, Vol. 1: 199–231. CRC Press, Boca Raton, Florida.	
157.	Chevron Species Profile and Threat Database: *Chelonia mydas — Green Turtle*. Department Australia. 2005. Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Gorgon Development. Chevron Australia, Perth, Western Australia.	
158.	Hatase H, Sato K, Yamaguchi M, Takahashi K and Tsukamoto K (2006) Individual variation in feeding habitat use by adult female green sea turtles (*Chelonia mydas*): Are they obligately neritic herbivores? *Oecologia*, 149: 52-64.	
159.	DCCEEW. 2024. Species Profile and Threat Database*: Eretmochelys imbricata — Hawksbill Turtle*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1766 [Accessed March 2024]	
160.	Miller, J.D., Dobbs, K.A., Limpus, C.J., Mattocks N.J. and André M.L. 1998. Long-distance migrations by the hawksbill turtle, Eretmochelys imbricata, from	

Ref. No.	Description	Document ID
	north-eastern Australia. Wildlife Research 25, 89-95. https://doi.org/10.1071/WR96086	
161.	DCCEEW. 2021. Hawksbill turtle (*Eretmochelys imbricata*). Department of Climate Change, Energy, the Environment and Water. Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/environment/marine/marine-species/marine-turtles/hawksbill [Accessed March 2024]	
162.	Fossette, S., Ferreira, L. C., Whiting, S. D., King, J., Pendoley, K., Shimada, T., Speirs, M., Tucker, A. D., Wilson, P. and Thums, M. 2021. Movements and distribution of hawksbill turtles in the Eastern Indian Ocean. Global Ecology and Conservation. 29. https://doi.org/10.1016/j.gecco.2021.e01713.	
163.	DCCEEW. 2024. Species Profile and Threat Database: *Caretta caretta — Loggerhead Turtle*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1763 [Accessed March 2024]	
164.	Spotila, J.R (2004). *Sea turtles: a complete guide to their biology, behavior, and conservation.* Baltimore, Maryland: The Johns Hopkins University Press and Oakwood Arts.	
165.	Baldwin, R., G. Hughes & R. Prince. 2003. *Loggerhead turtles in the Indian Ocean*. In: Bolten, A. & B. Witherington, eds. Loggerhead sea turtles. Washington: Smithsonian Books.	
166.	Western Australian Department of Environment and Conservation (WA DEC). 2009. *Marine turtles in Western Australia: Loggerhead Turtle*. Available from: http://www.naturebase.net/content/view/2462/1401.	
167.	Limpus, CJ. 2008. *A biological review of Australian Marine Turtles: 1. Loggerhead Turtle Caretta caretta (Linneaus).* Queensland Environment Protection Agency.	
168.	Plotkin, PT, MK Wicksten, and AF Amos. 1993. “Feeding ecology of the loggerhead sea turtle Caretta caretta in the northwestern Gulf of Mexico.” *Marine Biology* 115(1):1.	
169.	Last, P.R., Stevens, J.D. 2009. *Sharks and rays of Australia*. CSIRO Publishing, Collingwood. ISBN-13: 9780674 034112.	
170.	Gleiss, A., Wright, S., Liebsch, N. & Wilson, R. 2013. Contrasting diel patterns in vertical movement and locomotor activity of Whale sharks at Ningaloo Reef. *Marine Biology,* 160, 2981–2992.	
171.	Department of the Environment. 2023. *Rhincodon typus in Species Profile and Threats Database*. Department of the Environment, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/sprat [Accessed: August 2023].	
172.	Sleeman, J.C., Meekan, M.G., Fitzpatrick, B.J., Steinberg, C.R., Ancel, R. and Bradshaw, C.J.A. 2010. Oceanographic and atmospheric phenomena influence the abundance of whale sharks at Ningaloo Reef, Western Australia. *Journal of Experimental Marine Biology and Ecology* 382. 77–81.	
173.	AIMS. 2017. Migration Patterns of Whale Sharks 2005–2008. Australian Institute of Marine Science. Available from: https://apps.aims.gov.au/metadata/view/6c763a30-1603-4be2-b38f-a18c7eb283cf [Accessed: September 2023].	
174.	Wilson, S.G., Polovina, J.J., Stewart, B.S. & Meekan, M.G. 2006. Movements of Whale sharks (Rhincodon typus) tagged at Ningaloo Reef, Western Australia. *Marine Biology,* 148,1157-1166.	
175.	DBCA.2017. *Pilbara Inshore Islands Nature Reserves*. Parks and Wildlife Service, Department of Biodiversity, Conservation and Attractions,	

Ref. No.	Description	Document ID
	Government of Western Australia. Available from: https://parks.dpaw.wa.gov.au/park/pilbara-inshore-islands [Accessed: August 2023].	
176.	DEWHA. 2012. *Species group report card –seabirds and migratory shorebirds.* Department of Sustainability, Environment, Water, Population and Communities, Public Affairs, Canberra, Australian Capital Territory.	
177.	Marchant, S. and Higgins, P.J. (eds) 1990, *Handbook of Australian, New Zealand and Antarctic birds, volume 1: ratites to ducks, part A: ratites to petrels*, Oxford University Press, Melbourne.	
178.	Cannell, B., Hamilton, S. and Driessen, J. 2019. *Wedge-tailed shearwater foraging behaviour in the Exmouth region*. Report for Woodside Energy Ltd. University of Western Australia and Birdlife Australia.	
179.	Department of the Environment. 2023. *Ardenna pacifica in Species Profile and Threats Database.* Department of the Environment, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/sprat. [Accessed: August 2023].	
180.	Morris, K., Burbidge, A.A., Drew, M. and Kregor, G. 2002. *Mammal Monitoring, Barrow Island Nature Reserve October 2002*. Unpublished report for ChevronTexaco, Perth, Western Australia.	
181.	Chevron Australia. 2005. *Gorgon Gas Development and Jansz Feed Gas Pipeline: Terrestrial and Subterranean Baseline State and Environmental Impact Report.* Chevron Australia, Perth, Western Australia.	G1-TE-H-0000-REPX027
182.	Surman, C. A., Nicholson, L. W., and Phillips, R. A. 2018. Distribution and patterns of migration of a tropical seabird community in the Eastern Indian Ocean. *Journal of Ornithology,* 159(3), 867-877.	
183.	Dunlop, J.N., Cheshire, N.B. and Wooler, R.D. 1988. *Observations on the marine distribution of Tropicbirds, Sooty and Bridled Terns, and Gadfly Petrels from the eastern Indian Ocean*. Records of the Western Australian Museum 14(2), 237-247.	
184.	Garnett, S.T., Szabo, J.K. and Dutson, G. 2011. *The Action Plan for Australian Birds 2010*. Birds Australia, CSIRO Publishing, Melbourne.	
185.	DCCEEW. 2024. Species Profile and Threat Database: *Phaethon lepturus lepturus — White-tailed Tropicbird (Indian Ocean)*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=66986 [Accessed March 2024].	
186.	Pennycuick, C.J., Schaffner, F.C., Fuller, M.R., Holliday, H., Obrecht, L., and Sternberg, L. 1990. *Foraging Flights of the White-Tailed Tropicbird (Phaethon lepturus): Radiotracking and Doubly-Labelled Water*. Colonial Waterbirds. 13(2): 96-102. https://doi.org/10.2307/1521574	
187.	Dunlop, J.N., Surman, C.A. and Wooller, R.D. 2001. *The marine distribution of seabirds from Christmas Island*, Indian Ocean, Emu - Austral Ornithology, 101:1, 19-24. http://dx.doi.org/10.1071/MU00060	
188.	DCCEEW. 2024. Species Profile and Threat Database: *Sternula nereis nereis — Australian Fairy Tern*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=82950 [Accessed March 2024]	
189.	Higgins, P.J. & Davies, S.J.J.F. 1996. *Handbook of Australian, New Zealand and Antarctic birds. Volume 3: Snipe to Pigeons*, Oxford University Press, Melbourne.	

Ref. No.	Description	Document ID
190.	Lindsey, T.R. (1986). *The Seabirds of Australia*. North Ryde, NSW: Angus and Robertson.	
191.	Moro, D. and MacAulay, I. [no date]. *A Guide to the Birds of Barrow Island*. Chevron Australia, Perth, Western Australia. Available from: https://www.researchgate.net/publication/276412113_A_guide_to_the_birds_of_Barrow_Island [Accessed August 2023].	
192.	NCVA (2024). NCVA- Interactive Map. National Conservation Values Atlas: Interactive Map. Department of Climate Change, Energy, the Environment and Water. Government of Australia, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf [Accessed March 2024].	
193.	Del Hoyo, J., Elliott, A., Sargatal, J. 1996. *Handbook of the Birds of the World, vol. 3*: Hoatzin to Auks. Lynx Edicions, Barcelona, Spain.	
194.	Surman, C. A., Nicholson, L.W. (2009). *A survey of the breeding seabirds and migratory shorebirds of the Houtman Abrolhos*, Western Australia. Corella 33(4).	
195.	DBCA. 2017. *Shorebirds and seabirds of the Pilbara coast and islands.* Department of Biodiversity, Conservation and Attractions, Government of Western Australia. Available from: https://exploreparks.dbca.wa.gov.au/sites/default/files/2023-03/shorebirds-and-seabirds-of-the-pilbara-coast-and-islands.pdf	
196.	DCCEEW. 2023. Biologically Important Areas of Regionally Significant Marine Species (2023). Spatial database available from: http://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B1F77132E-5A84-4D82-A4DF-4D930AE27AD5%7D [Accessed: August 2023]	
197.	Milton, D.A., G.C. Smith & S.J.M. Blaber. 1996. Variable success in breeding of the Roseate Tern Stern dougallii on the northern Great Barrier Reef. *Emu*.–6:123--131.	
198.	Surman, C.A. and Wooller, R.D. 2003. Comparative feeding ecology of five sympatric terns at a sub-tropical island in the eastern Indian Ocean. *J Zool* 259:219–230	
199.	DCCEEW. 2024. Species Profile and Threat Database: *Megaptera novaeangliae — Humpback Whale*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=38 [Accessed March 2024].	
200.	Thums, M., Waayers, D., Huang, Z., Pattiaratchi, C., Bernus, J. and Meekan, M. 2017. Environmental predictors of foraging and transit behaviour of Flatback Turtles Natator depressus. *Endangered Species Research*, 32: 333-349.	
201.	DCCEEW. 2024. Species Profile and Threat Database: *Chelonia mydas — Green Turtle*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1765 [Accessed March 2024]	
202.	Limpus, C.J. 2002. *Western Australian Marine Turtle Review.* Western Australian Department of Conservation and Land Management. Available from: https://library.dbca.wa.gov.au/static/FullTextFiles/022468.pdf	
203.	Fish and Wildlife Service. 2023. *Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for Green Sea Turtle*. Federal Register: The Daily Journal of the United States Government. Fish and Wildlife Service, 88 FR 46376. Accessed from: https://www.federalregister.gov/documents/2023/07/19/2023-	

Ref. No.	Description	Document ID
	14225/endangered-and-threatened-wildlife-and-plants-designation-of-critical-habitat-for-green-sea-turtle	
204.	EPA. 2016. *Environmental Factor Guideline – Marine Environmental Quality*. Environmental Protection Authority, Government of Western Australia. Available from: https://www.epa.wa.gov.au/sites/default/files/Policies_and_Guidance/Guideline-Marine-Environmental-Quality-131216_2.pdf [Accessed March 2023].	
205.	Chevron Australia. 2010. *Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Wheatstone Project.* Chevron Australia, Perth, Western Australia. Available at: Environmental Approvals — Australia.chevron.com [Accessed: March 2023].	
206.	Wenziker, K., McAlpine, K., Apte, S. and Masini, R. 2006. *North West Shelf Joint Environmental Management Study: Background Quality for Coastal Marine Waters of the North West Shelf, Western Australia.* Technical Report No. 18. CSIRO and Department of Environment, Perth, Western Australia. Available from: http://www.cmar.csiro.au/nwsjems/reports/NWSJEMS_TR18.pdf [Accessed: August 2023].	
207.	Chevron Australia. 2022. *Gorgon Gas Development and Jansz Feed Gas Pipeline Environmental Performance Report 2022*. Available from: https://australia.chevron.com/-/media/australia/our-businesses/documents/gorgon-gas-development-and-jansz-feed-gas-pipeline-environmental-performance-report-2022.pdf [Accessed: September 2023]	ABU210700340
208.	Fields, D.M., Handegard, N.O., Dalen, J., Eichner, C., Malde, K., Karlsen, Ø., Skiftesvik, A.B., Durif, C.M.F., Browman, H.I. and Ratilal. P. 2019. Airgun blasts used in marine seismic surveys have limited effects on mortality, and no sublethal effects on behaviour or gene expression, in the copepod *Calanus finmarchicus*. *ICES Journal of Marine Science*, 76(7), 2033-2044.	
209.	DBCA. 2022. *Islands in the Pilbara – Visitor Guide*. Parks and Wildlife Service, Department of Biodiversity, Conservation and Attractions, Western Australian Government. Available from: https://exploreparks.dbca.wa.gov.au/sites/default/files/2022-04/islands-in-the-pilbara-visitor-guide.pdf [Accessed March 2023].	
210.	DBCA. 2022. *Ningaloo Coast, Nyinggulu – Visitor Guide*. Parks and Wildlife Service, Department of Biodiversity, Conservation and Attractions, Western Australian Government. Available from: https://exploreparks.dbca.wa.gov.au/park/nyinggulara-national-park-ex-ningaloo [Accessed March 2023].	
211.	DBCA. 2023. *Dampier Archipelago island reserves.* Department of Biodiversity, Conservation and Attractions, Western Australian Government. Available from: https://exploreparks.dbca.wa.gov.au/park/dampier-archipelago-island-reserves [Accessed: September 2023].	
212.	DBCA. 2023. *Pilbara Islands Nature Reserves.* Department of Biodiversity, Conservation and Attractions, Western Australian Government. Available from: https://exploreparks.dbca.wa.gov.au/park/pilbara-islands-nature-reserves [Accessed: September 2023].	
213.	YMAC. 2019. *Gnulli native title group celebrates native title win.* Yamatji Marlpa Aboriginal Corporation. Available from: https://www.ymac.org.au/wp-content/uploads/2019/12/191218-Gnulli-Native-Title-Determination-MEDIA-RELEASE-FINAL.pdf [Accessed: September 2023].	
214.	DCCEW. 2021. *About Australia's heritage*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/parks-heritage/heritage/about [Accessed: September 2023].	

Ref. No.	Description	Document ID
215.	Benjamin, J., O'Leary, M., McDonald, J, Wiseman, C., McCarthy, J., Beckett, E., Morrison, P., Stankiewicz, F., Leach, J., Hacker, J., Baggaley, P., Jerbic, K., Fowler, M., Fairweather, J., Jeffries, P., Ulm, S., and Bailey, G. 2020. Aboriginal artefacts on the continental shelf reveal ancient drowned cultural landscapes in northwest Australia. *PLoS ONE* 15(7): e0233912. https://doi.org/10.1371/journal.pone.0233912	
216.	Deckker, P., Moros, M., Perner, K., Blanz, T., Wacker, L., Schneider, R., Barrows, T., O'Loingsigh, T., and Jansen, E. 2020. Climatic evolution in the Australian region over the last 94 ka – spanning human occupancy - and unveiling the Last Glacial Maximum. *Quaternary Science Reviews* 249: 106593. https://doi.org/10.1016/j.quascirev.2020.106593.	
217.	O'Leary, M. J., Paumard, V. and Ward, I. 2020. Exploring Sea Country through high-resolution 3D seismic imaging of Australia's NW shelf: Resolving early coastal landscapes and preservation of underwater cultural heritage. *Quaternary Science Reviews* 239: 106353. https://doi.org/10.1016/j.quascirev.2020.106353	
218.	Veth, P., Ward, I., Manne, T., Ulm, S., Ditchfield, K., Dortch, J., Hook, F., Petchey, F., Hogg, Al., Questiaux, D., Demuro, M., Arnold, L., Spooner, N., Levchenko, V., Skippinton, J., Byrne, C., Basgall, M., Zeanah, D., Belton, D., Helmholz, P., Kendrick, P. 2017. Early human occupation of a maritime desert, Barrow Island, North-West Australia. *Quarternay Science Reviews* 168: 19-29. https://doi.org/10.1016/j.quascirev.2017.05.002	
219.	Benjamin, J., O'Leary, M., McCarthy, J., Reynen, W., Wiseman, C., Leach, J., Bobeldyk, S., Buchler, J., Kermeen, P., Langley, M., Black, A., Yoshida, H., Parnum, I., Stevens, A., Ulm, S., McDonald, J., Veth, P. and Bailey, G. 2023. Stone artefacts on the seabed at a submerged freshwater spring confirm a drowned cultural landscape in Murujuga, Western Australia. *Quaternary Science Reviews* 313: 108190. https://doi.org/10.1016/j.quascirev.2023.108190	
220.	Smyth, D. 1994. *Understanding Country: The Importance of Land and Sea in Aboriginal and Torres Strait Islander Societies*. Canberra, Council for Aboriginal Reconciliation.	
221.	Smyth Dermot. 2007. *Sea Countries of the North-West.* Literature review on Indigenous connection to and uses of the North West Marine Region. Available from: https://parksaustralia.gov.au/marine/pub/scientific-publications/archive/nw-sea-countries.pdf [Accessed: September 2023].	
222.	AIATSIS. (n.d.). *The Marlaloo Songline*. Australian Institute of Aboriginal and Torres Strait Islander Studies. Available from: https://aiatsis.gov.au/explore/marlaloo-songline [Accessed: October 2023]	
223.	Deadly Story (n.d.). *Songlines*. Deadly Story. Available from: https://deadlystory.com/page/culture/Life_Lore/Songlines [Accessed: October 2023]	
224.	Nunn, P. and Reid, N. 2015. Aboriginal Memories of Inundation of the Australian Coast Dating from More than 7000 Years Ago. *Australian Geographer* 47(1):11-47. https://doi.org/10.1080/00049182.2015.1077539.	
225.	Kearney, A., O'Leary, M. and Platten, S. 2023. Sea Country: Plurality and knowledge of saltwater territories in Indigenous Australian contexts. *The Geographical Journal* 189(1): 104-116.https://doi.org/10.1111/geoj.12466.	
226.	Bureau of Meteorology. [n.d.]. *Climate Statistics for Australian Locations.* Summary Statistics Barrow Island (site number 005058). Available at: http://www.bom.gov.au/climate/averages/tables/cw_005058.shtml	
227.	Bureau of Meteorology. [n.d.]. *Climate Statistics for Australian Locations:* Summary Statistics for Onslow (site number 005016). Available from: http://www.bom.gov.au/climate/averages/tables/cw_005016.shtml	

Ref. No.	Description	Document ID
228.	DCCEEW. [n.d.]. *Key Ecological Features in Species Profile and Threats Database*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/sprat-public/action/kef/search [Accessed: January 2023].	
229.	Last, P., Lyne, V., Yearsley, G., Gledhill, D., Gomon, M., Rees, T. and White, W. 2005. *Validation of national demersal fish datasets for the regionalisation of the Australian continental slope and outer shelf (>40 metres depth).* Department of the Environment and Heritage, CSIRO Marine and Atmospheric Research, Hobart. Available from: https://parksaustralia.gov.au/marine/pub/scientific-publications/archive/nmb-fish-report.pdf [Accessed: September 2023].	
230.	Donovan, A., Brewer, D., van der Velde, T. and Skewes, T. 2008. *Scientific descriptions of four selected key ecological features (KEFs) in the north-west bioregion: final report.* A report to the Department of the Environment, Water Heritage and the Arts, CSIRO Marine and Atmospheric Research, Hobart.	
231.	Gunn, J.S., Stevens, J.D., Davis, T.L.O. & Norman, B.M. 1999. Observations on the short-term movements and behaviour of whale sharks (Rhincodon typus) at Ningaloo Reef, Western Australia. *Marine Biology*, 135, 553-559.	
232.	Waples, K. and Hollander, E. 2008. N*ingaloo research progress report: discovering Ningaloo – latest findings and their implications for management.* Ningaloo Research Coordinating Committee, Department of Environment and Conservation, Western Australian Government, Perth.	
233.	DoE. 2023. *Commonwealth waters adjacent to Ningaloo Reef in Species Profile and Threats Database*. Department of the Environment, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/sprat-public/action/kef/view/14;jsessionid=E5A9865E74A072485B13F9F5E10A5A4E [Accessed: July 2023].	
234.	Rees, M., Heyward, A., Cappo, M., Speare, P. and Smith, L. 2004. N*ingaloo Marine Park – initial survey of seabed biodiversity in intermediate and deeper waters.* Report prepared for the Australian Government Department of the Environment and Heritage, Canberra, Australian Capital Territory.	
235.	Sleeman, J.C., Meekan, M.G., Wilson, S.G., Jenner, C.K.S., Jenner, M.N., Boggs, G.S., Steinberg, C.C. and Bradshaw, C.J.A. 2007. Biophysical correlates of relative abundances of marine megafauna at Ningaloo Reef, Western Australia. *Marine and Freshwater Research*, 58, 608-623.	
236.	DoE. 2023. *Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula in Species Profile and Threats Database.* Department of the Environment, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/sprat [Accessed: July 2023].	
237.	DoE. 2023. *Glomar Shoals in Species Profile and Threats Database.* Department of the Environment, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/sprat [Accessed: July 2023].	
238.	Fletcher, W.J. and Santoro, K. 2009. *State of the fisheries report 2008/09.* Western Australian Department of Fisheries, Perth.	
239.	ABARES. 2021. *ABARES Fisheries Status Report map data: All Fisheries combined (ALLFSY): fishing intensity and maximum area fished, annual map data for 2010 to 2020*. ABARES, Canberra, Australian Capital Territory.	
240.	ABARES [n.d.]. *Annual Fishery Status Reports Map Data.* ABARES, Canberra, Australian Capital Territory. Available from: https://www.agriculture.gov.au/abares/research-topics/fisheries/fishery-status/fsr-map-data [Accessed: September 2023].	

Ref. No.	Description	Document ID
241.	ABARES. 2023. Chapter 5: North West Slope Trawl Fishery. In: *ABARES Fishery Status Reports 2023.* Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, Australian Capital Territory. Available from: https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1035183/6 [Accessed: October 2023].	
242.	ABARES. 2021, *ABARES Fisheries Status Report map data: Western Deepwater Trawl Fishery (WDWTF): fishing intensity and maximum area fished, annual map data for 2010 to 2020*. ABARES, Canberra, Australian Capital Territory.	
243.	ABARES. 2022. Chapter 13: Western Deepwater Trawl Fishery. In: *ABARES Fishery Status Reports 2022.* Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, Australian Capital Territory. Available from: https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1034121/0 [Accessed: September 2023].	
244.	ABARES. 2021, *ABARES Fisheries Status Report map data: Western Tuna and Billfish Fishery (WTBF): fishing intensity and maximum area fished, annual map data for 2010 to 2020*. ABARES, Canberra, Australian Capital Territory.	
245.	ABARES. 2023. Chapter 23: Western Tuna and Billfish Fishery. In: *ABARES Fishery Status Reports 2023*. Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, Australian Capital Territory. Available from: https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1035183/24 [Accessed: October 2023].	
246.	ABARES. 2019. *Commonwealth Fisheries Data Extract for 2014-2018*. Available by request from the Australian Bureau of Agricultural and Resource Economics and Sciences from data collected by the Australian Fisheries Management Authority.	
247.	DPIRD. 2020. *Recreational fishing*. Department of Primary Industries and Regional Development, Perth, Western Australia. Available from: https://www.fish.wa.gov.au/Fishing-and-Aquaculture/Recreational-Fishing/Pages/default.aspx [Accessed: March 2023].	
248.	Ryan, K.L., Lai, E.K.M., Smallwood C.B. 2022. *Boat-based recreational fishing in Western Australia 2020/21.* Fisheries Research Report No. 327. Department of Primary Industries and Regional Development, Western Australia. 221pp. Available from: https://www.fish.wa.gov.au/Documents/research_reports/frr327.pdf [Accessed: April 2023].	
249.	DOF. 2009.*Customary Fishing Policy*. Department of Fisheries. Government of Western Australia. Available from: https://www.fish.wa.gov.au/Documents/customary_fishing/customary_fishing_policy.pdf [Accessed: September 2023].	
250.	DPIRD. 2015. *Customary fishing – frequently asked questions*. Department of Primary Industries and Regional Development, Perth, Western Australia. Available from: https://www.fish.wa.gov.au/Fishing-and-Aquaculture/Customary-Fishing/Pages/Customary-Fishing-FAQ.aspx [Accessed: January 2023].	
251.	Tourism Research Australia. 2022. *State Tourism Satellite Account 2020–21: Western Australia summary*. Tourism Research Australia, Canberra Australian Capital Territory. Available from: https://www.tra.gov.au/en/economic-analysis/tourism-satellite-accounts/state-tourism-satellite-account.html [Accessed: September 2023].	
252.	Schianetz, K., Jones, T., Kavanagh, L., Walker, P., Lockington, D., Wood D. 2009. The practicalities of a Learning Tourism Destination: a case study of the Ningaloo Coast. *International Journal of Tourism Research*, 11(6), 567–581.	

Ref. No.	Description	Document ID
253.	DISR. 2023. *Regional Geology of the Northern Carnarvon Basin.* Department of Industry, Science and Resources. Canberra, Australian Capital Territory. Available from: https://www.ga.gov.au/scientific-topics/energy/province-sedimentary-basin-geology/petroleum/acreagerelease/northerncarnarvon [Accessed: September 2023].	
254.	Chevron Australia. 2023. *Jansz-io Subsea Compression Installation Project Overview.* Chevron Australia, Perth, Western Australia. Available at: https://australia.chevron.com/our-businesses/upcoming-activities/jansz-io-compression [Accessed: September 2023].	
255.	Woodside. 2020, *Scarborough Offshore Project Proposal.* Woodside Energy, Perth, Western Australia. Available from: https://docs.nopsema.gov.au/A724553 [Accessed: September 2023].	
256.	Woodside. 2022, *Scarborough Seabed Intervention and Trunkline Installation Environment Plan.* Woodside Energy, Perth, Western Australia. Available from: https://docs.nopsema.gov.au/A1027151 [Accessed: March 2024].	
257.	Woodside. 2021, *Julimar Operations Environment Plan.* Woodside Energy, Perth, Western Australia. Available at: https://docs.nopsema.gov.au/A771970 [Accessed: September 2023].	
258.	Woodside. 2023. *Julimar Development Phase 3 Drilling and Subsea Installation Environment Plan.* Woodside Energy, Perth, Western Australia. Available from: https://docs.nopsema.gov.au/A1040648 [Accessed: March 2024].	
259.	Santos. 2022. *Varanus Island Hub Operations Environment Plan for Commonwealth Waters.* Santos Ltd, Perth, Western Australia. Available from: https://docs.nopsema.gov.au/A850917 [Accessed: September 2023].	
260.	Woodside. 2019. *Pluto Facility Operations Environment Plan Summary.* Woodside Energy, Perth, Western Australia. Available from: https://docs.nopsema.gov.au/A680743 [Accessed: September 2023].	
261.	Chevron Australia. 2022. *Wheatstone Project Start-up and Operations Environment Plan* Chevron Australia, Perth, Western Australia. Available from: https://docs.nopsema.gov.au/A853704 [Accessed: September 2023].	
262.	AHO. 2020. *Fact Sheet: Navigation – Maritime Military Firing Practice and Exercise Areas*. Australian Hydrographic Office, Department of Defence, Australian Government. Available from: https://www.hydro.gov.au/factsheets/FS_Navigation-Firing_Practice_and_Exercise_Areas.pdf [Accessed March 2023].	
263.	Defence. 2022. *Defence Unexploded Ordnance in Australia Mapping Application.* Department of Defence, Australian Government. Available from: https://uxo-map.defence.gov.au/ [Accessed: February 2023].	
264.	Parks Australia. [n.d.]. *Australian Marine Parks.* Parks Australia, Australian Government. Available from: https://parksaustralia.gov.au/marine/ [Accessed: September 2023].	
265.	DPLH. [n.d.]. *Aboriginal Cultural Heritage Inquiry System*. Department of Planning, Lands and Heritage, Perth, Western Australia. Available from https://espatial.dplh.wa.gov.au/ACHIS/index.html?viewer=ACHIS [Accessed October 2023]	
266.	UNESCO. [n.d.]. *Ningaloo Coast.* UNESCO, World Heritage Convention. Available from: https://whc.unesco.org/en/list/1369/ [Accessed: March 2023].	
267.	DCCEEW. 2023. *National Heritage Places – The Ningaloo Coast*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/parks-heritage/heritage/places/national/ningaloo [Accessed: March 2023].	

Ref. No.	Description	Document ID
268.	DCCEEW. [n.d.] *Australasian Underwater Cultural Heritage Database*. Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/parks-heritage/heritage/underwaterheritage/auchd [Accessed October 2023]	
269.	AIATSIS. 2018. *Holborow on behalf of the Yaburara and Mardudhunera People v State of Western Australia (No 3) [2018] FCA 1108*. Available from: https://aiatsis.gov.au/ntpd-resource/1746 [Accessed: October 2023]	
270.	OGUK. 2014. *Guidance on Risk Related Decision Making Issue 2.* Oil and Gas United Kingdom, London, England.	
271.	Standards Australia / Standards New Zealand. 2018. I*SO 31000:2009 Risk management – Principles and guidelines*. Sydney, Australia / Wellington, New Zealand	
272.	Standards Australia / Standards New Zealand. 2012. *HB 203:2012. Managing environment-related risk*. Sydney, Australia / Wellington, New Zealand	
273.	NOPSEMA. 2020. *Guidance Note: ALARP.* National Offshore Petroleum Safety and Environmental Management Authority, Perth, Western Australia. Available from: https://www.nopsema.gov.au/assets/Guidance-notes/A138249.pdf [Accessed: February 2022].	
274.	Chevron Australia. 2020. *ABU OE Risk Management Process*. Chevron Australia, Perth, Western Australia.	OE-03.01.01
275.	Chevron Australia. 2010. *Chevron Wheatstone RT-1 Trials: Trench 2 & 4 – RT-1 Turbidity Measurements Field Report.* Chevron Australia, Perth, Western Australia. (SSS-1005-OP-RPT-035)	
276.	Chevron Australia. 2010. *Chevron Wheatstone RT-1 Trials: Trench 3 – RT-1 Turbidity Measurements Field Report.* Chevron Australia, Perth, Western Australia.	SSS-1005-OP-RPT-031
277.	NERA. 2018. *Environment Plan Reference Case – Anchoring of Vessels and Floating Facilities*. National Energy Resources Australia, Department of Industry, Innovation and Science. Available from: https://referencecases.nera.org.au/Attachment?Action=Download&Attachment_id=224 [Accessed: September 2023].	
278.	Dernie, K. M., Kaiser, M. J., Richardson, E. A., & Warwick, R. M. 2003. Recovery of soft sediment communities and habitats following physical disturbance. *Journal of Experimental Marine Biology and Ecology*, 285, 415-434.	
279.	White, D.J., Leckie, S.H.F., Draper, S. and Zakarian, E. 2015. Temporal Changes in Pipeline-Seabed Condition, and Their Effect on Operating Behaviour. In: *Proceedings of the ASME 2015 34th International Conference on Ocean, Offshore and Arctic Engineering.* Volume 1: Offshore Technology; Offshore Geotechnics. St. John's, Newfoundland, Canada.	
280.	Leckie, S.H.F., Mohr, H., Draper, S., McLean, D.L., White, D.J. and Cheng, L. 2016. Sedimentation-induced burial of subsea pipelines: Observations from field data and laboratory experiments. *Coastal Engineering*, 114, 137–158.	
281.	Fraser, M.W., Short, J., Kendrick, G., McLean, D., Keesing, J., Byrne, M., Caley, J.M., Clarke, D., Davis, A.R., Erftemeijer, P.L.A., Field, S., Gustin-Craig, S., Huisman, J., Keough, M., Lavery, P., Masini, R., McMahon, K., Mengersen, K., Rasheed, M., Statton, J., Stoddart, J., Wu P. 2017. Effects of dredging on critical ecological processes for marine invertebrates, seagrasses and macroalgae, and the potential for management with environmental windows using Western Australia as a case study. *Ecological Indicators*, 78, 229–242.	

Ref. No.	Description	Document ID
282.	Pineda, M.C., Duckworth, A. and Webster, N. 2016. Appearance matters: sedimentation effects on different sponge morphologies. *Journal of the Marine Biological Association of the United Kingdom*, 96, 481–492.	
283.	Fowler, A.M., Chick, R.C. and Stewart, J. 2018. Patterns and drivers of movement for a coastal benthopelagic fish, Pseudocaranx georgianus, on Australia's southeast coast. *Scientific Reports*, 8, 16738.	
284.	Chevron Australia. 2023. *Chevron Marine Standard Non Tankers: Corporate OE Standard.* Chevron Shipping, United States of America.	
285.	Chevron Australia. 2020. *Gorgon Gas Development and Jansz Feed Gas Pipeline Air Quality Management Plan.* Chevron Australia, Perth, Western Australia.	G1-NT-PLNX0000301
286.	BP. 2011. *Shah Deniz 2 Infrastructure Project Environmental & Socio-Economic Impact Assessment*. BP Development Pty Ltd, Azerbaijan. Available from: https://www.bp.com/en_az/azerbaijan/home/news/reports/environmental-and-social-documentation/shah-deniz-/shah-deniz-stage-2.html	
287.	UN Climate Change. n.d. *Glossary*. United Nations Framework Convention on Climate Change. Available from: https://unfccc.int/resource/cd_roms/na1/ghg_inventories/english/8_glossary/Glossary.htm [Accessed: November 2023]	
288.	CER. [n.d.]. *Greenhouse gases and energy*. Clean Energy Regulator, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.cleanenergyregulator.gov.au/NGER/About-the-National-Greenhouse-and-Energy-Reporting-scheme/Greenhouse-gases-and-energy [Accessed: September 2023].	
289.	WRI and WBCSD. 2013. *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (Revised Edition).* World Resources Institute and World Business Council for Sustainable Development.	
290.	DISER. 2021. *Australia's whole-of-economy Long-Term Emissions Reduction Plan*. Australian Government Department of Industry, Science, Energy and Resources, Canberra, Australian Capital Territory.	
291.	DCCEEW. 2023. *Safeguard Mechanism Reforms.* Department of Climate Change, Energy, the Environment and Water, Canberra, Australian Capital Territory. Available from: https://consult.dcceew.gov.au/safeguard-mechanism-reform-consult-on-design [Accessed: May 2023].	
292.	Chevron Australia. 2006. *Final Environmental Impact Statement / Response to Submission on the Environmental Review and Management Programme for the Proposed Gorgon Development.* Chevron Australia, Perth, Western Australia.	
293.	Chevron Australia. 2015. *Gorgon Gas Development and Jansz Feed Gas Pipeline: Greenhouse Gas Abatement Program.* Chevron Australia, Perth, Western Australia.	G1-NT-PLNX0000012
294.	IPCC. 2021. *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp.	
295.	IPCC. 2021. Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy,	

Ref. No.	Description	Document ID
	J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.	
296.	IPCC. 2022. *Sixth Assessment Report Impacts, Adaptation and Vulnerability.* Intergovernmental Panel on Climate Change, United Nations. Available from: https://www.ipcc.ch/report/ar6/wg2/. [Accessed: May 2023].	
297.	IEA. 2019. *The Role of Gas in Today's Energy Transitions.* Available from: https://www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions [Accessed in May 2023]	
298.	IEA. 2021. *A Roadmap for the Global Energy sector.* Available at: https://www.iea.org/reports/net-zero-by-2050 [Accessed: May 2023]	
299.	Field, C.B., V.R. Barros, K.J. Mach, M.D. Mastrandrea, M. van Aalst, W.N. Adger, D.J. Arent, J. Barnett, R. Betts, T.E. Bilir, J. Birkmann, J. Carmin, D.D. Chadee, A.J. Challinor, M. Chatterjee, W. Cramer, D.J. Davidson, Y.O. Estrada, J.-P. Gattuso, Y. Hijioka, O. Hoegh-Guldberg, H.Q. Huang, G.E. Insarov, R.N. Jones, R.S. Kovats, P. Romero-Lankao, J.N. Larsen, I.J. Losada, J.A. Marengo, R.F. McLean, L.O. Mearns, R. Mechler, J.F. Morton, I. Niang, T. Oki, J.M. Olwoch, M. Opondo, E.S. Poloczanska, H.-O. Pörtner, M.H. Redsteer, A. Reisinger, A. Revi, D.N. Schmidt, M.R. Shaw, W. Solecki, D.A. Stone, J.M.R. Stone, K.M. Strzepek, A.G. Suarez, P. Tschakert, R. Valentini, S. Vicuña, A. Villamizar, K.E. Vincent, R. Warren, L.L. White, T.J. Wilbanks, P.P. Wong, and G.W. Yohe. 2014. Technical summary. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. *Part A: Global and Sectoral Aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 35-94.	
300.	DAWE. 2021. *The Australian Government's Threatened Species Strategy 2021-2031.* Australian Government: Department of Agriculture, Water and the Environment, Canberra, Australian Capital Territory.	
301.	Chevron. 2023. *Enabling Human Progress: 2023 Corporate Sustainability Report.* Chevron Corporation, United States of America. Available from https://www.chevron.com/-/media/shared-media/documents/chevron-sustainability-report-2022.pdf. [Accessed: December 2023]	
302.	Chevron. 2023. *Advancing Energy Progress: 2023 Climate change resilience: report*. Chevron Corporation, United States of America. Available from: https://www.chevron.com/-/media/chevron/sustainability/documents/climate-change-resilience-report.pdf [Accessed: September 2023].	
303.	Elvidge, C.D., Zhizhin, M., Baugh, K., Hsu, F. and Ghosh, T. 2016. Methods for Global Survey of Natural Gas Flaring from Visible Infrared Imaging Radiometer Suite Data*. Energies* 2016, 9(1), 14	
304.	Fisher D. 2017. *Earth Engine Users Summit: Characterising Gas Flares from Single Channel SWIR Observations.* Kings College London, London	
305.	Planck M. 1914. *The Theory of Heat Radiation.* P. Blakiston's Son & Co. Philadelphia, United States of America.	
306.	Hick, P. 1995. *Spectral measurement of illumination sources at Thevenard Island: a preliminary study of the probable effects of gas flares and oil facility lights on Green Turtles and a subsequent revisit to measure a range of gas-flow rates.* CSIRO, unpublished report.	
307.	Pendoley K (2000) The influence of gas flares on the orientation of green turtle hatchlings at Thevenard Island, Western Australia. In: *Pilcher N, Ismail G(eds)*	

Ref. No.	Description	Document ID
	Sea turtles of the Indo-Pacific; research management and conservation. ASEAN Academic Press, London, 130–142.	
308.	Santos. 2021. *Dorado Development Offshore Project Proposal*. Santos WA Northwest Pty Ltd, Perth, Western Australia. Available from: https://info.nopsema.gov.au/offshore_projects/49/show_public [Accessed: September 2023].	
309.	Kato Energy. 2021. *Corowa Development Offshore Project Proposal.* KATO Energy Pty Ltd, Cottesloe, Western Australia. Available from: https://info.nopsema.gov.au/offshore_projects/42/show_public [Accessed: September 2023].	
310.	Kato Energy. 2021. *Amulet Development Offshore Project Proposal.* KATO Energy Pty Ltd, Cottesloe, Western Australia. Available from: https://www.nopsema.gov.au/node/1755 [Accessed: September 2023].	
311.	Pendoley. 2020. *Dorado FPSO Light Modelling.* Pendoley Environmental Pty Ltd, Booragoon, Western Australia. Prepared for CDM Smith on behalf of Santos, In: Dorado Development Offshore Project Proposal.	
312.	Xodus. 2020. *Corowa Development Facility and Flare Light Assessment.* Xodus Group, Perth, Western Australia. Prepared for KATO Energy, In: Corowa Development Offshore Project Proposal.	
313.	SKM and ERM. 2008. *Torosa South-1 (TS-1) Pilot Appraisal Well. Environmental Monitoring Programme – Development of Methodologies (Part1).* Report produced for Woodside Energy by Sinclair Knight Mertz and Environmental Resources Management, unpublished report.	
314.	Horch, K. W., J. P. Gocke, M. Salmon, and R. B. Forward. 2008. Visual spectral sensitivity of hatchling loggerhead (Caretta caretta L.) and leatherback (Dermochelys coriacea L.) sea turtles, as determined by single-flash electroretinography. *Marine and Freshwater Behaviour and Physiology.* 41: 79–91.	
315.	Woodside. 2014. *Browse FLNG Development, Draft Environmental Impact Statement. EPBC 2013/7079.* November 2014. Woodside Energy, Perth, Western Australia.	
316.	EPA. 2010. *Environmental Assessment Guidelines. No.5 Environmental Assessment Guideline for Protecting Marine Turtles from Light Impacts.* Environmental Protection Authority, Western Australia. Available from: https://www.epa.wa.gov.au/sites/default/files/Policies_and_Guidance/EAG%205%20Lights%20Turtle%2011110.pdf [Accessed: September 2023].	
317.	DSEWPaC. 2012. Species group report card – marine reptiles: supporting the marine bioregional plan for the North-west Marine Region. Department of Sustainability, Environment, Water, Population and Communities, Canberra, ACT. Available from: https://www.dcceew.gov.au/sites/default/files/env/pages/1670366b-988b-4201-94a1-1f29175a4d65/files/north-west-report-card-reptiles.pdf [Accessed May 2024].	
318.	Limpus, C.J., Kamrowski, R.L. and Riskas, K.A. 2015. Darkness is the best lighting management option at turtle nesting beaches. In: *Proceedings of the Second Australian and Second Western Australian Marine Turtle Symposia,* Perth, Western Australia. [Whiting, S.D. and Tucker, A. eds.] Science Division, Department of Parks and Wildlife, Perth, Western Australia, p56.	
319.	Robertson, K., Booth, D.T. and Limpus, C.J. 2016. An assessment of 'turtle-friendly' lights on the sea-finding behaviour of Loggerhead Turtle hatchlings (Caretta caretta). *Wildlife Research* 43, 27–37.	
320.	Chevron Australia. 2018. *Gorgon Gas Development and Jansz Feed Gas Pipeline: Long-term Marine Turtle Management Plan.* Chevron Australia, Perth, Western Australia.	GOR-COP-01728

Ref. No.	Description	Document ID
321.	Wilson, P., Pendoley, K., Whiting, S., Pattiaratchi, C., Meekan, M. and Thums, M. 2022. Response of turtle hatchlings to light emitting diodes at sea. *Marine and Freshwater Research*, 73, 689-702.	
322.	Rodríguez, A., Arcos, J.M., Bretagnolle, V., Dias M.P., Holmes N.D. et al. 2019. Future Directions in Conservation Research on Petrels and Shearwaters. *Frontiers in Marine Science*, 6, 94.	
323.	Wiese, F., Montevecchi, W.A., Davoren, G.K, Huettmann, F., Diamond, A.W. and Linke, J. 2001. Seabirds at risk around offshore oil platforms in the north-west Atlantic. *Marine Pollution Bulletin*, 42(12), 1285–1290.	
324.	Imber M. 1975. Behaviour of petrels in relation to the moon and artificial lights. *Notornis*, 22(4), 302- 306.	
325.	Marquenie, J., Donners, M., Poot, H., Steckel, W. and de Wit, B. 2013. Bird-Friendly Light Sources: Adapting the Spectral Composition of Artificial Lighting. *IEEE Industry Applications Magazine,* 19, 56–62.	
326.	Marangoni, L. F. B., Davies, T., Smyth, T., Rodríguez, A., Hamann, M., Duarte, C., Pendoley, K., Berge, J., Maggi, E. and Levy, O. 2022. Impacts of artificial light at night in marine ecosystems—A review. *Global Change Biology*, 28, 5346–5367.	
327.	Ueki, N. and Wakabayshi, K-I. 2018. 12 – Dynein-mediated photobehavioral responses in Chlamydomonas. In: *Dyneins: Structure, Biology and Disease (Second Edition) Volume One: The Biology of Dynein Motors,* Academic Press, pp 368–385. ISBN 9780128094716.	
328.	Taylor, B.L., Chivers, S.J., Larese, J. and Perrin, W.F. 2007. *Generation length and percent mature estimates for IUCN assessments of Cetaceans.* Southwest Fisheries Science Centre, Southwest Fisheries Science Centre Administrative Report.	
329.	Murphy, E. and King E.A. 2022. Chapter 2 - Principles of Environmental Noise. In: *Environmental Noise Pollution (Second Edition)* [Enda Murphy, Eoin A. King eds.], Elsevier,9-51. ISBN 9780128201008.	
330.	Warren, V. E., M.W. Koessler, A. M. Muellenmeister, D. H. Stroot and C.R. McPherson. 2023. *Gorgon Gas Development: Backfill Fields: Acoustic and Animal Movement Modelling for Assessing Marine Fauna Sound Exposures.* Document 02937, Version 1.0 DRAFT. Technical report by JASCO Applied Sciences for Xodus Group. Appendix D.	
331.	MacDonnell, J. 2016. Shelburne Basin Venture Exploration Drilling Project: Sound Source Characterization, 2016 Field Measurements of the Stena IceMAX. Document 01296, Version 3.0. Technical report by JASCO Applied Sciences for Shell Canada Limited	
332.	IOGP. 2020. *Review on Existing Data on Underwater Sounds Produced by the Oil and Gas Industry.* A report prepared by Seiche Ltd [Jiménez-Arranz, G., Banda, N., Cook, S. and Wyatt, R.] for the Joint Industry Programme on E&P Sound and Marine Life IOGP E&P Sound and Marine Life Programme.	
333.	APPEA. 2016. *Underwater Sound and Vibration from Offshore Petroleum Activities and their Potential Effects on Marine Fauna: An Australian Perspective*. Available from: https://appea.com.au/wp-content/uploads/2017/08/CMST-Underwater-Sound-and-Vibration-from-Offshore-Activities.pdf [Accessed: April 2024]	
334.	Woodside. 2021. *Angel Operations Environment Plan*. Available from: https://docs.nopsema.gov.au/A819903 [Accessed: April 2024]	
335.	Tougaard, Jakob and Griffiths, Emily T. 2020. *Harbour porpoises and the construction of Nord Stream 2 gas pipeline. Assessment of the impact on porpoises in the Natura2000 Hoburg's Bank and Midsjöbanks*, Swedish Baltic.	

Ref. No.	Description	Document ID
	Aarhus University, DCE – Danish Centre for Environment and Energy, 29 pp. Scientific Report No. 398	
336.	McPherson, C.R., Z. Li, C.C. Wilson, K.A. Kowarski, and M.W. Koessler. 2021. *Beach Otway Development Acoustic Monitoring: Characterisation, Validation, and Marine Mammals.* Document 02424, Version 2.0. Technical report by JASCO Applied Sciences for Beach Energy Limited.	
337.	Richardson, W.J., Greene, C.R., Malme, C.I and Thomson, D.H. 1995. *Marine Mammals and Noise*. Academic Press, San Diego ISBN: 978-0-08-057303-8.	
338.	Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D.A., Bartol, S., Carlson, T.J., Coombs, S., Ellison, W.T. and Gentry, R.L. 2014. Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. *SpringerBriefs in Oceanography*, Volume ASA S443/SC1.4 TR-2014. ASA Press. 87 pp	
339.	Southall, B.L., Finneran, J.J., Reichmuth, C.J., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P. and Tyack, P.L. 2019. Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals,* 45(2), 125-232. https://doi.org/10.1578/AM.45.2.2019.125.	
340.	NOAA. 2018. *2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts.* U.S. Dept. of Commerce, National Marine Fisheries Service. NOAA Technical Memorandum NMFS-OPR-59.	
341.	Tcherkashnev, S. 2020. *Improvement of Borehole Seismic Data Quality Control and Assessment by Statistical Approach.* Thesis presented for the Degree of Master of Philosophy (Geophysics) of Curtin University.	
342.	NOAA. 2019. ESA Section 7 Consultation Tools for Marine Mammals on the West Coast. National Oceanic and Atmospheric Administration, U.S.A. Available from: ESA Section 7 Consultation Tools for Marine Mammals on the West Coast | NOAA Fisheries [Accessed September 2023].	
343.	Payne, J.F., C. Andrews, L. Fancey, D. White, and J. Christian. 2008. Potential Effects of Seismic Energy on Fish and Shellfish: An Update since 2003. Report 2008/060. Canadian Science Advisory Secretariat. 22 p. https://waves-vagues.dfo-mpo.gc.ca/Library/335123.pdf.	
344.	Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, J.M. Semmens, and Institute for Marine and Antarctic Studies. 2016a. Assessing the Impact of Marine Seismic Surveys on Southeast Australian Scallop and Lobster Fisheries. Impacts of Marine Seismic Surveys on Scallop and Lobster Fisheries. Fisheries Ressearch & Development Corporation. FRDC Project No 2012/008, University of Tasmania, Hobart. 159 p.	
345.	Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, and J.M. Semmens. 2016b. Seismic air gun exposure during early-stage embryonic development does not negatively affect spiny lobster Jasus edwardsii larvae (Decapoda:Palinuridae). Scientific Reports 6: 1-9. https://doi.org/10.1038/srep22723.	
346.	Popper, A.N. 2017. *Potential for Impact of Cumulative Sound Exposure on Fishes During a Seismic Survey.* Prepared on behalf of ERM for Santos Offshore Pty Ltd, Bethany 3D Seismic Survey Environment Plan. Available at: https://docs.nopsema.gov.au/A680658 [Accessed September 2023].	
347.	McCauley, R.D., J. Fewtrell, A.J., Duncan, C., Jenner, M.-N. et al. 2000. *Marine seismic surveys: Analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid.* Centre for Marine Science and Technology, Curtin University of Technology, Western Australia. Project CMST 163, Report R99-15, prepared for Australian Petroleum Production Exploration Association. Available from:	

Ref. No.	Description	Document ID
	https://cmst.curtin.edu.au/wp-content/uploads/sites/4/2016/05/McCauley-et-al-Seismic-effects-2000.pdf [Accessed September 2023].	
348.	Finneran, J.J., Henderson, E.E., Houser, D.S., Jenkins, K., Kotecki, S. and Mulsow, J. 2017. *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III).* Technical report [Bowman, V., Martin, C., Rider, S., Shield, J., Tishler, M. and Weeks, R. (eds.)] Space and Naval Warfare Systems Center Pacific (SSC Pacific). 183 p.	
349.	Erbe, C., Schoeman, R.P., Peel, D. and Smith, J.N. 2021.It Often Howls More than It Chugs: Wind versus Ship Noise Under Water in Australia's Maritime Regions. *Journal of Marine Science and Engineering*, 9, 47.	
350.	INPEX. 2009. *Ichthys Gas Filed Development Project*: Appendix 15, Review of Literature on Sound in the Ocean and Effects of Noise on Marine Fauna. INPEX Browse Ltd.	
351.	RPS, 2022. Underwater Noise Review. Report for Saoirse Wave Energy Limited. JA2339–REPT–01–R0. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjQv_WmuIyHAxUbUGwGHfKRDaUQFnoECAsQAQ&url=https%3A%2F%2Fassets.gov.ie%2F259834%2F08d571d3-6a74-47a4-98f0-f02ee3ba9568.pdf&usg=AOvVaw2bjDLZAAzNOTvFo3yw-Im0&opi=89978449 [Accessed 20 June 2024].	
352.	AMSA. 2023. Craft Tracking System Records January 2023. Australian Maritime Safety Authority, Canberra, Australian Capital Territory. Available from: https://www.operations.amsa.gov.au/Spatial/DataServices/DigitalData [Accessed September 2023].	
353.	McKenna, M.F., Ross, D., Wiggins, S.M. and Hildebrand, J.A. 2012. Underwater radiated noise from modern commercial ships. *Journal of the Acoustical Society of America*, 131(1), 92–103.	
354.	McPherson, C.R., Li, Z., Wilson, C.C., Kowarski, K.A. and Koessler, M.W. 2021. *Beach Otway Development Acoustic Monitoring: Characterisation, Validation, and Marine Mammals. Document 02424, Version 2.0.* Technical report by JASCO Applied Sciences for Beach Energy Limited. In: Beach (ed.). Environment Plan Appendices Geographe Subsea Installation & Commissioning (VIC/L23). Available from: https://docs.nopsema.gov.au/A802937 [Accessed September 2023].	
355.	Richardson W.J., Fraker, M.A., Wursig, B. and Wills, R.S. 1985. Behaviour of bowhead whales (Balaena mysticetus), summering in the Beaufort Sea: Reactions to industrial activities. *Biological Conservation*. 32. 195–230.	
356.	Richardson, W.J., Greene, C.R., Malme, C.I and Thomson, D.H. 1995. *Marine Mammals and Noise*. Academic Press, San Diego	
357.	McCauley, R.D. 1998. *Radiated underwater noise measured from the drilling rig ocean general, rig tenders Pacific Ariki and Pacific Frontier, fishing vessel Reef Venture and natural sources in the Timor Sea, Northern Australia*. Prepared by Rob McCauley for Shell Australia.	
358.	Parry, G.D. and Gason, A. 2006. *The effect of seismic surveys on catch rates of rock lobsters in western Victoria*, Australia. Fisheries Research 79:272-284.	
359.	Carroll, A.G., Przeslawski, R., Duncan, A., Gunning, M. and Bruce, B., 2017. A critical review of the potential impacts of marine seismic surveys on fish and invertebrates. *Marine Pollution Bulletin 114*: 9- 24.	
360.	Popper, A.N., Hawkins, A.D., Sand, O., Sisneros, J.A. 2019. Examining the hearing abilities of fishes. *Journal of the Acoustical Society of America,* 146(2), 948.	

Ref. No.	Description	Document ID
361.	Wardle, C.S., Carter, T.J., Urquhart, G.G., Johnstone, A.D.F., Ziolkowski, A.M., Hampson, G. and Mackie. D. 2001. Effects of seismic air guns on marine fish. *Continental Shelf Research,* 21, 1005–1027.	
362.	Carroll, A.G., Przeslawski, R., Duncan, A., Gunning, M. and Bruce, B. 2017. A critical review of the potential impacts of marine seismic surveys on fish and invertebrates. *Marine Pollution Bulletin*, 114, 9–24.	
363.	Lara RA, Vasconcelos RO. Impact of noise on development, physiological stress and behavioural patterns in larval zebrafish. *Sci Rep.* 2021 Mar 23;11(1):6615. doi: 10.1038/s41598-021-85296-1. PMID: 33758247; PMCID: PMC7988139.Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7988139/	
364.	D.M. Fields, N.O. Handegard, J. Dalen, C. Eichner, K. Malde, Ø. Karlsen, A.B. Skiftesvik, C.M.F. Durif, H.I. Browman, P. Ratilal. Airgun blasts used in marine seismic surveys have limited effects on mortality, and no sublethal effects on behaviour or gene expression, in the copepod Calanus finmarchicus. ICES (Int. Counc. Explor. Sea) *J. Mar. Sci.*, 76 (7) (2019), pp. 2033-2044, 10.1093/icesjms/fsz126	
365.	Popper, A.N. and Hawkins, A.D. 2019. An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. *Journal of Fish Biology,* 94(5), 692–713.	
366.	Aspirault, Ariane & Winkler, Gesche & Jolivet, Aurélie & Audet, Céline & Chauvaud, Laurent & Juanes, Francis & Olivier, Frédéric & Tremblay, Réjean. (2023). Impact of vessel noise on feeding behavior and growth of zooplanktonic species. *Frontiers in Marine Science*. 10. 1111466. 10.3389/fmars.2023.1111466. https://www.frontiersin.org/articles/10.3389/fmars.2023.1111466/full	
367.	DeRuiter, S.L. and Doukara, K.L. 2012. Loggerhead turtles dive in response to airgun sound exposure. *Endangered Species Research,* 16(1), 55–63.	
368.	Weir, C. 2007. Observations of marine turtles in relation to seismic airgun sound off Angola. *Marine Turtle Newsletter,* 116,17–20.	
369.	Hazel, J., Lawler, I.R., Marsh, H. and Robson, S. 2007. Vessel speed increases collision risk for the green turtle Chelonia mydas. *Endangered Species Research*, 3, 105–113.	
370.	Sprogis, K.R., Videsen, S. and Madsen, P.T. 2020. Vessel noise levels drive behavioural responses of humpback whales with implications for whale-watching. *eLife*, 9, e56760.	
371.	McCauley, R.D., Jenner, M.N., Jenner, C., McCabe, K.A. and Murdoch, J. 1998. The response of humpback whales (Megaptera novaeangliae) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. *The APPEA Journal*, 38(1), 692–707.	
372.	Dunlop, R.A., Noad, M.J., McCauley, R.D., Kniest, E., Paton, D. and Cato, D.H. 2015. The behavioural response of humpback whales (Megaptera novaeangliae) to a 20 cubic inch air gun. *Aquatic Mammals,* 41(4), 412.	
373.	Goldbogen, J.A., Southall, B.L., DeRuiter, S.L., Calambokidis, J., Friedlaender, A.S., Hazen, E.L. and Kyburg, C. 2013. Blue whales respond to simulated mid-frequency military sonar. In: *Proceedings of the Royal Society B: Biological Sciences,* 280(1765), 20130657.	
374.	Southall, B.L., Nowacek, D.P., Miller, P.J. and Tyack, P.L. 2016. Experimental field studies to measure behavioral responses of cetaceans to sonar. *Endangered Species Research*, 31, 293-315.	
375.	Wood, J; Southall, B.L; Tollit, D.J, 2012. *PG&E offshore 3-D Seismic Survey Project EIR* – Marine Mammal Technical Draft Report. SMRU Ltd	

Ref. No.	Description	Document ID
376.	Erbe, Christine; Reichmuth, Colleen; Cunningham, Kane; Lucke, Klaus; Dooling, Robert, 2016. Communication masking in marine mammals: A review and research strategy*. Marine Pollution Bulletin*. 15-38	
377.	Terhune, J; Stewart, R; Ronald, K, 1979. Influence of vessel noises on underwater vocal activity of harp seals. *Canadian Journal of Zoology*. 1337-1338.	
378.	Cunningham, K; Mountain, D. 2014. Simulated masking of right whale sounds by shipping noise: incorporating a model of the auditory periphery. *J. Acoust. Soc*. Am. 1632-1640	
379.	Tennessen, J; Parks, S. 2016. *Acoustic propagation modelling indicates vocal compensation in noise improves communication range for North Atlantic right whales*. Endanger. Species Res. 225- 237	
380.	Cholewiak, D; Clark, C; Ponirakis, D; Frankel, A; Hatch, L; Risch, D. 2018. *Communicating amidst the noise: modelling the aggregate influence of ambient and vessel noise on baleen whale communication space in a national marine sanctuary*. Endanger Species. 59-75	
381.	Gomez, C; Lawson, J; Wright, A; Buren, A; Tollit, D; Lesag, V. 2016. A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy. *Canadian Journal of Zoology*. 801-819	
382.	Clark, Christopher; Ellison, William; Southall, Brandon; Hatch, Leila; Van Parijs, Sofie; Frankel, Adam; Ponirakis, Dimitri. 2009. Acoustic masking in marine ecosystems: intuitions, analysis, and implication. *Marine Ecology Progress Series*. 201-222	
383.	McDonald, M.A; Hildebrand, J.A; Webb, S.C. 1995. Blue and fin whales observed on a seafloor array in the Northeast Pacific. *J. Acoust. Soc*. Am. 712-721	
384.	Parks, S.E; Clark, C.W; Tyack, P.L. 2007. Short-and long-term changes in right whale calling behavior: The potential effects of noise on acoustic communication. *J. Acous. Soc. of America*. 3752- 3731	
385.	Di Lorio, L; Clark, W. 2010. Exposure to seismic survey alters blue whale acoustic communication. *Biology Letters*. 51-54.	
386.	Castellote, M; Clark, C.W; Lammers, M.O. 2012. Acoustic and behavioural changes by fin whales (Balaenaptera physalus) in response to shipping and airgun noise. *Bio. Cons*. 115-122	
387.	Hotchkin, C; Parks, S. 2013. The Lombard effect and other noise induced vocal modifications: insight from mammalian communication systems. *Biological Reviews*. 809-824	
388.	McGarry, T., Boisseau, O., Stephenson, S. and Compton, R. 2017. *Understanding the Effectiveness of Acoustic Deterrent Devices (ADDs) on Minke Whale (Balaenoptera acutorostrata), a Low-Frequency Cetacean.* (Report No. RPS Report EOR0692). Report by Offshore Renewables Joint Industry Programme (ORJIP). Report for Carbon Trust.	
389.	MMSA. 2008. *Alaska Outer Continental Shelf, Beaufort Sea and Chukchi Sea Planning Areas*. EIS, Vol 2. US Department of the Interior, Minerals Management Service, Alaska OCS Region, United States of America.	
390.	Pendleton, D.E., Holmes, E.E., Redfern, J., Zhang, J., 2020. Using modelled prey to predict the distribution of a highly mobile marine mammal. *Divers. Distrib*. 26, 1612–1626.	
391.	National Marine Fisheries Service. 2024. U*pdate to: Technical Guidance for Assessing the 4 Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 3.0): Underwater and In Air Criteria for Onset of Auditory Injury and*	

Ref. No.	Description	Document ID
	Temporary Threshold Shifts. U.S. Dept. of 6 Commer., NOAA. NOAA Technical Memorandum NMFS-OPR	
392.	Houser, D.S. (2021). “When Is Temporary Threshold Shift Injurious to Marine Mammals?,” 18 *Journal of Marine Science and Engineering* 9, 757.	
393.	Finneran, J. (2024) *Marine mammal auditory weighting functions and exposure functions for US Navy Phase 4 acoustic effects analyses*, Naval Information Warfare Center Pacific	
394.	[ANSI] American National Standards Institute and [ASA] Acoustical Society of America. S1.1-2013. American National Standard: Acoustical Terminology. NY, USA. https://webstore.ansi.org/Standards/ASA/ANSIASAS12013.	
395.	Yost, W.A. 2007. Fundamentals of Hearing: An Introduction. Fifth Edition. Elsevier Press (Academic), New York, NY. 338pp	
396.	Schlundt, C.E, J.J. Finneran, D.A. Carder, and S.H Ridgway. 2000. Temporary shift in masked hearing thresholds of bottlenose dolphins, Tursiops truncatus, and white whales, Delphinapterus leucas, after exposure to intense tones. The Journal of the Acoustical Society of America. 107. 3496-508. 10.1121/1.429420.	
397.	Finneran, J.J., C.E. Schlundt, D.A. Carder, J.A. Clark, J.A. Young, J.B. Gaspin, and S.H. Ridgway. 2000. Auditory and behavioral responses of bottlenose dolphins (Tursiops truncatus) and a beluga whale (Delphinapterus leucas) to impulsive sounds resembling distant signatures of underwater explosions. Journal of the Acoustical Society of America 108(1): 417-431. https://doi.org/10.1121/1.429475.	
398.	Finneran, J.J., C.E. Schlundt, R.L. Dear, D.A. Carder, and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. Journal of the Acoustical Society of America 111(6): 2929-2940. https://doi.org/10.1121/1.1479150.	
399.	DAWE. 2021. *Guidance on key terms within the Blue Whale Conservation Management Plan.* Department of Agriculture, Water and Environment, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/environment/epbc/publications/guidance-key-terms-blue-whale-conservation-management-plan [Accessed: September 2023].	
400.	NOAA. 2021. *Species Directory – Blue Whale.* National Oceanic and Atmospheric Administration, U.S.A. Available from: https://www.fisheries.noaa.gov/species/blue-whale [Accessed: September 2023].	
401.	UNESCO. 2003. *Convention for the Safeguarding of the Intangible Cultural Heritage.* United Nations Educational, Scientific and Cultural Organization, Paris, France. Available from: https://ich.unesco.org/en/convention [Accessed December 2023]	
402.	DEWR. 2007. *EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales.* Department of the Environment and Water Resources, Australian Government, Canberra, Australian Capital Territory.	
403.	NERA. 2017. *Environment Plan Reference Case: Planned discharge of sewage, putrescible waste and grey water.* National Energy Resources Australia, Department of Industry, Innovation and Science. Available from: https://referencecases.nera.org.au/Article?Action=View&Article_id=128 [Accessed: September 2023].	
404.	CE Delft. 2017. *The Management of Ship-Generated Waste On-board Ships.* Technical Report prepared for the European Maritime Safety Agency, EMSA/OP/02/2016, Publication code: 17.7I85.50. Available from: https://cedelft.eu/publications/the-management-of-ship-generated-waste-on-board-ships/ [Accessed: September 2023].	

Ref. No.	Description	Document ID
405.	Woodside. 2008. *Maxima 3D Marine Seismic Survey, Environmental Compliance Report, February 2008*. Submitted to Department of Environment and Conservation, Western Australian Government, Perth, pp. 121.	
406.	McDonald, S.F., Hamilton, S.J., Buhl, K.J. and Heisinger, J.F. 1996. Acute toxicity of fire control chemicals to Daphnia magna (Straus) and Selenastrum capricornutum (Printz). *Ecotoxicology and Environmental Safety*, 33, 62–72.	
407.	Moody, C.A. and Field, J.A. 2000. Perfluorinated Surfactants and the Environmental Implications of Their Use in Fire-Fighting Foams. *Environmental Science and Technology*, 34(18), 3864–3870.	
408.	Solberg. 2013. *Aquatic Impacts of Firefighting Foams.* Technical Whitepaper [Schaefer, T., General Manager, Asia Pacific, Solberg].	
409.	IFSEC Global. 2014. *Environmental impact of foam.* Industry article [Cortina, T., Executive Director Firefighting Foam Coalition, USA]. Available from: https://www.ifsecglobal.com/uncategorized/environmental-impact-of-foam/ [Accessed: September 2023].	
410.	ANSUL. 2007. *Environmental Impact of ANSULITE® AFFF Products.* Technical Bulletin Number 52, Form No. F 82289-3. Ansul Incorporated.	
411.	McIntyre, A.D. and Johnson, R. 1975. Effects of nutrient enrichment from sewage in the sea. In: *Discharge of sewage from sea outfalls* [*Gameson, A.L.H. ed.].* New York, Pergamon Press. pp. 131–141.	
412.	Abdellatif, E.M., Ali, O.M., Khalil, I.F. and Nyonje, B.M. 1993. Effects of Sewage Disposal into the White Nile on the Plankton Community. *Hydrobiologia,* 259, 195–201.	
413.	Axelrad, D.M., Poore, G.C.B., Arnott, G.H., Bault, J., Brown, V., Edwards, R.R.C. and Hickman, N. 1981. The Effects of Treated Sewage Discharge on the Biota of Port Phillip Bay, Victoria, Australia. In: [Neilson, B.J., Cronin, L.E. (eds.)] *Estuaries and Nutrients. Contemporary Issues in Science and Society*. Humana Press.	
414.	Parnell, P.E. 2003. The effects of sewage discharge on water quality and phytoplankton of Hawai'ian Coastal Waters. *Marine Environmental Research*, 44, 293–311.	
415.	Chevron Australia. 2020. *ABU Hazardous Materials Management Procedure: ABU Standardised OE Procedure.* Chevron Australia, Perth, Western Australia.	OE-03.11.1045
416.	Asia Pacific Applied Science Associates. 2014. *Quantitative Oil Spill Modelling – Jansz. Q0331.* Unpublished report prepared for Chevron Australia, Perth, Western Australia	
417.	Chevron Australia, 2015. *Wheatstone Project Offshore Facilities and Produced Formation Water Discharge Management Plan: Stage 1*. Chevron Australia, Perth, Western Australia.	WS0-0000-HES-PLN-CVX-000-00101–000
418.	INPEX. 2010. *Ichthys Gas Field Development Project: Draft Environmental Impact Statement.* INPEX, Perth, Western Australia. Available from: https://ntepa.nt.gov.au/your-business/public-registers/environmental-impact-assessments-register/completed-assessments/register/ichthys-gas-field-development-inpex/draft-environmental-impact-statement-eis [Accessed September 2023].	
419.	ConocoPhillips. 2018. *Barossa Area Development Offshore Project Proposal.* ConocoPhillips Australia Exploration Pty Ltd, West Perth, Western Australia. Available from: https://docs.nopsema.gov.au/A598153 [Accessed: September 2023].	
420.	Shell. 2020. *Crux Project Offshore Project Proposal.* Shell Australia Pty Ltd, Perth, Western Australia. Available from: https://docs.nopsema.gov.au/A742335 [Accessed: September 2023].	

Ref. No.	Description	Document ID
421.	Webster, L., Russle, M., Hussy, I., Packer, G., Dalgarno, E.J., Moore, D.C., Moffat, C.F. 2012a. *Environmental Assessment of the Elgin Gas Field Incident – Report 3*, Water Update. Marine Scotland Science Report 12/12.	
422.	Webster, L., Russle, M., Hussy, I., Packer, G., Philips, L.A., Dalgarno, E.J., Moore, D.C., Moffat, C.F. 2012c. *Environmental Assessment of the Elgin Gas Field Incident – Report 4, Fish Muscle* .Marine Scotland Science Report 13/12.	
423.	Webster, L., Russle, M., Hussy, I., Packer, G., Philips, L.A., Dalgarno, E.J., Craig, A., Moore, D.C., Jaspars, M, Moffat, C.F. 2012b. *Environmental Assessment of the Elgin Gas Field Incident – Report 5, Fish and Sediment Update.* Marine Scotland Science Report 17/12.	
424.	Staples, C.A., Williams, J.B., Craig, G.R. and Roberts, K.M. 2001. Fate, effects and potential environmental risks of ethylene glycol: a review. *Chemosphere*, 43, 377–383.	
425.	CEFAS. 2022. *Offshore Chemical Notification Scheme (OCNS)*. Centre for Environment Fisheries and Aquaculture Science, UK. Available from: https://www.cefas.co.uk/cefas-data-hub/offshore-chemical-notification-scheme/hazard-assessment/ [Accessed: November 2022].	
426.	DOE. 2023. *Continental slope demersal Fish Communities KEF in Species Profile and Threats Database.* Department of the Environment, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/sprat-public/action/kef/view/79 [Accessed: September 2023].	
427.	Neff J.M. 2005. *Composition, environmental fates, and biological effects of water based drilling muds and cuttings discharged to the marine environment: a synthesis and annotated bibliography.* Report prepared for the Petroleum Environmental Research Forum (PERF). Available from American Petroleum Institute, Washington, DC. 73 pp	
428.	Chevron Australia. 2014. *Gorgon Expansion Project Metocean Design Criteria.* Chevron Australia, Perth, Western Australia.	G4-TE-T-UG01-REPX002
429.	Chevron Australia. 2020. *Chrysaor-Dionysus / Geryon-Eurytion Metocean Design Criteria.* Chevron Australia, Perth, Western Australia.	G1-TE-Z-UG00-REPX029
430.	Hinwood, J.B., Potts, A.E., Dennis, L.R., Carey, J.M., Houridis, H., Bell, R.J., Thomson, J.R., Boudreau, P. and Ayling, A.M. 1994. Drilling Activities. In: *Environmental Implications of Offshore Oil and Gas Developments in Australia: The Findings of an Independent Scientific Review* [John M. Swan; Jerry M. Neff; and Peter Colin Young (eds.)]. Australian Petroleum Exploration Association, Sydney, NSW.	
431.	IAOGP. 2016. *Environmental fates and Effects of Ocean Discharge of Drilling Cuttings and Associated Drilling Fluids from Offshore Oil and Gas Operations*. Report 543, International Association of Oil Gas Producers.	
432.	CSA. 2004. *Gulf of Mexico Comprehensive Synthetic Based Drilling Muds Monitoring Program.* Continental Shelf Associates Inc. Final Report submitted to SBM Research Group. Volumes I-II, Technical Results; Volume III Appendices.	
433.	CSA. 2006. *Effects of oil and gas exploration and development on selected continental slope sites in the Gulf of Mexico*. Volume II: Technical report. OCS Study MMS 2006-045. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS region, New Orleans, LA. 636 pp.	
434.	Dorn, P.B., Rhodes, I.A., Wong, D.C.L., Van Compernolle, R., Farmayan, W.F., Ray, J.P., James, B. and Hii, K.K. 2007. *Assessment of the Fate and Ecological Risk of Synthetic Paraffin Based Drilling Mud Discharges Offshore Sarawak and Sabah (Malaysia)*. Paper presented at the SPE Asia Pacific	

Ref. No.	Description	Document ID
	Health, Safety, and Security Environment Conference and Exhibition, Bangkok, Thailand.	
435.	Correa, I.C.S, Toldo, E.E. Jr. and Toledo, F.A.L. 2010. Impacts on seafloor geology of drilling disturbance in shallow waters. *Environmental Monitoring and Assessment*, 167, 7–16.	
436.	Pozebon, D., Santos, J.H.Z., Peralba, M.C.R., Maia, S.M., Barrionuevo, S. and Pizzolato, T.M. 2009. Metals, arsenic and hydrocarbons monitoring in marine sediment during drilling activities using NAFs, *Deep Sea Research Part II: Topical Studies in Oceanography*, 56(1–2), 22-31.	
437.	Jones, R., Wakeford, M., Currey-Randall, L., Miller, K. and Tonin, H. 2021. Drill cuttings and drilling fluids (muds) transport, fate and effects near a coral reef mesophotic zone, *Marine Pollution Bulletin*, 172, 112717.	
438.	Abdul Wahab, M., Fromont, J., Gomez, O., Fisher, R., Jones, R., 2017. Comparisons of benthic filter feeder communities before and after a large-scale capital dredging program. *Marine Pollution Bulletin,* 122, 176–193.	
439.	Fisher, R., Stark, C., Ridd, P., Jones, R., 2015. Spatial patterns in water quality changes during dredging in tropical environments. *PLoS One,* 10(12), e014330.	
440.	Hinwood, J.B., Poots, A.E., Dennis, L.R., Carey, J.M., Houridis, H., Bell, R., Thomson, J.R., Boudreau, P. and Ayling, A.M. Australian Marine and Offshore Group Pty Ltd, 1994. The Environmental Implication of Drilling activities. In: Swan, J.M., Neff, J.M. and Young, P.C. (Eds) *Environmental Implications of Offshore Oil and Gas Development in Australia* – The Findings of an Independent Scientific Review. Australian Petroleum Exploration Association, Sydney, pp 123–207	
441.	Neff, Jerry M. 2010. *Fate and effects of water based drilling muds and cuttings in cold water environments.* Unpublished report, Scientific Review prepared for Shell Exploration and Production Company, Houston, Texas.	
442.	Terrens G.W., Gwyther D. and Keogh M.J. 1998. Environmental Assessment of Synthetic-based Drilling Mud Discharges to Bass Strait, Australia. *The APPEA Journal*, 38, 610-625.	
443.	CIN. 2017. *Chemical Hazard Assessment and Risk Management, for the use and discharge of chemicals used offshore.* User Guide version 1.5. CHARM Implementation Network.	
444.	Ellis, J.I., Fraser, G., Russell, J., 2012. *Discharged drilling waste from oil and gas platforms and its effects on benthic communities.* Mar. Ecol. Prog. Ser. 456, 285–302. https://doi.org/10.3354/meps09622.	
445.	Jones, R., Wakeford, M., Currey-Randall, L., Miller, K. and Tonin, H. 2021. *Drill cuttings and drilling fluids (muds) transport, fate and effects near a coral reef mesophotic zone*, Marine Pollution Bulletin, 172, 112717.	
446.	Burton, J., Marshall, N., Phillips, A., 1968. Solubility of barium sulphate in sea water. *Nature* 217, 834.	
447.	Smit, M., Holthaus, K.I.E., Trannum, H.C., Neff, J.M., Kjeilen-Eilertsen, G., Jak, R.G., Singsaas, I., Huijbregts, M.A.J., Hendriks, A.J., 2008. Species sensitivity distributions.	
448.	Neff, J.M. 2008. Estimation of Bioavailability of Metals from Drilling Mud Barite. *Integrated Environmental Assessment and Management* 4(2): 184-193	
449.	IFC. 2015. *Environmental, Health, and Safety Guidelines for Offshore Oil and Gas Development.* International Finance Corporation, World Bank Group. Available at: https://www.ifc.org/content/dam/ifc/doc/mgrt/final-jun-2015-offshore-oil-and-gas-ehs-guideline.pdf [Accessed: September 2023].	

Ref. No.	Description	Document ID
450.	Crecelius, E., Trefry, J., McKinley, J., Lasorsa, B. and Trocine, R. 2007. *Study of barite solubility and the release of trace components to the marine environment.* U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OC5 Study MMS 2007-061. 176 pp.	
451.	BP. 2019. *Ironbark-1 Exploration Drilling Environment Plan.* BP Developments Australia Pty Ltd, Melbourne, Victoria. Available from: https://docs.nopsema.gov.au/A738920 [Accessed: September 2023]	
452.	IOGP. 2021. *Environmental Effects and Regulation of Offshore Drill Cuttings Discharges.* International Association of Oil and Gas Producers, Report 602.	
453.	Jensen, T., Palerud, R., Olsgard, F. and Bakke, S.M. 1999. *Dispersion and effects of synthetic drilling fluids in the environment.* Norwegian Ministry of Oil and Energy Technical Report No. 99-3507. Prepared by Olsgård Consulting, Akvaplan-niva, and Det Norske Veritas. 66 pp	
454.	Melton, H.R., Smith, J.P., Martin, C.R., Nedwed, T.J., Mairs, H.L. and Raught, D.L. 2000. Offshore discharge of drilling fluids and cuttings – a scientific perspective on public policy. Brazil. In: *Proceedings of the Rio Oil and Gas Expo and Conference 2000,* BR04B0542.	
455.	Chevron Australia. 2020. *wells fluid field guidelines offshore*. Chevron Australia, Perth, Western Australia. .	ABU140600044
456.	ABARES. 2023. Chapter 5: North West Slope Trawl Fishery. In: *ABARES Fishery Status Reports 2023.* Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, Australian Capital Territory. Available from: https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1035183/6 [Accessed: October 2023].	
457.	ABARES. 2022. Chapter 13: Western Deepwater Trawl Fishery. In: *ABARES Fishery Status Reports 2022.* Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, Australian Capital Territory. Available from: https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1034121/0 [Accessed: September 2023].	
458.	DPIRD. 2019. *Fish Cube WA Data Extract for 1999-2019*. Available by request from DPIRD.	
459.	NOPSEMA. 2020. *Safety zones and the Area to Be Avoided.* Guidance Note: A494246National Offshore Petroleum Safety and Environmental Management Authority, Perth, Western Australia. Available from: https://www.nopsema.gov.au/sites/default/files/documents/2021-03/A494246.pdf [Accessed: September 2023].	
460.	Peel, D., Smith, J. and Childerhouse S. 2018. Vessel Strike of Whales in Australia: The Challenges of Analysis of Historical Incident Data. *Frontiers in Marine Science,* 5, 69.	
461.	Santos. 2020. *Santos Offshore – Impact Assessment of Bird Deterrent Systems at Offshore WHP on Seabirds.* Application for a permit to install and operate bird deterrence equipment on offshore platforms 'Reindeer' and 'John Brookes' in WA (E2020/0173). Available from: https://www.dcceew.gov.au/sites/default/files/env/consultations/5537458c-2e35-443a-970d-c28b8cf9131f/files/e2020-0173-impact-assessment-bird-deterrent-systems-offshore-whp-seabirds.pdf [Accessed: September 2023].	
462.	Chevron Australia. 2015. *Gorgon Gas Development and Jansz Feed Gas Pipeline: Five year Environmental Performance Report (August 2010 – August 2015)*. Chevron Australia, Perth, Western Australia.https://australia.chevron.com/-/media/australia/our-businesses/documents/gorgon-and-jansz-feed-gas-pipeline-5-year-environmental-performance-report-2010-2015.pdf	

Ref. No.	Description	Document ID
463.	Chevron Australia. 2020. *Gorgon Gas Development and Jansz Feed Gas Pipeline: Five year Environmental Performance Report 2015-2020*. Chevron Australia, Perth, Western Australia.	ABU200101038
464.	Chevron Australia. 2021. *Gorgon Gas Development and Jansz Feed Gas Pipeline Environmental Performance Report 2021*. Available at: https://australia.chevron.com/-/media/australia/our-businesses/documents/gorgon-gas-development-and-jansz-feed-gas-pipeline-environmental-performance-report-2021.pdf [Accessed: September 2023]	
465.	Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S. and Podesta, M. 2001. Collisions between ships and whales. *Marine Mammal Science,* 17(1), 35–75.	
466.	DoE. 2017. *National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna 2017*. Department of the Environment, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/sites/default/files/documents/vessel-strike-strategy.pdf [Accessed: September 2023].	
467.	Barnthouse, L.W. 2013. Impacts of entrainment and impingement on fish populations: A review of the scientific evidence. *Environmental Science & Policy,* 31, 149-156.	
468.	Le Gouvello, D.Z.M., Hart-Davis, M.G., Backeberg, B.C. and Nel, R. 2020. Effects of swimming behaviour and oceanography on sea turtle hatchling dispersal at the intersection of two ocean current systems. *Ecological Modelling,* 431,109130.	
469.	Jones River Landing. 2013. *Sea Turtles and Power Plants.* News article contributed to Jones River Landing Environmental Heritage Center, Cape Cod Bay, Massachusetts, USA. Available from: https://jonesriver.org/ecology/sea-turtles-and-power-plants/ [Accessed September 2023].	
470.	Dolman, S., Williams-Grey, V., Asmutis-Silvia, R. and Isaac, S. 2006. *Vessel collisions and cetaceans: What happens when they don't miss the boat.* A Whale and Dolphin Conservation Society Science Report. Available from: https://au.whales.org/wp-content/uploads/sites/3/2018/08/whales-and-ship-strikes.pdf [Accessed: May 2024].	
471.	Mackay, A.I., Bailluel, F., Childerhouse, S., Donnelly, D., Harcourt, R., Parra, G.J. and Goldsworthy, S.D. 2015. *Offshore migratory movement of southern right whales: addressing critical conservation and management needs*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2015/000526-1. SARDI Research Report Series No. 859.	
472.	Ruppel, C.D., Weber, T.C., Staaterman, E.R., Labak, S.J. and Hart, P.E. 2022. Categorizing Active Marine Acoustic Sources Based on Their Potential to Affect Marine Animals. *J. Mar. Sci. Eng.,* 10, 1278.	
473.	Marine Pest Sectoral Committee. 2018. *National biofouling management guidelines for non-trading vessels.* Department of Agriculture and Water Resources, Canberra, Australian Capital Territory. Available from: https://www.marinepests.gov.au/sites/default/files/Documents/non-trading-vessel-biofouling-guidelines.pdf [Accessed September 2023].	
474.	MIAL 2020. *Marine Biosecurity Management of Vessels Servicing the Offshore Resources Industry.* Marine Industry Australia Limited. An Environment Plan Reference Case submitted for formal NOPSEMA advice. Available from: https://mial.org.au/wp-content/uploads/2022/05/201029-Final-Published-Biosecurity-Reference-Case-1.pdf [Accessed: January 2021].	
475.	DAFF 2003. *Domestic vessel movements and the spread of marine pests. Risks and management approaches.* Department of Agriculture, Fisheries and Forestry, Canberra, Australian Capital Territory. Available from:	

Ref. No.	Description	Document ID
	https://www.dcceew.gov.au/sites/default/files/documents/domestic-vessel-imp-risks.pdf [Accessed September 2023].	
476.	CSIRO. 1999. *Marine Biological Invasions of Port Phillip Bay, Victoria.* [Hewitt, C.L., Campbell, M.L., Thresher, R.E. and Martin, R.B. 1999 (eds.)], Technical Report 20, CSIRO, Division of Marine Research, 344 p.	
477.	Hewitt, C.L., Campbell, M.L., Thresher, R.E., et al. 2004. Introduced and cryptogenic species in Port Phillip Bay, Victoria, Australia. *Marine Biology,* 144, 182–202.	
478.	Mineur, F, Johnson, M.P., Maggs, C.A. and Stegenga. H. 2007. Hull fouling on commercial ships as a vector of macroalgal introduction. *Marine Biology,* 151, 1299–1307.	
479.	DAWE. [n.d.] *The Introduction of Marine Pests to the Australian Environment via Shipping.* Department of Agriculture, Water and the Environment, Canberra, Australian Capital Territory. Available from: https://www.dcceew.gov.au/environment/biodiversity/threatened/nominations/ineligible-ktp/introduction-marine-pests-via-shipping [Accessed March 2021].	
480.	Paulay, G., Kirkendale, L., Lambert, G. and Meyer, C. 2002. Anthropogenic biotic interchange in a coral reef ecosystem: A case study from Guam. *Pacific Science*, 56(4), 403–422.	
481.	Forrest, B.M., Gardner, J.P. and Taylor, M.D. 2009. Internal borders for managing invasive marine species. *Journal of Applied Ecology*, 46(1), 46-54.	
482.	DOE. 2023. *Ancient coastline at 125 m depth contour KEF in Species Profile and Threats Database.* Department of the Environment, Canberra, Australian Capital Territory. Available from: https://www.environment.gov.au/sprat-public/action/kef/view/9 [Accessed: September 2023].	
483.	Glasby, T.M., Connell, S.D., Holloway, M.G. and Hewitt, C.L., 2007. Nonindigenous biota on artificial structures: could habitat creation facilitate biological invasions. *Marine Biology*, 151, 887–895.	
484.	Dafforn, K.A., Glasby, T.M. and Johnston, E.L., 2009. Links between estuarine condition and spatial distributions of marine invaders. *Diversity and Distributions,* 15(5), 807–821.	
485.	Dafforn, K.A., Johnston, E.L. and Glasby, T.M. 2009. Shallow moving structures promote marine invader dominance. *Biofouling*, 25(3), 277-287.	
486.	BRS 2007. *Designated Exchange Areas Project – Providing Informed Decision on the Discharge of Ballast Water in Australia (Phase II).* Designated Exchange Area Project Final Report [Knight, E., Barry, S., Summerson, R., Cameron S., Darbyshire R. (eds.)] for the Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry, Canberra, Australian Capital Territory.	
487.	Sliwa, C. and Bax, N. 2002. *National Introduced Marine Pest Information System (NIMPIS)*. Final Report for National Heritage Trust Coast and Clean Seas Project 21246, CSIRO Marine Research. Available from: https://publications.csiro.au/rpr/download?pid=procite:e774e447-ccc4-4d0c-b189-bd1b40faf214&dsid=DS1 [Accessed: September 2023].	
488.	IMO. 2017. *International Convention for the Control and Management of Ships' Ballast Water and Sediments (Ballast Water Convention).* International Maritime Organisation.	
489.	Ceccarelli, D. M. 2009. *Impacts of plastic debris on Australian marine wildlife*. Report by C&R Consulting for the Department of the Environment, Water, Heritage and the Arts.	
490.	DSEWPaC. 2011. *National recovery plan for threatened albatrosses and giant petrels 2011-2016.* Department of Sustainability, Environment, Water, Population and Communities, Australian Government, Canberra, Australian	

Ref. No.	Description	Document ID
	Capital Territory. Available at: https://www.dcceew.gov.au/sites/default/files/documents/albatrosses-and-giant-petrels-recovery-plan.pdf [Accessed: September 2023].	
491.	Derraik, JGB, 2002, The pollution of the marine environment by plastic debris: a review, *Marine Pollution Bulletin,* vol. 44, pp. 842–852.	
492.	Murphy, F., Russell, M., Ewins, C. and Quinn, B. 2017. The uptake of macroplastic & microplastic by demersal & pelagic fish in the Northeast Atlantic around Scotland. *Marine Pollution Bulletin*, 122, 353–359.	
493.	Spouge, J. 1999. *Guide to Quantitative Risk Assessment for Offshore Installations.* Centre for Marine and Petroleum Technology.	
494.	Chevron Australia, 2022. *ABU – Lifting and Rigging Control of Work Manual.* Chevron Australia, Perth, Western Australia	OE-03.06.1074
495.	GOMO. 2013. *Guidelines for Offshore Marine Operations*. Revision 0611-1401. Available from: https://www.g-omo.info/gomo [Accessed: September 2023].	
496.	RPS. 2023. *Greater Gorgon – West Tryal Rocks Oil Spill Modelling*. RPS Robina, Queensland. [Attached in Appendix C of this OPP]	
497.	AMSA. 2023. *Technical guideline for preparing contingency plans for marine and coastal facilities.* Australian Maritime Safety Authority, Australian Government, Canberra, Australia Capital Territory. Available from: https://www.amsa.gov.au/sites/default/files/np-gui-012-technical-guidelines-contingency-plans-15082023_0.pdf [Accessed: September 2023].	
498.	AMSA. 2022. *Annual Report 2021–22*. Australian Maritime Safety Authority, Australian Government, Canberra, Australia Capital Territory. Available from: https://www.amsa.gov.au/sites/default/files/annual-report-2021-2022.pdf [Accessed: September 2023].	
499.	Parks and Wildlife. [n.d.]. *Regional information: Pilbara.* Available from: https://exploreparks.dbca.wa.gov.au/tourism-region/pilbara [Accessed: September 2023].	
500.	IPIECA. 2015. *Impacts of oil spills on shorelines: good practice guidelines for incident management and emergency response personnel.* International Petroleum Industry Environmental Conservation Association, International Association of Oil & Gas Producers. Available from: https://www.ipieca.org/resources/impacts-of-oil-spills-on-shorelines [Accessed: September 2023].	
501.	Kostka, J.E., Prakash, O., Overholt, W.A., Green, S.J., Freyer, G., Canion, A., Delgardio, J., Norton, N., Hazen, T.C. and Huettel, M. 2011. Hydrocarbon-degrading bacteria and the bacterial community response in gulf of Mexico beach sands impacted by the deepwater horizon oil spill. *Applied and Environmental Microbiology,* 77(22), 7962-74.	
502.	Baca, B., Rosch, E., DeMicco, E.D. and Schuler, P.A. 2014. *TROPICS*: 30-year Follow-up and Analysis of Mangroves, Invertebrates, and Hydrocarbons. In: *International Oil Spill Conference Proceedings (2014),* 2014(1), 1734–1748.	
503.	Dean, T.A., Stekoll, M.S., Jewett, S.C., Smith, R.O. and Hose, J.E. 1998. Eelgrass (Zostera marina L.) in Prince William Sound, Alaska: Effects of the Exxon Valdez oil spill. *Marine Pollution Bulletin*, 36, 201–210.	
504.	Taylor, H.A. and Rasheed, M.A., 2011. Impacts of a fuel oil spill on seagrass meadows in a subtropical port, Gladstone, Australia – the value of long-term marine habitat monitoring in high risk areas. *Marine Pollution Bulletin,* 63, 431–437.	
505.	Shigenaka, G. 2001. *Toxicity of oil to reef building corals: a spill response perspective.* National Oceanic and Atmospheric Administration (NOAA)	

Ref. No.	Description	Document ID
	Technical Memorandum, National Ocean Service, Office of Research and Restoration 8, Seattle, USA.	
506.	Negri, A.P. and Heyward, A.J. 2000. Inhibition of fertilization and larval metamorphosis of the coral Acropora millepora (Ehrenberg, 1834) by petroleum products. *Marine Pollution Bulletin,* 41(7-12), 420–427.	
507.	DEC. 2011. *Long-term coral community monitoring in the Montebello/Barrow Islands marine protected areas: site descriptions and summary analysis of baseline data collected in December 2006.* Marine Science Program Data Report MSPDR9, Department of Environment and Conservation, Western Australian Government, Perth. Available from: https://library.dbca.wa.gov.au/static/Journals/080598/080598-09.pdf [Accessed: September 2023].	
508.	Girard, F. and Fisher, C.R. 2018. Long-term impact of the Deepwater Horizon oil spill on deep-sea corals detected after seven years of monitoring. *Biological Conservation*, 225, 117-127.	
509.	French-McCay, D.P. 2002. Development and Application of an Oil Toxicity and Exposure Model, OilToxEx, *Environmental Toxicology and Chemistry*, 21(10), 2080–2094.	
510.	AMSA. [n.d.]. *The Effects of Maritime Oil Spills on Wildlife including Non-Avian Marine Life.* Teaching Resources, Australian Maritime Safety Authority, Canberra, Australian Capital Territory. Accessed from: https://www.operations.amsa.gov.au/kids-and-teachers-resources/kids/teachers/Tech_Paper/index.html [Accessed: September 2023].	
511.	D'Souza E, Patankar V, Arthur R, Marbà N, Alcoverro T. Seagrass Herbivory Levels Sustain Site-Fidelity in a Remnant Dugong Population. *PLoS One*. 2015 Oct 22;10(10):e0141224. doi: 10.1371/journal.pone.0141224. PMID: 26492558; PMCID: PMC4619644.	
512.	NOAA. 2010. *Oil and sea turtles: biology planning and response.* US Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Response and Restoration.	
513.	Yaghmour, F., Els, J., Maio, E., Whittington-Jones, B., Samara, F., El Sayed, Y., Ploeg, R., Alzaabi, A., Philip, S., Budd, J. and Mupandawana, M. 2022. Oil spill causes mass mortality of sea snakes in the Gulf of Oman. *Science of The Total Environment*, Vol. 825. Available from: https://doi.org/10.1016/j.scitotenv.2022.154072 [Accessed April 2023].	
514.	AMSA. 2010. Response to the Pacific adventurer: operational and technical issues reports. Australian Maritime Safety Authority, Canberra, ACT.	
515.	Watson, J.E.M., Joseph, L.N., and Watson, A.W.T. 2009. A rapid assessment of the impacts of the Montara oil leak on birds, cetaceans and marine reptiles. Prepared on behalf of the Australian Government Department of the Environment, Water, Heritage and the Arts by the Spatial Ecology Laboratory, University of Queensland, Brisbane.	
516.	Gagnon, M.M. 2009. Report on biopsy collections from specimens collected from the surrounds of the West Atlas oil leak – sea snake specimen. Curtin University, Perth, Western Australia.	
517.	Fosette, S., Loewenthal, G., Peel, L.R., Vitenbergs, A., Hamels, M.A., Douglas, C.R., Tucker, A.D., Mayer, F. and Whiting, S.D. 2021. Using Aerial Photogrammetry to Assess Stock-Wide Marine Turtle Nesting Distribution, Abundance and Cumulative Exposure to Industrial Activity. *Remote Sensing*. 13, 1116	
518.	A. D. McIntyre, J. M. Baker, A. J. Southward, W. R. P. Bourne, S. J. Hawkins and J. S. Gray. 1981. *The Long-Term Effects of Oil Pollution on Marine Populations, Communities and Ecosystems*. Philosophical Transactions of the	

Ref. No.	Description	Document ID
	Royal Society of London. Series B, Biological Sciences Vol. 297, No. 1087, pp. 401-411	
519.	Intecsea. 2015. *Gorgon Development: Liquid Release Modelling – Gorgon and Jansz Flowline Release modelling for spill assessment*. Intecsea, WorleyParsons Group. Unpublished report prepared for Chevron Australia Pty Ltd.	
520.	Peakall, D.B., Wells, P.G. and Mackay, D. 1987. A hazard assessment of chemically dispersed oil spills and seabirds. *Marine Environmental Research* 22(2):91–106.	
521.	Nicolson, L. 2022. *Ningaloo Lighthouse Resort Development: Seabird and Shorebird Review and Artificial Light Assessment*. Pendoley Environmental Pty Ltd. Available from: https://www.epa.wa.gov.au/sites/default/files/PER_documentation2/Appendix%20O%20%20-%20Ningaloo%20Lighthouse%20Resort%20Development%20Seabirds%20Shorebirds%20Review_Rev0.pdf [Accessed April 2023].	
522.	Holdway, D.A. 2002. The acute and chronic effects of wastes associated with offshore oil and gas production on temperate and tropical marine ecological processes. *Marine Pollution Bulletin* 44(3):185– 203.	
523.	Shigenaka, G. 2011. Chapter 27 – Effects of Oil in the Environment. In: M. Fingas, ed. *Oil Spill Science and Technology*. Gulf Professional. 985-1024.	
524.	Davis, H.K., Moffat, C.F. and Shepherd, N.J. 2002. Experimental Tainting of Marine Fish by Three Chemically Dispersed Petroleum Products, with Comparisons to the Braer Oil Spill. *Spill Science & Technology Bulletin*. 7(5–6): 257– 278.	
525.	Challenger, G. and Mauseth, G. 2011. Seafood safety and oil spills. In: M. Fingas, ed. *Oil Spill Science and Technology*. 1083-1100.	
526.	Gagnon, M.M. and Rawson, C. 2011. *Montara Well Release, Monitoring Study S4A – Assessment of Effects on Timor Sea Fish*. Curtin University, Perth, Australia.	
527.	Gohlke, J.M. 2011. A Review of Seafood Safety after the Deepwater Horizon Blowout. *Environmental Health Perspectives*. 119(8):1062– 1069.	
528.	Jung, J. 2011. Biomarker Responses in Pelagic and Benthic Fish Over One Year Following the Hebei Spirit Oil Spill (Taean, Korea). *Marine Pollution Bulletin*. 62(8):1859– 1866	
529.	Law, R.J. 1997. *Hydrocarbons and PAH in Fish and Shellfish from Southwest Wales following the Sea Empress Oil Spill in 1996*. International Oil Spill Conference Proceedings 1997 (1): 205–211	
530.	Rawson, C., Gagnon, M.M. and Williams, H. 2011. *Montara Well Release Olfactory Analysis of Timor Sea Fish Fillets*. Curtin University, Perth, Western Australia.	
531.	PTTEP. 2013. *Montara Environmental Monitoring Program: Report of Research*. PTTEP Australia, West Perth, Western Australia. Available from: https://www.au.pttep.com/wp-content/uploads/2019/09/2013-Report-of-Research-Book-vii-1.pdf [Accessed April 2023].	
532.	Smyth Dermot. 2007. *Sea Countries of the North-West*. Literature review on Indigenous connection to and uses of the North West Marine Region. Available at: https://parksaustralia.gov.au/marine/pub/scientific-publications/archive/nw-sea-countries.pdf [Accessed: April 2024]	
533.	Smyth, D. 1994. *Understanding Country: The Importance of Land and Sea in Aboriginal and Torres Strait Islander Societies*. Canberra, Council for Aboriginal Reconciliation.	

Ref. No.	Description	Document ID
534.	RPS. 2023. *Greater Gorgon – Geryon-Eurytion Oil Spill Modelling*. RPS, Robina, Queensland. [Attached in Appendix C of this OPP]	
535.	RPS. 2023. *Greater Gorgon – The Chrysaor and Dionysus Oil Spill Modelling*. RPS, Robina, Queensland. [Attached in Appendix C of this OPP]	
536.	RPS. 2023. *Greater Gorgon – Semele Oil Spill Modelling*. RPS, Robina, Queensland. [Attached in Appendix C of this OPP]	
537.	RPS. 2023. *Greater Gorgon – Chandon Oil Spill Modelling*. RPS, Robina, Queensland. [Attached in Appendix C of this OPP]	
538.	IPIECA. 2017. *Guidelines on implementing spill impact mitigation assessment (SIMA)*. International Petroleum Industry Environmental Conservation Association, London, United Kingdom.	
539.	Chevron Australia. 2023. *ABU Source Control Emergency Response Plan – Exploration Drilling*. Chevron Australia, Perth, Western Australia.	ABU220800006
540.	Spouge, J. 2011. *Assessment of the Risk of Pollution from Marine Oil Spills in Australian Ports and Waters*. Det Norske Veritas (for the Australian Maritime Safety Authority), London, United Kingdom.	
541.	Holand, P. 2017. *Loss of Well Control Occurrence and Size Estimators, Phase I and II*. ExproSoft AS, Trondheim, Norway. Available from: https://www.bsee.gov/sites/bsee.gov/files/tap-technical-assessment-program/765aa.pdf [Accessed April 2023].	
542.	IOGP. 2019. Risk Assessment Data Directory Blowout Frequencies. Report 434-02	
543.	NRDA. 2012. *Natural Resource Damage Assessment April 2012 Status Update for the Deepwater Horizon Oil Spill*. Natural Resource Damage Assessment, United States of America.	
544.	Hook, S., Batley, G., Holoway, M., Irving P. and Ross, A. 2016. *Oil Spill Monitoring Handbook*. CSIRO Publishing	
545.	Almeda, R., Baca, S., Hyatt, C. and Buskey, E.J. 2014. Ingestion and sublethal effects of physically and chemically dispersed crude oil on marine planktonic copepods. *Ecotoxicology*, 23 (2014), pp. 988-1003	
546.	ITOPF. 2011. *Effects of Oil Pollution on the Marine Environment*. Technical Information Paper 13. The International Tanker Owners Pollution Federation Ltd. London, United Kingdom.	
547.	Huntley, M. and Lopez, M. 1992. Temperature-Dependant Production of Marine Copepods: A Global Synthesis. *The American Naturalist*, 140(2): 201-42. DOI: 10.1086/285410.	
548.	Richardson, A.J., Matear, R.J. and Lenton, A. 2017. *Potential impacts on zooplankton of seismic surveys*. CSIRO, Australia.	
549.	National Oceanic and Atmospheric Administration. 2002. *Environmental Sensitivity Index Guidelines*. Version 3. National Oceanic and Atmospheric Administration, Washington, United States of America.	
550.	Ori, S. 2017. *Seven Years After Deepwater Horizon, Offshore Oil Has Flourished Amid Tighter Regulation*. Forbes, United States of America. Available from: https://www.forbes.com/sites/ucenergy/2017/04/17/seven-years-after-deepwater-horizon-industry-has-flourished-amid-tighter-regulation/#383a00f328b6 [Accessed August 2023].	
551.	AMSA. 2020. *National Plan for Maritime Environmental Emergencies*. 2020 Edition. Australian Maritime Safety Authority, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.amsa.gov.au/sites/default/files/national-plan-maritime-envrironmental-emergencies-2020.pdf [Accessed February 2023].	

Ref. No.	Description	Document ID
552.	AMSA. 2020. *National Plan for Maritime Environmental Emergencies*. 2020 Edition. Australian Maritime Safety Authority, Australian Government, Canberra, Australian Capital Territory. Available from: https://www.amsa.gov.au/sites/default/files/national-plan-maritime-envrironmental-emergencies-2020.pdf [Accessed February 2023].	
553.	DoT. 2019. *State hazard plan: Maritime environmental emergencies*. Maritime Environment Emergency Response Unit, Department of Transport, Fremantle, Western Australia. Available from: www.transport.wa.gov.au/mediaFiles/marine/MAC_P_StateHazardPlanMaritimeEnviroEmergMEE.pdf [Accessed February 2023].	
554.	Department of Planning and Environment. 2021. *Cumulative Impact Assessment Guidelines for State Significant Projects*. NSW Government, New South Wales. Available from: https://www.planning.nsw.gov.au/sites/default/files/2023-03/cumulative-impact-assessment-guidelines-for-ssp.pdf [Accessed July 2023].	
555.	The Planning Inspectorate. 2019. *UK guideline: Advice Note Seventeen: Cumulative effects assessment relevant to nationally significant infrastructure projects*. The Planning Inspectorate, United Kingdom.	
556.	Minerals Council of Australia. 2015. *Cumulative Environmental Impact Assessment Industry Guide*. Minerals Council of Australia, Kingston, Australian Capital Territory. Available from: https://minerals.org.au/wp-content/uploads/2023/01/Cumulative_Environmental_Impact_Assessment_Industry_Guide_FINAL_0.pdf [Accessed July 2023].	
557.	NOPSEMA. 2014. *Streamlining Offshore Petroleum Environmental Approvals*. Strategic Assessment Report. National Offshore Petroleum Safety and Environmental Management Authority, Perth, Western Australia. Available from: https://www.industry.gov.au/sites/default/files/streamlining_offshore_petroleum_environmental_approvals_strategic_assessment_report.pdf [Accessed August 2023].	
558.	Chevron. 2023. *Gorgon Gas Development Pipeline and Subsea Infrastructure Installation and Pre-Commissioning Environmental Plan*. Accessed https://info.nopsema.gov.au/environment_plans/638/show_public	GOR-COP-0290
559.	Chevron Australia. 2023. *Jansz-Io Compression Project to Proceed*. Media Statement. Chevron Australia, Perth, Western Australia. Available from: https://australia.chevron.com/news/2021/jansz-io-compression-project-to-proceed [Accessed July 2023].	
560.	Woodside Energy. 2023. *Scarborough Gas Project and Pluto Train 2*. Woodside Energy, Perth, Western Australia. Available from: https://www.woodside.com/what-we-do/growth-projects/scarborough [Accessed July 2023].	
561.	Woodside 2023. WA-34-L *Pyxis Drilling and Subsea Installation Environment Plan*. Available from https://docs.nopsema.gov.au/A1036979 [Accessed March 2024].	
562.	Arienzo, M. Progress on the Impact of Persistent Pollutants on Marine Turtles: A Review. *J. Mar. Sci. Eng*. 2023, 11, 266. https://doi.org/10.3390/jmse11020266	
563.	NOAA. 2023. Turbidity in the Greater Atlantic Region. *Guidance for action agencies on how to address turbidity in their Effects Analysis.* Section 7 Effects Analysis: Turbidity in the Greater Atlantic Region | NOAA Fisheries	
564.	USEPA. 2000. *Regulations Governing the Taking and Importing of Marine Mammals; Endangered and Threatened Fish and Wildlife; Cook Inlet Beluga Whales.* Federal Register: Regs Governing the Taking and Importing of Marine	

Ref. No.	Description	Document ID
	Mammals; Endangered and Threatened Fish and Wildlife; Cook Inlet Beluga Whales	
565.	Tyack PL. 2008. Implications for marine mammals of large-scale changes in the marine acoustic environment. *J Mammal* 89: 549–558.	
566.	McCauley, R. D., Gavrilov, A. N., Jolliffe, C. D., Ward. R., Gill P. C. 2018. Pygmy blue and Antarctic blue whale presence, distribution and population parameters in southern Australia based on passive acoustics. *Deep Sea Research Part II: Topical Studies in Oceanography.* Volumes 157–158, November–December 2018, Pages 154-168. https://www.sciencedirect.com/science/article/pii/S0967064517303958#ab0010	
567.	Standards Australia / Standards New Zealand. 2015. *AS/NZS ISO 14001:2015 Environmental management systems—Requirements with guidance for use*. Sydney, Australia / Wellington, New Zealand.	
568.	Chevron. 2011. *ABU OE Information Management Upstream and Gas Standard*. Chevron Corporation, United States of America	OE-03.02.01
569.	Chevron. 2022. *ABU Management of Change for Facilities and Operations: Upstream and Gas Standardised OE Process*. Chevron Corporation, United States of America.	OE-04.00.01
570.	Chevron. 2015. *ABU Surface Equipment Reliability & Integrity Process (SERIP) Base Business – Standardized OE Process*. Chevron Corporation, United States of America.	OE-05.03.01
571.	Chevron. 2023. *Environment Risk Assessment and Management Procedure*. Chevron Corporation, United States of America.	
572.	Chevron. 2023. *Environment Risk Assessment and Management Procedure*. Chevron Corporation, United States of America.	
573.	Chevron. 2018. *ABU OE Assurance Corporate Process*. Chevron Corporation, United States of America.	OE-12.01.01
574.	Chevron Australia. 2023. *ABU OE Assurance Priorities & Plan*. Chevron Australia, Perth, Western Australia	ABU161100798
575.	Chevron. 2023. *2023 Operational Excellence Data Reporting Standard*. Chevron Corporation, United States of America	
576.	Chevron. 2020. *OE Corporate Standard Incident Investigation*. Chevron Corporation, United States of America	
577.	Chevron Australia. 2022. *II&R Execution Manual: ABU Incident Investigation and Reporting*. Chevron Australia, Perth, Western Australia.	OE-09.00.01
578.	Chevron Australia. 2018. *Emergency Management Chevron Corporate ABU Standarised OE Process*. Chevron Australia, Perth, Western Australia.	OE-11.01.01
579.	Chevron Australia. 2018. *Business Continuity Planning Chevron Corporation: ABU Standardized OE Process*. Chevron Australia, Perth, Western Australia	OE-11.01.1110
580.	Gauthreaux, S.A. and Belser, C.G. 2006. Effects of artificial night lighting on migrating birds. In: E*cological Consequences of Artificial Night Lighting*, Rich C and Longcore T, Editors. Island Press: Washington, D.C., USA, p:67–93	271 jic
581.	Marquenie J., Donners M., Poot H., Steckel W de Wit B. 2013. *Bird-Friendly Light Sources: Adapting the Spectral Composition of Artificial Lighting*. Industry Applications Magazine, IEEE. 19. 56–62. 10.1109/MIAS.2012.2215991.	272 jic
582.	Commonwealth of Australia. 2022. *Wildlife Conservation Plan for Seabirds*. Department of Agriculture, Water and Environment, Canberra, ACT. Available at: https://www.dcceew.gov.au/sites/default/files/documents/wildlife-conservation-plan-for-seabirds.pdf [Accessed: June 2023]	237 jic

Gorgon Gas Development: Backfill Fields Offshore Project Proposal

Appendices

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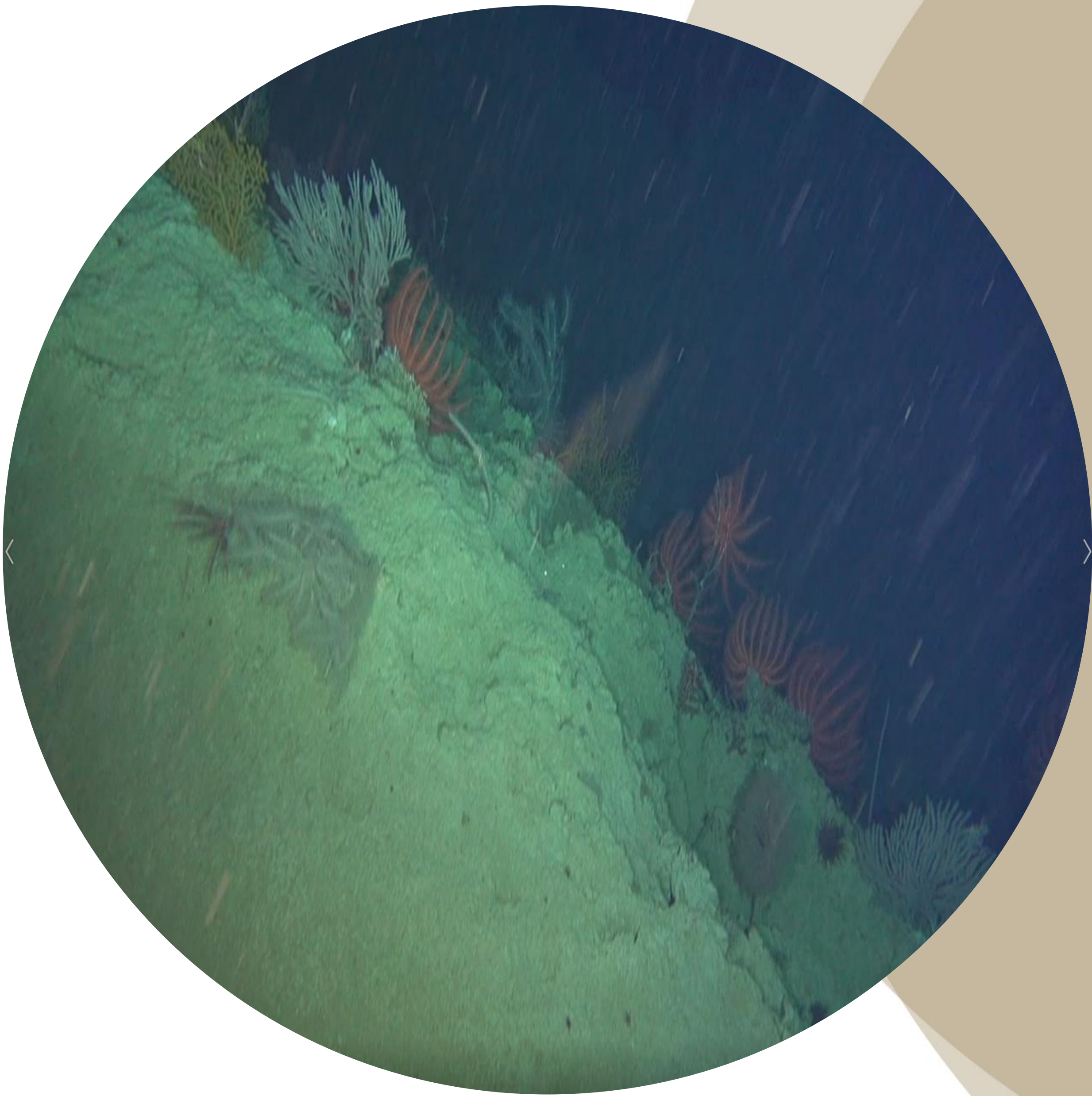
List of appendices

Appendix A Gorgon Backfill Fields Benthic Survey 2022



Gorgon Backfill Fields Benthic Survey 2022

Survey Report

Chevron Australia Pty Ltd

September 2023

411012-00488

Advisian
Worley Group

advisian.com

Disclaimer

Company details

Advisian Pty Ltd
50 098 008 818
Level 14, 240 St George's Terrace, Perth WA
Perth WA 6000
Australia
T: +61 8 9485 3811

PROJECT 411012-00488: Gorgon Backfill Fields Benthic Survey 2022 - Survey Report

Rev	Description	Author	Review	Advisian approval	Revision date	Client approval	Approval date
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3		K. Inostroza	L. Chiaroni	M. Westera	27/09/23		

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Executive Summary

Chevron Australia Pty Ltd (CAPL) are developing an Offshore Project Proposal (OPP) to work towards approvals for the development of several new fields to tie-in existing Gorgon Development infrastructure (Gorgon Foundation Project) in the Greater Gorgon area (collectively known as Gorgon Gas Development: Backfill Fields; GBF) which will include the installation of multiple subsea facilities such as flowlines, umbilicals and drill centres/well infrastructure sites. To inform the OPP and support future environmental approvals, CAPL commissioned Advisian Pty Ltd to characterise the marine benthic environment within the GBF project area, which is defined as a 5 km buffer around all indicative subsea infrastructure. The final flowlines and umbilical routes have not been identified yet by CAPL however, survey sites are focused on indicative flowline and umbilical routes, tie-in locations and proposed drill centres. The scope of works included: 1) the development of a preliminary benthic habitat map to identify areas of significance (such as Key Ecological Features; KEFs) and notable benthic features and identify survey sites for field verification; and 2) to undertake an environmental survey of benthic habitat, sediment, benthic infauna, marine water and fish assemblages within the GBF project area.

Prior to the field survey, a preliminary benthic habitat map spanning 500 m from all potential benthic disturbance footprints was generated using all available geophysical data provided by CAPL, which included multibeam echo sounder, backscatter, sidescan sonar, 3D seismic, and geotechnical sediment data. Images were processed and enhanced where possible to identify geomorphic habitat types. The map identified eight broad habitats within the GBF project area, and identified three KEFs (elements of the Commonwealth marine environment that are considered to be of regional importance; DCCEEW, 2022) that intersect with some of the GBF project area: 'Exmouth Plateau', 'Continental Slope Demersal Fish Communities', and 'Ancient Coastline at 125 m depth contour' (hereafter 'Ancient Coastline'). From this map, sampling sites were identified for ground-truthing based on the geomorphic attributes, the presence of benthic features within these KEFs, and areas with data deficiency and other points of interest. Following the completion of in field ground-truthing, the project operational area was expanded from 500 m to a 5 km radius around all potential subsea facilities, and was further mapped using all available desktop resources. No ground truthing of benthic habitats was undertaken within the expanded operational area footprint.

The field survey was completed between the 26th April and 11th May 2022 on board Skandi Singapore (DOF Subsea Pty Ltd). Benthic habitat and fish survey data were collected along transects using a remotely operated vehicle (ROV). The ROV had a forward-facing high definition (HD) camera to collect video footage for habitat mapping and fish assemblages, and a downward-facing HD camera that captured still images and video footage for benthic cover. The vessel position and ROV were tracked using survey grade positioning equipment. The ROV was also used to deploy all sampling equipment to the seafloor including push corers for the collection of sediments and benthic infauna, Niskin bottles for water sampling above the seabed, and a water quality probe to measure conductivity, temperature and depth throughout the water column. Surface water samples were also collected from the vessel. All sediment samples were analysed for hydrocarbons, total metals/metalloids, particle size distribution, total organic carbon (TOC) and moisture content. All water samples were analysed for hydrocarbons, dissolved and total metals, dissolved organic carbon (DOC), TOC, total dissolved solids (TDS) and nutrients.

Benthic habitat mapping following ground-truthing confirmed that a mixture of habitat types were present within the proposed GBF project area. Where the GBF project area intersects with the Exmouth

Plateau KEF, the benthic habitat is dominated by irregular seabed with bioturbation, irregular and smooth seabed floor with bare substrates, and mounds on the seafloor of bare substrate. In the Exmouth Plateau KEF that lies within the GBF project area, two large discrete scarps with 3-dimensional hard structure (i.e., rock) cross through the indicative flowline from east to west, likely providing biota with suitable habitat. Where the GBF project area crosses with the Continental Slope Demersal Fish Communities KEF, irregular and smooth seabed with bare substrates and discrete depressions of bare substrate, and scarps with bare substrate were the most dominant benthic features. Topographically complex rock reefs and scarps were also present traversing through the GBF project area between ~400–800 m depths that were colonised by cnidarians, echinoderms, sponges and a mixture of these biotic groups. Mapping of the GBF project area that lies within the Ancient Coastline KEF shows that the benthic habitat consisted of smooth seabed with bioturbation and appeared devoid of non-cryptic biota.

Benthic habitat mapping of low slope areas (defined as areas within the GBF project area containing proposed infrastructure located outside of KEFs in the lower slope and Kangaroo Syncline areas) showed a mixture of low structural habitats present within the Chandon DC-1 to JMT corridor. The benthic habitat within the Jansz to Geryon and Eurytion corridors comprised smooth seabed with bioturbation and irregular seabed with bare substrate, with intermittent mounds with bare substrate and scattered patches of depressions over bare substrate. The benthic habitats within the Chrysaor and Dionysus to Gorgon corridor are predominantly characterised by smooth and irregular seabed with either bare substrate or bioturbation.

Benthic habitat mapping around proposed drill centres and tie in locations that are located outside a KEF and not in a low slope area, which include Jansz DC2, G & E DC-1, Semele DC-1, Semele DC-2, BCH40 and WTR DC-1, were of low structural complexity and dominated by smooth seabed with bioturbation. Ground truthing transects at each of these locations did not reveal any epifaunal communities.

The benthic cover at 14 proposed drill centres and tie-in locations showed that bare sediment with no biota was the dominant benthic category. Benthic cover along some transects at Chandon DC-1, Jansz JMT, Jansz DC2, Semele DC-1, Semele DC-2, BCH42 and BCH43 comprised of occasional boulders over bare sediment and bioturbation in bare sediment. Gorgon M1 was the only site with bioturbation and very low cover of cnidarians.

For fish assemblages, Ancient Coastline KEF recorded a total of 18,011 individuals from 13 fish taxa compared to the Exmouth Plateau (165 individuals from 14 taxa), Continental Slope Demersal Fish Communities (165 individuals from 14 taxa) and out of KEF area (11,800 individuals belonging to 28 taxa). The fish assemblage across most KEFs were by dominated trevallies such as *Seriola dumerili* (Carangidae), *Carcharhinus* sp1 (Carcharhinidae), an unidentified anguilliform fish, and an unidentified baitfish species. The crustacean assemblage was greatest in the Exmouth Plateau KEF and outside of KEF areas, comprising of 228 individuals from seven taxa and 236 total individual crustaceans from seven taxa, respectively. Prawns were the most dominant crustacean taxa found across all KEFs.

Of the four geomorphic features (plateau slope, trench/trough slope, slope, and deep/hole/valley slope), the slope geomorphic features had the largest number of individual fish species (30,033) belonging to 37 taxa followed by the deep/hole/valley slope with 187 individuals from 16 fish taxa. Between 110 and 236 individual crustaceans were recorded across all geomorphic features with the exception for slope which only recorded five individuals.

A total of 922 invertebrate individuals from 26 taxa were recorded across all sites. The invertebrate assemblage included feather stars, jellyfish, sea cucumbers, sea stars, sea urchins and squids.

For sediment samples located within proposed drill centres and tie in locations, concentrations of all hydrocarbons were below the laboratory limit of reporting (LOR). Concentrations of all metals and metalloids were all below their relevant ANZG (2018) default guideline values (DGVs), with the exception of nickel. TOC concentrations were relatively low across all samples. Sediments primarily consisted of well-sorted clays and silts that were odourless and contained the occasional small shell fragments. A total of five individual benthic infauna belonging to three families were collected across four sites.

No hydrocarbons were detected in water samples collected from the surface and near the seabed across the GBF project area. Concentrations of all dissolved and total metals in water samples met the relevant DGVs except for dissolved cobalt and copper. Measurable levels of DOC, TOC, TDS and nutrients were detected in the water samples. Water profiles were consistent across the sites and showed a gradual decrease in temperature and conductivity with increasing depth while salinity was relatively consistent with depth. At the deeper sites, three water masses were identified in the water column: low salinity surface waters (upper ~180 m), higher salinity mid-waters (~185–250 m) and low salinity bottom waters (~250–1310 m depth).

Overall, the benthic environment is characteristic of the North Carnarvon Basin and the North West Shelf region and is typical of an undisturbed tropical offshore environment (Heyward et al., 2001; Falkner et al., 2009; Williams et al., 2010). This survey did not find any benthic communities and habitats of regional significance.

Acronyms and Abbreviations

Acronym/abbreviation	Definition
°C	Degrees Celsius
2D	Two dimensional
3D	Three dimensional
AAIW	Antarctic Intermediate Water
ANZG	Australian and New Zealand Guidelines
BCH	Benthic communities and habitats
BS	Backscatter
BTEX	Benzene, toluene, ethylbenzene and xylenes
CATAMI	Collaborative and Automated Tools for Analysis of Marine Imagery
CoC	Chain of custody
CTD	Conductivity, temperature and depth
DC	Drill centre
DGV	Default guideline value
DEM	Digital elevation model
DistLM	Distance-based linear modelling
DOC	Dissolved organic carbon
DPIRD	Department of Primary Industries and Regional Development
fps	Frames per second
G & E	Geryon and Eurytion
GBF	Gorgon Backfill Fields
GIS	Geographic information system
GPS	Global positioning system
HD	High-definition
KEF	Key Ecological Features
km/h	Kilometre per hour
LOR	Limit of reporting
MBES	Multibeam echo sounder
mS/cm	MilliSiemens per centimetre

Acronym/abbreviation	Definition
NATA	National Association of Testing Authorities
nMDS	Non-parametric multidimensional scaling
OPP	Offshore Project Proposal
PAH	Polycyclic aromatic hydrocarbons
PEP	Project Execution Plan
PERMANOVA	Parametric analysis of variance
PSD	Particle size distribution
PSU	Practical Salinity Unit
QA/QC	Quality assurance and quality control
ROV	Remotely operated vehicle
RPD	Relative percent difference
RSD	Relative standard deviation
SAGA GIS	System for Automated Geoscientific Analyses
SE	Standard error
SICW	Southern Indian Central Water
SSS	Sidescan sonar
TMS	Tether management system
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TPI	Topographic Position Index
TRH	Total recoverable hydrocarbons
TSW	Tropical Surface Water
WTR	West Tryal Rocks

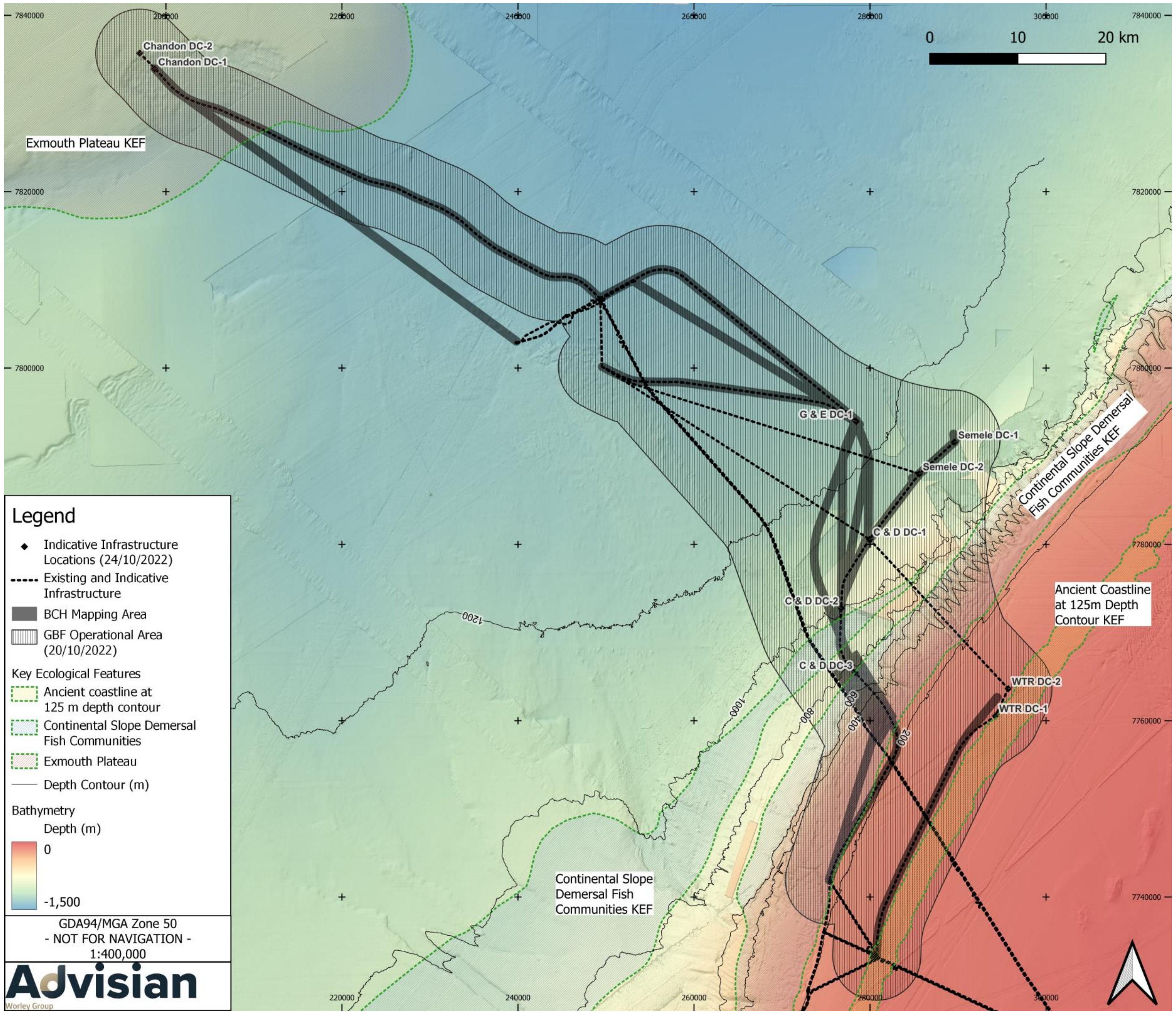
1 Introduction

1.1 Background

Chevron Australia Pty Ltd (CAPL) are developing an Offshore Project Proposal (OPP) to work towards approvals for the development of several new fields to tie-in existing Gorgon Development infrastructure (Gorgon Foundation Project) in the Greater Gorgon area: Geryon, Eurytion, Chandon, Semele, Chrysaur, Dionysus and West Tryal Rocks (WTR) (hereafter; collectively known as Gorgon Gas Development: Backfill Fields, GBF; Figure 1-1). The fields are located between ~60–130 km north-west of Barrow Island, Western Australia, in water depths ranging from 150 m (WTR) to 1,300 m (Chandon). Multiple subsea facilities such as flowlines, umbilicals and drill centres/well infrastructure sites may be required for the development of each field. Although the final flowlines and umbilical routes have not been identified yet by CAPL, the study sites are focused on indicative flowline and umbilical routes, tie-in locations and indicative drill centres.

The GBF project area spans three Key Ecological Features[1] (KEF) of the Commonwealth marine environment; from the Exmouth Plateau in the west, to the Continental Slope Demersal Fish Communities, and Ancient Coastline at 125 m depth contour (hereafter Ancient Coastline) (Figure 1-1). These KEFs are likely to be relatively topographically complex and support a range of benthic habitats and organisms such as soft deep-sea coral, sea fans (gorgonians), sponges as well as regionally significant stocks of demersal fishes. To inform the OPP and support future environmental approvals, CAPL commissioned Advisian Pty Ltd (Advisian) to characterise the marine benthic environment within the GBF project area.

[1] Key Ecological Features are elements of the Commonwealth marine environment that are considered to be of regional importance for either a region's biodiversity or its ecosystem function and integrity (DCCEEW, 2022).



Notes:

1. BCH = Benthic communities and habitat, GBF = Gorgon Backfill Fields, KEF = Key Ecological Feature, WTR = West Tryal Rocks
2. The GBF operational area has been expanded to a 5 km radius around the GBF project area post-field survey, as further discussed in Section 3.4

Figure 1-1 Overview of Gorgon Backfill Fields project area with conceptual subsea facilities in relation to Key Ecological Features of the area

1.2 Project Location and Geomorphology

To better understand the geomorphic characteristics of the GBF project area, which is defined as a 500 m radius around the proposed drill centres and tie-in locations, and a 500 m buffer around all associated subsea flowlines, CAPL and Advisian undertook a desktop study to develop a preliminary benthic habitat map. To develop this map, CAPL provided Advisian all available geophysical data to classify the habitat type based on discernible physical geomorphic or other notable benthic features. This map was then used to identify and inform targeted survey sites where information within the GBF project area may have been lacking. Refer to Section 2 for more details.

The primary geomorphic features in the GBF project area include the continental shelf, the upper, middle, and lower continental slope, the Kangaroo Syncline, and the Exmouth Plateau. The continental shelf is generally defined as extending from the nearshore environment to the shelf break at approximately 200 m water depth. The shelf features varied terrain including both modern sedimentary deposits and the remains of low sea level shoreline features (Geoscience Australia, 2022). The shallower continental slope deposits comprise mixed sediments, including both modern terrigenous (river derived) and carbonate (biogenic) materials, as well as the often-coarse preserved remains of ancient sediments [relict intraclasts] (James et al., 2004). The continental slope is characterised by complex and often steep submarine canyon systems, smooth sedimentary fans, and abrupt landslide scars.

The deep-water area separating Barrow Island from the Exmouth Plateau is known as the Kangaroo Syncline. This area includes mostly featureless seabed and the remains of older landslide deposits and sedimentary fans. The majority of the GBF project area is within this deeper area (800–1350 m) and is typically dominated by hemipelagic-pelagic sandy muds (high carbonate foraminiferal and nannofossil 'ooze'), which mantles all but the steepest of seabed features. Rates of sediment deposition and disturbance are low in these environments and even highly pronounced seabed features can be very old and may be draped with many metres of pelagic sediments (Hengesh et al., 2013).

The Exmouth Plateau is located in the Northwest Province and covers an area of approximately 49,310 km^2 (Heap and Harris, 2008). The plateau is an ancient, stranded section of continental crust that now resides in water depths typically greater than 1000 m. The plateau has associated lower continental slope features including landslide scars. The seascape is generally considered not unique in the regional context however it is believed that the expansive surface and large size may modify deep water flow and generate internal tides (Brewer et al., 2007). The Exmouth Plateau has been described as an area of low habitat heterogeneity, however, is considered to be an important area of biodiversity for offshore communities (DSEWPaC, 2012).

The GBF project area also intersects through three KEFs at different locations: proposed Chandon drill centre and associated flowline/umbilical corridors are located within the Exmouth Plateau KEF; flowlines in the Chrysaor and Dionysus fields are within Continental Slope Demersal Fish Communities KEF; and flowlines stemming from Gorgon GMT to WTR DC-1 in the WTR field are located within the Ancient Coastline KEF (Figure 1-1). The Exmouth Plateau KEF is recognised for its biodiversity values, with unique seafloor features ecological properties of regional significance, which apply to both the benthic and pelagic habitats within this KEF (DSEWPaC, 2012). The Continental Slope Demersal Fish Communities is an area on the Australian continental slope with a high diversity of demersal fish assemblages and high levels of endemism (DSEWPaC, 2012). This KEF has documented more than 500 fish species, 76 of which are endemic, making it the most diverse continental slope bioregion in Australia (Last et al., 2005). Demersal fish species occupy two distinct demersal community types, or biomes, associated with the upper slope (water depth of 225–500 m) and the mid-slope (750–1000 m). The Ancient Coastline is an area of hard substrate (i.e., rock escarpments) that may be associated with enhanced species richness and higher diversity relative to surrounding areas of predominantly soft sediment. Likely fauna associated with the hard substrate of the ancient coastline include sponges, molluscs, echinoderms, corals, and crinoids (DSEWPaC, 2012).

1.3 Project Objective and Scope

The primary objective of this project was to describe the marine benthic environment (benthic habitats and communities; BCH) within the GBF project area. Secondary, we used the field mobilisation to broadly characterise other elements of the GBF project area, including marine water and sediment quality, demersal fish and benthic infaunal assemblages.

The scope of work included:

1. Development of a preliminary benthic habitat map based on assessment of geomorphic features to identify areas of significance (such as KEFs) and notable benthic features within the GBF project area and identify survey sites for field verification
2. Complete a visual benthic survey within identified survey sites to:
    a) verify the presence/absence of prominent and/or complex seabed features and other BCH across the GBF project area to further inform the preliminary habitat map
    b) describe and quantify BCH across a subset of representative sites
    c) opportunistically describe demersal fishes and identify fish and habitat associations within surveyed areas
3. Broadly characterise the water and sediment quality and composition within the GBF project area.
4. Describe the benthic infaunal assemblages within a subset of representative sites

This report presents the results of the field survey and includes both preliminary and refined benthic habitat assessment and mapping.

2 Preliminary Benthic Habitat Mapping Methods and Results

2.1 Data Acquisition

A preliminary benthic habitat map within the GBF project area was developed prior to the field survey to classify key benthic and geomorphic features of the seabed, and identify areas with insufficient information to describe the existing environment. To support the development of this map, all available geophysical data was provided by CAPL (Table 2-1), which included data collected from shipborne and underwater vehicles:

- Multibeam echo sounder (MBES) data, which provided a medium to high resolution 3-dimensional (3D) bathymetric terrain model of the seabed, from which morphological features were identified. Bathymetric grids of 2 m, 3 m, 5 m, 10 m and 20 m resolution were supplied.
- Backscatter (BS) data, which is a product derived from MBES outputs that represents the strength of the acoustic signal returning from the seabed. This allows an assessment of seabed textural qualities (e.g., hardness or roughness) which can help in identifying features not otherwise visible in the bathymetry data.
- Sidescan Sonar (SSS) data, which is similar to BS however, it typically has higher resolution, allowing identification of fine-scale objects and textures, but lower spatial accuracy.
- 3D Seismic data, which comprises an acoustic reflection that can be processed to create a bathymetric terrain model similar to MBES.
- Geotechnical sediment data, including the results of 349 sediment descriptions as well as qualitative sediment assessments from SSS data.

Table 2-1 Details of the available geophysical data within the Gorgon Backfill Fields project area

Data Type	Number of Files	Grid Cell Resolution (m)	Areas Covered
MBES data	31	2, 3, 5, 10, 20	Most of the study area
BS data	6	1, 2, 3, 5	Same area as MBES
SSS data	69	0.2, 0.3, 0.5	Various narrow track lines covering less than 50% of the study area
3D Seismic data	3	10, 20, 25	Most of the study area

Note:
1. BS = Backscatter, MBES = multibeam echo sounder, SSS = sidescan sonar

2.2 Image Processing

MBES imagery was processed into a number of derivative products, to delineate seabed features at a variety of scales. Quantitative bathymetric analysis techniques were used to split the project area into multiple polygons for final interpretation. Bathymetric terrain derivatives were calculated using the powerful software tool SAGA GIS (System for Automated Geoscientific Analyses). These included:

- Shaded relief bathymetry: a 'sun shading' software rendering process was applied to the bathymetry dataset, which enhances textural features that are large enough to be captured by the mapping and processing equipment used (Yokoyama et al., 2002).
- Topographic roughness: roughness was computed by subtracting the minimum depth from the maximum depth value in a defined-neighbourhood around a central pixel. The neighbourhood is defined as the 8 nearest cells to a central pixel. Roughness is equal to the maximum depth displacement in a 3 by 3 grid of digital elevation model (DEM) cells around a central point. Given how roughness is calculated, it is always given as a value greater than or equal to zero. Values of zero or those close to zero indicate flat areas, whereas larger roughness values indicate increasingly steep or complex terrain (Riley et al., 1999).
- Topographic Position Index (TPI): the TPI algorithm compares a DEM cell value to the mean value of its neighbours. The mean value is calculated based on the shape selected by the user. Positive values represent features typically higher than surrounding features, negative values represent lower features, and values near zero are either flat or areas of constant slope (Watkins, 2020).
- Quantitative Seabed Slope (°): slope was defined as the ratio of rise to run over the defined-neighbourhood area. In geospatial data, slope is defined as the steepness of a surface or its inclination and is always positive. It should be noted that slope cannot differentiate between a mound and a depression, or a ridge and a valley (Evans, 1979; Florinsky, 2009).
- BS/SSS: indicates the strength of the returning signal as received by the vessel-mounted MBES or SSS system. This can indicate much finer scale textural and hardness information relating to the seabed. Note that only a derived image of BS was provided, which limits the potential classification techniques which can be applied. Images were locally stretched in order to maximise the resolving capability. High BS (typically white) indicates a harder/rougher seabed, whereas low BS (typically black) typically indicates a softer/smoother seabed.

2.3 Data Coverage and Quality

Data reliability buffers were applied that represent the distribution of the source data. A combination of MBES and SSS imagery with a resolution ranging from 0.2–10 m were considered more reliable, spatially accurate and of higher confidence, whereas 3D seismic/MBES combination with a resolution range of 10–25 m was considered of moderate (adequate) confidence.

2.4 Classification of Habitat

Due to the high spatial variability and availability of data types, no fully automated classification techniques could be implemented. However, using the derived terrain and textural feature layers, physical seabed features could be recognized and manually interpreted according to the following documented techniques:

- Morphological features (Dove et al., 2020)
- Terrain feature segmentation (Watkins, 2020)
- Sedimentary bedforms (Ashley, 1990)
- Shelf and slope classification (Butler et al., 2017, James et al., 2004)
- Submarine landslide interpretation (Hengesh et al., 2013)
- Debris fans (Posamentier and Walker, 2006)

- Habitat mapping surrogacy assumptions (McArthur et al., 2010)
- Habitat mapping assumptions (EPA, 2016)
- Submarine canyons (Huang et al., 2014, 2018)
- Collaborative and Automated Tools for Analysis of Marine Imagery (CATAMI) classification scheme (Althaus et al., 2015).

Using the shaded relief, slope, TPI, roughness and backscatter information, seabed features were visually assessed for any discernible physical geomorphic or other notable benthic features. Assessments were made for potential sediment type, presence of rock or subsurface rock, relief, slope and sedimentary bedforms according to the CATAMI classification scheme (Althaus et al., 2015; Table 2-2). These features were nested within common boundaries in order to allow geographic information system (GIS) polygon attribution. Additionally, a morphological descriptor nested with the CATAMI scheme was also provided (Table 2-3). On-screen delineation of polygon boundaries was undertaken at a scale of 1:5000 using a desktop GIS software package.

Table 2-2 Collaborative and Automated Tools for Analysis of Marine Imagery classification scheme with feature descriptors

CATAMI	Feature Descriptors
Substrate Type 1 (S1)	Consolidated/ Hard (CAAB 82 001001) Unconsolidated/ Soft (CAAB 82 001005)
Substrate Type 2 (S2)	Fine sand/ mud (CAAB 82001015 + 82001016 Undifferentiated) Coarse sand (CAAB 82 001014) Pebble/ Gravel (CAAB 82001006)
Substrate Type 3 (S3)	Veneer Rock (CAAB 82 001002)
Relief Type 1 (R1)	Flat (CAAB 82 003001), Roughness <0.05 Low / Moderate (CAAB 82 003002) High (CAAB 82 003005), Roughness >0.1
Relief Type 2 (R2)	Low <1 m (CAAB 82 003003) Moderate 1-3 m (CAAB 82 003004) High >3 m (CAAB 82 003006) Wall (CAAB 82 003007) Other
Bedform Type 1 (B1)	None (CAAB 82 002001) 2D (CAAB 82 002002) 3D (CAAB 82 002006) Other
Bedform Type 2 (B2)	Ripples <10 cm (CAAB 82 002003) Waves >10 cm (CAAB 82 002004)

CATAMI	Feature Descriptors
	Large waves >0.75 m Very large waves >5 m Irregular
Bedform Type 3 (B3)	Small <10 m Medium 10–50 m Large 50–100 m Very large >100 m

Table 2-3 Attribute table (final substrate descriptor relating to Collaborative and Automated Tools for Analysis of Marine Imagery classification)

Morphological Descriptor	Description	Bathymetry	Slope/Topographic Position	Relative BS/SSS	CATAMI (S1/S2/S3/R1/R2/B1/B2/B3)
Bare seabed	Featureless sedimentary terrain	Smooth, no identifiable features, fine or coarse sediment	Typically, less than 2°, no topographic features	Low, no discernible feature	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: N/A R1: FLAT R2: N/A B1-3: N/A
Mostly bare seabed	Mostly flat sediment terrain with very minor features	Smooth with rare identifiable but unmappable regular bedforms or mounds. Fine or coarse sediment	Typically, less than 2°, very minor topographic features	Low, rare and small discernible features	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: N/A R1: FLAT R2: N/A B1-3: N/A
Irregular Seabed	Mostly flat sediment terrain with minor features which may be derived from underlying geology	Smooth with identifiable, regular but small bedforms or mounds. Fine or coarse sediment	Typically, less than 2°, minor topographic features	Low, rare and small discernible features	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: N/A R1: LOW-MOD R2: LOW B1: OTHER B2: IRREGULAR B3: N/A

Morphological Descriptor	Description	Bathymetry	Slope/Topographic Position	Relative BS/SSS	CATAMI (S1/S2/S3/R1/R2/B1/B2/B3)
Rock Veneer	Area of buried bedrock/rocks or cemented sediments with very low sediment input (Starved). Also known as low profile reef	Uneven, rugged and irregular features, often angular or linear. Fine or coarse sediment	Typically, less than 2°, highly variable but low-profile topographic features. Signs of subsurface structure must be apparent	Varied, mostly high	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: VENEER R1: LOW-MODERATE R2: LOW or MODERATE B1: OTHER B2: IRREGULAR B3: N/A
Mound	Locally elevated Sediment or Rock Veneer feature which comprising rubble, geological or biological in origin	Bathymetric features measurable in profile. Isolated, smooth-edged feature. No structure indicating active sand wave or dune	Varied but smooth slope. TPI index high	Varies depending on incidence angle, typically very high	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: VENEER R1: LOW-MODERATE or HIGH R2: MODERATE or HIGH B1: OTHER B2: IRREGULAR B3: N/A
Rock Reef	Bedrock or other consolidated material outcrop	Rough bathymetric features measurable in profile	Varied complex slope. TPI index high	High/variable	S1: CONSOLIDATED S2: N/A S3: ROCK R1: LOW-MODERATE or HIGH R2: MODERATE or HIGH

Morphological Descriptor	Description	Bathymetry	Slope/Topographic Position	Relative BS/SSS	CATAMI (S1/S2/S3/R1/R2/B1/B2/B3)
					B1: OTHER B2: IRREGULAR B3: N/A
Depression / Scour	Local depression which may be geological or biological in origin (Linear Scour or Pockmark)	Bathymetric features measurable in profile (low)	Varied slope. TPI index low	Varies depending on incidence angle	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE S3: VENEER or N/A R1: LOW-MODERATE or HIGH R2: LOW or MODERATE or HIGH B1: OTHER B2: IRREGULAR B3: N/A
Scarp	Bedrock or other consolidated material outcrop, subject to landslide erosion	Rough bathymetric features measurable in profile	Typically, greater than 15°, may have steep sides	Varies depending on incidence angle	S1: CONSOLIDATED S2: N/A S3: ROCK R1: LOW-MODERATE or HIGH R2: MODERATE or HIGH B1: OTHER B2: IRREGULAR B3: N/A
Bedforms/Ripples/ Ribbons (Small, Medium	Active or once active sediment bedforms indicating wave or	May be visible bathymetric features or may	Varied, wavelength and amplitude measured in profile (Ashley, 1990)	Varies depending on incidence angle. Typically, low	S1: UNCONSOLIDATED S2: FINE SAND-MUD, COARSE

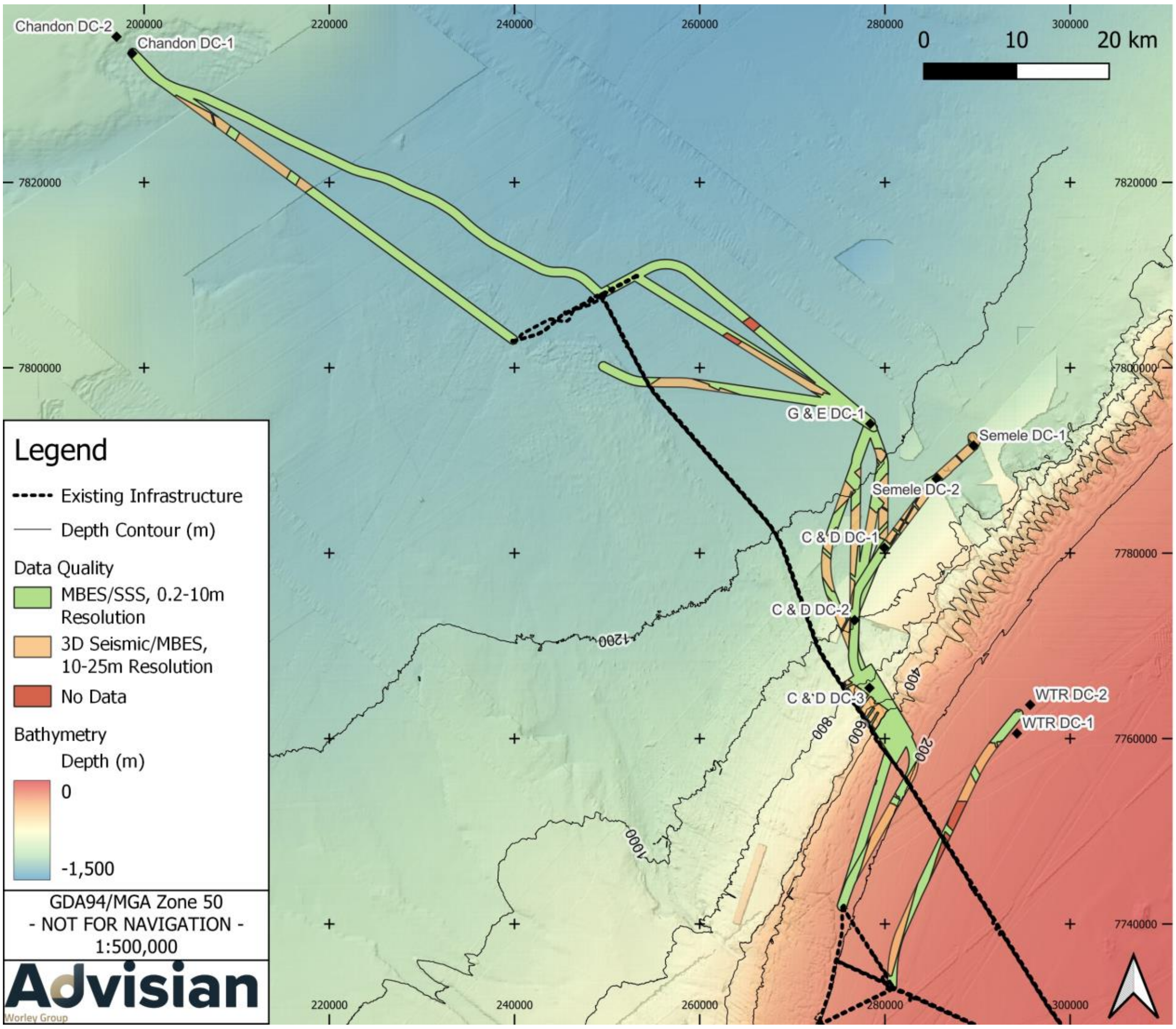
Morphological Descriptor	Description	Bathymetry	Slope/Topographic Position	Relative BS/SSS	CATAMI (S1/S2/S3/R1/R2/B1/B2/B3)
2 or 3 dimensional, Irregular)	current action on the seabed	only occur in backscatter if small			S3: N/A R1: LOW-MODERATE or HIGH R2: MODERATE or HIGH B1: 2D or 3D B2: ANY B3: ANY

Note:
1. N/A = not applicable

2.5 Results

2.5.1 Mapping Confidence

A total of 31,053 hectares (ha) of benthic habitat was initially mapped within the GBF project area, which spanned 500 m from all preliminary indicative subsea infrastructure. Of this, 23,600 ha was mapped with high confidence based on the MBES and SSS imagery classification, and 6,721 ha was mapped with moderate confidence using 3D seismic/MBES imagery (Figure 2-1). The remaining 733 ha was classified as low confidence as there were no data available (Figure 2-1). Areas with no data included small sections along the proposed Geryon and Eurytion (G & E) to Jansz corridors, and sections along the proposed WTR corridor (Figure 2-1).



Note:

1. C & D = Chrysaor and Dionysus, DC = drill centre, G & E = Geryon and Eurytion, MBES = multibeam echo sounder, SSS = sidescan sonar, WTR = West Tryal Rocks

Figure 2-1 Mapping confidence within the Gorgon Backfill Fields project area

2.5.2 Preliminary Habitat Mapping

Preliminary mapping of seabed geomorphology identified a total of eight broad geomorphic feature types, including mostly bare sediments, bedforms, irregular seabed, mounds, depression/scours, rock veneer, rock reef and scarp (Figure 2-2). Areas mapped with no polygons reflect data gaps where mapping could not be completed (Figure 2-2). The GBF project area is dominated by bare and irregular bare seabed, which comprised over 75% of the mapped area. Rock reef or areas that potentially feature exposed bedrock comprised ~10%.

Most of the GBF project area is dominated by recent or ancient landslide features. These features include incipient failure ridges and depressions on the shelf edge, a series of very steep escarpments (head scarps), signs of large translational and rotational mass movements, chaotic debris accumulations, isolated blocks and distal debris fans with associated soft sediment 'crevasse' structures. Many areas have their morphology determined by rocky outcrops or rock debris. However, as pelagic marine sediment is known to cover most of the area, it is likely that all but the steepest areas may comprise a mosaic of outcrop or sediment cover.

The edge of the Exmouth Plateau KEF was mapped, showing sediment covered landslide features. Geomorphic habitats intersected with the Continental Slope Demersal Fish Communities KEF, forming highly complex and sometimes steep terrain. No Ancient Coastline KEF features were detected within the GBF project area. The Ancient Coastline KEF is known to exist in shallower water, particularly from the 60–80 m depth range (DSEWPaC, 2012).

No canyon features were observed in the GBF project area; however, these are known to occur close to the area in the Continental Shelf transition zone. Coarse sediment could not be detected with the available data, however, patches of high SSS anomaly on the shelf edge may indicate the presence of coarse material. Furthermore, the available SSS and high resolution MBES data was highly variable, meaning that the quality varied making interpretation harder in some cases, and fine scale features will have been missed in many areas.

The preliminary habitat map was reviewed by Advisian and CAPL marine environmental specialists to determine field survey sampling sites for further ground-truthing, which were based on the spatial representation of all geomorphic attributes throughout the GBF project area, the presence of benthic features within KEFs, and areas with data deficiency and other points of interest.

Advisian
Worley Group

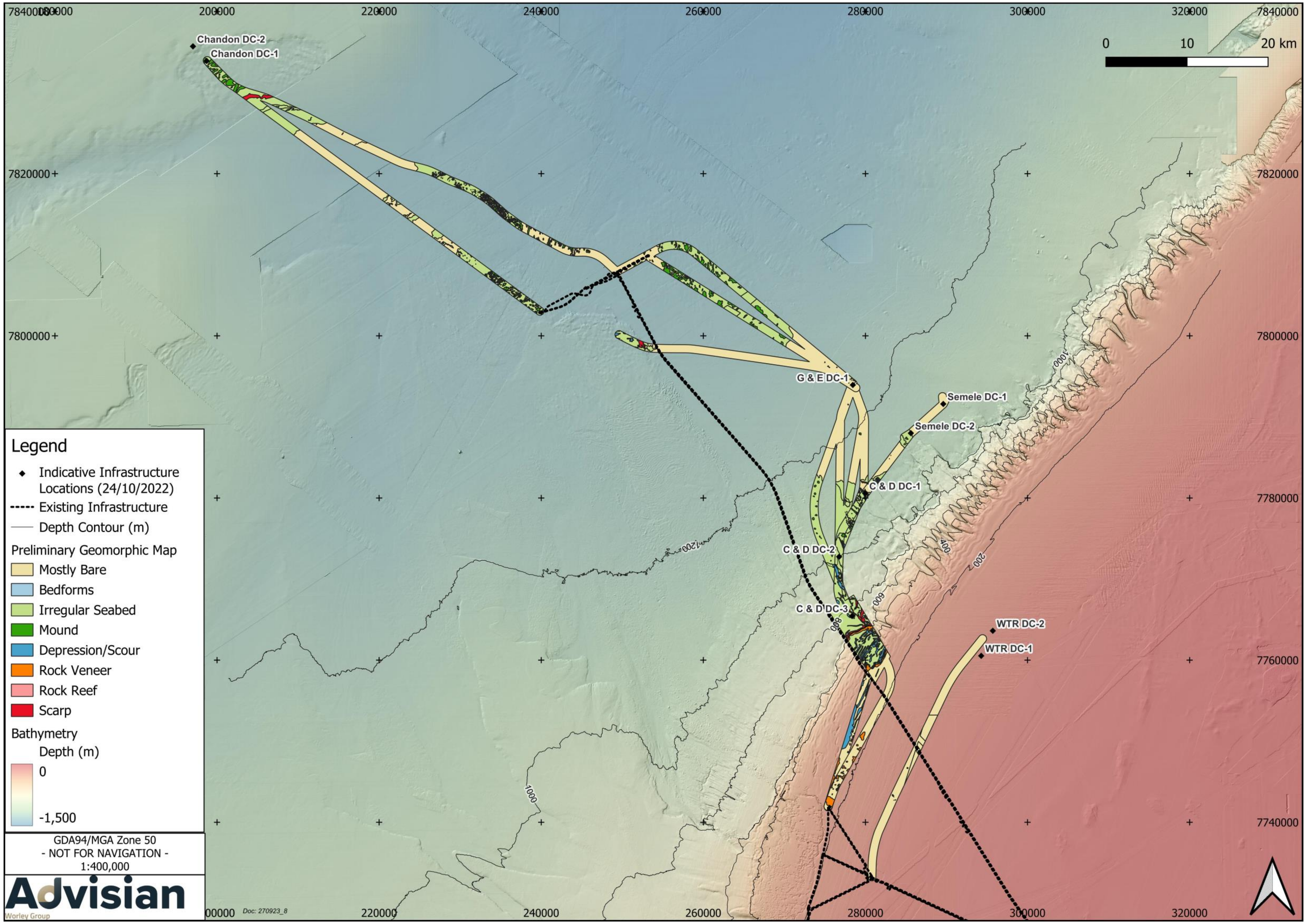


Figure 2-2 Preliminary benthic habitat maps based on assessment of geomorphic features within the Gorgon Backfill Fields project area

3 Field Survey Methods

3.1 Field Survey Scope

The main objective of this field survey was to investigate the physical and biological characteristics of the seabed features in the identified survey sites. Advisian delivered this scope in partnership with DOF Subsea under CAPL. Advisian led the scientific scope and DOF Subsea provided the vessel Skandi Singapore, the marine survey equipment for positioning of the vessel, and the remotely operated vehicle (ROV). DOF Subsea and CAPL were responsible for communicating with Barrow Island central control room to coordinate and approve permits (e.g., Permit to Work) to operate and undertake the field sampling program in GBF.

The primary field survey components and environmental monitoring parameters are summarised in Table 3-1.

Table 3-1 Summary of field survey monitoring parameters

Field Survey Component	Monitoring Parameters
Habitat Mapping	• Qualitative description of benthic habitats across a large project scale
Marine Benthic Survey	• Quantitative description of benthic cover and type at a subset of GBF project area
Fish Assemblage Survey	• Abundance, composition and size of fish assemblages and their association with key habitat types and other environmental variables • Description of mobile invertebrates and epifauna
Sediment Quality	• Hydrocarbons, metals, particle size distribution (PSD), total organic carbon (TOC) and moisture content
Benthic Infauna	• Benthic infauna composition
Water Quality	• Hydrocarbons, metals, TOC, dissolved organic carbon (DOC), total dissolved solids (TDS), nutrients • Water column profiling to describe physical water quality parameters (temperature, salinity, conductivity and depth)

3.2 Permits

In order to collect sediment infauna, Advisian applied for an Instrument of Exemption from the Department of Primary Industries and Regional Development (DPIRD) in line with the Fish Resources Management Act 1994 and Regulations, Section 7, and Regulation 6. Advisian were granted this permit by DPIRD on 26 April 2022 (Appendix A).

3.3 Survey Schedule

The field survey was completed between the 26th April and 11th May 2022. Table 3-2 details the field schedule for high level activities completed during the GBF field survey. Further details on field survey timing can be found in the Field Survey Summary Report (Advisian, 2022a).

Table 3-2 Field survey schedule

Date	Activity
26 April 2022	Mobilised to Dampier and boarded the Skandi Singapore vessel Transit to survey sites
27 April 2022	ROV test dives and calibrations
28 April – 3 May 2022	Complete benthic habitat survey at sites BCH16, BCH19, BCH17, Gorgon M1, BCH10, BCH13, BCH21, BCH23, BCH30, BCH18, BCH22, BCH25, BCH12, BCH04, BCH11, BCH03 and C&D DC3 (and water and sediment quality samples)
4 May 2022	Complete benthic habitat survey and water and sediment quality sites (where applicable) for sites BCH15, C & D DC-2, BCH14, NTB3 and BCH05 Freight chemical samples
5 –10 May 2022	Complete benthic habitat survey and water and sediment quality sites (where applicable) for sites G & E DC-1, BCH29, BCH18, BCH07, Jansz DC2, Jansz JMT, BCH28, BCH06, BCH09, BCH08, BCH02, BCH01, Chandon DC-1, BCH31, Semele DC-2, Semele DC-1, BCH42, BCH40, BCH43, BCH41, BCH32, WTR DC-1, BCH27, BCH33, BCH34, BCH35, BCH36, BCH24, Gorgon BMT
10 May 2022	Scope completed
11 May 2022	Pack equipment, freight samples Demobilise from Dampier

3.4 Survey Locations

Following the development of a preliminary benthic habitat map (Section 2.5), survey sites (Figure 3-1) for benthic habitat mapping, sediment and water quality sampling were selected based on:

- the spatial representation of all geomorphic attributes throughout the GBF project area (drill centres and associated well infrastructure, and flowlines/umbilical corridors)
- the presence of benthic features within KEFs
- areas with data deficiency and other points of interest
- to understand the composition of sediment at potential drill centres and tie-in locations
- to understand background concentrations of marine water quality near proposed infrastructure locations.

In response to an increase in project operational area post-field survey, the originally proposed 500 m radius around proposed manifold and tie-in locations and associated flowlines has been expanded to a 5 km radius around the GBF project area (as per Figure 1-1). Classification and mapping procedures for benthic habitats that fall within the 5 km operational buffer area is described in Section 3.6.5, and the distribution of benthic habitats within the 5 km operational buffer area are presented in Sections 4.1.1 and 4.1.2.

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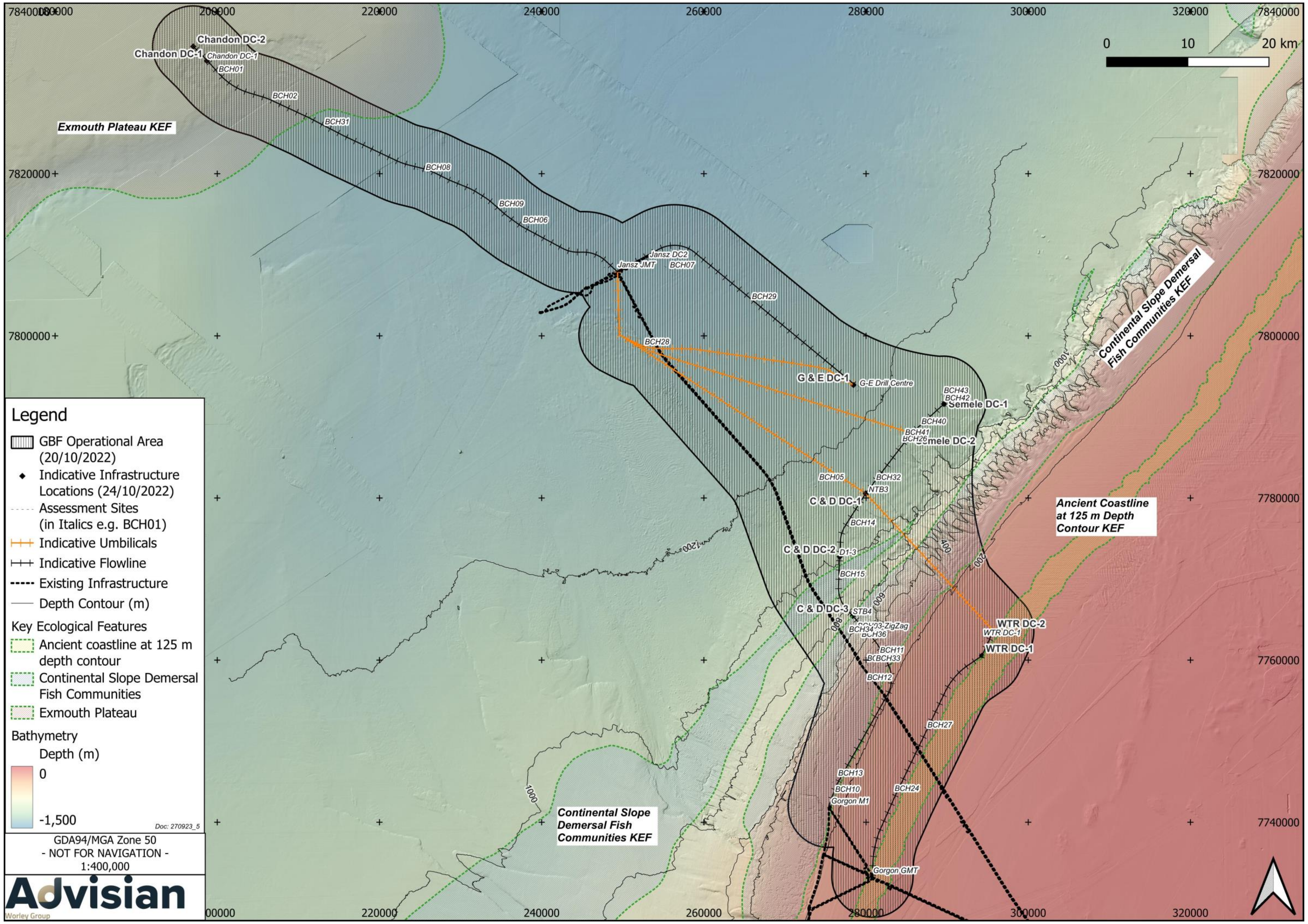

Note:

1. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus, DC = drill centre, G & E = Geryon and Eurytion, GBF = Gorgon Backfill Fields, KEF = Key Ecological Features, WTR = West Tryal Rocks

Figure 3-1 Gorgon Backfill Fields project area with survey sites for benthic habitat mapping, sediment and water quality sampling

3.5 Project Equipment

3.5.1 Remotely Operated Vehicle

A work class ROV (TRITON XLX) was provided and operated by DOF Subsea and used to deploy all sampling equipment to the seafloor (habitat and fish survey cameras, water quality profiler, sediment and infauna corers, and Niskin bottles) (Figure 3-2). The ROV was deployed while connected to a tether management system (TMS). Once the ROV was near the seabed, the ROV was detached from the TMS and was flown at approximately 1.5 m above the seabed at approximately 0.7 knots (1.3 km/h) while recording video footage of benthic habitat and fish assemblages. This speed ensured adequate image quality was captured.

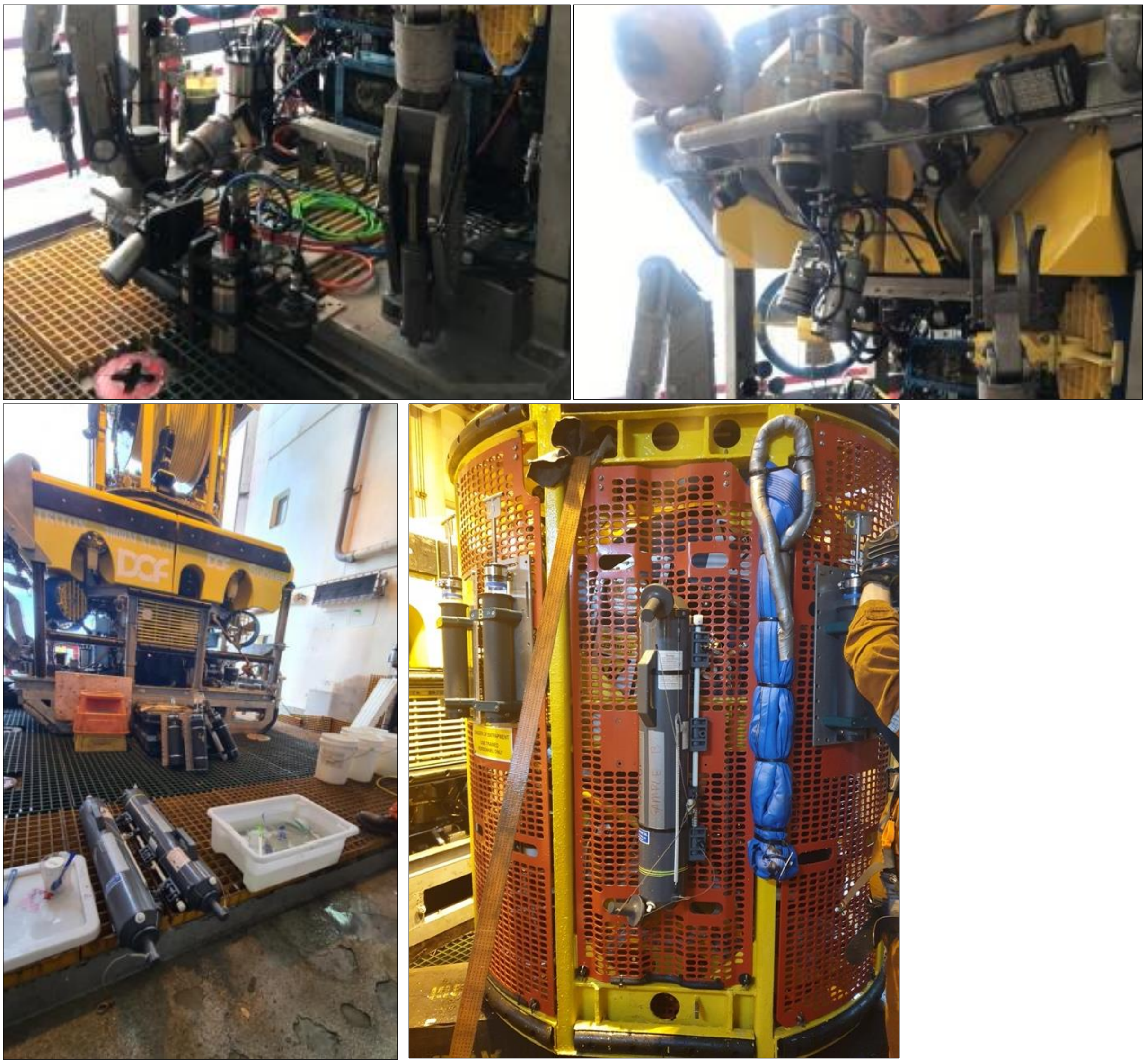

Figure 3-2 Remotely operated vehicle and tether management system with cameras, sediment corers and Niskin bottles attached

3.5.2 Habitat Mapping and Fish Survey Cameras

The ROV utilised the forward-facing high-definition (HD) camera (30° angle) for the collection of video footage for habitat mapping and demersal fish assemblages, and a downward facing camera (90° angle) for collection of marine benthic survey data (Table 3-3). The ROV pan and tilt HD camera captured suitable additional footage and provided a backup in the event of failure of the primary forward-facing camera. Two sets of cameras were also included as redundancy in case of equipment failure. All camera systems were controlled from the surface with a live feed ensuring correct operating and capture of the required data. All cameras were powered from the surface through the ROV tether.

Table 3-3 Camera systems mounted on the remotely operated vehicle

Camera	Tasks
1 x forward-facing camera (~30º)	• Capture benthic habitat and demersal fish data • Subsea HD wide angle camera Kongsberg/Imenco OE14-504 (1080i/720p 50 frames per second; fps) • External lighting system –Imenco SeaLED 300 (15,000 lumens) was added to the ROV for illumination (camera pan/tilt/zoom/altitude and set to forward and approximately 30° tilt)
1 x downward facing camera (~90º)	• Capture 'still' images of benthic habitat for percent cover • 1CAM Mk5 camera (stills/4K/1080p 60 fps) • Lighting system – Aquorea Mk2 LED/strobe mounted away from camera • Laser scale
ROV Pan & Tilt (HD video)	• General ROV navigation

Note:
1. HD = High definition, ROV = remotely operated vehicle

3.5.3 Sediment Sampling Push Corers

Raytech push corers were used for the collection of marine sediments. Each push corer was comprised of a Perspex core tube with T-bar handle, a one-way valve and the corer housing (Table 3-4).

Sets of push cores were attached to the ROV TMS and transported to the seabed. Using the ROV manipulator arm, a core was removed from its holster style housing and pushed into the sediment while holding on to the T-bar handle (Figure 3-3). The one-way valve at the top of the chamber allowed water to escape during the capture of sediment. The sample was retained in the corer by suction as the corer was withdrawn from the sediment. The core containing sediment sample was then returned to the housing, which has a tapered, rubber plug at the base of the housing to retain the sample in the corer. Once the ROV surfaced, the T-bar and valve were removed and the core with its rubber plug was removed from the housing with.

Cores of two different internal diameters were used: 60 and 100 mm. Specifications of the push corers are provided in Table 3-4.

Table 3-4 Push corer specifications

Corer internal diameter (mm)	Total length (mm)	Insertion into sediment (mm)	Maximum volume of sediment retrieved (ml)	~Weight of wet sediment (kg)	Weight of corer empty (kg)	Weight of holster and mount (kg)	Weight of corer full (kg) in holster
60	575	355	1,003	1.73	1.5	2	5.23
100	575	355	2,788	4.8	2	3	9.8

Figure 3-3 Raytech push corer and attachment plate (left) and milk crate style carrier (right)

3.5.4 Niskin Bottles

Niskin bottles were used for the collection of surface and near-bottom water samples (Figure 3-4). For the collection of water at depth, one 10 L externally sprung Niskin bottle was attached vertically to the TMS (Figure 3-2) and activated by the ROV manipulator arm to secure containment of the sample at the target location. A second 10 L Niskin bottle was attached to the ROV to provide redundancy in case of failure to collect a water sample from the primary unit mounted to the TMS. All near-bottom water sampling was undertaken prior to sediment sampling to ensure the seabed was not disturbed and a clean water sample was collected.

Surface waters were sampled at each location using a 10 L Niskin bottle deployed over the side of the vessel using a davit arm. Once the Niskin bottle settled approximately 1 m below the surface, the activating weight was dropped to release the springs and close the bottle.

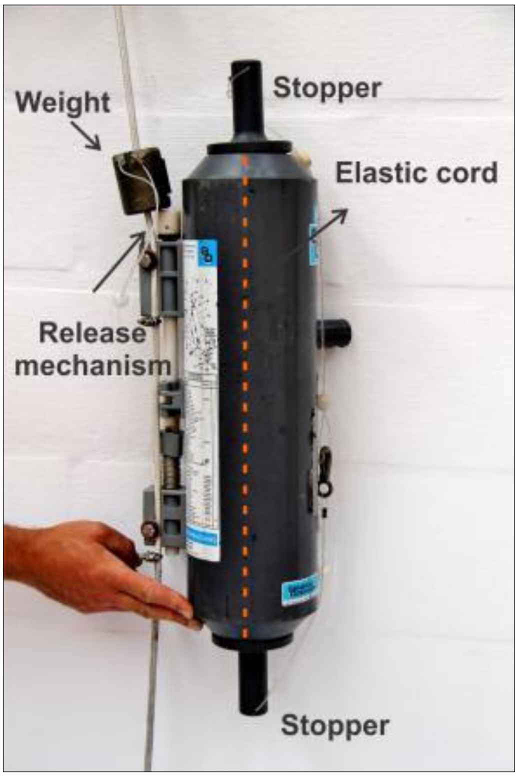

Figure 3-4 Niskin bottle (VLIZ 2022)

3.5.5 Water Quality Profiler

A calibrated Valeport Midas SVX2 water quality probe was used to collect physico-chemical profiles of the water column, specifically conductivity (MilliSiemens per centimetre; mS/cm), temperature (°C), depth (meters; m, below sea level) (CTD), and salinity (Practical Salinity Unit; PSU) (Figure 3-5). The probe was attached to the ROV and logged data on the downcast (surface to seabed) and upcast (seabed to surface) for each dive, in addition to transects along the bottom (just above the seabed). Specifications of the probe are provided in the PEP (Advisian, 2022b).

Figure 3-5 Valeport water quality probe for physico-chemical sampling parameters

3.5.6 Subsea Positioning

The vessel was equipped with a differential global positioning system, and an ultra-short baseline acoustic positioning system was placed on the ROV to track its position during sampling operations. A hand-held global positioning system (GPS) was used as a secondary GPS in verification of vessel location in relation to each sampling site.

3.6 Benthic Habitat Survey

3.6.1 Survey Sites

Benthic habitat transects were positioned across predicted geomorphic transition zones (i.e., an area where a shift in geomorphic features is apparent) to capture highly variable environments, which are typically attributed with diverse benthic habitats and epifaunal communities. This approach also enabled the validation of predicted benthic habitat boundaries. Seabed imagery for benthic habitat mapping was collected at a total of 39 sites within the originally proposed GBF project area (500 m radius around proposed drill centres, tie-in locations and associated subsea flowlines) (Figure 3-1; Table 3-5), as this smaller footprint represented areas of most-likely benthic disturbance at the time of field mobilisation. At each benthic survey site, video footage was collected along ~2 km-long transects using the ROV, capturing a total of approximately 45.4 km of benthic imagery across the Project area.

Of these 39 sites, 14 sites were identified within more discrete disturbance areas (i.e., proposed drill centres and tie-in locations will be subject to localized disturbance through drilling installation activities; Table 3-5). Within each of the 14 survey sites, five haphazard transects of variable length (ranging from 102–570 m) were surveyed to allow quantitative assessment of benthic cover (%) at these sites. These data were also used to inform habitat mapping objectives. Haphazard transects were positioned by applying a random point generator across the spatial extent of each site that had been adjusted to existing seabed infrastructure (Figure 3-6).

Table 3-5 Benthic habitat mapping and benthic cover survey sites

Field	Site Name	Survey Date	Facility / BCH Transect	Easting	Northings	Depth Range (m)	Habitat Mapping Site	Benthic Cover Site[1]
Chandon	Chandon DC-1	7/05/2022	Proposed Drill Centre	198899	7833791	1,100–1,200	✓	✓
	BCH01	7/05/2022	BCH Transect	200918	7832022	1,200–1,300	✓	
	BCH02	6/05/2022	BCH Transect	207775	7828300	1,200–1,300	✓	
	BCH31	7/05/2022	BCH Transect	212359	7826383	1,300–1,400	✓	
	BCH08	6/05/2022	BCH Transect	226558	7819703	1,300–1,400	✓	
	BCH09	6/05/2022	BCH Transect	235129	7815472	1,300–1,400	✓	
	BCH06	6/05/2022	BCH Transect	238540	7813367	1,300–1,400	✓	
	Jansz JMT	5/05/2022	Tie in	249098	7807831	1,300–1,400	✓	✓
Geryon and Eurytion (G & E)	Jansz DC2	5/05/2022	Tie in	253210	7809856	1,300–1,400	✓	✓
	BCH07	5/05/2022	BCH Transect	256861	7807601	1,300–1,400	✓	
	BCH28	6/05/2022	BCH Transect	253595	7798894	1,200–1,300	✓	
	BCH29	5/05/2022	BCH Transect	266573	7803572	1,300–1,400	✓	
	G & E DC-1	5/05/2022	Proposed Drill Centre	278876	7793169	1,200–1,300	✓	✓
Chrysaor and Dionysus (C & D)	BCH05	4/05/2022	BCH Transect	273569	7781327	1,100–1,200	✓	
	BCH14	4/05/2022	BCH Transect	277661	7775678	1,000–1,100	✓	
	C & D DC-2	4/05/2022	Proposed Drill Centre	276899	7772322	1,000–1,100	✓	✓
	BCH15	4/05/2022	BCH Transect	276638	7769400	900–1,000	✓	
	C & D DC-3	3/05/2022	Proposed Drill Centre	278747	7765155	700–800	✓	✓
	BCH03 – ZIGZAG	3/05/2022	BCH Transect	277706	7763557	500–600	✓	
	BCH34	9/05/2022	BCH Transect	277665	7763570	700–800	✓	

Field	Site Name	Survey Date	Facility / BCH Transect	Easting	Northings	Depth Range (m)	Habitat Mapping Site	Benthic Cover Site[1]
	BCH36	9/05/2022	BCH Transect	279285	7762860	200–300	✓	
	BCH11	3/05/2022	BCH Transect	281368	7761555	200–300	✓	
	BCH04	3/05/2022	BCH Transect	280271	7759126	200–400	✓	
	BCH33	9/05/2022	BCH Transect	281572	7758993	200–300	✓	
	BCH12	1/05/2022	BCH Transect	280344	7756362	200–300	✓	
	BCH13	29/04/2022	BCH Transect	275791	7744842	200–300	✓	
	BCH10	28/04/2022	BCH Transect	276682	7744321	200–300	✓	
	Gorgon M1	28/04/2022	Tie in	275354	7741583	200–300	✓	✓
Semele	BCH42	7/05/2022	Proposed Drill Centre	290128	7792145	1,100–1,200	✓	✓
	BCH43	8/05/2022	Proposed Drill Centre	289623	7792140	1,100–1,200	✓	✓
	BCH40	8/05/2022	BCH Transect	286880	7789035	1,100–1,200	✓	✓
	BCH41	8/05/2022	BCH Transect	285124	7787323	1,100–1,200	✓	✓
	BCH26	8/05/2022	BCH Transect	283944	7786339	1,100–1,200	✓	
	BCH32	8/05/2022	BCH Transect	281605	7782094	1,100–1,200	✓	
	NTB3	4/05/2022	Proposed Drill Centre	280281	7780314	1,100–1,200	✓	✓
WTR	WTR DC-1	9/05/2022	Proposed Drill Centre	294288	7762283	100–200	✓	✓
	BCH27	9/05/2022	BCH Transect	288135	7752668	100–200	✓	
	BCH24	10/05/2022	BCH Transect	283879	7744470	100–200	✓	
	Gorgon GMT	10/05/2022	Tie in	280989	7733571	100–200	✓	✓

Notes:
1. Within these sites, a set of 5 haphazard transects were collected to allow quantitative assessment of the BCH
2. BCH = Benthic communities and habitat, DC = drill centre, WTR = West Tryal Rocks

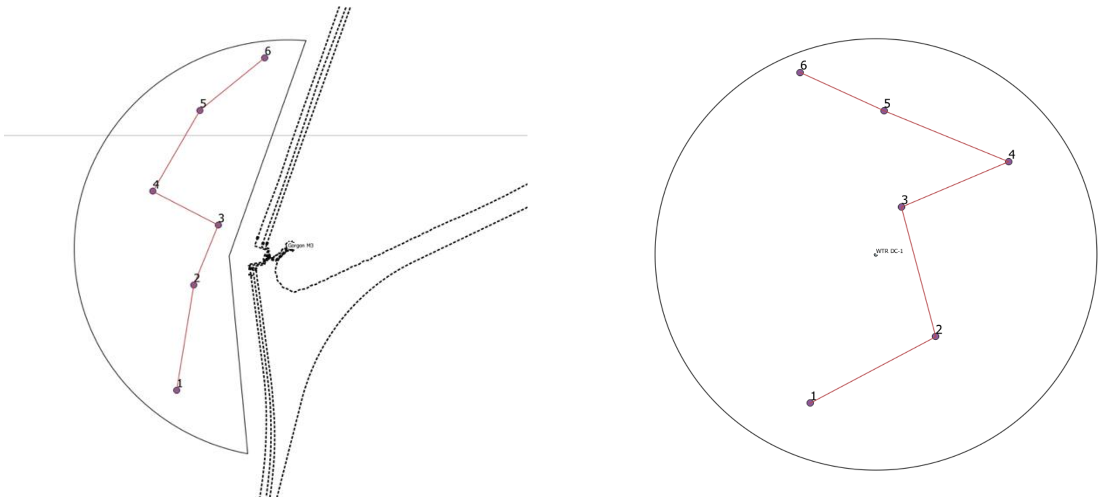

Figure 3-6 Nominal sampling layout for haphazard transects around tie-in locations (left) and proposed drill centres (right)

3.6.2 Benthic Habitat Data Collection

Video footage was collected along the transects outlined in Table 3-5. A video log was maintained throughout the recording. The video log was used to note the start and end times of each transect, as well as for scientific notes such as key physical and biological attributes, and biota (including semi-quantitative descriptions where appropriate). These video logs were used to aid the classification of data. All video footage was stored on external hard drives by the ROV operator and transferred daily to backup hard drives for transport back to Advisian.

3.6.3 Video Classification

Classification of benthic habitat (39 sites) and benthic cover (14 sites) was conducted according to a set of standardised classification categories based on the CATAMI classification scheme (Table 3-6; CATAMI, 2014; Althaus et al., 2015) developed with CAPL. Analysis and classification of video footage for benthic habitat was completed using TransectMeasure (SeaGIS, 2022a) by a marine scientist experienced in image classification. Following classification, the time and classification log were merged with the position and time log to provide a single file with a classification for every position where valid video footage was obtained. Example images of benthic habitat and biotic categories extracted from the video images are provided in Appendix B.

Analysis and classification of video footage (5 x 50 m transects) for benthic cover was also undertaken using TransectMeasure (SeaGIS, 2022a). TransectMeasure was set to randomly pause, enabling 20 images to be extracted per transect (n=100). Ten random points were generated on each image (n = 200/transect) and each point was classified based on the CATAMI classification scheme (Table 3-6).

Table 3-6 Habitat classification categories applied to image analysis for benthic habitat mapping and benthic cover

Habitat Categories	Biota Categories
Relief/Slope	**Biota**
Low (<1 m)	Sponges
Moderate (<3 m)	Cnidaria
High (>3 m)	Echinoderms
Wall	Sponges, Cnidaria
Substrate	Sponges, Echinoderms
Unconsolidated (soft)	Cnidaria, Echinoderms
Consolidate (hard)	Mixed biota (all 3)
Substrate size/appearance	
Sand/mud (<2 mm)	
Sand/mud (<2 mm) and occasional boulders	
Cobbles	
Boulders	
Rock (Outcropping bedrock)	
Modifier	
Bare	
Biota only	
Bioturbation and bare	
Bioturbation and occasional veneer only	
Bioturbation with biota and occasional veneer	
Ripples (<10 cm height) and bare	
Ripples (<10 cm height) with biota and sparse veneer with biota	
Veneer with biota	
Unknown	

3.6.4 Video Quality Assurance and Quality Control Assessment

Following completion of the video classification, a quality assurance and quality control (QA/QC) assessment was performed by Advisian personnel to determine confidence in video analysis techniques. Each video analyser was assigned 5% of processed video transects to re-process and note errors. The video QA/QC assessment is detailed in Appendix C.

3.6.5 Classification and Mapping Procedures

To characterise the benthic habitat and potential occurrence of significant BCH in areas away from ground truthing transects (between 500 m and 5 km from the proposed subsea facilities), a predictive mapping approach known as supervised classification was adopted. Supervised classification techniques use an artificial intelligence algorithm to statistically compare specific attributes of multiple raster layers of known sites of interest. Supervised classification is a ‘bottom up’ approach (Brown et al., 2011) whereby the *in-situ* ground truthing transects are used to inform the organization and segmentation of the broad scale environmental data, and is applied at the same taxonomic level as the ground truthing data.

For this study, the video footage captured by the ROV is used to verify the distribution of epibenthic BCH of interest (e.g., bare seabed, cnidaria, sponges, or a combination of categories). The verified BCH is then spatially linked with characteristics of the seabed terrain derived from the 3D seismic data to build a predictive model of a large component of the mapping area.

3.6.5.1 Bathymetric Derivatives

A 25 m cell size bathymetric digital terrain model derived from 3D seismic data was available for a large proportion of the GBF project area (including the entire escarpment area) and was free of data artefacts. A series of 'derivative' terrain layers were created to extract additional information about the type of seabed terrain that most commonly support the observed BCH. The derivatives calculated for each cell included:

- Depth: depth in metres of the seabed for every cell, with implications for water pressure and light penetration.
- Roughness: derived from the bathymetric dataset by subtracting the minimum depth from the maximum depth value in a defined-neighbourhood around a central pixel (Riley et al., 1999). The neighbourhood is defined as the eight nearest cells to a central pixel (a 3 m x 3 m area). Values of zero or close to zero indicate flat areas, whereas larger roughness values indicate increasingly complex terrain. For this study, roughness was a good proxy for the complex terrain associated with rocky outcrops on the seabed. Smaller scale sediment ripples can also appear to have high seabed roughness values; however, ripples were not a common seabed characteristic in the GBF project area.
- Slope: slope is the ratio of rise to run over a defined neighbourhood area. For this study, the seabed away from the coastline was typically very flat, and slopes greater than five degrees were rare and often indicative of interesting features. Higher slopes are often associated with seabed features that are important for ecological habitats such as reef edges and drop offs.
- Aspect: the facing direction of the local neighbourhood area of seabed, defined as slope orientation in degrees clockwise from north, with implications for exposure to oceanic currents (Florinsky, 2016).
- Relative TPI (two scales): the TPI distinguishes topographic features such as a hilltops, valley bottoms, exposed ridges, flat plains and slopes. It is calculated by comparing the elevation of each pixel above or below its surrounding neighbours. The number of neighbours compared (i.e., the scale of the neighbourhood) is of critical importance, therefore two scales were calculated and

incorporated. Smaller neighbourhood sizes are better at detecting small-scale features whereas larger neighbourhood sizes better detect large features (Guisan et al., 1999; Wilson and Gallant, 2000).

- Total Curvature: measured 3D curvature of the local topographic surface (Wilson, 2018).
- Morphometric Protection Index: analyses the immediate surrounding of each cell up to a given distance and evaluates how the relief protects it, describing canyon or pinnacle reef environments (Olaya, 2002).

These seabed terrain indices were calculated for the GBF project area, and merged in a desktop GIS software package to directly 'stack' all pixel values into an n-dimensional multiband raster image.

3.6.6 Model Training

The ground truthing habitat layer was compiled into a GIS for integration with the supervised classification algorithm. For each training dataset point, a single consistent and unified class was attributed, which included:

- Bare seabed (including areas that support mobile echinoderms)
- Cnidaria
- Sponges
- Sponges and Cnidaria.

Using spatial analysis techniques, the 'training' dataset was linked to the corresponding terrain characteristics. This dataset was used to train the random forest classifier for habitat prediction.

A random forest classifier known as an ensemble machine learning method, was employed to predict the distribution of habitats across the GBF project area. The classifier was trained on the small dataset of biota types and their locations using the derivative terrain layers as predictor variables. The random forest approach was chosen for its ability to handle complex and non-linear relationships, robustness to noise, and resistance to overfitting. This technique was only applied to the 'slope break' component of the GBF project area as this was the only region with available high quality bathymetry dataset. Areas in deeper waters (the 1200 m contour that defined the outer limit) with no biota recorded in the ground truthing survey were not included. Supervised data classification was undertaken in a Python-based software implementation Dzetsaka (Karasiak, 2016). Once imported, the seven composite bands (the derivative terrain layers outlined in Section 3.6.5.1) were overlain with the habitat-attributed training dataset, and were analysed to determine the spectral statistics relevant to each habitat layer. The classification was then run on the entire dataset, allowing the program to assess the band spectral values for each pixel cell. For the dominant habitat classification, the algorithm assigns one of the four main habitat types to each cell: bare seabed, cnidaria, sponges, and sponges and cnidaria. For the presence-absence assessment, the cells are attributed to either 1 (unknown), 2 (known to be absent) or 3 (known to be present).

For validation and error assessment, a 'bootstrap' subset of data was withheld from the training dataset; 90% of original data pixels were used to train the model, and the remaining 10% dataset was used by the model to evaluate its own performance.

3.6.6.1 Results of the Model Training

The results show that the BCH are likely to be found along areas with very steep escarpments (Figure 3-7), which coincides with the observational data. The overall accuracy of the self-assessment model, which is a comparison of the 10% training pixels withheld from the classification with classified pixels in the same location, was 92% (Kappa statistic of 98.7%), suggesting a strong correlation, and a Cohens Kappa value of 0.48, indicating a moderate correlation between the datasets and a low probability of the influence of random chance.

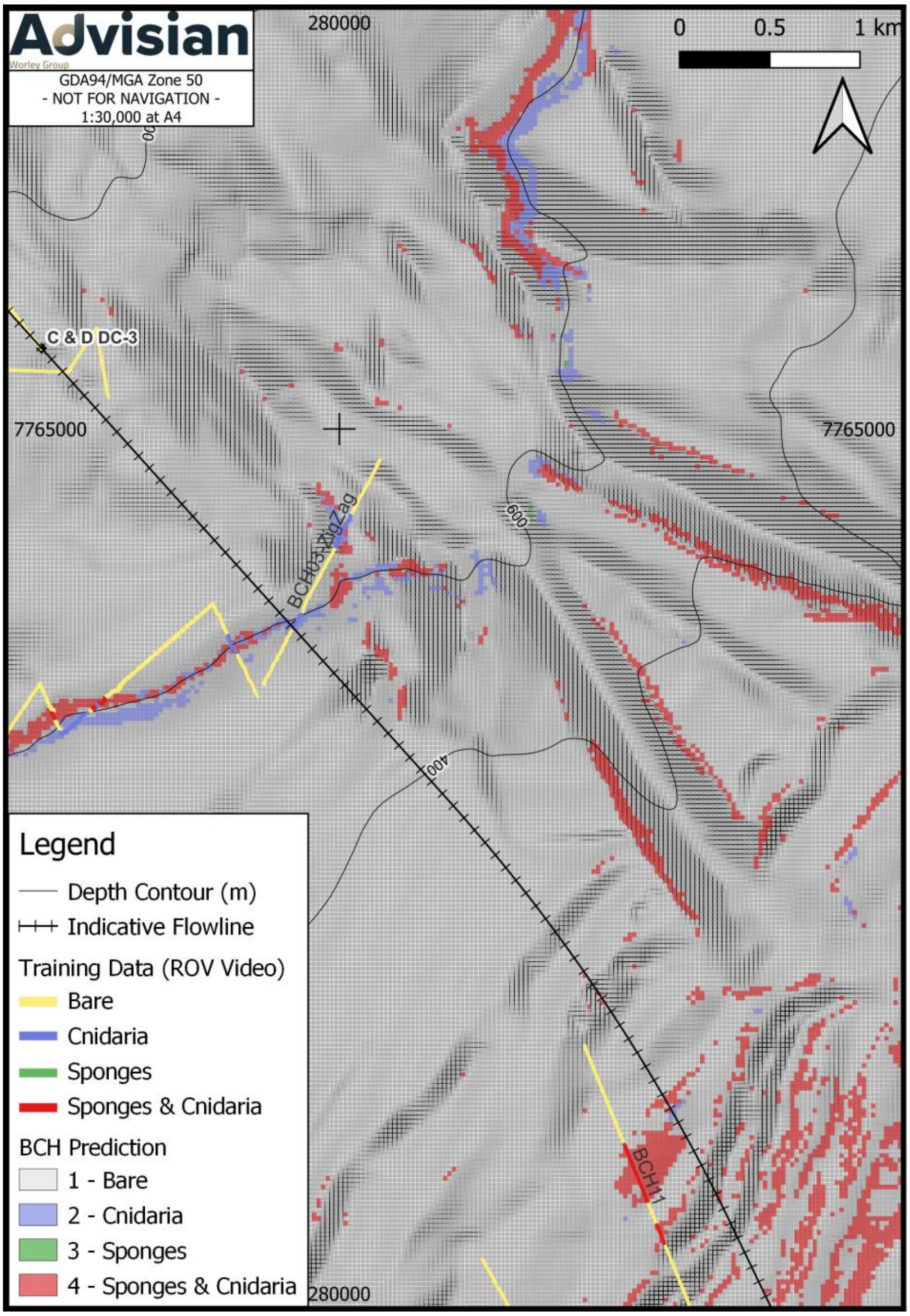

Figure 3-7 Example of a supervised classification map of the East Scarp-Tryal area within the Gorgon Backfill Fields project area

3.7 Fish Assemblage Surveys

3.7.1 Survey Sites

A total of 11 sites were examined to describe and compare the fish and crustacean assemblages (Table 3-7). Of these sites, two sites were located within the Exmouth Plateau KEF, four sites were within the Continental Slope Demersal Fish Communities KEF, and one site was located within the Ancient Coastline KEF, while the remaining four sites were located outside any KEFs (Table 3-7). The sites also covered four geomorphic features (Heap & Harris, 2008) including plateau slope, deep/hole/valley slope, trench/tough slope, and slope (Table 3-7).

Table 3-7 Fish survey sites

Field	Site Name	Key Ecological Feature	Geomorphic Feature	Survey Date	Easting	Northings	Depth Range (m)
Chandon	BCH01	Exmouth Plateau	Plateau slope	7/05/2022	198899	7833791	1,100–1,200
	BCH02	Exmouth Plateau	Plateau slope	7/05/2022	200918	7832022	1,200–1,300
Chrysaor and Dionysus (C & D)	C &D DC-3	Outside of any KEF	Trench/ tough slope	3/05/2022	278747	7765155	700–800
	BCH04	Continental Slope Demersal Fish Communities	Slope	3/05/2022	280271	7759126	200–400
	BCH11	Continental Slope Demersal Fish Communities	Slope	3/05/2022	281368	7761555	200–300
	BCH12	Continental Slope Demersal Fish Communities	Slope	1/05/2022	280344	7756362	200–300
	BCH33	Continental Slope Demersal Fish Communities	Slope	9/05/2022	281572	7758993	200–300
Semele	NTB3	Outside of any KEF	Deep/hole/ valley slope	4/05/2022	280281	7780314	1,100–1,200
WTR	WTR DC-1	Outside of any KEF	Slope	9/05/2022	294288	7762283	100–200
	BCH24	Outside of any KEF	Slope	10/05/2022	283879	7744470	100–200
	Gorgon GMT	Ancient Coastline	Slope	10/05/2022	280989	7733571	100–200

Note:
1. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus, DC = drill centre, KEF = Key Ecological Feature, WTR = West Tryal Rocks

3.7.2 Fish Assemblage Data Collection

Video footage was collected along the transects outlined in Table 3-7 using the forward-facing HD camera (30° angle) on the ROV (Section 3.5.2).

3.7.3 Fish Species Classification System

Classification of the video footage was completed using EventMeasure Stereo (SeaGIS, 2022b). Each fish, crustacean and other mobile invertebrate that was encountered along each transect was identified to the lowest taxonomic resolution possible and enumerated as outlined in Goetze et al. (2019). Any fish that re-entered the field of view was not re-counted.

3.7.4 Statistical Treatment and Analysis

Due to the varying transects lengths collected at each site, the length of all transects were standardised to 200 m to allow for a robust statistical analysis and is a similar length to other studies conducted in the North West Shelf (Saunders et al., 2021). For six transects along three sites (C & D DC-3, NTB3 and Gorgon GMT), transects lengths ranged from 112 and 198 m and as such, the entire transect was used for analyses. For transects greater than 200 m, the first 200 m section of the transect was selected for statistical analysis. Where transect lengths were greater than 400 m, the transect was split into multiple replicate 200 m lengths with a 10 m gap to separate the transects.

To determine whether there are any differences between the fish and crustacean assemblages among water masses, among KEFs, and among the geomorphic features, three different statistical designs were used, each comprising of a two-factor design:

Design one – Water mass

- Water mass = fixed factor with three levels: Tropical Surface Water (TSW), Southern Indian Central Water (SICW), Antarctic Intermediate Water (AAIW)
- Site = random factor nested within water mass, varying levels depending on replication

Design two – KEFs

- KEF = fixed factor with four levels: Exmouth Plateau, Continental Slope Demersal Fish Communities, Ancient Coastline, and Outside of any KEF
- Site = random factor nested within KEF, varying levels depending on replication

Design three – Geomorphic features

- Geomorphic feature = fixed factor with four levels: slope, trench/trough, deep/hole/valley, plateau
- Site = random factor nested within geomorphic feature, varying levels depending on replication.

All statistical analyses, including post-hoc tests on significant factors, were undertaken using non-parametric analysis of variance (PERMANOVA) in the software package PRIMER with PERMANOVA+ (Primer-E Ltd, Version 7.0.18; Anderson, 2008; Clarke & Gorley, 2015). Fish assemblage data were fourth root transformed and crustacean assemblage data were square root transformed prior to analysis to down-weigh the contribution of dominant species and allow rarer groups to play a part in the analyses. The Bray-Curtis dissimilarity measure was used on the multivariate dataset prior to analysis with PERMANOVA.

Results of multivariate analysis (fish and crustacean assemblages) were presented graphically using a non-parametric multidimensional scaling (nMDS) plot to visualise any patterns in two-dimensional space. Vectors were overlaid on the nMDS plot to illustrate the strength and direction of the Pearson's correlation (>0.5) of individual taxa to the dataset.

To investigate the effect of depth on the composition of the multivariate fish and crustacean assemblages, a distance-based linear modelling (DistLM) was completed. For this analysis, depth was the explanatory variable, and the fish or crustacean assemblages were the dependent variables.

Data were not transformed prior to univariate analyses of number of fish and crustaceans, and number of fish taxa and crustacean taxa. Euclidean distance was used as a dissimilarity measure for univariate analyses. Results were presented using bar graphs of means and standard errors (SE) to illustrate patterns among the factors of interest.

Refer to Appendix D for more details on the methodology of fish assemblages.

3.8 Sediment Sampling

Sediment sampling comprised of two separate assessments: sediment characterisation (chemistry and composition) and benthic infauna. Sample collection for both types of assessments were completed simultaneously using ROV-operated push corers.

3.8.1 Sediment Sample Collection

Sediment quality sampling sites were selected to understand the chemistry and composition of sediment at potential drill centres and tie-in locations. These sites were sampled to characterise the sediment quality prior to any disturbance or potential contamination arising from development activities (e.g., drilling and cutting disposal), providing a broad-level baseline understanding of project area.

Sediment samples were collected using push corers operated by the ROV manipulator arm (Section 3.5.3). At each site (Table 3-8), three replicate sediment cores (of 100 mm internal diameter) were collected and analysed for sediment chemistry, and two replicate sediment cores (60 mm internal diameter) were collected for benthic infauna (Table 3-9). This approach was a reduction in effort compared with the PEP (Advisian, 2022a) due to time constraints encountered in the field. A total of 30 samples for chemistry (excluding QA/QC samples; Section 3.8.4) from ten sites (Table 3-8) were collected. For benthic infauna, a total of 28 samples (14 sites with two replicate samples collected from each site) were collected.

Table 3-8 Sediment sampling sites

Field	Site Name	Survey Date	Easting	Northings	Depth Range (m)
Chandon	Chandon DC-1	7/05/2022	198899	7833791	1,100–1,200
Chrysaor and Dionysus	C & D DC-3	3/05/2022	278747	7765155	700–800
	C & D DC-2	4/05/2022	276899	7772322	1,000–1,100
Geryon and Eurytion	G & E DC-1	5/05/2022	278876	7793169	1,200–1,300
Semele	NTB3	4/05/2022	280281	7780314	1,100–1,200
	Semele DC-1	7/05/2022	290128	7792145	1,100–1,200

Field	Site Name	Survey Date	Easting	Northings	Depth Range (m)
	Semele DC-2	8/05/2022	289623	7792140	1,100–1,200
	Semele BCH1	8/05/2022	286880	7789035	1,100–1,200
	Semele BCH2	8/05/2022	285124	7787323	1,100–1,200
WTR	WTR DC-1	9/05/2022	294288	7762283	100–200

Note:
1. C & D = Chrysaor and Dionysus, DC = drill centre, G & E = Geryon and Eurytion, WTR = West Tryal Rocks

Table 3-9 Sediment samples for each core size

Parameters	Corer Size	Core Sample Depth	Sample Sites per Location	Replicate Samples
Sediment chemistry and composition	100 mm	5 cm	1	3
Benthic infauna	60 mm	10 cm	1	2

3.8.2 Sediment Chemistry Sample Processing and Labelling

All sediment samples were processed and preserved according to Australian and New Zealand Standards (AS/NZS 5667.1:1998) and the requirements of the analytical laboratories. On the recovery of samples to the surface, each core was deposited into core trays, assessed for physical properties (e.g., odour, sediment grain size and the presence of organic matter, marine organisms, shells and other relevant features), and photographed with the relevant site identification prior to sample processing. All sampling equipment including the push corers and core trays, were washed with laboratory grade decontamination solution (Decon 90) and rinsed thoroughly with clean seawater. Field personnel wore disposable sterile nitrile gloves at all times during the sampling process which were changed between sampling collections at each site.

For the analysis of sediment chemistry and composition (PSD), the top 5 cm of sediment sample from each of three replicate cores were extracted and homogenised in a glass bowl until the texture and colour was uniform. The sediment sample was then placed into laboratory supplied containers (Table 3-10) and labelled with the date and time of sampling, field location and site number (sample unique identifier). All samples were stored in a refrigerator and each sample was recorded on a field sheet.

Chain of custody (CoC) documentation was used for all stages of the sample processing and storage. Field sheets and data tracking sheets were used to ensure all sites were sampled and samples were properly stored, labelled, preserved and delivered to the laboratories within the recommended holding times. However, due to the remote location of sampling sites, recommended holding times for the analyses of some analytes (TRH, BTEX and moisture content) were exceeded for sites WTR DC-1 and Semele 4. Such exceedances should be taken into consideration when interpreting the results. CoC tables are presented in Appendix E.

3.8.3 Sample Analysis

Sediment samples were analysed using standard laboratory methods at ALS Environmental (Perth), a National Association of Testing Authorities (NATA) accredited laboratory. Samples were analysed for hydrocarbons (total recoverable hydrocarbons [TRH], benzene, toluene, ethylbenzene and xylenes [BTEX], and polycyclic aromatic hydrocarbons [PAHs]), total metals/metalloids, PSD, TOC and moisture content (Table 3-10). Sediment concentrations were compared to Australian and New Zealand Guidelines (ANZG; ANZG, 2018) default guideline values (DGVs), and upper guideline values (GV-High) if required.

Table 3-10 Chemical and physical analysis of sediment samples

Parameter	ALS Limit of Reporting (LOR) as per Quote EP/246/22 (mg/kg)[1]	Container, Preservation and Holding Time (as per ALS Methods)
TRH		
C_6–C_{10} fraction	10	*250 ml Soil Glass Jar – Unpreserved Chilled <6 degrees Celsius (°C) Holding Time: 14 days
>C_{10}–C_{16} fraction	50	
>C_{16}–C_{34} fraction	100	
>C_{34}–C_{40} fraction	100	
Total TRHs	–	
BTEX		
Benzene	0.2	*250ml Soil Glass Jar – Unpreserved Chilled <6°C Holding Time: 14 days
Toluene	0.5	
Ethylbenzene	0.5	
Xylenes (sum M&P and O)	0.5	
PAHs if TRH recorded		
Naphthalene	0.005	*250ml Soil Glass Jar – Unpreserved Chilled <6°C Holding Time: 14 days
Acenaphthylene	0.004	
Acenaphthene	0.004	
Fluorene	0.004	
Phenanthrene	0.004	
Anthracene	0.004	
Fluoranthene	0.004	
Pyrene	0.004	
Benz(a)anthracene	0.004	
Chrysene	0.004	
Benzo(b,k)fluoranthene	0.004	
Benzo(a)pyrene	0.004	
Indeno(1,2,3-cd)pyrene	0.004	

Parameter	ALS Limit of Reporting (LOR) as per Quote EP/246/22 (mg/kg)[1]	Container, Preservation and Holding Time (as per ALS Methods)
Dibenz(a,h)anthracene	0.004	
Benzo(g,h,i)perylene	0.004	
Total PAHs	0.004	
Metals (total only)		
Silver	0.1 (1.0, 4.0)	*250ml Soil Glass Jar – Unpreserved Chilled <6°C Holding Time: 180 days
Aluminium	50	
Arsenic	1.0 (20, 70)	
Barium	10	
Cadmium	0.1 (1.5, 10)	
Cobalt	0.5	
Chromium	1.0 (80, 370)	
Copper	1.0 (65, 270)	
Iron	50	
Manganese	10	
Nickel	1.0 (21, 52)	
Lead	1.0 (50, 220)	
Zinc	1.0 (200, 410)	
Mercury	0.01 (0.15, 1.0)	
Others		
PSD (laser diffraction and wet sieving)	–	2 x 500 ml snap lock bag – PSD Bag Chilled <6°C Holding Time: 180 days
TOC (%)	0.02%	150ml Soil Glass Jar – Unpreserved Chilled <6°C Holding Time: 28 days
Moisture (%)		*250ml Soil Glass Jar – Unpreserved Chilled <6°C Holding Time: 14 days

Notes:

1. Value in parentheses for total metals is the ANZG (2018) default guideline value (DGV), and guideline value high (GV-High)
2. Asterisks (*) denotes a shared laboratory container
3. BTEX = Benzene, toluene, ethylbenzene and xylenes, PAH = polycyclic aromatic hydrocarbons, PSD = particle size distribution, TOC = total organic carbon, TRH = total recoverable hydrocarbons

3.8.4 Quality Assurance and Quality Control Analysis

As part of the NATA requirements, the following QA/QC samples were collected in the field to ensure data integrity:

- Sediment field blanks were used to test for potential contamination of sediment samples during the sampling process. The blank sample consisted of acid washed and heated soil to remove organic content. The blank sample was processed using the same methods and equipment as the actual sediment samples and was analysed for hydrocarbons. A field blank was collected at sites G & E DC-1 and WTR DC-1.
- Duplicate sediment samples (two extra cores) were collected at sites Semele BCH2 and WTR DC-1 to test for inter-laboratory variability. Two independent samples (i.e., two separate grabs) were collected at the same location and were analysed by the secondary laboratory (ALS on the east coast of Australia) for metals and moisture content.
- Triplicate sediment samples were collected at site WTR DC-1 to test for intra-laboratory variability. Three independent samples (i.e., three separate grabs) were collected at the same location and were analysed by the primary laboratory for metals and moisture content.

The accuracy of sediment analyses was determined by quantifying the differences between the concentrations of analytes in the duplicate and triplicate samples. The relative percent difference (RPD) was calculated for duplicate samples and the relative standard deviation (RSD) was calculated for the triplicate sample using the methods outlined in the National Assessment Guidelines for Dredging (Commonwealth of Australia, 2009). The RPD and RSD calculations are determined as follows:

$$\text{RPD}\ (\%) = \frac{(\text{difference between replicates})\ \text{x}\ 100}{(\text{average of the replicates})}$$

$$\text{RSD}\ (\%) = \frac{(\text{standard deviation of replicates})\text{x}\ 100}{(\text{average of replicates})}$$

Values for RPD and RSD greater than 50% may signify that sediments are either heterogenous, or greatly differ in grain size. RPD/RSD calculations were not completed where one or more of the replicates were below the laboratory limit of reporting (LOR).

In addition to the field QA/QC samples, laboratory analyses included quality control testing of sediment samples to include:

- 5% method blanks (one analysed within each process lot of 20 samples)
- 10% laboratory duplicates (two analysed within each process lot of 20 samples)
- 5% laboratory control samples (one analysed within each process lot of 20 samples)
- 5% matrix spikes (one analysed within each process lot of 20 samples).

All QA/QC samples were analysed within laboratory holding times and in accordance with NATA quality control procedures (Appendix I). QA/QC samples were not required for benthic infauna samples.

3.8.5 Benthic Infauna Collection and Processing

Sediment samples for infauna were collected using methods similar to Hook et al. (2016) in which the top 10 cm of sediment sample from both cores were used. If the sample contained less than 10 cm, the depth of sample was noted on the field sheet and the whole sample was used. Samples were sieved on site to 1 mm, placed into a calico bag and were preserved in 100% ethanol before transporting to the laboratory. CoC documentation was used for all stages of the sample processing and storage.

Benthic infauna samples were processed by Benthic Australia. Laboratory processing of sediment samples for benthic infauna included:

- Sample sorting – the separation of biological material from sediment, shell-hash, and other non-living biological material retained by sieving. Rose Bengal may be added to stain the biological material and facilitate the sorting process.
- Species identification and enumeration – the accurate identification (using stereomicroscopy) of all invertebrates found in a sample to the lowest reliable taxonomic level and the counting of invertebrate numbers in each taxonomic category.

Invertebrates were identified to the lowest reliable taxonomic level using appropriate standard identification guides and keys for the taxonomic groups. After sorting, identification and counting, invertebrates were stored in 70% isopropyl alcohol.

3.9 Water Sampling

3.9.1 Water Sample Collection

Sampling sites for water quality were selected to ensure sufficient spatial representation across the GBF project area whilst still maintaining alignment with planned ROV benthic survey deployment locations. Sampling for water ensured a high-level baseline dataset was obtained prior to any disturbance or potential contamination arising from development activities (e.g., drilling and cutting disposal), and allows for valid comparisons in the unlikely event of a discharge or spill event(s).

Replicate water samples were collected from the surface and near the seabed at each site (n = 4 per site; Table 3-11) using a Niskin bottle (Section 3.5.4). Samples were collected from approximately 1 m below the surface using a Niskin bottle deployed over the side of the vessel, and from near the seabed (~5–10 m above) from ROV-activated Niskin bottles attached to the ROV TMS. At site Jansz JMT, the second Niskin bottle attached to the ROV was not loaded and only one of two water samples from near the seabed was collected. As such, a total of 31 samples (excluding QA/QC samples; Section 3.9.4) from eight sites (Table 3-11) were collected.

Table 3-11 Water quality sampling sites

Field	Site Name	Survey Date	Number of Surface Samples	Number of Near Seabed Samples	Facility / BCH Transect	Easting	Northings	Depth Range (m)
Chandon	Jansz JMT	5/05/2022	1	2	Tie in	249098	7807831	1,300–1,400
	Chandon DC-1	7/05/2022	2	2	Proposed Drill Centre	198899	7833791	1,100–1,200

Field	Site Name	Survey Date	Number of Surface Samples	Number of Near Seabed Samples	Facility / BCH Transect	Easting	Northings	Depth Range (m)
Chrysaor and Dionysus	C & D DC-3	3/05/2022	2	2	Proposed Drill Centre	278747	7765155	700–800
Geryon and Eurytion	G & E DC-1	5/05/2022	2	2	Proposed Drill Centre	278876	7793169	1,200–1,300
	BCH28	6/05/2022	2	2	BCH Transect	253595	7798894	1,200–1,300
Semele	NTB3	4/05/2022	2	2	Proposed Drill Centre	280281	7780314	1,100–1,200
WTR	WTR DC-1	9/05/2022	2	2	Proposed Drill Centre	294288	7762283	100–200
	Gorgon GMT	10/05/2022	2	2	Tie in	280989	7733571	100–200

Note:
1. BCH = Benthic communities and habitat, C & D Chrysaor and Dionysus, DC = drill centre, G & E = Geryon and Eurytion, WTR = West Tryal Rocks

3.9.2 Water Chemistry Sample Processing and Labelling

All water samples were processed and preserved according to Australian and New Zealand Standards (AS/NZS 5667.1:1998) and the requirements of the analytical laboratories. For all samples, water from the Niskin bottle was emptied directly into the laboratory containers in order to decrease chance of contamination (Table 3-12). All sampling equipment including the Niskin bottles, were washed with Decon 90 and rinsed thoroughly with clean seawater. Field personnel wore disposable sterile nitrile gloves at all times during the sampling process which were changed between sampling collections at each site. Filtering of water samples was completed by the laboratory, where required. All sample containers were labelled with the date and time of sampling, field location and site number (sample unique identifier). All samples were stored in a refrigerator and each sample was recorded on a field sheet.

CoC documentation was used for all stages of the sample processing and storage (Appendix E). Field sheets and data tracking sheets were used to ensure all water sampling sites were sampled and samples were properly stored, labelled, preserved and delivered to the laboratories within the recommended holding times. However, due to the remote location of sampling sites, recommended holding times for the analyses of some analytes were exceeded for some samples, including TRH and TDS for surface and seabed water samples at NTB3, and TDS for surface and seabed water samples at C & D DC-3. Such exceedances should be taken into consideration when interpreting the results.

3.9.3 Sample Analysis

Water samples were analysed using standard laboratory methods at ALS Environmental (Perth), a NATA-accredited laboratory. Samples were analysed for hydrocarbons (TRH, BTEX, PAHs), total and dissolved metals, DOC, TOC, TDS, total phosphorus (TP) and total nitrogen (TN) (Table 3-12). Concentrations were compared to ANZG (2018) DGVs for 99% species protection.

Table 3-12 Chemical analysis of water samples

Parameter	ALS LOR as per Quote EP/246/22 (μg/L)[1]	Container & Holding time (ALS Methods)
TRH		
C_6–C_{10} fraction	20	100 ml amber glass Chilled <6°C Holding Time: 7 days
>C_{10}–C_{16} fraction	100	
>C_{16}–C_{34} fraction	100	
>C_{34}–C_{40} fraction	100	
Total TRHs	-	
BTEX		
Benzene	1.0 (500)	2 x 40 ml volatile organic chemical vials, preserved Chilled <6°C Holding Time: 14 days
Toluene	2.0 (110)	
Ethylbenzene	2.0 (50)	
Xylenes (sum M&P and O)	2.0	
Total BTEX	1.0	
PAHs if TRH recorded		
Naphthalene	1.0 (50)	100 ml amber glass Chilled <6°C Holding Time: 7 days
Acenaphthylene	1.0	
Acenaphthene	1.0	
Fluorene	1.0	
Phenanthrene	1.0 (0.6)	
Anthracene	1.0 (0.01)	
Fluoranthene	1.0	
Pyrene	1.0	
Benz(a)anthracene	1.0	
Chrysene	1.0	
Benzo(b,k)fluoranthene	1.0	
Benzo(a)pyrene	0.5 (0.1)	
Indeno(1,2,3-cd) pyrene	1.0	
Dibenz(a,h)anthracene	1.0	
Benzo(g,h,i)perylene	1.0	

Parameter	ALS LOR as per Quote EP/246/22 (µg/L)[1]	Container & Holding time (ALS Methods)
Total PAHs	0.5	
Metals (total and dissolved)		
Silver	0.1 (0.8)	60 ml clear high-density polyethylene (U-T ORC) bottle – Unfiltered/filtered, laboratory acidified Chilled <6°C Holding Time: 180 days
Aluminium	5.0	
Arsenic	0.5	
Barium	1.0	
Cadmium	0.2 (0.7)	
Cobalt	0.05 (0.005)	
Copper	0.2 (0.3)	
Iron	5.0	
Manganese	0.5	
Nickel	0.5 (7.0)	
Lead	0.2 (2.2)	
Zinc	5.0 (7.0)	
Mercury	0.1 (0.1)	
Chromium III	0.001 (7.7)	60 ml clear plastic bottle – preserved with sodium hydroxide, filtered/unfiltered Chilled <6°C Holding Time: 28 days
Chromium VI	0.001 (0.14)	
Others		
DOC (mg/L)	1.0	40 ml amber bottle, filtered and preserved with sulfuric acid Chilled <6°C Holding Time: 28 days
TOC (mg/L)	1.0	40 ml amber vial, preserved with sulfuric acid Chilled <6°C Holding Time: 28 days
TDS (mg/L)	10	500 ml clear plastic bottle Chilled <6°C Holding Time: 7 days
TP (mg/L)	0.01	60 ml clear plastic bottle, preserved with sulfuric acid Chilled <6°C
TN (mg/L)	0.1	

Parameter	ALS LOR as per Quote EP/246/22 (µg/L)[1]	Container & Holding time (ALS Methods)
		Holding Time: 28 days

Notes:
1. Value in parentheses is the ANZG (2018) default guideline value (DGV) for 99% species protection
2. °C = Celsius degrees, BTEX = benzene, toluene, ethylbenzene and xylenes, DOC = dissolved organic carbon, LOR = limit of reporting, PAH = polycyclic aromatic hydrocarbons, TDS = total dissolved solids, TOC = total organic carbon, TN = total nitrogen, TP = total phosphorus, TRH = total recoverable hydrocarbons

3.9.4 Quality Assurance and Quality Control Analysis

As part of the NATA requirements, the following QA/QC samples were collected in the field to ensure data integrity:

- Duplicate water samples were collected to test for inter-laboratory variability. Two independent samples (i.e., two separate grabs) were collected at the same location and were analysed by the secondary laboratory (ALS on the east coast of Australia) for dissolved and total metals, TN, TP, DOC, TOC and TDS. Duplicate samples were collected from near the seabed at G & E DC-1, near the seabed at Gorgon GMT, and surface sample at WTR DC-1.
- Equipment water blanks were processed while at site WTR DC-1 to test for potential contaminants in the sampling equipment. Water blank samples were used on the four Niskin bottles (one attached to the ROV and another to the TMS, and two on the surface) and were analysed by the primary laboratory for dissolved and total metals, hydrocarbons and TN, TP, DOC, TOC and TDS.

Similar to sediment samples, laboratory analyses included quality control testing of water samples to include 5% method blanks, 10% laboratory duplicates, 5% laboratory control samples, and 5% matrix spikes. All QA/QC samples were analysed within laboratory holding times and in accordance with NATA quality control procedures (Appendix I).

3.10 Water Profiling

3.10.1 Data Acquisition and Presentation

Profiles of the water column were collected by the water quality profiler attached to the ROV (Section 3.5.5). CTD measurements were collected at 35 sites, as presented in Table 3-13. After all sites were completed, the water quality profiler was removed from the ROV and data downloaded to a laptop. Salinity was calculated by the CTD processing software using EOS-80 (Practical Salinity) equations.

Table 3-13 Summary of CTD sampling sites, start/end times, depth, and up/down cast

Field	Site Name	Upcast (U)/ Downcast (D)	Survey Date	Start Time	End Time	Depth (m)
Chandon	Jansz JMT	U	6/5/2022	00:34	01:13	1,356
	BCH06	D	6/5/2022	08:47	09:28	1,364
	BCH09	U	6/5/2022	13:56	14:37	1,364
	BCH08	D	6/5/2022	16:10	16:51	1,361
	BCH02	D	6/5/2022	20:47	21:55	1,276
	BCH01	D	7/5/2022	01:24	02:08	1,206

Field	Site Name	Upcast (U)/ Downcast (D)	Survey Date	Start Time	End Time	Depth (m)
	Chandon DC-1	U	7/5/2022	06:14	08:27	1,206
	BCH31	D	7/5/2022	10:43	12:16	1,326
Chrysaor and Dionysus	Gorgon M1	D	28/4/2022	18:53	19:09	219
	BCH13	U	29/4/2022	02:25	02:39	226
	BCH12	D	1/5/2022	20:03	20:37	234
	BCH03 – ZIGZAG	U	3/5/2022	15:10	16:27	702
	C & D DC-3	D	3/5/2022	19:03	19:48	746
	BCH15	D	4/5/2022	01:21	01:55	929
	BCH14	D	4/5/2022	10:03	11:24	1,092
	BCH05	D	4/5/2022	20:30	21:01	1,165
	BCH33	D	9/5/2022	16:05	16:26	232
	BCH34	D	9/5/2022	19:24	19:49	752
	BCH36	U	9/5/2022	22:47	23:08	381
	C & D DC-2	U	4/5/2022	04:39	06:04	1,007
Geryon and Eurytion	G & E DC-1	D	5/5/2022	00:47	01:29	1,228
	BCH29	D	5/5/2022	08:01	08:46	1,319
	BCH07	D	5/5/2022	13:31	14:12	1,348
	BCH28	D	6/5/2022	03:03	03:44	1,317
Semele	NTB3	U	4/5/2022	17:20	19:08	1,130
	Semele DC-2	D	7/5/2022	20:11	20:54	1,143
	Semele DC-1	D	8/5/2022	01:06	01:48	1,142
	BCH40	D	8/5/2022	08:15	09:04	1,170
	BCH26	D	8/5/2022	14:52	15:43	1,160
	BCH41	D	8/5/2022	18:49	21:10	1,161
	BCH32	D	9/5/2022	22:35	23:15	1,172
WTR	BCH04	D	3/5/2022	04:01	04:18	256
	WTR DC-1	D	9/5/2022	03:27	03:39	139
	BCH27	D	9/5/2022	10:40	12:27	141
	Gorgon GMT	D	10/5/2022	05:17	05:26	136

Note:

1. BCH = Benthic communities and habitat, C & D Chrysaor and Dionysus, DC = drill centre, G & E = Geryon and Eurytion, WTR = West Tryal Rocks

Data are presented as profiles of temperature, salinity and conductivity against depth for each site. Additionally, temperature-salinity plots were presented for the deepest site at each field to evaluate localised water masses that may be present in the area. Outliers in the water column profiles were removed.

Depth profiles were also recorded by the ROV (recorded as altitude) during each deployment (transect) in the GBF project area.

4 Results

4.1 Benthic Habitat

The overall distribution of benthic habitats within the GBF project area (within the 5 km operational area buffer) is presented in Figure 4-1. The overall benthic habitat map is split into seven maps to show the fine scale seabed features with higher resolution. The seven maps include the 1) Exmouth Plateau area (Figure 4-2), 2) North Jansz area (Figure 4-3), 3) Jansz area (Figure 4-4), 4) North East Semele area (Figure 4-5), 5) North Gorgon area (Figure 4-6), 6) East Scarp-Tryal area (Figure 4-7), and 7) South Gorgon area (Figure 4-8).

Advisian
Worley Group

Chevron

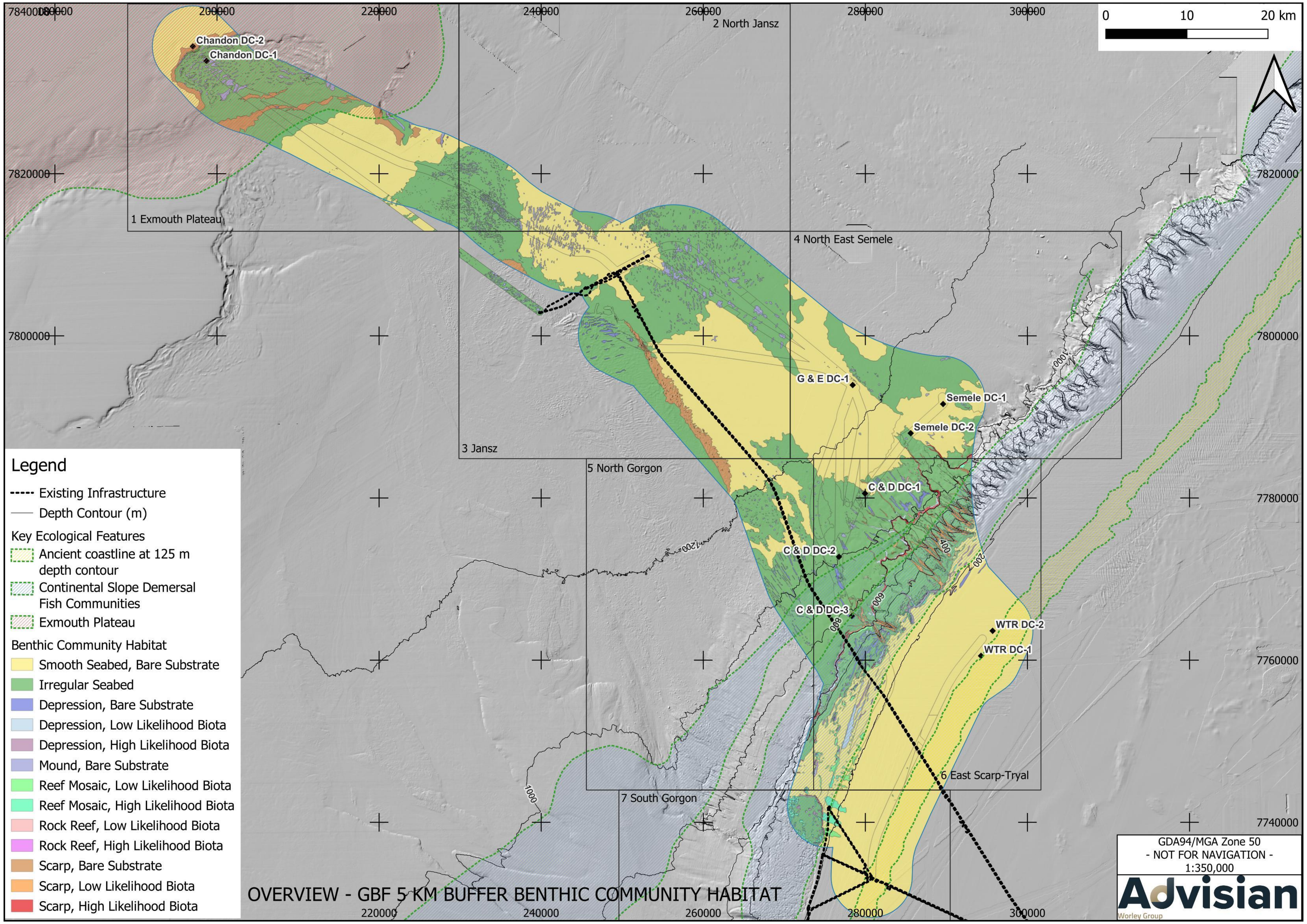

Figure 4-1 Overall distribution of benthic habitats within the Gorgon Backfill Fields project area, subdivided into seven broad areas (1 Exmouth Plateau, 2 North Jansz, 3 Jansz, 4 North East Semele, 5 North Gorgon, 6 East Scarp-Tryal, and 7 South Gorgon areas)

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Worley Group

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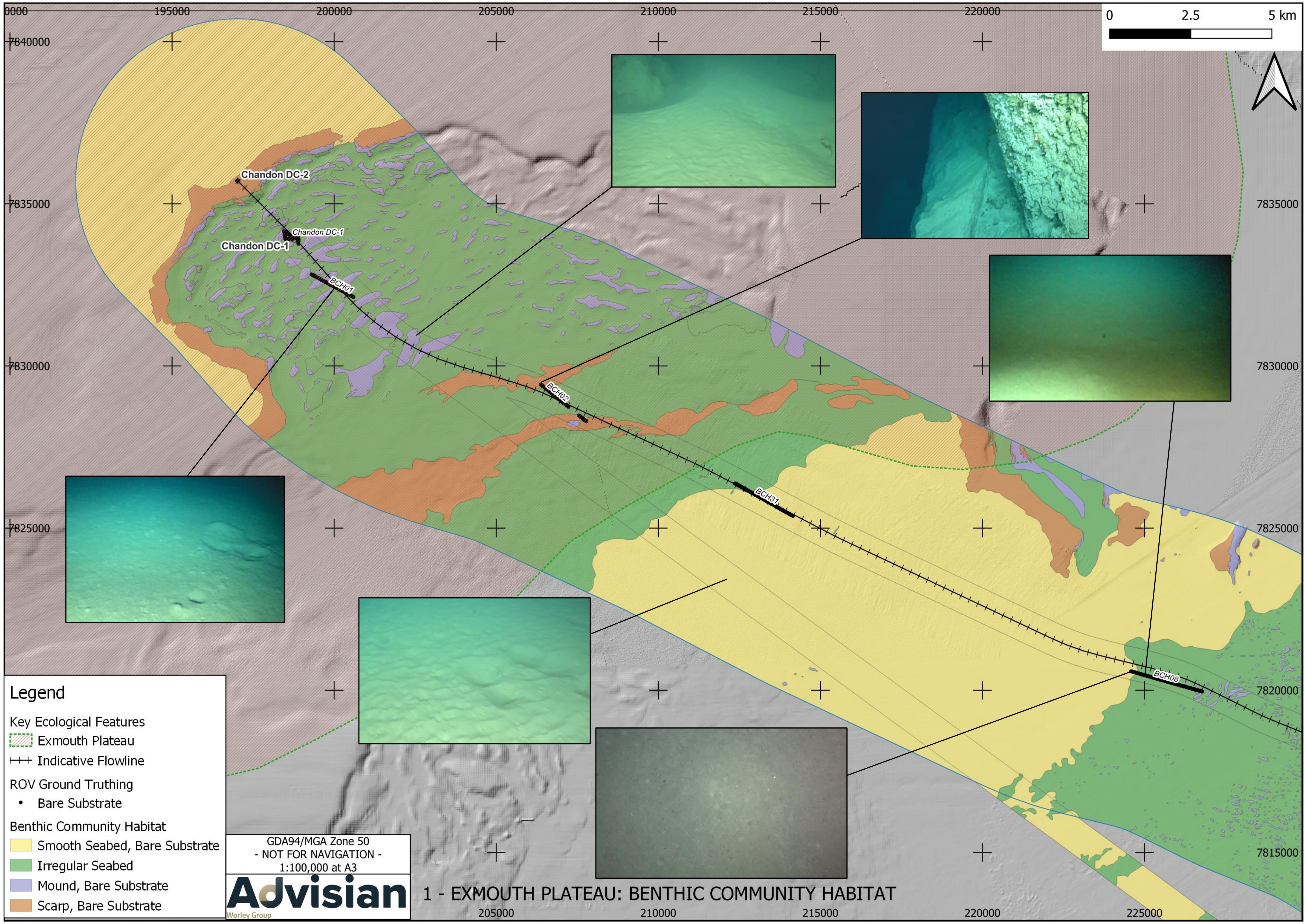


Figure 4-2 Distribution of benthic habitats within the Exmouth Plateau area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats

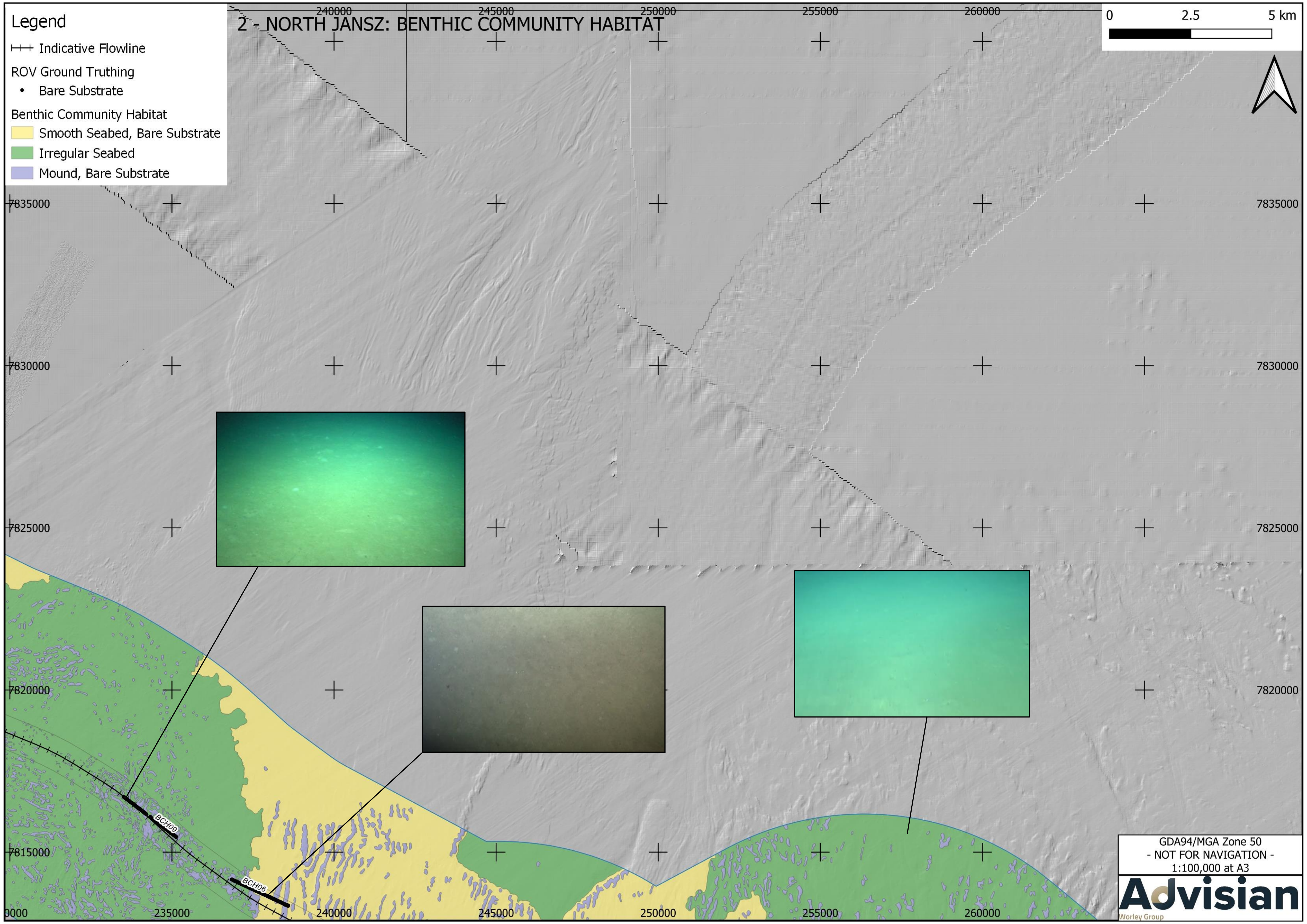


Figure 4-3 Distribution of benthic habitats within the North Jansz area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habit

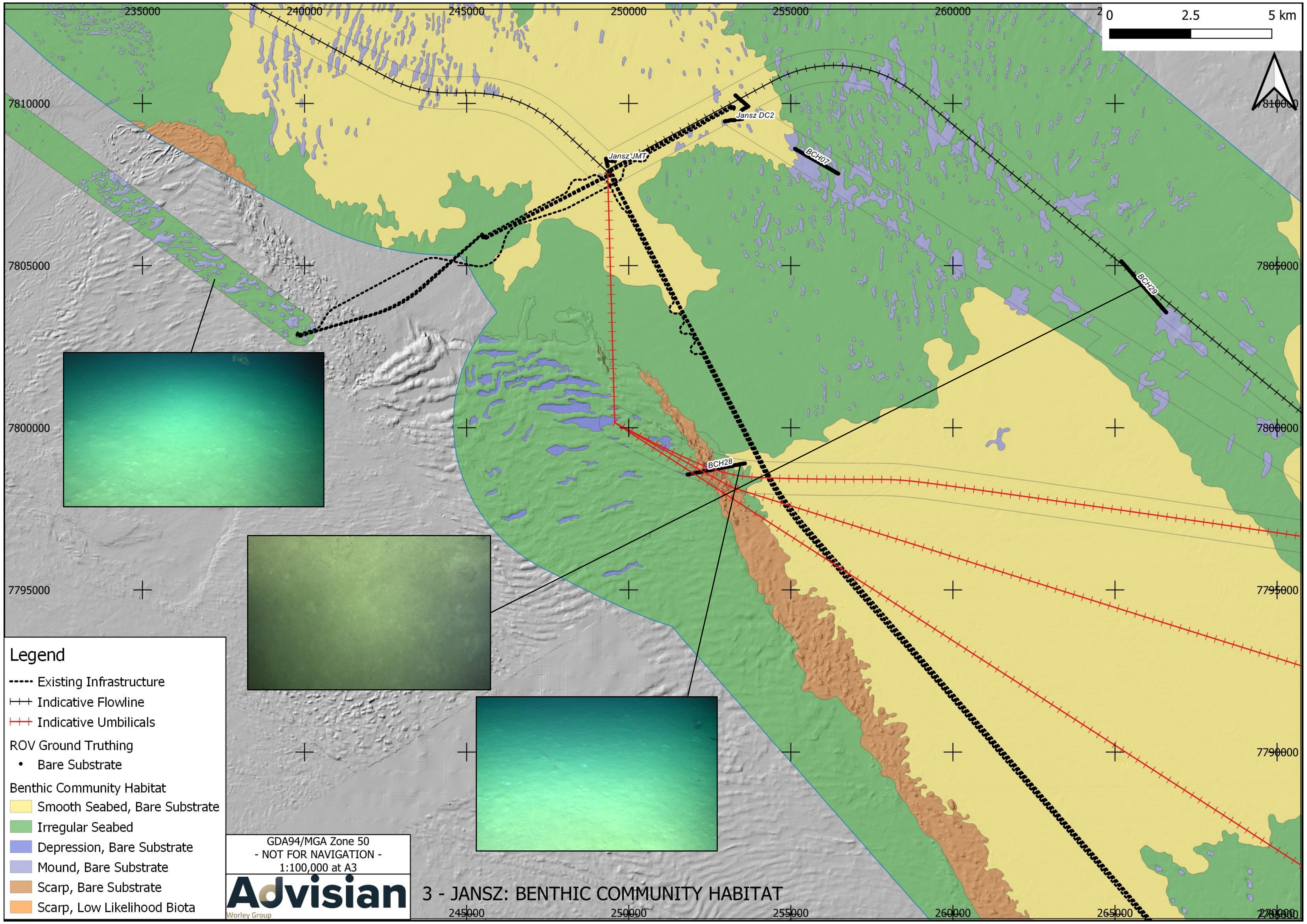


Figure 4-4 Distribution of benthic habitats within the Jansz area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats

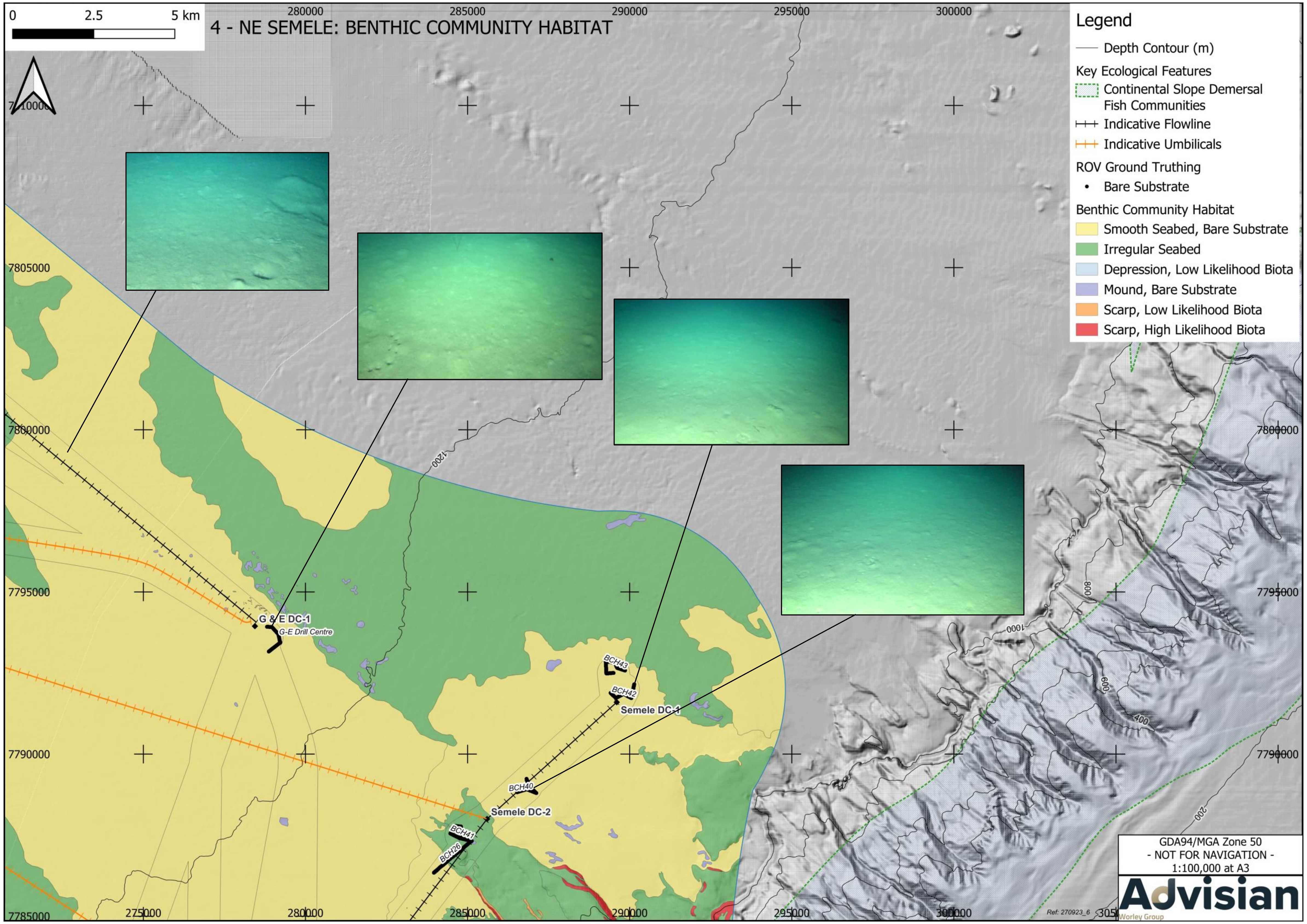


Figure 4-5 Distribution of benthic habitats within the North East Semele area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats

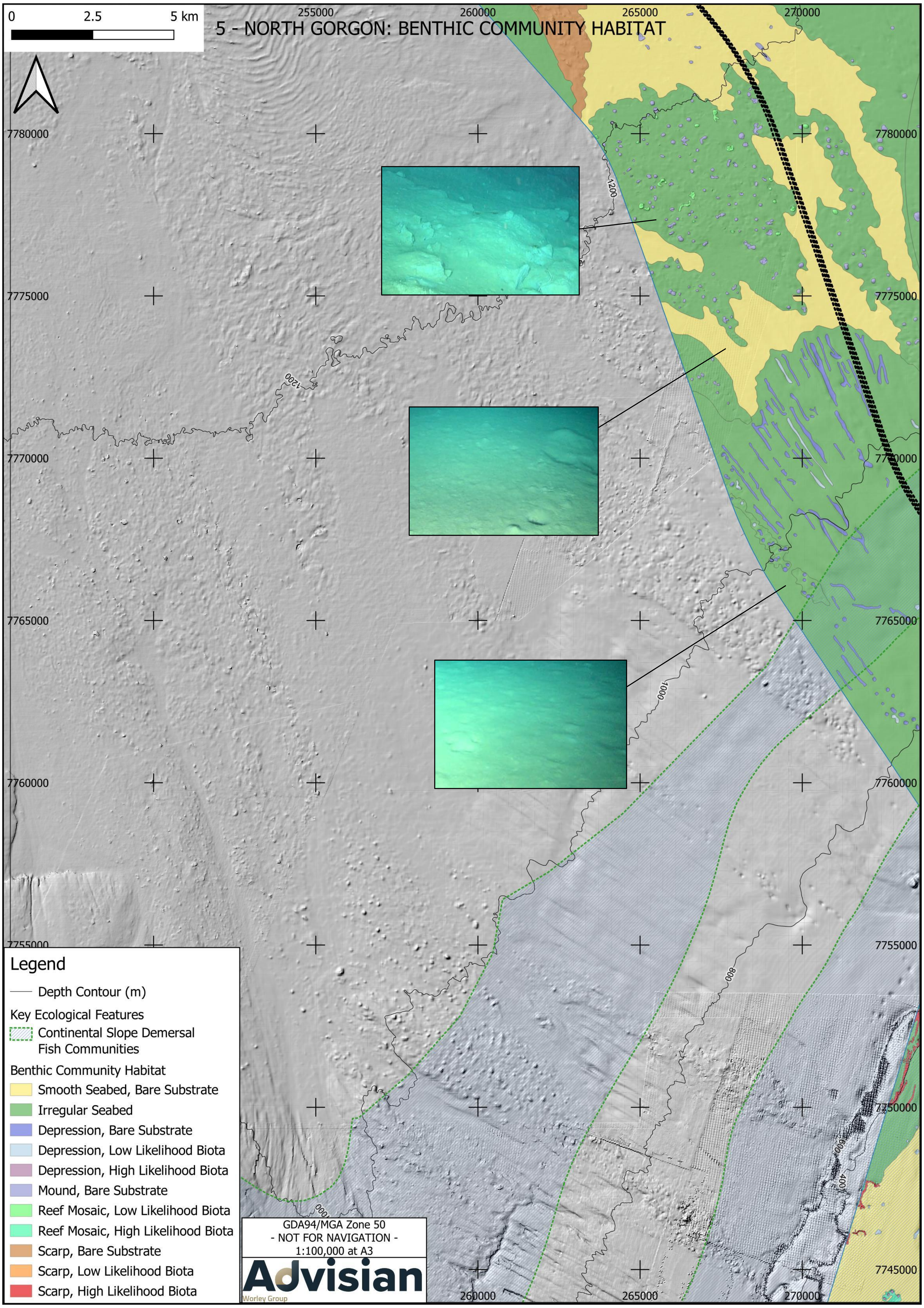


Figure 4-6 Distribution of benthic habitats within the North Gorgon area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats

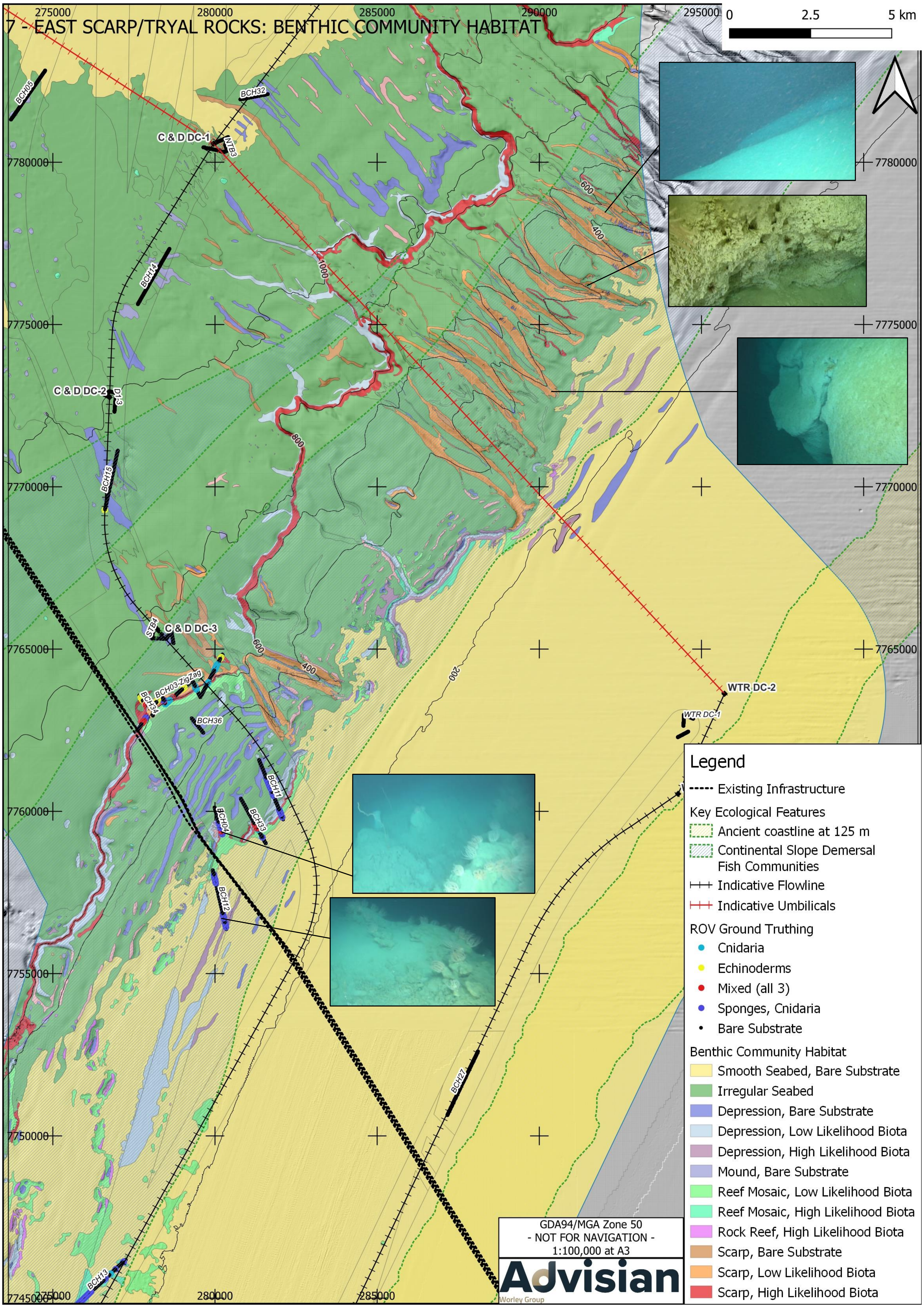


Figure 4-7 Distribution of benthic habitats within the East Scarp-Tryal area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats

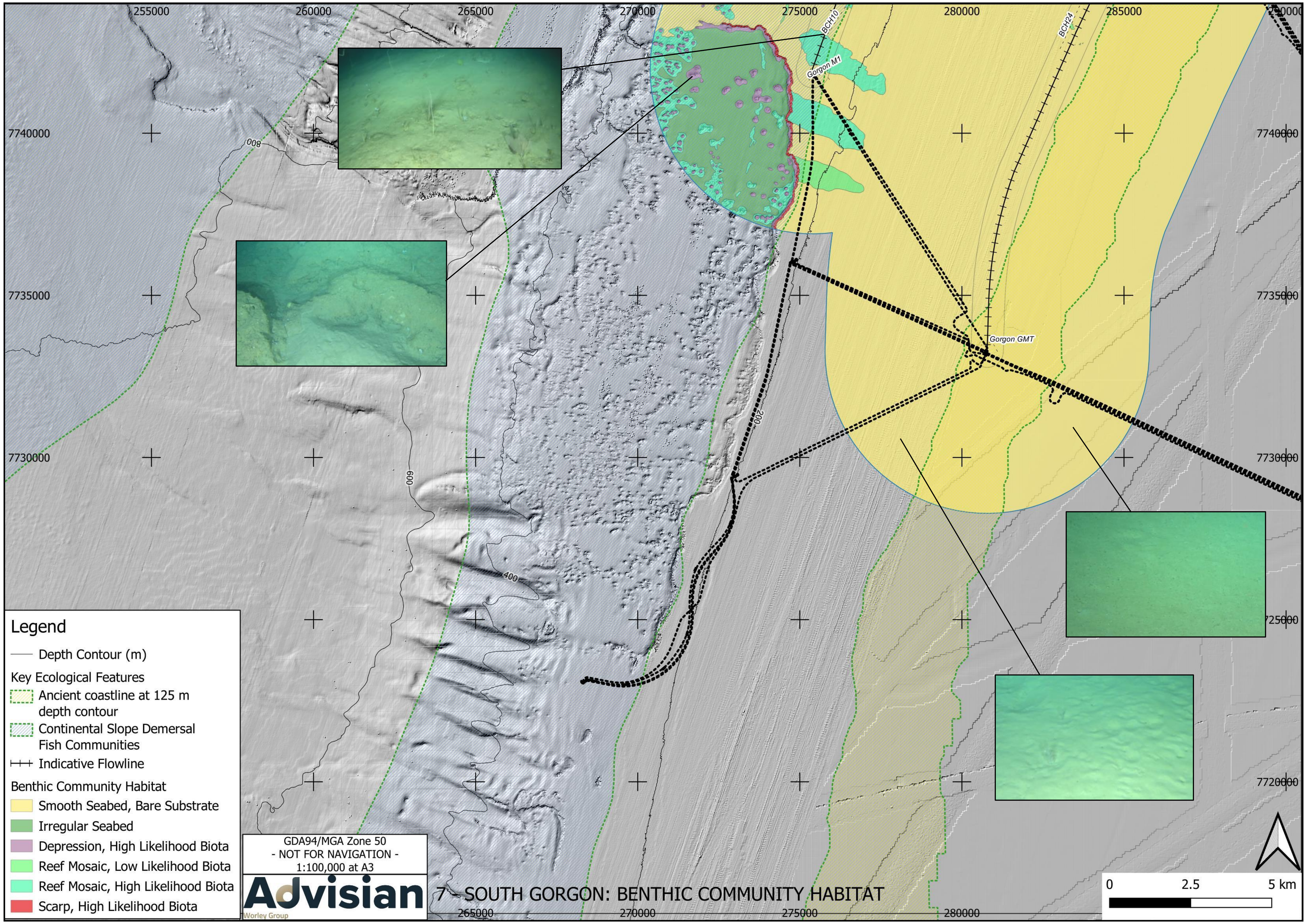


Figure 4-8 Distribution of benthic habitats within the South Gorgon area of Gorgon Backfill Fields project area, with representative images of the benthic communities and habitats

4.1.1 Benthic Communities and Habitats at Key Ecological Features

The distribution of benthic habitats in the Exmouth Plateau KEF is presented in Figure 4-2. Mapping shows the Exmouth Plateau KEF is dominated by mixed habitats comprising irregular seabed with bioturbation, irregular and smooth seabed floor with bare substrates, and mounds on the seafloor of bare substrate. The seabed immediately surrounding the proposed Chandon drill centre (Chandon DC-1), out to ~5 km east and west, and approximately 6 km along the proposed associated flowline comprise of bioturbated irregular seabed and large patches of depressions over bare substrate (as seen in BCH01). Little to no biota is predicted to occur in these bare substrates. In the Exmouth Plateau KEF that lies within the GBF project area, three large discrete scarps with bare substrate are present. Of these scarps, two scarps approximately 5.5 km and 2.5 km from the KEF border, cross through the indicative flowline from east to west, likely representing the edge of the Exmouth Plateau. The third scarp that runs from east to west and is ~500 m wide, is located ~1.4 km north of Chandon DC-1. Given that scarps or steep slopes may comprise of 3D hard structure (i.e., rock) and other structural features, the presence of biota is more likely, although not detected along the transect in this area (BCH02) due to the variable distribution across these habitats.

Mixed benthic habitats comprising irregular and smooth seabed of bare substrates, discrete depressions over bare substrate and scarps with bare substrate are the most dominant benthic features in the Continental Slope Demersal Fish Communities KEF (Figure 4-6, Figure 4-7 and Figure 4-8). A mixture of habitats is present along the proposed flowline route from benthic transect BCH15 to the proposed C & D DC-3 drill centre, including irregular seabed with bioturbation and bare substrate, depressions with bioturbation, and patches of scarps with bare substrate. Larger scarps (in relation to the scarp adjacent to the proposed C & D DC-3 drill centre) are mostly evident north, south and east of C & D DC-3 within the GBF project area which appear to follow changes in depth contours (Figure 4-7). A mixture of habitats and benthic communities extend along the indicative flowline from the proposed C & D DC-3 drill centre to the Gorgon M1 tie in location (Figure 4-4), including the presence of a continuous south-west to north-east scarp with low and high likelihood of biota, discrete patches of depressions over bare substrate, and reef mosaic adjacent to the scarps with a low likelihood of biota. Sections of rock reef mosaic that cross through the indicative flowline is colonised by sponges and cnidarians as identified in benthic transects BCH03 – ZIGZAG and BCH11 within the KEF (Figure 4-7). Topographically complex scarps in a south-west to north-east orientation with low and high likelihood of biota are present traversing through the GBF project area within the Continental Slope Demersal Fish Communities KEF between ~400–800 m depths. Ground-truthing transects (BCH34, BCH03 – ZIGZAG, BCH04, BCH11 and BCH33) verified the presence of cnidarians, echinoderms, sponges and a mixture of these biotic groups along these scarps (Figure 4-3) in varying percent cover (from low [<10%] to high cover [>80%]). Patches of reef mosaic with a low likelihood of biota, and rock reef and depressions with a high likelihood of biota are present to the west of the C & D DC-3 to Gorgon M1 corridor, which are likely to support sponges and cnidarians, as verified by benthic habitat transects BCH13 and BCH10 (Figure 4-7 and Figure 4-8). A scarp orientated north to south with a high likelihood of biota is present ~650 m west of Gorgon M1 tie in location and runs parallel to existing subsea infrastructure (Figure 4-8).

Mapping of the GBF project area (proposed flowline/umbilical corridors) that lie within the Ancient Coastline KEF only captures the existing infrastructure and Gorgon GMT proposed tie-in location (Figure 4-8). The benthic habitat at Gorgon GMT and the GBF project area within this KEF only consists of smooth seabed with bioturbation and bare substrate and appears to be devoid of biota, as further evidenced by ground-truthing (Figure 4-7 and Figure 4-8).

4.1.2 Benthic Communities and Habitats at Low Slope Areas

Low slope areas are defined as areas within the GBF project area that contain the proposed flowlines and umbilical corridors situated outside of KEFs in the lower slope and Kangaroo Syncline areas, and are characterised by low structural complexity/rugosity and carbonate and clay muds. These include benthic habitat transects collected along BCH31 and BCH08 (Figure 4-2), BCH09 and BCH06 (Figure 4-3) within the Chandon DC-1 to JMT corridor, BCH07, BCH28 and BCH29 (Figure 4-4) in the Jansz to Geryon and Eurytion (G & E) corridors, and BCH26 (Figure 4-5) BCH05, BCH14, BCH32 and proposed NTB3 drill centre (Figure 4-7) within the Chrysaor and Dionysus (C & D) to Gorgon corridor.

A mixture of habitats was present along the Chandon to JMT corridor however all were of low structural complexity: irregular and/or smooth seabed either with bioturbation or bare substrate, and scattered patches of depression over bare substrate. No epifaunal communities were noted during ground-truthing transects across this area (Figure 4-2, Figure 4-3 and Figure 4-4). These habitats of low structural complexity extend out to the boundary of the GBF project area, with the exception of scarps with bare substrate which are present between benthic habitat transects BCH31 and BCH08, and approximately 1.8 km north from the proposed flowline (Figure 4-2).

Benthic habitats along the proposed flowline and umbilical routes from Jansz DC2 to G & E DC-1 comprises smooth seabed with bioturbation and irregular seabed with bare substrate with intermittent mounds with bare substrate, and scattered patches of depressions over bare substrate (Figure 4-4). Geomorphic feature mapping identified a continuous scarp with bare substrate near the Jansz Field Control Station (FCS), orientated north to south and parallel to existing subsea infrastructure (Figure 4-4). Small patches along the scarp are identified as areas with low likelihood of biota (Figure 4-4). Despite this, the ground-truthing transect of this area (benthic transect BCH28) did not identify the presence of epifauna due to a thick coverage of sediment.

The benthic habitats within the low slope area of the C & D to Gorgon corridor are predominantly characterised by smooth and irregular seabed with either bare substrate or bioturbation. Along the Semele to C & D corridor, scarps orientated north to south are located ~500 m south of the proposed flowline near benthic habitat transect BCH26, with a low and high likelihood of biota (Figure 4-5). Seabed areas of depressions with bare substrate and high likelihood of biota are present along BCH05, BCH14 and BCH32 that extend further out within the GBF project area (Figure 4-7). Scarps orientated south-west to north-east with bare substrate are situated ~60 m north and ~1 km south of the proposed NTB3 drill centre that crosses through the indicative flowlines (Figure 4-7). As verified with ground-truthing, no epifauna were identified on the scarps with bare substrate (Figure 4-7). The scarp located north of the proposed NTB3 drill centre extends further out within the GBF project area in a south-easterly direction (Figure 4-5). The benthic habitat surrounding the proposed C & D drill centre (C & D DC-2), which is situated outside of the Continental Slope Demersal Fish Communities KEF on the northern border, consists primarily of irregular seabed with bare substrate.

4.1.3 Benthic Communities and Habitats at Proposed Drill Centres

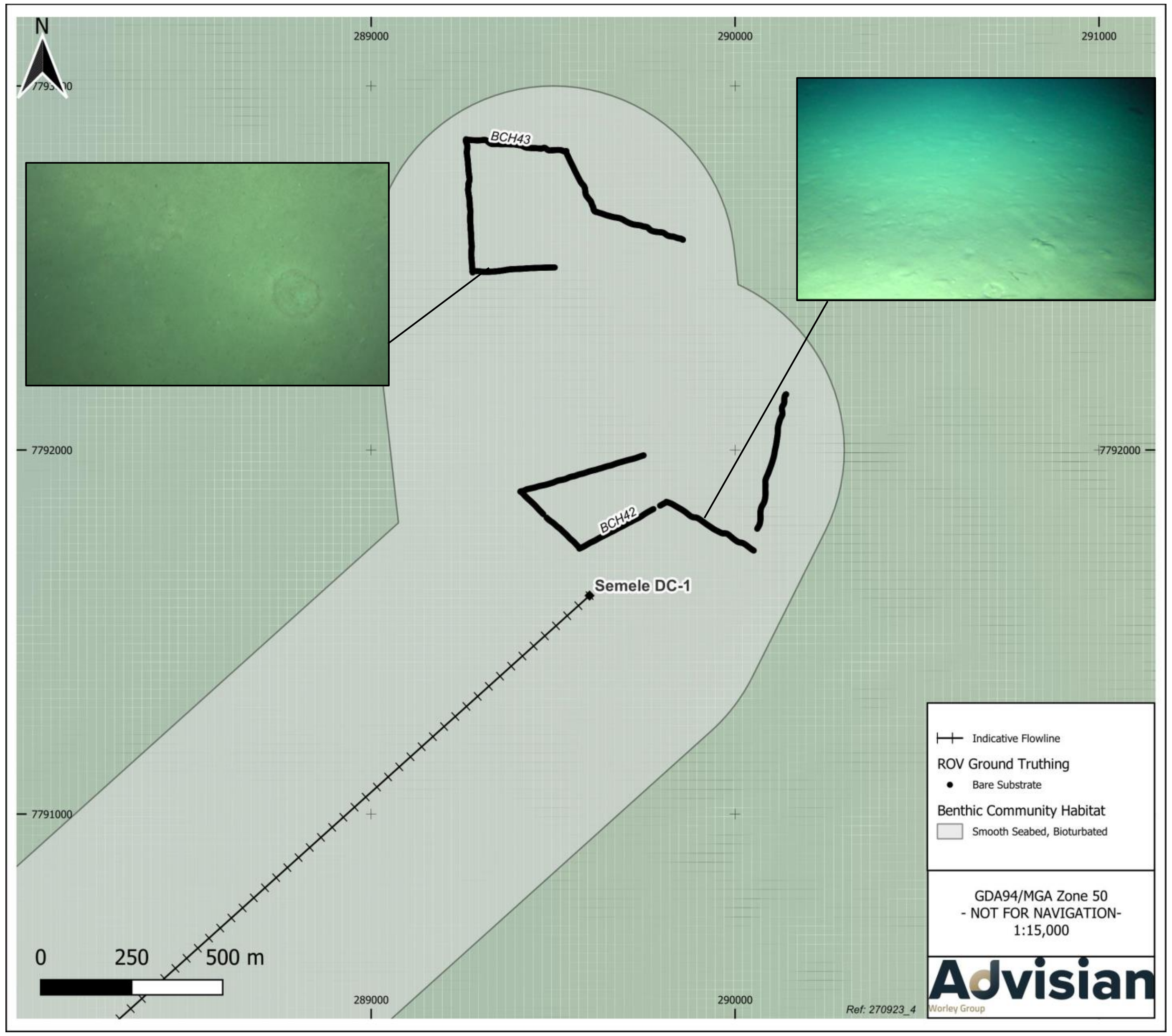
The type of BCH present in proposed drill centres that are located within a KEF (Chandon DC-1 in the Exmouth Plateau KEF; and C & D DC-2 and C & D DC-3 within the Continental Slope Demersal Fish Communities KEF) are described in Section 4.1.1 Similarly, benthic habitat mapping of the proposed NTB3 drill centre that is situated in a low slope area, is described in Section 4.1.2

The benthic habitats immediately surrounding the Jansz DC2 tie-in (Figure 4-9) is characterised as low structural complexity, with smooth seabed with bioturbation and isolated patches of mounds with bioturbation. Similarly, the G & E DC-1 is primarily comprised of smooth seabed with bioturbation and scattered patches of bedforms with bare substrate to the north and north-east of the proposed drill centre (Figure 4-9). Ground truthing transects at each of these locations did not reveal any notable epifaunal communities.

The benthic habitat around the proposed drill centres Semele DC-1 and Semele DC-2, and benthic habitat transect BCH40 (Figure 4-10) and associated flowlines is of low structural complexity and dominated by smooth seabed with bioturbation. Irregular seabed with bioturbation and a mound with bare substrate is present around BCH41 (Figure 4-5). Ground truthing transects at each of these locations did not reveal any epifaunal communities.

Similarly to the proposed Semele drill centre sites, low structural complexity is present at WTR DC-1 and comprises only of smooth seabed with bioturbation (Figure 4-11) and no presence of biota.

Figure 4-9 Distribution of benthic habitats within Jansz DC2 tie in location (left) and Geryon and Eurytion drill centre (G & E DC-1) (right) with representative images of the benthic communities and habitats



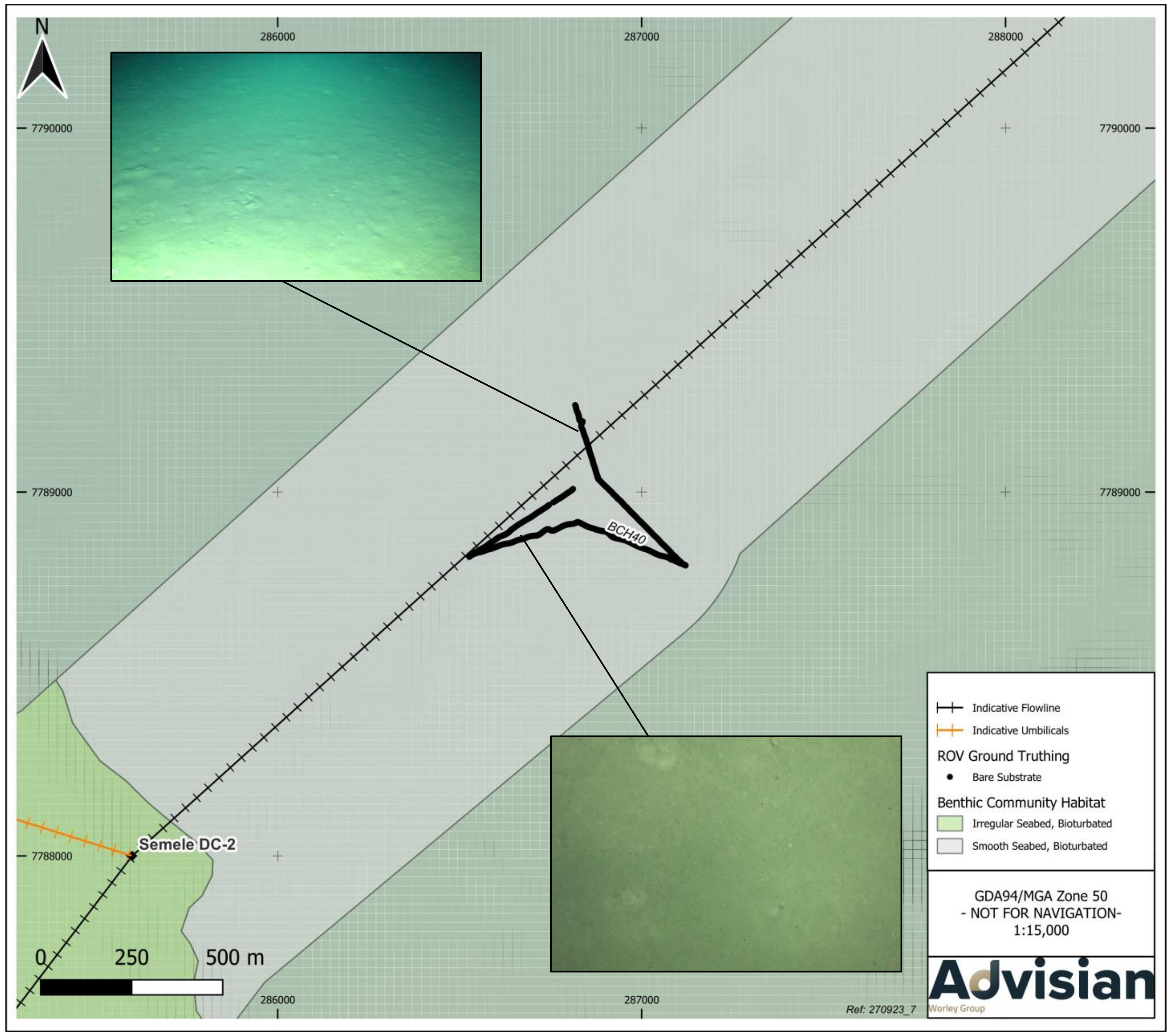


Figure 4-10 Distribution of benthic habitats within BCH42 and BCH43 (left) and BCH40 (right) with representative images of the benthic communities and habitats

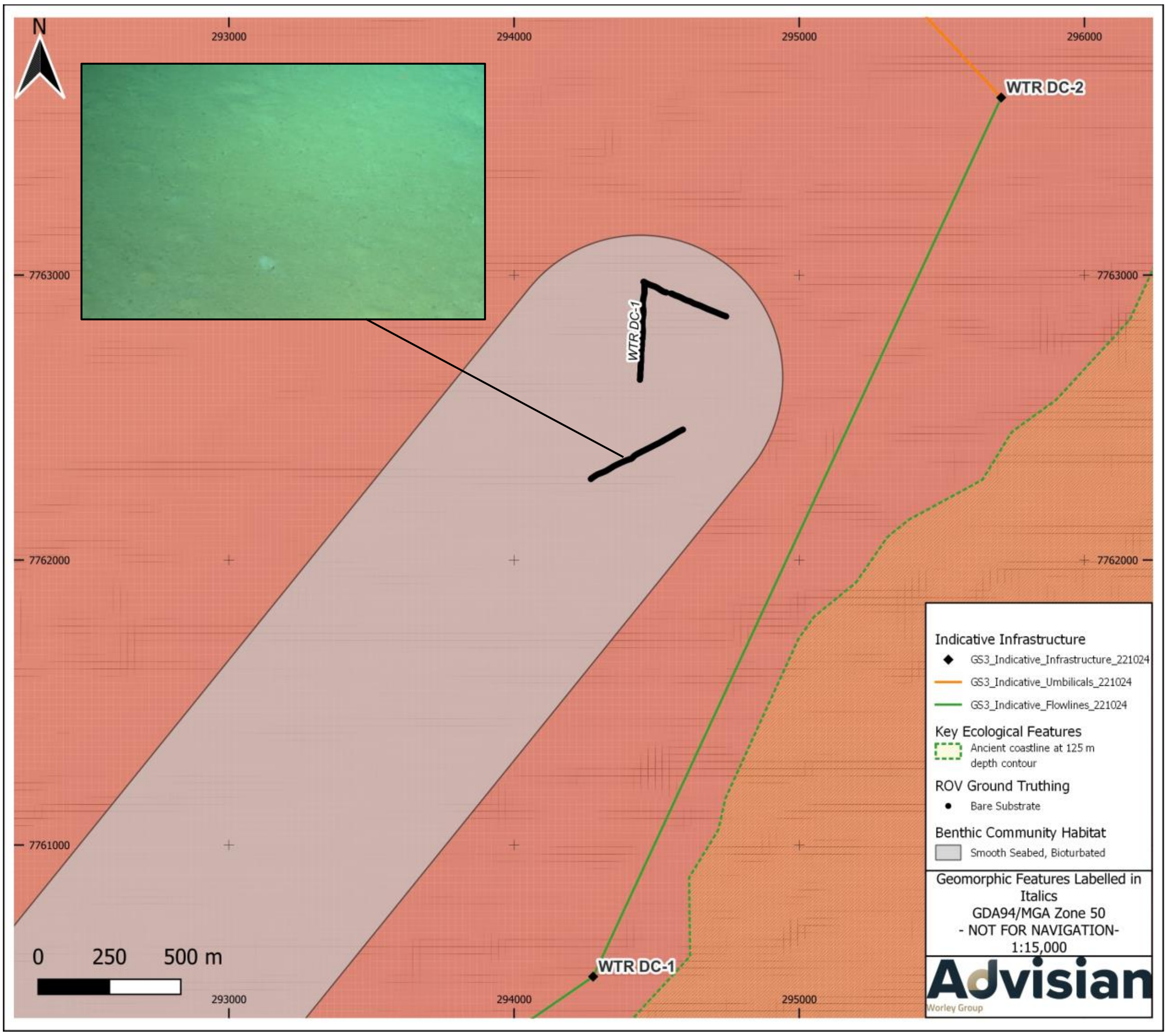


Figure 4-11 Distribution of benthic habitats within WTR DC-1 with a representative image of the benthic communities and habitats

4.2 Benthic Cover

Across the 12 sites that are proposed drill centres and tie-in locations and 2 benthic habitat transect sites, bare sediment (soft unconsolidated sand/mud <2 mm) with no biota was the dominant benthic category (Figure 4-12). Along one or more transects at sites Chandon DC-1, Jansz JMT, Semele DC-1, BCH42 and BCH43, bioturbation in bare sediment was observed in small quantities (with a range of 0.5–39% cover; Figure 4-12). The occasional presence of boulders over bare sediment was observed along some transects at Jansz JMT, Jansz DC-2, Semele DC-1 and Semele DC- 2, ranging between 50% and 100% percent cover (Figure 4-12). Bioturbation with cnidarians was only observed at site Gorgon M1 where they contributed to 1% of the overall cover (Figure 4-12). Overall, the proposed drill centre & tie-in locations are considered to be relatively devoid of epifauna.

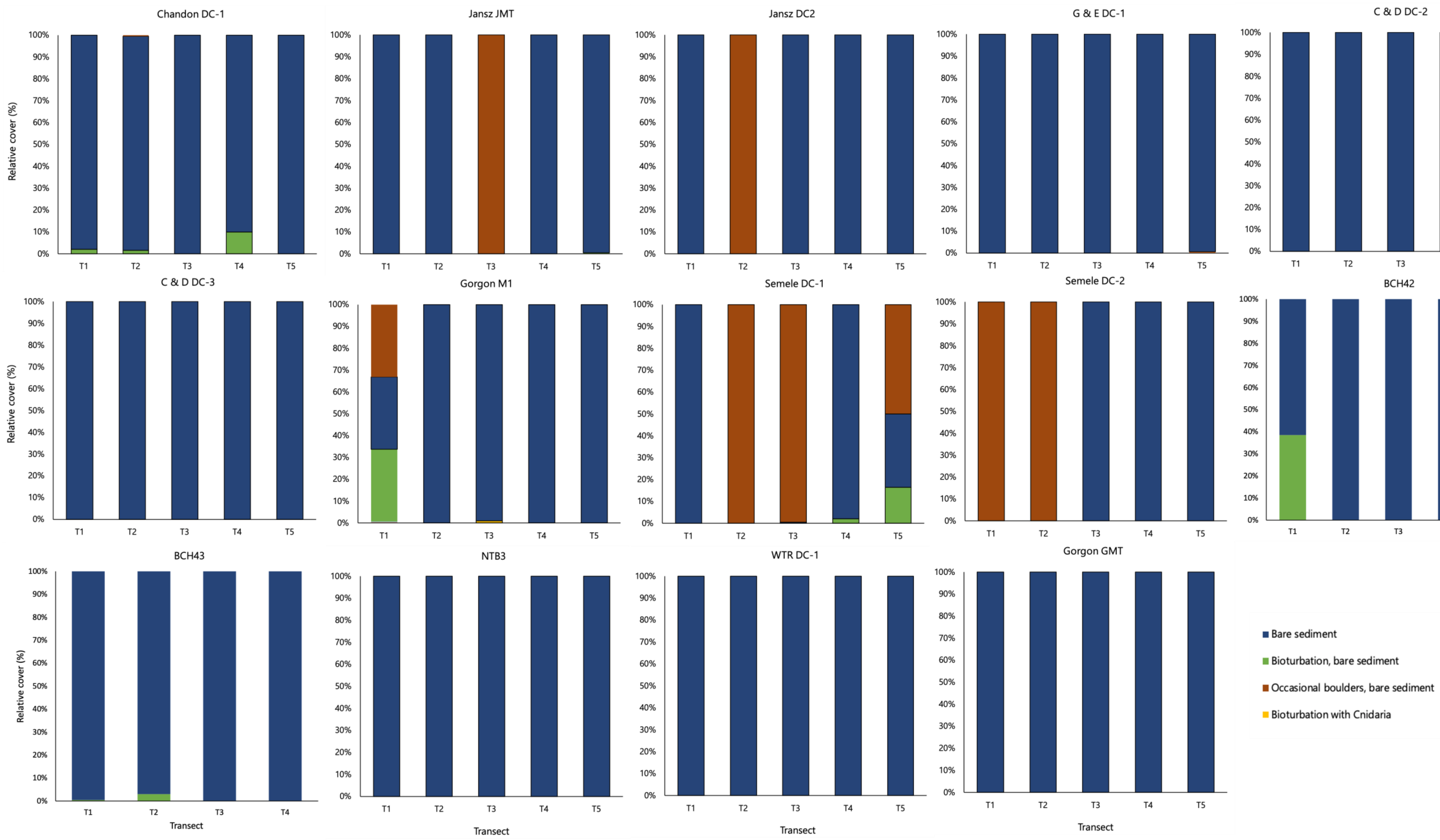


Figure 4-12 Benthic cover (%) along haphazard transects

4.3 Fish Assemblage

Refer to the Fish Report presented in Appendix D for more details on the results.

4.3.1 General Description of Fish and Crustacean Assemblages at Key Ecological Features

In the Exmouth Plateau KEF, a total of 165 individual fish from 14 taxa were identified. The fish assemblage was dominated by an unidentified anguilliform fish and *Bathypterois* sp1 (family Ipnopidae), together representing over 65% of the total number of individual fish recorded. Other abundant taxa included *Aldrovandia* sp1 and *Aldrovandia* sp2 (Halosauridae), and *Macrouridae* sp2 (Macrouridae, rat tails). The crustacean assemblage in the Exmouth Plateau KEF consisted of 228 individuals from seven taxa. A species of red prawn was the most dominant crustacean taxa representing over 81% of the total number of individuals, followed by a pink prawn and an orange prawn.

Within the Continental Slope Demersal Fish Communities KEF, a total of 468 fish belonging to 25 taxa were recorded. The fish assemblage was dominated by Trevallies (Carangidae) with four species from three genera accounting for 256 of the individuals observed. The five most abundant fish taxa were *Decapterus kurroides*, *Decapterus* sp1 and *Seriola dumerili* (Carangidae), an unidentified bait fish, and *Synodontidae* sp2 (Synodontidae). Only one site (BCH04) in this KEF recorded crustaceans. At this site, a total of three crustaceans from three taxa (two from infraorder Anomura, and one from infraorder Achelata) were recorded.

The Ancient Coastline KEF recorded a total of 18,011 individuals from 13 fish taxa. The fish assemblage was dominated by Trevallies (Carangidae) with three species representing 14,231 of the total individuals. The most abundant fish taxa were *Carangoides* sp1 and *Seriola dumerili* (Carangidae), an unidentified baitfish, *Carcharhinus* sp1 (Carcharhinidae), and *Rachycentron canadum* (Rachycentridae). Only one crustacean (unidentified prawn species) was recorded at Gorgon GMT.

At the four sites (C & D DC-3, NTB3, WTR DC-1 and BCH24) outside of KEF areas, a total of 11,800 individual fish belonging to 28 taxa were identified. The five most abundant taxa were *Trachurus novaezelandiae* and *Seriola dumerili* (Carangidae), an unidentified baitfish species, an unidentified anguilliform fish species, and *Carcharhinus* sp1 (Carcharhinidae). 11,007 of the total individual fish were recorded at site BCH24, which was dominated by *Trachurus novaezelandiae* (78% of total individuals) and an unidentified baitfish species (21% of total individuals). There were 236 total individual crustaceans recorded from seven taxa, with all sites dominated by a red prawn species. The red prawn species accounted for 66 of the 107 total individuals observed in site NTB3, whereas only one unidentified prawn species identified at site WTR DC-1

4.3.2 General Description of Fish and Crustacean Assemblages at Geomorphic Features

The fish and crustacean assemblages at the plateau slope, which contains the same two sites as the Exmouth Plateau KEF (BCH01 and BCH02), is described in Section 4.3.1.

The trench/trough slope contained 59 individual fish from 14 taxa. The fish assemblage was distinguished by Macrouridae species, Halosauridae species, and an unidentified anguilliform species (eel-like fish), which accounted for 82% of the total recorded individuals. The four most abundant taxa were the unidentified anguilliform species (28 individuals), *Macrouridae* sp4 (eight individuals) and *Macrouridae* sp2 (Macrouridae; four individuals), and *Synaphobranchus* sp1 (Synaphobranchidae; four individuals). The crustacean assemblage in the trench/trough slope geomorphic feature consisted of 128 individuals belonging to five taxa. The assemblage was dominated by a red prawn species, which made up 80% of the total individuals and was also the most abundant taxa for each transect in site C & D DC-3. The other abundant crustacean species included a dark prawn species, a second red prawn species, and an orange prawn species.

The slope geomorphic feature comprised of seven sites (BCH04, BCH11, BCH12, BCH33, WTR DC-1, BCH24 and Gorgon GMT), where a total of 30,033 individual fish species belonging to 37 taxa were recorded. The fish assemblage was dominated by Trevallies (Carangidae) with 23,208 individuals from seven taxa. The five most abundant species were *Carangoides* sp1, *Trachurus novaezelandiae* and *Seriola dumerili* (Carangidae), an unidentified baitfish species, and Carcharhinus sp1 (Carcharhinidae), which together accounted for 98% of the total individuals. Only three sites in this geomorphic feature contained crustaceans: WTR DC-1, BCH04 and Gorgon GMT. The crustacean assemblage consisted of five total individuals recorded from four taxa.

In the deep/hole/valley slope geomorphic feature, there were 16 fish taxa and a total of 187 individuals recorded. The fish assemblage was dominated by an unidentified anguilliform fish species, representing 54% of the individuals observed, followed by *Aldrovandia* sp1, *Aldrovandia* sp2, and *Aldrovandia affinis* (Halosauridae), and *Macrouridae* sp1 (Macrouridae). The crustacean assemblage consisted of 110 total individuals recorded from four taxa. The assemblage was dominated by a red prawn species which accounted for 70% of the total individuals across the NTB3 site.

4.3.3 General Description of Invertebrate Assemblage

A total of 922 invertebrate individuals from 26 taxa were recorded across all sites. The invertebrate assemblage included one feather star (Cormatulida) species, four jellyfish (Scyphozoa) species, seven sea cucumber (Holothuroidea) species, seven sea star (Asteroidea) species, six sea urchin (Echinoidea) species and one squid (Cephlapod) species. The assemblage was dominated by a brown jellyfish species which accounted for 69% of the total number of individuals and were mostly recorded at site BCH24.

4.3.4 Comparison of Fish and Crustacean Assemblages Between Water Masses

The deeper water fish assemblages of the AAIW mass were significantly different ($p<0.001$) to the shallower water fish assemblages in both the SICW and the TSW water masses (Figure 4-13). The AAIW were characterised by species including two *Aldrovandia* spp. (Halosauridae), a Macrouridae species, a species of unidentified anguilliform fish, and a Bathypterois species (Ipnopidae) (Figure 4-13). A greater abundance of *Trachurus novaezelandiae* (Carangidae), an unidentified bait fish, and whaler shark *Carcharhinus* sp1 were observed at the TSW, whereas the SICW water mass was characterised by a high abundance of *Seriola dumerilii* (Carangidae) and *Carcharhinus plumbeus* (Figure 4-13).

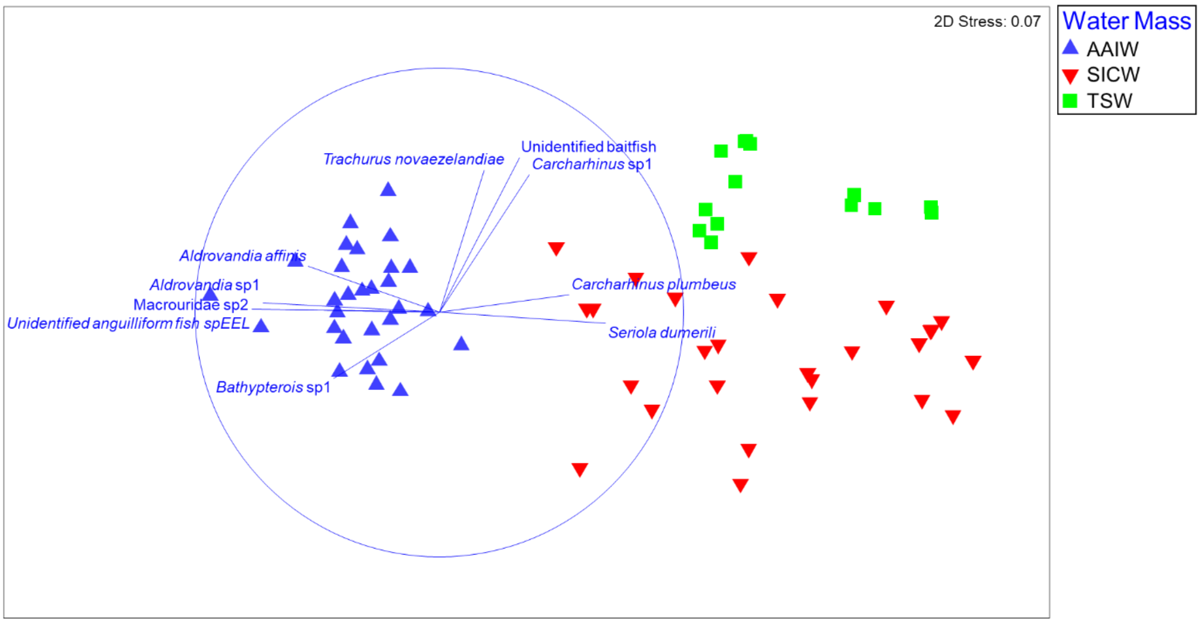


Figure 4-13 Non-metric multidimensional scaling plot illustrating the differences in fish assemblages among the Antarctic Intermediate Water (AAIW), Southern Indian Central Water (SICW) and Tropical Surface Water (TSW) masses

A greater mean number of fish per transect were identified in the TSW mass (1684 ± 358 no. fish) compared to SICW and AAIW (118 ± 38 and 16 ± 2 no. fish, respectively). There was no significant difference ($p>0.05$) in the mean number of fish taxa per transect between water masses. On average each transect had ~four and six fish taxa.

The crustacean assemblages of the deeper AAIW mass were significantly different ($p<0.001$) to the shallower assemblages in the SICW and the TSW water masses. The most strongly correlated taxa to the AAIW mass were all prawns.

The mean number of crustaceans and mean number of taxa were both significantly greater in the AAIW (27 ± 3 no. crustaceans; 3 ± 0.2 no. taxa) than SICW (0.1 ± 0.1 no. crustaceans; 0.1 ± 0.1 no. taxa) and TSW (0.1 ± 0.1 no. crustaceans; 0.1 ± 0.1 no. taxa).

4.3.5 Comparison of Fish and Crustacean Assemblages Among Key Ecological Features

The fish assemblages of the Continental Slope Demersal Fish Communities KEF were significantly different to the fish assemblages at the Exmouth Plateau KEF and outside any KEFs ($p<0.05$; Figure 4-14a). This difference was primarily driven by two *Aldrovandia* spp. (Halosauridae), a Macrouridae species, an unidentified anguilliform fish, and a Bathypterois (Ipnopidae) species (Figure 4-14a).

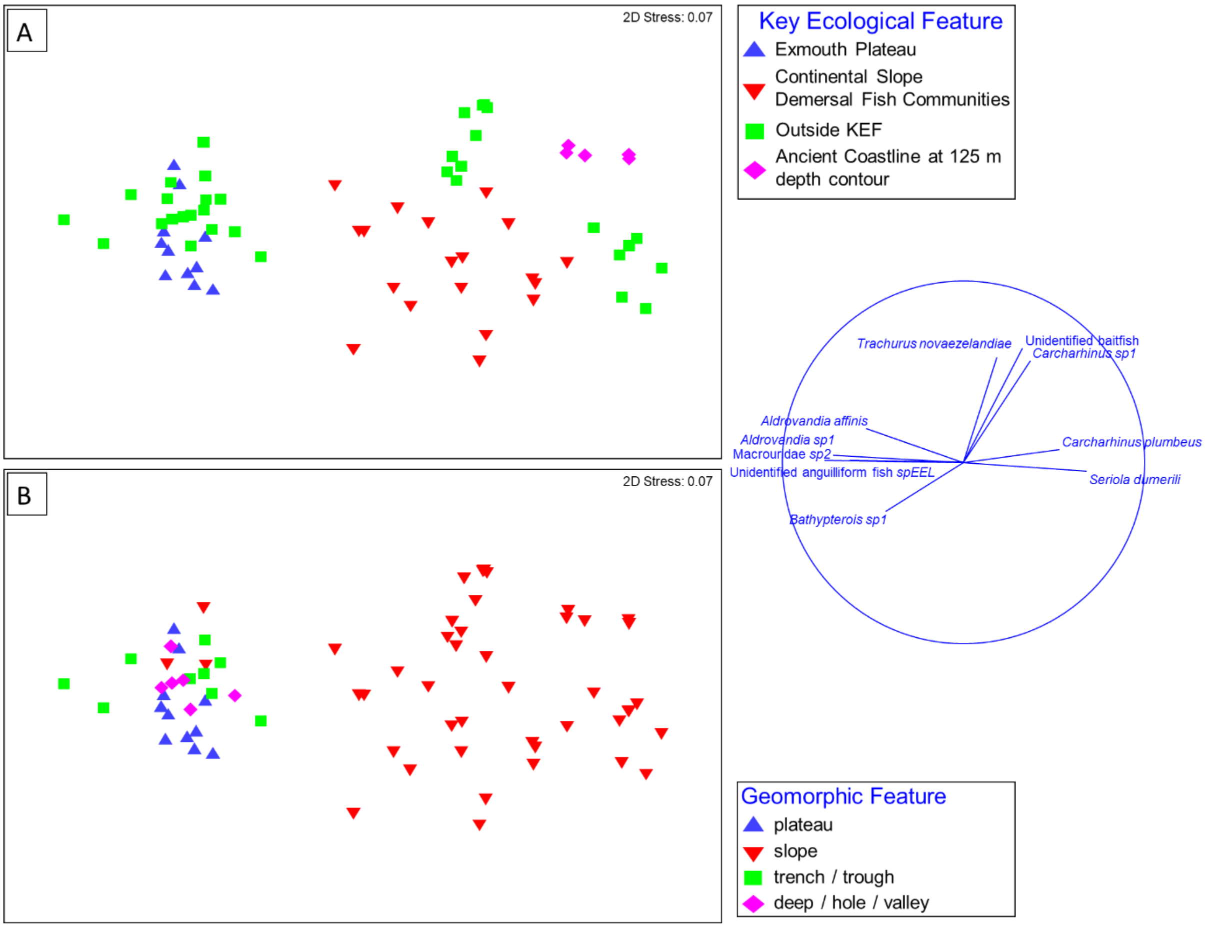


Figure 4-14 Non-metric multidimensional scaling plot illustrating the differences in fish assemblages among a) Key Ecological Features, and b) geomorphic features

The Ancient Coastline KEF had a greater mean number of fish per transect (3021 ± 150 no. fish) compared to Continental Slope Demersal Fish Communities KEF (25 ± 5 no. fish), Exmouth Plateau (13 ± 1 no. fish) and outside of KEF (322 ± 108 no. fish). There was no significant difference in the mean number of fish taxa between KEFs. Between five and nine fish taxa were recorded at each KEF.

The crustacean assemblage of the Exmouth Plateau KEF was significantly different ($p = 0.05$) to that of the Continental Slope Demersal Fish Communities KEF and the Ancient Coastline KEF. The crustacean assemblage of the Continental Slope Demersal Fish Communities KEF was also different to the crustacean assemblage at areas outside any KEF. Both the Exmouth Plateau and outside any KEF, which are located in deeper waters, were primarily driven by all prawn taxa.

The mean number of crustaceans and mean number of taxa were statistically greater in the Exmouth Plateau (17 ± 2 no. crustaceans; 3 ± 0.4 no. taxa) and outside any KEF (16 ± 4 no. crustaceans; 2 ± 0.3 no. taxa) compared to Ancient Coastline (0.2 ± 0.2 no. crustaceans; 0.2 ± 0.2 no. taxa) and Continental Slope Demersal Fish Communities KEFs (0.2 ± 0.1 no. crustaceans; 0.2 ± 0.1 no. taxa).

4.3.6 Comparison of Fish and Crustacean Assemblages Among Geomorphic Features

The fish assemblage of the slope geomorphic feature was significantly different ($p<0.05$) to the plateau, trench/trough and deep/hole/valley slope, and was driven by shallower fish species such as *Trachurus novaezelandiae* (Carangidae), unidentified baitfish, *Carcharhinus* sp1, *Carcharhinus plumbeus* (Carcharhinidae), and *Seriola dumerili* (Carangidae; Figure 4-14b).

The mean number of fish was higher on the slope (598 ± 156 no. fish) than any other geomorphic features (plateau: 13 ± 1 no. fish; trench/trough: 12 ± 2 no. fish; deep/hole/valley: 27 ± 5 no. fish), however, there were large variations in the number of fish among samples. There was no significant difference in the mean number of fish taxa between geomorphic features. Between five and seven fish taxa were recorded at each geomorphic feature.

The crustacean assemblage of the shallower water slope geomorphic feature was significantly different ($p = 0.001$) compared to the other deeper water geomorphic features, in which deeper waters was the primary driven by the crustacean taxa.

Although not statistically significant, the mean number of crustaceans was lower in the slope geomorphic feature (3 ± 2 no. crustaceans) and highest at the trench/trough (41 ± 6 no. crustaceans), while deep/hole/valley and plateau were similar (15 ± 2 and 17 ± 2 no. crustaceans). The mean number of crustacean taxa was significantly lower in the slope (0.4 ± 0.2 no. taxa) compared to the deep/hole/valley (3 ± 0.3 no. taxa), plateau (3 ± 0.4 no. taxa), and trench/trough (3 ± 0.3 no. taxa) geomorphic features.

4.3.7 Composition of Fish and Crustacean Assemblages

For both fish and crustacean assemblages, water depth was an important predictor of the multivariate composition of assemblages. The DistLM analysis for fish assemblages showed that depth alone explained 27% of the variation in the fish assemblage composition ($R^2 = 0.27177$, pseudo $F_{(1,69)} = 25.751$, $p<0.001$). for the crustacean assemblages, water depth explained 73% of the variation in the assemblage composition ($R^2 = 0.72716$, pseudo-$F_{(1,69)} = 183.9$, $p<0.001$).

4.4 Sediment Chemistry

Laboratory reports for sediment samples are presented in Appendix F. Photos of the sediment cores are provided in Appendix G.

4.4.1 Hydrocarbons

Concentrations of hydrocarbons (TRH, BTEX and PAHs) in all sediment samples were below the laboratory LOR.

4.4.2 Metals and Metalloids

Concentrations of all metals and metalloids in sediment samples located within proposed drill centres and tie-in locations all met their relevant ANZG (2018) DGVs[2], with the exception of nickel (Table 4-1,

[2] There are no ANZG (2018) DGVs for aluminium, barium, cobalt, iron and manganese.

Figure 4-15). Total nickel in all three replicate samples collected from Chandon DC-1 exceeded the ANZG (2018) DGV of 21 mg/kg however, were below the GV-High values (Table 4-1, Figure 4-15). Nickel concentrations across the remaining sites were slightly below the ANZG (2018) DGV (Table 4-1, Figure 4-15).

Concentrations of other total metals (aluminium, arsenic, barium, cobalt, copper, iron, manganese, lead, zinc and mercury) in sediments at Chandon DC-1 were slightly higher compared to the other sites (Table 4-1, Figure 4-15). Slightly higher metal concentrations at Chandon DC-1 may be linked to the higher content of clay-sized fraction sediments (see Section 4.4.3). It is also possible that these higher concentrations of metals are linked to sample contamination during the collection of or sub-sampling of cores (see Section 4.4.5), as the sample location is far beyond any industrial infrastructure and operational areas. Site WTR DC-1 also had notably and consistently lower concentrations for all metals (Table 4-1, Figure 4-15).

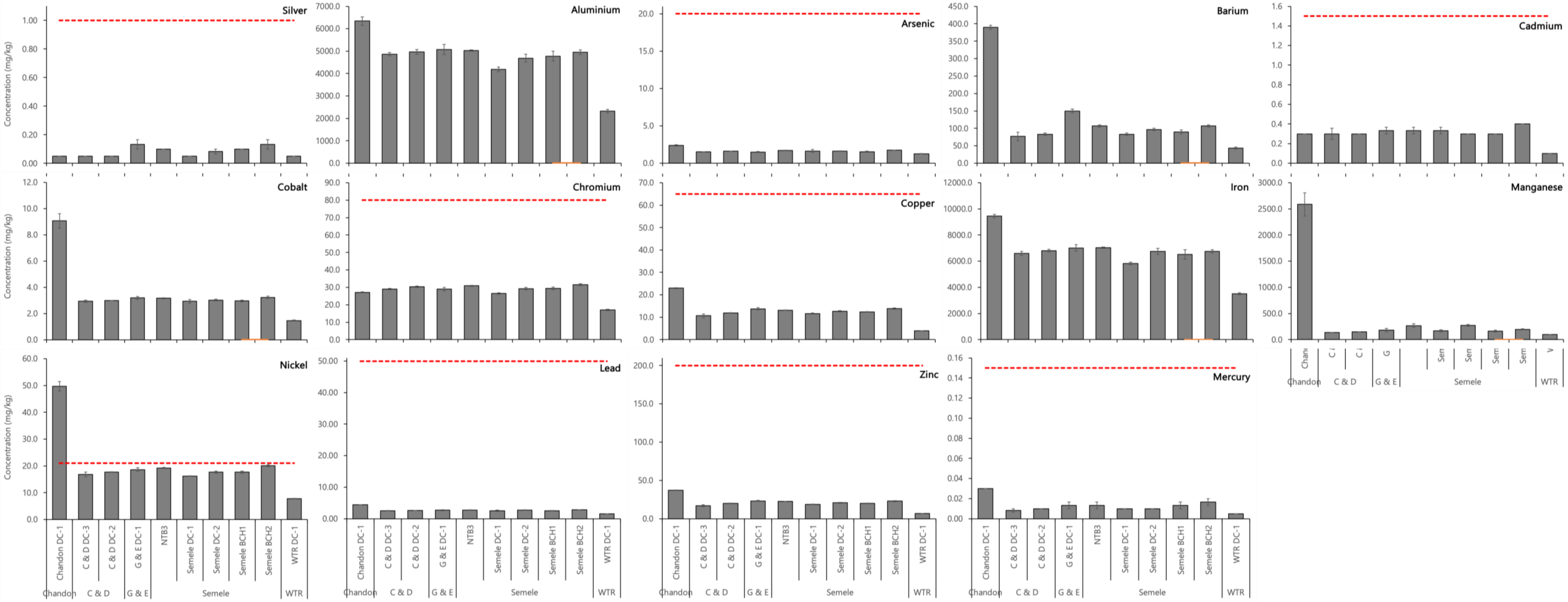
Concentrations of mercury were not detected in any replicate sediment samples collected at C & D DC-3, WTR DC-1, and WTR DC-2. Concentrations of silver were also absent in replicate sediment samples collected at Chandon DC-1, C & D DC-3, C & D DC-2, Semele DC-1 and WTR DC-1 (Table 4-1, Figure 4-15).

With the exception of elevated concentrations of some metals in sediments at Chandon DC-1 and the consistently lower concentrations of all metals at WTR DC-1 likely attributed to the particle size distributions found in each survey site (see Section 4.4.3), there were no other discernible trends in for metal concentrations across the sites.

Table 4-1 Total metal concentrations (mean ± SE) in sediment samples

Field and Site Name	Parameter (mg/kg)	Silver	Aluminium	Arsenic	Barium	Cadmium	Cobalt	Chromium	Copper	Iron	Manganese	Nickel	Lead	Zinc	Mercury
	LOR	0.1	50	1.0	10	0.1	0.5	1.0	1.0	50	10	1.0	1.0	1.0	0.01
	DGV[1]	1	–	20	–	1.5	–	80	65	–	–	21	50	200	0.15
	GV-High[1]	4	–	70	–	10	–	370	270	–	–	52	220	410	1.0
Chandon	Chandon DC-1	<0.1 ± 0.00	6346.7 ± 186.7	2.39 ± 0.08	390 ± 5.77	0.30 ± 0.00	9.07 ± 0.55	27.2 ± 0.27	23.0 ± 0.26	9440 ± 134.5	2586.7 ± 220.6	**49.7 ± 1.80**	4.40 ± 0.00	37.1 ± 0.49	0.03 ± 0.00
Chrysaor and Dionysus	C & D DC-3	<0.1 ± 0.00	4863.3 ± 79.7	1.53 ± 0.01	76.7 ± 12.0	0.30 ± 0.06	2.93 ± 0.09	29.0 ± 0.34	10.6 ± 0.79	6596.7 ± 143.1	134.0 ± 4.51	16.8 ± 0.92	2.57 ± 0.03	17.1 ± 1.35	0.01 ± 0.00
	C & D DC-2	<0.1 ± 0.00	4963.3 ± 104.0	1.60 ± 0.02	83.3 ± 3.33	0.30 ± 0.00	3.00 ± 0.00	30.3 ± 0.50	11.9 ± 0.10	6810 ± 100.2	148.0 ± 4.58	17.7 ± 0.10	2.60 ± 0.00	20.0 ± 0.33	0.01 ± 0.00
Geryon and Eurytion	G & E DC-1	0.13 ± 0.03	5073.3 ± 230.7	1.49 ± 0.07	150 ± 5.77	0.33 ± 0.03	3.20 ± 0.12	29.0 ± 1.05	13.8 ± 0.52	7020 ± 244.4	181.3 ± 32.6	18.6 ± 0.73	2.70 ± 0.15	23.3 ± 0.84	0.01 ± 0.00
Semele	NTB3	0.10 ± 0.00	5033.3 ± 29.6	1.71 ± 0.03	106.7 ± 3.33	0.33 ± 0.03	3.17 ± 0.03	30.9 ± 0.26	13.1 ± 0.09	7033.3 ± 48.4	267.7 ± 36.1	19.2 ± 0.19	2.77 ± 0.09	22.5 ± 0.21	0.01 ± 0.00
	Semele DC-1	<0.1 ± 0.00	4183.3 ± 105.9	1.64 ± 0.19	83.3 ± 3.33	0.33 ± 0.03	2.93 ± 0.13	26.5 ± 0.45	11.7 ± 0.22	5833.3 ± 104.8	171.3 ± 18.8	16.2 ± 0.09	2.53 ± 0.19	18.9 ± 0.37	0.01 ± 0.00
	Semele DC-2	0.08 ± 0.02	4686.7 ± 170.5	1.62 ± 0.06	96.7 ± 3.33	0.30 ± 0.00	3.03 ± 0.07	29.2 ± 0.69	12.6 ± 0.35	6753.3 ± 240.3	272.3 ± 19.9	17.6 ± 0.44	2.73 ± 0.07	20.9 ± 0.64	0.01 ± 0.00
	Semele BCH1	0.10 ± 0.00	4773.3 ± 218.4	1.55 ± 0.06	90.0 ± 5.77	0.30 ± 0.00	2.97 ± 0.07	29.4 ± 0.74	12.3 ± 0.15	6506.7 ± 359.6	160.7 ± 19.3	17.7 ± 0.42	2.53 ± 0.13	20.2 ± 0.40	0.01 ± 0.00
	Semele BCH2	0.13 ± 0.03	4953.3 ± 109.7	1.74 ± 0.01	106.7 ± 3.33	0.40 ± 0.00	3.23 ± 0.09	31.6 ± 0.54	13.9 ± 0.32	6746.7 ± 122.5	197.7 ± 11.7	20.0 ± 0.38	2.83 ± 0.03	23.0 ± 0.50	0.02 ± 0.00
WTR	WTR DC-1	<0.1 ± 0.00	2326.7 ± 76.9	1.28 ± 0.01	43.3 ± 3.33	0.10 ± 0.00	1.47 ± 0.03	17.0 ± 0.33	3.9 ± 0.06	3506.7 ± 69.4	98.3 ± 31.76	7.8 ± 0.18	1.57 ± 0.03	6.8 ± 0.06	<0.01 ± 0.00

Notes:
1. DGV and GV-High values derived from ANZG (2018)
2. For ease of identification, concentrations above the DVG (ANZG, 2018) are shown in **bold**
3. All metal data are the average of three replicate sediment samples
4. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus, DC = drill centre, DGV = default guideline value, G & E = Geryon and Eurytion, GV-High = guideline value high, LOR = limit of reporting, WTR = West Tryal Rocks



Notes:

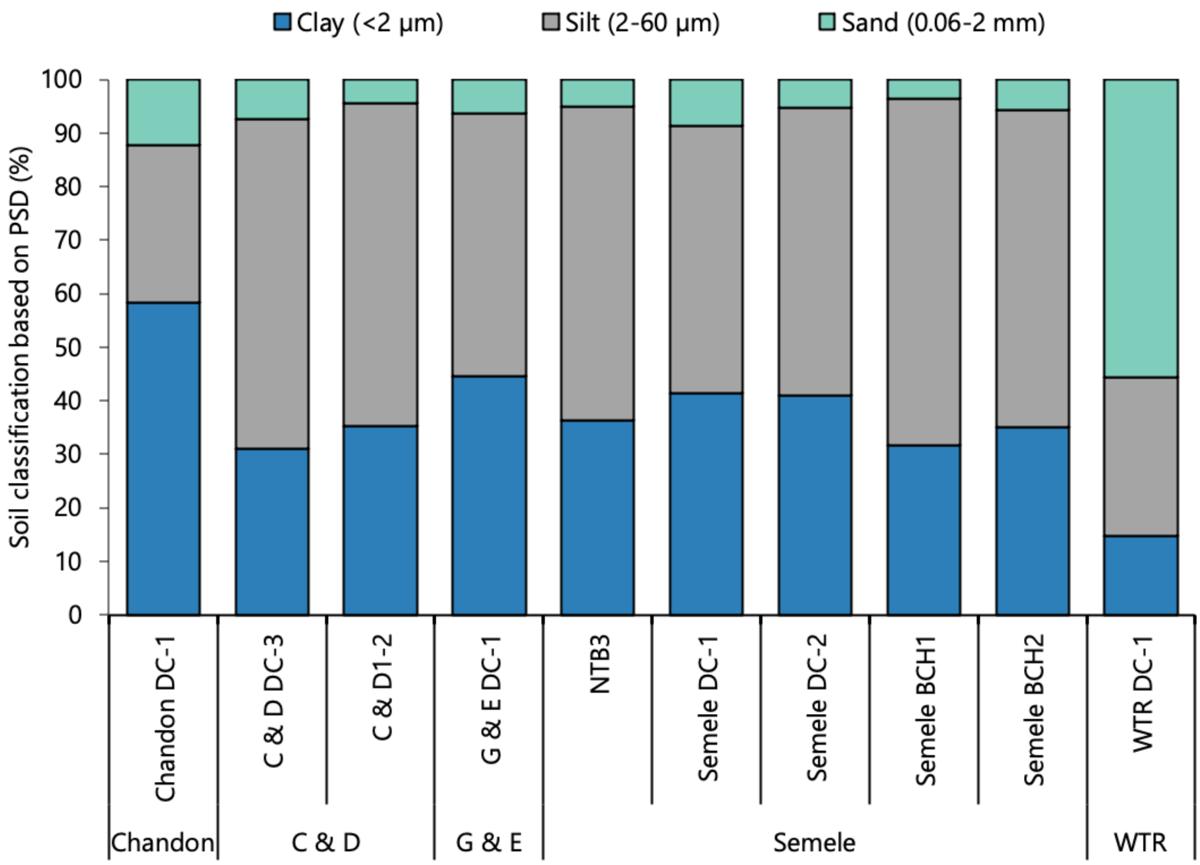
1. If results were below the LOR, half the LOR was used for graphing purposes
2. Red dashed line denotes the ANZG (2018) DGV value; no ANZG (2018) DGV value exists for aluminium, barium, cobalt, iron and manganese
3. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus fields, DC = drill centre, G & E = Geryon and Eurytion fields, WTR = West Tryal Rocks

Figure 4-15 Total metal concentrations (mean ± SE) in sediment samples

4.4.3 Particle Size Distribution

Sediment samples were comprised of well-sorted silts and clay, brown in colour, odourless and with occasional small (>2 mm) shell fragments. No anoxic layer was present in any of the samples. There was no visible biota or vegetation recovered from these samples.

All samples were predominantly comprised of clays (<2 µm), silts (2–60 µm) and sands (0.06–2 mm) (Figure 4-16). All sites with the exception of WTR DC-1 and Chandon DC-1, were dominated by silt fraction ranging from 29 to 65%, while clay-sized fractions ranged from 31 to 58% (Figure 4-16). Sediments at WTR DC-1 were dominated by sand (56%) and clay (58%) was the dominant sediment fraction at Chandon DC-1, whereas all other sites comprised of <13% sand (Figure 4-16).



Note:
1. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus fields, DC = drill centre, G & E = Geryon and Eurytion fields, PSD = particle size distribution, WTR = West Tryal Rocks

Figure 4-16 Sediment particle size distribution across the Gorgon Backfill Fields project sites

4.4.4 Other Parameters

There is no ANZG (2018) guideline value for TOC in sediments. TOC concentrations were low, ranging from 0.51 to 1.36% (Table 4-2). Higher TOC concentrations were detected at C & D DC-2, G & E DC-1, and sites within the Semele field, while sediments at WTR DC-1 had lower TOC content (Table 4-2).

Lower TOC concentrations in sediments at WTR DC-1 may be attributed to the higher sand content (refer to Section 4.4.3).

Moisture content of sediment samples was generally consistent across the sites, ranging from 40.5 to 61.3% (Table 4-2).

Table 4-2 Sediment total organic carbon and moisture content across the Gorgon Backfill Fields project sites

Field and Site Name	Parameter (mg/kg)	TOC (%)	Moisture (%)
	LOR	–	–
	DGV	–	–
	GV-High	–	–
Chandon	Chandon DC-1	0.81 ± 0.08	61.3 ± 0.52
Chrysaor and Dionysus	C & D DC-3	1.10 ± 0.01	55.4 ± 1.03
	C & D DC-2	1.36 ± 0.20	56.3 ± 0.69
Geryon and Eurytion	G & E DC-1	1.24 ± 0.05	57.5 ± 1.18
Semele	NTB3	1.26 ± 0.03	58.7 ± 0.32
	Semele DC-1	1.30 ± 0.08	58.0 ± 1.05
	Semele DC-2	1.27 ± 0.08	59.0 ± 0.20
	Semele BCH1	1.34 ± 0.05	57.7 ± 0.57
	Semele BCH2	1.23 ± 0.04	61.1 ± 0.25
WTR	WTR DC-1	0.51 ± 0.01	40.5 ± 0.84

Notes:
1. DGV = Default guideline value, GV-High = guideline value high, LOR = limit of reporting, TOC = total organic carbon
2. C & D = Chrysaor and Dionysus fields, DC = drill centre, G & E = Geryon and Eurytion fields, WTR = West Tryal Rocks

4.4.5 Quality Assurance and Quality Control Assessment

Intra-laboratory duplicates analysed for metals and moisture content were within acceptable limits of their assigned RPD (30%), indicating that the sediment samples were relatively homogeneous and/or small to no differences in laboratory methods for sample preparation and analysis. Intra-laboratory triplicates analysed for metals were within their RSD with the exception of cadmium that exceeded its assigned RSD. Variability between triplicate samples may be caused by heterogeneity between samples and/or differences in laboratory methods for sample preparation and analysis. The concentrations of cadmium in sediments should be noted as uncertain rather than precise measurements. A breakdown of the QA/QC assessment for sediment samples is provided in Appendix I.

Concentrations of hydrocarbons (TRH and BTEX) in the sediment field blanks were below the laboratory LOR suggesting there was no contamination during the sediment sampling process.

The results of laboratory quality control testing of sediment samples (method blanks, laboratory duplicates, laboratory control samples, and matrix spikes) are presented in Appendix F.

4.5 Benthic Infauna

A total of five individual benthic infauna belonging to three families across three phyla (Sipuncula, Annelida and Mollusca) were collected from all the sediment sites (Table 3-8). Semele DC-1 and Semele DC-2 had one and two individual Sipunculids or marine worms, respectively, while Semele BCH1 had one individual mollusc (Aplacophora family). One polychaete worm (Annelida) was identified in WTR DC-1.

The benthic infauna laboratory results provided by Benthic Australia are included in Appendix J.

4.6 Water Chemistry

Laboratory reports for water samples are presented in Appendix H.

4.6.1 Hydrocarbons

Concentrations of hydrocarbons (TRH, BTEX and PAHs) in all water samples were all below the laboratory LOR.

4.6.2 Metals

Concentrations of all dissolved metals in water samples met their relevant ANZG (2018) DGVs for 99% species protection[3], with the exception of copper and cobalt (Table 4-3, Figure 4-17). Dissolved copper was at the 99% DGV of 0.3 µg/L for either one or both replicate samples from the surface at BCH38 and WTR DC-1 and from near the seabed at NTB3, whereas dissolved copper exceeded the DGV in both replicate samples collected from the surface at Chandon DC-1 and Gorgon GMT (Table 4-3). All samples were below the 95% species protection guideline value of 1.3 µg/L. It is possible that there may have been a copper source from the vessel during the sampling process that led to the contamination of the samples, particularly those collected from surface waters.

Dissolved cobalt concentrations in one replicate water sample near the seabed at Gorgon GMT exceeded the 99% DGV of 0.05 µg/L (Table 4-3). Furthermore, one surface sample at Gorgon GMT had higher total lead concentrations than other sites; however, these exceedances may be due to contamination during the sampling process, as the remaining samples at these sites have low or below laboratory LOR concentrations.

Concentrations for dissolved and/or total aluminium, arsenic, barium, iron, manganese, nickel, lead and zinc were detected in either surface and/or near seabed water samples (Figure 4-18), while cadmium, silver and chromium VI concentrations in surface and seabed water samples were all below laboratory LOR.

Dissolved and total barium concentrations were notably higher in water samples near the seabed at all of the deeper sites (all sites with the exception of WTR DC-1 and Gorgon GMT; see Table 3-5 for depths). There were no other discernible trends observed for dissolved nor total metal concentrations across the sites.

[3] There are no ANZG (2018) 99% default guideline values for aluminium, arsenic, barium, iron and manganese.

Table 4-3 Dissolved and total mean concentrations in water samples

Field and Site Name		Parameter (µg/L)	Silver	Aluminium	Arsenic	Barium	Cadmium	Cobalt	Copper	Iron	Manganese	Nickel	Lead	Zinc	Chromium III	Chromium VI
		LOR	0.1	5.0	0.5	1.0	0.2	0.05	0.2	5.0	0.5	0.5	0.2	5.0	0.001	0.001
		DGV 99%	0.8	–	–	–	0.7	0.05	0.3	–	–	7.0	2.2	7.0	7.7	0.14
Chandon	Jansz JMT	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.65 (1.75)	5.0 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.25 (0.35)	5.3 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed*	<0.1 (<0.1)	<5.0 (<5.0)	1.70 (1.90)	13.0 (13.0)	<0.2 (<0.2)	<0.05 (<0.05)	<0.2 (0.3)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
	Chandon DC-1	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.65 (1.80)	5.0 (6.0)	<0.2 (<0.2)	<0.05 (<0.05)	**0.95** (0.85)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (5.75)	1.80 (1.80)	13.0 (12.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.15 (0.2)	<5.0 (<5.0)	0.48 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
Chrysaor and Dionysus	C & D DC-3	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.80 (1.90)	4.0 (6.5)	<0.2 (<0.2)	<0.05 (<0.05)	<0.2 (<0.2)	<5.0 (<5.0)	<0.5 (<0.5)	1.58 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (4.8)	2.00 (1.90)	9.0 (14.5)	<0.2 (<0.2)	<0.05 (<0.05)	<0.2 (<0.2)	<5.0 (10.3)	<0.5 (<0.5)	0.68 (0.88)	<0.2 (0.25)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
Geryon and Eurytion	G & E DC-1	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.70 (1.70)	5.0 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.2 (0.3)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (<5.0)	1.80 (1.80)	12.5 (13.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.15 (0.15)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	0.3 (0.3)	4.25 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
	BCH28	Surface	<0.1 (<0.1)	<5.0 (4.3)	1.55 (1.65)	5.0 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.3 (0.25)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (4.3)	1.70 (1.85)	13.0 (13.0)	<0.2 (<0.2)	<0.05 (<0.05)	<0.2 (<0.2)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	0.15 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
Semele	NTB3	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.75 (1.70)	4.5 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.25 (0.2)	4.8 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (<5.0)	1.90 (1.80)	12.0 (12.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.3 (0.15)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (0.48)	0.35 (0.15)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
WTR	WTR DC-1	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.90 (1.85)	4.5 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	0.3 (0.5)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (<5.0)	1.85 (1.85)	5.0 (4.5)	<0.2 (<0.2)	<0.05 (<0.05)	<0.2 (<0.2)	<5.0 (4.8)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (0.15)	3.75 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
	Gorgon GMT	Surface	<0.1 (<0.1)	<5.0 (<5.0)	1.90 (1.90)	4.5 (5.0)	<0.2 (<0.2)	<0.05 (<0.05)	**1.0** (0.75)	<5.0 (<5.0)	<0.5 (<0.5)	<0.5 (<0.5)	<0.2 (3.75)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)
		Seabed	<0.1 (<0.1)	<5.0 (<5.0)	1.95 (1.90)	4.0 (4.5)	<0.2 (<0.2)	**0.0625** (0.0625)	<0.2 (<0.2)	<5.0 (<5.0)	<0.5 (1.00)	<0.5 (<0.5)	<0.2 (<0.2)	<5.0 (<5.0)	<0.001 (<0.001)	<0.001 (<0.001)

Notes:
1. Results indicated are the dissolved and (total) values
2. DGV for 99% species protection values derived from ANZG (2018)
3. For ease of identification, concentrations for dissolved metals above the DGV 99% species protection are shown in **bold**
4. All data are the average of two replicate samples
5. Asterisk (*) denotes that only one water sample near seabed was collected
6. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus, DC = drill centre, DGV = default guideline value, G & E = Geryon and Eurytion, LOR = limit of reporting, WTR = West Tryal Rocks

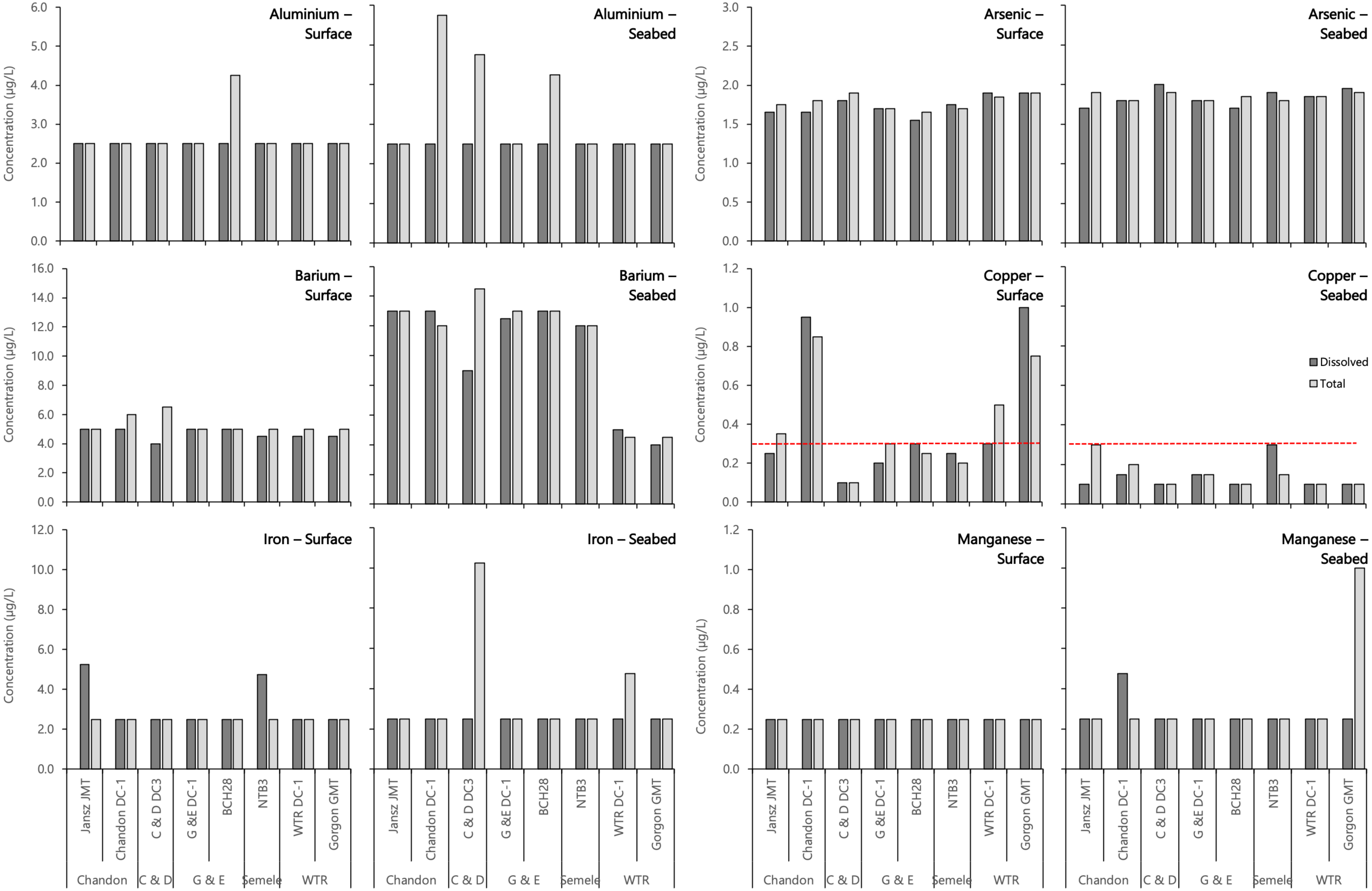


Figure 4-17 Dissolved (dark grey) and total (light grey) metal concentrations in water samples across the Gorgon Backfill Fields project sites. Red dashed line denotes the ANZG (2018) default guideline values 99% species protection

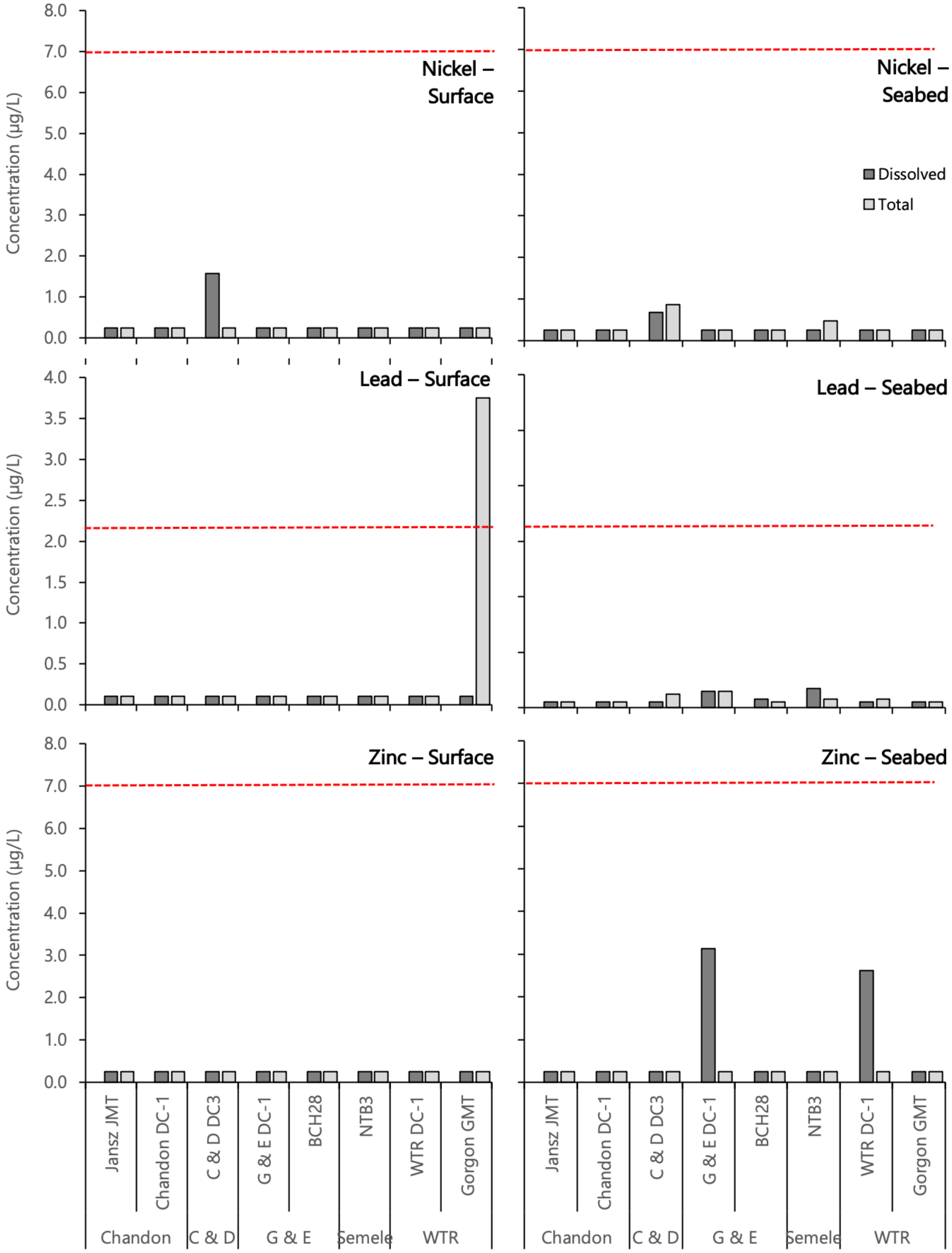


Figure 4-18 Dissolved (dark grey) and total (light grey) metal concentrations in water samples across the Gorgon Backfill Fields project sites. Red dashed line denotes the ANZG (2018) default guideline values 99% species protection

4.6.3 Other Parameters

Average DOC and TOC concentrations ranged from 0.5 to 2.0 mg/L and 0.5 to 2.0 mg/L, respectively. Average DOC concentrations were between 1.5 and 2.5-fold higher in surface waters compared to water samples collected from near the seabed at Jansz JMT, Chandon DC-1, C & D DC-3 and NTB3. Concentrations of TOC were on average higher in surface waters than near the seabed at Chandon DC-1 and C & D DC-3, whereas TOC concentrations were higher near the seabed at shallower sites WTR DC-1 and Gorgon GMT (100–200 m depth).

TDS ranged from 37,000 to 39,900 mg/L from surface and seabed samples across all sampling sites (Table 4-4). Across most sites (with the exception of Jansz JMT, Chandon DC-1 and Gorgon GMT), average TDS concentration were slightly higher in surface waters. TP and TN in surface and seabed water samples ranged 0.01 to 0.12 mg/kg, and 0.10 to 0.75 mg/kg, respectively (Table 4-4). At all sites, water samples near the seabed had higher mean TP concentrations (between 1.2 to 10-fold) compared to surface samples. A similar trend to TP concentration was observed for mean TN concentrations, whereby TN concentration were between 2 to 3-fold higher in water samples near the seabed compared to surface samples at all sites except for sites within the WTR field.

Table 4-4 Other parameter concentrations in water samples

Field and Site Name		Parameter (mg/L)	DOC	TOC	TDS	TP	TN
		LOR	–	–	–	–	–
		DGV 99%	–	–	–	–	–
Chandon	Jansz JMT	Surface	1.50	0.50	38,500	0.06	0.25
		Seabed*	0.50	0.50	38,700	0.10	0.70
	Chandon DC-1	Surface	1.50	1.00	38,000	0.01	0.25
		Seabed	0.50	0.75	38,600	0.11	0.75
Chrysaor and Dionysus	C & D DC-3	Surface	2.00	2.00	39,150	0.03	0.35
		Seabed	0.75	1.00	39,100	0.09	0.70
Geryon and Eurytion	G & E DC-1	Surface	0.50	0.50	38,350	0.02	0.25
		Seabed	0.50	0.50	38,050	0.09	0.70
	BCH28	Surface	1.00	0.50	39,050	0.01	0.25
		Seabed	1.00	0.50	38,850	0.09	0.70
Semele	NTB3	Surface	0.75	0.50	38,300	0.02	0.20
		Seabed	0.50	0.50	37,000	0.12	0.70
WTR	WTR DC-1	Surface	1.50	1.00	39,650	0.04	0.30
		Seabed	2.00	2.00	39,200	0.05	0.25
	Gorgon GMT	Surface	1.50	1.50	38,750	0.01	0.25

Field and Site Name		Parameter (mg/L)	DOC	TOC	TDS	TP	TN
		LOR	–	–	–	–	–
		DGV 99%	–	–	–	–	–
		Seabed	1.50	2.00	39,900	0.03	0.10

Notes:
1. All data are the average of two replicate samples
2. Asterisk (*) denotes that only one water sample near seabed was collected
3. C & D = Chrysaor and Dionysus, DC = drill centre, DGV = default guideline value, DOC = dissolved organic carbon, G & E = Geryon and Eurytion, LOR = limit of reporting, TDS = total dissolved solids, TN = total nitrogen, TOC = total organic carbon, TP = total phosphorus, WTR = West Tryal Rocks

4.6.4 Quality Assurance and Quality Control Assessment

Intra-laboratory duplicates analysed for metals and moisture content were within their assigned RPD of 30% for all samples with the exception of total manganese in Gorgon GMT near the seabed that exceeded its RPD (31.5%). Variability between duplicates can be caused by heterogeneity between splits and/or differences in laboratory methods for sample preparation and analysis. As such, the concentrations for manganese in seabed water samples should be recognised as uncertain rather than precise measurements. A breakdown of the QAQC assessment for samples is provided in Appendix I.

Blank water samples collected from the Niskin bottles contained measurable concentrations of TDS, dissolved barium, copper, manganese and zinc, total aluminium, barium, copper, iron, manganese, lead and zinc, DOC, TOC, TRHs (all fractions) and BTEX (except for benzene and ethylbenzene). The concentrations of these parameters suggest the likelihood of contamination during the water sampling process and as such, these parameters at site WTR DC-1 should be recognised as uncertain rather than precise measurements.

The results of laboratory quality control testing of water samples (method blanks, laboratory duplicates, laboratory control samples, and matrix spikes) are presented in Appendix H.

4.7 Water Quality Profiles

Depth profiles of each transect site recorded by the ROV are presented in Appendix K.

Warmer temperatures were seen in the top 50 m of water across all sampling sites, ranging from 27.7°C to 29.2°C, and gradually decreased in temperature with increasing depth (Figure 4-19). Water temperatures dropped to minimum of ~3.9–4.2°C in depths ~1,350 m (Figure 4-19).

Salinity was relatively consistent with depth, ranging from 32.3 to 36.3 PSU (Figure 4-19). Conductivity showed a similar trend to temperature, in which conductivity ranged from 52.9 to 57.4 mS/cm between the surface and 50 m, and gradually declined with depth, reaching a minimum of ~33.1 mS/cm at ~1,350 m (Figure 4-19).

For the temperature-salinity plots, the water quality profiles for the deepest site at each field indicated that the ocean environment around the sampling sites are relatively consistent across the GBF project area and are typical for the region. Across the five fields (Chandon, C & D, G & E, Semele and WTR), three separate water masses can be identified in Figure 4-20:

- Low salinity surface water ranging from 34.6–35.3 PSU with a temperature range of ~18–28°C; upper ~180 m of water column
- Higher salinity mid-waters with a salinity and temperature range of 35.4–36 PSU and 15–20°C, respectively; centred between 185 and 250 m depth
- Lower salinity bottom waters with a salinity and temperature range of 34.7–35.4 PSU ~3.5–15°C, respectively; between 250 to ~1,310 m depth.

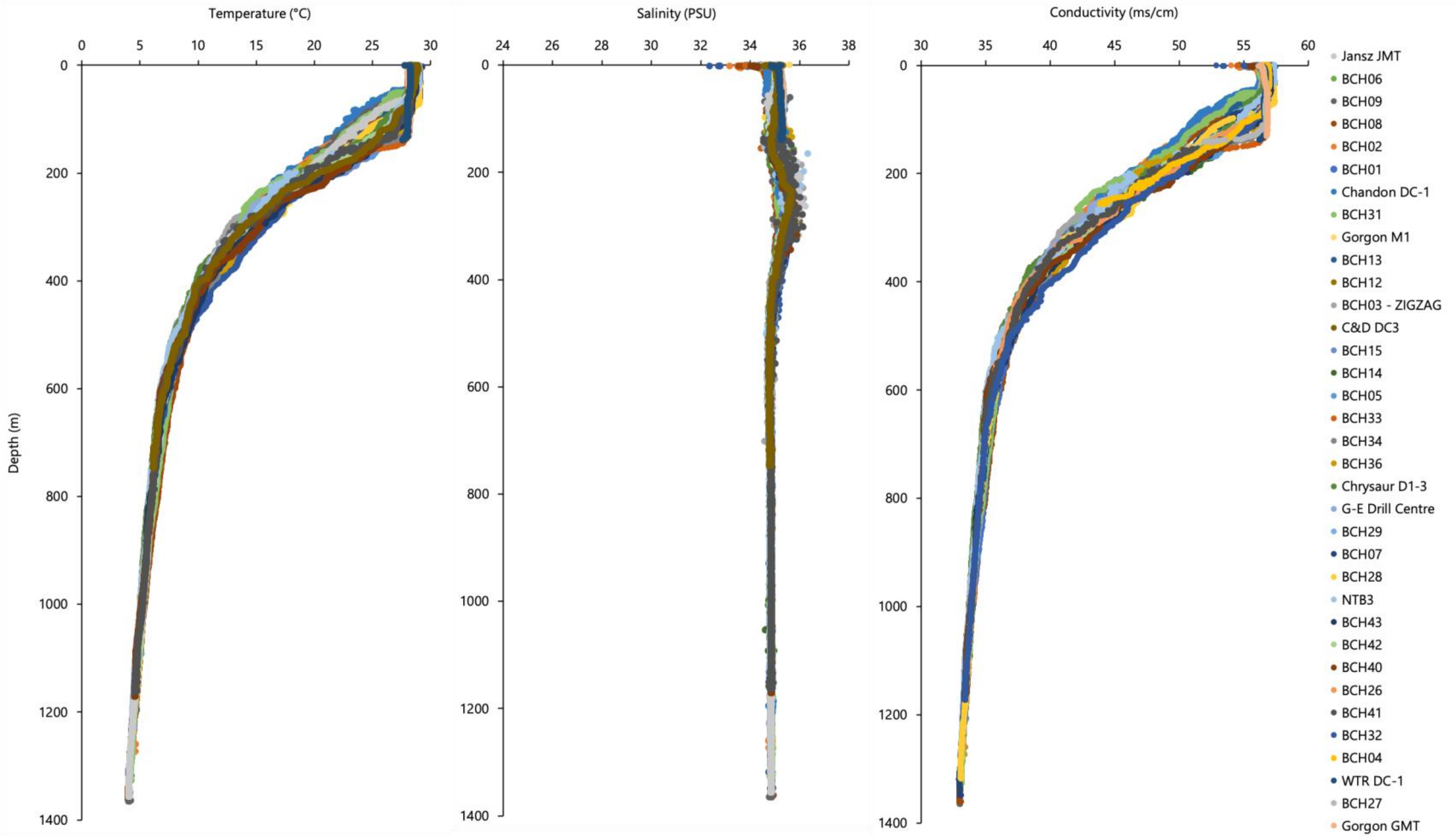
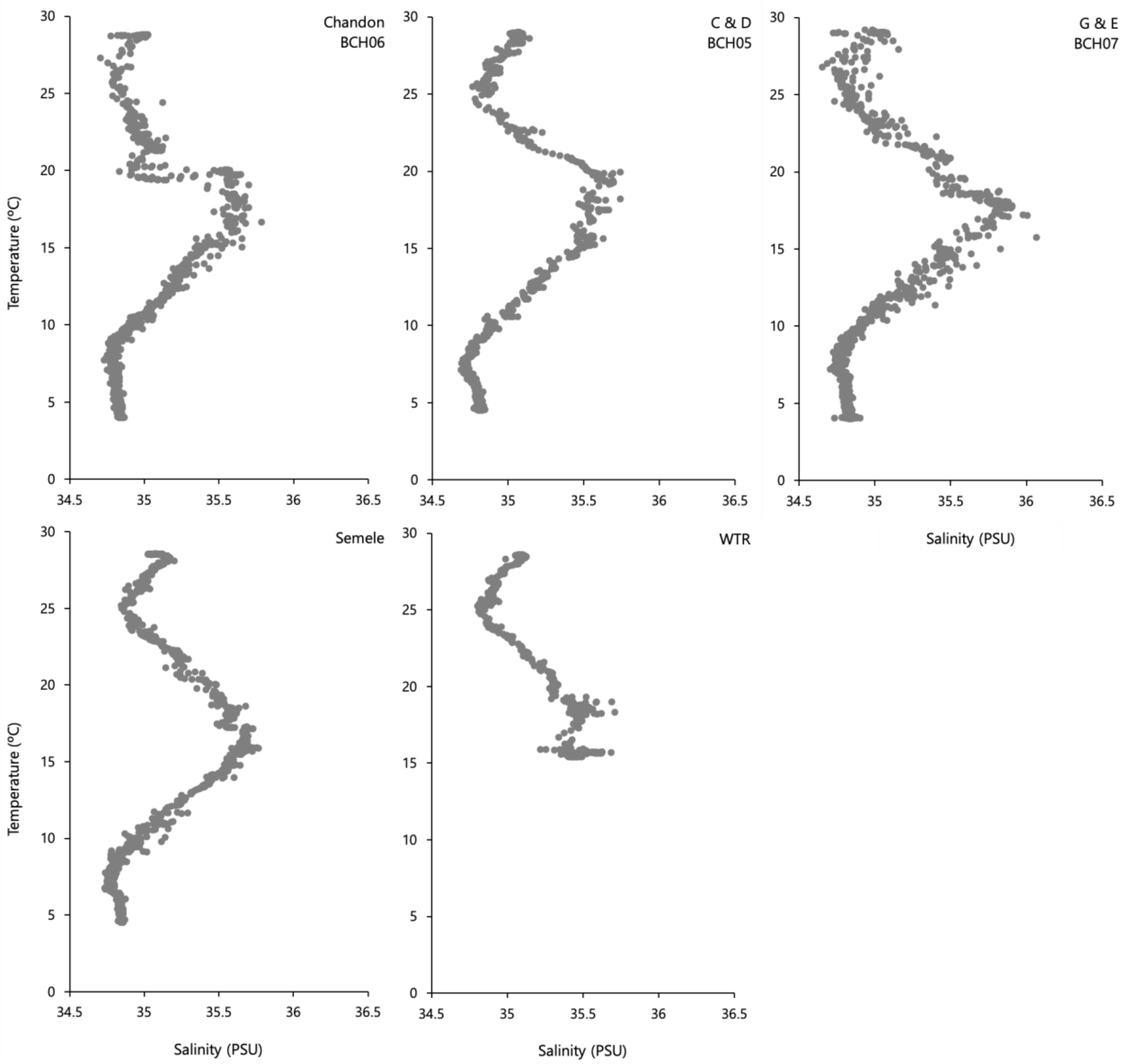


Figure 4-19 Water quality profiles at all sampling sites within the Gorgon Backfill Fields project area



Note:

1. BCH = Benthic communities and habitat, C & D = Chrysaor and Dionysus, G & E = Geryon and Eurytion, PSU = practical salinity unit, WTR = West Tryal Rocks

Figure 4-20 Temperature-salinity measured at the deepest sites at each field (Chandon, Chrysaor and Dionysus, Geryon and Eurytion, Semele, and WTR)

5 Discussion and Conclusion

To inform the OPP and support future environmental approvals for the development of several new fields in the GBF, Advisian were commissioned by CAPL to characterise the marine benthic environment within the GBF project area. Specifically, the objectives of this study were to develop a validated benthic habitat map of the project area based on assessment of geomorphic features and BCH, describe the demersal fish assemblages associated with areas of interest, and to broadly characterise the water and sediment quality of the GBF project area.

5.1 Benthic Habitat Mapping

There was a strong positive correlation between the preliminary and final benthic habitat maps following the ground-truthing survey, meaning that the available geophysical data (SSS, MBES and 3D seismic) allowed for a good interpretation of the key benthic and geomorphic features of the seabed across the wider area without further ground-truthing effort.

The GBF project area, which is a 5 km radius from proposed or indicative subsea infrastructure, sits along the continental slope located between the continental shelf and the abyssal plain/deep ocean floor in the Exmouth Plateau in water depths ranging from 100 to 1,300 m (Heap et al., 2005; Falkner et al., 2009). Overall, the distribution of benthic habitat within the GBF project area comprises mostly a mixture of flat sediment terrain with bioturbation or bare sediment, and isolated areas of high structural complexity, typical of the Northern Carnarvon Basin (Falkner et al., 2009; Geoscience Australia, 2022). The mapped benthic habitats were representative of known regional and local habitats and no new benthic habitats or communities to the bioregion were observed.

The benthic habitat in shallower waters (<200 m) within and surrounding Gorgon GMT consisted of mostly smooth seabed with bioturbation and no epibenthic biota observed. Located within the Ancient Coastline KEF, the region is identified as having unique seafloor features comprising areas of hard substrate that may provide areas for higher diversity and enrich species richness compared to soft sediment areas (DSEWPaC, 2012; DCCEEW, 2022). However, at the Gorgon GMT survey site, minimal topographic seabed features (e.g., consolidated substrate) were observed (Puotinen and Currey-Randall, 2020; Currey-Randall et al., 2021), which may indicate a layer of soft substrate over consolidated hard substrate that is unlikely to provide significant habitat to biota. Furthermore, the positioning of existing Gorgon GMT facilities on which this survey site boundary was based, would have likely targeted seabed areas of low structural complexity.

Between 200 m and 1000 m depths within the Continental Slope Demersal Fish Communities KEF, a diversity of benthic habitats were present along the seabed, including irregular and smooth seabed, depressions, reef mosaics and discrete fault scarps. The topographically complex scarps that traverse through the GBF project area are indicative of extensive canyon systems (Geoconsult, 2005; Advisian, 2019) formed by the gradual erosion of the continental slope. These scarps which are adjacent to the proposed C & D DC-3 drill centre and sections along its associated flowline routes to Gorgon M1, hosts typical deep-sea benthic biota. These biota were sparsely distributed and limited to isolated individual biota including sponges, echinoderms and cnidarians, which resemble benthic compositions previously found along continental slope seabed habitats at depths of 700–1,000 m (Heyward et al., 2001; Williams et al., 2010; Advisian, 2019).

The benthic habitat along the Chandon to JMT and Jansz DC2 to G & E DC-1 corridors, which are situated between 1,000 m and 1,400 m in low slope areas, consisted primarily of relatively flat terrain.

Isolated fault scarps with bare substrates are present around the proposed NTB3 drill centre and its associated flowline routes heading north (to benthic transects near Semele and G & E DC-1). It is probable that these scarps are steep and affect deep sea currents, transport of marine propagules and water temperatures, which in turn determine the composition of marine biotic assemblages present. Unlike the scarps within the Continental Slope Demersal Fish Communities KEF which have shown to provide high structural complexity in shallower (200–1000 m) waters, scarps in deeper waters may not provide suitable habitat for marine biota including invertebrates.

In deeper waters (1,200–1,300 m) within the Exmouth Plateau KEF, two large fault scarps ~7 km and ~11 km from Chandon DC-1 are positioned west to east and cross through the indicative flowline route. These scarps however, are devoid of epibenthic fauna as observed in the ground-truthing videos. The remaining benthic habitats were relatively uniform and dominated by irregular seabed with bioturbation or bare substrate and have a low likelihood of providing epibiota with significant habitat. Similar to the low slope areas, deep water areas of complex bathymetry appear to support sparse to no biota (Advisian, 2019). It is probable that the spatial distribution of benthic biota across different benthic habitats depends on several factors such as water temperature, sediment characteristics, food availability, depth, and the nature of the underlying substrate. Furthermore, the seabed sediments are likely to host benthic infauna such as polychaetes, however, larger sediment grab samples instead of cores are required to verify their presence (e.g., Gardline, 2009; Section 5.5) given that no benthic infauna were collected within the Exmouth Plateau KEF during this survey.

5.2 Benthic Cover

Based on the distribution of benthic habitats mapped and the percent cover of benthic habitats in each proposed drill centre and tie-in locations and 2 benthic habitat transects, bare sediment (soft unconsolidated sand/mud) with no biota was the dominant benthic category with greatest benthic cover. These results are comparable to previous studies of the Exmouth Plateau (Falkner et al., 2009), Continental Slope Demersal Fish Communities (DSEWPaC, 2012) and Ancient Coastline (Currey-Randall et al., 2021) that identified soft sediments (sand and mud/silt) as the dominant substrate type in deeper waters with less than 15% benthos cover and <1% cover of boulder/rock reef substrate.

Of the 12 sites examined that consists of proposed drill centres and tie-in locations and 2 benthic habitat transects, the only biota present were cnidarians (over bioturbated sediments) that were detected at Gorgon M1, albeit at a very low percent cover. The presence of biota may suggest that unconsolidated soft sand/mud may only be present as a veneer over the top of consolidated hard substrate. Furthermore, some sites (Jansz JMT, Jansz DC-2, Semele DC-1 and Semele DC-2) showed more structurally complex habitat, including occasional boulders over bare sediment. Although higher or rougher topographic features were not identified in any of the captured still images, habitat mapping of C & D DC-3 and NTB3 proposed drill centres suggests that consolidated and steep scarps are present and may support benthic communities.

5.3 Fish Assemblage

Distinct fish and crustacean assemblages were found across the GBF project area which were strongly influenced by water depth. Shallower and warmer sites located in the TSW mass within the Ancient Coastline KEF had a greater number of fish recorded than other sites, with a mean of 3000 fish per transect in the Ancient Coastline KEF and 1700 fish per transect across all sites in the TSW mass. These shallower sites were characterised by sharks and Carangidae such as *Trachurus novaezelandiae* (yellowtail scad). The fish assemblages of the deeper continental slope were mostly dominated by

Carangidae, Macrouridae (rat tails), Halosauridae (halosaurs) and unidentified anguilliform (eel-like) fishes. This zone was characterised by the SICW mass and included the slope geomorphic feature and the Continental Slope Demersal Fish Communities KEF. Although there were large differences in the number of fish observed across the GBF project area among water masses, KEFs and geomorphic features, the average diversity of fishes remained consistent across the sites. Furthermore, while the deeper sites had lower numbers of fishes, the number of fish taxa was the same as the shallower sites.

The patterns of assemblage composition, abundance and number of taxa identified in both the fish and crustaceans sampled support that there is a different fauna associated with the deeper waters of greater than 800 m depth and the AAIW mass. A similar pattern was suggested by Saunders et al. (2021) and has previously been reported (Last et al., 2009). This change in fauna is likely linked to the AAIW, as the cold deep-water and lower saline current has a strong influence on the distribution of fish communities as seen in the south-west region between the Great Australian Bight and north of the Ningaloo Reef where its core fluctuates with depth from 875 m at 27.50°S to 520 m around 21.50°S (Williams et al., 1996; 2001; Woo & Pattiaratchi, 2008). A recent survey in a similar area covered water depths between 360 and 870 m and identified that a similar faunal break occurred between 700 and 800 m water depth (Saunders et al., 2021). A break between mid-slope and shelf-break fish assemblages at water depths of between 700 and 900 m was also reported by Williams et al. (2001) in the North West Cape.

5.4 Sediment Chemistry

The quality of sediments at proposed drill centre and tie-in locations met the ANZG (2018) environmental guidelines at all sites and for all parameters tested, except for nickel which only exceeded at Chandon DC-1. All other sediment sampling sites also contained detectable concentrations of nickel just below ANZG (2018) DGV. Given that this was a baseline study and no previous activities have occurred in the proposed drill centres and tie-in locations, the detection of nickel across a range of depths (from 100 m at WTR DC-1 to 1300 m at G & E DC-1) is indicative of naturally occurring nickel in sediments.

The presence of nickel may be linked to the sediments' composition (PSD) and organic matter content (Munksgaard and Parry, 2002). The sediments at all sites were mainly composed of clays and silts with TOC concentrations below 1%, suggesting that there has been no enrichment of organic matter in these sediments. However, the high binding capacity of finer-sized particles (clays and silt fractions) will likely result in higher concentrations of naturally occurring nickel in sediments. This is evident in all sediment samples except for sediments in WTR DC-1 which is dominated by sand-size fractions.

The sediments in the Exmouth Plateau are of lithogenic origin consisting of high carbonate content (>55%; McLoughlin and Young, 1985) and largely comprise of sandy mud and muddy sand while larger-size sediment fractions are common in shallower depths along the Northern Carnarvon Basin (Baker et al., 2008). In summary, sediments are generally in a pristine condition, as expected given the absence of anthropogenic activities.

5.5 Benthic Infauna

Despite the limited number of individuals collected, the benthic infauna found were primarily in both deep-sea sediments (1100–1200 m) around proposed drill centres Semele DC-1, Semele DC-2 and Semele BCH1, and shallower seabed (100–200 m) at WTR DC-1. The benthic infauna collected in this study, which included marine worms, a mollusc and polychaete worm, is similar to previous seabed surveys in the north-west shelf region (Heyward et al., 2001; Falkner et al., 2009; Advisian, 2019) whereby polychaetes and crustaceans are the dominant epibenthic and infaunal invertebrates of soft sediment habitats. Although few individuals were collected in this study, other surveys in the North West Shelf region have also recorded a sparse distribution of epifaunal and infaunal benthic biota, with abundances ranging from one to 47 individuals (Heyward et al., 2001; Advisian, 2019).

The sediments around the proposed drill centres were free of hydrocarbons, had low concentrations of metals and TOC content, indicating that these sediments used by the infauna are free of contaminants and there was no evidence of enrichment of organic matter. The quantity and distribution of infauna found in this survey suggests that other factors such as sediment type, depth, temperature and food supply to the benthos (Basford et al., 1990; Künitzer et al., 1992; Levin and Gage, 1998) may be affecting the type and quantity of infauna inhabiting the area. Of the five individuals collected, four of the benthic infauna were found in sediments consisting of high silt and clay content, whereas one individual biota was collected in a shallower area with sediments dominated by sand. It is possible that homogeneous sediments provide less niches and support a lower diversity of benthic infauna than heterogeneous sediment (e.g., Gray, 1974). This survey did not find any endemic benthic infauna.

It is possible that the low number of benthic infauna collected in this survey may also be due to the sampling equipment. Compared to traditional box corers, push corers capture a smaller surface area of seabed that may have missed benthic infaunal communities of low density. Furthermore, it is possible that the standard sieve size of 1 mm (Hook et al., 2016) used may have lost smaller-sized individuals (<1 mm), particularly in deep-ocean sediments where lower organism densities and potentially smaller infauna sizes may occur (Gage et al., 2002).

5.6 Water Chemistry

A range of water quality parameters were collected across a range of sites within the GBF project area to understand background conditions. With the exception of dissolved copper and cobalt, metal and hydrocarbon concentrations in water samples were either below laboratory LORs, or below available 99% species protection DGVs, which is typical of an undisturbed tropical offshore environment.

Copper is a natural and essential trace element required by many marine organisms but in high concentrations is one of the most toxic trace metals in seawater (Mackey, 1984; ANZG, 2018). The natural presence of copper in surface water samples may vary in concentrations over time, in response to physical oceanographic effects such as tide and wind and/or seasonal differences (Wenziker et al., 2006). Copper is also released into the water column during physical and chemical weathering of the underlying geology (OzCoasts, 2013). However, the elevated levels of copper detected in some seawater samples may also suggest an alternative copper source such as wind-blown dust, fossil fuel burns, survey vessel discharges and antifouling paints may have contaminated the samples during the sampling process (Richon & Tagliabue, 2019). It is possible that some contamination occurred during sampling, with anomalous results for cobalt and lead being detected in some samples.

Nutrient concentrations across the GBF project area were consistently low across the sampling sites. Surface waters had lower concentrations of nutrients than bottom waters. These results are consistent with nutrient concentrations reported in previous studies in deep-water environments in the North West Shelf (Holloway et al., 1985; URS, 2007; Gardline, 2009), which are influenced by the Indonesian Throughflow. Given that slightly higher concentrations of nutrients were evident near the seafloor compared to the sea surface, it is likely that there are no physical processes such as upwelling (wave or current-induced) of deeper waters occurring in the region (Mackey, 1984).

5.7 Water Quality Profiles

Water quality profiles were consistent between sites, with a warm and low salinity surface layer (to ~180 m depth) overlying a broad thermocline/subsurface salinity maximum (between 185–250 m depth), followed by the colder, lower salinity waters of the deeper ocean (~250–1,350 m). The CTD data collected within the GBF project area allowed the identification of tropical surface waters corresponding with the southward-flowing Leeuwin Current and the deeper south Indian central water mass along with the subsurface Leeuwin Undercurrent which moves equator-ward along the Western Australian coast at deeper depths. Similar water mass structures have been identified in the Gascoyne region (Woo & Pattiaratchi, 2008; Pattiaratchi & Woo, 2009, BMT Oceanica, 2016). Oceanic processes such as currents in the water column can be used to understand the type and distribution of seabed habitat.

5.8 Conclusion

This survey report details the existing marine benthic environment and geomorphological seabed features within the GBF project area. In line with the scope of works, a preliminary benthic habitat map was developed based on assessment of geomorphic features derived from sonar and seismic survey data, and a visual benthic survey was completed to validate BCH. Further to this, we described the demersal fish and habitat associations across areas of interest, and broadly characterised the water and sediment quality and infaunal assemblages of the project area.

Overall, the benthic environment is characteristic of the North Carnarvon Basin and the North West Shelf region and is dominated by mixture of benthic habitats of low topographic features with few benthic biota. Sections of seabed between 200 m and 1000 m depths within the Continental Slope Demersal Fish Communities KEF and Exmouth Plateau KEF was comprised of topographically complex scarps with sparse benthic biota that are typically found in deeper waters (>200 m). Though these benthic habitats are well represented regionally, further consideration of the most suitable placement of subsea facilities may be warranted as the project matures to minimise potential impacts to the BCH within the GBF project area (i.e., along scarp and reef mosaic habitats with low and high likelihood of biota).

Water and sediment samples collected from within the GBF project area were free from contaminants and typical of an undisturbed tropical offshore environment. Although there were a few exceedances of some metal concentrations in water and sediment samples compared to ANZG (2018) guideline values, these concentrations could either be a result of contamination during the sampling process, or reflect natural background levels given the absence of anthropogenic activities in the area.

6 References

Advisian (2019). Scarborough Offshore Benthic Marine Habitat Assessment. Prepared for Woodside Energy Limited by Advisian, Report No. -EN-REP-0001, Perth, Western Australia, February 2019.

Advisian (2022a). Greater Gorgon Area New Field Marine Benthic Survey 2022: Field Survey Summary Report. Prepared for Chevron Australia Pty Ltd by Advisian, Report No. 411012-00488_002, Perth, Western Australia, August 2022

Advisian (2022b). Greater Gorgon Area New Field Marine Benthic Survey 2022: Project Execution Plan. Prepared for Chevron Australia Pty Ltd by Advisian, Report No. 411012-00488_001, Perth, Western Australia, April 2022

Althaus, F., Hill, N., Ferrari, R., Edwards, L., Przeslawski, R., Schönberg, C.H.L., et al. (2015). A Standardised Vocabulary for Identifying Benthic Biota and Substrata from Underwater Imagery: The CATAMI Classification Scheme. PLoS ONE, 10(10): DOI: https://doi.org/10.1371/journal.pone.0141039.

Anderson, M., Gorley, R., Clarke, K. (2008). PERMANOVA+ for PRIMER: guide to software and statistical methods. Primer-E, Plymouth 214

Ashley, G.M. (1990). Classification of large-scale subaqueous bedforms; a new look at an old problem. Journal of Sedimentary Research, 60(1):160-172.

ANZG (2018). Australian and New Zealand guidelines for fresh and marine water quality, Volume 1: The Guidelines. Prepared by Australian and New Zealand Environment and Conservation Council, Canberra, Australian Capital Territory, 2018

Baker, C., Potter, A., Tran, M., Heap, A.D. (2008). Sedimentology and geomorphology of the northwest marine region: a spatial analysis. Geoscience Australia Record, 2008/07, 220pp.

Basford, D., Eleftheriou, A., Raffaelli, D. (1990). The infauna and epifauna of the northern North Sea. Netherlands Journal of Sea Research, 25(1-2):165-173.

BMT Oceanica (2016). Offshore Canyons of Western Australia: Cape Range Canyon Literature Review and Enfield Canyon 2015 Environment Survey. Prepared for Woodside Energy Limited by BMT Oceanica Pty Ltd, Report No. 1247_003/2_Rev1, Perth, Western Australia, February 2016.

Brewer, D.T., Lyne, V., Skewes, T.D., Rothlisberg, P. (2007). Trophic systems of the North West Marine Region. Report to the Australian Government Department of the Environment and Water Resources by CSIRO, Cleveland.

Butler, C., Lucieer, V., Walsh, P., Flukes, E., Johnson, C. (2017). Seamap Australia [Version 1.0] the development of a national benthic marine classification scheme for the Australian continental shelf. Hobart, Australia, Institute for Marine and Antarctic Studies, University of Tasmania. 52pp. (Australian National Data Service (ANDS) High Values Collection (HVC) #19). DOI: http://dx.doi.org/10.25607/OBP-459.

CATAMI (2014). CATAMI classification scheme for scoring marine biota and substrata in underwater imagery. Prepared by CATAMI Technical Working Group, Version 1.4, Available from http://catami.github.io/catami-docs/CATAMI_Classification_Scheme_v1.4_Technical_document.pdf.

CAPL (2022). Request for Proposal - Greater Gorgon Area New Field Marine Benthic Survey. Prepared for Worley by Chevron Australia Pty Ltd, Perth, Western Australia, February 2022.

Clarke, K.R., Gorley. R.N. (2015). PRIMER v7: User Manual/Tutorial. PRIMER-E Ltd: Plymouth, United Kingdom.

Currey-Randall, L.M., Galaiduk, R., Stowar, M., Vaughan, B.I., Miller, K.J. (2021). Mesophotic fish communities of the ancient coastline in Western Australia. PloS one, 16(4):p.e0250427.

DCCEEW (2022) Species Profile and Threats Database – Key Ecological Features. Department of Climate Change, Energy, the Environment and Water. Available from https://www.environment.gov.au/sprat-public/action/kef/search

DSEWPaC (2012). Marine bioregional plan for the North-west Marine Region – prepared under the Environment Protection and Biodiversity Conservation Act 1999. Prepared by Department of Sustainability, Environment, Water, Population and Communities, Canberra, ACT.

Dove, D., Nanson, R., Bjarnadóttir, L.R., Guinan, J., Gafeira, J., Post, A., Dolan, M.F.J., Stewart, H., Arosio, R., Scott, G., (2020). A two-part seabed geomorphology classification scheme: (v.2) Part 1: Morphology Features Glossary. Open report prepared by the mim-ga geomorphology working group DOI: 10.5281/ZENODO.4075248.

EPA (2016). Technical Guidance: Protection of Benthic Communities and Habitats. Environmental Protection Authority

Evans, I.S. (1979). An integrated system of terrain analysis and slope mapping. Final report on grant DA-ERO-591-73-G0040, University of Durham, England.

Falkner, I., Whiteway, T., Przeslawski, R., Heap, A.D. (2009). Review of ten key ecological features (KEFs) in the North-west Marine Region. Record 2009/13. Geoscience Australia, Canberra.

Florinsky, I.V. (2009). Computation of the third-order partial derivatives from a digital elevation model. International Journal of Geographical Information Science, 23(2):213-231.

Florinsky, I.V. (2016). Digital terrain analysis in soil science and geology. United Kingdom, Academic Press.

Gage, J., Hughes, D., Gonzalez Vecino, J. (2002). Sieve size influence in estimating biomass, abundance and diversity in samples of deep-sea macrobenthos. January 2002. Marine Ecology Progress Series, 225:97-107.

Gardline (2009). Browse LNG Development Environmental Survey June to July 2009 Environmental Baseline Report. Prepared for Woodside Energy Limited by Gardline Marine Services Pty Ltd, Perth, Western Australia.

Geoconsult (2005). Pluto AUV Survey 2005. Volume 1 of 18 Part 1 Summary of Results.

Geoscience Australia (2022). Regional Geology of the Northern Carnarvon Basin. Report by Geoscience Australia, Australian Government.

Goetze, J.S., Bond, T., McLean, D.L., Saunders, B.J., Langlois, T.J., Lindfield, S., Fullwood, L.A., Driessen, D., Shedrawi, G., Harvey, E.S. (2019). A field and video analysis guide for diver operated stereo-video. Methods in Ecology and Evolution, 10(7):1083-1090.

Gray, J.S. (1974). Animal-sediment relationships. Oceanography and Marine Biology - An Annual Review, 12:223-261.

Guisan, A., Weiss, S.B., Weiss, A.D. (1999). GLM versus CCA spatial modelling of plant species distribution. Plant Ecology, 143:107-122.

Heap, A.D., Harris, P.T., Hinde, A., Woods, M. (2005). Benthic Marine Bioregionalisation of Australia's Exclusive Economic Zone - Report to the National Oceans Office on the Development of a National Benthic Marine Bioregionalisation in support of Regional Marine Planning. Prepared by Geoscience Australia, Canberra, ACT.

Heap, A.D., Harris, P.T. (2008). Geomorphology of the Australian margin and adjacent seafloor. Australian Journal of Earth Sciences, 55:555-585.

Hengesh, J.V., Dirstein, J.K., Stanley, A.J. (2013). Landslide Geomorphology Along the Exmouth Plateau Continental Margin, North West Shelf, Australia. Australian Geomechanics Journal, 48:71-604.

Heyward, A., Rees, M., Wolff, C., Smith, L. (2001). Exploration of Biodiversity - Data Report on Benthic Habitats and Biological Collections from an Initial Benthic Survey Conducted in the Region of WA-271-P, Draft Report prepared for Woodside Energy Limited by AIMS.

Holloway, P.E., Humphries, S.E., Atkinson, M., Imberger, J. (1985). Mechanisms for nitrogen supply to the Australian North West Shelf. Australian Journal of Marine and Freshwater Research, 36:753-764.

Hook, S., Batley, G.E., Holloway, M., Irving, P., Ross, A. (2016). Oil Spill Monitoring Handbook. CSIRO Publishing.

Huange, Z., Nichol, S.L., Harris, P.T., Caley, M.J. (2014). Classification of submarine canyons of the Australian continental margin. Marine Geology, 357:362-383.

Huange, Z., Schlacher, T.A., Nichol, S., Williams, A., Althaus, F., Kloser, R. (2018). A conceptual surrogacy framework to evaluate the habitat potential of submarine canyons. Progress in Oceanography, 169: 199-213.

James, N.P., Done, Y., Kyser, T.K., Dix. G.R., Collins, L.B. (2004). The importance of changing oceanography in controlling late Quaternary carbonate sedimentation on a high-energy, tropical, oceanic ramp: north-western Australia. Sedimentology 51:1179-1205.

Karasiak, N. (2016). Dzetsaka QGIS Classification plugin. Available from https://github.com/nkarasiak/dzetsaka, DOI: 10.5281/zenodo.2552284.

Künitzer, A., Basford, D., Craeymeersch, J.A., Dewarumez, J.M., Dörjes, J. et al. (1992). The benthic infauna of the North Sea: species distribution and assemblages. ICES Journal of Marine Science, 49:127-143.

Last, P., Lyne, V., Yearsley, G., Gledhill, D., Gommon, M., Rees, T., White, W. (2005). Validation of national demersal fish datasets for the regionalisation of the Australian continental slope and outer shelf (>40 m depth). Australian Government Department of the Environment and Heritage and CSIRO Marine Research, Australia.

Last, P.R., Stevens, J.D. (2009). Sharks and rays of Australia. CSIRO publishing, Collingwood, Victoria

Levin, L.A., Gage, J.D. (1998). Relationships between oxygen, organic matter and the diversity of bathyal macrofauna. Deep Sea Research Part II: Topical Studies in Oceanography, 45(3):129-163. DOI: https://doi.org/10.1016/S0967-0645(97)00085-4.

Mackey, D. (1984). Trace Metals and the Productivity of Shelf Waters off North West Australia. Australian Journal of Marine and Freshwater Research, 35:505-516.

McArthur, M.A., Brooke, B., Przeslawski, R., Ryan, D.A., Lucieer, V.L., Nichol, S., McCallum, A.W., Mellin, C., Cresswell, I.D., Radke, L.C. (2010). On the use of abiotic surrogates to describe marine benthic biodiversity. Estuarine, Coastal and Shelf Science, 88:21-32.

McLoughlin, R.J., Young, P.C. (1985). Sedimentary provinces of the fishing grounds of the north west shelf of Australia: grain-size frequency analysis of surficial sediments. Australian Journal of Marine and Freshwater Research, 36:671-681.

Munksgaard, N.C., Parry, D.L. (2002). Metals, arsenic and lead isotopes in near-pristine estuarine and marine coastal sediments from northern Australia. Marine and Freshwater Research, 53(3):719-729.

Olaya, V. (2002). Visualizing Topography by Openness: A New Application of Image Processing to Digital Elevation Models. Photogrammetric Engineering and Remote Sensing, 68(3):257-266.

OzCoasts (2013). Metal contaminants. Australian Online Coastal Information. Available from https://ozcoasts.org.au/indicators/biophysical-indicators/metal_contaminants/

Pattiaratchi, C., Woo, M. (2009). The mean state of the Leeuwin Current system between North-West Cape and Cape Leeuwin. Journal of the Royal Society of Western Australia, 92:221-241.

Posamentier, H.W., Walker, R.G. (2006). Deep-Water Turbidites and Submarine Fans. SEPM Society for Sedimentary Geology, 84, DOI: https://doi.org/10.2110/pec.06.84.

Puotinen, M., Currey-Randall, L. (2020). Characterising the Ancient Coastline Key Ecological Feature: Fish and benthic communities. North West Shoals to Shore Research Program Symposium, Crawley, Western Australia, September 23-24, 2020. Available from https://www.aims.gov.au/sites/default/files/2020-10/2.4_nwss_theme_2_-_characterising_kef_benthic_mpuotinen_final_rev_0.pdf

Richon, C., Tagliablue, A. (2019). Insights Into the Major Processes Driving the Global Distribution of Copper in the Ocean From a Global Model. Global Biogeochemical Cycles, 33(12):1594-1610.

Riley, S.J., De Gloria, S.D., Elliot, R. (1999). A Terrain Ruggedness that Quantifies Topographic Heterogeneity. Intermountain Journal of Science, 5(1-4):23-27.

Saunders, B.J., Galaiduk, R., Inostroza, K., Myers, E.M.V., Goetze, J.S., Westera, M., Twomey, L., McCorry, D., Harvey, E.S. (2021). Quantifying Patterns in Fish Assemblages and Habitat Use Along a Deep Submarine Canyon-Valley Feature Using a Remotely Operated Vehicle. Frontiers in Marine Science, 8:https://doi.org/10.3389/fmars.2021.608665

SeaGIS (2022a). TransectMeasure – single camera biological analysis tool. Accessed 20 July 2022. http://www.seagis.com.au/transect.html

SeaGIS (2022b). EventMeasure – event logging and 3D measurement. Accessed 10 October 2022. https://www.seagis.com.au/event.html

URS (2007). Scott Reef Environmental Survey 5: ROV Inspection of Deep Water Outer Reef Habitats. Prepared for Woodside Energy Limited by URS Australia Pty Ltd, Perth, Western Australia, June 2007.

VLIZ (2022). Water equipment – Niskin bottle. Vlaams Instituut voor de Zee, Flanders Marine Institute. Available from https://www.vliz.be/en/Niskinbottle

Watkins, R. (2020). Terrain Metrics and Landscape Characterization from Bathymetric Data: SAGA GIS Methods and Command Sequences. Available from https://www.ncei.noaa.gov/data/oceans/coris/library/NOAA/CRCP/other/other_crcp_publications/PIBHMC/linkages_project_methods_final.pdf

Wenziker, K., McAlpine, K., Apte, S., Masini, R. (2006). Background quality for coastal marine waters of the North West Shelf, Western Australia. North West Shelf Joint Environmental Management Study, Technical Report No. 18, Western Australia, June 2006.

Williams, A., Dunstan, P., Althaus, F., Barker, B., McEnnulty, F., Gowlett-Holmes, K., Keith, G. (2010). Characterising the Seabed biodiversity and Habitats of the Deep Continental Shelf and Upper Slope off the Kimberley coast, NW Australia. Prepared for Woodside Energy Limited by CSIRO, pp. 95.

Williams, A., Koslow, J.A., Last, P.R. (2001). Diversity, density and community structure of the demersal fish fauna of the continental slope off western Australia (20 to 35°S). Marine Ecology Progress Series, 212:247-263.

Williams, A., Last, P.R., Gomon, M.F., Paxton, J.R. (1996). Species composition and checklist of the demersal ichthyofauna of the continental slope off Western Australia (20-35°5). Records of the Western Australian Museum, 18:135-155.

Wilson, J.P. (2018). Environmental applications of digital terrain modeling. John Wiley & Sons.

Wilson, J.P., Gallant, J.C. (2000): Primary Topographic Attributes. In: Wilson, J.P., Gallant, J.C. [Eds.]: Terrain Analysis: Principles and Applications, John Wiley & Sons, p.51-85.

Woo, M., Pattiaratchi, C. (2008). Hydrography and water masses off the Western Australian coast. Deep-Sea Research Part I-Oceanographic Research Papers, 55:1090-1104.

Yokoyama, R., Shirasawa, M., Pike, R.J. (2002). Visualizing topography by openness: A new application of image processing to digital elevation models. Photogrammetric Engineering and Remote Sensing, 68:251-266.

Appendix A
Exemption from Fish Resources Management Act 1994 and Regulations, Section 7, and Regulation 6

Office use only
EXEMPTION NUMBER:

Fish Resources Management Act 1994
Section 7(2)(e)

INSTRUMENT OF EXEMPTION

I, Nathan Harrison, Director, Aquatic Resource Management, as delegate of the Minister for Fisheries pursuant to Section 7(2) (e) of the *Fish Resources Management Act 1994*, do HEREBY EXEMPT the persons specified in **Schedule 1** from the provisions of the *Fish Resources Management Act 1994* and associated subsidiary legislation which would otherwise prevent those persons from lawfully pursuing the activity specified in **Schedule 2**, using the methods specified in **Schedule 3**, for the area and period specified in **Schedule 4**, subject to the conditions specified in **Schedule 5.**

Schedule 1
Persons

Persons exempted	Exemption holder
Luca.Chiaroni +61 498 014 575 Luca.Chiaroni@Advisian.com And Employees of Worley Services Pty Ltd	Applicant: Worley Services Pty Ltd, trading as Advisian Address: Level 14, 240 St Georges Terrace, Perth, 6000 Telephone No: (08) 9485 3811

Schedule 2
Activity and Purpose

Marine Benthic Survey of the Greater Gorgon Area. This project performs habitat mapping and marine benthic surveys for seven new fields in the Greater Gorgon area on the Northwest Shelf.

Schedule 3
Fishing Methods

A key component of the baseline program is a sediment quality survey sampling and testing for metals, nutrients, and total organic carbon. Sediment samples will be collected via Push Cores to a depth of 40 cms.

Although some sediment infauna will be obtained through sediment push core samples, fish or other biota are an incidental catch. It is expected that the total biomass collected from the survey will be less than 10 kgs.

Schedule 4
Area and Period

Marine Benthic Survey Surveys will be conducted within the Greater Gorgon area located in the Northern Carnarvon Basin Surveys. The fields are located around 130 km northwest of Barrow Island, Western Australia (WA), in water depths ranging from 150 m to 1300 m. The study area covers an area of approximately

2000 square kilometres. Sediment samples will be conducted within these new fields indicated in Figure 1

From the date of signing until 10 October 2022.

Locations to be sampled

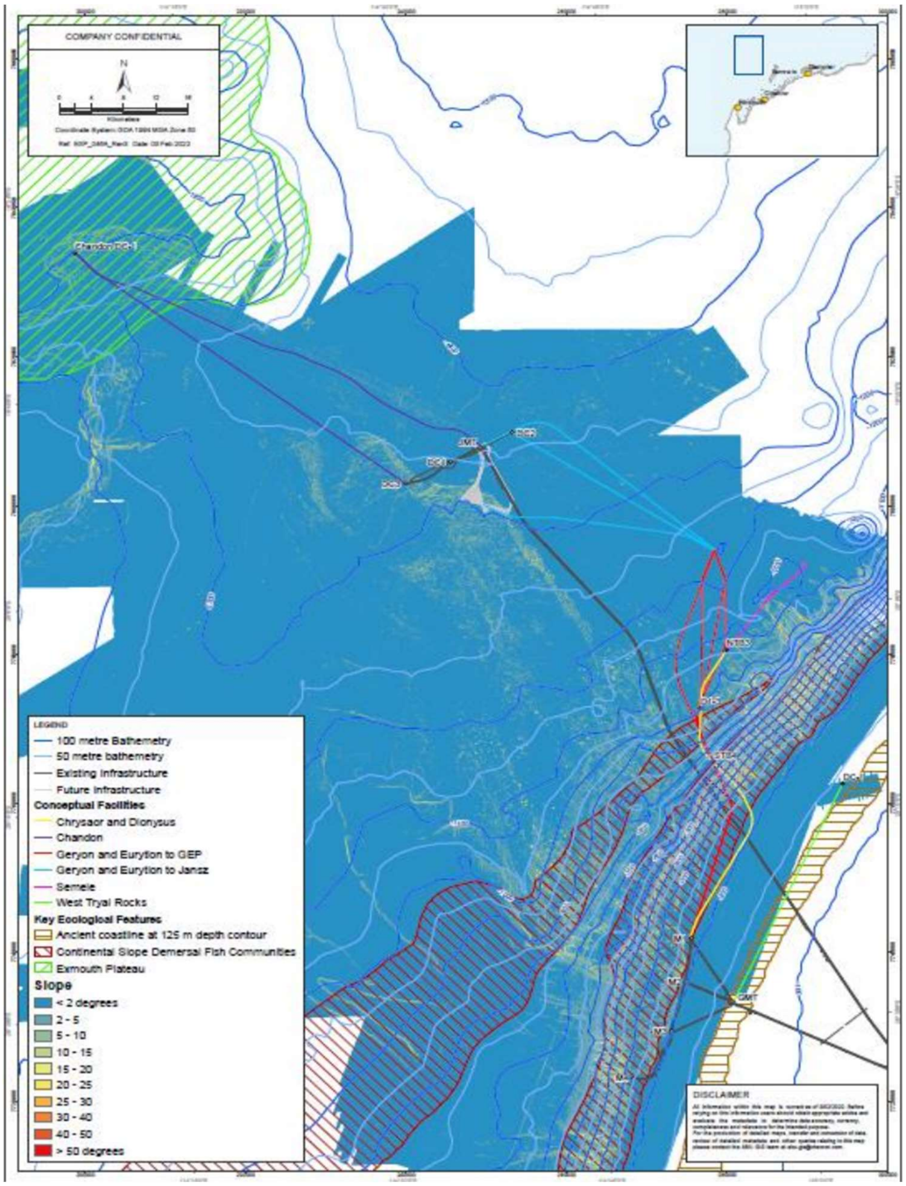


Figure 1: Overview of the greater Gorgon survey area

Schedule 5

Conditions

1. The exemption holder must advise the Department by calling FishWatch 1**800 815 507** at least 12 hours prior to commencing every sampling trip under the exemption, of:

   a) the Exemption holder's full name;
   b) the Exemption holder's contact numbers;
   c) the nearest Office of the Department;
   d) the location of the Exemption and the proposed place and time of landing of any fish retained under the authority of this Exemption;
   e) the Exemption number;
   f) the Exemption start date and time;
   g) the Exemption end date and time;
   h) the name and registration of any vessels/s and the registration of any vehicle/s used to transport any fish retained under the authority of this Exemption;
   i) the species and number of fish intended to be collected under the authority of this Exemption; and
   j) the Call date and time.

2. The exemption holder must ensure the Department is notified via FishWatch **1800 815 507** of any changes to the nomination information, including collection trip cancelations or variations to the date or time.

3. The person(s) exempt **(Schedule 1)** must carry a copy of this Exemption when they are carrying out the activities provided for by this Exemption or when transporting any species collected under this Exemption. The exemption holder must also retain the call reference number (provided by the call centre upon making the prior nomination to fish). A copy of the Exemption must be made available for inspection by a Fisheries and Marine Officer on request.

4. Where any vessel and / or vehicle is being used to take fish and / or samples pursuant to this exemption, the persons specified in **Schedule 1,** must ensure that these vehicles:

   a. be made visibly identifiable as belonging to the client or the persons specified in **Schedule 1;** and
   b. display a sign that is at least 600mm x 600mm, with a minimum character size of 50 mm, stating "Operating under Exemption No." along with the Exemption Number.

5. Where any fishing gear is being used to take fish and / or samples pursuant to this exemption, the persons specified in **Schedule 1,** must ensure that the fishing gear is visibly identifiable as belonging to those specified in **Schedule 1,** along with the Exemption Number, by attaching either marked surface floats or waterproof tags.

6. The persons specified in **Schedule 1,** must only use the sampling methods described in **Schedule 3** while operating under the authority of this Exemption.

7. No other fishing activities, other than those under the authority of this Exemption, are to be undertaken during any sampling trip.

8. The exemption holder must obtain any additional approvals or permissions to complete the activities specified under this Exemption should it be prohibited by other Western Australian or Commonwealth legislation.

9. The Director Aquatic Resource Management can at his discretion revoke this Exemption at any time.

10. If a fish or fish sample is removed from the collection site, it must be disposed of on land, in municipal waste, and not be returned to the marine environment or any water body.

11. Any person specified in **Schedule 1,** must not fish or collect samples, under the authority of this exemption, in any marine protected areas; including State Marine Nature Reserves, Marine Park Sanctuary Zones, Fish Habitat Protection Areas or Reef Observation Areas, without the specific written permission of the Department of Biodiversity, Conservation and Attractions Manager, Marine Science and the Department of Primary Industries and Regional Development's Director, Aquatic Resource Management or Director, Aquatic Science and Assessment.

12. All samples taken pursuant to this exemption, must only be transported in vessels or vehicles described as required under **Condition 1. (h).**

13. Any collected specimen or by-catch that are displaying invasive characteristics or are suspected or recognised invasive aquatic species identified in the Fish Resources Management Regulations 1995 (Schedule 5, Noxious Fish), and/or in the current version of the Western Australian Prevention List for Introduced Marine Pests, Department of Fisheries, found on the DPIRD website must not be returned to the water.

    http://www.fish.wa.qov.au/Documents/biosecurity/noxious fish list.pdf
    http://www.fish.wa.gov.au/Documents/biosecurity/epa introduced marine pests

    Noting these lists may be amended from time to time.

14. Any specimens retained in accordance with **Condition 13** must be humanely euthanized and kept in a sealed plastic bag or container, separate from any other fish and either kept on ice or refrigerated (but not frozen), until further advice is obtained from DPIRD.

15. The holder of the Exemption must report to the DPIRD via FISHWATCH (ph 1800 815 507) or by email at aquatic.biosecurity@dpird.wa.gov.au, within 24 hours following the:
    a) Initial detection of:
        a. a listed noxious fish

b. a suspected or recognised invasive aquatic species not previously known from the sampled waters; or
c. an introduced aquatic pest, or
d. a disease, and

b) Subsequent analysis and confirmation of fish/species identified in **Condition 13** above or by any other further investigation.

Nathan Harrison
DIRECTOR, AQUATIC RESOURCE MANAGEMENT
as delegate of Minister for Fisheries

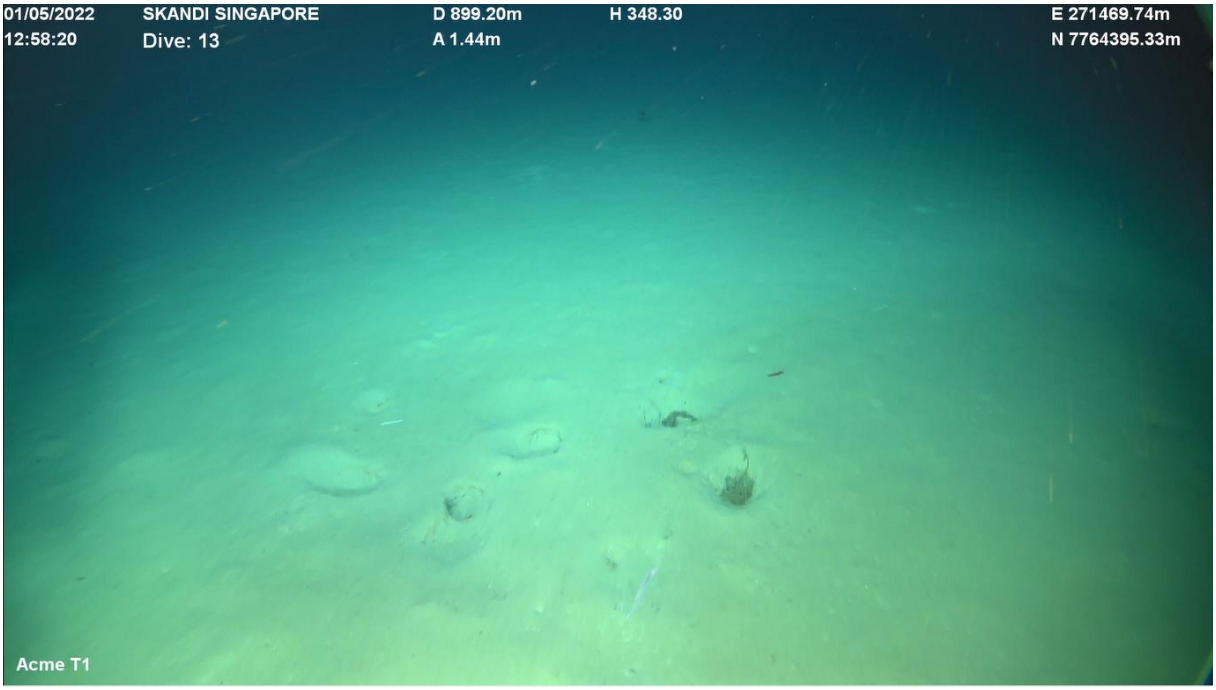
26 April 2022

Appendix B
Habitat Mapping Categories and Example Images (Based on CATAMI Classifications)

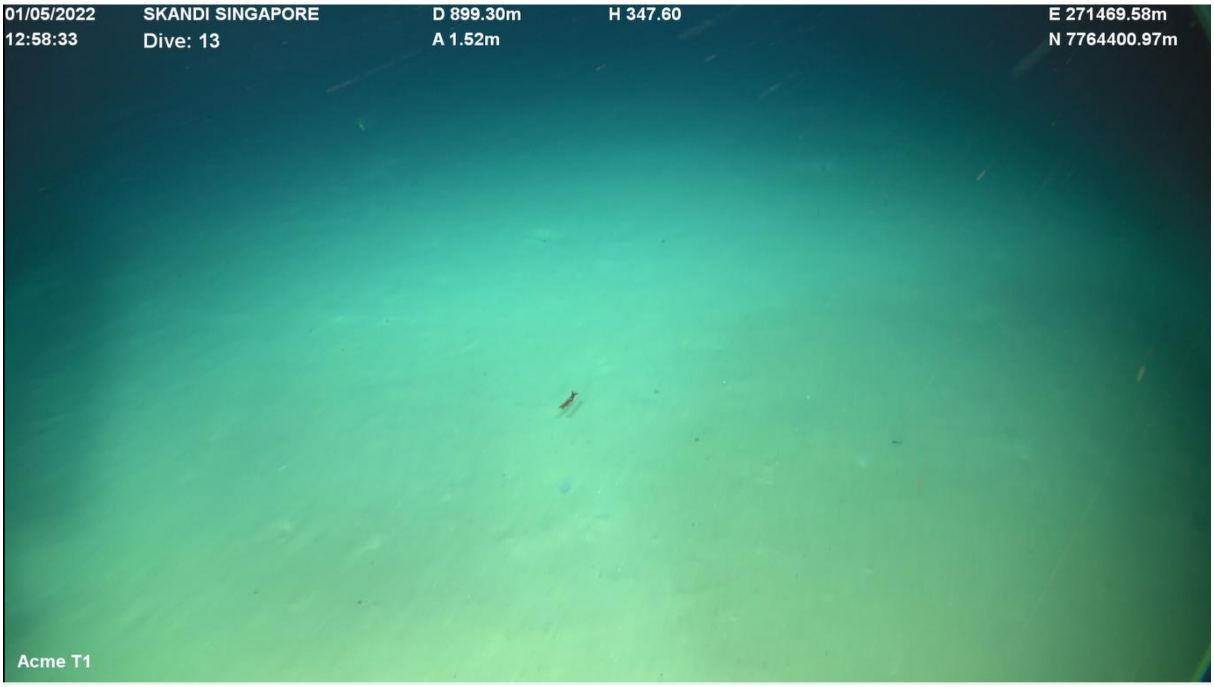
Morphological Descriptor	Description	Bathymetry	Slope/Topographic Position	Relative Backscatter/ Sidescan
Bedforms	Active or once active sediment bedforms indicating wave or current action on the seabed.	May be visible bathymetric features, or may only occur in backscatter if small.	Varied, wavelength and amplitude measured in profile (Ashley 1990).	Varies depending on incidence angle. Typically low.
Depression-Scour	Local depression which may be geological or biological in origin (Scour or Pockmark).	Bathymetric features measurable in profile (low).	Varied slope. TPI index low.	Varies depending on incidence angle.
Irregular Seabed	Mostly flat sediment terrain with minor features which may be derived from underlying geology.	Smooth with identifiable, regular but small bedforms or mounds. Fine or coarse sediment.	Typically, less than 2°, minor topographic features.	Low, rare and small discernible features.
Mostly Bare	Mostly flat sediment terrain with very minor features.	Smooth with rare identifiable but unmappable regular bedforms or mounds. Fine or coarse sediment.	Typically, less than 2°, very minor topographic features.	Low, rare and small discernible features.
Mound	Locally elevated Sediment or Rock Veneer feature which comprising rubble, geological or biological in origin.	Bathymetric features measurable in profile. Isolated, smooth edged feature. No structure indicating active sand wave or dune.	Varied but smooth slope. TPI index high.	Varies depending on incidence angle, typically very high.
Rock Reef	Bedrock or other consolidated material outcrop.	Rough bathymetric features measurable in profile.	Varied complex slope. TPI index high.	High/variable.
Rock Veneer	Area of buried bedrock/rocks or cemented sediments with very low sediment input (Starved). Also known as low profile reef.	Uneven, rugged and irregular features, often angular or linear. Fine or coarse sediment.	Typically, less than 2°, highly variable low profile topographic features. Signs of subsurface structure must be apparent.	Varied, mostly high.
Scarp	Bedrock or other consolidated material outcrop, subject to landslide erosion.	Rough bathymetric features measurable in profile.	Typically, greater than 15°, may have steep sides	Varies depending on incidence angle.

Advisian
Worley Group

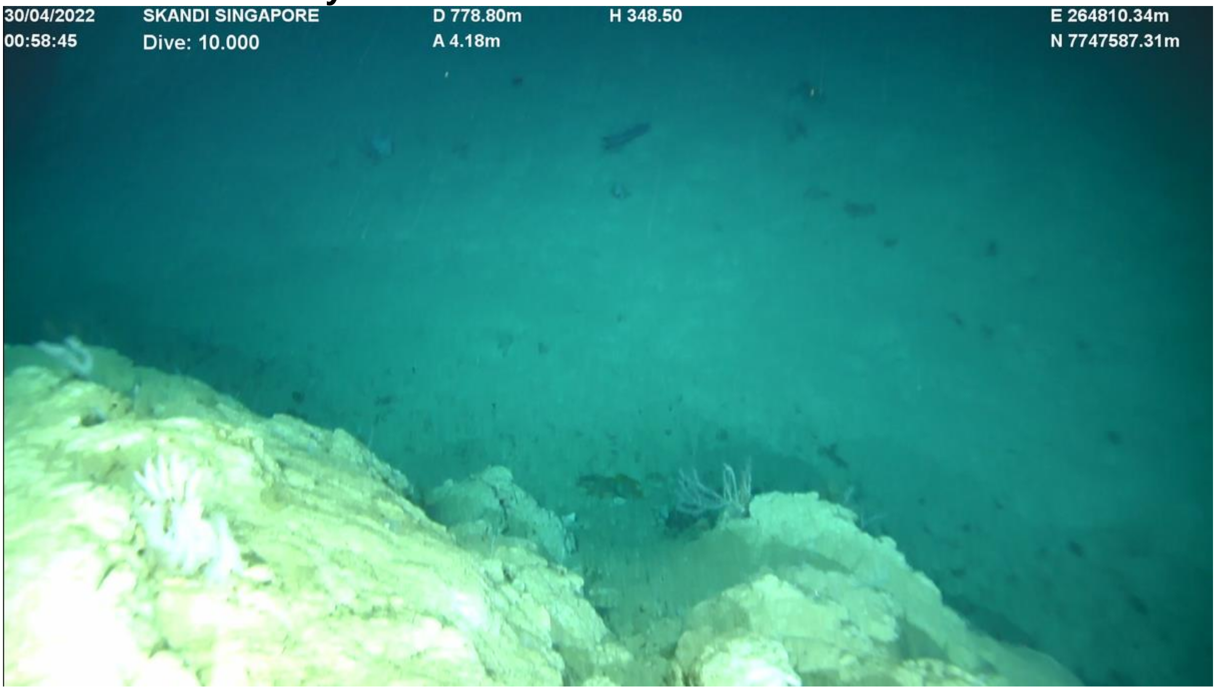
Flat > Unconsolidated (soft) > Sand/mud (<2 mm) >Bioturbation with bare sediment



Flat > Unconsolidated (soft) > Sand/mud (<2 mm) >Bare sediment

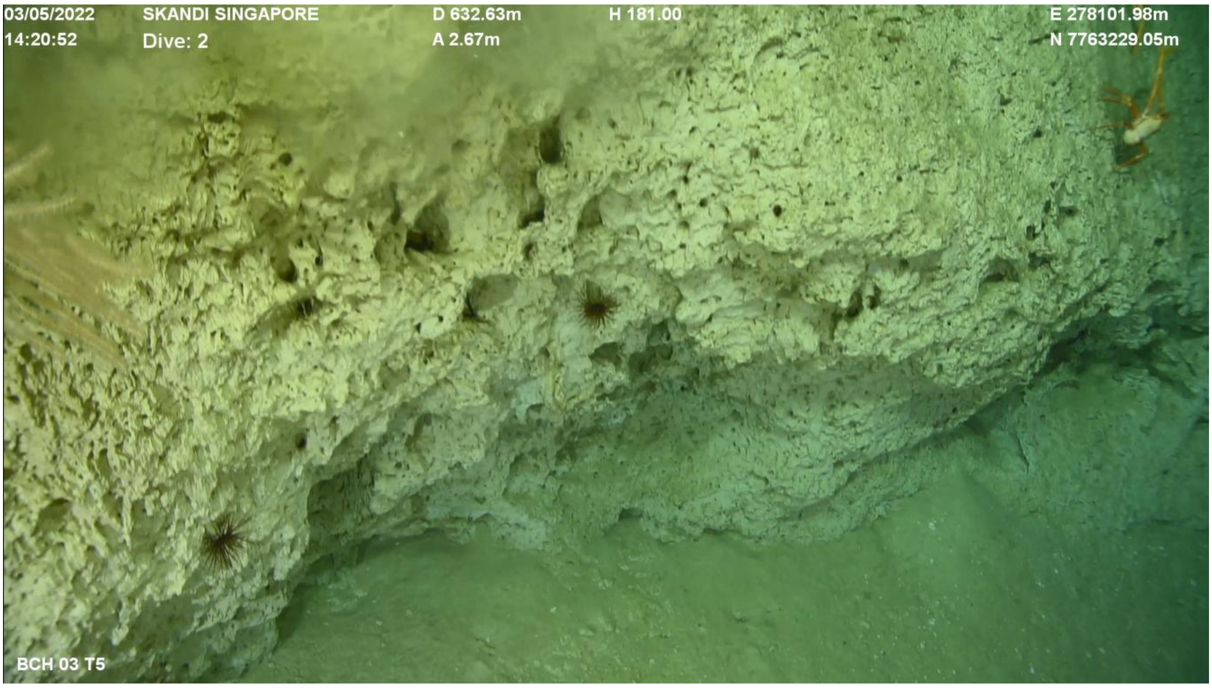


High > Consolidated (hard) > Rock (Outcropping bedrock) >Bioturbation with occasional veneer only

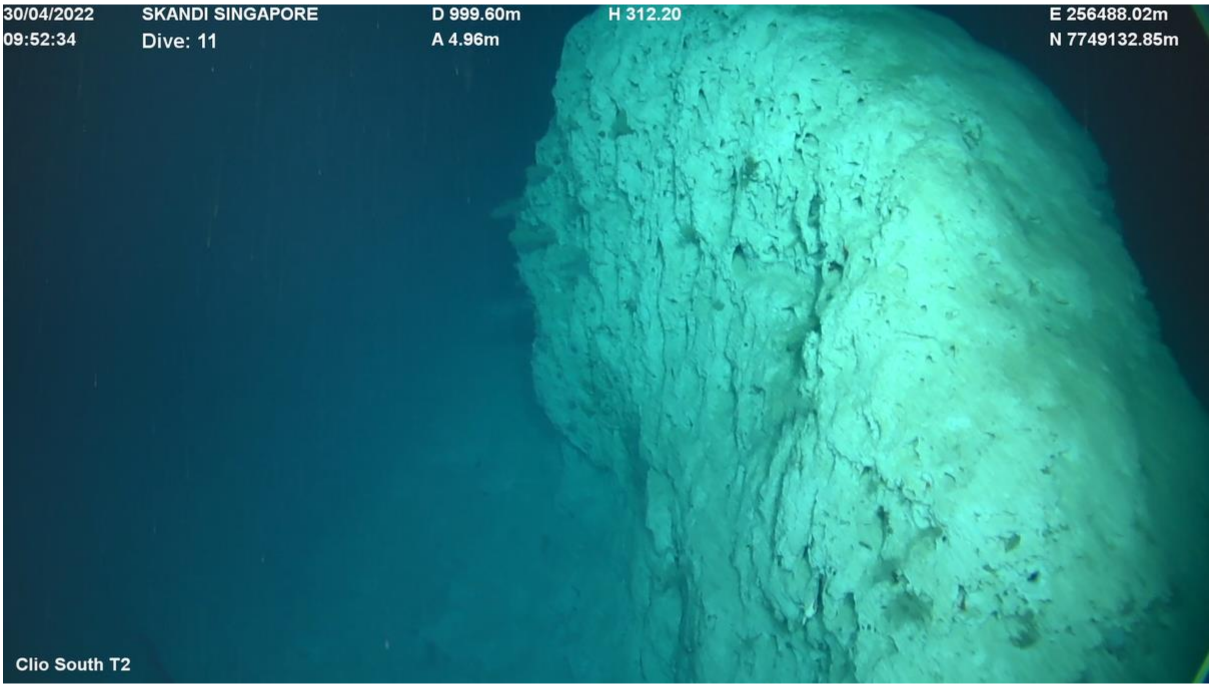


High > Consolidated (hard) > Rock (Outcropping bedrock) >Bioturbation with biota > Mixed biota

High > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Cnidaria

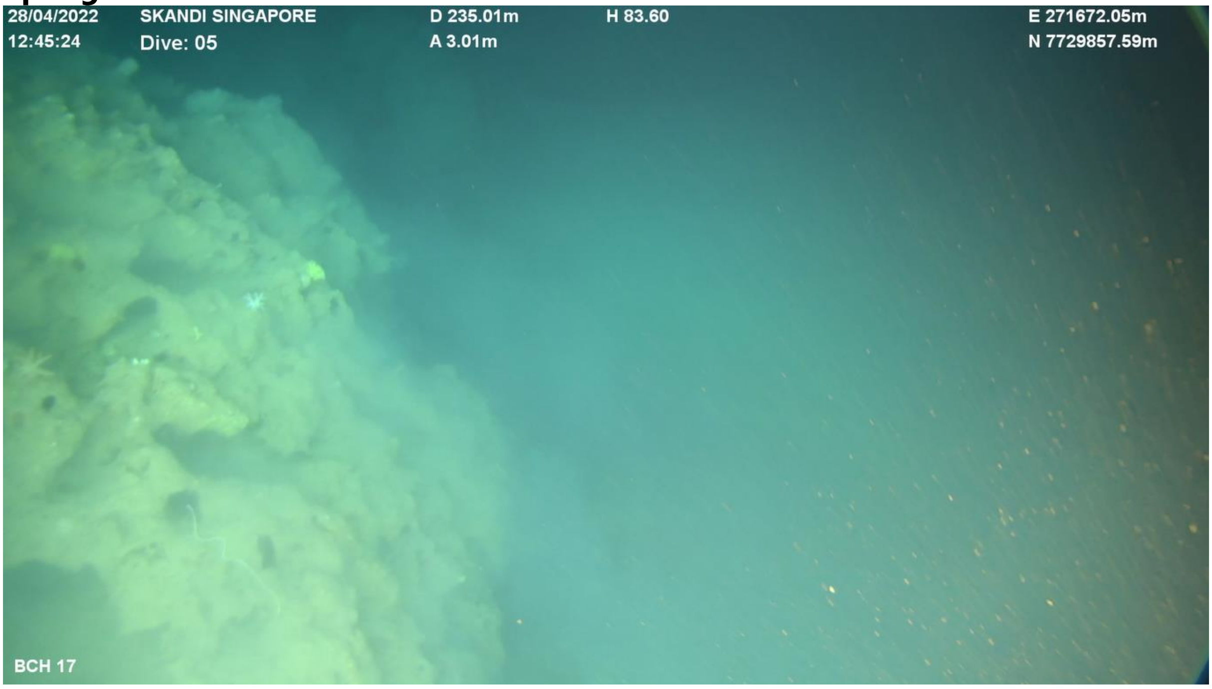


High > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Sponge

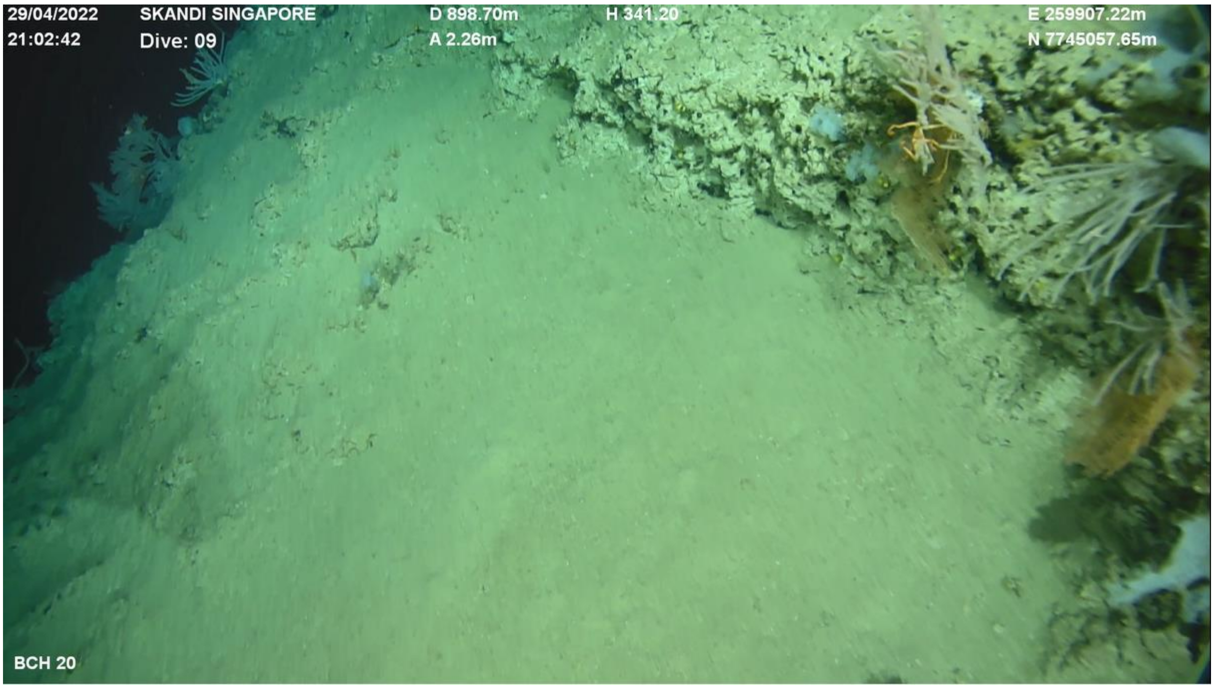


Advisian
Worley Group

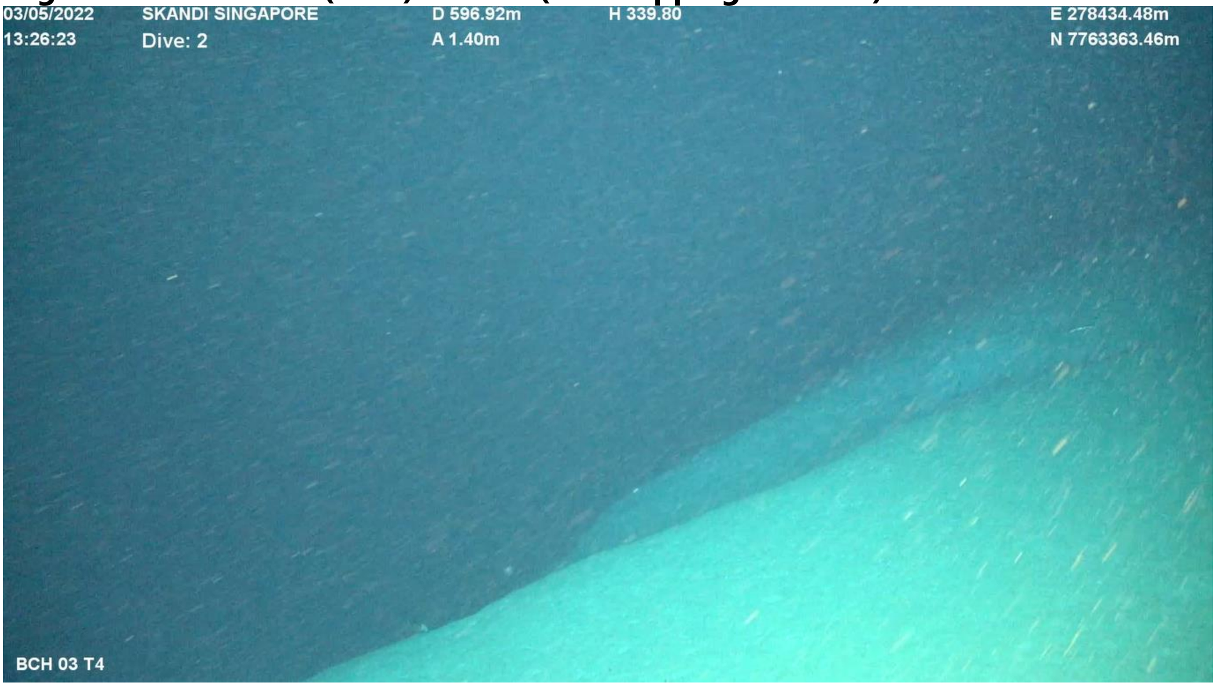
High > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Sponge and Cnidaria

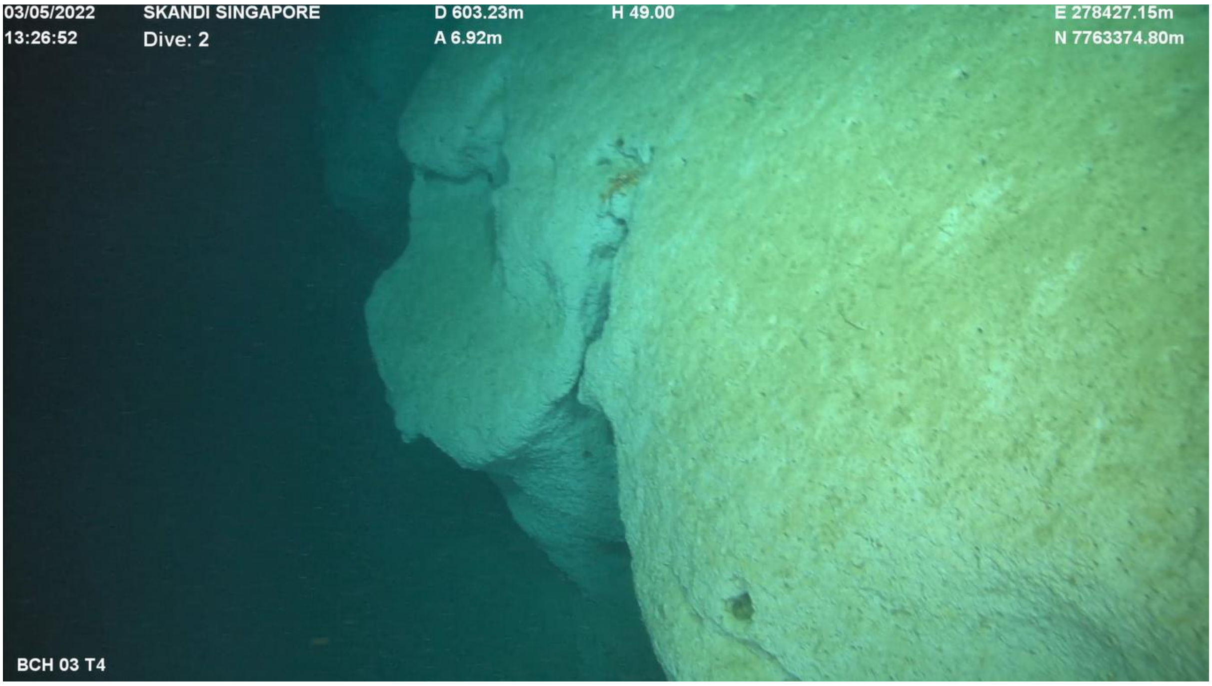


High > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Mixed biota

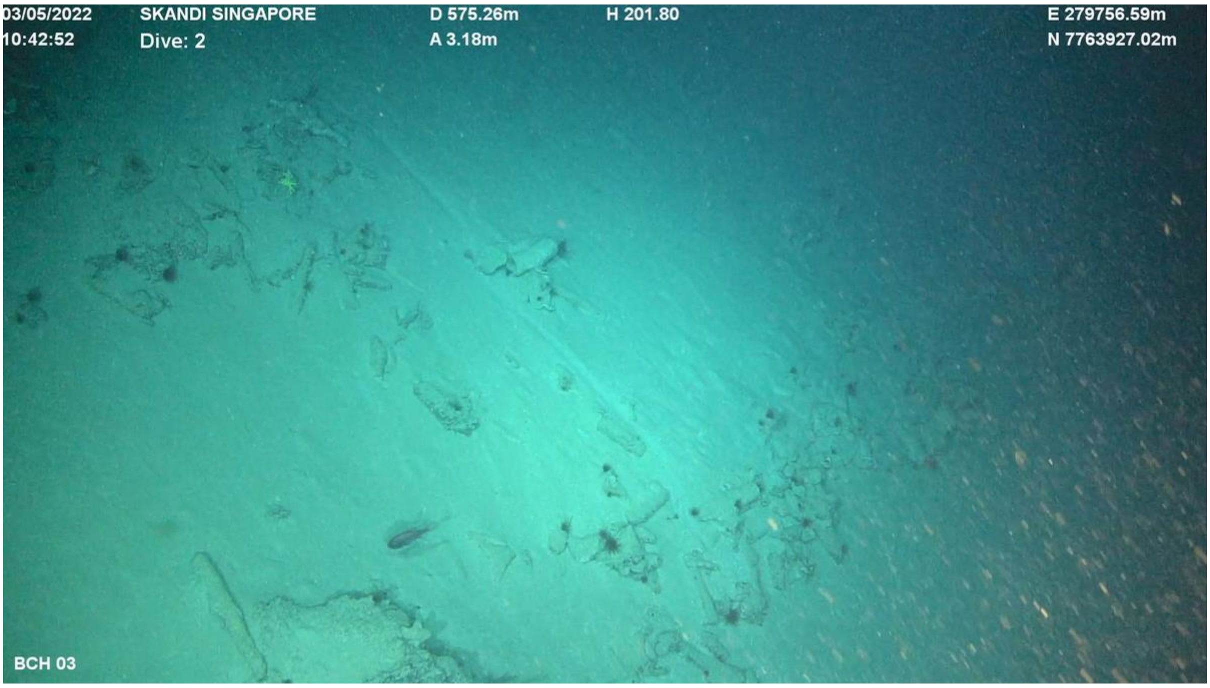


High > Consolidated (hard) > Rock (Outcropping bedrock) > Bare sediment



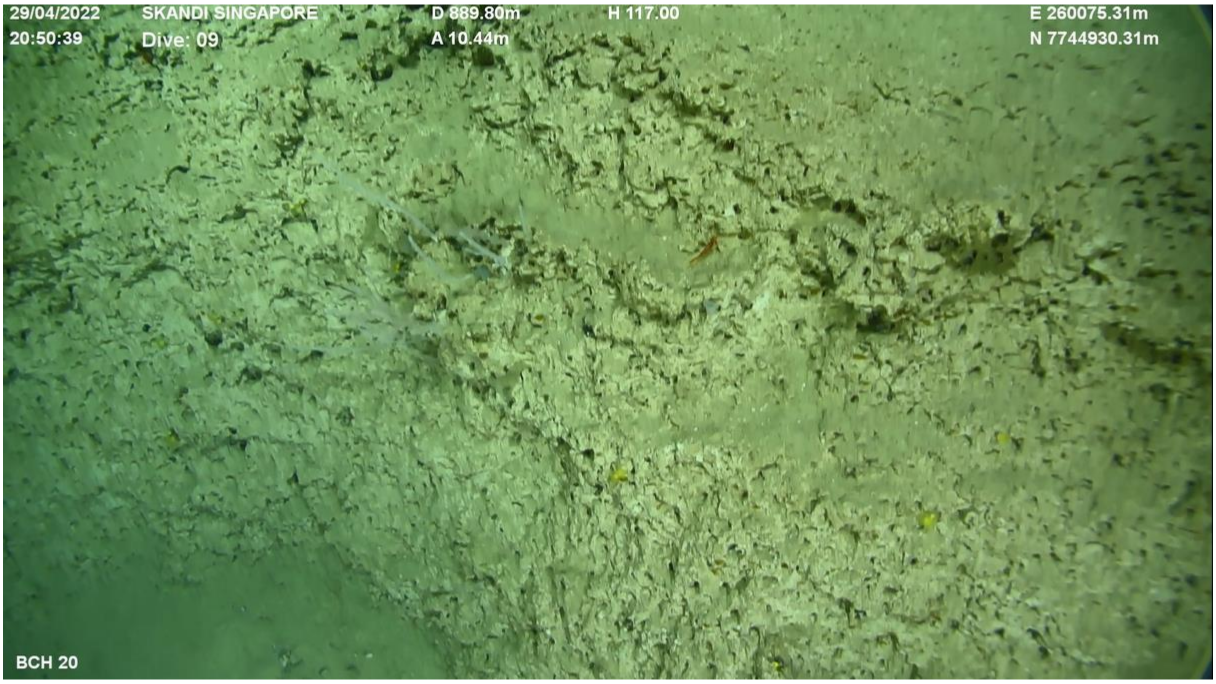


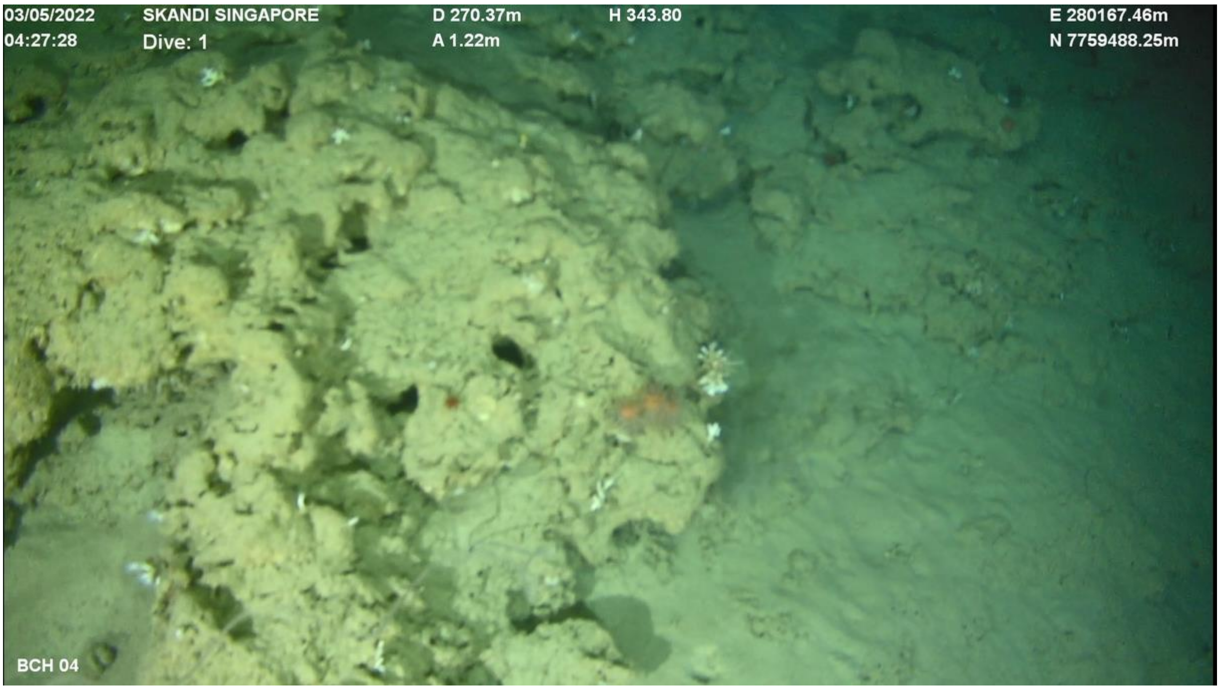
High > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota > Cnidaria



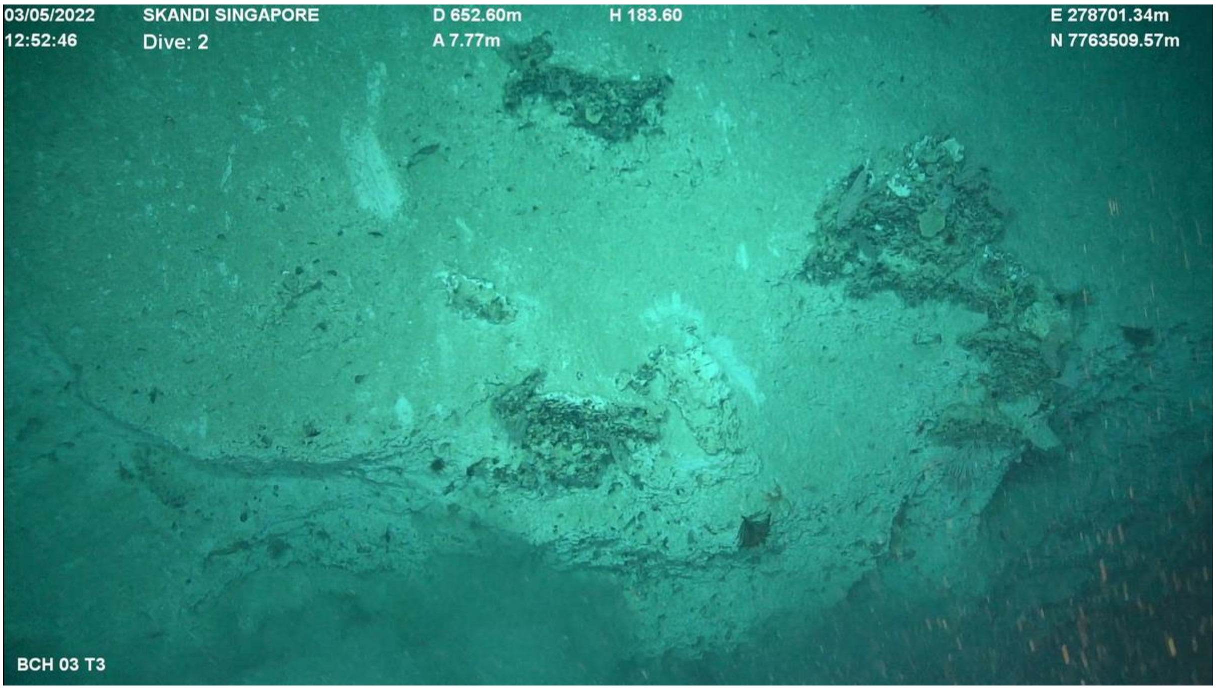
High > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota > Sponge and Echinoderm

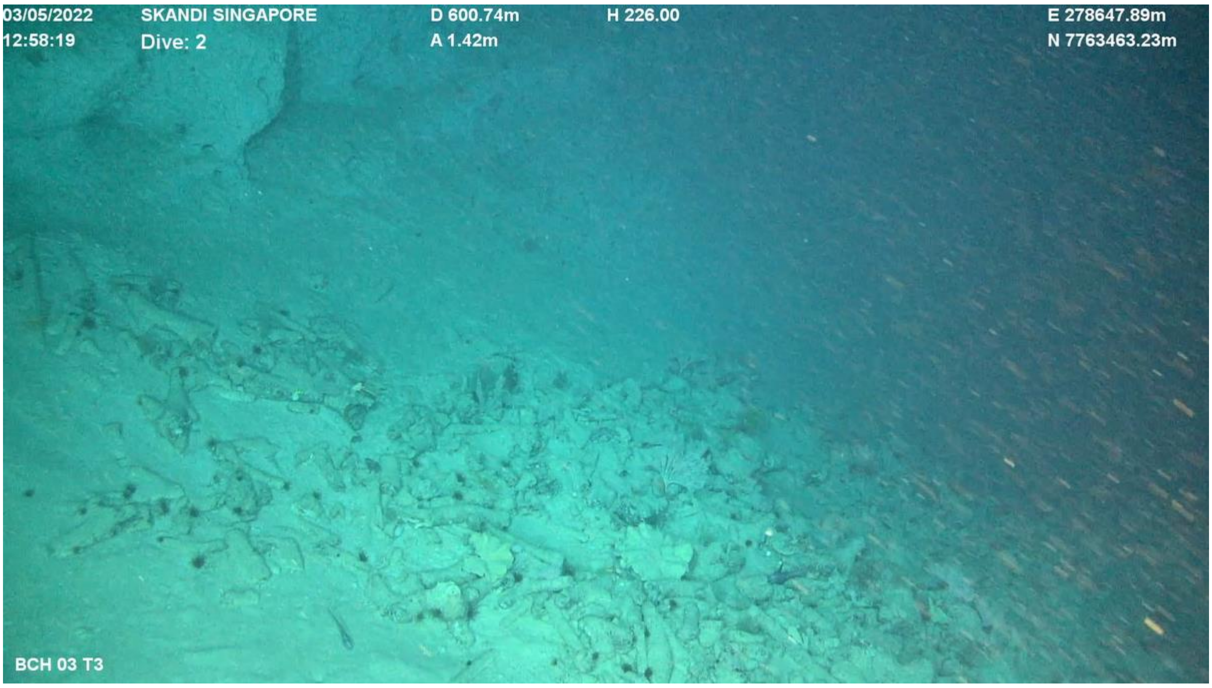
High > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota > Sponge and cnidaria



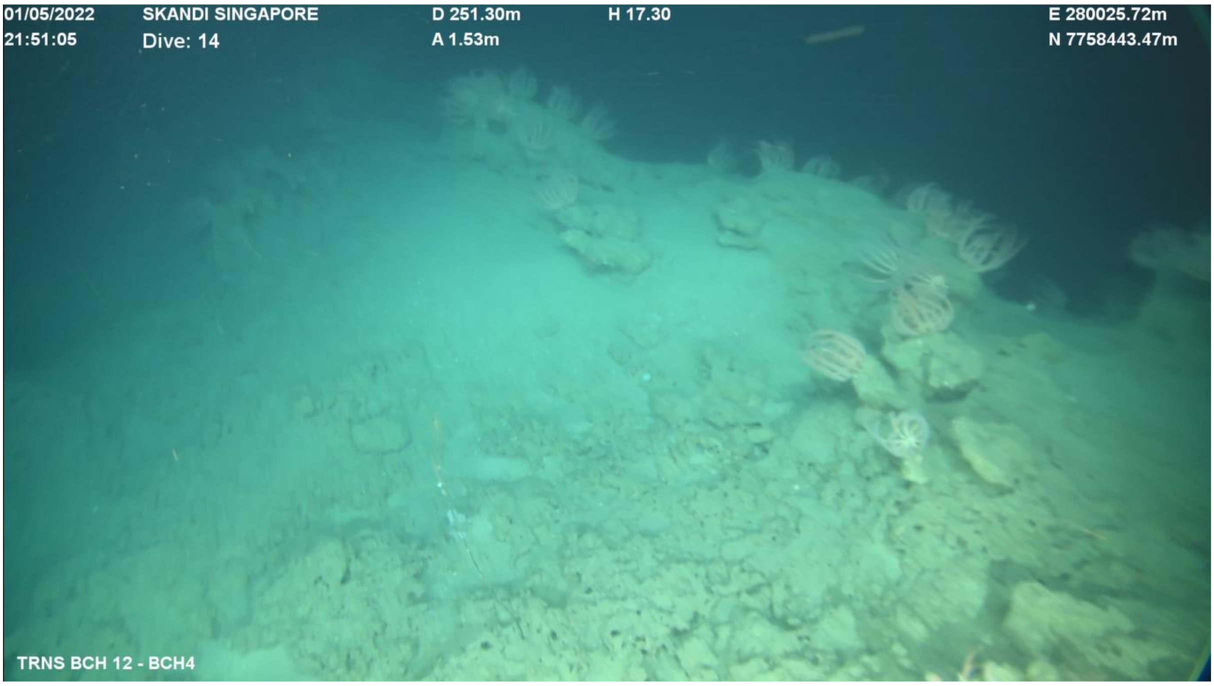


High > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota > Mixed biota

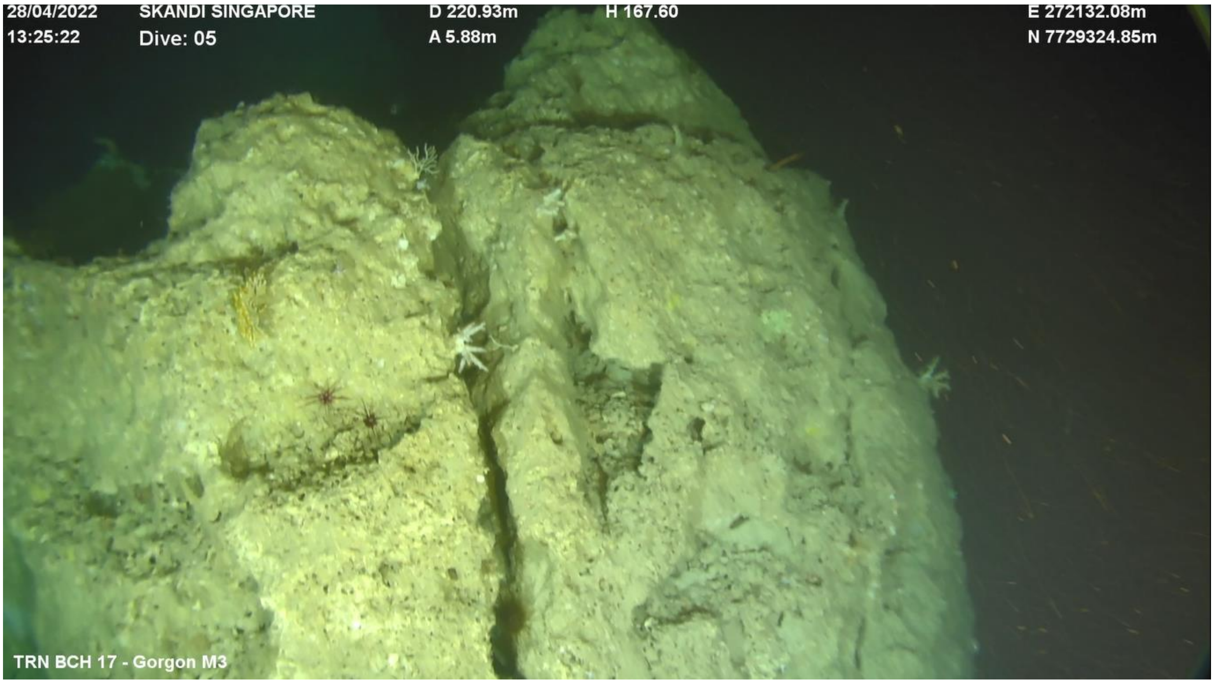




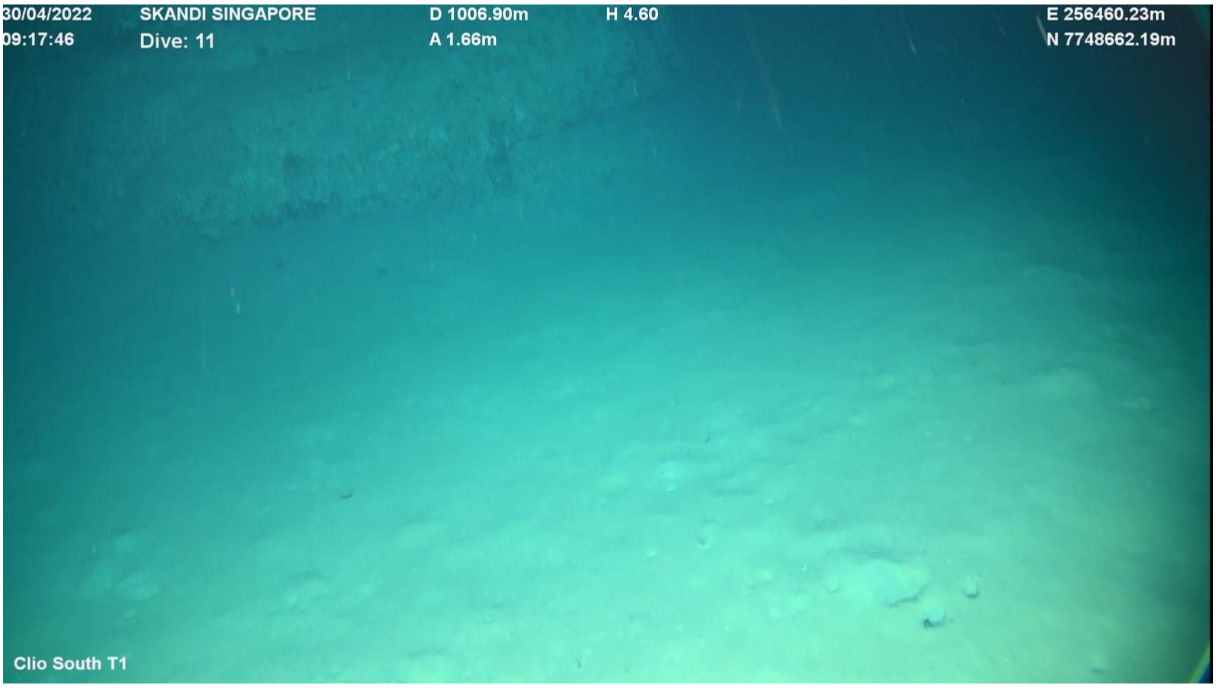
High > Consolidated (hard) > Boulders > Biota only > Cnidaria and Echinoderm



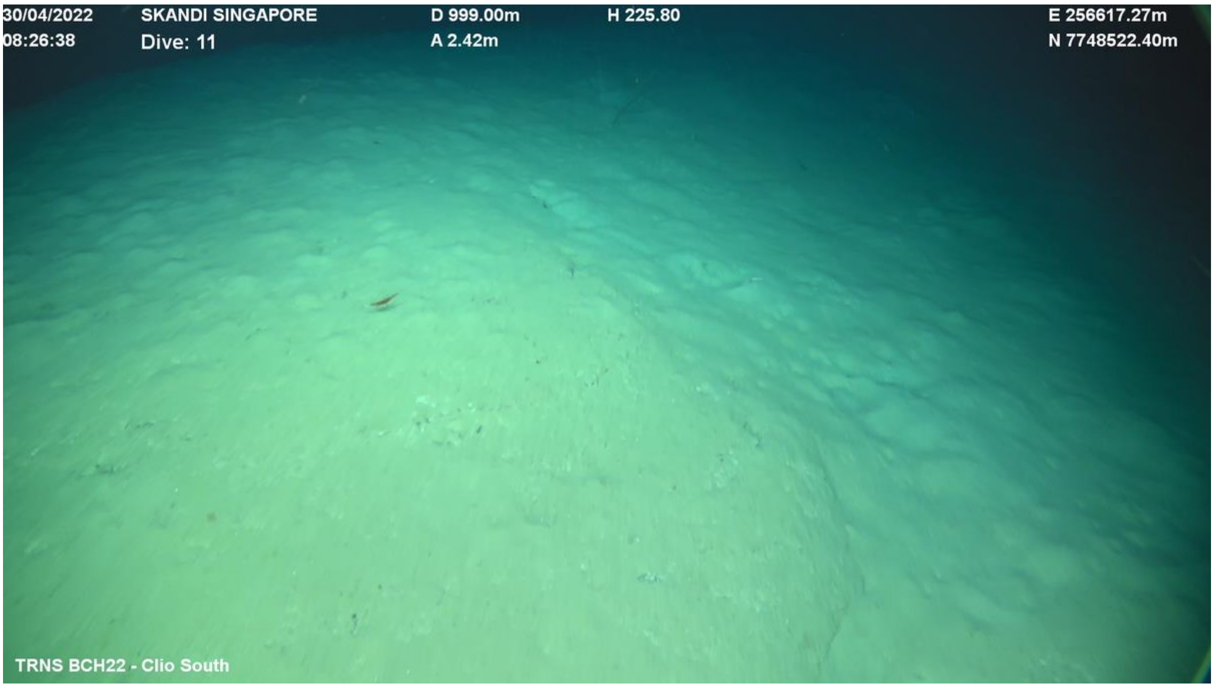
High > Consolidated (hard) > Boulders > Biota only > Mixed biota



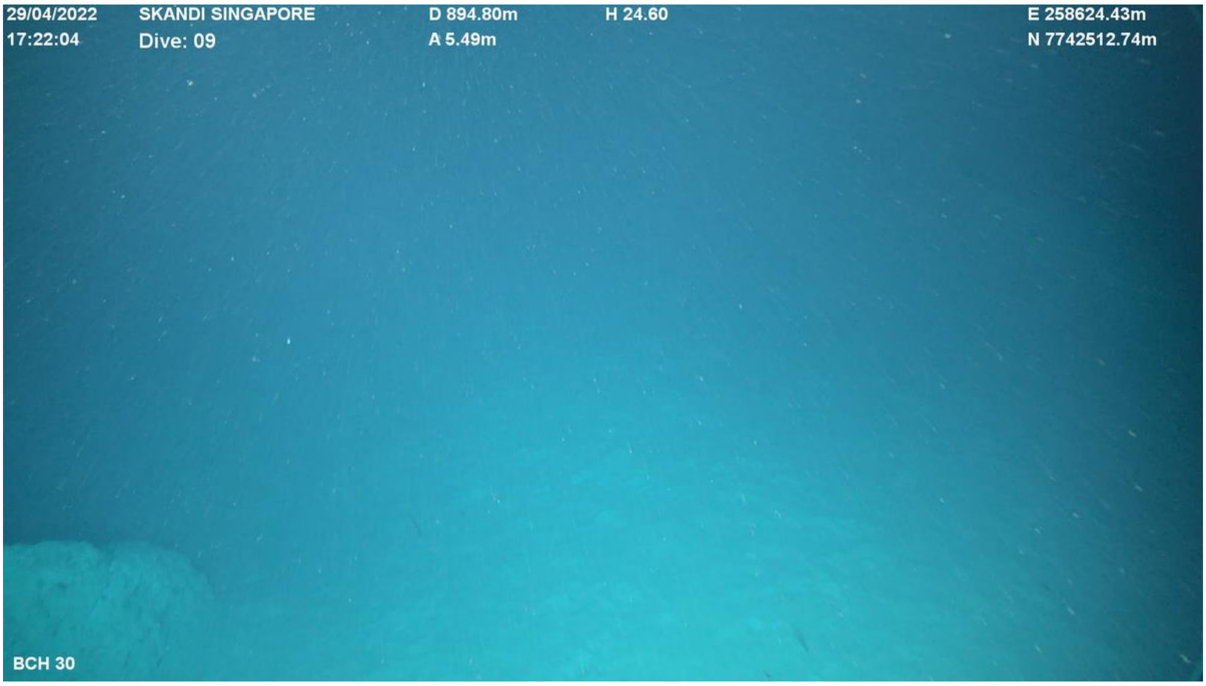
High > Unconsolidated (soft) > Sand/mud (<2 mm) and occasional boulders > Bioturbation and occasional veneer only



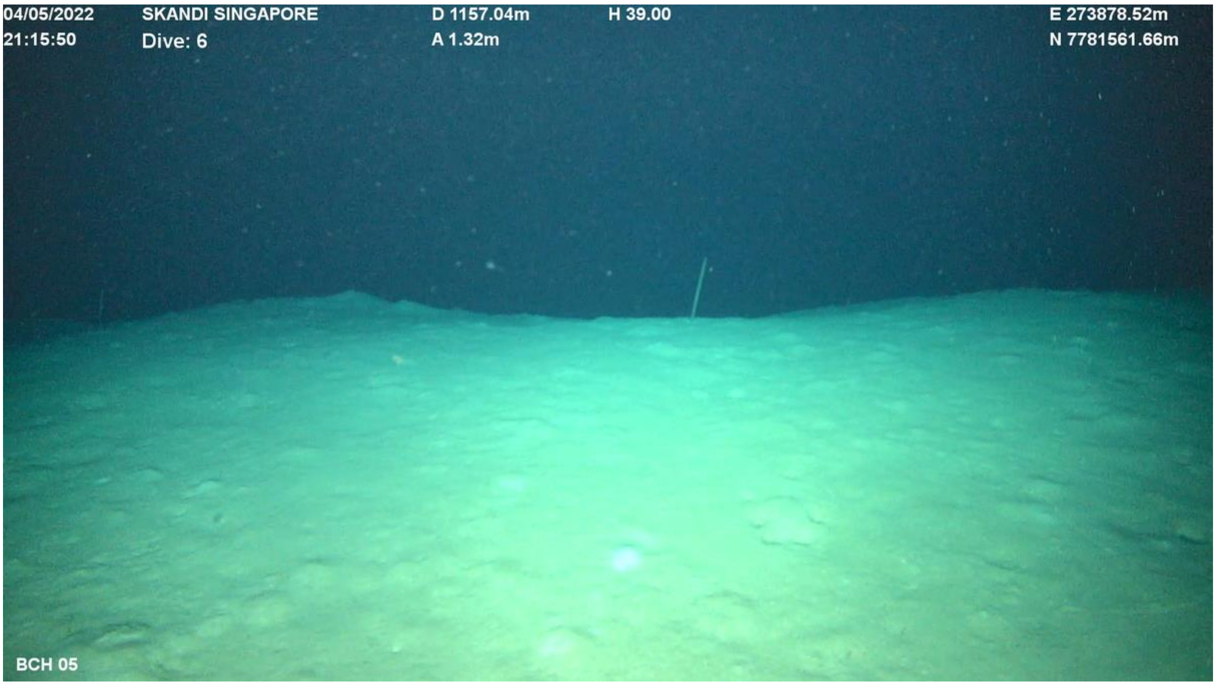
High > Unconsolidated (soft) > Sand/mud (<2 mm) and occasional boulders > Bioturbation only



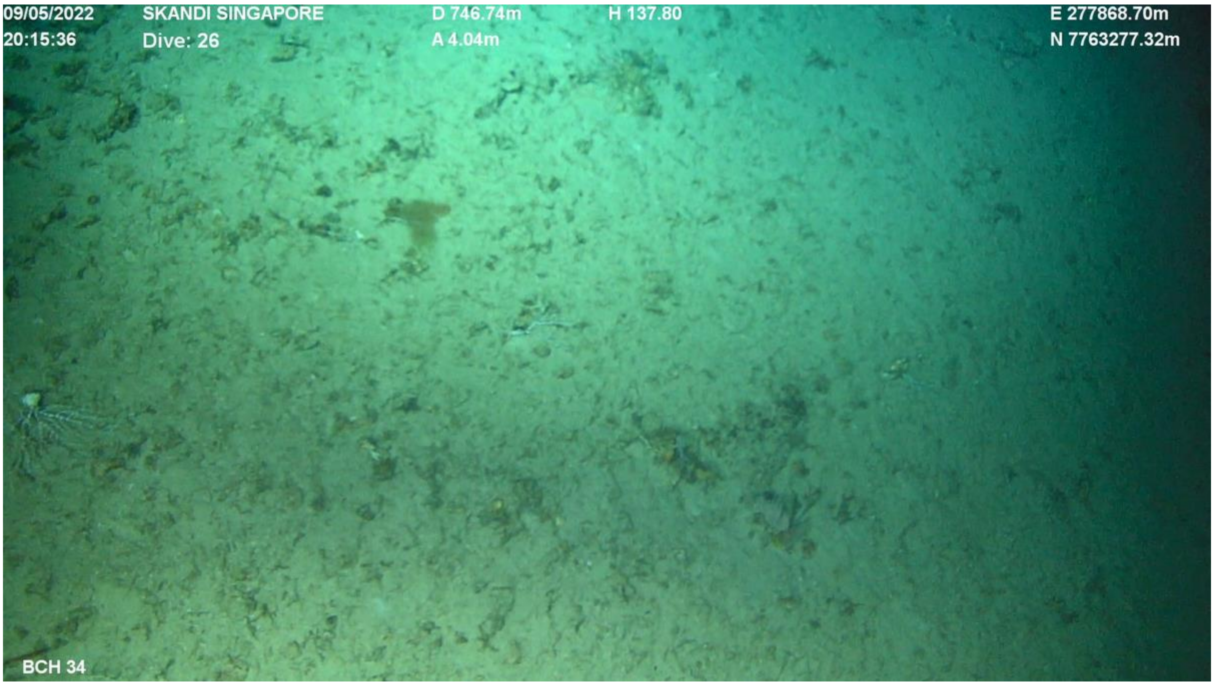
High > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation only



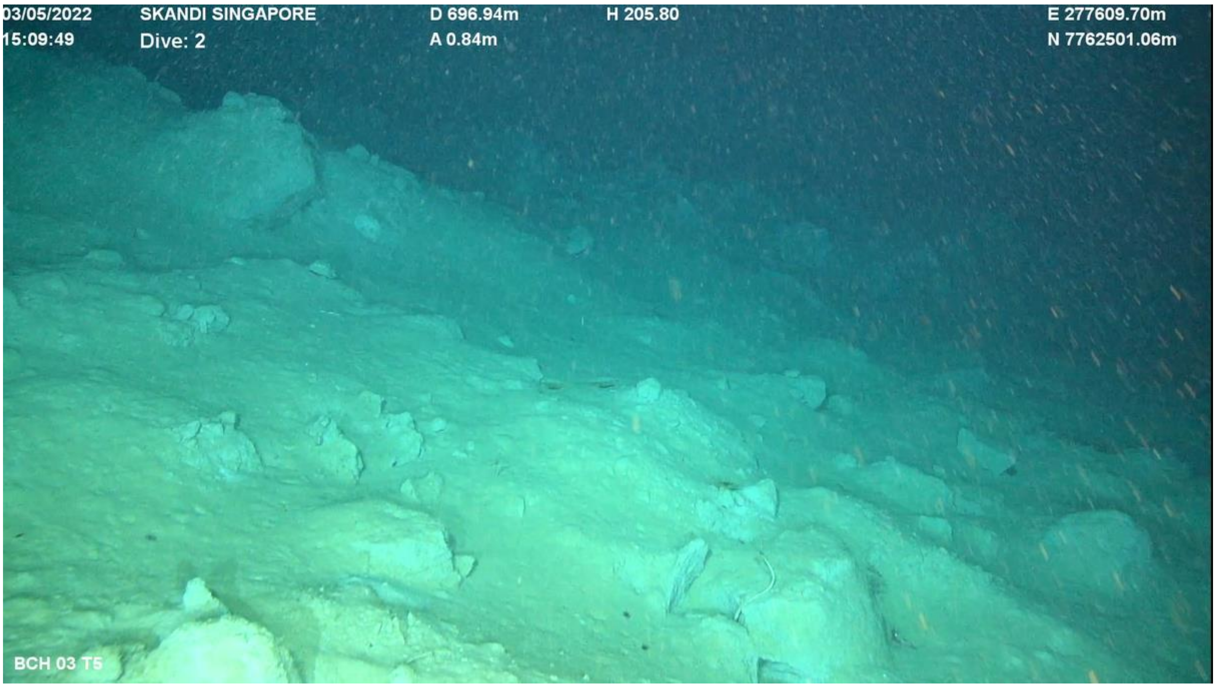
High > Unconsolidated (soft) > Sand/mud (<2 mm) > Bare sediment

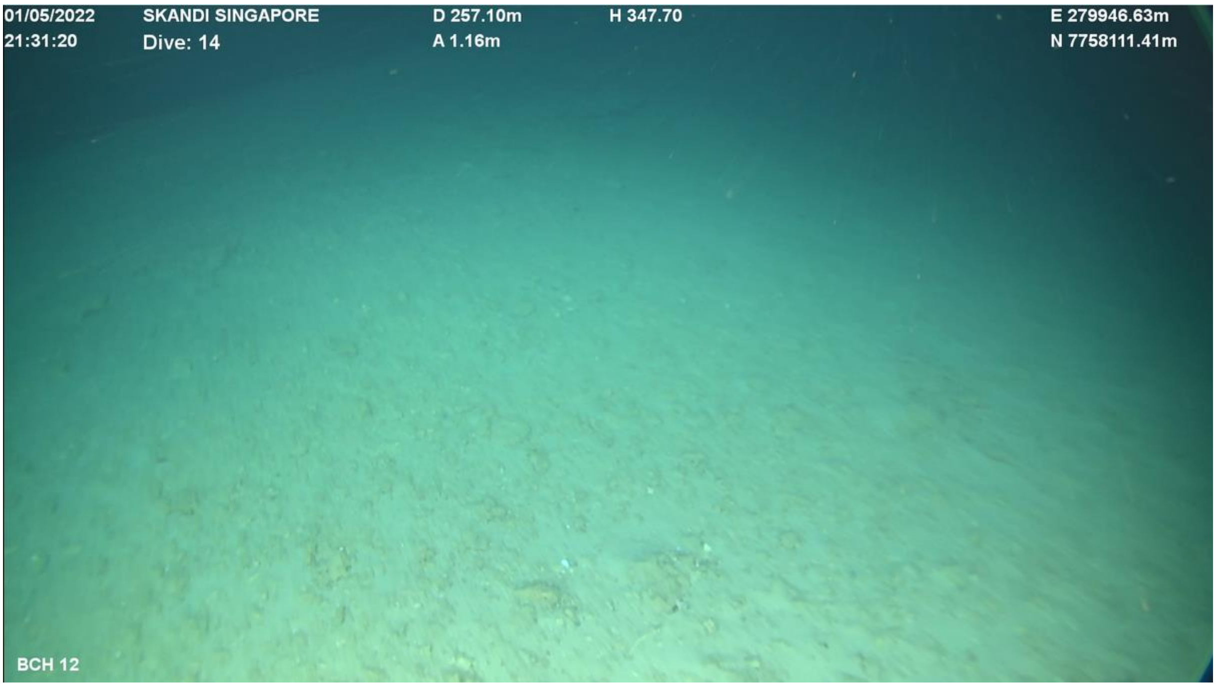


Low > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation with biota and occasional veneer > Sponge

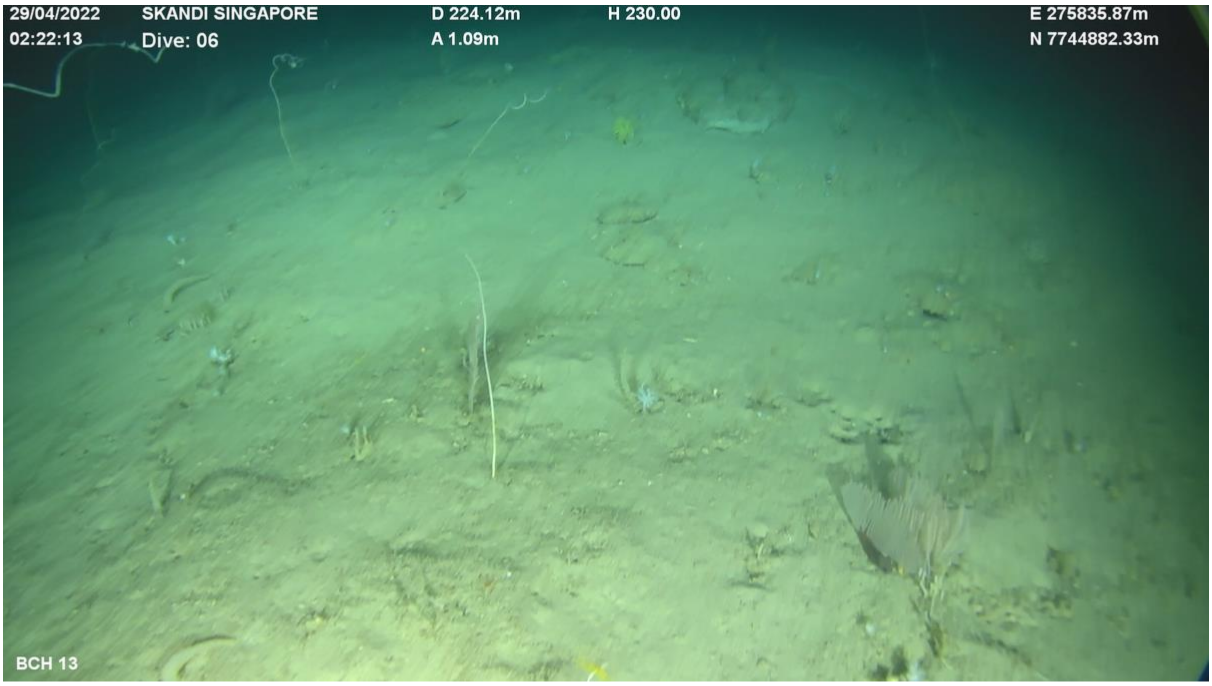


Low > Consolidated (hard) > Rock (Outcropping bedrock) > Bare sediment

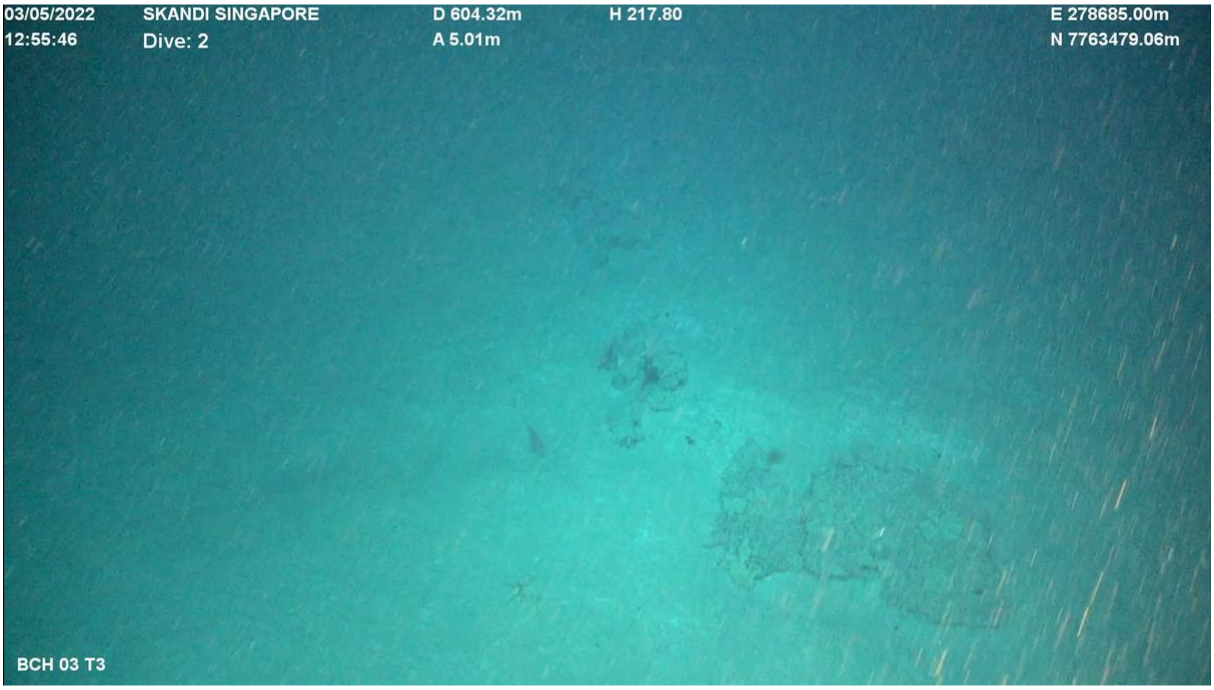


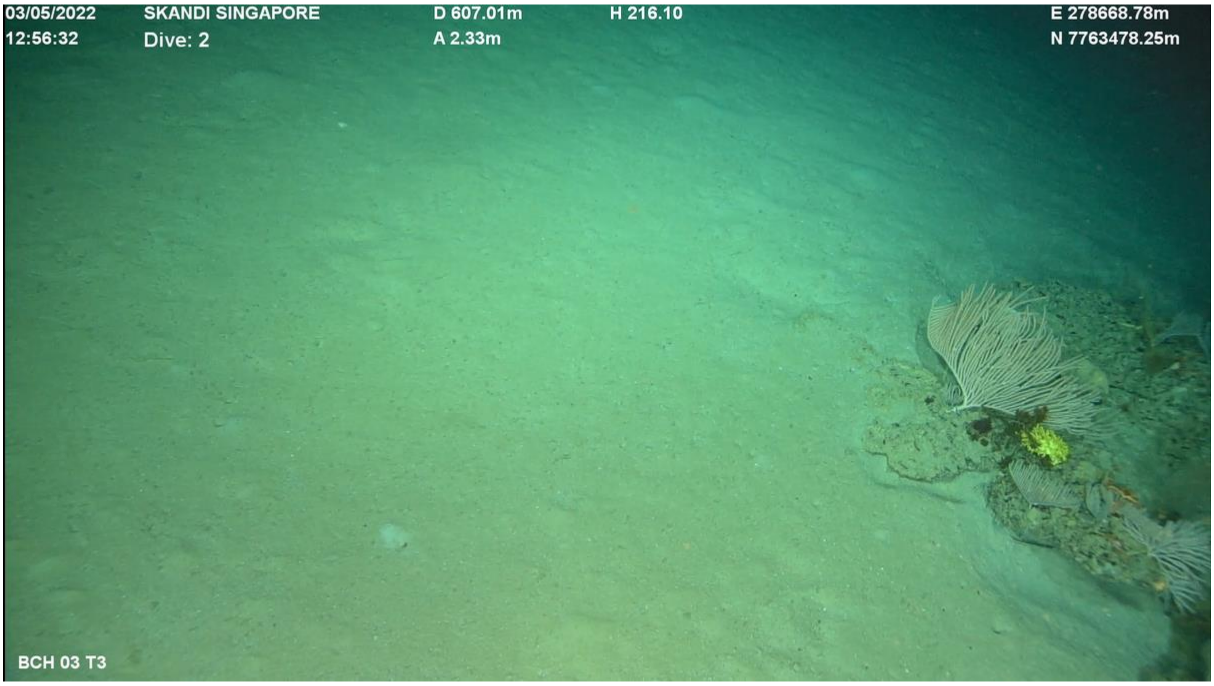


Low > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation with biota and occasional veneer > Sponge and cnidaria

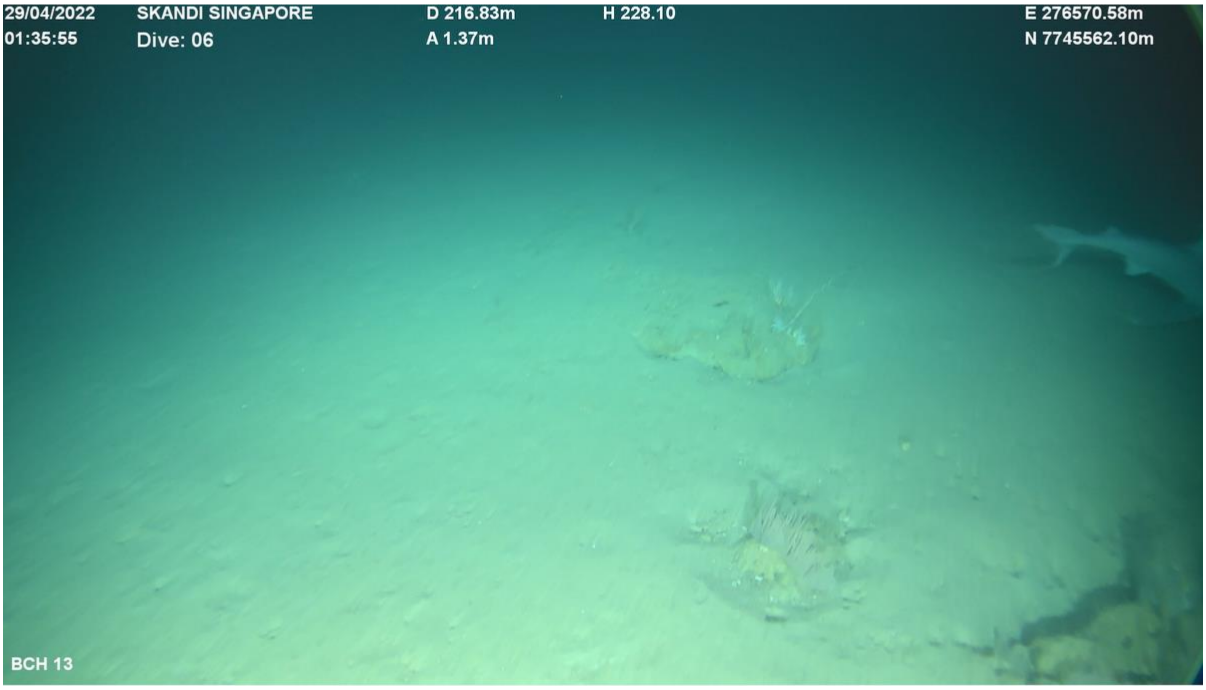


Low > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota> Mixed biota

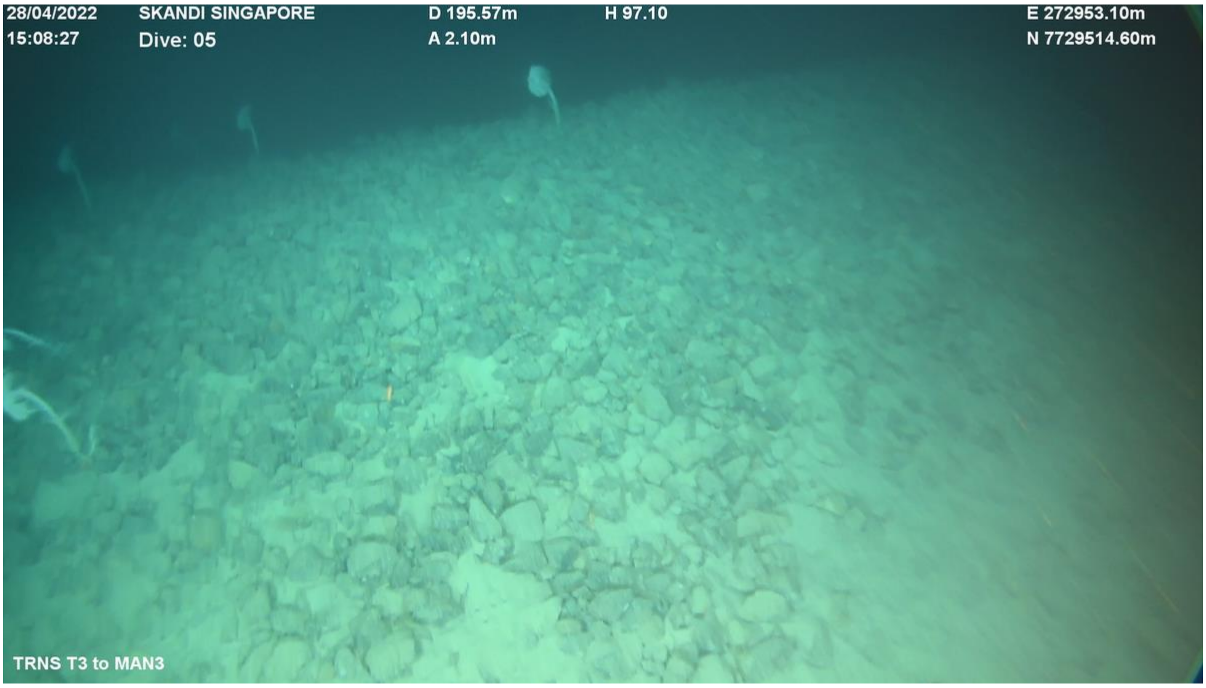




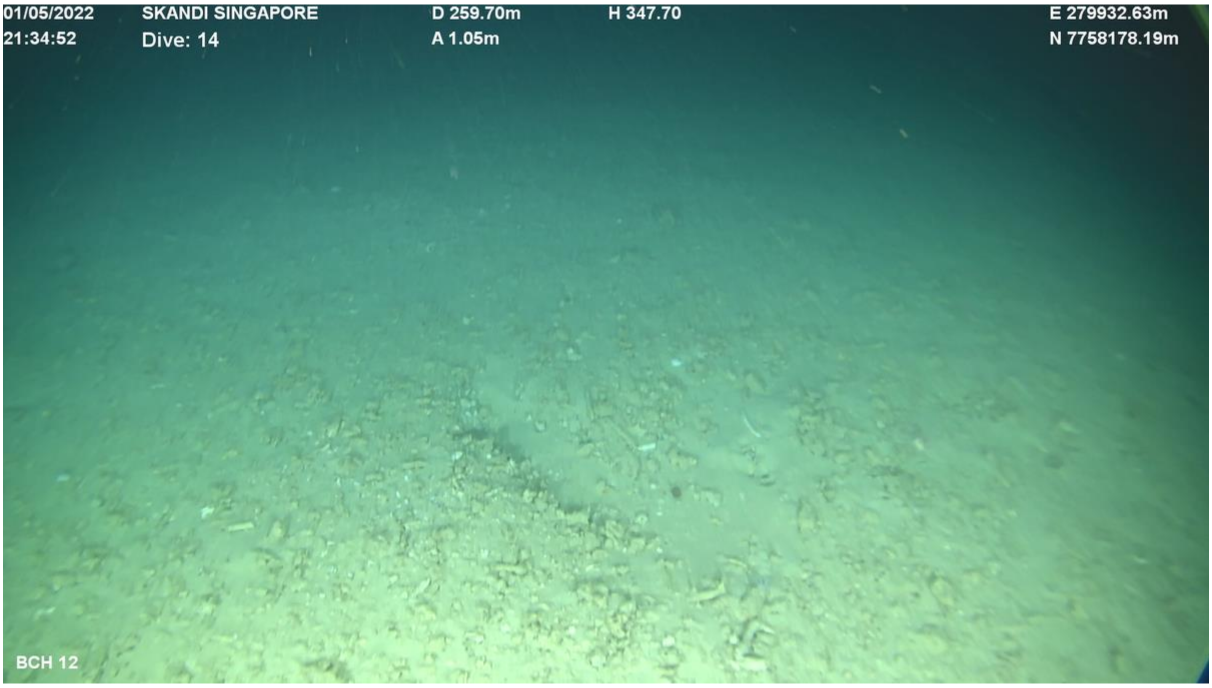
Low > Consolidated (hard) >Boulders > Bioturbation with biota and occasional veneer > Sponge and cnidaria



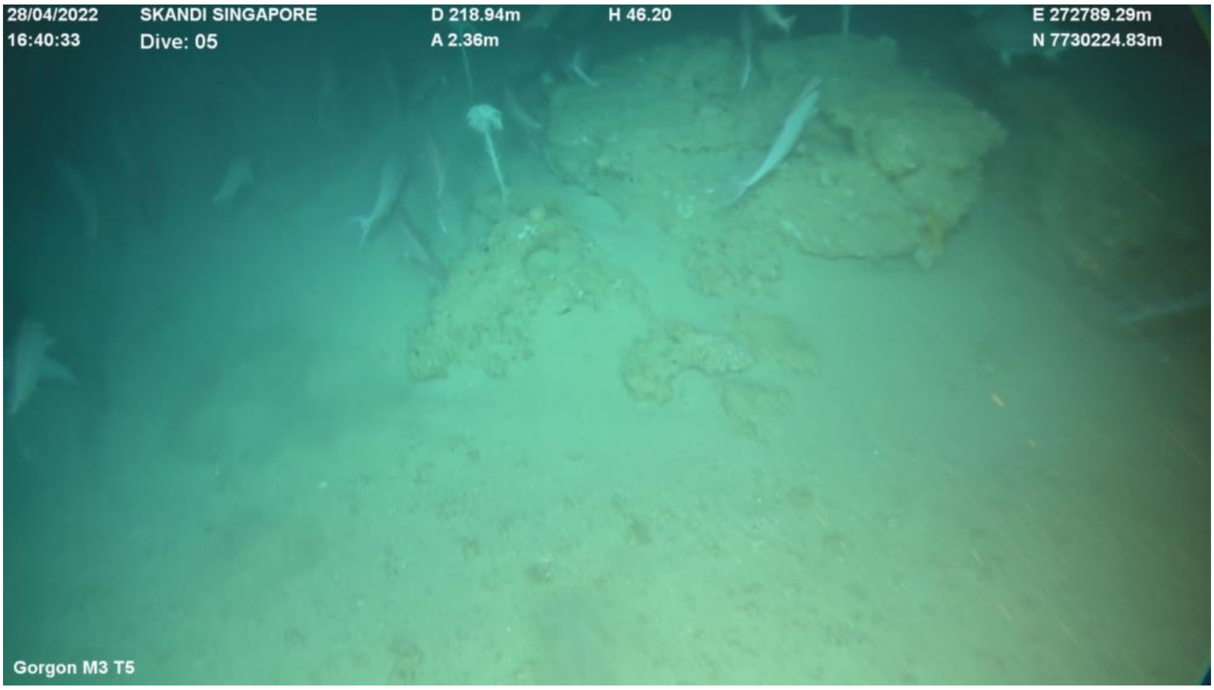
Low > Consolidated (hard) > Cobbles > Biota only > Cnidaria



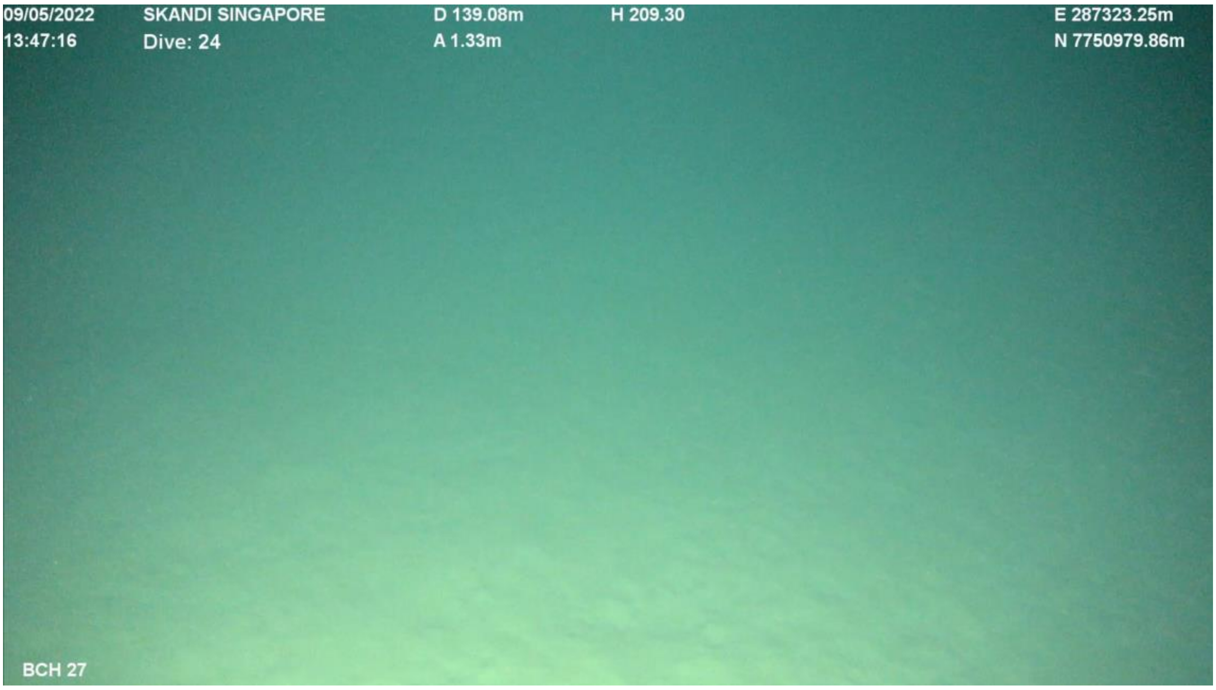
Low > Consolidated (hard) > Cobbles > Bare sediment



Low > Unconsolidated (soft) > Sand/mud (<2 mm) and occasional boulders > Bioturbation with biota > Mixed biota

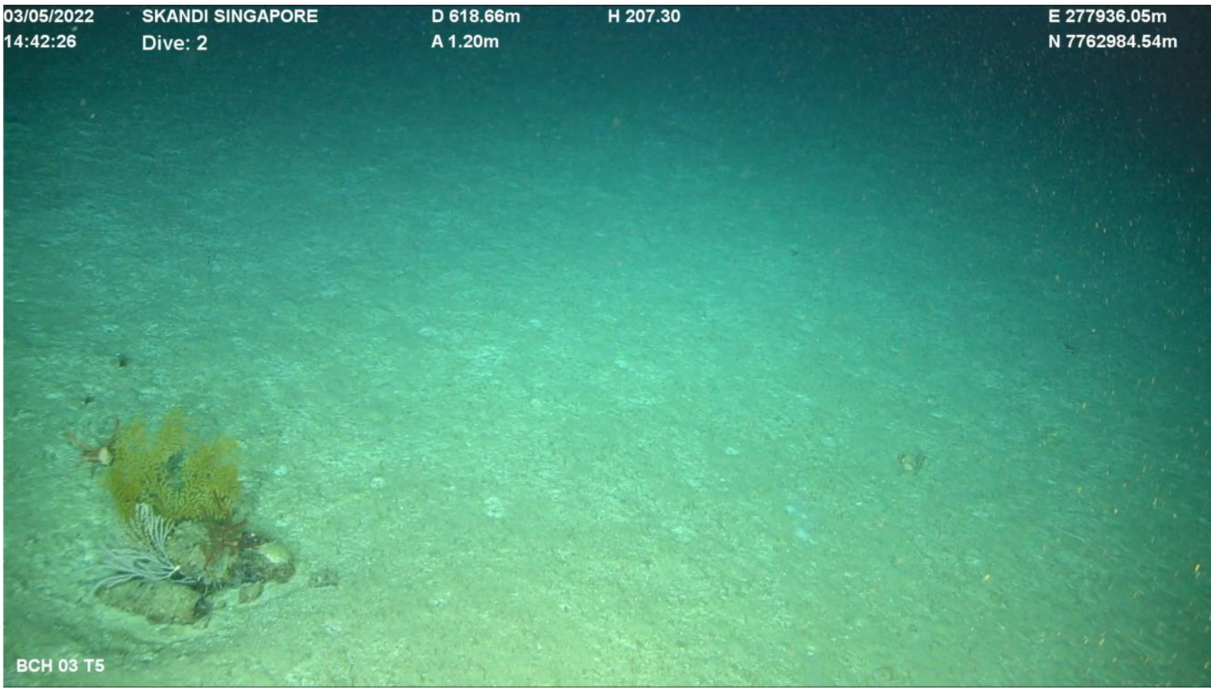


Low > Unconsolidated (soft) > Sand/mud (<2 mm) and occasional boulders > Bioturbation only

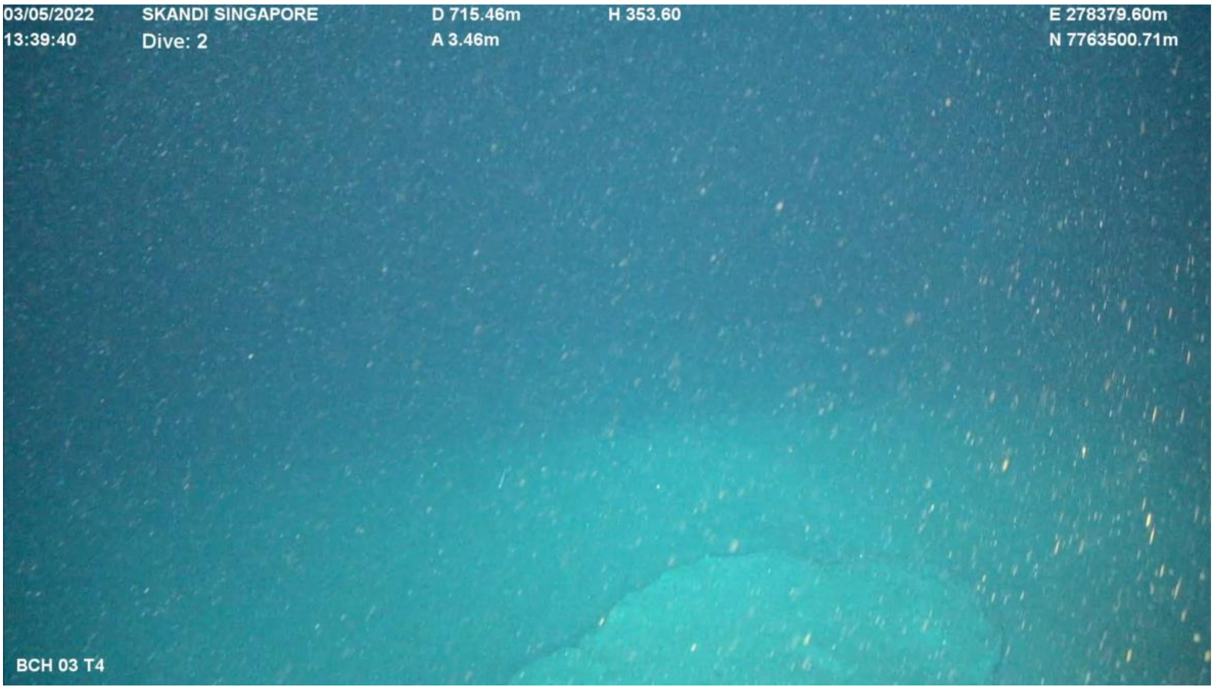


Low > Unconsolidated (soft) > Sand/mud (<2 mm) and occasional boulders > Biota only > Sponge and cnidaria

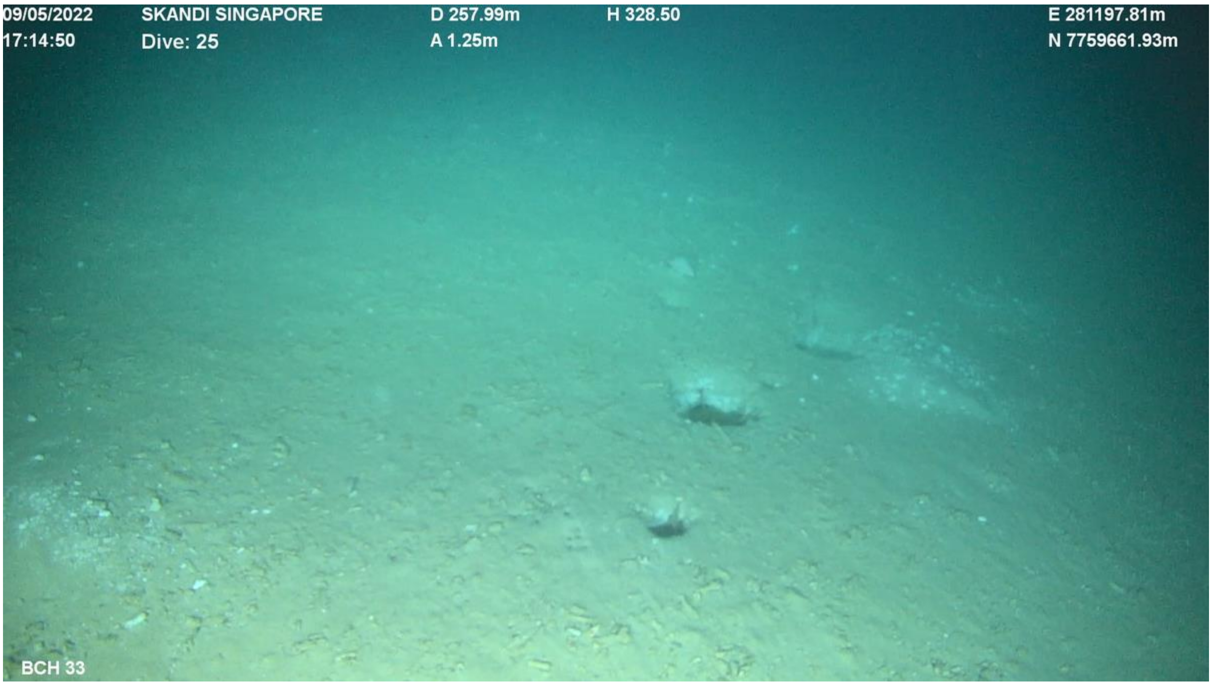
Low > Unconsolidated (soft) > Sand/mud (<2 mm) and occasional boulders > Biota only > Mixed biota



Low > Unconsolidated (soft) > Sand/mud (<2 mm) and occasional boulders > Bare sediment

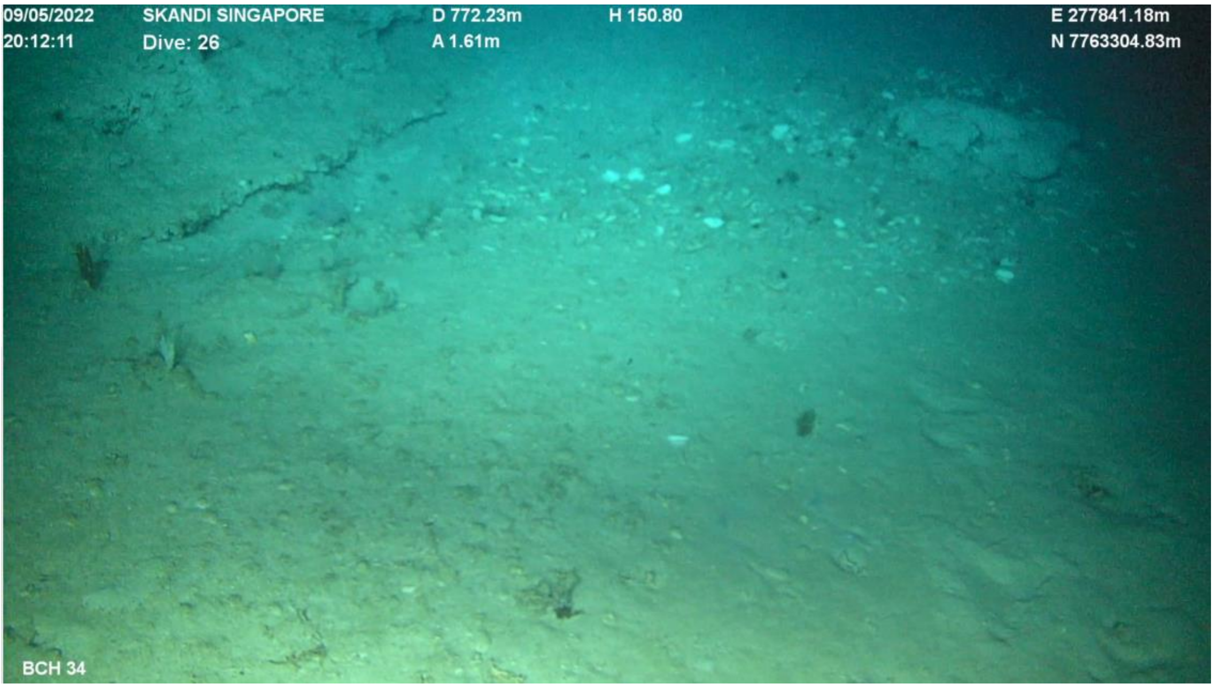


Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation and occasional veneer only

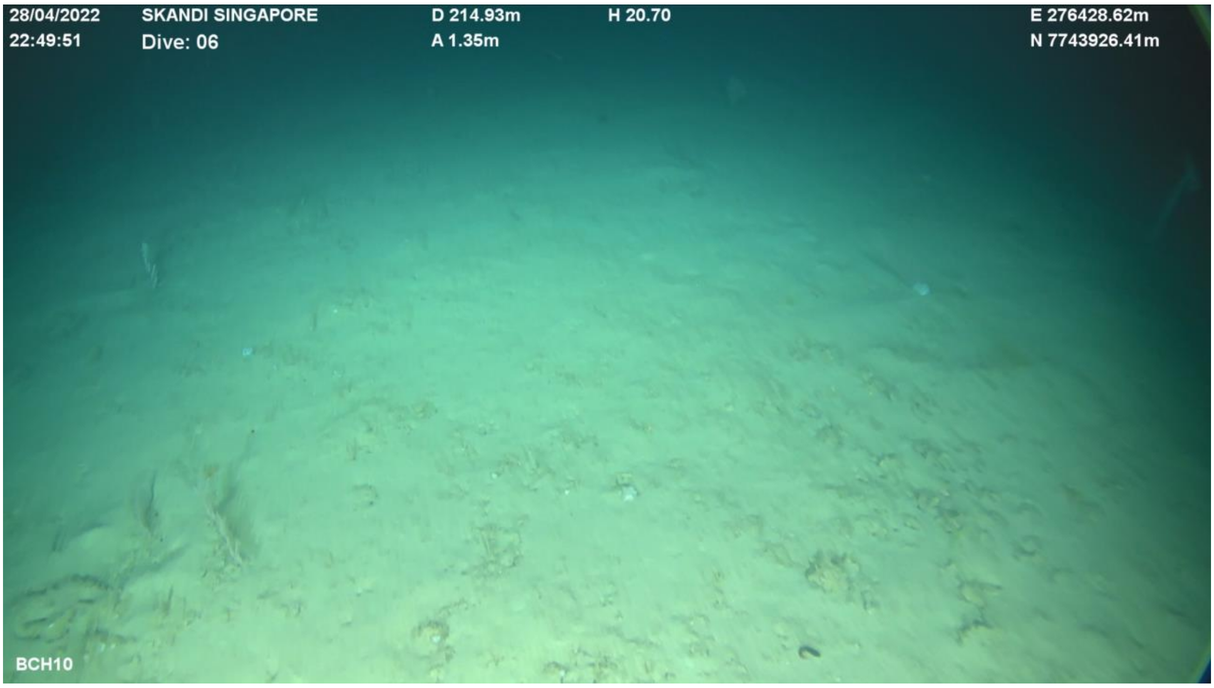


Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer > Cnidaria

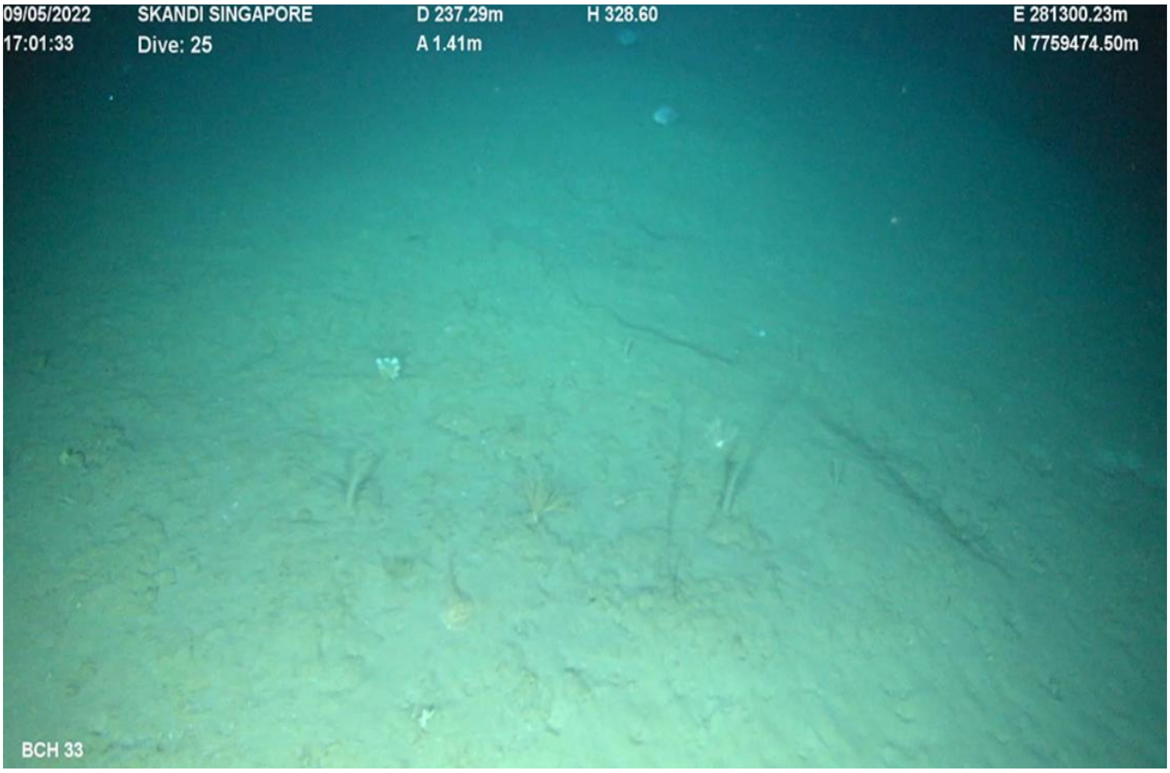
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer > Sponge



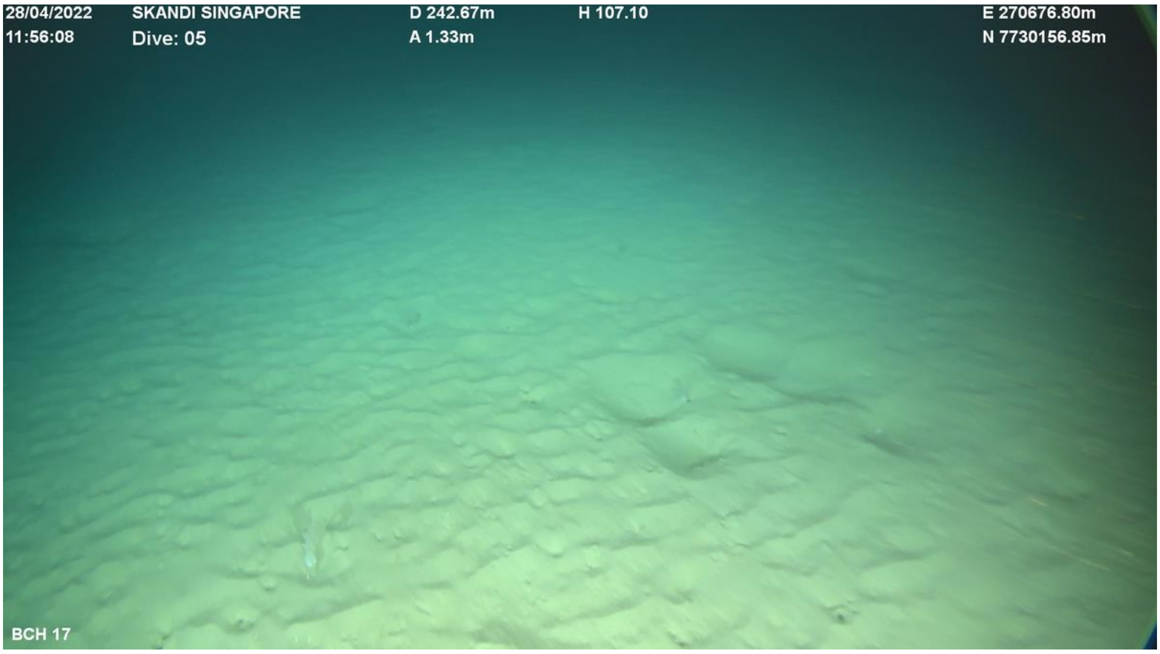
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer > Sponge and cnidaria



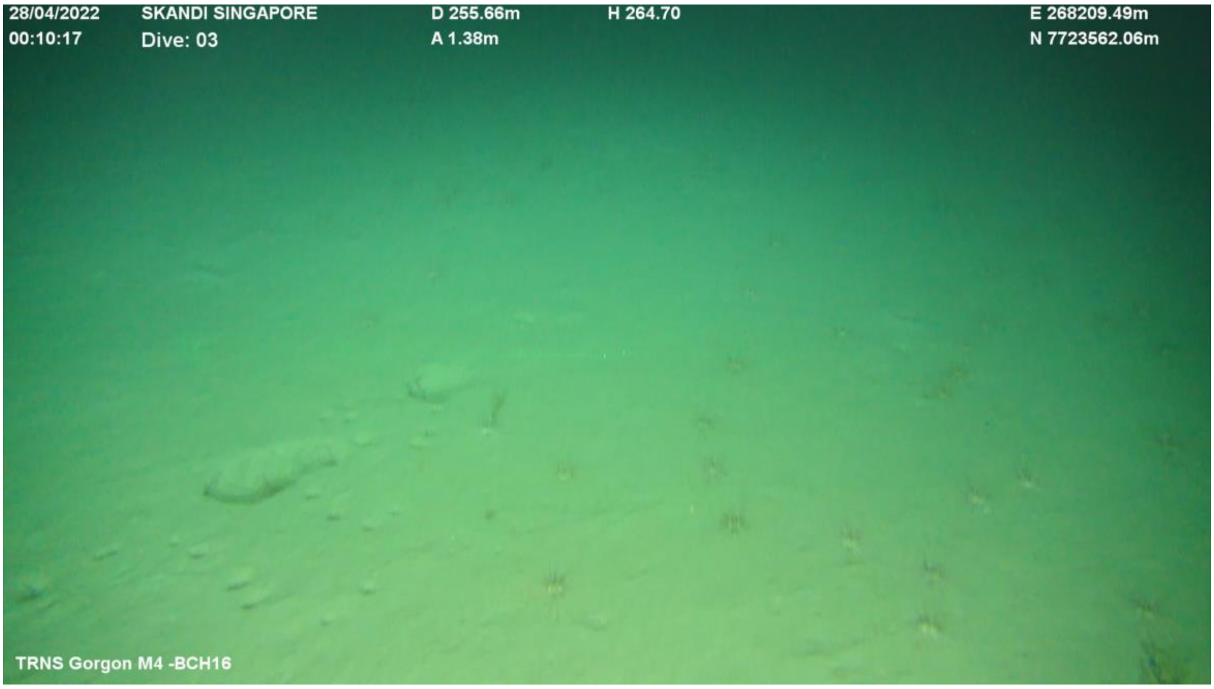
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer > Mixed biota



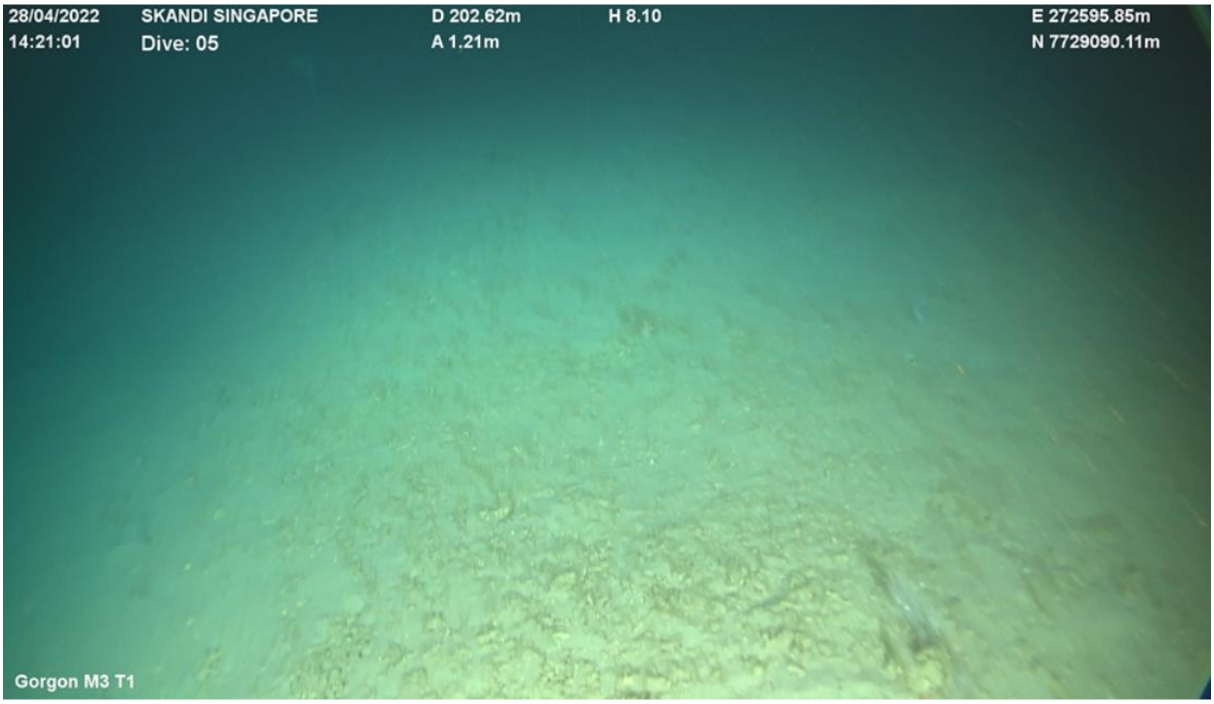
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Cnidaria



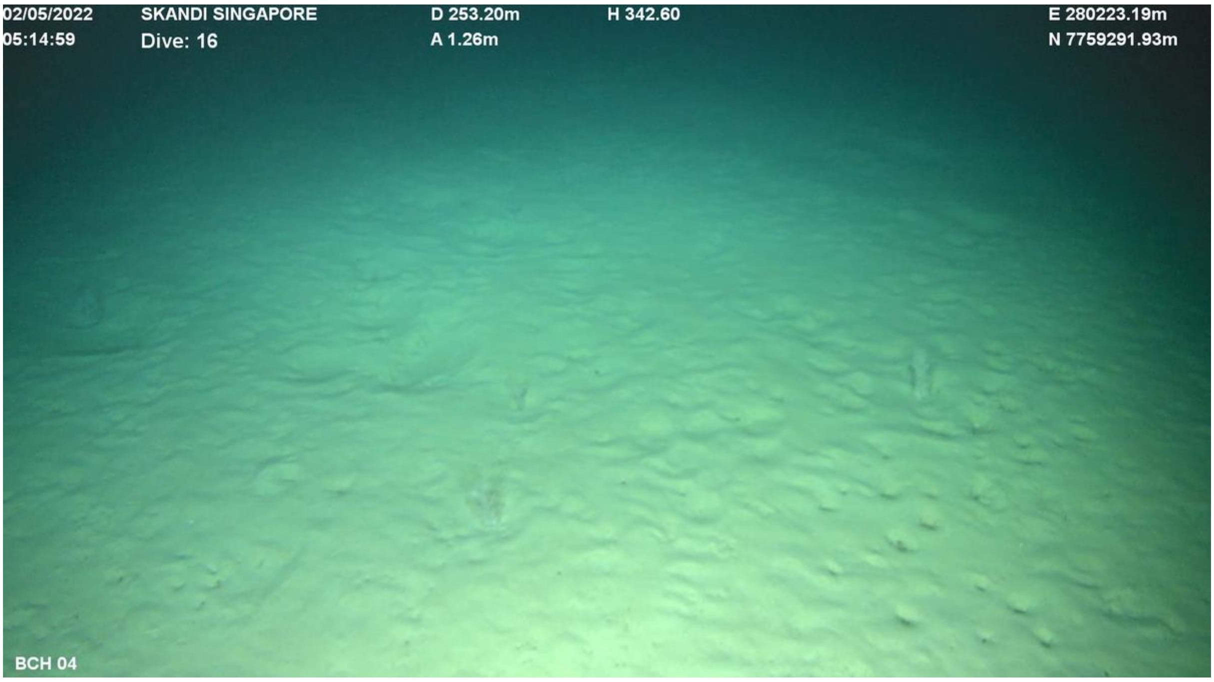
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Echinoderm



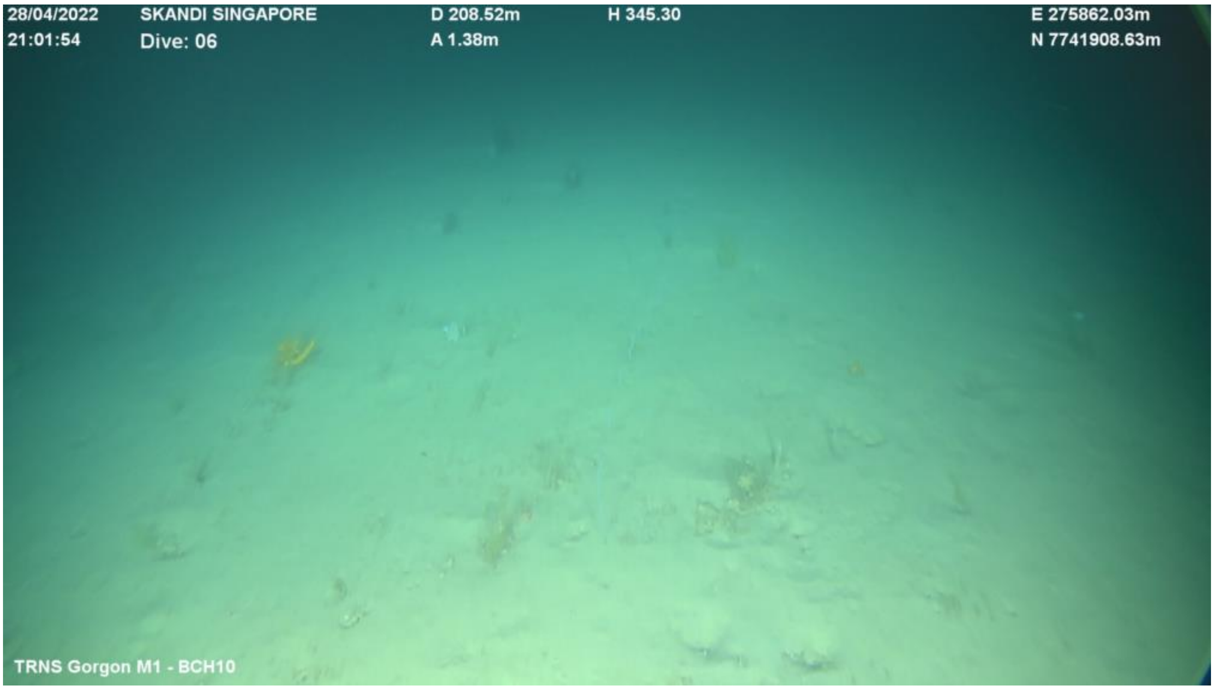
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Sponge



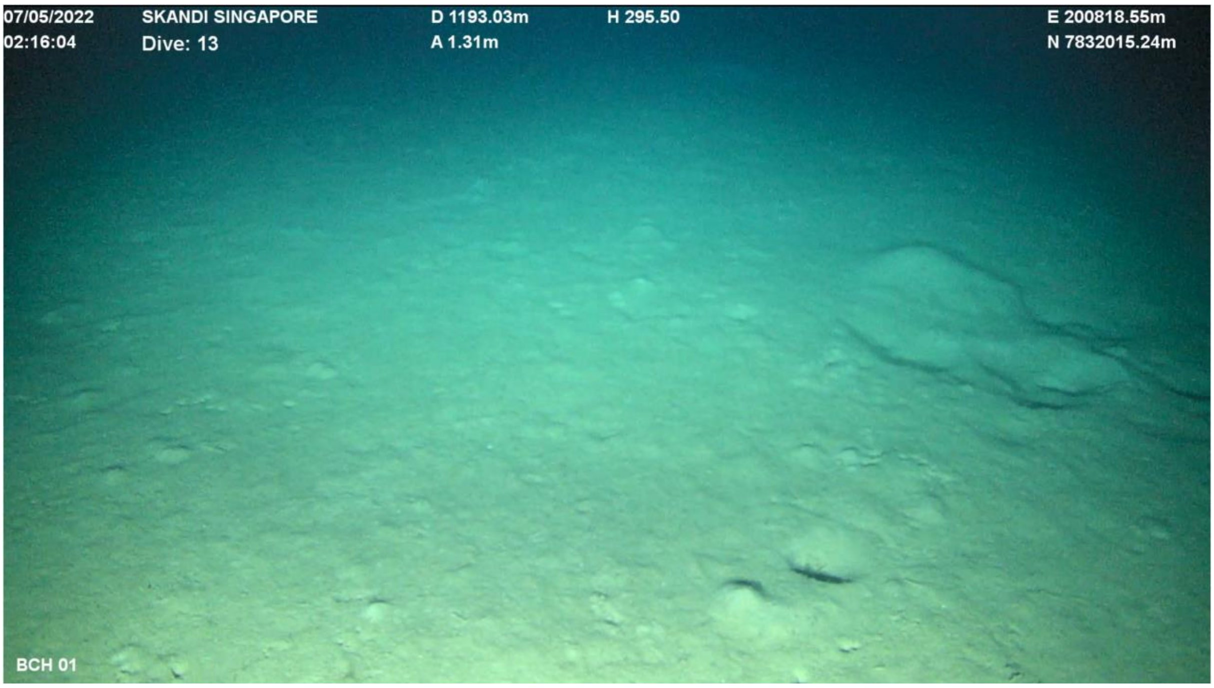
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Sponge and cnidaria



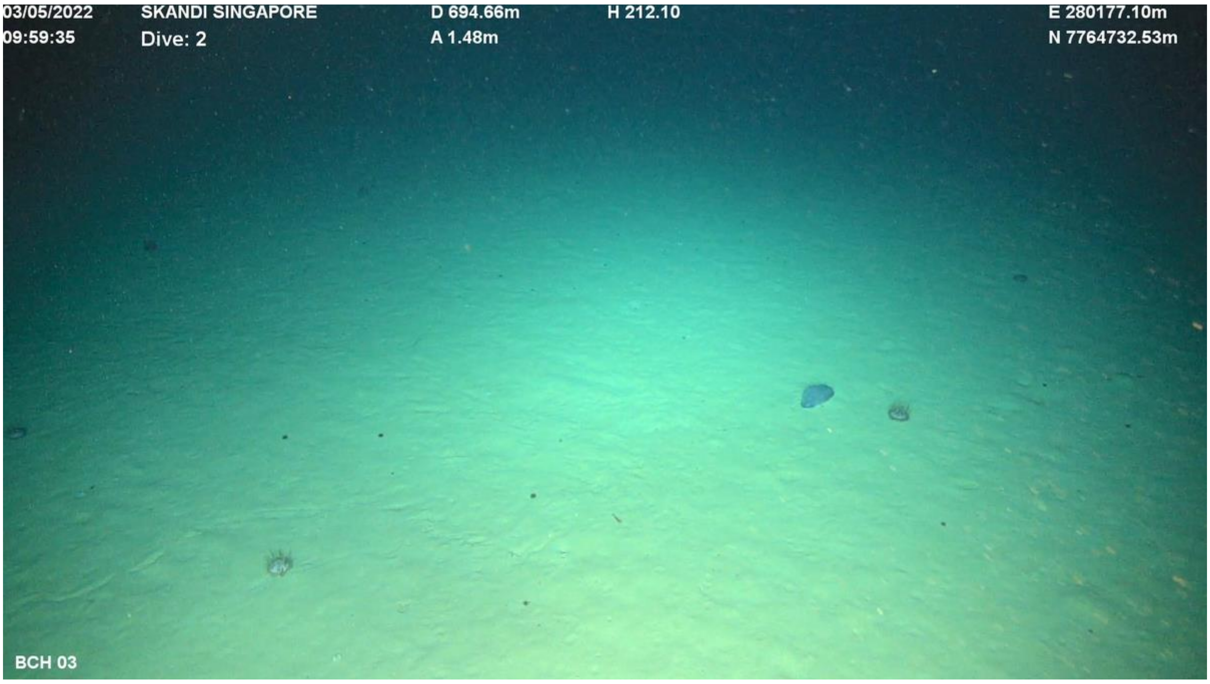
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Mixed biota



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation only

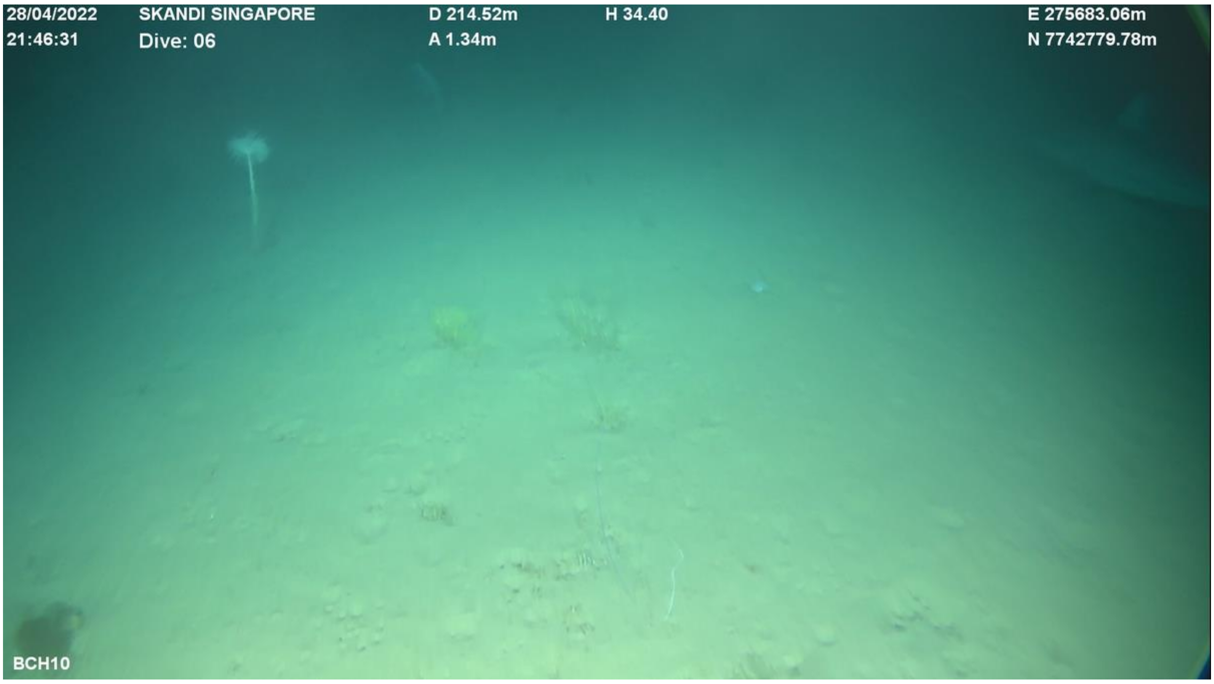


Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Biota only > Echinoderms



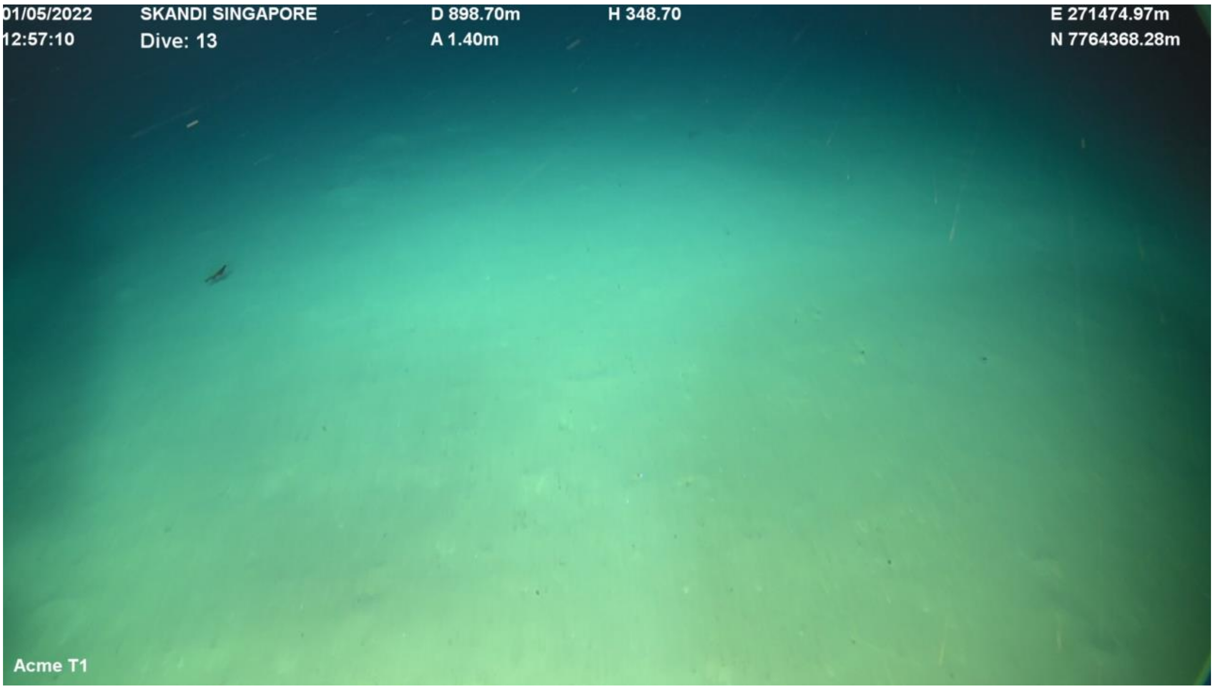
Advisian
Worley Group

Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Biota only > Cnidaria

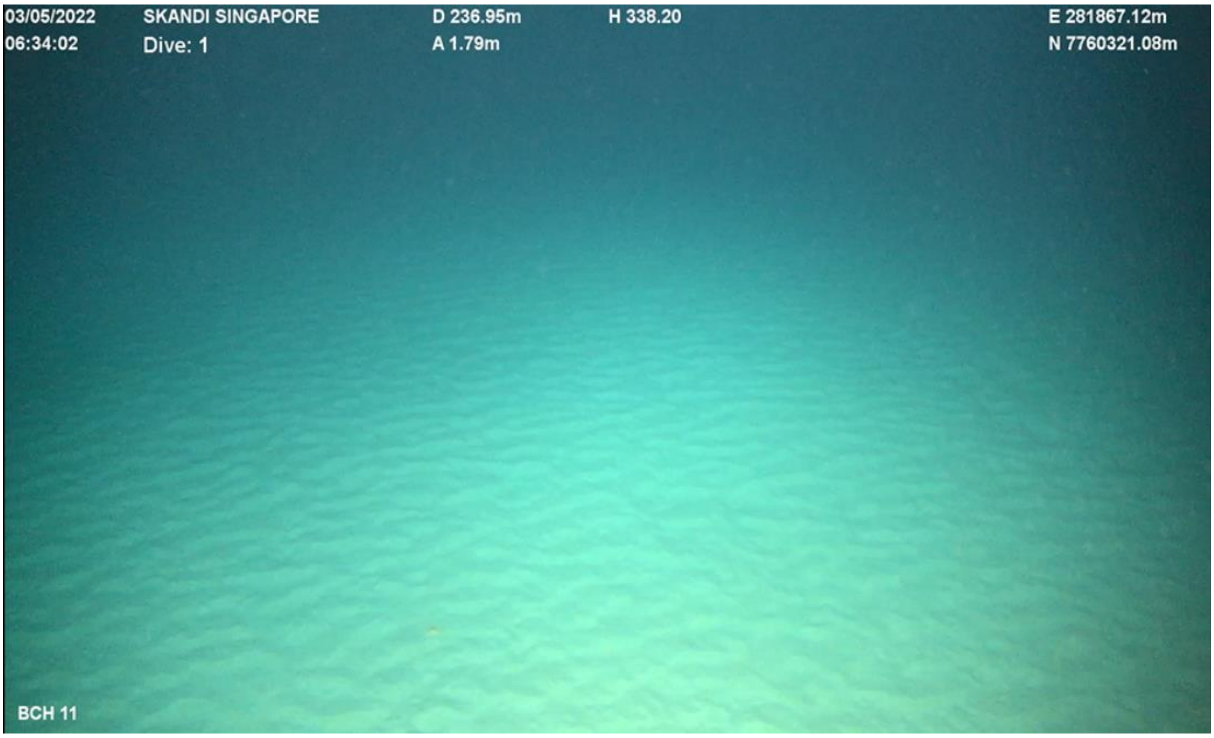


Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Biota only > Cnidaria and echinoderms

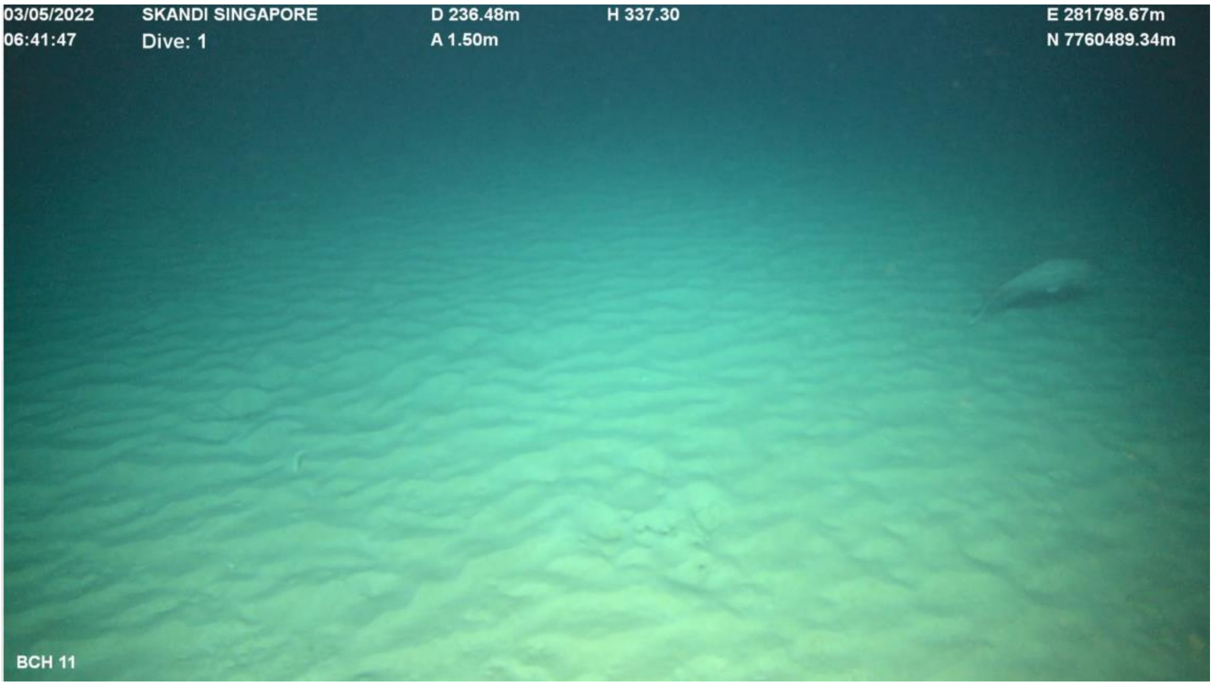
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Bare sediment



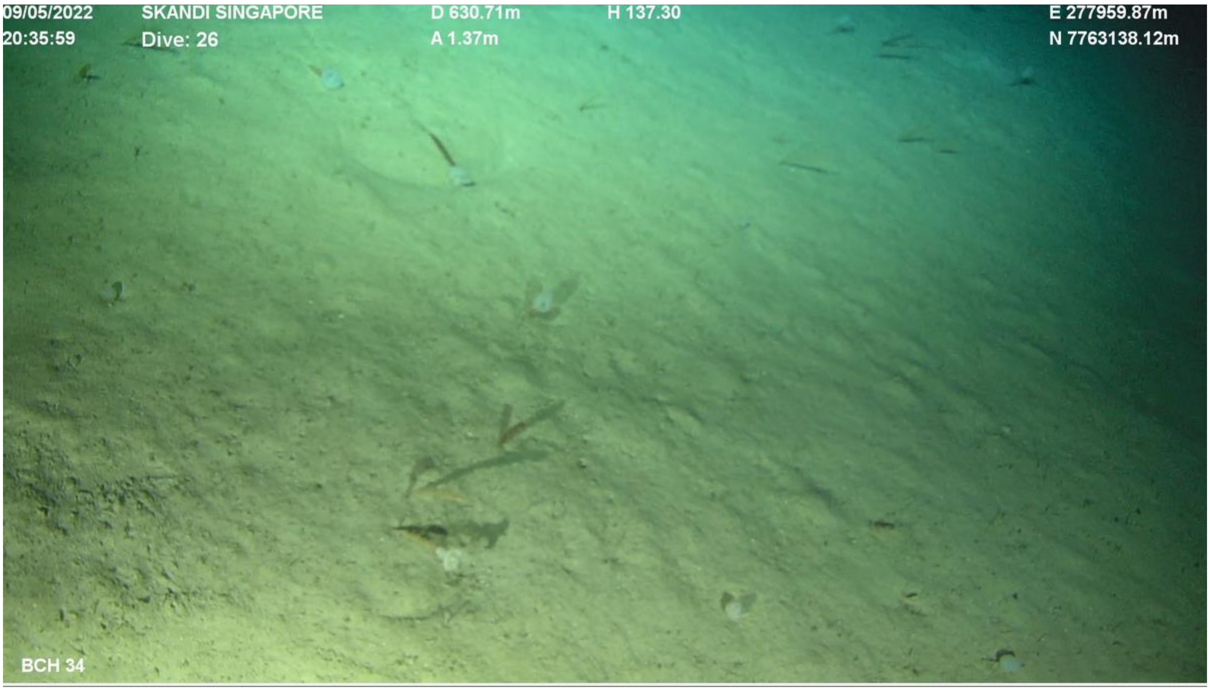
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Ripples (<10 cm height) with bare sediment



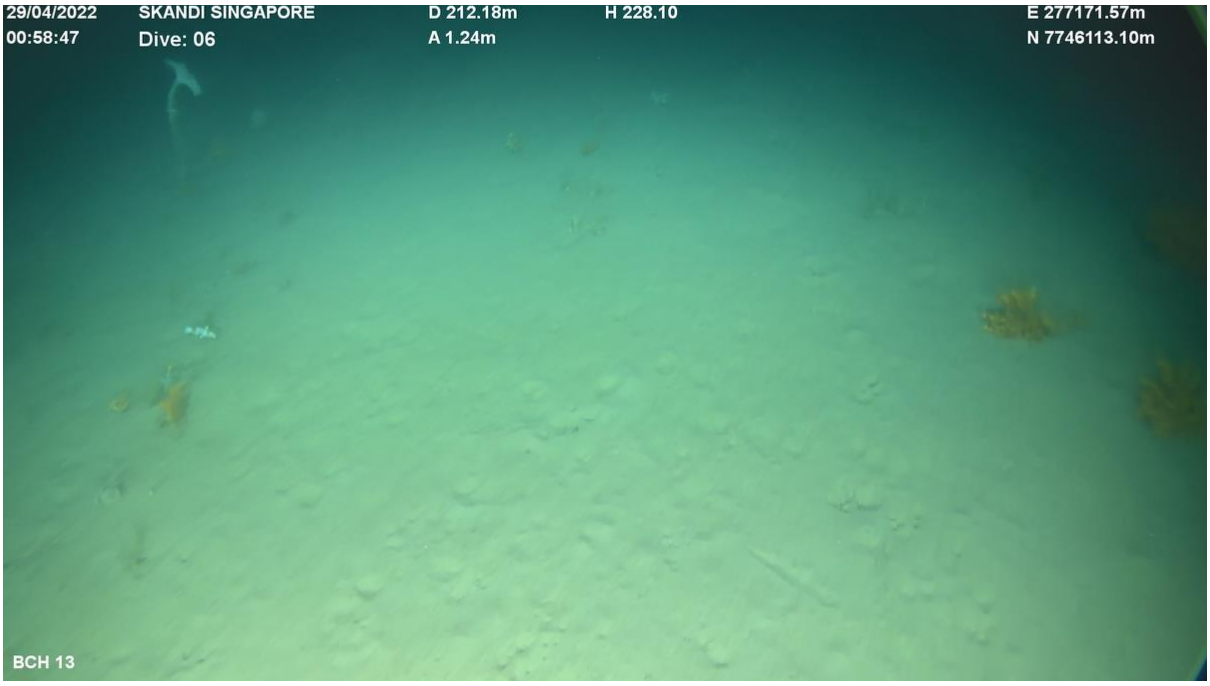
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Ripples (<10 cm height) with biota > Sponges and cnidaria



Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Biota only > Sponge



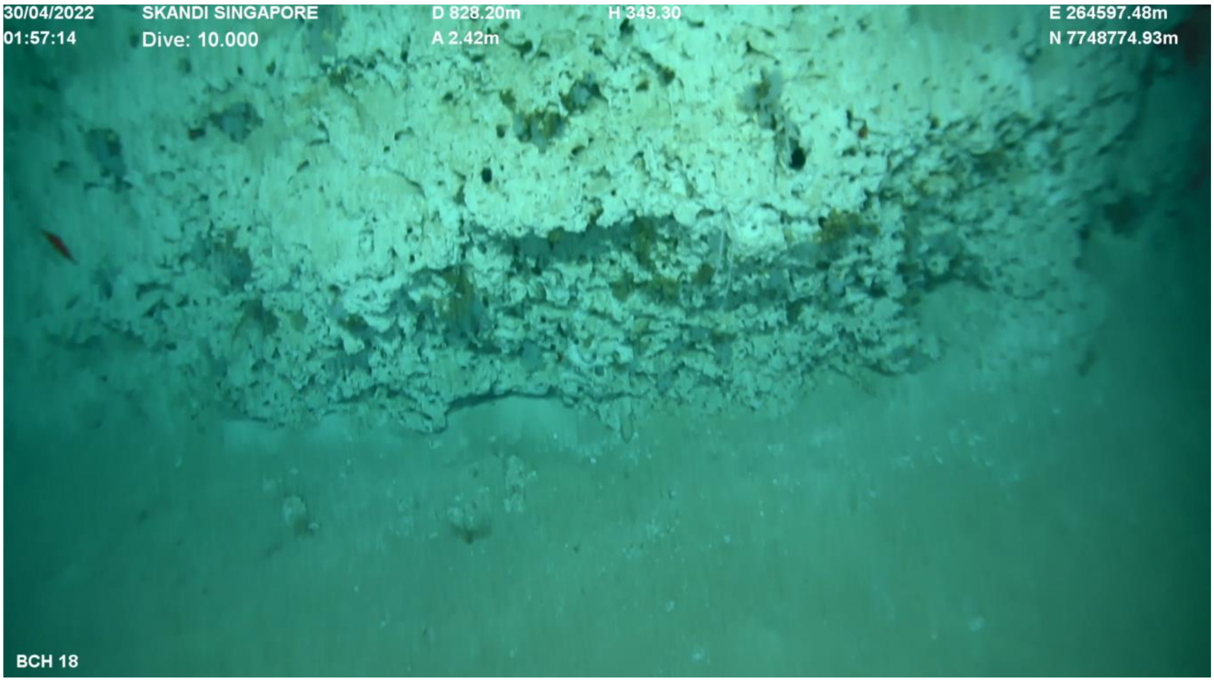
Low > Unconsolidated (soft) > Sand/mud (<2 mm) > Biota only > Sponge and cnidaria



Advisian
Worley Group

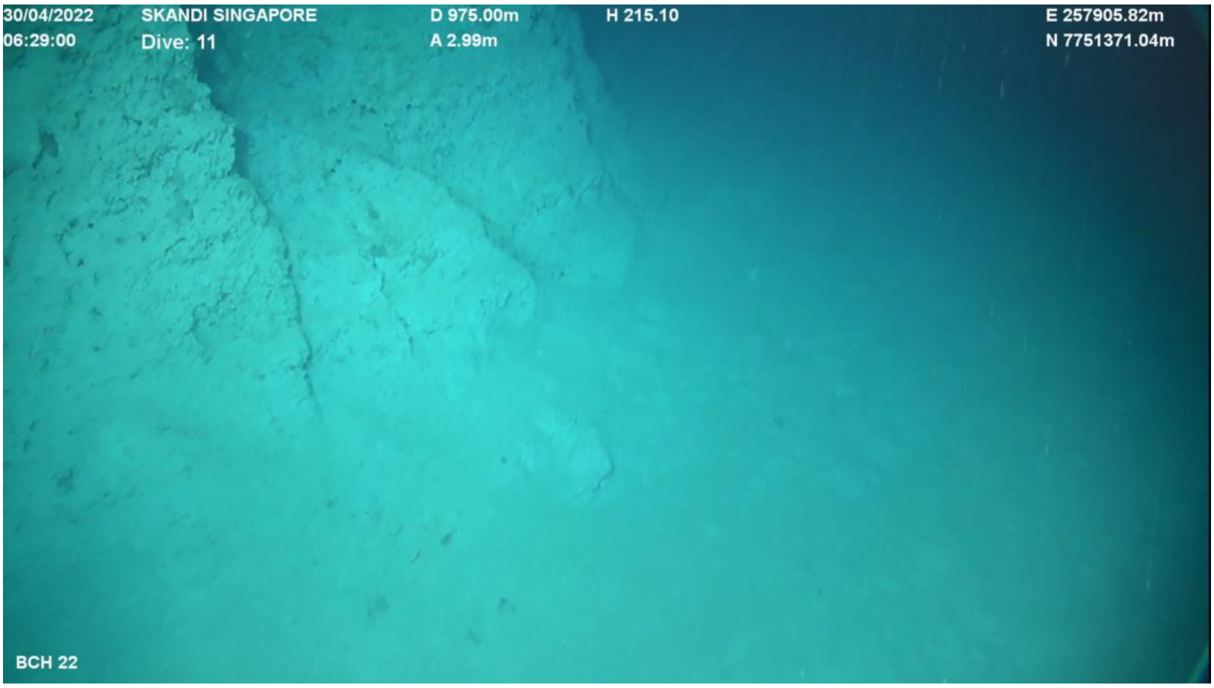
Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation with biota and occasional veneer > Sponge

Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation with biota and occasional veneer > Sponge and cnidaria

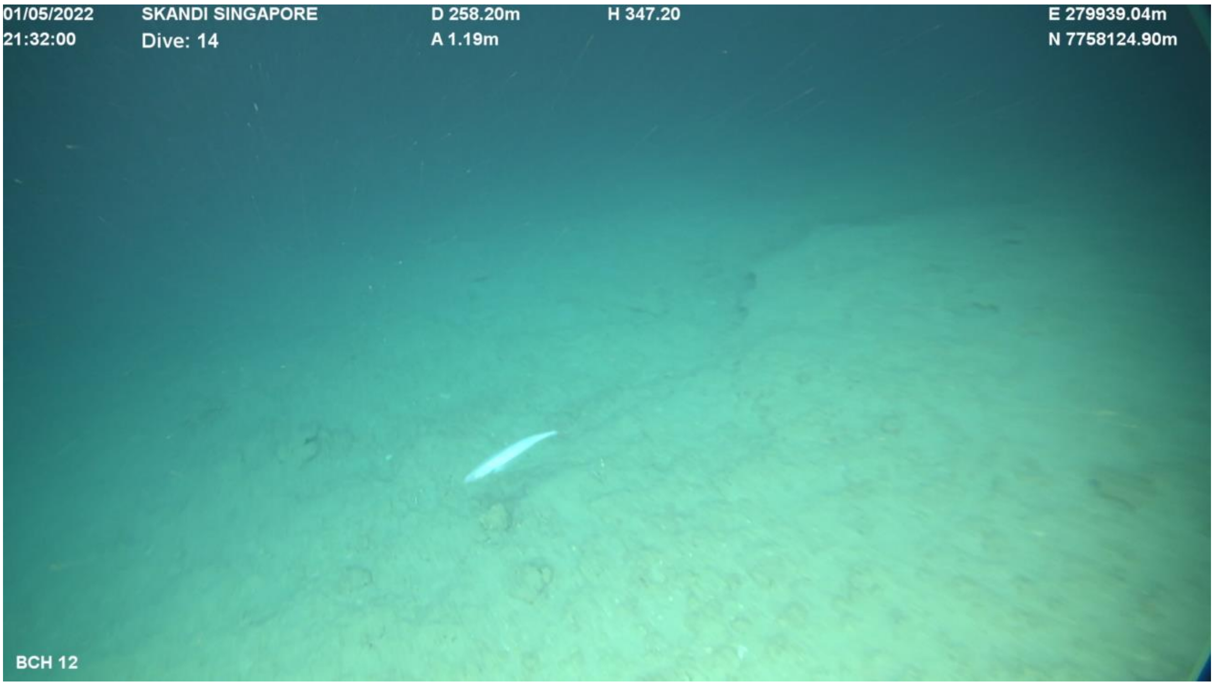


Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation with biota and occasional veneer > Mixed biota

Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Bioturbation only



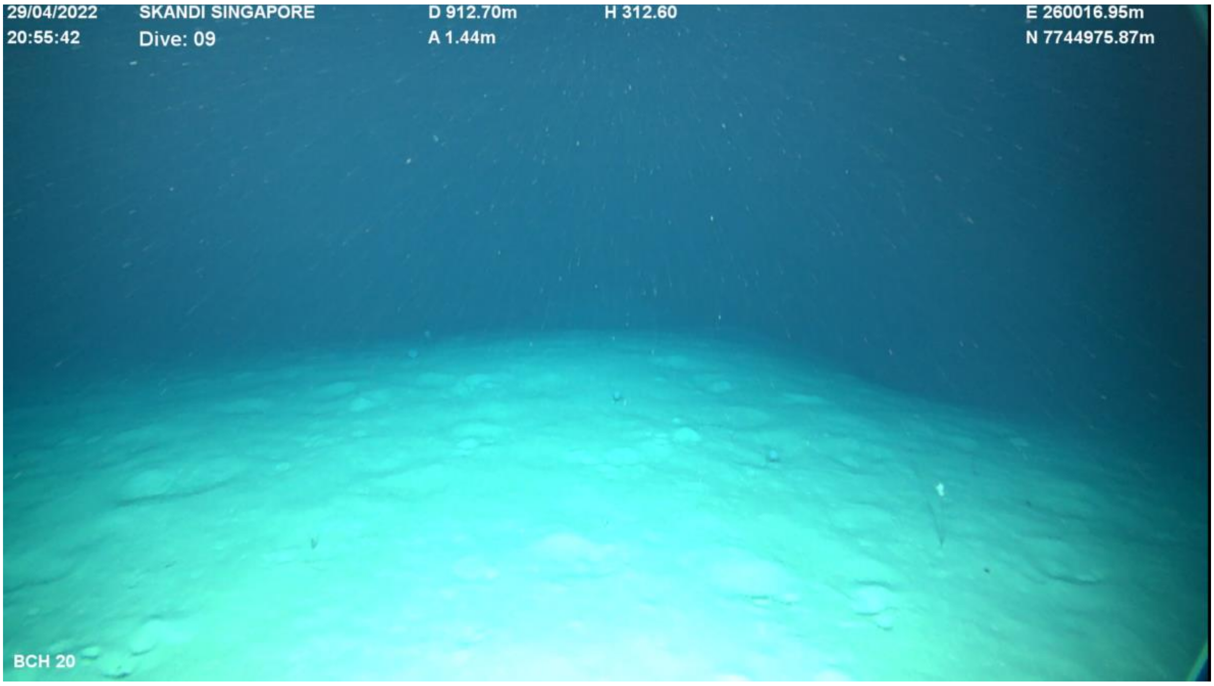
Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Bare sediment



Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Sponge and cnidaria

Advisian
Worley Group

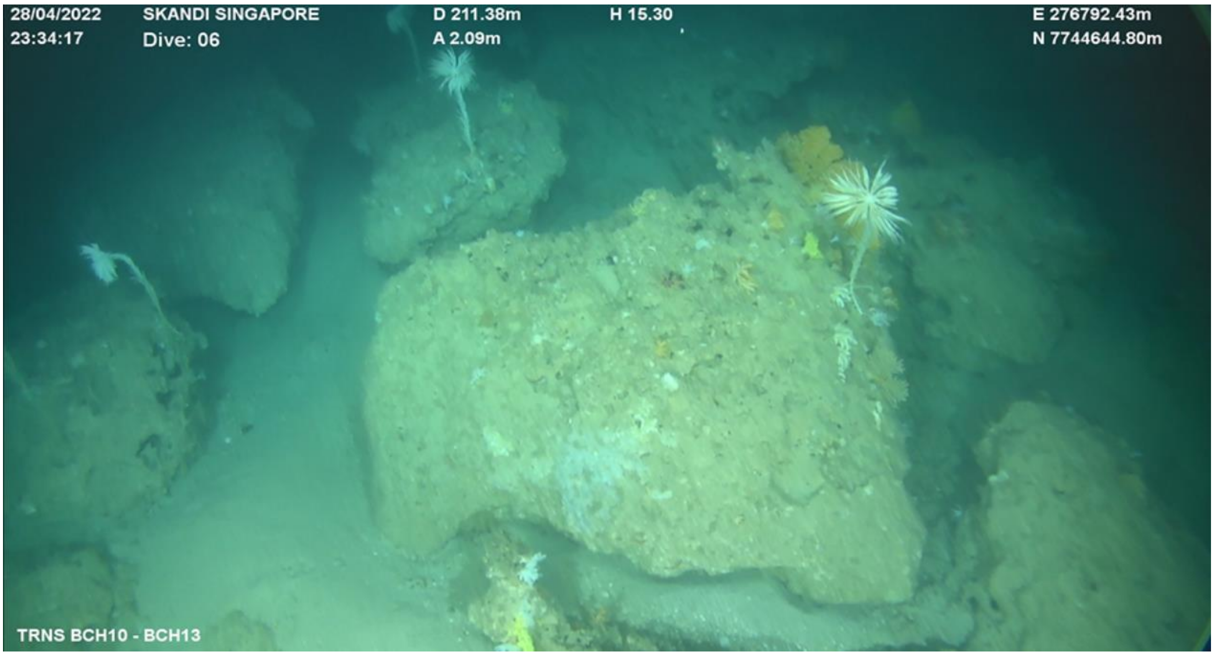
Moderate > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota> Sponge and cnidaria



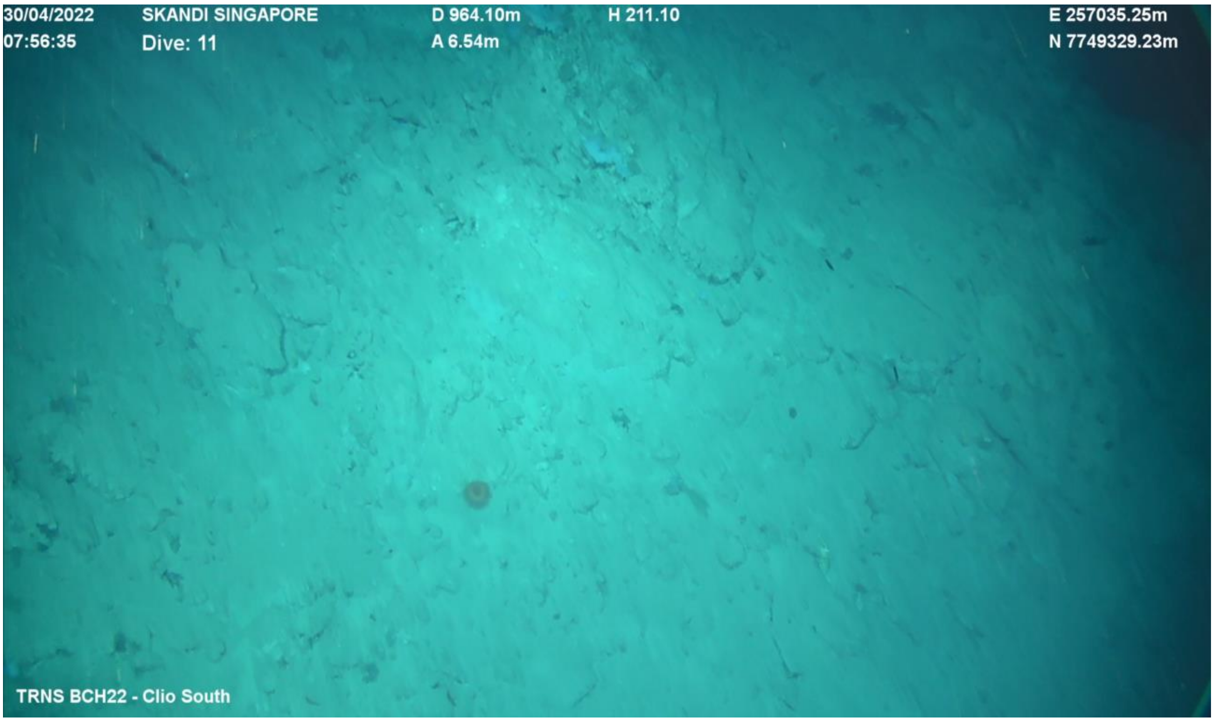
Moderate > Consolidated (hard) > Boulders > Biota only > Cnidaria

Advisian
Worley Group

Moderate > Consolidated (hard) > Boulders > Biota only > Mixed biota



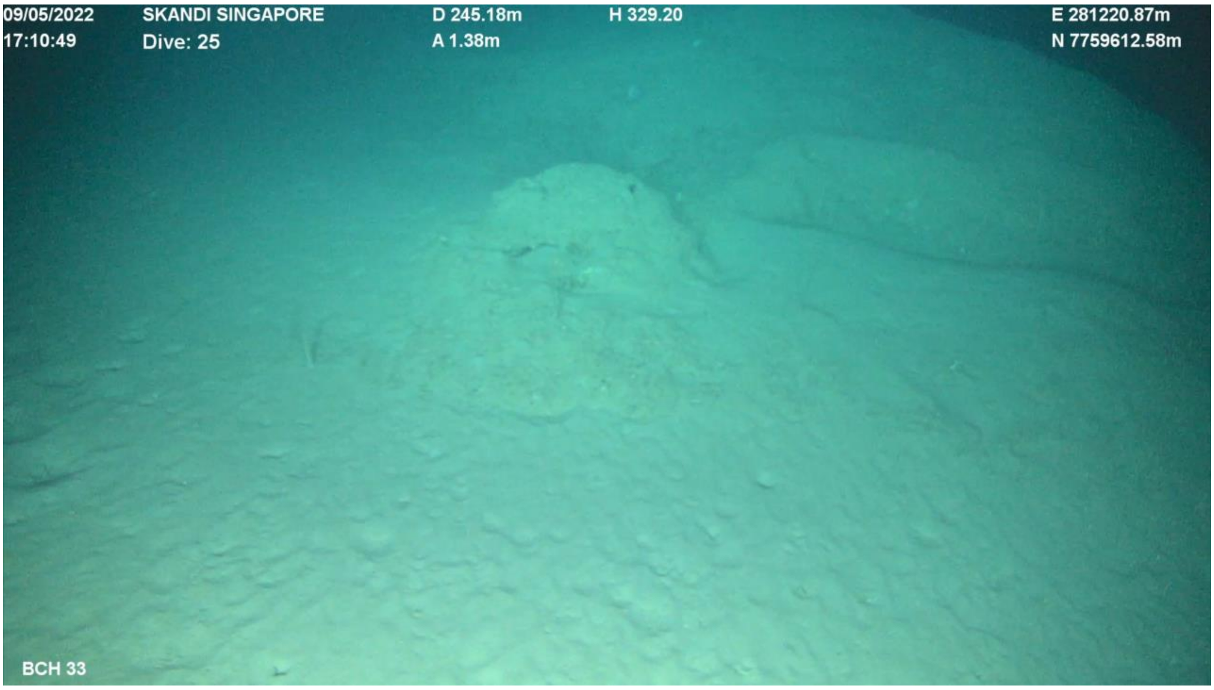
Moderate > Consolidated (hard) > Cobbles > Bioturbation with biota > Sponge and echinoderms



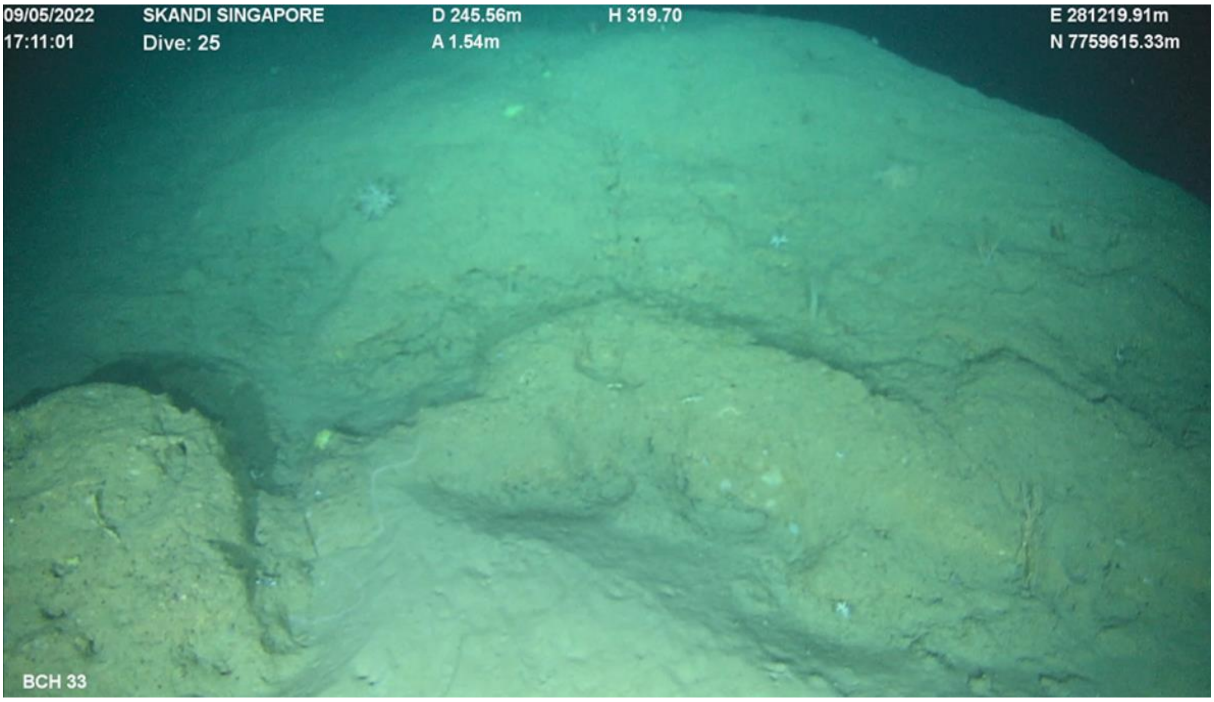
Moderate > Consolidated (hard) > Cobbles > Bare sediment

Moderate > Consolidated (hard) > Cobbles > Biota only > Sponge and cnidaria

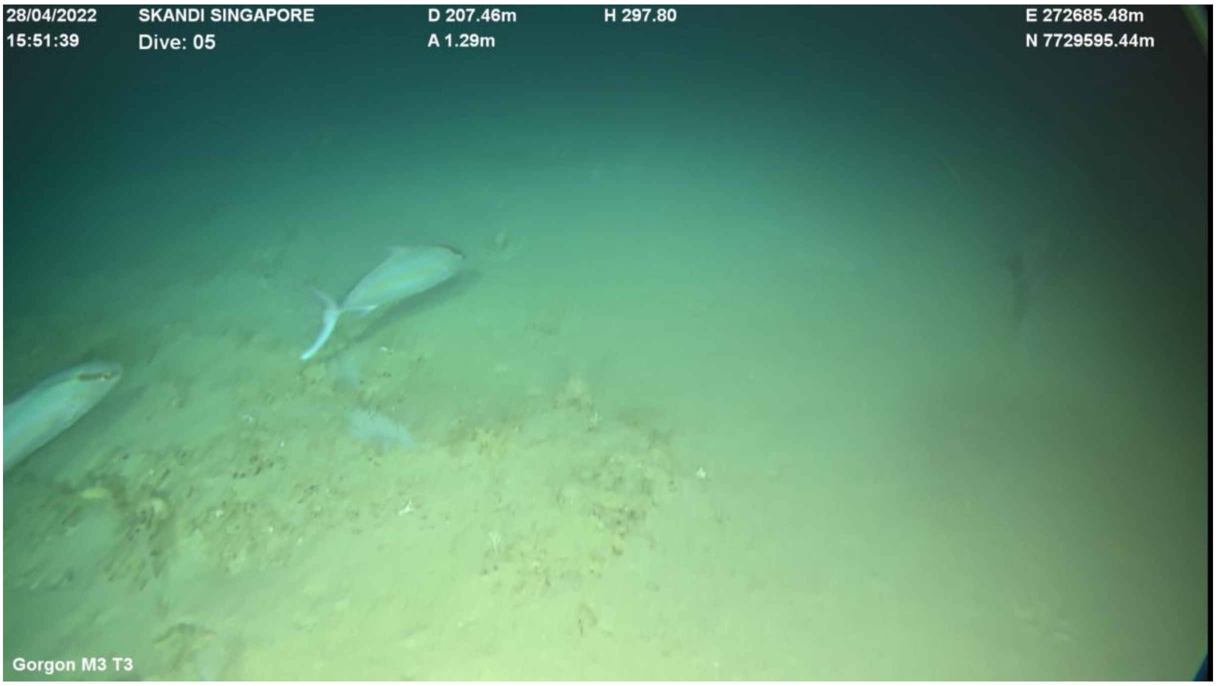
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) and occasional boulders > Bioturbation with biota and occasional veneer > Sponge



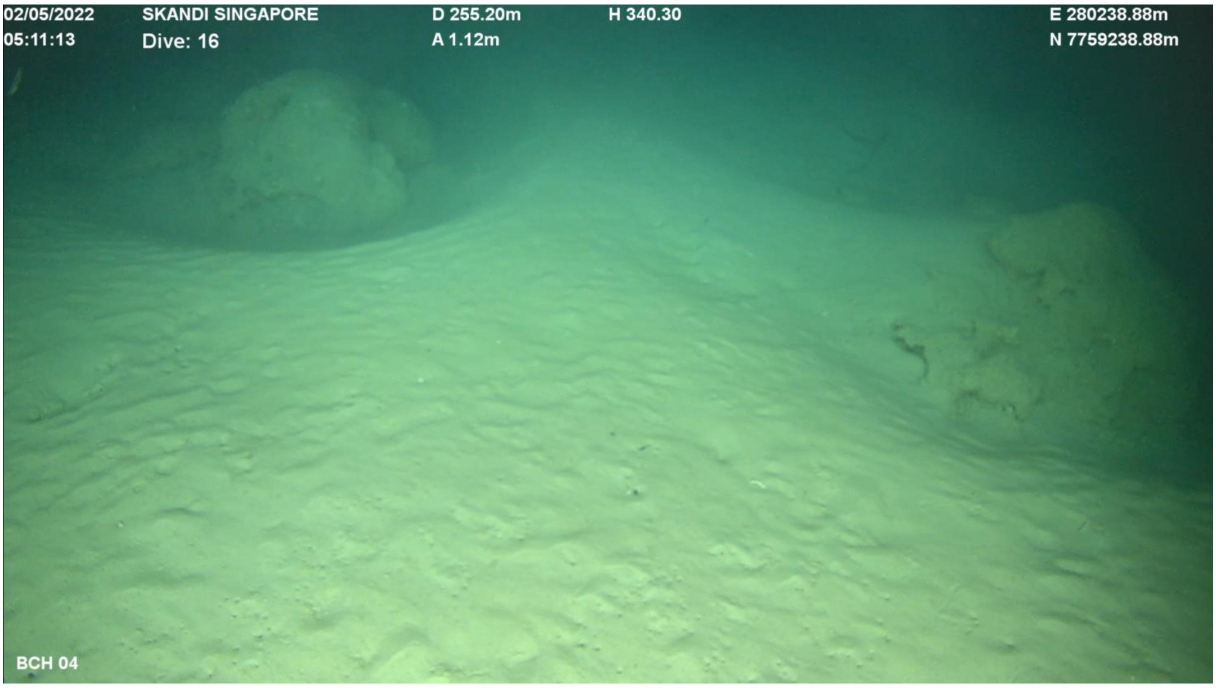
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) and occasional boulders > Bioturbation with biota and occasional veneer > Mixed biota



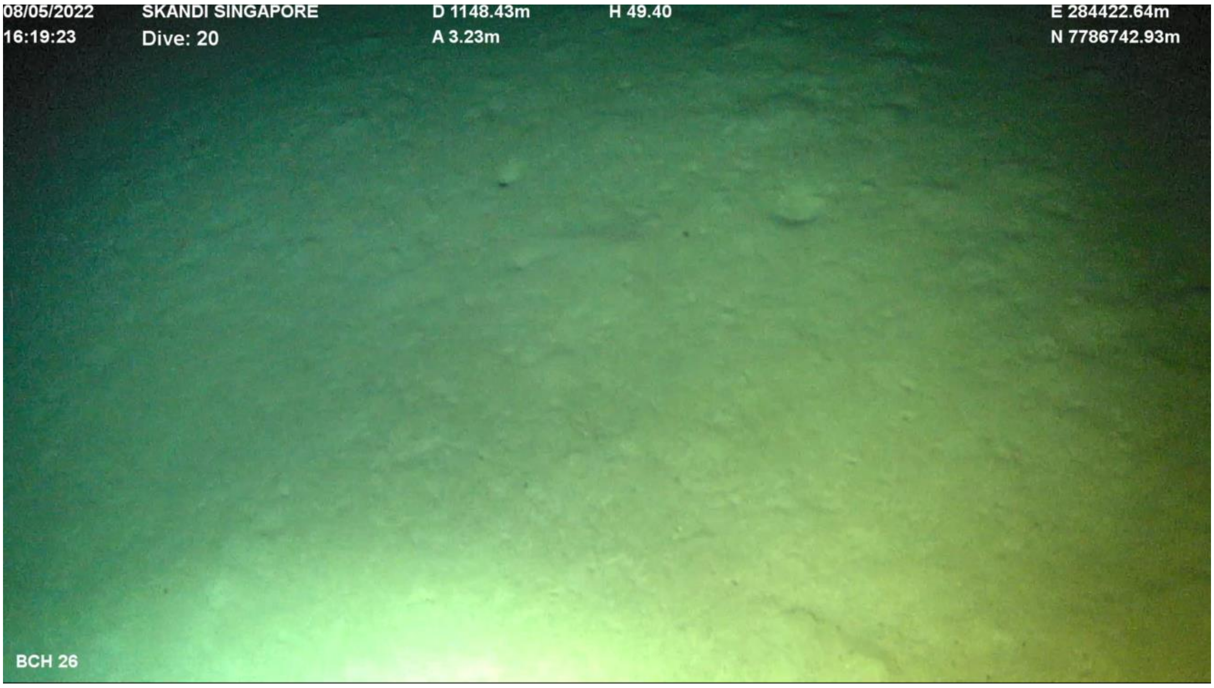
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) and occasional boulders > Bioturbation with biota and occasional veneer > Mixed biota



Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) and occasional boulders > Bare sediment

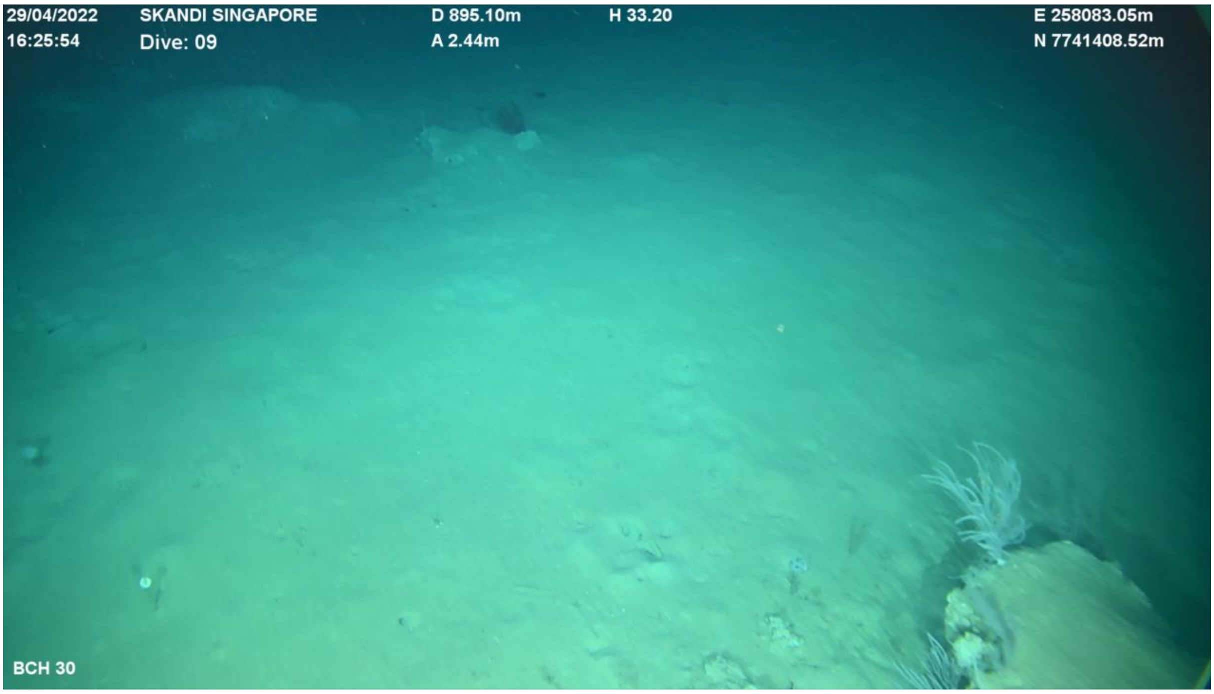


Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with occasional veneer

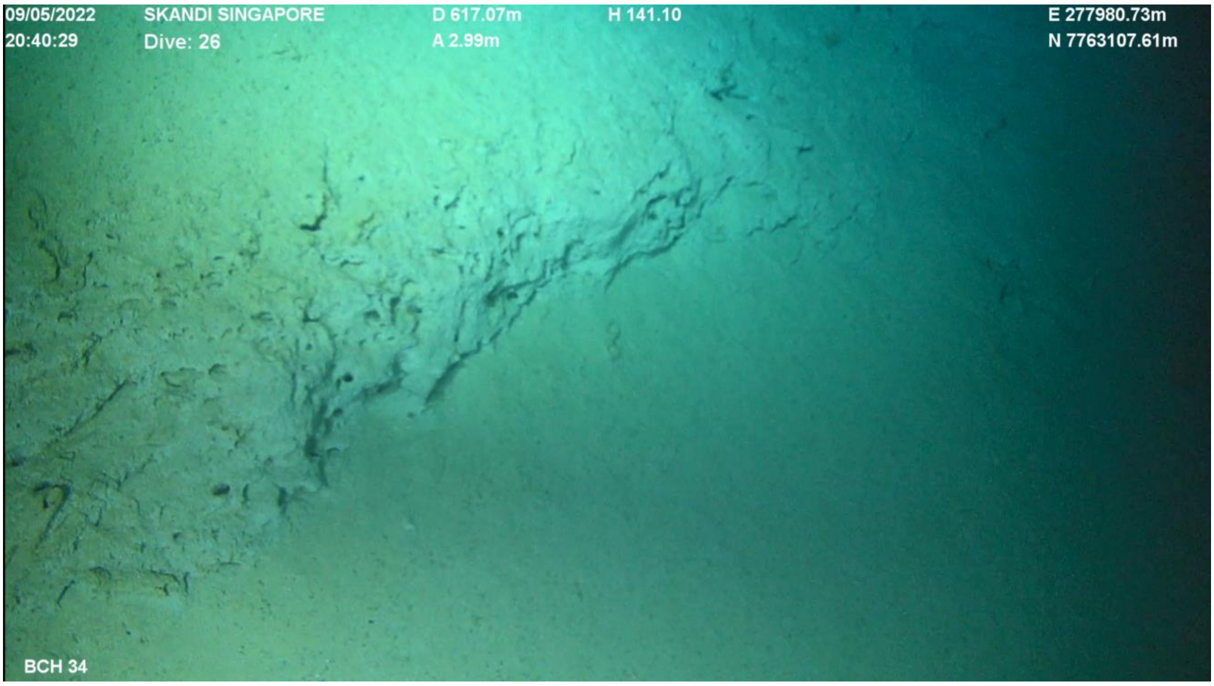


Advisian
Worley Group

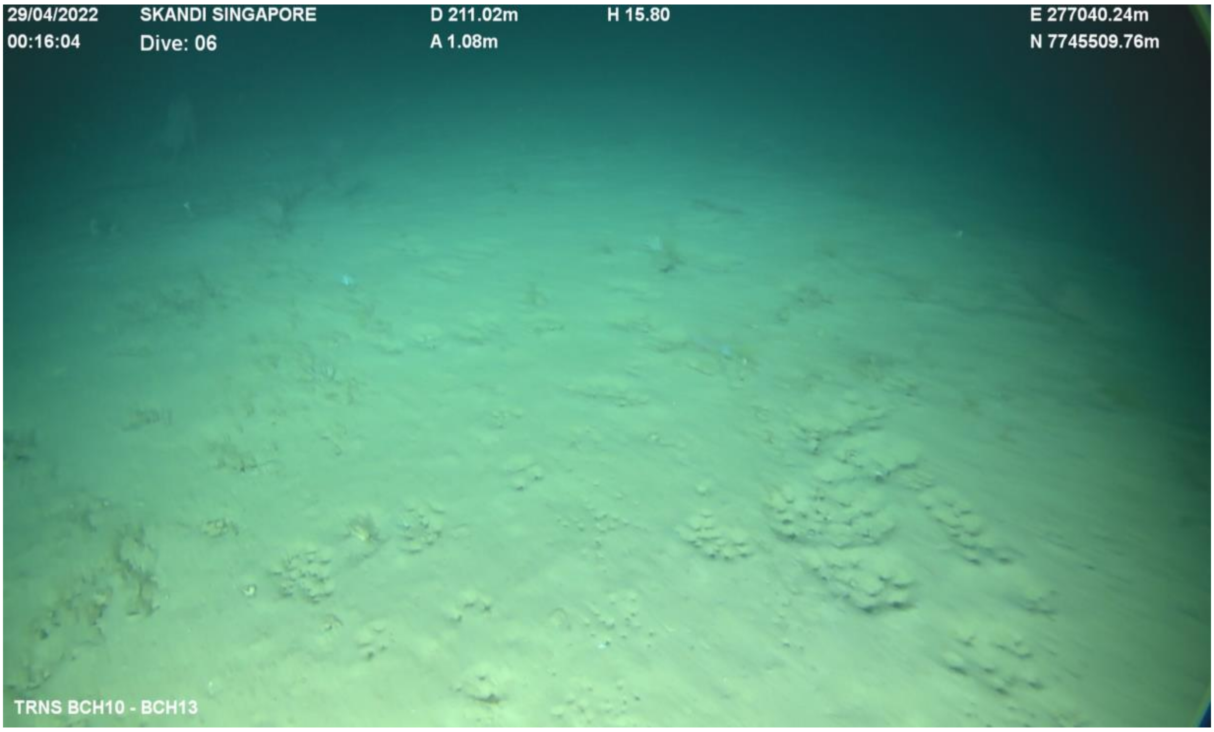
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer> Cnidaria



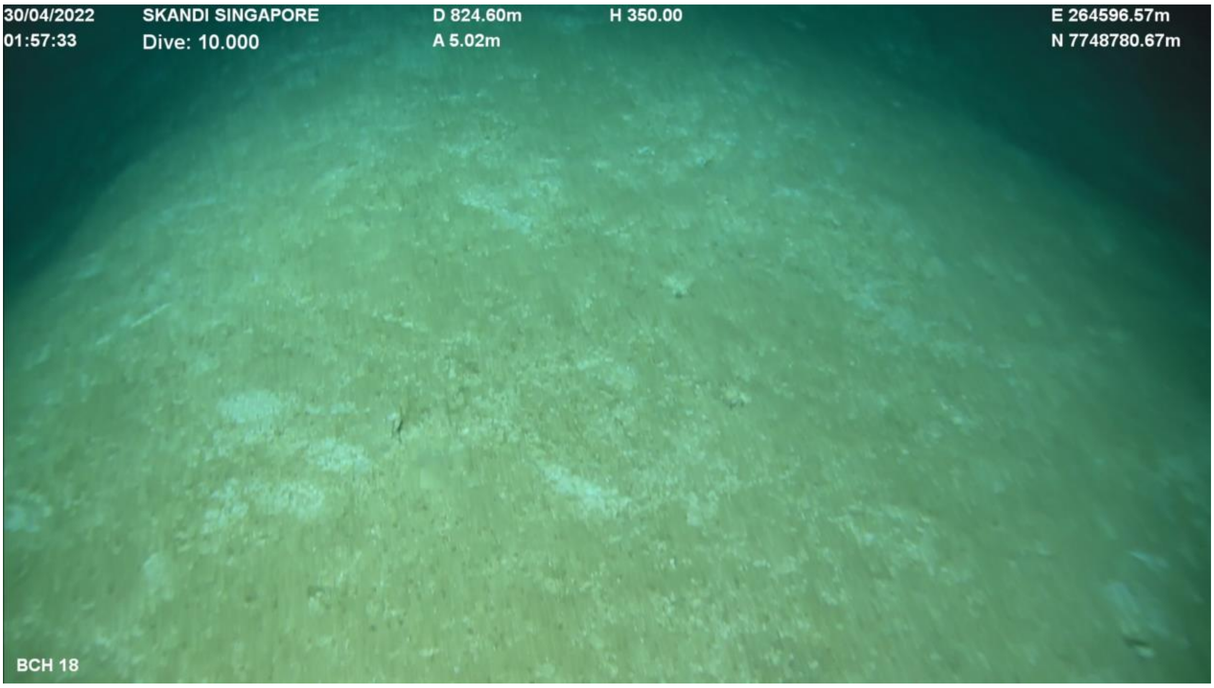
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota and occasional veneer> Sponge



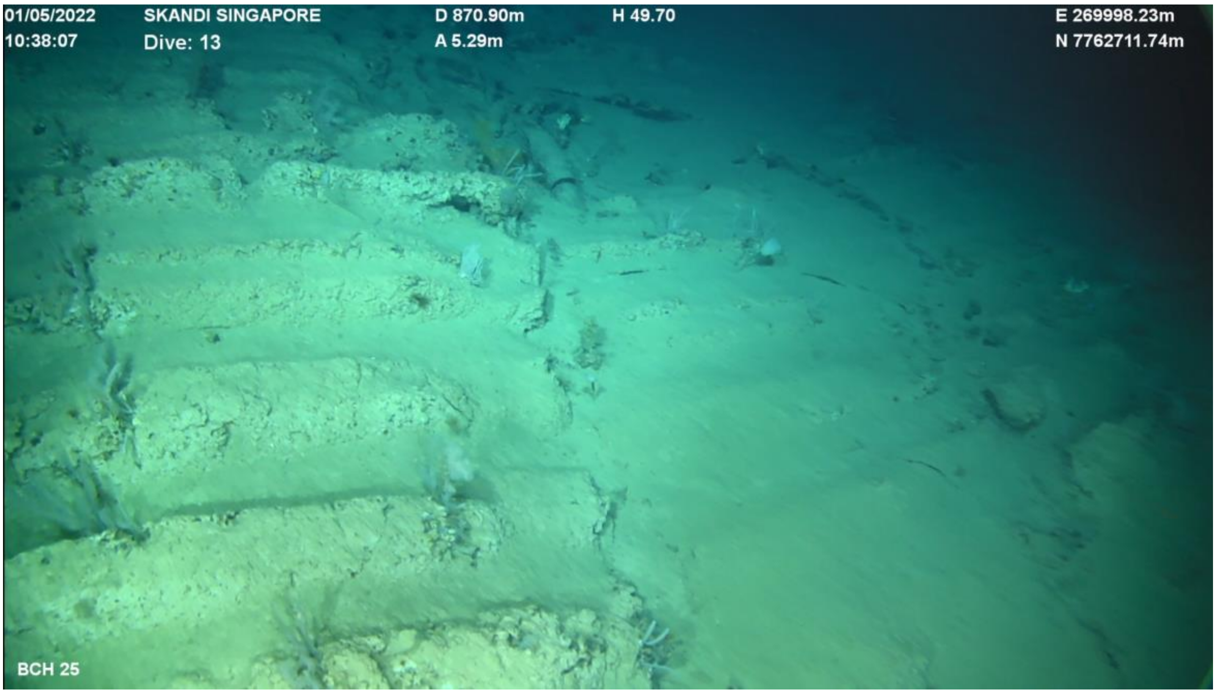
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation with biota > Sponge



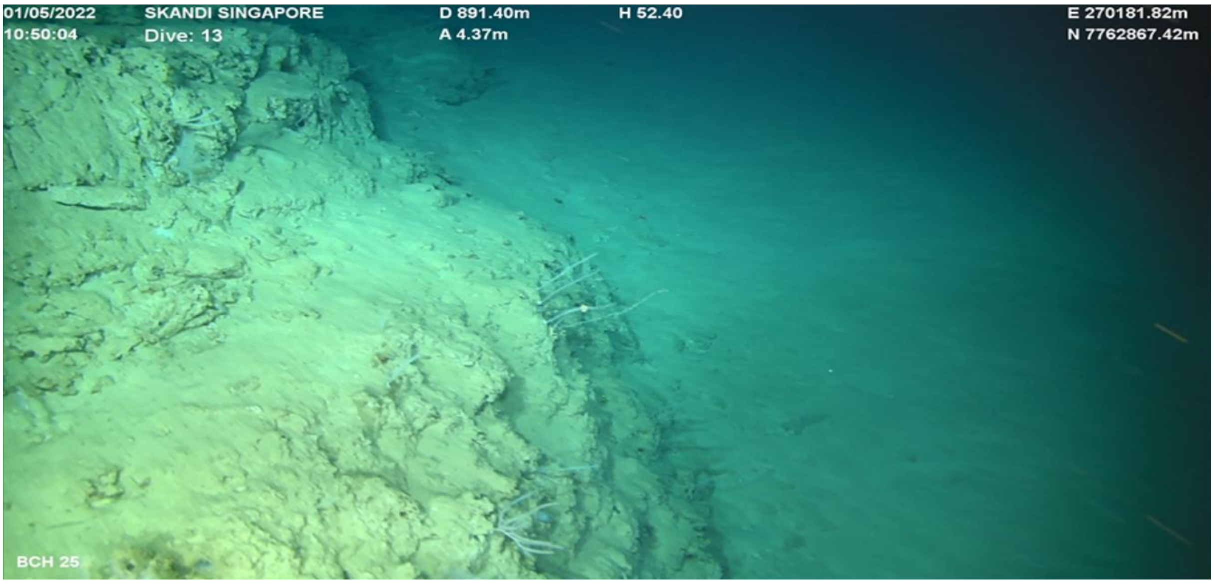
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Bioturbation only



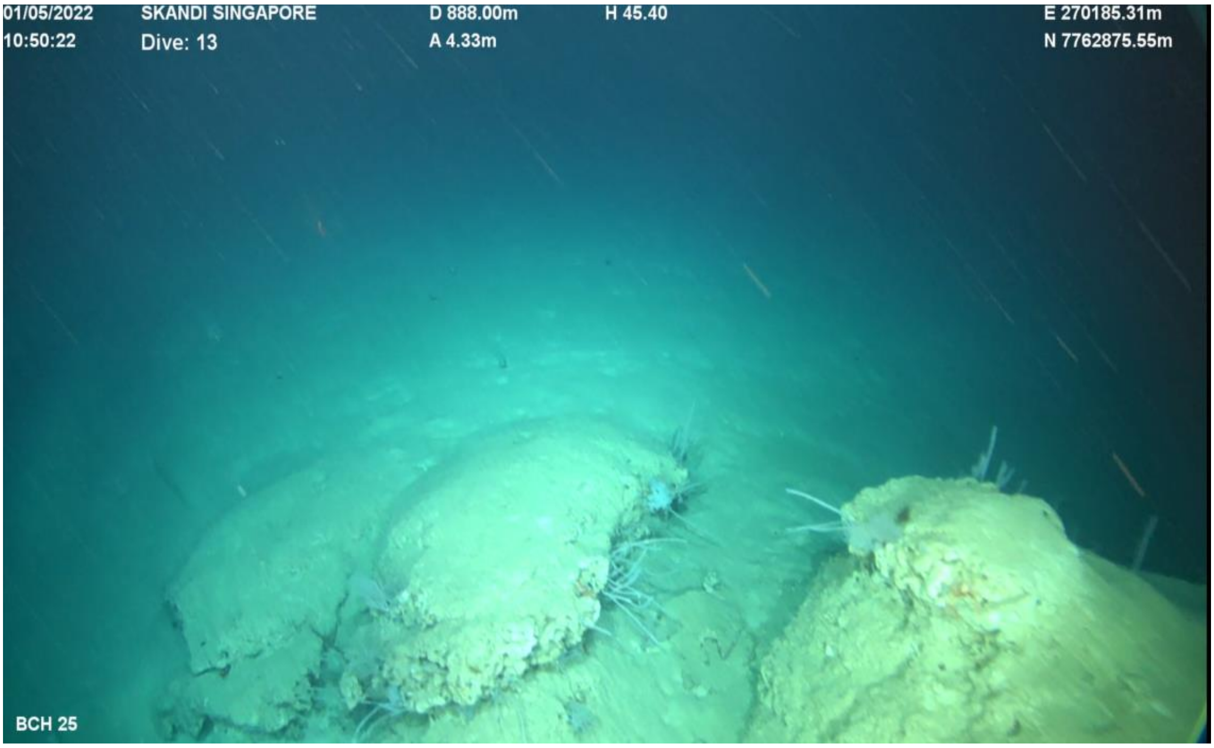
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Ripples (<10 cm height) with biota and sparse veneer > Mixed biota



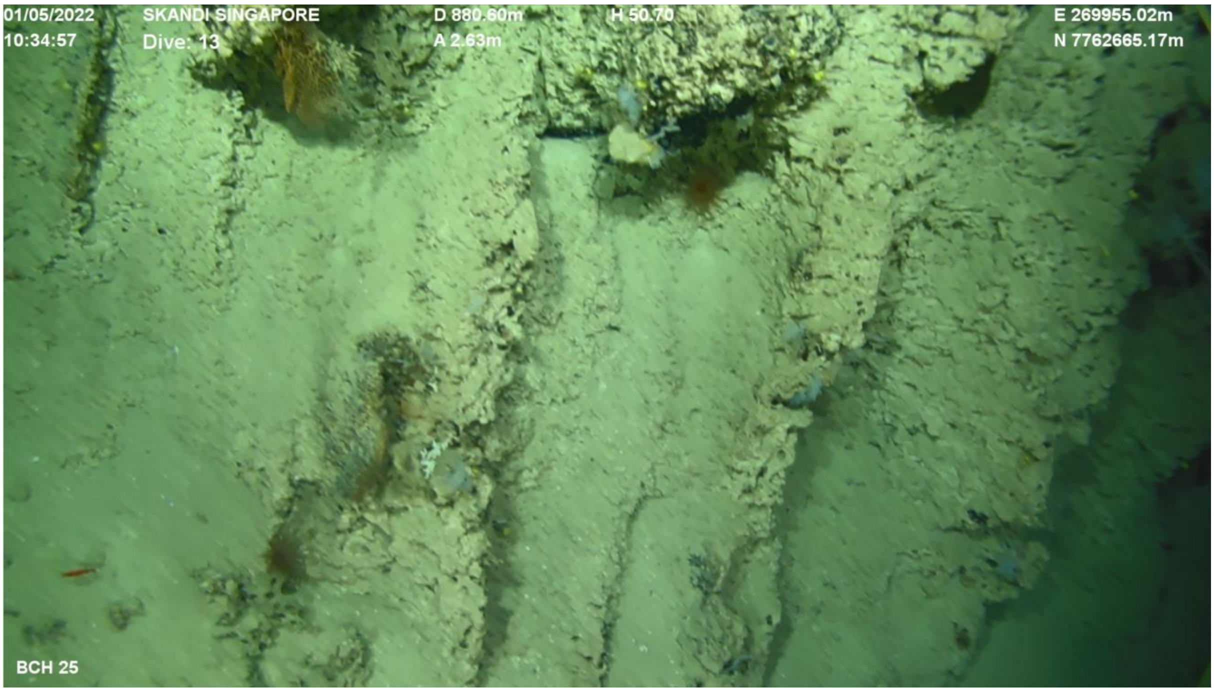
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Veneer with biota > Cnidaria



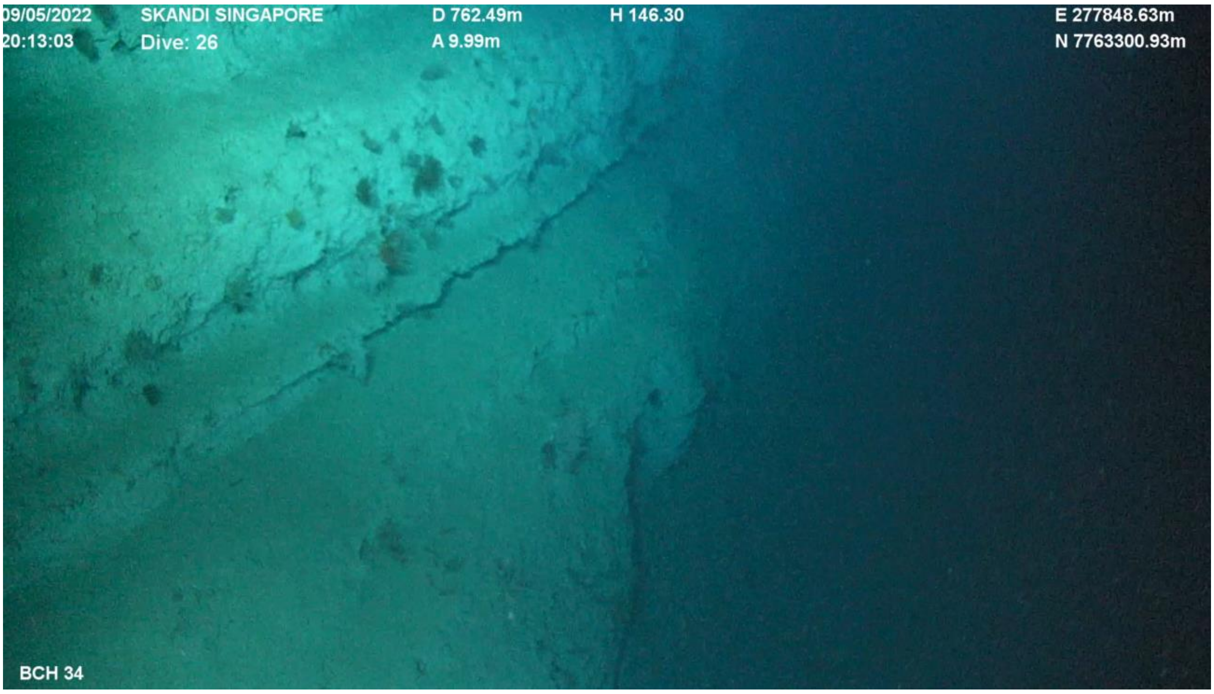
Moderate > Unconsolidated (soft) > Sand/mud (<2 mm) > Veneer with biota > Mixed biota



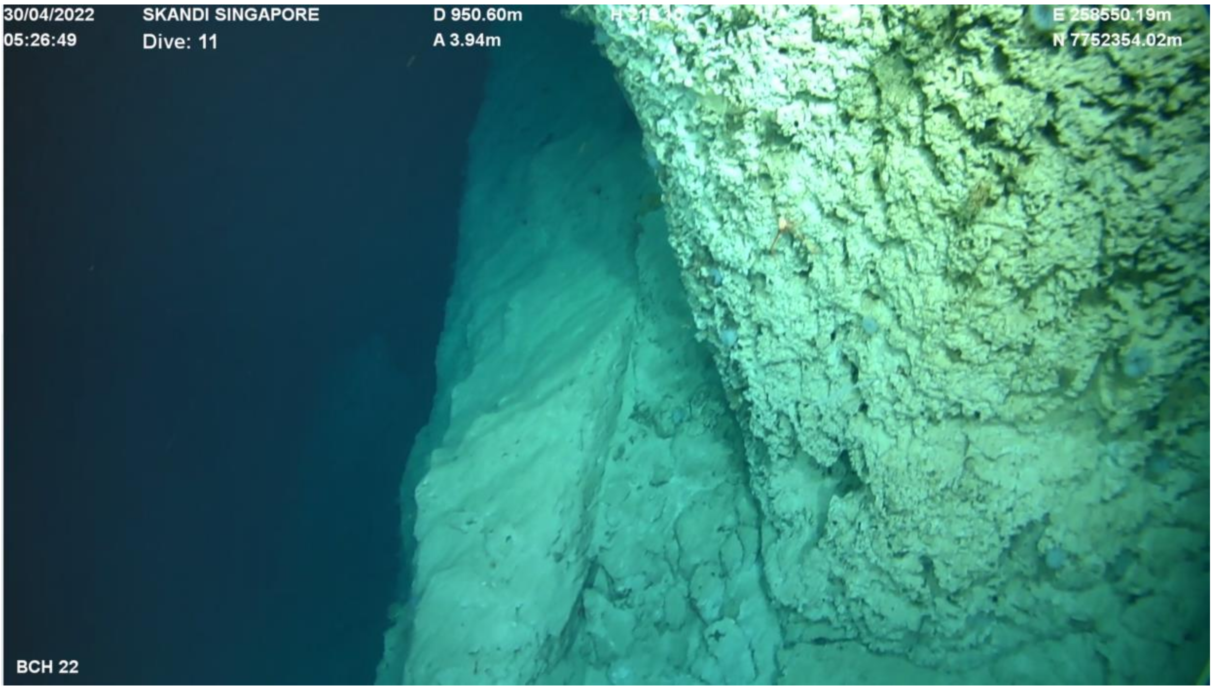
Wall > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Cnidaria



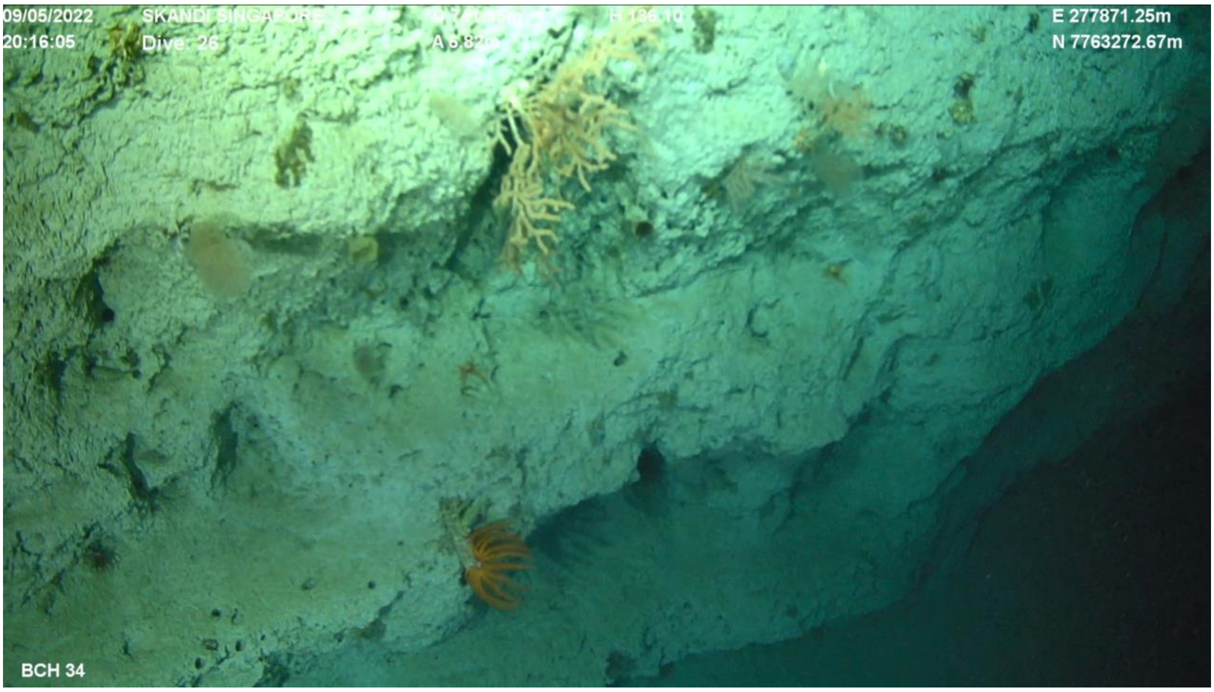
Wall > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Sponge



Wall > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Sponge and cnidaria



Wall > Consolidated (hard) > Rock (Outcropping bedrock) > Biota only > Mixed biota



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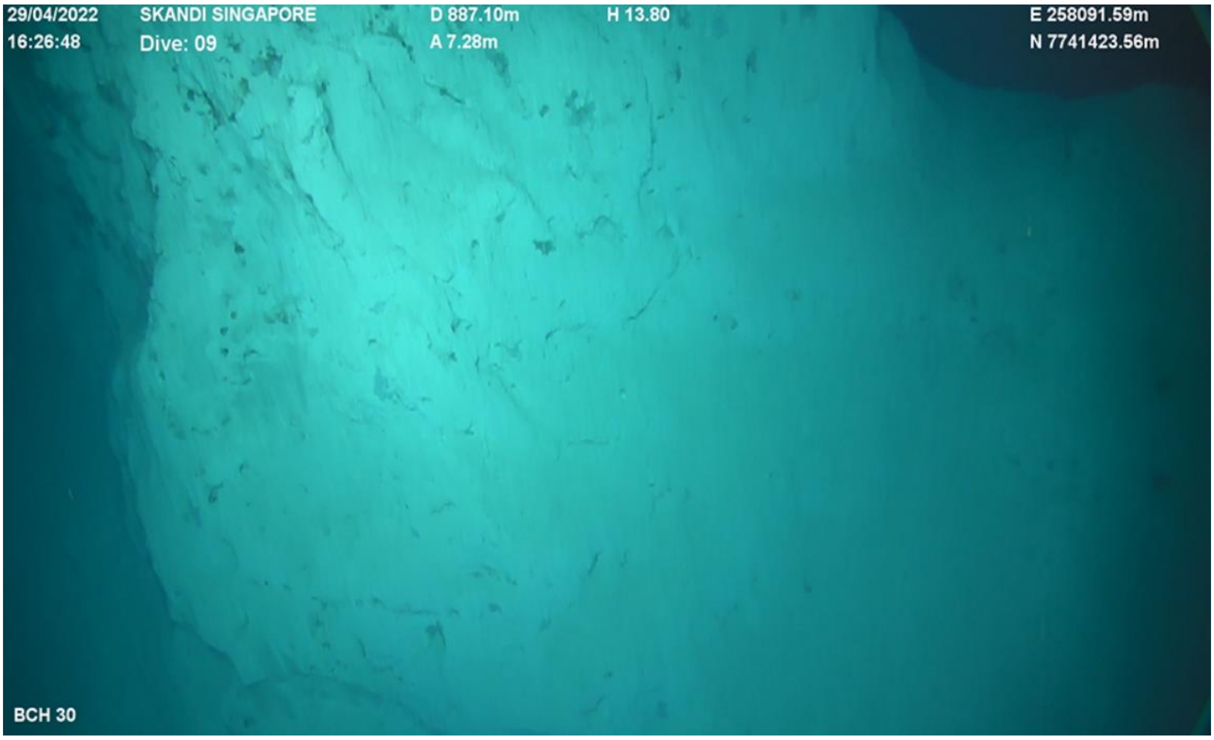
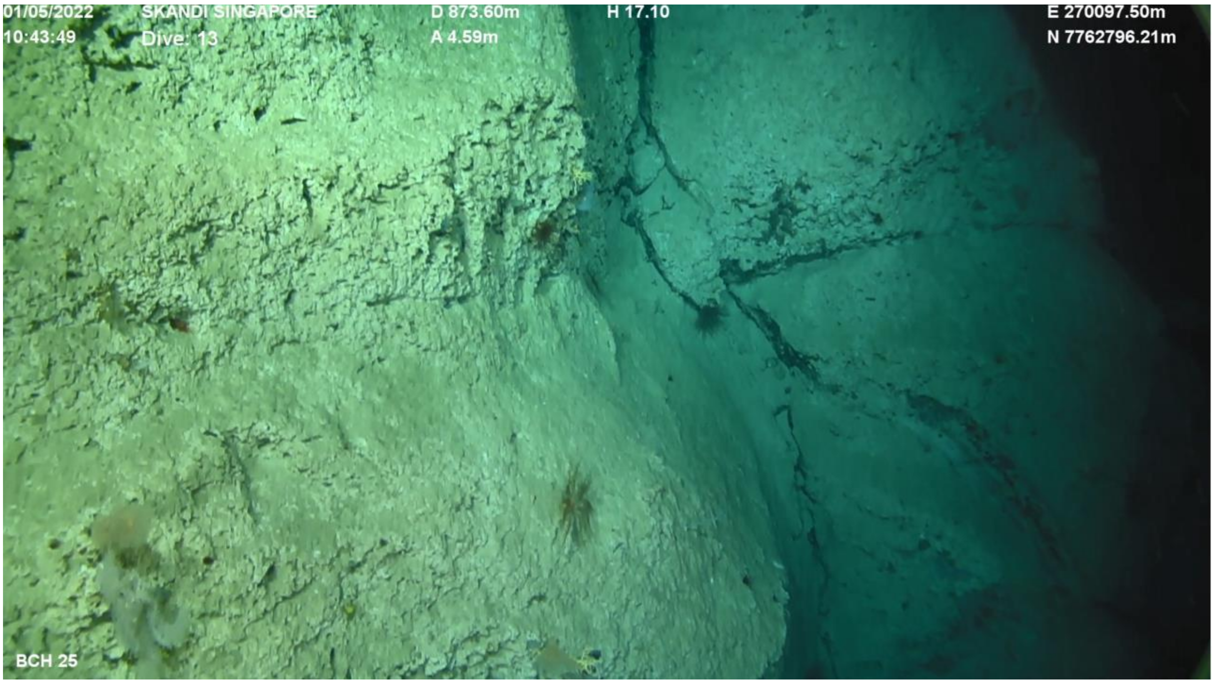
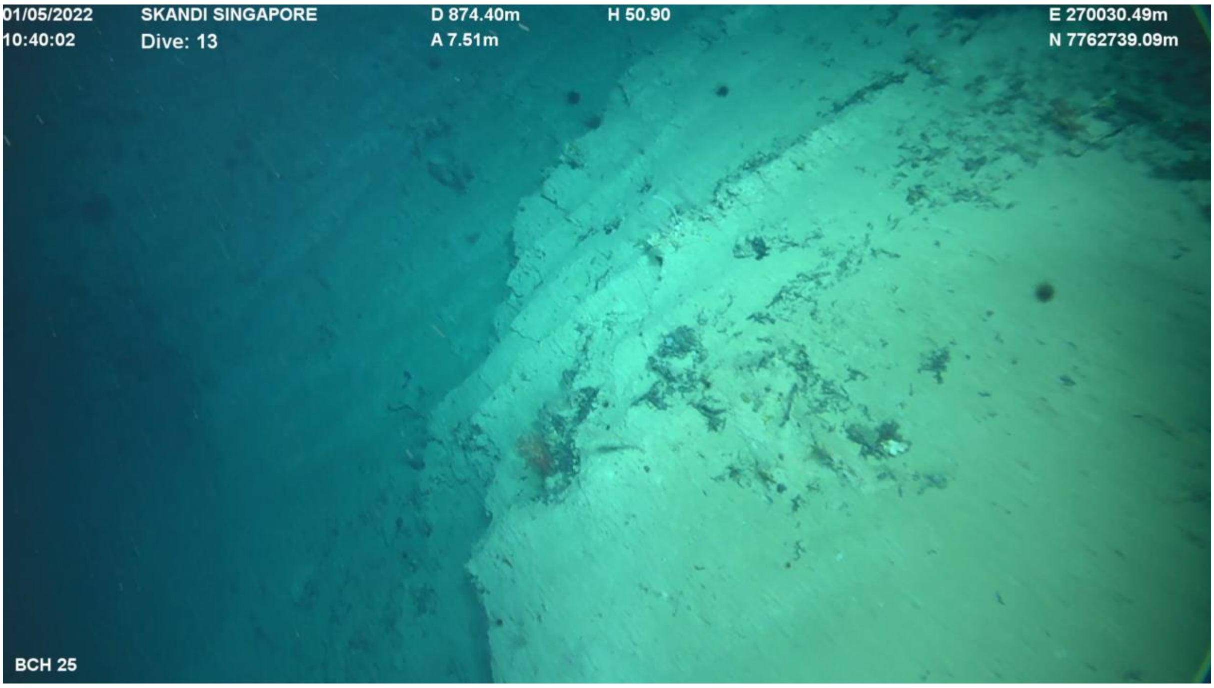
Wall > Consolidated (hard) > Rock (Outcropping bedrock) > Bare sediment



Wall > Consolidated (hard) > Rock (Outcropping bedrock) > Veneer with biota > Mixed biota



Wall > Unconsolidated (soft) >Sand/mud (<2 mm) > Veneer with biota > Mixed biota



Appendix C Video Analysis Quality Assurance and Quality Control

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Appendix C Video analysis QAQC

Throughout the benthic habitat video analysis Advisian marine scientists analysed 631 AVI video files in Transect Measure (SeaGIS 2021) software using agreed CATAMI habitat classifications. A video QAQC process was preformed after the initial analysis, where 5% of analysed videos were re-analysed by a different Advisian scientist (Table 1-1). Each QAQC video was re-analysed using the Transect Measure function which assigns a random video frame within a video file. Each random frame was checked using the CATAMI habitat classifications to determine if the appropriate habitat classification had been assigned during that video timestamp. Throughout the re-analysis of 31 QAQC videos none required to be corrected.

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Table 1-1 TransectMeasure video analysis QAQC checks.

QAQC Number	File name	Frame	Time (HMS)	Original Classification	QAQC Classification Check
1	Semele Well 4 T3_2022-05-08_181807_Ch1_01.avi	0	17:41.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
2	Acme T1_2022-05-01_122717_Ch1_00.avi	44995	57:01.8	Low (<1 m), Unconsolidated (soft), Sand/mud (<2 mm), Bioturbation with no biota	Correct
3	BCH 03 T2_2022-05-03_110838_Ch1_00.avi	8376	14:37.0	Low (<1 m), Unconsolidated (soft), Sand/mud (<2 mm), Bioturbation with no biota	Correct
4	Semele Well 4 T2_2022-05-08_173330_Ch1_00.avi	29856	52:59.2	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
5	BCH 03 T3_2022-05-03_130140_Ch1_02.avi	0	02:03.0	Low (<1 m), Unconsolidated (soft), Sand/mud (<2 mm), Biota only, Cnidaria	Correct
6	BCH 04_2022-05-02_021434_Ch1_00.avi	7347	19:23.3	Low (<1 m), Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct

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7	TRNS BCH 11 - BCH 03_2022-05-03_082146_Ch1_02.avi	89	22:10.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
8	TRNS BCH 11 - BCH 03_2022-05-03_072150_Ch1_00.avi	579	22:11.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
9	BCH 33_2022-05-09_162619_Ch1_00.avi	0	25:54.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
10	Chandon DC-1 T2_2022-05-07_045221_Ch1_00.avi	590	51:55.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
11	Chandon DC-1 T1_2022-05-07_044653_Ch1_01.avi	2446	48:05.8	Low (<1 m) Unconsolidated (soft)Sand/mud (<2 mm) Bioturbation with no biota	Correct
12	BCH 25_2022-05-01_095939_Ch1_00.avi	22206	14:13.7	Wall Consolidate (hard) Rock (Outcropping bedrock) Biota only Sponges, Cnidaria	Correct
13	Dionysis NTB3 T1_2022-05-04_152846_Ch1_00.avi	44586	57:53.4	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct

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14	Chrysaor Central D1_3 T5_2022-05-04_055432_Ch1_00.avi	0	53:58.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
15	BCH 34_2022-05-09_201041_Ch1_01.avi	8549	15:56.0	Wall Consolidate (hard) Rock (Outcropping bedrock) Biota only Mixed (all 3)	Correct
16	Jansz DC2 T1_2022-05-05_173552_Ch1_00.avi	0	35:25.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
17	BCH 33_2022-05-09_162619_Ch1_00.avi	21569	40:16.8	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
18	STB4 T2_2022-05-03_200849_Ch1_00.avi	0	26:53.5	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
19	TRNS BCH 06 - BCH 09_2022-05-06_113431_Ch1_01.avi	44728	33:58.1	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
20	TRNS BCH 12 - BCH4_2022-05-01_213849_Ch1_00.avi	27253	56:43.1	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with biota Mixed (all 3)	Correct
21	BCH 25_2022-05-01_102939_Ch1_01.avi	8302	34:58.4	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct

22	TRNS BCH 30 - BCH 20_2022-04-29_173448_Ch1_00.avi	994	34:42.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
23	BCH 17_2022-04-28_111142_Ch1_00.avi	14040	21:00.6	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Ripples (<10 cm height) with no biota	Correct
24	BCH 01_2022-05-07_024821_Ch1_02.avi	1836	49:09.4	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
25	BCH 03 T2_2022-05-03_110838_Ch1_00.avi	8376	14:37.0	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) No biota	Correct
26	Acme T3_2022-05-01_133845_Ch1_00.avi	37430	03:26.2	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) No biota	Correct
27	BCH 14_2022-05-04_122516_Ch1_02.avi	2428	40:26.1	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) No biota	Correct
28	BCH 14_2022-05-04_112519_Ch1_00.avi	11583	32:27.3	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct
29	Acme T4_2022-05-01_140716_Ch1_00.avi	34468	29:59.7	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) No biota	Correct
30	BCH 01_2022-05-07_020825_Ch1_00.avi	18402	20:17.1	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) No biota	Correct

31	TRNS Jansz DC2 - JMT_2022-05-05_202938_Ch1_02.avi	44922	59:05.9	Low (<1 m) Unconsolidated (soft) Sand/mud (<2 mm) Bioturbation with no biota	Correct

Appendix D
Fish Survey Report

Greater Gorgon Benthic Habitat Survey; Fish and Crustacean assemblages

November 2022

Ben Saunders, Melanie Stott, Karl Schramm, Damon Driessen

Version	Author	Recipients	Organisation	Date
1	Ben Saunders	Mark Westera	Advisian Pty. Ltd.	11/11/2022
2	Ben Saunders	Mark Westera	Advisian Pty. Ltd.	03/02/2023

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List of acronyms and abbreviations

Acronym/Abbreviation	Definition
AAIW	Antarctic Intermediate Water
CAPL	Chevron Australia Pty Ltd
CTD	Conductivity, Temperature and Depth
df	Degrees of Freedom
DistLM	Distance based Linear Model
GBF	Gorgon Gas Development Back Fields
GF	Geomorphic Features
KEF	Key Ecological Features
MC	Monte-Carlo
MS	Mean squares
nMDS	Non-metric Multidimensional Scaling
OPP	Offshore Project Proposal
PERMANOVA	Permutational Multivariate Analysis of Variance
perms	Permutations
P(perm)	P value calculated from permutations of the data
Res	Residuals
ROV	Remotely Operated Vehicle
SE	Standard Error
SICW	Southern Indian Central Water
SS	Sum-of-squares
TSW	Tropical Surface Water
WTR	Western Tryal Rocks

1. Introduction

Chevron Australia Pty Ltd (CAPL) are developing an Offshore Project Proposal (OPP) to work towards approvals for the development of several new fields to tie-in existing Gorgon Development infrastructure (Gorgon Foundation Project) in the Greater Gorgon area: Geryon, Eurytion, Chandon, Semele, Chrysaur, Dionysus and West Tryal Rocks (WTR) (hereafter; collectively known as Gorgon Gas Development: Backfill Fields, GBF; Figure 1). The fields are located between ~60–130 km north-west of Barrow Island, Western Australia, in water depths ranging from 150 m (WTR) to 1,300 m (Chandon). Multiple subsea facilities such as flowlines, umbilicals and drill centres/well infrastructure sites may be required for the development of each field. Although the final flowlines and umbilical routes have not been identified yet by CAPL, the study sites are focused on indicative flowline and umbilical routes, tie-in locations and indicative drill centres.

The GBF project area spans three Key Ecological Features (KEF) of the Commonwealth marine environment; from the Exmouth Plateau in the west, to the Continental Slope Demersal Fish Communities, and Ancient Coastline at 125 m depth contour (Figure 1). These KEFs are likely to be relatively topographically complex and support a range of benthic habitats and organisms such as soft deep-sea coral, sea fans (gorgonians), sponges as well as regionally significant stocks of demersal fishes. To inform the OPP and support future environmental approvals, CAPL commissioned Advisian Pty Ltd (Advisian) to characterise the marine benthic environment within the GBF project area. Curtin University were commissioned to describe fish and crustacean assemblages within the GBF project area.

In northwest Western Australia, the marine region is recognised as a biodiversity hotspot (Fox and Beckley, 2005), and supports economically important industries, including commercial fisheries (Gaughan and Santoro, 2020) and oil and gas (Bond et al., 2018; McLean et al., 2018). The shallow water fish assemblages in this area are relatively well studied, however, a substantial amount of these industries operate in the deep sea (Armstrong et al., 2012), and the deeper marine habitats and their associated biodiversity are relatively understudied and poorly understood in this region (Currey-Randall et al., 2021). This is because sampling in deep water is expensive and logistically challenging (Saunders et al., 2021; Wellington et al. 2021), and previous studies have relied on extractive and destructive techniques such as trawling (Williams et al. 2001). Research on deep-water ecosystems using non-invasive methods, such as remotely operated vehicles (ROVs) (Schramm et al., 2020; Sward et al., 2019), is important as these ecosystems are vulnerable to anthropogenic impacts (Rogers, 2015) and they provide structurally diverse and ecologically important habitats for marine species, many of which may not have been described (Appeltans et al., 2012).

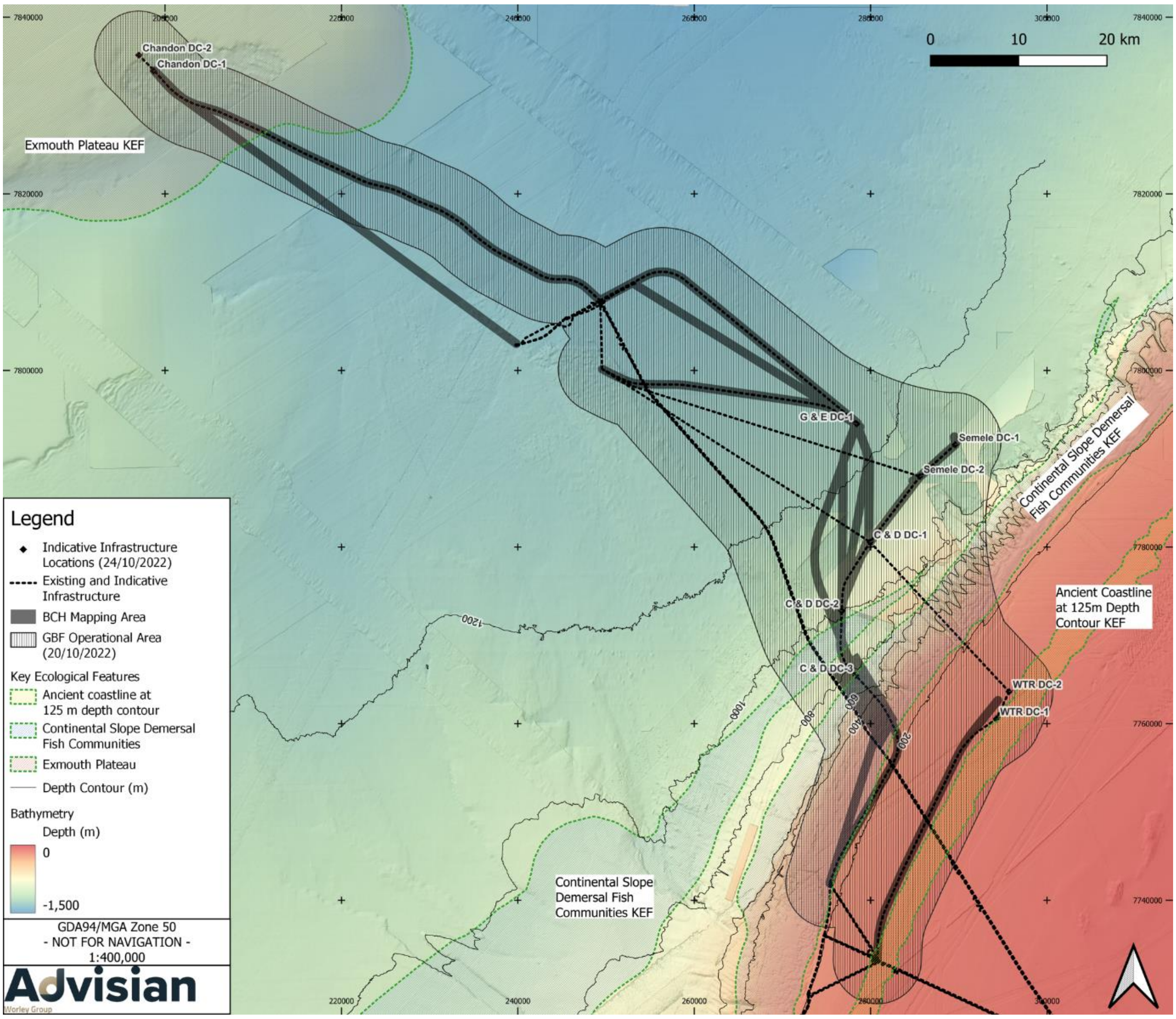


Figure 1. Context map illustrating existing and indicative infrastructure locations, the mapping area and the locations of the Key Ecological Features (KEFs). Map supplied by Advisian Pty. Ltd.

Key ecological features (KEFs) are areas in the marine ecosystem of regional importance as they are recognised as having high biodiversity or significant ecosystem function (Falkner et al., 2009). In northwest Western Australia, there are 13 KEFs, however, there is limited information on the faunal diversity and habitat structure in these areas, particularly those located in deeper water (Currey-Randall et al., 2021). The KEFs in the study area are the Exmouth Plateau, Continental Slope Demersal Fish Communities, and Ancient Coastline at 125 m depth contour, which are some of the least studied KEFs in Australia (Hayes et al., 2015). As the pressures on the marine environment intensify, the function and biodiversity of the ecosystems associated with KEFs need to be described and understood to manage and mitigate these impacts (Saunders et al., 2021).

The deep sea marine environments in this region are diverse and can be characterised by their geomorphic features (Heap and Harris, 2008), which may be associated with distinctive biological assemblages (Last et al., 2010). In the deeper waters of northwest Western Australia which encompass the study area, the geomorphic features (GFs) of interest are: 1) Plateaus; 2) Trench/troughs; 3) Deep/hole/valleys; and 4) Slopes. Plateaus are defined as areas of high elevation bordered by closely spaced contours of increasing depth, while trenches and troughs can be defined by an elongate depression of V-shaped/flat bottom contours of increasing depth, bordered on both sides by more closely spaced contours of decreasing depth (Heap and Harris, 2008). Deep/hole/valley features are concave or tapered depressions bordered by closely enclosed contours and laterally converging contours of increasing depth (Heap and Harris, 2008).

The aims of this study are:

1) To describe the fish and crustacean assemblages in a regional and environmental context.
2) To describe and compare the fish and crustacean assemblages within the KEFs.
3) To describe and compare the fish and crustacean assemblages within each Geomorphic Feature.

2. Methods

Study Site

The survey was conducted off the north-west coast of Western Australia. The survey encompassed a large area of seabed located between 55 and 185 km to the north-west of Barrow Island in water depths ranging from approximately 130 m to approximately 1270 m. The survey area encompassed three KEFs. These features were the Ancient coastline at 125 m depth contour, the Continental Slope Demersal Fish Communities, and the Exmouth Plateau. The survey also covered four Geomorphic areas (Figure 3). These were the continental slope, trench/trough, deep/hole/valley, and plateau GFs. Each site was classified according to the KEF and GF in which it was situated (Appendix Table 1).

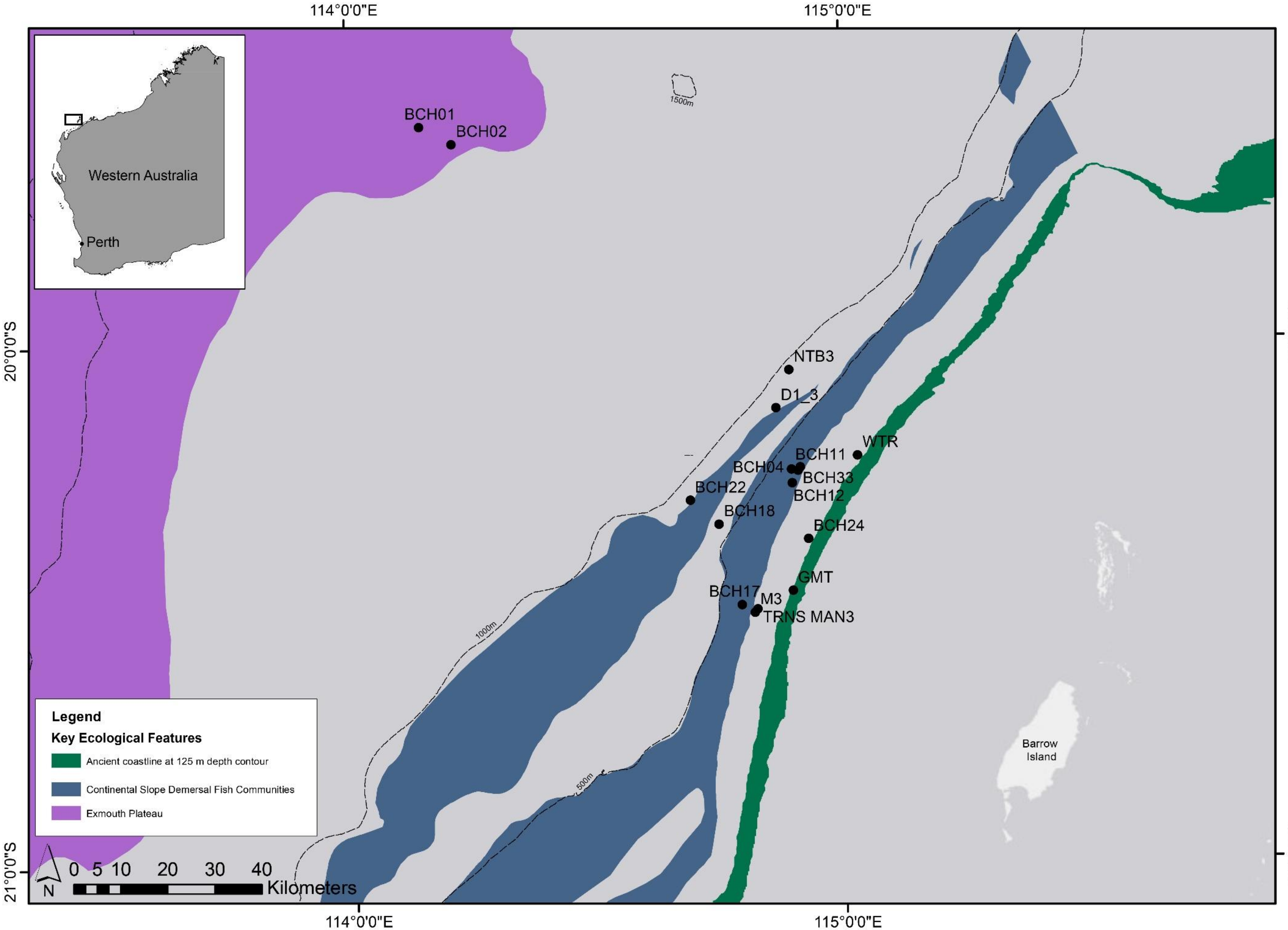


Figure 2. Context map illustrating the survey sites overlaid upon a map of the Key Ecological Features (KEFs) (Falkner et al., 2009). The inset illustrates the location of the study area off the coast of Western Australia.

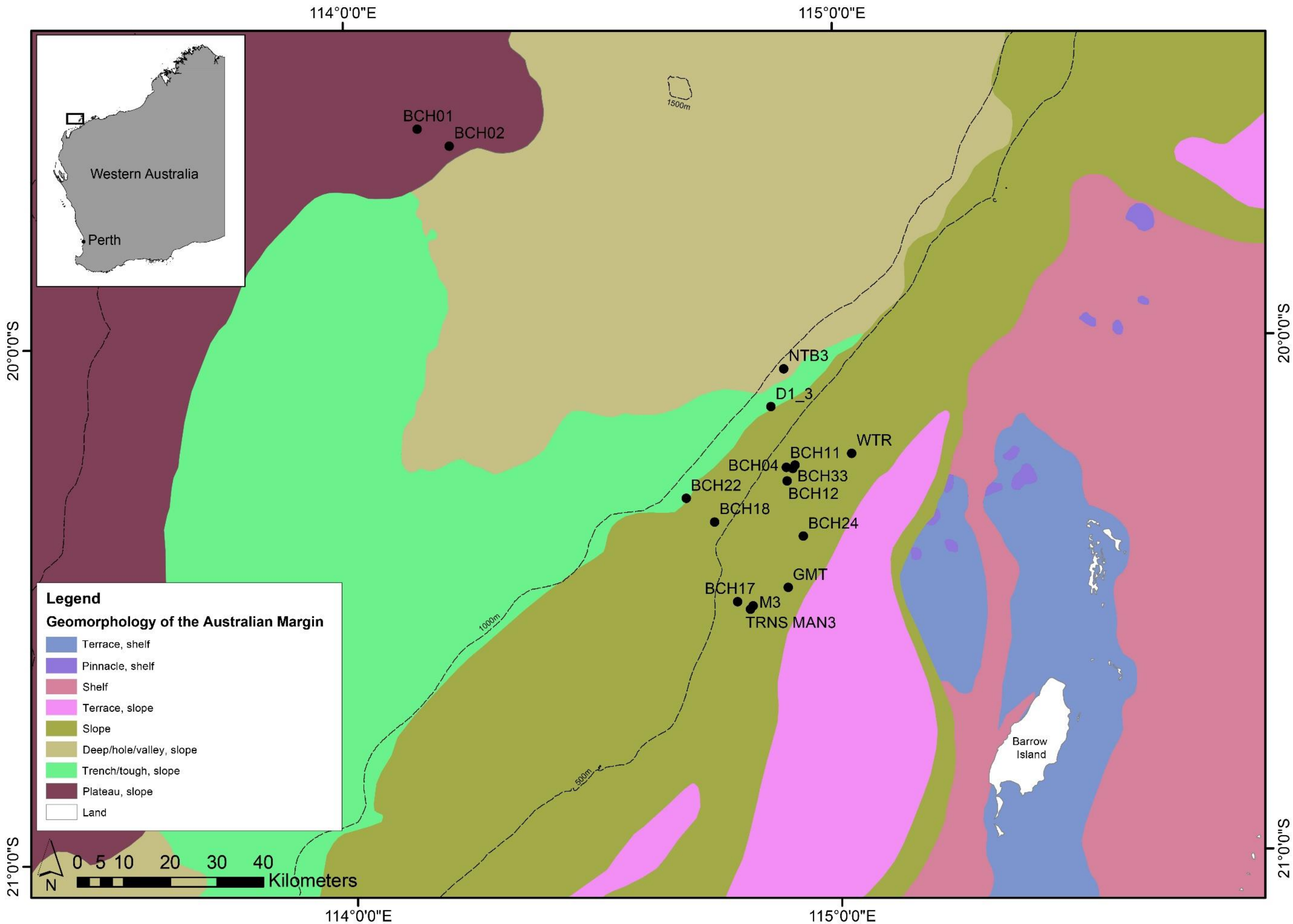


Figure 3. Context map illustrating the survey sites overlaid upon a map of the Geomorphology of the Australian Margin, or Geomorphic features (GFs) (Heap and Harris, 2008). The inset illustrates the location of the study area off the coast of Western Australia.

Video collection and analysis

Video transects were collected using a working class Remotely Operated Vehicle (ROV), fitted with a forward and slightly downward facing high definition video camera and flood lighting.

Video footage was analysed using the EventMeasure Stereo software (SeaGIS 2022). Identifications were made of fish, crustaceans and other mobile invertebrate species. An extensive reference library of images and videos in combination with taxonomic literature (for example Poore et al., 2008; Last & Stevens, 2009; Swainston, 2010; Flynn & Pogonoski, 2012) and online resources (for example Froese & Pauly, 2022; CSIRO, 2022) were used to aid species identification. In many cases identification to species level was not possible. In such cases species were identified to the lowest taxonomic resolution that was possible and the species was labelled with a descriptive annotation. In some cases, it was consistently difficult to observe identifying features, the taxa were very small, or the footage collected was not of a quality that allowed identification of taxa to a low taxonomic resolution. In these cases a conservative approach was taken and these were classified according to morphological descriptions. This was often the case for crustaceans and other mobile invertebrates. When identifying the decapod crustaceans, there were a number of species observed which could have been classified as either Dendrobranchiata (prawns) or Caridea (true shrimp). The only way to distinguish between this suborder and infraorder is by gill structure, which can't be inferred from the video. Therefore we took a conservative approach to identification and these decapod crustaceans are referred to as 'prawn' species differentiated by morphology, for example, Red prawn sp1. By taking this approach diversity could be measured, even where positive identification to low taxonomic level was not possible.

Using the EventMeasure software each fish or mobile invertebrate individual that was encountered along each transect was identified and counted following the principles outlined in Goetze et al. (2019). Where a fish could be positively identified as re-entering the field of view immediately after leaving the field of view it was not re-counted. However, in most cases each individual encountered was recorded.

Initial species identifications were made by analysts with experience in the identification of deep-water Australian fish and crustacean species. Identifications were made in a collaborative environment where difficult identifications could be discussed between analysts. Once analysed another experienced analyst made a secondary species identification check. As it was difficult to describe many of the organisms to a low taxonomic resolution, a particular emphasis was placed on consistent application of identifications and naming conventions.

Environmental situation.

The environmental situation was characterised from Conductivity, Temperature and Depth (CTD) data that were collected for most sites. For each transect site the CTD data for Salinity (PSU) and temperature (°C) were taken as the mean of the last minute (60 observations) of the CTD cast. If a CTD cast was not recorded at a specific site the values were taken from the nearest cast with the most similar depth (Appendix Table 1). The salinity, temperature and depth data were used to characterise the oceanographic conditions and identify the water mass in which each site was located following Woo and Pattiaratchi (2008).

Standardisation of transect length for statistical analysis.

The surveys conducted at each site were of varying transect lengths. To allow robust statistical analysis a standard transect length of 200 m was chosen. This transect length was selected as it is similar to the 250 m length used in similar surveys (Saunders et al., 2021) and only six of the transect sites had a sampled length that was less than 200 m. At transects sites with a sampled length that was less than

200 m the whole length of transect was used. These transect sites and their respective lengths are outlined in Table 1. Because so few transects were less than 200 m in length, and the length of most of these was close to 200 m no multiplication factor or standardisation factor was applied to the abundance data. This allowed the same statistical approach to be used for analysis of the abundance based data (fish/crustacean assemblage data, number of fish/crustaceans) and diversity data (number of fish/crustacean taxa).

Table 1. The transect sites with a total length of less than 200 m

Transect site	Transect length (m)
Chrysaor Central D1_3 T4	189
Dionysus NTB3 T2	112
Dionysus NTB3 T3	191
Gorgon GMT T2	198
Gorgon GMT T3	141
Gorgon GMT T4	172

At transect sites that had a length greater than 200 m, the first 200 m section of the transect were selected for statistical analysis. At sites where the length sampled was greater than 400 m the transect was broken up into multiple replicate 200 m lengths with a 10 m gap to separate transects. These transects sites and their respective number of replicate 200 m transects are listed in Table 2. This approach resulted in a total of 71 replicate transects across the survey area.

Table 2. Transect sites with multiple replicate transects, and the number of replicate transects at each.

Transect site	Number of 200 m transects
BCH 01	6
BCH 02	5
BCH 04	4
BCH 11	4
BCH 12	2
BCH 17	6
BCH 18	3
BCH 22	5
BCH 24	5
BCH 33	3
Dionysus NTB3 T1	3
Gorgon M3 T1	2
Gorgon M3 T4	2
Gorgon M3 T5	2

Statistical analysis

All statistical analysis was conducted using PRIMER version 7 (Clarke & Gorley 2015) and the PERMANOVA + add in for PRIMER (Anderson et al 2008). Fish and crustacean assemblage data were visually assessed for dominant taxa using shade plots. The data were transformed to reduce the influence of any single dominant taxa. Fish assemblage data was fourth root transformed, and the crustacean assemblage data were square root transformed for statistical analysis. A Bray-Curtis similarity matrix was constructed on the transformed data and this was used for further multivariate statistical analysis.

To investigate the effect of depth on the composition of the multivariate fish and crustacean assemblages a Distance based Linear Model (DistLM) was constructed. For this analysis depth was the explanatory variable, and the fish or crustacean assemblages were the dependent variables.

To address the three aims of the study three different statistical designs were used. These were to assess differences in the fish and crustacean assemblages among water masses, among the KEFs, and among the GFs. For each analysis site was nested within the factor of interest as a random factor. The replicate transects were allocated sites according to their location, Figure 3, Appendix Table 1). Transect Trans Man 3 was allocated to site M3 for statistical analysis as this transect was directly adjoining site M3 (Appendix Table 1).

The statistical designs for each test were:

Water Mass

Factor 1 Water Mass, Fixed, three levels; Tropical Surface Water (TSW), Southern Indian Central Water (SICW), Antarctic Intermediate Water (AAIW).

Factor 2 Site, Random, nested within Water Mass, varying levels depending upon replication

Key Ecological Features

Factor 1 KEF, Fixed, four levels; Ancient Coastline at 125 m depth contour, Continental Slope Demersal Fish Communities, Exmouth Plateau, and Outside any KEF.

Factor 2 Site, Random, nested within KEF, varying levels depending upon replication

Geomorphic Features

Factor 1 Geomorphic Feature, Fixed, four levels; slope, trench/trough, deep/hole/valley, plateau.

Factor 2 Site, Random, nested within Geomorphic Feature, varying levels depending upon replication

Non-metric Multidimensional Scaling (nMDS) plots were used to illustrate patterns in the fish and crustacean assemblages according to each of the factors of interest. Vectors were overlaid that illustrate the strength and direction of the Pearson's correlation of individual taxa to the data. Taxa with a correlation of greater than 0.5 are illustrated.

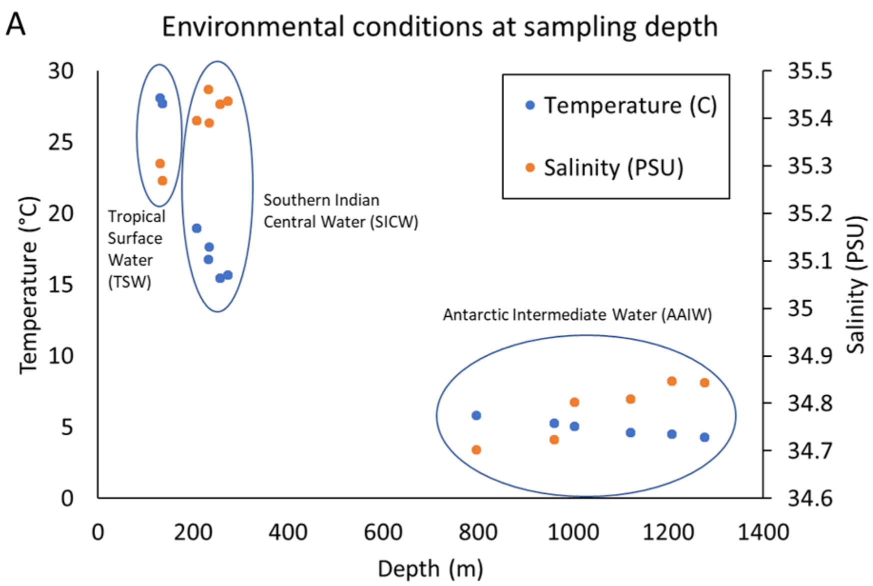
Post-hoc pairwise tests in PERMANOVA were done when statistically significant differences between levels of the factors of interest were detected. Post-hoc pairwise tests were also done where visual differences among means were apparent on the plots, or where the P value of the test for a factor of interest approached the convention of 0.05. This approach to testing for differences was taken following the precautionary principle because of the variable numbers of replicate samples between the levels of the factors of interest. Where the numbers of unique permutations was low Monte-Carlo (MC) bootstrapping was used to calculate the P value.

Univariate tests of the number of fish, number of fish taxa, number of crustaceans, and number of crustacean taxa were carried out according to the same statistical design. For these univariate tests the data were not transformed, and a Euclidean distance resemblance matrix was used. Plots of means and standard errors were used to illustrate patterns among the factors of interest.

3. Results

Environmental situation

The CTD data collected at sampling depth revealed three distinct temperature and salinity regimes (Figure 4). Following Woo and Pattiaratchi (2008) three water masses were identified through the relationship between temperature and salinity (Figure 4B). These were the same three water masses identified in Saunders et al. (2021). The shallowest sites, in water depths less than 150m, were characterised by high temperatures (~28 °C) and salinities of 35.3 PSU (Figure 4). This was identified as the Tropical Surface Water (TSW) water mass. The sites sampled in between 200 and 270 m water depth were characterised by a higher salinity (35.39 – 35.46 PSU) and a water temperature between 15 and 19 °C (Figure 4). These were classified as Southern Indian Central Water (SICW). The deepest sites, at 800 m or greater water depth had cold temperatures (less than 6 °C) and salinity less than 34.8 PSU (Figure 4). This was Antarctic Intermediate Water (AAIW) (Woo and Pattiaratchi, 2008).



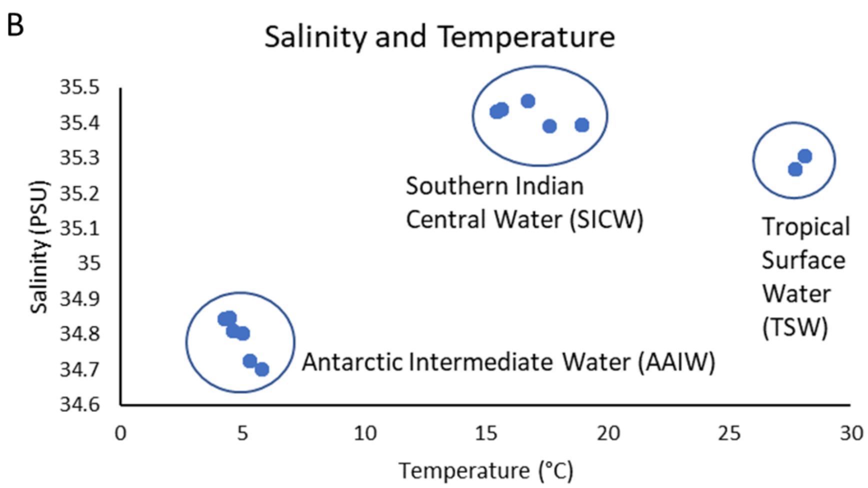


Figure 4. Environmental conditions at sampling depths. A illustrates the change in both Temperature and Salinity with depth. B illustrates the relationship between Salinity and Temperature. Circles indicate groupings of samples by the three identified water masses.

General descriptions of the survey areas
Key Ecological Feature (KEF)

Continental Slope Demersal Fish Communities

Within the Continental Slope Demersal Fish Communities KEF, a total of 4.11 km of transect was analysed, where 28 fish taxa were recorded with a total of 519 fish. The fish assemblage was dominated by Trevallies (Carangidae), with 4 species from 3 genera accounting for 271 of the individuals observed. The five most abundant fish taxa were *Decapterus* sp1, *Seriola dumerili*, an unidentified bait fish, *Decapterus kurroides,* and Synodontidae sp2 (Table 3). Five transect sites were located within the Continental Slope Demersal Fish Communities KEF. These were BCH04, BCH11, BCH12, BCH17, and BCH33. The transect length at these sites was 867 m, 932 m, 412 m, 1280 m, and 619 m respectively. At BCH04 the most abundant fish taxa were an unidentified bait fish, Synodontidae sp2, and *Decapterus* sp1, accounting for 82 of the 105 individuals recorded on the transect (Appendix Table 2). The most abundant taxa at BCH11 were *Seriola dumerili*, *Decapterus* sp1, and Synodontidae sp2, which accounted for over 93% of the total recorded individuals at the site (Appendix Table 2). *Decapterus* sp1 and Synodontidae sp2 were also the most abundant taxa at BCH17, whereas site BCH12 was dominated by *Decapterus kurroides* (Appendix Table 2). BCH33 had a large number of an unidentified anguilliform fish taxa and an abundance of Synodontidae sp3 and *Pristipomoides typus* (Appendix Table 2). Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 3. Most abundant fish taxa in the Continental Slope Demersal Fish Communities KEF transects

Family	Taxa	Number of individuals
Carangidae	*Decapterus kurroides*	63
	Decapterus sp1	103
	Seriola dumerili	91
Synodontidae	Synodontidae sp2	52
N/A	unidentified bait fish	69

Only two of the five sites in Continental Slope Demersal Fish Communities KEF recorded crustaceans; BCH04 and BCH17. At these sites, a total of 5 crustaceans were recorded, with each being different taxa. Two were from the infraorder Anomura, one from the infraorder Brachyura, one from the infraorder Achelata, and one unknown (Table 4). Images of the ten most abundant crustacean taxa across the survey area are presented in Appendix 1 Table 29.

Table 4. Crustacean taxa in the Continental Slope Demersal Fish Communities KEF transects

Infraorder	Family	Taxa	Number of individuals
Anomura	Galatheidae	Galatheidae sp. G	1
Brachyura	Homolidae	Homolidae spH	1
Achelata	Ibacinae	*Ibacus* spI	1
Anomura	Parapaguridae	Parapaguridae spPP	1
unknown	N/A	Red prawn sp7	1

Ancient Coastline at 125 m depth contour

The Ancient Coastline at 125 m depth contour KEF sites recorded 13 fish taxa with a total of 18,011 individuals along 1.03 km of transect. The fish assemblage was dominated by Trevallies (Carangidae), with three species representing 14,231 of the total individuals. The most abundant fish taxa were *Carangoides* sp1, an unidentified baitfish, *Seriola dumerili*, *Carcharhinus* sp1, and *Rachycentron canadum* (Table 5). The five transects which make up the Ancient Coastline at 125 m depth contour KEF were all located at the Gorgon GMT site, with transect lengths of 269 m, 198 m, 141 m, 172 m, and 247 m, respectively. At transect 1 (T1) the most abundant fish taxa were an unidentified baitfish species and *Carangoides* sp1 which together made up 3,451 of the 3,591 total observed number of fish (Appendix Table 2). *Carangoides* sp1 represented more than 95% of the total observed fish individuals in T2, with the next most abundant taxa being *Seriola dumerili* (Appendix Table 2). T3 and T5 were also dominated by *Carangoides* sp1, representing more than 94% and 97% of the total fish respectively, with *Seriola dumerili* as the next most abundant taxa in T3, and *Carcharhinus* sp1 in T5 (Appendix Table 2). *Carangoides* sp1 was also the most abundant taxa in T4, with unidentified bait fish the second most abundant taxa recorded in the transect (Appendix Table 2). Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 5. Most abundant fish taxa in the Ancient Coastline at 125m depth contour KEF transects

Family	Taxa	Number of individuals
Carangidae	*Carangoides* sp1	13,835
	Seriola dumerili	381
Carcharhinidae	*Carcharhinus* sp1	189
Rachycentridae	*Rachycentron canadum*	45
N/A	unidentified baitfish	3,454

Only one crustacean was recorded in the Ancient Coastline at 125m depth contour KEF, at the Gorgon GMT T1 site; an unidentified prawn species (Appendix Table 3).

Exmouth Plateau

The Exmouth Plateau KEF was represented by two sites; BCH01 and BCH02, which recorded a total of 165 individuals from 14 taxa in 2.57 km of transect. The lengths of the transect at each site were 1437 m and 1129 m respectively. The fish assemblage was dominated by an unidentified anguilliform fish and *Bathypterois* sp1, together representing over 65% of the total number of individual fish recorded. Other abundant taxa included *Aldrovandia* sp1, *Aldrovandia* sp2, and Macrouridae sp2 (Table 6). At BCH01, *Bathypterois* sp1 was the most abundant taxa with 30 of the total 73 individual fish, with the second most abundant taxa being an unidentified anguilliform fish (Appendix Table 2). The same two taxa were also the most abundant at the BCH02 site, but the unidentified anguilliform fish was by far the most dominant, representing almost 60% of the total recorded individual fish for the transect (Appendix Table 2). Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 6. Most abundant fish taxa in the Exmouth Plateau KEF transects

Family	Taxa	Number of individuals
N/A	unidentified anguilliform fish	70
Ipnopidae	*Bathypterois* sp1	38
Halosauridae	*Aldrovandia* sp1	11
	Aldrovandia sp2	7
Macrouridae	Macrouridae sp2	8

The crustacean assemblage for the Exmouth Plateau KEF consisted of seven taxa with a total of 228 individuals recorded. Red prawn sp7 was the most dominant crustacean taxa representing over 81% of the total number of individuals. The next most abundant species was pink prawn sp9 and orange prawn sp8 (Table 7). At BCH01, red prawn sp7 dominated the site with 107 of the recorded 128 total individuals, with pink prawn sp9 the next most abundant taxa with 9 individuals (Appendix Table 3). Similarly, red prawn sp7 and pink prawn sp9 at BCH02 accounted for 78% and 14% of the total number of individuals recorded respectively (Appendix Table 3). Images of the ten most abundant crustacean taxa across the survey area are presented in Appendix 1 Table 29.

Table 7. Most abundant crustacean taxa in the Exmouth Plateau KEF transects

Taxa	Number of individuals
Red prawn sp7	185
Pink prawn sp9	23
Orange Prawn sp8	9

Sites outside the KEFs

There were 21 sites outside of the KEF areas, with a total of 9.05 km of transect analysed, with transect lengths ranging from 112 m to 1242 m (Table 8). These sites recorded a total of 15,828 individual fish from 41 taxa. The five most abundant taxa from these sites were *Trachurus novaezelandiae, Seriola dumerili,* an unidentified baitfish species, an unidentified anguilliform fish species, and *Carcharhinus* sp1 (Table 9). 11,007 of the total individual fish were recorded at the BCH24 site, which was dominated by *Trachurus novaezelandiae* (78% of total individuals) and an unidentified baitfish species (21% of total individuals; Appendix Table 3). The Gorgon M3 sites were dominated by *Seriola dumerili* (99% of total individuals), whereas the WTR DC-1 sites had a high abundance of the unidentified baitfish species and *Trachurus novaezelandiae* (Appendix Table 2). Site BCH18 had an unidentified anguilliform fish species as its most abundant taxa, followed by Macrouridae sp2, while the TRNS MAN3 to T3 transect was dominated by *Seriola dumerili* (Appendix Table 2). The other sites (BCH22, Chrysaor Central D1_3 transects and Dionysus NTB3 transects) are summarised in their Geomorphic Feature (GF) sections. Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 8. Transect lengths of sites outside of the KEF areas

Site	Transect length (m)
BCH18	677
BCH22	1137
BCH24	1242
Chrysaor Central D1_3 T1	379
Chrysaor Central D1_3 T2	227
Chrysaor Central D1_3 T3	214
Chrysaor Central D1_3 T4	189
Dionysus NTB3 T1	690
Dionysus NTB3 T2	112
Dionysus NTB3 T3	191
Dionysus NTB3 T4	271
Gorgon M3 T1	546
Gorgon M3 T2	332
Gorgon M3 T3	359
Gorgon M3 T4	455
Gorgon M3 T5	407
TRNS MAN3 to T3	359
WTR DC-1 T1	366
WTR DC-1 T2	316
WTR DC-1 T3	271
WTR DC-1 T4	314

Table 9. Most abundant fish taxa in the sites outside of the KEF areas

Family	Taxa	Number of individuals
Carangidae	*Trachurus novaezelandiae*	8720
	Seriola dumerili	3858
Carcharhinidae	*Carcharhinus* sp1	101
N/A	unidentified baitfish	2685
N/A	unidentified anguilliform fish	155

Crustaceans were recorded in half of the sites outside the KEF areas; BCH18 and BCH22, the Chrysaor Central D1_3 transects, the Dionysus NTB3 transects, and at WTR DC-1 T1. A total of 694 individuals were recorded from 12 taxa, with all sites dominated by red prawn sp7 (Appendix Table 3). Red prawn sp7 accounted for 122 of the 143 total individuals observed on the BCH18 transect, whereas at WTR DC-1 T1 there was only one crustacean recorded; an unidentified prawn species (Appendix Table 3). The crustacean assemblages at the other sites (the Chrysaor Central D1_3 transects and the Dionysus NTB3 transects) are summarised in the GF section below.

General descriptions of the survey areas.

Geomorphic Feature (GF)

Deep/hole/valley

In the Deep/hole/valley GF there were 16 fish taxa and a total of 187 individuals recorded from 1.26 km of transect. The fish assemblage was dominated by an unidentified anguilliform fish species, representing 54% of the individuals observed. The next most abundant taxa were *Aldrovandia* sp1, followed by Macrouridae sp1, *Aldrovandia* sp2, and *Aldrovandia affinis* (Table 10). The four transects which make up the Deep/hole/valley GF were all located at the Dionysus NTB3 site. The first transect (T1) was dominated by the unidentified anguilliform fish species, accounting for 48 of the 70 recorded individuals (Appendix Table 2). This was similar for T2 and T4, with the unidentified anguilliform fish species most abundant in both transects and the 3 *Aldrovandia* species accounting for the vast majority of the remaining taxa recorded (Appendix Table 2). T3 again had the unidentified anguilliform fish as the most abundant taxa but was followed by Macrouridae sp1 and *Aldrovandia* sp1 (Appendix Table 2). Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 10. Most abundant fish taxa in the Deep/hole/valley GF transects

Family	Taxa	Number of individuals
N/A	unidentified anguilliform fish	101
Halosauridae	*Aldrovandia* sp1	19
	Aldrovandia sp2	8
	Aldrovandia affinis	7
Macrouridae	Macrouridae sp2	11

The crustacean assemblage in the Deep/hole/valley GF consisted of 110 individuals recorded from four taxa. The assemblage was dominated by red prawn sp7 which accounted for almost 71% of the total individuals across the sites (Table 11). The first transect (T1) had the highest number of individuals recorded, with the red prawn species as the most abundant taxa, representing 71% of the total number of individuals, with orange prawn sp8 as the next most abundant taxa (Appendix Table 3). T2 and T3 also had red prawn sp7 as the most abundant taxa, representing 83% and 71% of total individuals respectively, and both had a second red prawn, sp11 as the next most abundant taxa (Appendix Table 3). Red prawn sp7 again was the most abundant taxa in T4, followed by orange prawn sp8 and a second red prawn sp11 (Appendix Table 3).

Table 11. Crustacean taxa in the Deep/hole/valley GF transects

Taxa	Number of individuals
Red prawn sp7	78
Red prawn sp11	16
Orange prawn sp8	14
Pink prawn sp9	2

Slope

The Slope GF was made up of 22 sites with a total of 10.78 km of transect analysed, where 51 fish taxa were recorded with a total of 34,042 individuals. The fish assemblage was dominated by Trevallies (Carangidae) with 27,086 individuals from seven taxa. The five most abundant species were *Carangoides* sp1, *Trachurus novaezelandiae*, *Seriola dumerili*, an unidentified baitfish species, and *Carcharhinus* sp1, which together accounted for 98% of the total individuals (Table 12). The 22 sites in the Slope GF were BCH04, BCH11, BCH12, BCH17, BCH18, BCH24 and BCH33, the 5 Gorgon GMT transects, the 5 Gorgon M3 transects, the 4 WTR DC-1 transects, and the TRNS MAN3 to T3 site. Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 12. Most abundant fish taxa in the Slope GF transects

Family	Taxa	Number of individuals
Carangidae	*Carangoides* sp1	13,835
	Trachurus novaezelandiae	8,720
	Seriola dumerili	4,330
Carcharhinidae	*Carcharhinus* sp1	290
N/A	unidentified baitfish	6,208

Only five sites in the Slope GF contained crustaceans; BCH04, BCH17, BCH18 Gorgon GMT T1, and WTR DC-1 T1. The crustacean assemblage consisted of 150 individuals recorded from 11 taxa. Of these, 143 (95% of the total individuals) crustaceans were recorded from the BCH18 transect, which was dominated by two red prawn species, red prawn sp7 and red prawn sp11 (Appendix Table 3).

Plateau

The plateau GF contains the same two sites as the Exmouth plateau KEF (BCH01 and BCH02), so the fish and crustacean assemblages for this GF have been summarised above.

Trench/Trough

The Trench/Trough GF contained 129 individual fish from 17 taxa, recorded from 2.15 km of transect. The fish assemblage was distinguished by Macrouridae species, Halosauridae species, and an unidentified anguilliform species, which accounted for almost 88% of the total recorded individuals. The five most abundant taxa were the unidentified anguilliform species, *Aldrovandia* sp1, Macrouridae sp1, Macrouridae sp2, and Macrouridae sp4 (Table 13). Five transect sites were located in the Trench/Trough GF; BCH22 and the four Chrysaor Central D1_3 transects. Of the total individual fish, 70 were recorded at the BCH22 site, where the most abundant taxa was *Aldrovandia* sp1, followed by Macrouridae sp2 (Appendix Table 2). At the Chrysaor Central D1_3 sites, each transect had 9-18 total individual fish recorded, with the unidentified anguilliform species being the most abundant taxa for each site (Appendix Table 2). Images of each of these most abundant fish taxa are presented in Appendix 1 Table 28.

Table 13. Most abundant fish taxa in the Trench/Trough GF transects

Family	Taxa	Number of individuals
N/A	unidentified anguilliform fish	39
Halosauridae	*Aldrovandia* sp1	18
Macrouridae	Macrouridae sp1	7
	Macrouridae sp2	17
	Macrouridae sp4	17

The crustacean assemblage in the Trench/Trough GF consisted of eight taxa with 440 total individuals recorded. The assemblage was dominated by red prawn sp7, which made up almost 85% of the total individuals. The other abundant crustacean species included a dark prawn species (Dark prawn sp10), red prawn sp11, orange prawn sp8, and pink prawn sp9 (Table 14). Of the recorded crustaceans, 312 were found at the BCH22 site, which had red prawn sp7 as the most abundant taxa, representing almost 87% of the total individuals on that transect (Appendix Table 3). At the Chrysaor Central D1_3 sites T1-T4, the same red prawn species was also the most abundant taxa for each transect, representing 80%, 72%, 89%, and 75% of the total number of individuals on each respective transect (Appendix Table 3).

Table 14. Crustacean taxa in the Trench/Trough GF transects

Taxa	Number of individuals
Red prawn sp7	373
Dark prawn sp10	35
Red prawn sp11	12
Orange prawn sp8	10
Pink prawn sp9	6

Invertebrates

A total of 1,093 invertebrate individuals from 31 taxa were recorded across all sites. The invertebrate assemblage included 1 feather star (Cormatulida) species, 7 jellyfish (Scyphozoa) species, 7 sea cucumber (Holothuroidea) species, 8 sea star (Asteroidea) species, 7 sea urchin (Echinoidea) species and 1 squid (Cephlapod) species (Appendix Table 4). The assemblage was dominated by a brown jellyfish species (spJB) which accounted for 54% of the total number of individuals and were almost all recorded at site BCH22 (Appendix Table 4). The next most abundant taxa were *Peniagone* spPG, a purple sea cucumber species, Phormosomatidae spPH, and a purple sea urchin species (Table 15). Images of the ten most abundant invertebrate taxa are presented in Appendix 1 Table 30.

Table 15. Most abundant invertebrate taxa across all sites

Family	Taxa	Number of individuals
N/A	Brown jellyfish spJB	590
Elpidiidae	*Peniagone* spPG	83
N/A	Purple sea cucumber spSCP	64
Phormosomatidae	Phormosomatidae spPH	63
N/A	Purple sea urchin spSUBP	55

Statistical analysis

Fish assemblage

Across the whole survey area depth was an important predictor of the multivariate composition of the fish assemblage. A DistLM analysis found that depth alone explained 27% of the variation in the fish assemblage composition. (R^2 = 0.27177, Pseudo $F_{(1,69)}$ = 25.751, P<0.001).

Tests of differences in fish assemblage composition between water masses.

There was a significant difference in the fish assemblages of each of the three water masses (Table 16, Figure 5). The deeper water fish assemblages of the AAIW mass were different to the shallower water fish assemblages in both the SICW and the TSW water masses (Table 17). While some species were shared, the fish assemblage composition of the SICW and the TSW were also significantly different to one another (Table 19). The deeper waters of the AAIW were characterised by species that were correlated toward the left of the nMDS plot (Figure 5). These taxa included two *Aldrovandia* spp. (Halosauridae), a Macrouridae species, a species of Unidentified anguilliform fish, and a *Bathypterois* species (Ipnopidae). The fish assemblages of the TSW were separated from those of the SICW by a greater abundance of *Trachurus novaezelandiae* (Carangidae), an unidentified bait fish, and whaler shark *Carcharhinus* sp1 (Figure 5). The SICW water mass was characterised by a high abundance of *Seriola dumerilii* (Carangidae) and *Carcharhinus plumbeus*.

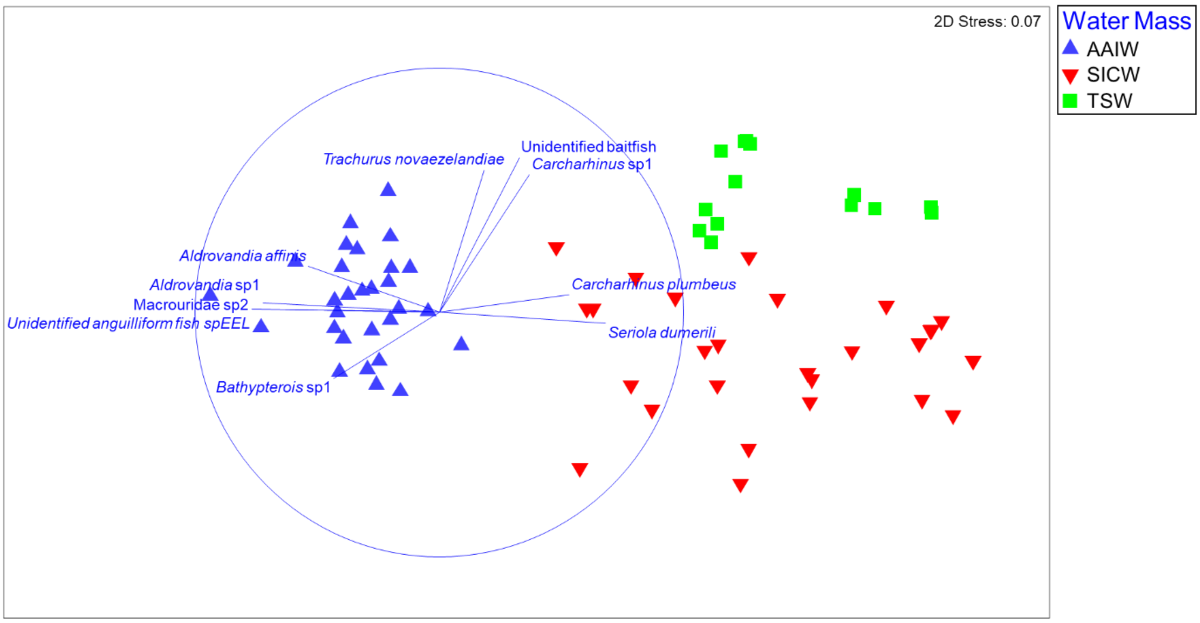


Figure 5. Non-metric Multidimensional Scaling Plot illustrating the difference in the multivariate composition of the fish assemblages among the Antarctic Intermediate Water (AAIW), Southern Indian Central Water (SICW) and Tropical Surface Water (TSW) masses. The length and direction of the vectors illustrated in blue indicates the strength and direction of the correlation of the named taxa to the data.

Table 16. Results of multivariate and univariate PERMANOVA tests for differences among water masses for the Fish Assemblage, the Total Number of Fish, and the Number of Fish Taxa.

Fish assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	91807	45903	5.691	**<0.001**
Site(Water Body)	12	102640	8553	6.677	<0.001
Res	56	71741	1281		
Total number of Fish					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	25538000	12769000	8.2766	**0.004**
Site(Water Body)	12	19772000	1647600	20.078	<0.001
Res	56	4595400	82061		
Number of Fish Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	18.854	9.43	0.513	0.611
Site(Water Body)	12	233.970	19.50	7.626	<0.001
Res	56	143.180	2.56		

Table 17. Post-hoc pairwise tests for differences in the multivariate Fish Assemblage composition between water masses. Statistically significant contrasts at α=0.05 are highlighted in bold.

Fish assemblage post-hoc comparisons between water masses			
Groups	t	P(perm)	perms
AAIW, SICW	2.79	**0.002**	9921
AAIW, TSW	2.93	**0.006**	8939
SICW, TSW	1.43	**0.040**	9435

The mean number of fish per transect was much greater in the TSW mass than in either the SICW or the AIW masses (Figure 6). Despite this, there was no statistically significant difference in the mean number of fish taxa per transect between water masses (Figure 7). On average each transect had between four and six fish taxa.

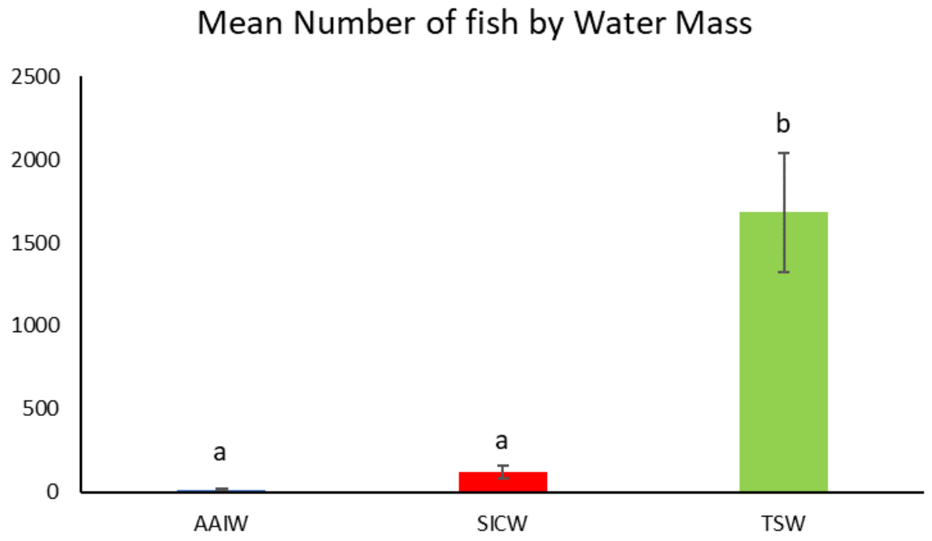


Figure 6. The mean (+- 1SE) number of fish per transect within each water mass. Letters above bars indicate statistically similar means at α = 0.05.

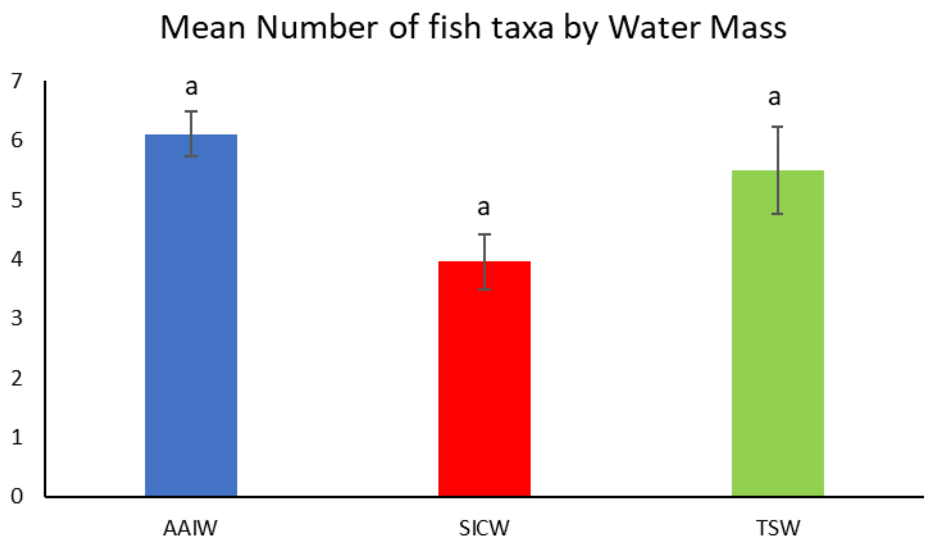


Figure 7. The mean (+- 1SE) number of fish taxa per transect within each water mass. Letters above bars indicate statistically similar means at α = 0.05.

Tests of differences in Fish assemblages among Key Ecological Features

There was a significant difference in the composition of the multivariate fish assemblage among the KEFs (Table 18). The fish assemblages of the Continental Slope Demersal Fish Communities KEF was different to those found at the Exmouth Plateau KEF and outside any KEFs (Table 19). This difference was driven by a number of fish species that were correlated toward the left of the nMDS plot (Figure 8a) in the direction of the deeper water samples from the Exmouth Plateau KEF and areas outside any KEF. These taxa included two *Aldrovandia* spp. (Halosauridae), a Macrouridae species, a species of Unidentified anguilliform fish, and a *Bathypterois* (Ipnopidae) species.

There was no statistically significant difference in the total number of fish among KEFs (Table 18). However, the P value of 0.054 is very close to the convention of α = 0.05, so post-hoc pairwise tests on the KEFs were done to confirm whether any differences did exist between KEFs. There was a much greater mean number of fish per transect at the Ancient Coastline at 125m depth contour KEF than at any of the other KEFs (Figure 9). In contrast, there was no statistically significant difference in the mean number of fish taxa between KEFs. Similar numbers of fish taxa were recorded at each KEF (Figure 10).

Table 18. Results of multivariate and univariate PERMANOVA tests for differences among Key Ecological Features (KEFs) for the Fish Assemblage, the Total Number of Fish, and the Number of Fish Taxa.

Fish assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	70242	23414	1.918	**0.012**
Site(KEF)	11	132420	12038	9.397	<0.001
Residual	56	71741	1281		
Total number of Fish					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	38602000	12867000	13.296	0.054
Site(KEF)	11	10490000	953640	11.621	0.001
Residual	56	4595400	82061		
Number of Fish Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	60.55	20.18	0.978	0.455
Site(KEF)	11	224.13	20.38	7.969	<0.001
Residual	56	143.18	2.56		

Table 19. Post-hoc pairwise tests for differences in the multivariate Fish Assemblage composition between Key Ecological Features. Where low numbers of permutations (perms) occur, the P(MC) value should be interpreted. Statistically significant contrasts at α=0.05 are highlighted in bold.

Fish assemblage post-hoc comparisons between KEFs				
Groups	t	P(perm)	perms	P(MC)
Exmouth Plateau, Continental Slope Demersal Fish Communities	2.15	**0.012**	1253	**0.004**
Exmouth Plateau, Outside KEF	1.01	0.220	8855	0.406
Exmouth Plateau, Ancient Coastline at 125 m depth contour	2.45	0.335	3	0.090
Continental Slope Demersal Fish Communities, Outside KEF	1.50	0.050	9926	**0.043**
Continental Slope Demersal Fish Communities, Ancient Coastline at 125 m depth contour	1.56	0.027	360	0.059
Outside KEF, Ancient Coastline at 125 m depth contour	1.15	0.437	6189	0.258

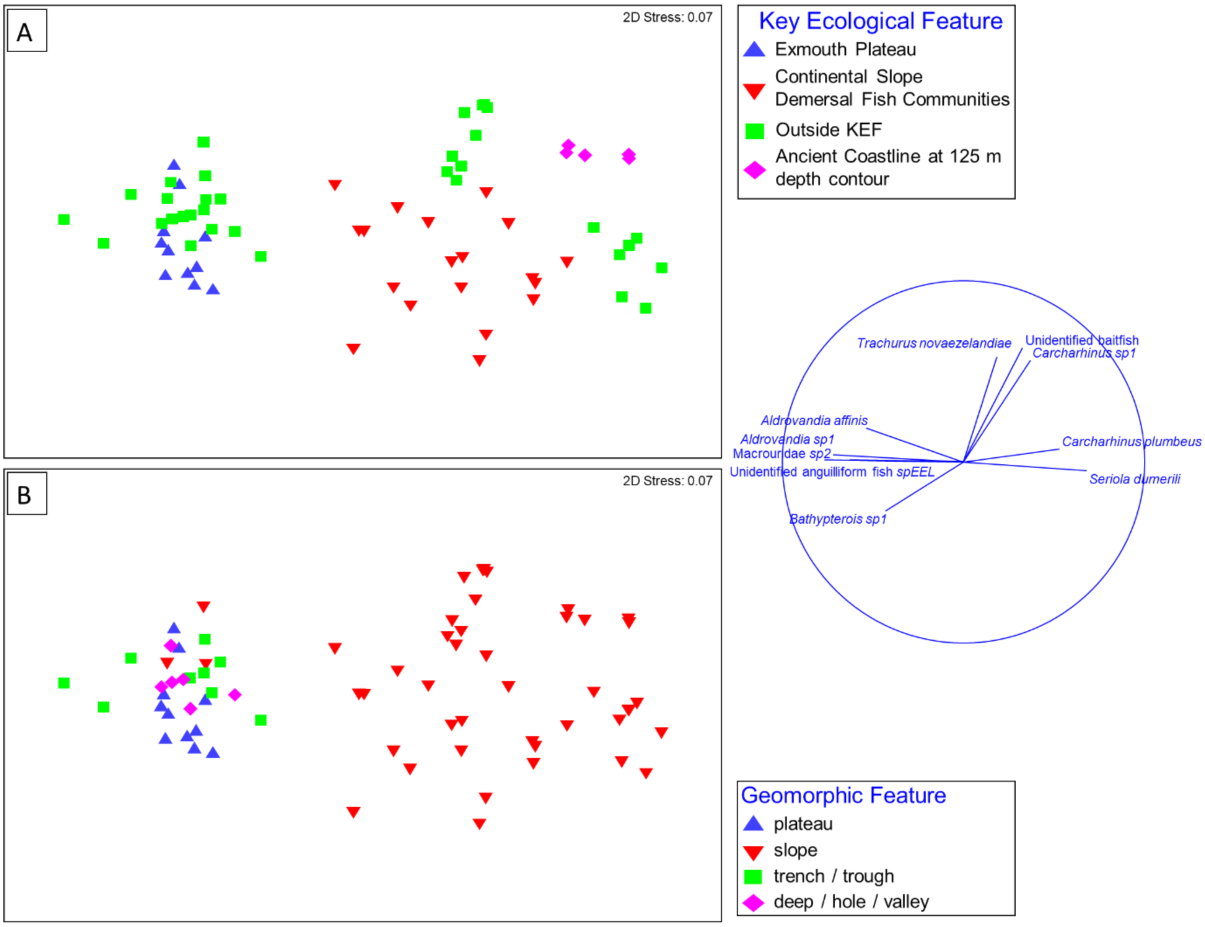


Figure 8. Non-metric Multidimensional Scaling Plots illustrating the difference in the multivariate composition of the fish assemblages among Key Ecological Features (KEFs) (A) and Geomorphic Features (GFs) (B). The length and direction of the vectors illustrated in blue indicates the strength and direction of the correlation of the named taxa to the data.

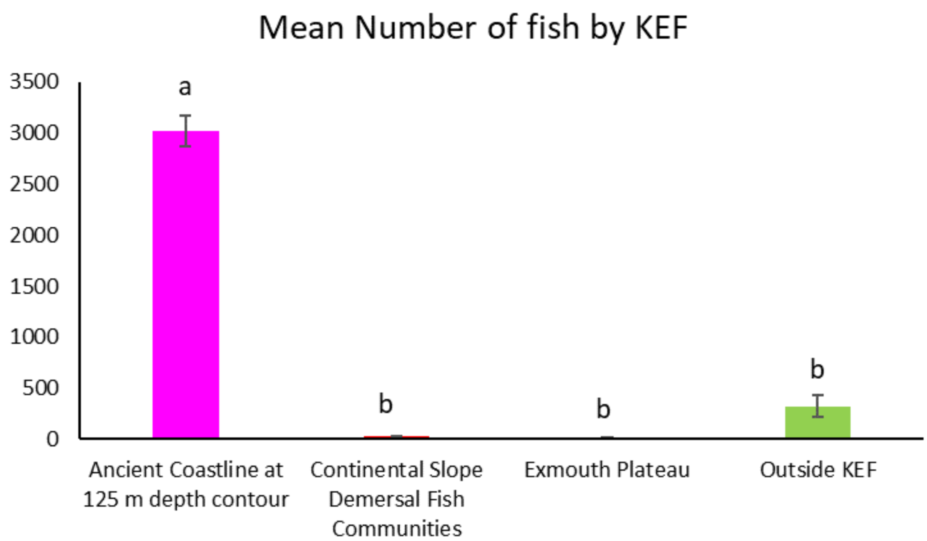


Figure 9. The mean (+- 1SE) number of fish per transect within each Key Ecological Feature (KEF). Letters above bars indicate statistically similar means at α = 0.05.

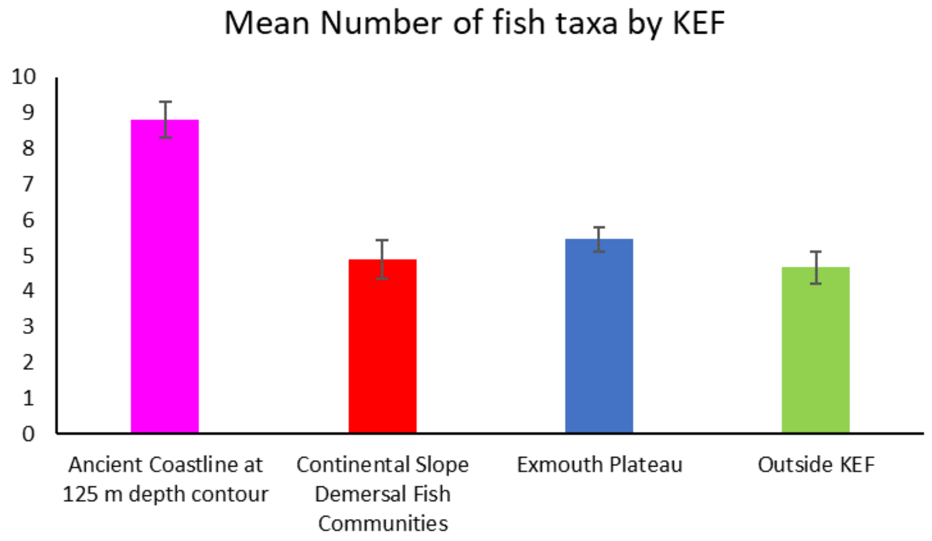


Figure 10. The mean (+- 1SE) number of fish taxa per transect within each Key Ecological Feature (KEF).

Tests of differences in Fish assemblages among Geomorphic Features

There was a significant difference in the composition of the multivariate fish assemblage among the GFs (Table 20Table 18). The fish assemblage of the slope GF was different to the plateau GF and the trench / trough GF (Table 21). This difference was driven by a number of fish species that were correlated toward the right of the nMDS plot (Figure 8b) in the direction of the shallower water slope samples. These taxa included *Trachurus novaezelandiae* (Carangidae), Unidentified baitfish, *Carcharhinus* sp1, *Carcharhinus plumbeus* (Carcharhinidae), and *Seriola dumerilii* (Carangidae) (Figure 8b).

There was no statistically significant difference in the total number of fish or the number of fish taxa per transect among GFs (Table 20). Qualitatively, the mean number of fish appeared higher on the slope GF than any other GFs (Figure 11), but there was a lot of variation in the number of fish associated with the slope among samples which is indicated by the large error bar (Figure 11). There was a similar number of fish taxa recorded among the GFs (Figure 12).

Table 20. Results of multivariate and univariate PERMANOVA tests for differences among Geomorphic Features (GFs) for the Fish Assemblage, the Total Number of Fish, and the Number of Fish Taxa.

Fish assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	75269	25090	1.790	**0.016**
Site(GF)	11	131010	11910	9.297	<0.001
Residual	56	71741	1281		
Total number of Fish					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	3935300	1311800	0.29333	0.652
Site(GF)	11	43753000	3977500	48.47	<0.001
Residual	56	4595400	82061		
Number of Fish Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	16.984	5.66	0.221	0.891
Site(GF)	11	264.02	24.00	9.387	<0.001
Residual	56	143.18	2.56		

Table 21. Post-hoc pairwise tests for differences in the multivariate Fish Assemblage composition between Geomorphic Features (GFs). Where low numbers of permutations (perms) occur, the P(MC) value should be interpreted. Statistically significant contrasts at α=0.05 are highlighted in bold.

Fish assemblage post-hoc comparisons between GFs				
Groups	t	P(perm)	perms	P(MC)
plateau, slope	1.61	0.010	9904	**0.020**
plateau, trench / trough	1.34	0.253	24	0.212
plateau, deep / hole / valley	0.80	0.672	6	0.639
slope, trench / trough	1.47	0.035	9907	**0.041**
slope, deep / hole / valley	1.19	0.084	9854	0.207
trench / trough, deep / hole / valley	0.98	0.673	6	0.526

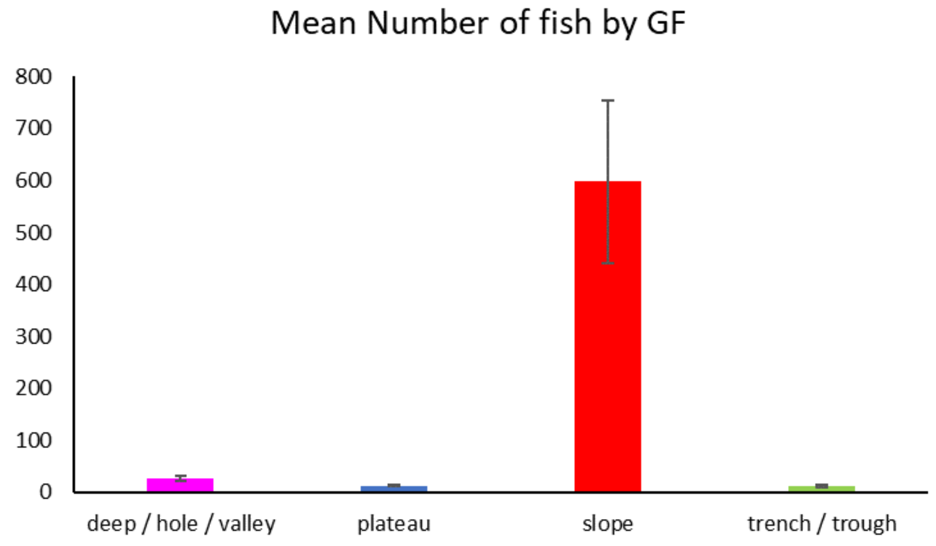


Figure 11. The mean (+- 1SE) number of fish per transect within each Geomorphic Feature (GF).

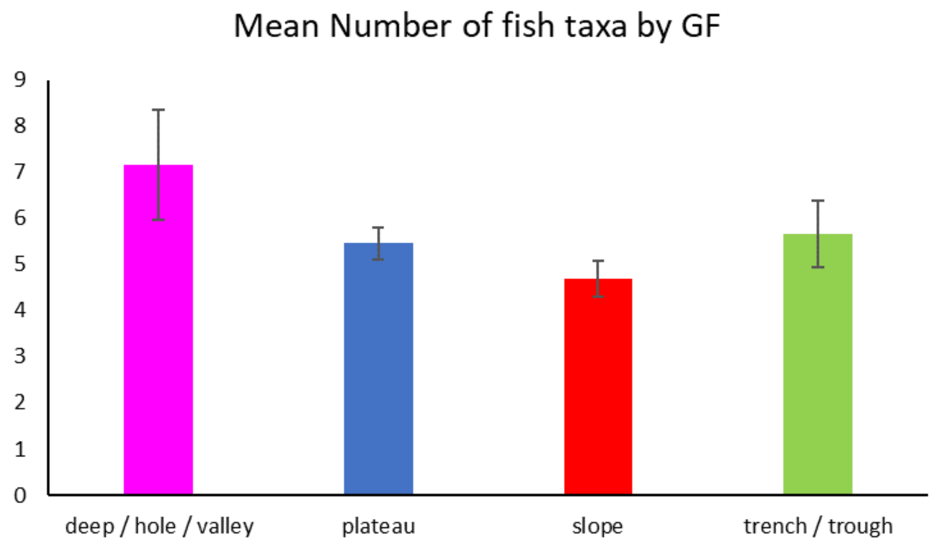


Figure 12. The mean (+- 1SE) number of fish taxa per transect within each Geomorphic Feature (GF).

Crustaceans

Across the whole survey area depth was a very important predictor of the multivariate composition of the crustacean assemblage. A DistLM analysis found that depth alone explained 73% of the variation in the crustacean assemblage composition (R^2 = 0.72716, Pseudo $F_{(1,69)}$ = 183.9, P<0.001).

Tests of differences in crustacean assemblage composition between water masses.

There was a significant difference in the crustacean assemblages of the three water masses (Figure 13, Table 22). Crustaceans were predominantly found in the deeper AAIW mass, and so the crustacean assemblage here was different to the shallower water SICW and the TSW water masses, which were not significantly different (Table 23). The abundance of all crustacean species was greater in the deeper waters of the AAIW, and correlated toward the right side of the nMDS plot (Figure 13). The most strongly correlated taxa were all prawns (Figure 13).

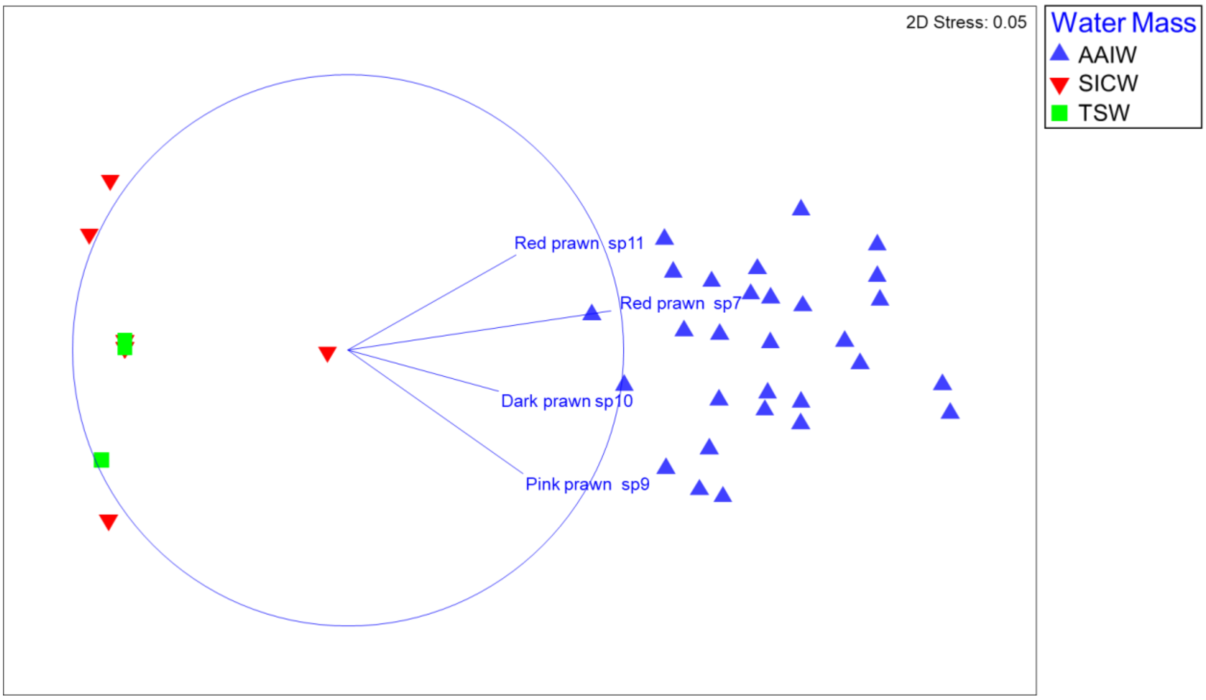


Figure 13. Non-metric Multidimensional Scaling Plot illustrating the difference in the multivariate composition of the crustacean assemblages among water masses. The length and direction of the vectors illustrated in blue indicates the strength and direction of the correlation of the named taxa to the data.

Table 22. Results of multivariate and univariate PERMANOVA tests for differences among water masses for the Crustacean Assemblage, the Total Number of Crustacean, and the Number of Crustacean Taxa.

Crustacean assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	82894	41447	50.744	**<0.001**
Site(Water Body)	12	10287	857	3.385	<0.001
Res	56	14184	253		
Total number of Crustaceans					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	12377	6189	11.572	**0.004**
Site(Water Body)	12	6857	571	23.341	<0.001
Res	56	1371	24		
Number of Crustacean Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
Water Body	2	149	74.50	85.218	**<0.001**
Site(Water Body)	12	10.766	0.90	1.617	0.115
Res	56	31.067	0.55		

Table 23. Post-hoc pairwise tests for differences in the multivariate Crustacean Assemblage composition between water masses. Statistically significant contrasts at α=0.05 are highlighted in bold.

Crustacean assemblage post-hoc comparisons between water masses			
Groups	t	P(perm)	perms
AAIW, SICW	8.36	**0.001**	9800
AAIW, TSW	6.08	**0.005**	8828
SICW, TSW	1.51	0.058	1193

The mean number of crustaceans, and the mean number of crustacean taxa were both significantly greater in the Antarctic Intermediate Water mass than either the Southern Indian Central or the Tropical Surface water masses (Table 22, Figure 14, Figure 15.). There was an average of 27 individual crustaceans and 3 crustacean taxa per transect in the AAIW water mass. The number of crustaceans and the number of crustacean taxa were similarly low in both the AAIW and the TSW water masses (Figure 14, Figure 15)

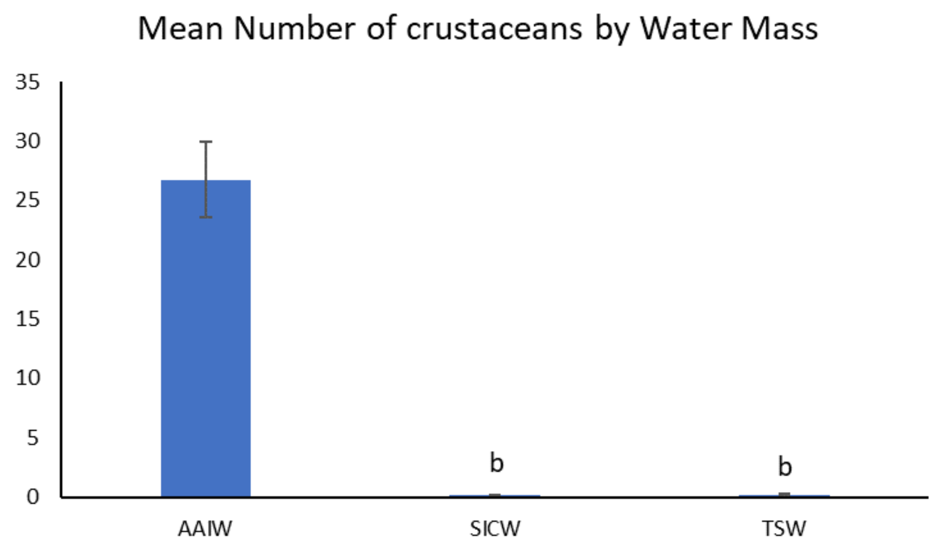


Figure 14. The mean (+- 1SE) number of crustaceans per transect within each water mass. Letters above bars indicate statistically similar means at α = 0.05.

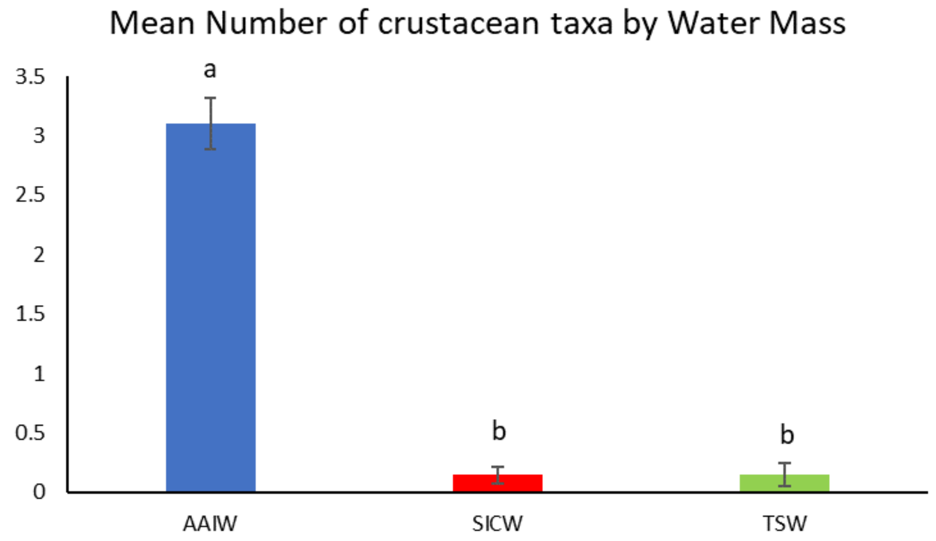


Figure 15. The mean (+- 1SE) number of crustacean taxa per transect within each water mass. Letters above bars indicate statistically similar means at α = 0.05.

Tests of differences in Crustacean assemblages among Key Ecological Features

There was not a statistically significant difference in the composition of the multivariate crustacean assemblage among the KEFs (Table 24). However, the P value of 0.057 is very close to the convention of α = 0.05, so post-hoc pairwise tests on the KEFs were done to confirm whether any differences did exist (Table 25). The crustacean assemblage of the Exmouth Plateau KEF was significantly different to that of the Continental Slope Demersal Fish Communities KEF and the Ancient Coastline at 125 m depth contour KEF (Table 25). The crustacean assemblage of the Continental Slope Demersal Fish Communities KEF was also different to the crustacean assemblage at areas Outside any KEF. These differences were driven by the crustacean taxa that were all correlated toward the right of the nMDS plot (Figure 16Figure 8a) in the direction of the deeper water samples from the Exmouth Plateau KEF and deeper areas outside any KEF. These taxa were all Prawn taxa.

There was no overall statistically significant difference in the total number of crustaceans among GFs (Table 24). However, qualitatively there was a greater number of crustaceans and crustacean taxa at the Exmouth Plateau and Outside KEFs than elsewhere. So post-hoc pairwise tests on the KEFs were done to confirm whether any differences did exist between KEFs.

There was a greater mean number of crustaceans, and a greater mean number of crustacean taxa at the Exmouth Plateau KEF than at the Ancient Coastline and Continental Slope Demersal Fish Communities KEFs (Figure 17, Figure 18). The mean number of crustaceans and number of crustacean taxa per transect Outside any KEF was also high, and statistically similar to the Exmouth Plateau KEF (Figure 17, Figure 18). However, there was variability within the Outside KEF samples, and the mean number of crustaceans was statistically similar to the mean number of crustaceans within the Ancient Coastline KEF (Figure 17). Similarly, the mean number of crustacean taxa Outside KEF was statistically similar to the number of crustacean taxa at both the Ancient Coastline and Continental Slope Demersal Fish KEFs (Figure 17, Figure 18).

Table 24. Results of multivariate and univariate PERMANOVA tests for differences among Key Ecological Features (KEFs) for the Crustacean Assemblage, the Total Number of Crustacean, and the Number of Crustacean Taxa.

Crustacean assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	42662	14221	2.646	**0.057**
Site(KEF)	11	58272	5297	20.915	<0.001
Residual	56	14184	253		
Total number of Crustaceans					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	5082	1694	1.2431	0.283
Site(KEF)	11	14772	1343	54.851	<0.001
Residual	56	1371	24		
Number of Crustacean Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
KEF	3	65.191	21.73	2.298	0.133
Site(KEF)	11	102.53	9.32	16.801	<0.001
Residual	56	31.067	0.55		

Table 25. Post-hoc pairwise tests for differences in the multivariate Crustacean Assemblage composition between Key Ecological Features (KEFs). Where low numbers of permutations (perms) occur, the P(MC) value should be interpreted. Statistically significant contrasts at α=0.05 are highlighted in bold.

Crustacean assemblage post-hoc comparisons between KEFs				
Groups	t	P(perm)	perms	P(MC)
Exmouth Plateau, Continental Slope Demersal Fish Communities	10.66	0.038	270	**<0.001**
Exmouth Plateau, Outside KEF	0.97	0.418	8110	0.383
Exmouth Plateau, Ancient Coastline at 125 m depth contour	5.48	0.339	3	**0.014**
Continental Slope Demersal Fish Communities, Outside KEF	2.01	0.071	9826	**0.045**
Continental Slope Demersal Fish Communities, Ancient Coastline at 125 m depth contour	1.18	0.390	72	0.260
Outside KEF, Ancient Coastline at 125 m depth contour	0.92	0.752	4395	0.414

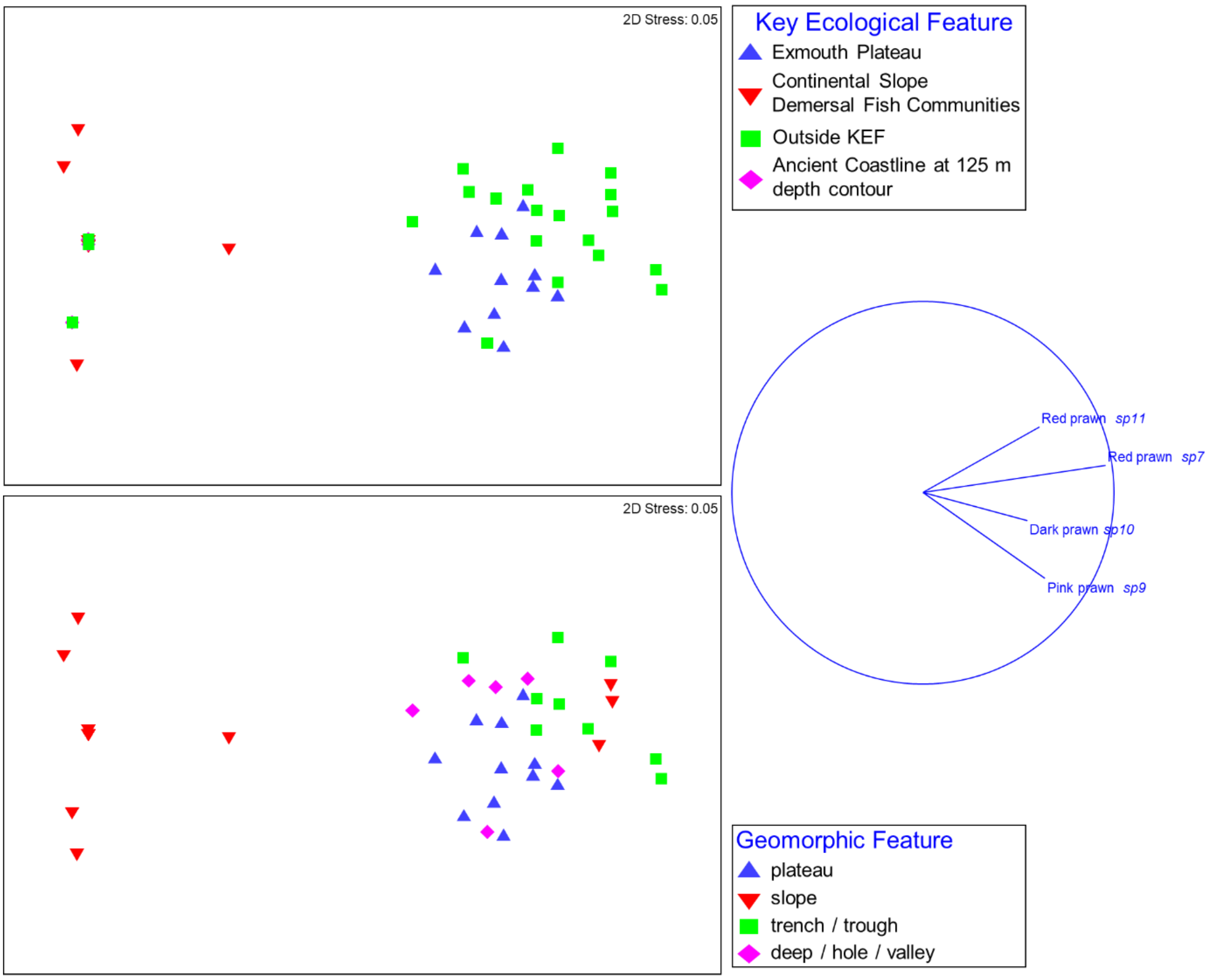


Figure 16. Non-metric Multidimensional Scaling Plots illustrating the difference in the multivariate composition of the crustacean assemblages among Key Ecological Features (KEFs) (A) and Geomorphic Features (GFs) (B). The length and direction of the vectors illustrated in blue indicates the strength and direction of the correlation of the named taxa to the data.

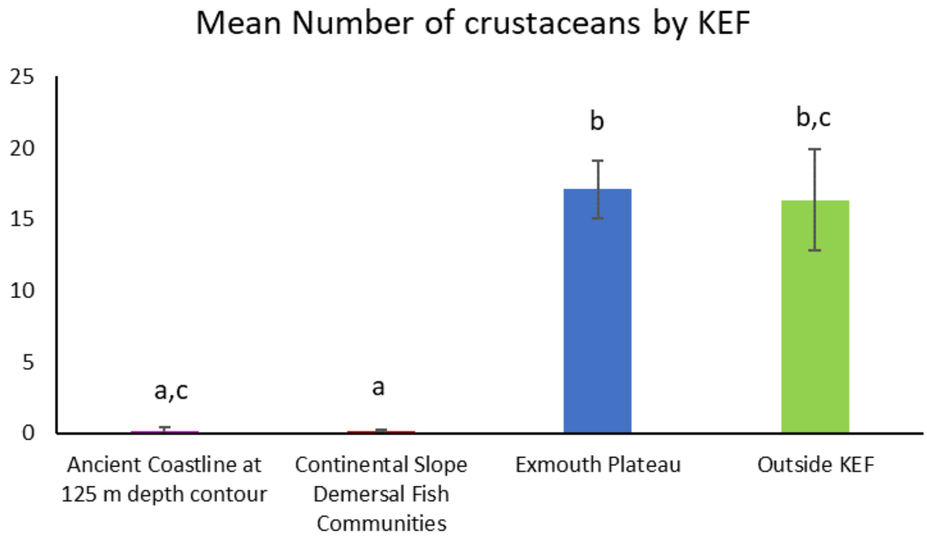


Figure 17. The mean (+- 1SE) number of crustaceans per transect within each Key Ecological Feature. Letters above bars indicate statistically similar means at α = 0.05.

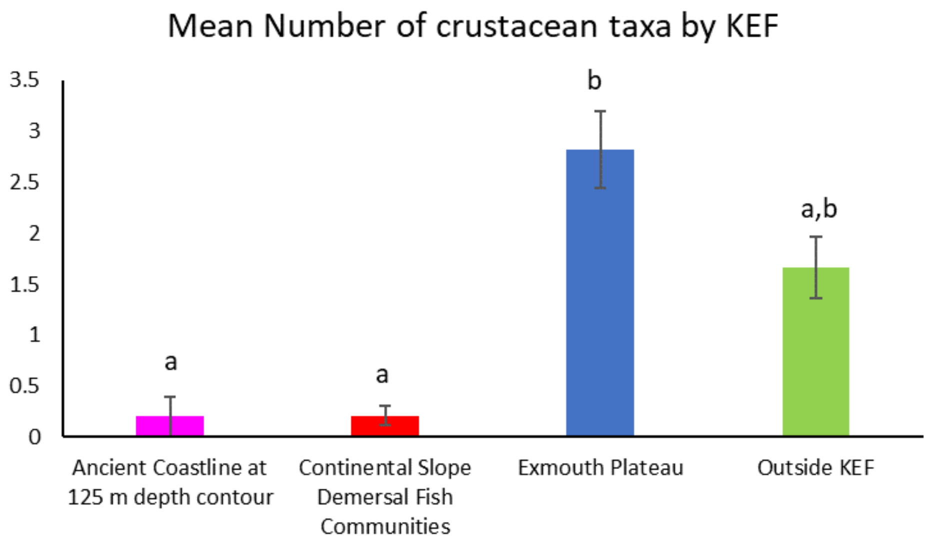


Figure 18. The mean (+- 1SE) number of crustacean taxa per transect within each Key Ecological Feature. Letters above bars indicate statistically similar means at α = 0.05.

Tests of differences in Crustacean assemblages among Geomorphic Features

There was a significant difference in the composition of the multivariate crustacean assemblage among the GFs (Table 26Table 20Table 18). The crustacean assemblage of the slope GF was different to the plateau GF, the trench / trough GF, and the Deep / hole / valley GF (Table 27). The crustacean assemblages of the plateau GF, the trench / trough GF, and the Deep / hole / valley GF were statistically similar (Table 27). The difference between the slope GF and the other GFs was driven by the crustacean taxa that were all correlated toward the right of the nMDS plot (Figure 16Figure 8b) in the direction of the deeper water samples and away from the shallower water samples of the slope GF.

There was no statistically significant difference in the total number of crustaceans per transect among GFs (Table 26). Qualitatively, the mean number of crustaceans appeared lowest on the slope GF and highest at the trench / trough GFs (Figure 19). Post-hoc pairwise tests confirmed that the mean number of crustaceans per transect was higher in the trench / trough GF than the slope GF (Figure 19). However, these were both statistically similar to the deep / hole / valley GF and the plateau GFs (Figure 19).

There was a statistically significant difference in the mean number of crustacean taxa per transect among the GFs (Table 26, Figure 20). The number of crustacean taxa at the trench / trough GF was higher than at the plateau or slope GFs (Figure 20). The number of crustacean taxa per transect in the plateau GF was also greater than at the slope GF (Figure 20). The mean number of crustacean taxa per transect at the deep / hole / valley GF was statistically similar to all the other GFs (Figure 20).

Table 26. Results of multivariate and univariate PERMANOVA tests for differences among Geomorphic Features (GFs) for the Crustacean Assemblage, the Total Number of Crustacean, and the Number of Crustacean Taxa.

Crustacean assemblage					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	67022	22341	9.695	**0.001**
Site(GF)	11	22393	2036	8.037	<0.001
Residual	56	14184	253		
Total number of Crustaceans					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	9210	3070	4.0291	0.083
Site(GF)	11	7401	673	27.481	<0.001
Residual	56	1371	24		
Number of Crustacean Taxa					
Source	df	SS	MS	Pseudo-F	P(perm)
GF	3	85.046	28.35	4.709	**0.017**
Site(GF)	11	58.57	5.32	9.598	<0.001
Residual	56	31.067	0.55		

Table 27. Post-hoc pairwise tests for differences in the multivariate Crustacean Assemblage composition between Geomorphic Features (GFs). Where low numbers of permutations (perms) occur, the P(MC) value should be interpreted. Statistically significant contrasts at α=0.05 are highlighted in bold.

Crustacean assemblage post-hoc comparisons between KEFs				
Groups	t	P(perm)	perms	P(MC)
plateau, slope	3.81	**0.019**	9505	**0.001**
plateau, trench / trough	1.42	0.164	6	0.211
plateau, deep / hole / valley	1.69	0.000	3	0.196
slope, trench / trough	4.00	**0.015**	9423	**0.001**
slope, deep / hole / valley	2.68	**0.093**	7761	**0.010**
trench / trough, deep / hole / valley	1.16	0.326	3	0.398

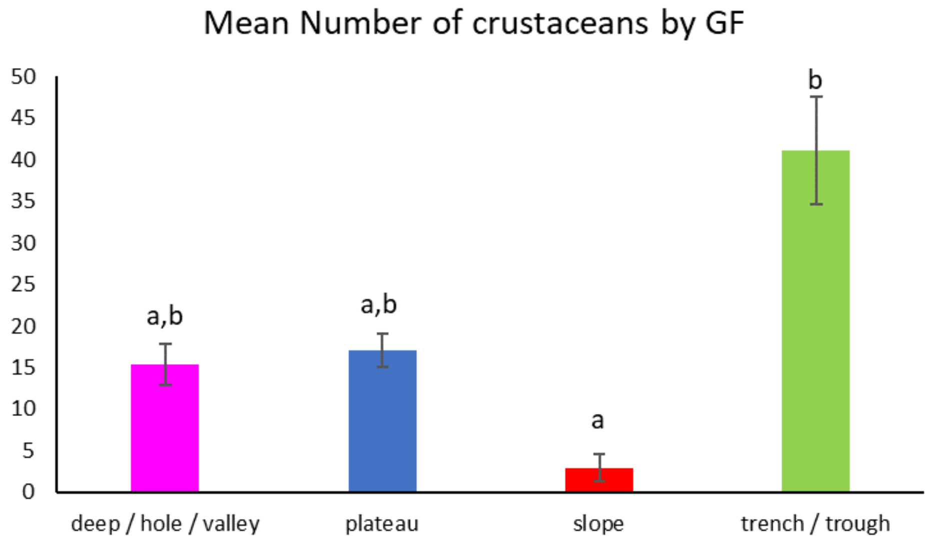


Figure 19. The mean (+- 1SE) number of crustaceans per transect within each Geomorphic Feature (GFs). Letters above bars indicate statistically similar means at α = 0.05.

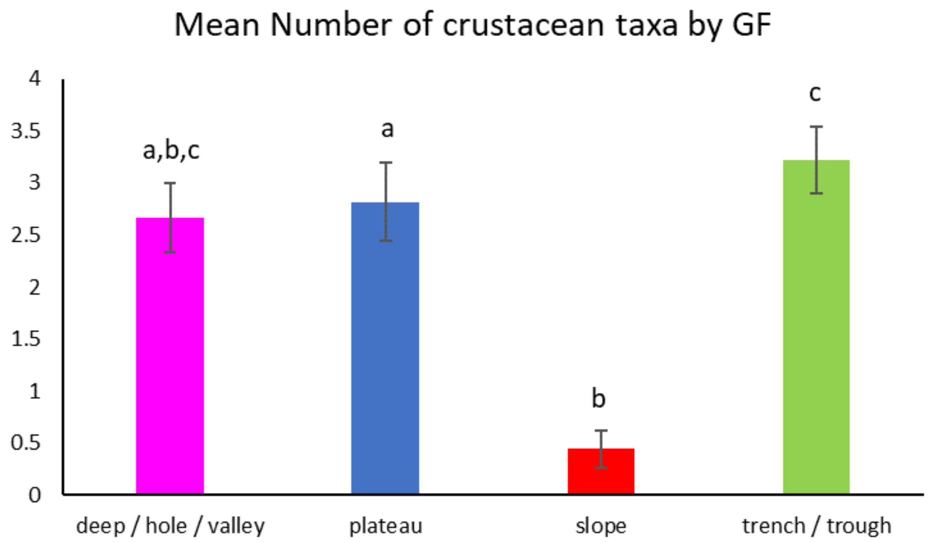


Figure 20. The mean (+- 1SE) number of Crustacean taxa per transect within each Geomorphic Feature (GF). Letters above bars indicate statistically similar means at α = 0.05.

4. Discussion

Distinct fish and crustacean assemblages were recorded across the survey area. These were strongly influenced by water depth, and the three water masses that were identified. Most notably, almost all crustaceans and crustacean taxa were recorded at the deeper sites in the AAIW mass. There was also a clear distinction in the fish assemblages, with the deeper sites being characterised by Macrouridae (rat tails), Halosauridae (halosaurs) and unidentified anguilliform (eel like) fishes. The shallower sites of the TSW mass and the Ancient Coastline at 125 m contour KEF were characterised by sharks and Carangidae such as *Trachurus novaezelandiae* (yellowtail scad). These shallower areas had a much greater number of fish recorded than elsewhere, with a mean of 3,000 fish per transect in the Ancient Coastline at 125 m contour KEF, and 1,700 fish per transect across all sites in the TSW. The fish assemblages of the deeper continental slope were also dominated by Carangidae, but here different taxa including two species of scad, *Decapterus kurroides* and *Decapterus* sp1, and *Seriola dumerili* (amberjack) were recorded. This zone was characterised by the SICW mass and included the slope GF and the Continental Slope Demersal Fish Communities KEF. Although there were large differences in the number of fish observed across the survey area among water masses, KEFs and GFs, the average diversity of fishes remained consistent across the survey area. While the deeper sites had lower numbers of fishes, the number of fish taxa was the same as at the shallower sites.

There were differences in patterns of assemblage composition, abundance and number of taxa in both the fish and crustaceans sampled that were associated with the deeper waters of greater than 800 m depth and the AAIW mass. A similar pattern was described by Saunders et al. (2021) and has previously been reported (Last et al., 2011). This faunal break can be attributed to the influence of the AAIW (Williams et al., 2001). This deep-water current is cold and has a lower salinity than the shallower water masses identified in this survey. The AAIW has a strong influence on the distribution of fish communities in the south-west region between the Great Australian Bight and north of the Ningaloo Reef. The depth of the AAIW fluctuates from 875 m at 27.50°S to 520 m around 21.50°S (Williams et al., 1996; 2001; Woo and Pattiaratchi, 2008). There was a break in the water depth of the samples collected during this survey, with no samples collected between 280 and 800 m water depth. Therefore the transition zone between water masses could not be identified. A recent survey in a similar area covered water depths between 360 and 870 m and identified that a similar faunal break occurred between 700 and 800 m water depth (Saunders et al., 2021). A break between mid-slope and shelf-break fish assemblages at water depths of between 700 and 900 m was also reported by Williams et al. (2001) in the northern area of their survey, which is a similar location to this one.

There were some limitations associated with the survey method that are likely to have influenced the fish and crustacean data that was recorded. The identification of many of the individuals observed was difficult because of the small size, distance from the camera, and the slight downward facing camera angle. For this reason, a conservative approach was taken where there was uncertainty in the identification, and many taxa were pooled to higher taxonomic groups. In particular, the group of unidentified anguilliform fishes and unidentified baitfish are likely to include multiple taxa. This could be partially mitigated by mounting video cameras lower down on the ROV platform, and facing directly forward, although this set up was used in Saunders et al. (2021) and similar issues with identification were encountered. In addition, some of the shallower sites sampled had very high abundances of fish, particularly *Decapterus* spp. (scads). Following the established procedure (Goetze et al., 2019) all fish encountered along a transect were counted, unless they could be positively identified as having been already counted, and to have re-entered the transect. Therefore, it’s possible that the abundances of these species may be inflated due to re-counts of the same individual. With a single video camera recording it is not possible to define the transect width and height, which could also lead to inflated numbers. A stereo-video system (Saunders et al., 2021) would overcome this issue by allowing the transect dimensions to be defined, and the three-dimensional position of each fish within the transect to be identified.

5. References

Anderson M, Gorley R, Clarke K (2008) PERMANOVA+ for PRIMER: guide to software and statistical methods. Primer-E, Plymouth 214

Appeltans, W., Ahyong, S. T., Anderson, G., Angel, M. V., Artois, T., Bailly, N., Bamber, R., Barber, A., Bartsch, I., Berta, A., Błażewicz-Paszkowycz, M., Bock, P., Boxshall, G., Boyko, C. B., Brandão, S. N., Bray, R. A., Bruce, N. L., Cairns, S. D., Chan, T.-Y., … Costello, M. J. (2012). The Magnitude of Global Marine Species Diversity. *Current Biology: CB*, *22*(23), 2189–2202.

Armstrong, C. W., Foley, N. S., Tinch, R., & van den Hove, S. (2012). Services from the deep: Steps towards valuation of deep sea goods and services. *Ecosystem Services*, *2*, 2–13.

Clarke KR, Gorley RN (2015) PRIMER v7: User Manual/Tutorial. PRIMER-E Ltd: Plymouth, UK.

Currey-Randall, L. M., Galaiduk, R., Stowar, M., Vaughan, B. I., & Miller, K. J. (2021). Mesophotic fish communities of the ancient coastline in Western Australia. *PloS One*, *16*(4), e0250427.

CSIRO (2022) Atlas of living Australia. http://ala.org.au/

Fox, N. J., & Beckley, L. E. (2005). Priority areas for conservation of Western Australian coastal fishes: a comparison of hotspot, biogeographical and complementarity approaches. *Biological Conservation*, *125*(4), 399-410.

Flynn A, Pogonoski J (2012) Guide to mesopelagic fishes of the southern Tasman Sea. CSIRO Marine and Atmospheric Research, Hobart, Tasmania

Froese R, Pauly D (2022) FishBase. World Wide Web electronic publication. www.fishbase.org/, version (06/2022)

Gaughan, D. J., & Santoro, K. (2020). Status reports of the fisheries and aquatic resources of Western Australia 2018/19. State of the fisheries.

Goetze J.S., Bond T., McLean D.L., Saunders B.J., Langlois T. J., Lindfield S., Fullwood L. A., Driessen D., Shedrawi G., Harvey E. S. (2019). A field and video analysis guide for diver operated stereo-video. *Methods in Ecology and Evolution, 10* (7), 1083-1090.

Heap, A. D., & Harris, P. T. (2008). Geomorphology of the Australian margin and adjacent seafloor. *Australian Journal of Earth Sciences*, *55*(4), 555–585.

Last PR & Stevens JD (2009) Sharks and rays of Australia. CSIRO publishing, Collingwood, Victoria

Last, P. R., Lyne, V. D., Williams, A., Davies, C. R., Butler, A. J., & Yearsley, G. K. (2010). A hierarchical framework for classifying seabed biodiversity with application to planning and managing Australia’s marine biological resources. *Biological Conservation*, *143*(7), 1675-1686.

McLean, D. L., Taylor, M. D., Partridge, J. C., Gibbons, B., Langlois, T. J., Malseed, B. E., ... & Bond, T. (2018). Fish and habitats on wellhead infrastructure on the north west shelf of Western Australia. *Continental Shelf Research*, *164*, 10-27.

Poore GCB, McCallum AW, Taylor J (2008) Decapod Crustacea of the continental margin of southwestern and central Western Australia: preliminary identifications of 524 species from FRV Southern Surveyor voyage SS10-2005. Museum Victoria, Melbourne, Victoria

Rogers, A. D. (2015). Environmental change in the deep ocean. *Annual Review of Environment and Resources*, *40*(1), 1-38.

Saunders, B. J., Galaiduk, R., Inostroza, K., Myers, E. M. V., Goetze, J. S., Westera, M., Twomey, L., McCorry, D., & Harvey, E. S. (2021). Quantifying Patterns in Fish Assemblages and Habitat Use Along a Deep Submarine Canyon-Valley Feature Using a Remotely Operated Vehicle. *Frontiers in Marine Science*, *8*. https://doi.org/10.3389/fmars.2021.608665

Schramm, K. D., Marnane, M. J., Elsdon, T. S., Jones, C., Saunders, B. J., Goetze, J. S., ... & Harvey, E. S. (2020). A comparison of stereo-BRUVs and stereo-ROV techniques for sampling shallow water fish communities on and off pipelines. *Marine Environmental Research*, *162*, 105198.

SeaGIS (2022) EventMeasure. SeaGIS Pty Ltd, www.SeaGIS.com.au

Swainston R (2010) Swainston's fishes of Australia. Penguin, Camberwell, Victoria

Sward, D., Monk, J., & Barrett, N. (2019). A systematic review of remotely operated vehicle surveys for visually assessing fish assemblages. *Frontiers in Marine Science, 6*, 134.

Wellington, C. M., Harvey, E. S., Wakefield, C. B., Abdo, D., & Newman, S. J. (2021). Latitude, depth and environmental variables influence deepwater fish assemblages off Western Australia. *Journal of Experimental Marine Biology and Ecology*, *539*, 151539.

Williams, A., Koslow, J. A., & Last, P. R. (2001). Diversity, density and community structure of the demersal fish fauna of the continental slope off western Australia (20 to 35°S). *Marine Ecology Progress Series*, *212*, 247–263.

Williams A, Last PR, Gomon MF, Paxton JR (1996) Species composition and checklist of the demersal ichthyofauna of the continental slope off Western Australia (20-35°5). *Records of the Western Australian Museum, 18*, 135-155

Woo M., & Pattiaratchi C. (2008). Hydrography and water masses off the western Australian coast. *Deep Sea Research Part I 55*, 1090–1104.

6. Appendix 1. Images of the most abundant fish, crustacean and mobile invertebrate taxa

Table 28. Images of the most abundant fish taxa across the survey area. Images of all the fish identified within the body of the report are listed. Images are organised alphabetically by family followed by taxa.

Family	Taxa	Image
Carangidae	*Carangoides* sp1	
Carangidae	*Decapterus kurroides*	
Carangidae	*Decapterus* sp1	
Carangidae	*Seriola dumerili*	

Family	Taxa	Image
Carangidae	*Trachurus novaezelandiae*	
Carcharhinidae	*Carcharhinus* sp1	
Halosauridae	*Aldrovandia affinis*	
Halosauridae	*Aldrovandia* sp1	
Halosauridae	*Aldrovandia* sp2	
Ipnopidae	*Bathypterois* sp1	

Family	Taxa	Image
Macrouridae	Macrouridae sp1	
Macrouridae	Macrouridae sp2	
Macrouridae	Macrouridae sp4	
Rachycentridae	*Rachycentron canadum*	
Synodontidae	Synodontidae sp2	
N/A	unidentified anguilliform fish	

Family	Taxa	Image
N/A	unidentified baitfish	

Table 29. Images of the ten most abundant crustacean taxa across the survey area. Images are organised alphabetically by family followed by taxa.

Family	Taxa	Image
Galatheidae	Galatheidae sp. G	
Homolidae	Homolidae spH	
Ibacinae	*Ibacus* spI	
Parapaguridae	Parapaguridae spPP	
N/A	Dark prawn sp10	
N/A	Orange prawn sp8	
N/A	Pink prawn sp9	

Family	Taxa	Image
N/A	Red prawn sp7	
N/A	Red prawn sp11	
N/A	Unidentified prawn species	

Table 30. Images of the ten most abundant mobile invertebrate taxa across the survey area. Images are organised alphabetically by family followed by taxa.

Family	**Taxa**	**Image**
Elpidiidae	*Peniagone* spPG	
Pelagothuriidae	*Enypniastes eximia*	
Phormosomatidae	Phormosomatidae spPH	
N/A	Brown jellyfish spJB	
N/A	Cormatulida sp. C	
N/A	Purple jellyfish spJP	

Family	Taxa	Image
N/A	Purple sea cucumber spSCP	
N/A	Purple sea urchin spSUBP	
N/A	Purple sea urchin small spSUP	
N/A	Sea star white spSSW	

Appendix E Sediment and Water Chain of Custody

Environmental Division
Brisbane
Work Order Reference
EB2215199

Telephone : + 61-7-3243 7222

CHAIN OF CUSTODY

ALS Environmental

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☐ADELAIDE 21 Burma Road Pooraka SA 5095 Ph: 08 8359 0890 E: adelaide@alsglobal.com
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☐GLADSTONE 46 Callemondah Drive Clinton QLD 4680 Ph: 07 7471 5600 E: gladstone@alsglobal.com
☐MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com
☐MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com
☐MUDGEE 27 Sydney Road Mudgee NSW 2850 Ph: 02 6372 6735 E: mudgee.mail@alsglobal.com
☐NEWCASTLE 5/585 Maitland Rd Mayfield West NSW 2304 Ph: 02 4014 2500 E: samples.newcastle@alsglobal.com
☐NOWRA 4/13 Geary Place North Nowra NSW 2541 Ph: 024423 2063 E: nowra@alsglobal.com
☐PERTH 10 Hod Way Malaga WA 6090 Ph: 08 9209 7655 E: samples.perth@alsglobal.com

CLIENT: Advisian

OFFICE: Lvl 14, 240 St Georges Terrace, Perth

PROJECT: Gorgon Benthic Survey 2022

ORDER NUMBER: 1

PROJECT MANAGER: Mark Westera — **CONTACT PH:** 0422 489 803

SAMPLER: Luca Chiaroni, Stephanie Watts — **SAMPLER MOBILE:** 0498 014 575

COC emailed to ALS? (YES / NO) — **EDD FORMAT (or default):**

Email Reports to (will default to PM if no other addresses are listed): **mark.westera@advisian.com**

Email Invoice to (will default to PM if no other addresses are listed): **mark.westera@advisian.com**

TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g.. Ultra Trace Organics)
☐ Standard TAT (List due date):
☐ Non Standard or urgent TAT (List due date):

ALS QUOTE NO.: EP-246-22_V2

COC SEQUENCE NUMBER (Circle)
COC: 1 2 3 4 3 4 5 6 5 6 7
OF: 1 2 3 4 3 4 5 6 5 6 7

FOR LABORATORY USE ONLY (Circle)
Custody Seal Intact? Yes No N/A
Free ice / frozen ice bricks present upon receipt? Yes No N/A
Random Sample Temperature on Receipt:
Other comment:

RELINQUISHED BY:	RECEIVED BY:	RELINQUISHED BY:	RECEIVED BY:
Luca Chiaroni	[signature]		
DATE/TIME:	DATE/TIME: 27/5/22 11:36	DATE/TIME:	DATE/TIME:

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ALS USE — SAMPLE DETAILS MATRIX: SOLID (S) WATER (W) — CONTAINER INFORMATION

ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).

LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	Mercury (Total)	Mercury (Dissolved)	DOC	TOC	TDS	TP/TN			Additional Information: Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
0																					
EP2205756-001	WTR DC-1_SURFACE_1	20220509	W		10				X	X	X	X	X	X	X	X		X			
EP2205756-011	GORGON GMT_SEABED_1	20220510	W		10				X	X	X	X	X	X	X	X		X			
TOTAL					20	0	0	0	2	2	2	2	2	2	2	2	0	2			

VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; NP=NaOH preserved Plastic; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
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Brisbane
Work Order Reference
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Telephone : + 61-7-3243 7222

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CLIENT: Advisian

OFFICE: Lvl 14, 240 St Georges Terrace, Perth

PROJECT: Gorgon Benthic Survey 2022

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PROJECT MANAGER: Mark Westera CONTACT PH: 0422 489 803

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☐ Standard TAT (List due date):
☐ Non Standard or urgent TAT (List due date):

ALS QUOTE NO.: EP-246-22_V2

COC SEQUENCE NUMBER (Circle)
COC: 1 2 3 4 5 6 7
OF: 1 2 3 4 5 6 7

FOR LABORATORY USE ONLY (Circle)
Custody Seal Intact? Yes No N/A
Free ice / frozen ice bricks present upon receipt? Yes No N/A
Random Sample Temperature on Receipt:
Other comment:

RELINQUISHED BY:	RECEIVED BY:	RELINQUISHED BY:	RECEIVED BY:
Luca Chiaroni	[signature]		
DATE/TIME:	DATE/TIME: 27/5/22 11:36	DATE/TIME:	DATE/TIME:

ALS USE | SAMPLE DETAILS MATRIX: SOLIDS (S) WATER (W) | CONTAINER INFORMATION

ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price)
Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).

LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) Total	Cromium (III & VI) - Dissolved	Mercury (Total)	Mercury (Dissolved)	DOC	TOC	TDS	TP/TN			Additional Information: Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
EP2205756-001	WTR DC-1_SURFACE_1	20220509	W		10				X	X	X	X	X	X	X	X		X			
EP2205756-011	GORGON GMT_SEABED_1	20220510	W		10				X	X	X	X	X	X	X	X		X			
TOTAL					20	0	0	0	2	2	2	2	2	2	2	2	0	2			

VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; NP=NaOH preserved Plastic; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

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Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com

Environmental Division
Brisbane
Work Order Reference
EB2215235

Telephone : + 61-7-3243 7222

CLIENT:	Advisian
OFFICE:	Lvl 14, 240 St Georges Terrace, Perth
PROJECT:	Gorgon Benthic Survey 2022
ORDER NUMBER:	1
PROJECT MANAGER:	Mark Westera
CONTACT PH:	0422 489 803
SAMPLER:	Luca Chiaroni, Stephanie Watts
SAMPLER MOBILE:	0498 014 575
COC emailed to ALS?	(YES)
EDD FORMAT (or default):	

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Email Invoice to (will default to PM if no other addresses are listed): mark.westera@advisian.com; connor.campbell@advisian.com

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g.. Ultra Trace Organics)

☐ Standard TAT (List due date): AS SOON AS POSSIBLE

☐ Non Standard or urgent TAT (List due date):

ALS QUOTE NO.: EP-246-22_V2

COC SEQUENCE NUMBER (Circle)

COC: 1 2 3 4 5 6 7

OF: 1 2 3 4 5 6 7

FOR LABORATORY USE ONLY: Custody Seal Intact? Free ice / frozen ice... Random Sample Te... Other comment: N/A N/A

RELINQUISHED BY:	RECEIVED BY:	RELINQUISHED BY:
Luca Chiaroni/Steph Watts	[signature]	
DATE/TIME: 26/05/22 1100	DATE/TIME: 27/5/22 11:30	DATE/TIME:

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).									Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAHs if TRH recorded	Metals (total only)	TOC (Total organic carbon) (%)	Particle Size Distribution (laser diffraction and wet sieving)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	Retain Excess sample for PSD anaysis	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
EP2205801-003	SEMELE WELL-4_1_3	20220508	S	150ml jar	1	x	x		x			x	x		
EP2205801-002	SEMELE WELL-4_1_2	20220508	S	150ml jar	1	x	x		x			x	x		
EP2205801-004	WTR DC-1-4_1_1	20220509	S	150ml jar	1	x	x		x			x	x		
EP2205801-009	WTR DC-2_2_3	20220509	S	150ml jar	1	x	x		x			x	x		
				TOTAL	4	4	4		4			4	4		

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).									Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Cromium (III & VI)	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
5	STB4_SURFACE_1	20220430	W	500ml clear plastic Green label -(P)	1								X		
5	STB4_SURFACE_1	20220430	W	60ml clear plastic - blue label -(NP)	1					X					UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
5	STB4_SURFACE_1	20220430	W	60ml clear plastic - purple label - (SP)	1									X	
5	STB4_SURFACE_1	20220430	W	40ml glass vial - (VS)	2		X								
5	STB4_SURFACE_1	20220430	W	40ml glass vial - filtered (VS)	1						X				FILTERED SAMPLE
5	STB4_SURFACE_1	20220430	W	40ml glass vial - (VS)	1							X			

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).									Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Cromium (III & VI)	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
5	STB4_SURFACE_1	20220430	W	100ml Amber Glass - orange label (AG)	1	X									
5	STB4_SURFACE_1	20220430	W	100ml Amber Glass - orange label (AG)	1			X							
5	STB4_SURFACE_1	20220430	W	60ml plastic red/green label - (P)	1				X						UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
6	STB4_SURFACE_2	20220430	W	500ml clear plastic Green label -(P)	1								X		
6	STB4_SURFACE_2	20220430	W	60ml clear plastic - blue label -(NP)	1					X					UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
6	STB4_SURFACE_2	20220430	W	60ml clear plastic - purple label - (SP)	1									X	
6	STB4_SURFACE_2	20220430	W	40ml glass vial - (VS)	2		X								
6	STB4_SURFACE_2	20220430	W	40ml glass vial - filtered (VS)	1						X				FILTERED SAMPLE
6	STB4_SURFACE_2	20220430	W	40ml glass vial - (VS)	1							X			
6	STB4_SURFACE_2	20220430	W	100ml Amber Glass - orange label (AG)	1	X									
6	STB4_SURFACE_2	20220430	W	100ml Amber Glass - orange label (AG)	1			X							
6	STB4_SURFACE_2	20220430	W	60ml plastic red/green label - (P)	1				X						UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
7	STB4_SEABED_1	20220430	W	500ml clear plastic Green label -(P)	1								X		
7	STB4_SEABED_1	20220430	W	60ml clear plastic - blue label -(NP)	1					X					UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
7	STB4_SEABED_1	20220430	W	60ml clear plastic - purple label - (SP)	1									X	
7	STB4_SEABED_1	20220430	W	40ml glass vial - (VS)	2		X								
7	STB4_SEABED_1	20220430	W	40ml glass vial - filtered (VS)	1						X				FILTERED SAMPLE
7	STB4_SEABED_1	20220430	W	40ml glass vial - (VS)	1							X			
7	STB4_SEABED_1	20220430	W	100ml Amber Glass - orange label (AG)	1	X									
7	STB4_SEABED_1	20220430	W	100ml Amber Glass - orange label (AG)	1			X							
7	STB4_SEABED_1	20220430	W	60ml plastic red/green label - (P)	1				X						UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
8	STB4_SEABED_2	20220430	W	500ml clear plastic Green label -(P)	1								X		
8	STB4_SEABED_2	20220430	W	60ml clear plastic - blue label -(NP)	1					X					UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
8	STB4_SEABED_2	20220430	W	60ml clear plastic - purple label - (SP)	1									X	
8	STB4_SEABED_2	20220430	W	40ml glass vial - (VS)	2		X								
8	STB4_SEABED_2	20220430	W	40ml glass vial - filtered (VS)	1						X				FILTERED SAMPLE

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).									Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Cromium (III & VI)	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
8	STB4_SEABED_2	20220430	W	40ml glass vial - (VS)	1							X			
8	STB4_SEABED_2	20220430	W	100ml Amber Glass - orange label (AG)	1	X									
8	STB4_SEABED_2	20220430	W	100ml Amber Glass - orange label (AG)	1			X							
8	STB4_SEABED_2	20220430	W	60ml plastic red/green label - (P)	1				X						UNFILTERED - there is only on bottle that needs to be split and filtered to analyse for dissolved and total metals.
				TOTAL	80	8	8	8	8	8	8	8	8	8	

0

VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).							Additional Information
LAB ID	**SAMPLE ID**	**DATE / TIME**	**MATRIX**	**TYPE & PRESERVATIVE** *(refer to codes below)*	**TOTAL CONTAINERS**	**TRH**	**BTEX**	**PAHs if TRH recorded**	**Metals (total only)**	**TOC (Total organic carbon) (%)**	**Particle Size Distribution (laser diffraction and wet sieving)**	**Retain Excess sample for PSD anaysis**	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
17	STB4_1_1	20220501	S	250ml JAR	1	x	x	x	x	x		x	
18	STB4_1_2	20220501	S	250ml JAR	1	x	x	x	x	x		x	
19	STB4_1_3	20220501	S	250ml JAR	1	x	x	x	x	x		x	
17	STB4_1_1	20220501	S	B (500mL bag)	1								
18	STB4_1_2	20220501	S	B (500mL bag)	1								
19	STB4_1_3	20220501	S	B (500mL bag)	1								
				TOTAL	39								

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved G
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

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SYDNEY 277-289 Woodpark Road Smithfield NSW 2164 Ph: 02 8784 8555 E: samples.sydney@alsglobal.com
TOWNSVILLE 14-15 Desma Court Bohle QLD 4818 Ph: 07 4796 0600 E: townsville.environmental@alsglobal.com
WOLLONGONG 99 Kenny Street Wollongong NSW 2500 Ph: 02 4225 3125 E: portkembla@alsglobal.com

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☐ Non Standard or urgent TAT (List due date):

ALS QUOTE NO.: EP-246-22_V2

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OF: 1 2 3 4 3 4 5 6 5 6 7

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Custody Seal Intact? Yes No N/A
Free ice / frozen ice bricks present upon receipt? Yes No N/A
Random Sample Temperature on Receipt: °C
Other comment:

RELINQUISHED BY: *Luca Chiaroni*
DATE/TIME:

RECEIVED BY: EG
DATE/TIME: 10/5/22 1620

RELINQUISHED BY:
DATE/TIME:

RECEIVED BY:

Environmental Division
Perth
Work Order Reference
EP2205671

Telephone : +61-8-9406 1301

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	
1	NTB3_SURFACE_1	20220504	W	500ml clear plastic Green label -(P)	1										X		
1	NTB3_SURFACE_1	20220504	W	60ml clear plastic - blue label -(NP)	1						X						
1	NTB3_SURFACE_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
1	NTB3_SURFACE_1	20220504	W	60ml clear plastic - purple label - (SP)	1											X	
1	NTB3_SURFACE_1	20220504	W	40ml glass vial - (VS)	2		X										
1	NTB3_SURFACE_1	20220504	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
1	NTB3_SURFACE_1	20220504	W	40ml glass vial - (VS)	1									X			
1	NTB3_SURFACE_1	20220504	W	100ml Amber Glass - orange label (AG)	1	X											
1	NTB3_SURFACE_1	20220504	W	100ml Amber Glass - orange label (AG)	1			X									
1	NTB3_SURFACE_1	20220430	W	60ml plastic red/green label - (P)	1				X								
1	NTB3_SURFACE_1	20220430	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
2	NTB3_SURFACE_2	20220504	W	500ml clear plastic Green label -(P)	1										X		
2	NTB3_SURFACE_2	20220504	W	60ml clear plastic - blue label -(NP)	1						X						
2	NTB3_SURFACE_2	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
2	NTB3_SURFACE_2	20220504	W	60ml clear plastic - purple label - (SP)	1											X	
2	NTB3_SURFACE_2	20220504	W	40ml glass vial - (VS)	2		X										
2	NTB3_SURFACE_2	20220504	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
2	NTB3_SURFACE_2	20220504	W	40ml glass vial - (VS)	1									X			
2	NTB3_SURFACE_2	20220504	W	100ml Amber Glass - orange label (AG)	1	X											

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).											Additional Information
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2	NTB3_SURFACE_2	20220504	W	100ml Amber Glass - orange label (AG)	1			X									
2	NTB3_SURFACE_2	20220430	W	60ml plastic red/green label - (P)	1				X								
2	NTB3_SURFACE_2	20220430	W	60ml plastic red/green label - (P)	1					X							
3	NTB3_SEABED_1	20220504	W	500ml clear plastic Green label -(P)	1										X		FILTERED SAMPLE
3	NTB3_SEABED_1	20220504	W	60ml clear plastic - blue label -(NP)	1						X						
3	NTB3_SEABED_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					
3	NTB3_SEABED_1	20220504	W	60ml clear plastic - purple label - (SP)	1											X	FILTERED SAMPLE
3	NTB3_SEABED_1	20220504	W	40ml glass vial - (VS)	2		X										
3	NTB3_SEABED_1	20220504	W	40ml glass vial - filtered (VS)	1								X				
3	NTB3_SEABED_1	20220504	W	40ml glass vial - (VS)	1									X			FILTERED SAMPLE
3	NTB3_SEABED_1	20220504	W	100ml Amber Glass - orange label (AG)	1	X											
3	NTB3_SEABED_1	20220504	W	100ml Amber Glass - orange label (AG)	1			X									
3	NTB3_SEABED_1	20220430	W	60ml plastic red/green label - (P)	1				X								
3	NTB3_SEABED_1	20220430	W	60ml plastic red/green label - (P)	1					X							
4	NTB3_SEABED_2	20220504	W	500ml clear plastic Green label -(P)	1										X		FILTERED SAMPLE
4	NTB3_SEABED_2	20220504	W	60ml clear plastic - blue label -(NP)	1						X						
4	NTB3_SEABED_2	20220505	W	60ml clear plastic - blue label -(NP)	1							X					
4	NTB3_SEABED_2	20220504	W	60ml clear plastic - purple label - (SP)	1											X	FILTERED SAMPLE
4	NTB3_SEABED_2	20220504	W	40ml glass vial - (VS)	2		X										
4	NTB3_SEABED_2	20220504	W	40ml glass vial - filtered (VS)	1								X				
4	NTB3_SEABED_2	20220504	W	40ml glass vial - (VS)	1									X			FILTERED SAMPLE
4	NTB3_SEABED_2	20220504	W	100ml Amber Glass - orange label (AG)	1	X											
4	NTB3_SEABED_2	20220504	W	100ml Amber Glass - orange label (AG)	1			X									
4	NTB3_SEABED_2	20220430	W	60ml plastic red/green label - (P)	1				X								
4	NTB3_SEABED_2	20220430	W	60ml plastic red/green label - (P)	1					X							
5	G-E DC_SURFACE_1	20220505	W	500ml clear plastic Green label -(P)	1										X		FILTERED SAMPLE
5	G-E DC_SURFACE_1	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
5	G-E DC_SURFACE_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					
5	G-E DC_SURFACE_1	20220505	W	60ml clear plastic - purple label - (SP)	1											X	FILTERED SAMPLE

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
5	G-E DC_SURFACE_1	20220505	W	40ml glass vial - (VS)	2		X										
5	G-E DC_SURFACE_1	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
5	G-E DC_SURFACE_1	20220505	W	40ml glass vial - (VS)	1									X			
5	G-E DC_SURFACE_1	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
5	G-E DC_SURFACE_1	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
5	G-E DC_SURFACE_1	20220505	W	60ml plastic red/green label - (P)	1				X								
5	G-E DC_SURFACE_1	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
6	G-E DC_SURFACE_2	20220505	W	500ml clear plastic Green label -(P)	1										X		
6	G-E DC_SURFACE_2	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
6	G-E DC_SURFACE_2	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
6	G-E DC_SURFACE_2	20220505	W	60ml clear plastic - purple label - (SP)	1											X	
6	G-E DC_SURFACE_2	20220505	W	40ml glass vial - (VS)	2		X										
6	G-E DC_SURFACE_2	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
6	G-E DC_SURFACE_2	20220505	W	40ml glass vial - (VS)	1									X			
6	G-E DC_SURFACE_2	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
6	G-E DC_SURFACE_2	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
6	G-E DC_SURFACE_2	20220505	W	60ml plastic red/green label - (P)	1				X								
6	G-E DC_SURFACE_2	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
7	G-E DC_SEABED_1	20220505	W	500ml clear plastic Green label -(P)	1										X		
7	G-E DC_SEABED_1	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
7	G-E DC_SEABED_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
7	G-E DC_SEABED_1	20220505	W	60ml clear plastic - purple label - (SP)	1											X	
7	G-E DC_SEABED_1	20220505	W	40ml glass vial - (VS)	2		X										
7	G-E DC_SEABED_1	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
7	G-E DC_SEABED_1	20220505	W	40ml glass vial - (VS)	1									X			
7	G-E DC_SEABED_1	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
7	G-E DC_SEABED_1	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
7	G-E DC_SEABED_1	20220505	W	60ml plastic red/green label - (P)	1				X								
7	G-E DC_SEABED_1	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) . Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
8	G-E DC_SEABED_2	20220505	W	500ml clear plastic Green label -(P)	1										X		
8	G-E DC_SEABED_2	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
8	G-E DC_SEABED_2	20220505	W	60ml clear plastic - blue label -(NP)	1							X					
8	G-E DC_SEABED_2	20220505	W	60ml clear plastic - purple label - (SP)	1											X	FILTERED SAMPLE
8	G-E DC_SEABED_2	20220505	W	40ml glass vial - (VS)	2		X										
8	G-E DC_SEABED_2	20220505	W	40ml glass vial - filtered (VS)	1								X				
8	G-E DC_SEABED_2	20220505	W	40ml glass vial - (VS)	1									X			FILTERED SAMPLE
8	G-E DC_SEABED_2	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
8	G-E DC_SEABED_2	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
8	G-E DC_SEABED_2	20220505	W	60ml plastic red/green label - (P)	1				X								
8	G-E DC_SEABED_2	20220505	W	60ml plastic red/green label - (P)	1					X							
9	QAQC_1	20220505	W	500ml clear plastic Green label -(P)	1										X		FILTERED SAMPLE
9	QAQC_1	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
9	QAQC_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					
9	QAQC_1	20220505	W	60ml clear plastic - purple label - (SP)	1											X	FILTERED SAMPLE
9	QAQC_1	20220505	W	40ml glass vial - (VS)	2		X										
9	QAQC_1	20220505	W	40ml glass vial - filtered (VS)	1								X				
9	QAQC_1	20220505	W	40ml glass vial - (VS)	1									X			FILTERED SAMPLE
9	QAQC_1	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
9	QAQC_1	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
9	QAQC_1	20220505	W	60ml plastic red/green label - (P)	1				X								
9	QAQC_1	20220505	W	60ml plastic red/green label - (P)	1					X							
10	JANSZ JMT_SURFACE_1	20220505	W	500ml clear plastic Green label -(P)	1										X		FILTERED SAMPLE
10	JANSZ JMT_SURFACE_1	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
10	JANSZ JMT_SURFACE_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					
10	JANSZ JMT_SURFACE_1	20220505	W	60ml clear plastic - purple label - (SP)	1											X	FILTERED SAMPLE
10	JANSZ JMT_SURFACE_1	20220505	W	40ml glass vial - (VS)	2		X										
10	JANSZ JMT_SURFACE_1	20220505	W	40ml glass vial - filtered (VS)	1								X				
10	JANSZ JMT_SURFACE_1	20220505	W	40ml glass vial - (VS)	1									X			FILTERED SAMPLE

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
10	JANSZ JMT_SURFACE_1	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
10	JANSZ JMT_SURFACE_1	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
10	JANSZ JMT_SURFACE_1	20220505	W	60ml plastic red/green label - (P)	1				X								
10	JANSZ JMT_SURFACE_1	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
11	JANSZ JMT_SURFACE_2	20220505	W	500ml clear plastic Green label -(P)	1										X		
11	JANSZ JMT_SURFACE_2	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
11	JANSZ JMT_SURFACE_2	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
11	JANSZ JMT_SURFACE_2	20220505	W	60ml clear plastic - purple label - (SP)	1											X	
11	JANSZ JMT_SURFACE_2	20220505	W	40ml glass vial - (VS)	2		X										
11	JANSZ JMT_SURFACE_2	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
11	JANSZ JMT_SURFACE_2	20220505	W	40ml glass vial - (VS)	1									X			
11	JANSZ JMT_SURFACE_2	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
11	JANSZ JMT_SURFACE_2	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
11	JANSZ JMT_SURFACE_2	20220505	W	60ml plastic red/green label - (P)	1				X								
11	JANSZ JMT_SURFACE_2	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
12	JANSZ JMT_SEABED_1	20220505	W	500ml clear plastic Green label -(P)	1										X		
12	JANSZ JMT_SEABED_1	20220505	W	60ml clear plastic - blue label -(NP)	1						X						
12	JANSZ JMT_SEABED_1	20220505	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
12	JANSZ JMT_SEABED_1	20220505	W	60ml clear plastic - purple label - (SP)	1											X	
12	JANSZ JMT_SEABED_1	20220505	W	40ml glass vial - (VS)	2		X										
12	JANSZ JMT_SEABED_1	20220505	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
12	JANSZ JMT_SEABED_1	20220505	W	40ml glass vial - (VS)	1									X			
12	JANSZ JMT_SEABED_1	20220505	W	100ml Amber Glass - orange label (AG)	1	X											
12	JANSZ JMT_SEABED_1	20220505	W	100ml Amber Glass - orange label (AG)	1			X									
12	JANSZ JMT_SEABED_1	20220505	W	60ml plastic red/green label - (P)	1				X								
12	JANSZ JMT_SEABED_1	20220505	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
13	BCH28_SURFACE_1	20220506	W	500ml clear plastic Green label -(P)	1										X		
13	BCH28_SURFACE_1	20220506	W	60ml clear plastic - blue label -(NP)	1						X						
13	BCH28_SURFACE_1	20220506	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE

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13	BCH28_SURFACE_1	20220506	W	60ml clear plastic - purple label - (SP)	1											X	
13	BCH28_SURFACE_1	20220506	W	40ml glass vial - (VS)	2		X										
13	BCH28_SURFACE_1	20220506	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
13	BCH28_SURFACE_1	20220506	W	40ml glass vial - (VS)	1									X			
13	BCH28_SURFACE_1	20220506	W	100ml Amber Glass - orange label (AG)	1	X											
13	BCH28_SURFACE_1	20220506	W	100ml Amber Glass - orange label (AG)	1			X									
13	BCH28_SURFACE_1	20220506	W	60ml plastic red/green label - (P)	1				X								
13	BCH28_SURFACE_1	20220506	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
14	BCH28_SURFACE_2	20220506	W	500ml clear plastic Green label -(P)	1										X		
14	BCH28_SURFACE_2	20220506	W	60ml clear plastic - blue label -(NP)	1						X						
14	BCH28_SURFACE_2	20220506	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
14	BCH28_SURFACE_2	20220506	W	60ml clear plastic - purple label - (SP)	1											X	
14	BCH28_SURFACE_2	20220506	W	40ml glass vial - (VS)	2		X										
14	BCH28_SURFACE_2	20220506	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
14	BCH28_SURFACE_2	20220506	W	40ml glass vial - (VS)	1									X			
14	BCH28_SURFACE_2	20220506	W	100ml Amber Glass - orange label (AG)	1	X											
14	BCH28_SURFACE_2	20220506	W	100ml Amber Glass - orange label (AG)	1			X									
14	BCH28_SURFACE_2	20220506	W	60ml plastic red/green label - (P)	1				X								
14	BCH28_SURFACE_2	20220506	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
15	BCH28_SEABED_1	20220506	W	500ml clear plastic Green label -(P)	1										X		
15	BCH28_SEABED_1	20220506	W	60ml clear plastic - blue label -(NP)	1						X	X					
15	BCH28_SEABED_1	20220506	W	60ml clear plastic - blue label -(NP)	1												FILTERED SAMPLE
15	BCH28_SEABED_1	20220506	W	60ml clear plastic - purple label - (SP)	1											X	
15	BCH28_SEABED_1	20220506	W	40ml glass vial - (VS)	2		X										
15	BCH28_SEABED_1	20220506	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
15	BCH28_SEABED_1	20220506	W	40ml glass vial - (VS)	1									X			
15	BCH28_SEABED_1	20220506	W	100ml Amber Glass - orange label (AG)	1	X											
15	BCH28_SEABED_1	20220506	W	100ml Amber Glass - orange label (AG)	1			X									
15	BCH28_SEABED_1	20220506	W	60ml plastic red/green label - (P)	1				X								

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15	BCH28_SEABED_1	20220506	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
16	BCH28_SEABED_2	20220506	W	500ml clear plastic Green label -(P)	1										X		
16	BCH28_SEABED_2	20220506	W	60ml clear plastic - blue label -(NP)	1						X						
16	BCH28_SEABED_2	20220506	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
16	BCH28_SEABED_2	20220506	W	60ml clear plastic - purple label - (SP)	1											X	
16	BCH28_SEABED_2	20220506	W	40ml glass vial - (VS)	2		X										
16	BCH28_SEABED_2	20220506	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
16	BCH28_SEABED_2	20220506	W	40ml glass vial - (VS)	1									X			
16	BCH28_SEABED_2	20220506	W	100ml Amber Glass - orange label (AG)	1	X											
16	BCH28_SEABED_2	20220506	W	100ml Amber Glass - orange label (AG)	1			X									
16	BCH28_SEABED_2	20220506	W	60ml plastic red/green label - (P)	1				X								
16	BCH28_SEABED_2	20220506	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
17	CHANDON DC-1_SURFACE_1	20220507	W	500ml clear plastic Green label -(P)	1										X		
17	CHANDON DC-1_SURFACE_1	20220507	W	60ml clear plastic - blue label -(NP)	1						X						
17	CHANDON DC-1_SURFACE_1	20220507	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
17	CHANDON DC-1_SURFACE_1	20220507	W	60ml clear plastic - purple label - (SP)	1											X	
17	CHANDON DC-1_SURFACE_1	20220507	W	40ml glass vial - (VS)	2		X										
17	CHANDON DC-1_SURFACE_1	20220507	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
17	CHANDON DC-1_SURFACE_1	20220507	W	40ml glass vial - (VS)	1									X			
17	CHANDON DC-1_SURFACE_1	20220507	W	100ml Amber Glass - orange label (AG)	1	X											
17	CHANDON DC-1_SURFACE_1	20220507	W	100ml Amber Glass - orange label (AG)	1			X									
17	CHANDON DC-1_SURFACE_1	20220507	W	60ml plastic red/green label - (P)	1				X								
17	CHANDON DC-1_SURFACE_1	20220507	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
18	CHANDON DC-1_SURFACE_2	20220507	W	500ml clear plastic Green label -(P)	1										X		
18	CHANDON DC-1_SURFACE_2	20220507	W	60ml clear plastic - blue label -(NP)	1						X						
18	CHANDON DC-1_SURFACE_2	20220507	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
18	CHANDON DC-1_SURFACE_2	20220507	W	60ml clear plastic - purple label - (SP)	1											X	
18	CHANDON DC-1_SURFACE_2	20220507	W	40ml glass vial - (VS)	2		X										
18	CHANDON DC-1_SURFACE_2	20220507	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) · Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
18	CHANDON DC-1_SURFACE_2	20220507	W	40ml glass vial - (VS)	1									X			
18	CHANDON DC-1_SURFACE_2	20220507	W	100ml Amber Glass - orange label (AG)	1	X											
18	CHANDON DC-1_SURFACE_2	20220507	W	100ml Amber Glass - orange label (AG)	1			X									
18	CHANDON DC-1_SURFACE_2	20220507	W	60ml plastic red/green label - (P)	1				X								
18	CHANDON DC-1_SURFACE_2	20220507	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
19	CHANDON DC-1_SEABED_1	20220507	W	500ml clear plastic Green label -(P)	1										X		
19	CHANDON DC-1_SEABED_1	20220507	W	60ml clear plastic - blue label -(NP)	1						X						
19	CHANDON DC-1_SEABED_1	20220507	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
19	CHANDON DC-1_SEABED_1	20220507	W	60ml clear plastic - purple label - (SP)	1											X	
19	CHANDON DC-1_SEABED_1	20220507	W	40ml glass vial - (VS)	2		X										
19	CHANDON DC-1_SEABED_1	20220507	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
19	CHANDON DC-1_SEABED_1	20220507	W	40ml glass vial - (VS)	1									X			
19	CHANDON DC-1_SEABED_1	20220507	W	100ml Amber Glass - orange label (AG)	1	X											
19	CHANDON DC-1_SEABED_1	20220507	W	100ml Amber Glass - orange label (AG)	1			X									
19	CHANDON DC-1_SEABED_1	20220507	W	60ml plastic red/green label - (P)	1				X								
19	CHANDON DC-1_SEABED_1	20220507	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
20	CHANDON DC-1_SEABED_2	20220507	W	500ml clear plastic Green label -(P)	1										X		
20	CHANDON DC-1_SEABED_2	20220507	W	60ml clear plastic - blue label -(NP)	1						X						
20	CHANDON DC-1_SEABED_2	20220507	W	60ml clear plastic - blue label -(NP)	1							X					FILTERED SAMPLE
20	CHANDON DC-1_SEABED_2	20220507	W	60ml clear plastic - purple label - (SP)	1											X	
20	CHANDON DC-1_SEABED_2	20220507	W	40ml glass vial - (VS)	2		X										
20	CHANDON DC-1_SEABED_2	20220507	W	40ml glass vial - filtered (VS)	1								X				FILTERED SAMPLE
20	CHANDON DC-1_SEABED_2	20220507	W	40ml glass vial - (VS)	1									X			
20	CHANDON DC-1_SEABED_2	20220507	W	100ml Amber Glass - orange label (AG)	1	X											
20	CHANDON DC-1_SEABED_2	20220507	W	100ml Amber Glass - orange label (AG)	1			X									
20	CHANDON DC-1_SEABED_2	20220507	W	60ml plastic red/green label - (P)	1				X								
20	CHANDON DC-1_SEABED_2	20220507	W	60ml plastic red/green label - (P)	1					X							FILTERED SAMPLE
0				TOTAL	240	20	20	20	20	20	20	20	20	20	20	20	

VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

PROJECT: Gorgon Benthic Survey 2022	ALS QUOTE NO.: EP-246-22_V2	COC SEQUENCE NUMBER (Circle) COC: 1 2 3 4 3 4 5 6 5 6 7 OF: 1 2 3 4 3 4 5 6 5 6 7	Free ice/frozen ice bricks present upon receipt? Yes No N/A Random Sample Temperature on Receipt: C Other comment:
ORDER NUMBER: 1			
PROJECT MANAGER: Mark Westera	CONTACT PH: 0422 499 803		

SAMPLER: Luca Chiaroni, Stephanie Watts	SAMPLER MOBILE: 0498 014 575	RELINQUISHED BY:	RECEIVED BY: MO 9:00	RELINQUISHED BY:	RECEIVED BY:
COC emailed to ALS? (YES / NO)	EDD FORMAT (or default):	Luca Chiaroni			
Email Reports to (will default to PM if no other addresses are listed): mark.westera@advisian.com		DATE/TIME:	DATE/TIME: 12/5/22	DATE/TIME:	DATE/TIME:
Email Invoice to (will default to PM if no other addresses are listed): mark.westera@advisian.com					

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).											Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAH	Metals (Total)	Metals (Dissolved)	Cromium (III & VI) - Total	Cromium (III & VI) - Dissolved	DOC	TOC	TDS	TP/TN	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
1	WTR DC-1_SURFACE_1	20220509	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
2	WTR DC-1_SURFACE_2	20220509	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
3	WTR DC-1_SEABED_1	20220509	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
4	WTR DC-1_SEABED_2	20220509	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
5	QAQC4	20220509	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
6	QAQC5	20220509	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
7	QAQC6	20220509	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
8	QAQC7	20220509	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
9	GORGON GMT_SURFACE_1	20220510	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
10	GORGON GMT_SURFACE_2	20220510	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
11	GORGON GMT_SEABED_1	20220510	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
12	GORGON GMT_SEABED_2	20220510	W		10	X	X	X	X	X	X	X	X	X	X	X	FILTERED SAMPLE (1 x 60ml clear plastic - blue label -(NP), 1 x 40ml glass vial - filtered (VS), 1 x 60ml plastic red/green label - (P))
TOTAL					120	12	12	12	12	12	12	12	12	12	12	12	

VH = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; NP=NaOH preserved Plastic; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

Environmental Division
Perth
Work Order Reference
EP2205756

Telephone : - 61-8-9406 1301

ALS Environmental

CHAIN OF CUSTODY

ALS Laboratory: please tick →

CLIENT: Advisian	TURNAROUND REQUIREMENTS : ☐ Standard TAT (List due date):		FOR LABORATORY USE ONLY (Circle)
OFFICE: Lvl 14, 240 St Georges Terrace, Perth	(Standard TAT may be longer for some tests e.g.. Ultra Trace Organics) ☐ Non Standard or urgent TAT (List due date):		Custody Seal Intact? Yes No N/A
PROJECT: Gorgon Benthic Survey 2022	ALS QUOTE NO.: EP-246-22_V2	COC SEQUENCE NUMBER (Circle)	Free ice / frozen ice bricks present upon receipt? Yes No N/A
ORDER NUMBER: 1		COC: 1 2 3 4 5 6 7	Random Sample Temperature on Receipt: °C
PROJECT MANAGER: Mark Westera	CONTACT PH: 0422 489 803	OF: 1 2 3 4 5 6 7	Other comment:

SAMPLER: Luca Chiaroni, Stephanie Watts	SAMPLER MOBILE: 0498 014 575	RELINQUISHED BY:	RECEIVED BY: ND	RELINQUISHED BY:	RECEIVED BY:
COC emailed to ALS? (YES / NO)	EDD FORMAT (or default):	Luca Chiaroni/Steph Watts			
Email Reports to (will default to PM if no other addresses are listed): mark.westera@advisian.com		DATE/TIME: 04/05/22 1045	DATE/TIME: 9:00 12/5/22	DATE/TIME:	DATE/TIME:
Email Invoice to (will default to PM if no other addresses are listed): mark.westera@advisian.com					

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

	ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).							Additional Information
	LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	TRH	BTEX	PAHs if TRH recorded	Metals (total only)	TOC (Total organic carbon) (%)	Particle Size Distribution (laser diffraction and wet sieving)	Retain Excess sample for PSD anaysis	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
		~~SEMELE WELL-3_1_1~~	20220508	S	150ml JAR	1	x	x	x	x	x		x	
		~~SEMELE WELL-3_1_1~~	~~20220508~~	S	B (500mL bag)	1						x		
X		~~SEMELE WELL-3_1_2~~	20220508	S	~~150ml JAR~~	1	x	x	x	x	x		x	
		~~SEMELE WELL-3_1_2~~	20220508	S	B (500mL bag)	1						x		
		~~SEMELE WELL-3_1_3~~	20220508	S	150ml JAR	1	x	x	x	x	x		x	
		~~SEMELE WELL-3_1_3~~	20220508	S	B (500mL bag)	1						x		
11	✓	SEMELE WELL-4_1_1	20220508	S	150ml JAR	1	x	x	x	x	x		x	
	✓	SEMELE WELL-4_1_1	20220508	S	B (500mL bag)	1						x		
2	✓	SEMELE WELL-4_1_2	20220508	S	150ml JAR	1	x	x	x	x	x		x	
	✓	SEMELE WELL-4_1_2	20220508	S	B (500mL bag)	1						x		
3	✓	SEMELE WELL-4_1_3	20220508	S	150ml JAR	1	x	x	x	x	x		x	
	✓	SEMELE WELL-4_1_3	20220508	S	B (500mL bag)	1						x		
4	✓	WTR DC-1-4_1_1	20220509	S	150ml JAR	1	x	x	x	x	x		x	
	✓	WTR DC-1-4_1_1	20220509	S	B (500mL bag)	1						x		
5	✓	WTR DC-1_1_2	20220509	S	150ml JAR	1	x	x	x	x	x		x	
	✓	WTR DC-1_1_2	20220509	S	B (500mL bag)	1						x		
6	✓	WTR DC-1_1_3	20220509	S	150ml JAR	1	x	x	x	x	x		x	
	✓	WTR DC-1_1_3	20220509	S	B (500mL bag)	1						x		
7	✓	WTR DC-1_2_1	20220509	S	250ml JAR	1	x	x	x	x	x		x	
	✓	WTR DC-1_2_1	20220509	S	B (500mL bag)	1						x		
8	✓	WTR DC-1_2_2	20220509	S	250ml JAR	1	x	x	x	x	x		x	
	✓	WTR DC-1_2_2	20220509	S	B (500mL bag)	1						x		
9	✓	WTR DC-1_2_3	20220509	S	250ml JAR	1	x	x	x	x	x		x	
	✓	WTR DC-1_2_3	20220509	S	B (500mL bag)	1						x		
10	✓	QAQC_BLANK 2	20220409	S	250ml JAR	1	x	x	x	x	x		x	
					TOTAL	25								

Environmental Division
Perth
Work Order Reference
EP2205801

Telephone : - 61-8-9406 1301

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Gla
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

Appendix F Laboratory Reports for Sediment Samples

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2215235**	Page	: 1 of 5
Client	: **ADVISIAN PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MARK WESTERA	Contact	: Customer Services EB
Address	: LEVEL 4 600 MURRAY STREET WEST PERTH WA, AUSTRALIA	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3243 7222
Project	: Gorgon Benthic Survey 2022	Date Samples Received	: 27-May-2022 10:00
Order number	: 1	Date Analysis Commenced	: 01-Jun-2022
C-O-C number	: ----	Issue Date	: 09-Jun-2022 13:38
Sampler	: Luca Chiaroni, Stephanie Watts		
Site	: ----		
Quote number	: EP/246/22		
No. of samples received	: 4		
No. of samples analysed	: 4		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Timothy Creagh	2IC Organic Chemist	Brisbane Organics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG048G (Hexavalent Chromium by Alkaline Digestion): Some samples were diluted due to matrix interference. LOR adjusted accordingly.
- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EG005T (Total Metals by ICP-AES): EB2215171-003 shows poor matrix spike recovery due to sample heterogeneity. This has been confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): EB2215331-031 shows poor duplicate results due to sample heterogeneity. This has been confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): EB2215331-033 shows poor matrix spike recovery due to sample heterogeneity. This has been confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): EB2215290-003 shows poor duplicate results due to sample heterogeneity. This has been confirmed by visual inspection.
- EG048G (Hexavalent Chromium by Alkaline Digestion): Sample EB2215235_001 (SEMELE WELL-4_1_3) shows poor matrix spike recovery due to matrix interferences.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	SEMELE WELL-4_1_3	SEMELE WELL-4_1_2	WTR DC-1_4_1_1	WTR DC-2_2_3	----
			Sampling date / time	08-May-2022 17:08	08-May-2022 17:08	09-May-2022 17:09	09-May-2022 17:09	----
Compound	CAS Number	LOR	Unit	EB2215235-001	EB2215235-002	EB2215235-003	EB2215235-004	--------
				Result	Result	Result	Result	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	57.6	58.2	35.4	35.0	----
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	3300	3460	1570	1490	----
Iron	7439-89-6	50	mg/kg	5130	5380	2800	2720	----
EG005(ED093)T: Total Metals by ICP-AES								
Barium	7440-39-3	10	mg/kg	80	90	30	30	----
Chromium	7440-47-3	2	mg/kg	24	25	14	13	----
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	1.62	1.63	1.27	1.23	----
Cadmium	7440-43-9	0.1	mg/kg	0.3	0.3	0.1	0.1	----
Chromium	7440-47-3	1.0	mg/kg	30.3	30.5	17.4	15.9	----
Copper	7440-50-8	1.0	mg/kg	12.8	13.2	3.7	3.4	----
Cobalt	7440-48-4	0.5	mg/kg	3.1	3.1	1.5	1.4	----
Lead	7439-92-1	1.0	mg/kg	2.6	2.7	1.6	1.5	----
Manganese	7439-96-5	10	mg/kg	173	216	96	92	----
Nickel	7440-02-0	1.0	mg/kg	18.9	19.1	7.5	7.1	----
Silver	7440-22-4	0.1	mg/kg	0.1	0.1	<0.1	<0.1	----
Zinc	7440-66-6	1.0	mg/kg	20.6	20.8	6.2	5.9	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	0.02	0.02	<0.01	<0.01	----
EG048: Hexavalent Chromium (Alkaline Digest)								
Hexavalent Chromium	18540-29-9	0.5	mg/kg	<4.0	<4.0	<2.0	<2.0	----
EG049: Trivalent Chromium								
Trivalent Chromium	16065-83-1	2	mg/kg	24	25	14	13	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	<10	<10	<10	----
C10 - C14 Fraction	----	50	mg/kg	<50	<50	<50	<50	----
C15 - C28 Fraction	----	100	mg/kg	<100	<100	<100	<100	----
C29 - C36 Fraction	----	100	mg/kg	<100	<100	<100	<100	----
^ C10 - C36 Fraction (sum)	----	50	mg/kg	<50	<50	<50	<50	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	<10	<10	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	10	mg/kg	<10	<10	<10	<10	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	SEMELE WELL-4_1_3	SEMELE WELL-4_1_2	WTR DC-1_4_1_1	WTR DC-2_2_3	----
			Sampling date / time	08-May-2022 17:08	08-May-2022 17:08	09-May-2022 17:09	09-May-2022 17:09	----
Compound	CAS Number	LOR	Unit	EB2215235-001	EB2215235-002	EB2215235-003	EB2215235-004	--------
				Result	Result	Result	Result	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction	----	50	mg/kg	<50	<50	<50	<50	----
>C16 - C34 Fraction	----	100	mg/kg	<100	<100	<100	<100	----
>C34 - C40 Fraction	----	100	mg/kg	<100	<100	<100	<100	----
^ >C10 - C40 Fraction (sum)	----	50	mg/kg	<50	<50	<50	<50	----
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	50	mg/kg	<50	<50	<50	<50	----
EP080: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	----
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	----
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	----
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	----
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	----
Naphthalene	91-20-3	1	mg/kg	<1	<1	<1	<1	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**104**	**91.8**	**94.6**	**95.7**	----
Toluene-D8	2037-26-5	0.2	%	**84.7**	**73.3**	**72.4**	**73.5**	----
4-Bromofluorobenzene	460-00-4	0.2	%	**101**	**90.5**	**92.4**	**89.5**	----

Surrogate Control Limits

Sub-Matrix: **SOIL**

Compound	*CAS Number*	*Recovery Limits (%)* Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	53	134
Toluene-D8	2037-26-5	60	131
4-Bromofluorobenzene	460-00-4	59	127

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	SEMELE WELL-4_1_1	SEMELE WELL-4_1_2	SEMELE WELL-4_1_3	WTR DC-1-4_1_1	WTR DC-1_1_2
			Sampling date / time	08-May-2022 00:00	08-May-2022 00:00	08-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205801-001	EP2205801-002	EP2205801-003	EP2205801-004	EP2205801-005
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	60.6	61.3	61.4	39.1	42.0
EA150: Particle Sizing								
+75µm	----	1	%	4	3	2	49	48
+150µm	----	1	%	2	1	1	11	10
+300µm	----	1	%	1	<1	<1	2	2
+425µm	----	1	%	<1	<1	<1	1	<1
+600µm	----	1	%	<1	<1	<1	<1	<1
+1180µm	----	1	%	<1	<1	<1	<1	<1
+2.36mm	----	1	%	<1	<1	<1	<1	<1
+4.75mm	----	1	%	<1	<1	<1	<1	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	35	34	36	14	15
Silt (2-60 µm)	----	1	%	60	60	58	30	29
Sand (0.06-2.00 mm)	----	1	%	5	6	6	56	56
Gravel (>2mm)	----	1	%	<1	<1	<1	<1	<1
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.41	2.30	2.38	2.44	2.43
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	4760	5140	4960	2260	2240
Iron	7439-89-6	50	mg/kg	6600	6990	6650	3390	3500
EG005(ED093)T: Total Metals by ICP-AES								
Barium	7440-39-3	10	mg/kg	110	110	100	40	50
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	1.72	1.76	1.75	1.25	1.28
Cadmium	7440-43-9	0.1	mg/kg	0.4	0.4	0.4	0.1	0.1
Chromium	7440-47-3	1.0	mg/kg	30.8	32.6	31.3	16.7	16.7
Copper	7440-50-8	1.0	mg/kg	13.6	14.5	13.5	3.8	3.9
Cobalt	7440-48-4	0.5	mg/kg	3.1	3.4	3.2	1.4	1.5
Lead	7439-92-1	1.0	mg/kg	2.8	2.9	2.8	1.5	1.6

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	SEMELE WELL-4_1_1	SEMELE WELL-4_1_2	SEMELE WELL-4_1_3	WTR DC-1-4_1_1	WTR DC-1_1_2
			Sampling date / time	08-May-2022 00:00	08-May-2022 00:00	08-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205801-001	EP2205801-002	EP2205801-003	EP2205801-004	EP2205801-005
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**186**	**221**	**186**	**95**	**99**
Nickel	7440-02-0	1.0	mg/kg	**19.6**	**20.8**	**19.7**	**7.5**	**7.7**
Silver	7440-22-4	0.1	mg/kg	**0.2**	**0.1**	**0.1**	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**22.8**	**23.9**	**22.2**	**6.7**	**6.8**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	**0.02**	**0.01**	**0.02**	<0.01	<0.01
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**1.30**	**1.20**	**1.19**	**0.50**	**0.52**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	<10	<10	<10	<10
C10 - C14 Fraction	----	50	mg/kg	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ **C10 - C36 Fraction (sum)**	----	50	mg/kg	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	<10	<10	<10
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	10	mg/kg	<10	<10	<10	<10	<10
>C10 - C16 Fraction	----	50	mg/kg	<50	<50	<50	<50	<50
>C16 - C34 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	50	mg/kg	<50	<50	<50	<50	<50
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	50	mg/kg	<50	<50	<50	<50	<50
EP080: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Sum of BTEX**	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ **Total Xylenes**	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Naphthalene	91-20-3	1	mg/kg	<1	<1	<1	<1	<1
EP080S: TPH(V)/BTEX Surrogates								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	SEMELE WELL-4_1_1	SEMELE WELL-4_1_2	SEMELE WELL-4_1_3	WTR DC-1-4_1_1	WTR DC-1_1_2
			Sampling date / time	08-May-2022 00:00	08-May-2022 00:00	08-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205801-001	EP2205801-002	EP2205801-003	EP2205801-004	EP2205801-005
				Result	Result	Result	Result	Result
EP080S: TPH(V)/BTEX Surrogates - Continued								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	64.4	71.5	68.2	67.1	71.7
Toluene-D8	2037-26-5	0.2	%	79.0	69.7	67.1	77.7	81.4
4-Bromofluorobenzene	460-00-4	0.2	%	71.8	64.4	61.2	69.4	76.7

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	WTR DC-1_1_3	WTR DC-2_1_1	WTR DC-2_2_2	WTR DC-2_2_3	QAQC_BLANK 2
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
				EP2205801-006	EP2205801-007	EP2205801-008	EP2205801-009	EP2205801-010
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	40.3	40.6	40.9	40.4	----
Moisture Content	----	1.0	%	----	----	----	----	7.3
EA150: Particle Sizing								
+75µm	----	1	%	47	52	56	54	----
+150µm	----	1	%	12	12	15	12	----
+300µm	----	1	%	2	2	3	2	----
+425µm	----	1	%	<1	1	2	1	----
+600µm	----	1	%	<1	<1	<1	<1	----
+1180µm	----	1	%	<1	<1	<1	<1	----
+2.36mm	----	1	%	<1	<1	<1	<1	----
+4.75mm	----	1	%	<1	<1	<1	<1	----
+9.5mm	----	1	%	<1	<1	<1	<1	----
+19.0mm	----	1	%	<1	<1	<1	<1	----
+37.5mm	----	1	%	<1	<1	<1	<1	----
+75.0mm	----	1	%	<1	<1	<1	<1	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	15	12	12	14	----
Silt (2-60 µm)	----	1	%	30	28	26	29	----
Sand (0.06-2.00 mm)	----	1	%	55	60	62	57	----
Gravel (>2mm)	----	1	%	<1	<1	<1	<1	----
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.36	2.36	2.42	2.42	----
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2480	2280	2230	2400	----
Iron	7439-89-6	50	mg/kg	3630	3530	3510	3610	----
EG005(ED093)T: Total Metals by ICP-AES								
Barium	7440-39-3	10	mg/kg	40	40	40	50	----
EG020-SD: Total Metals in Sediments by ICPMS								
Arsenic	7440-38-2	1.00	mg/kg	1.30	1.23	1.30	1.29	----
Cadmium	7440-43-9	0.1	mg/kg	0.1	0.1	0.1	0.2	----
Chromium	7440-47-3	1.0	mg/kg	17.7	16.7	16.7	17.5	----
Copper	7440-50-8	1.0	mg/kg	4.0	3.8	3.8	3.9	----
Cobalt	7440-48-4	0.5	mg/kg	1.5	1.5	1.5	1.5	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	WTR DC-1_1_3	WTR DC-2_1_1	WTR DC-2_2_2	WTR DC-2_2_3	QAQC_BLANK 2
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205801-006	EP2205801-007	EP2205801-008	EP2205801-009	EP2205801-010
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Lead	7439-92-1	1.0	mg/kg	**1.6**	**1.6**	**1.6**	**1.6**	----
Manganese	7439-96-5	10	mg/kg	**101**	**96**	**101**	**102**	----
Nickel	7440-02-0	1.0	mg/kg	**8.1**	**7.7**	**7.3**	**7.8**	----
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----
Zinc	7440-66-6	1.0	mg/kg	**6.9**	**6.7**	**6.6**	**6.8**	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.52**	**0.47**	**0.46**	**0.49**	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	<10	<10	<10	<10
C10 - C14 Fraction	----	50	mg/kg	<50	<50	<50	<50	----
C15 - C28 Fraction	----	100	mg/kg	<100	<100	<100	<100	----
C29 - C36 Fraction	----	100	mg/kg	<100	<100	<100	<100	----
^ **C10 - C36 Fraction (sum)**	----	50	mg/kg	<50	<50	<50	<50	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	<10	<10	<10
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	10	mg/kg	<10	<10	<10	<10	<10
>C10 - C16 Fraction	----	50	mg/kg	<50	<50	<50	<50	----
>C16 - C34 Fraction	----	100	mg/kg	<100	<100	<100	<100	----
>C34 - C40 Fraction	----	100	mg/kg	<100	<100	<100	<100	----
^ **>C10 - C40 Fraction (sum)**	----	50	mg/kg	<50	<50	<50	<50	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	50	mg/kg	<50	<50	<50	<50	----
EP080: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Sum of BTEX**	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ **Total Xylenes**	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Naphthalene	91-20-3	1	mg/kg	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	WTR DC-1_1_3	WTR DC-2_1_1	WTR DC-2_2_2	WTR DC-2_2_3	QAQC_BLANK 2
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205801-006	EP2205801-007	EP2205801-008	EP2205801-009	EP2205801-010
				Result	Result	Result	Result	Result
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	67.5	67.6	65.6	66.3	82.0
Toluene-D8	2037-26-5	0.2	%	76.0	76.8	74.5	75.7	95.3
4-Bromofluorobenzene	460-00-4	0.2	%	68.8	68.8	69.3	69.1	84.9

Surrogate Control Limits

Sub-Matrix: **SOIL**

Compound	CAS Number	Recovery Limits (%) Low	Recovery Limits (%) High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	63	132
Toluene-D8	2037-26-5	66	125
4-Bromofluorobenzene	460-00-4	60	124

Inter-Laboratory Testing

Analysis conducted by ALS Brisbane, NATA accreditation no. 825, site no. 818 (Chemistry) 18958 (Biology).

(SOIL) EP003: Total Organic Carbon (TOC) in Soil

Analysis conducted by ALS Newcastle, NATA accreditation no. 825, site no. 1656 (Chemistry) 9854 (Biology).

(SOIL) EA150: Soil Classification based on Particle Size

(SOIL) EA150: Particle Sizing

(SOIL) EA152: Soil Particle Density

Appendix G Sediment Core Photos

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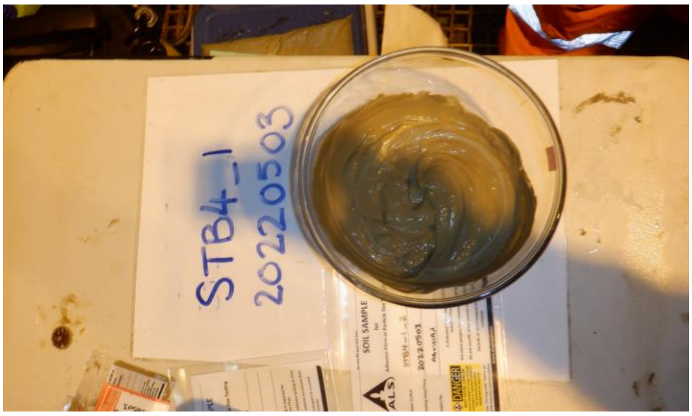
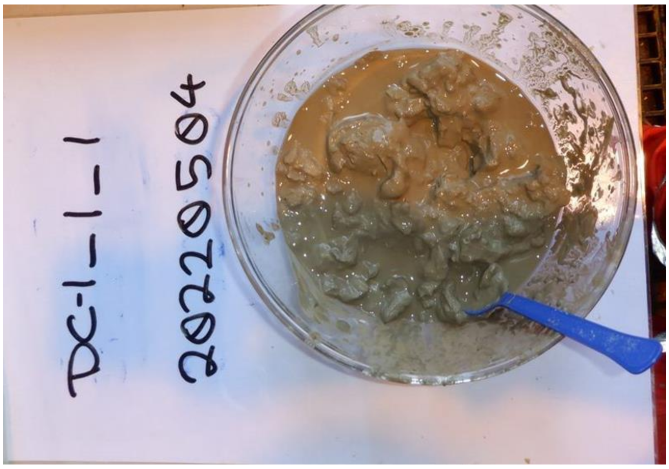
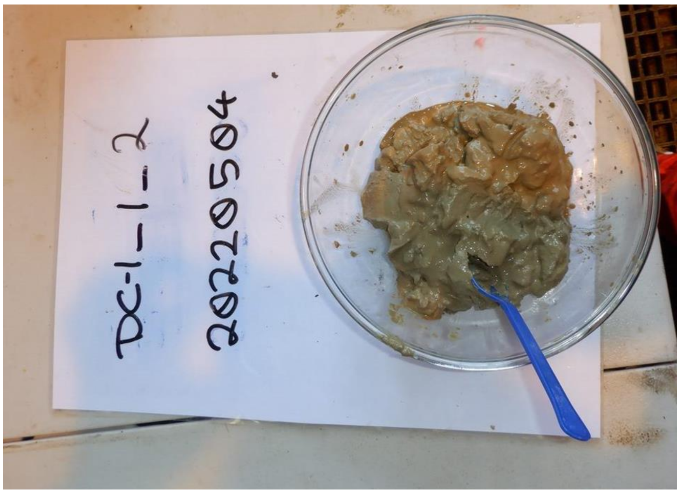
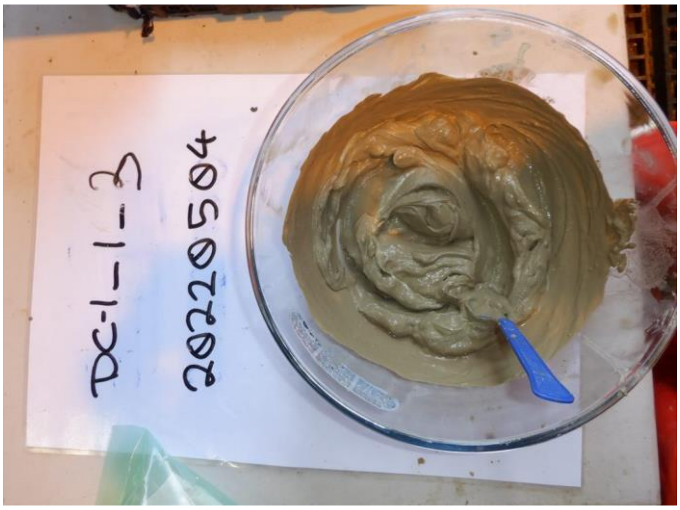
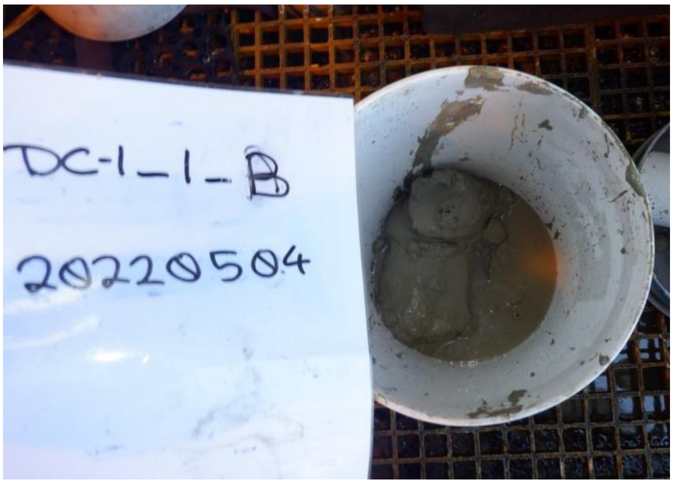
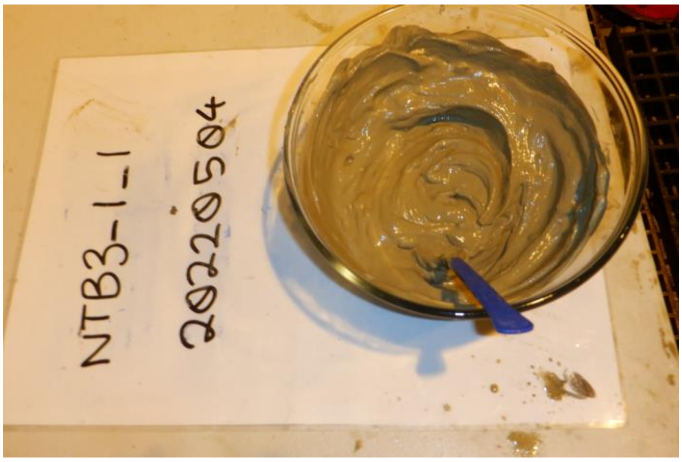
Appendix H Sediment core photos

Site/Sample	Photo
STB4_1	
STB4_3	
DC-1_1_1	

Site/Sample	Photo
DC-1_1_2	
DC-1_1_3	
DC-1_1_B	

Site/Sample	Photo
NTB3_1_1	
NTB3_1_1	
NTB3_1_3	

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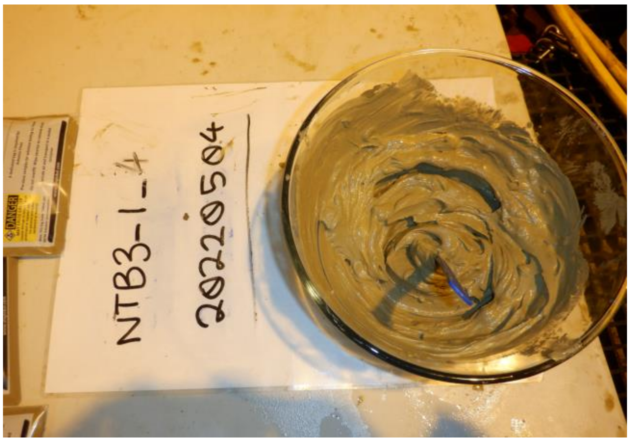
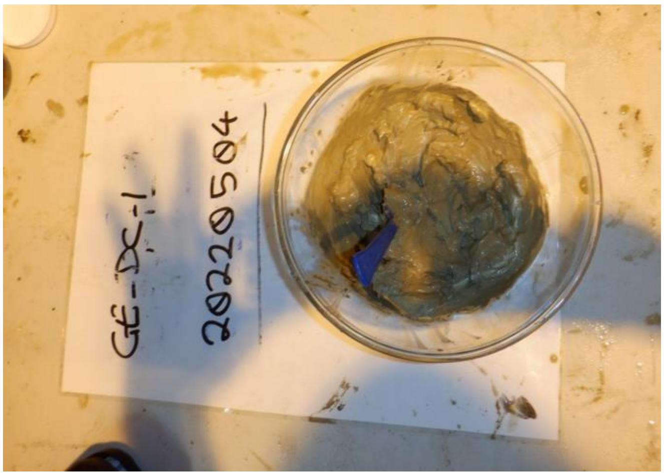
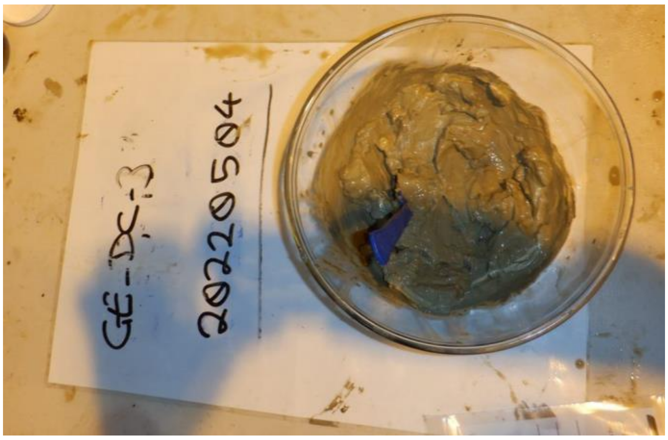
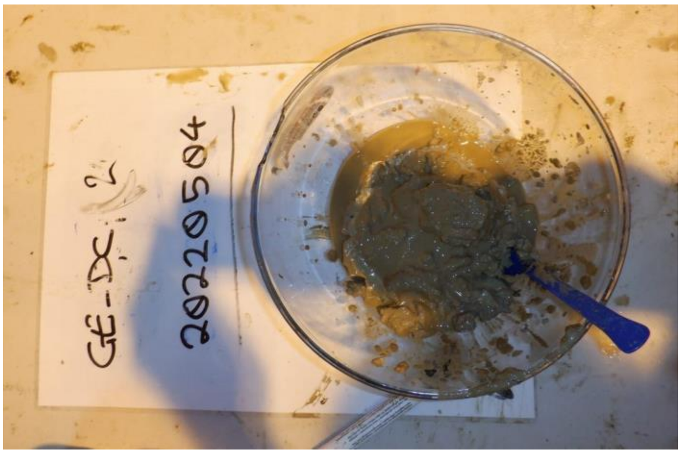
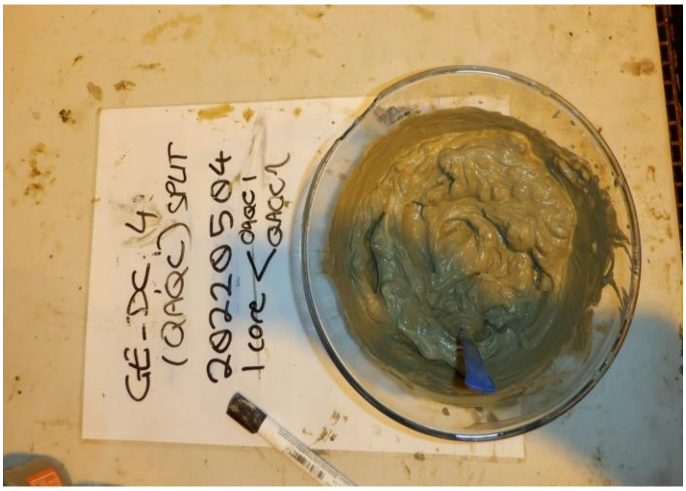
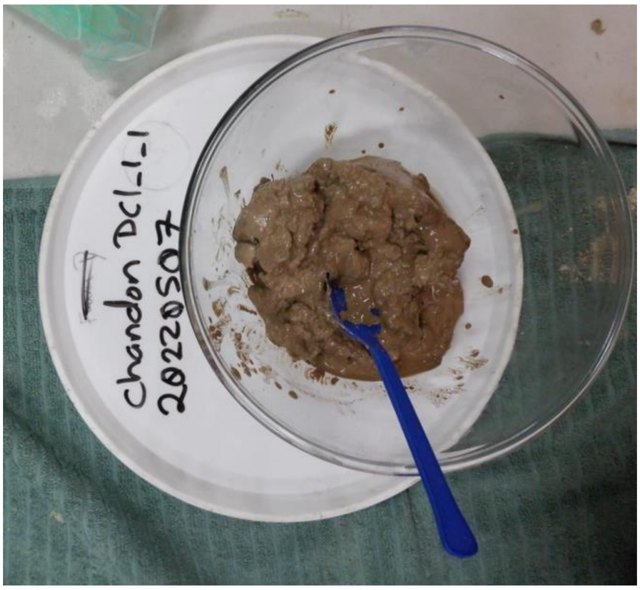
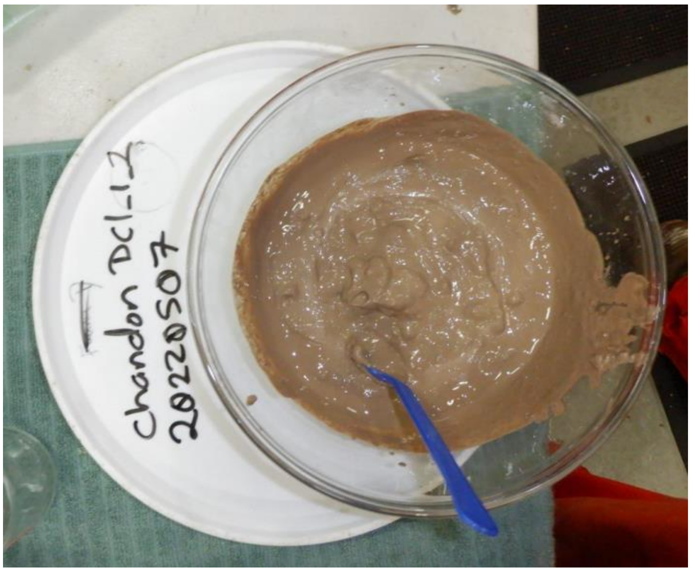
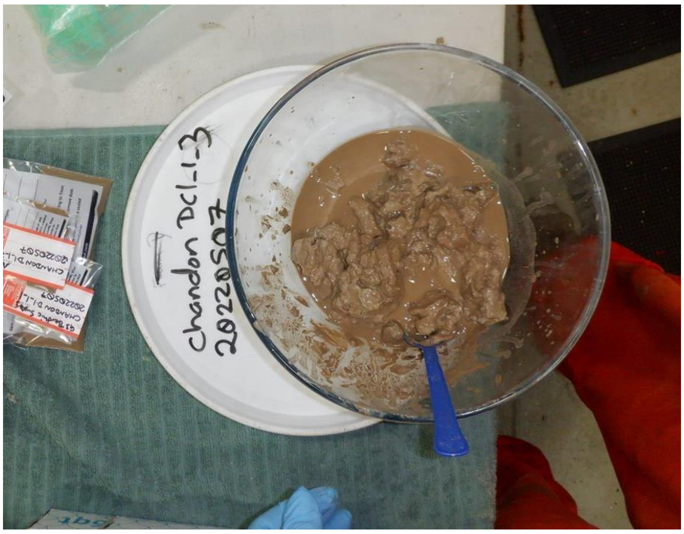
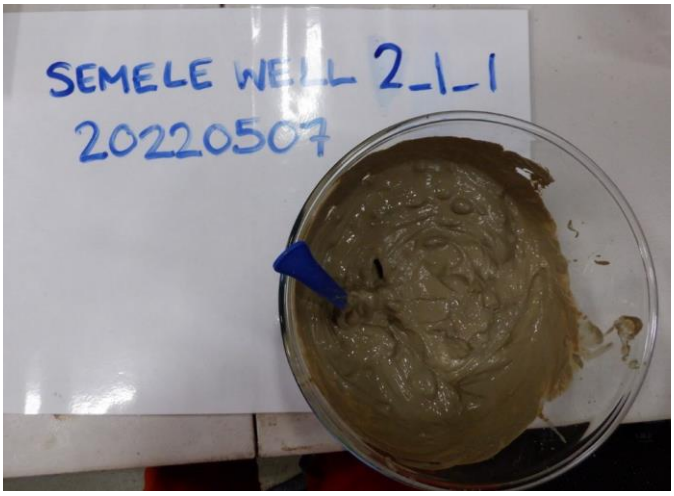
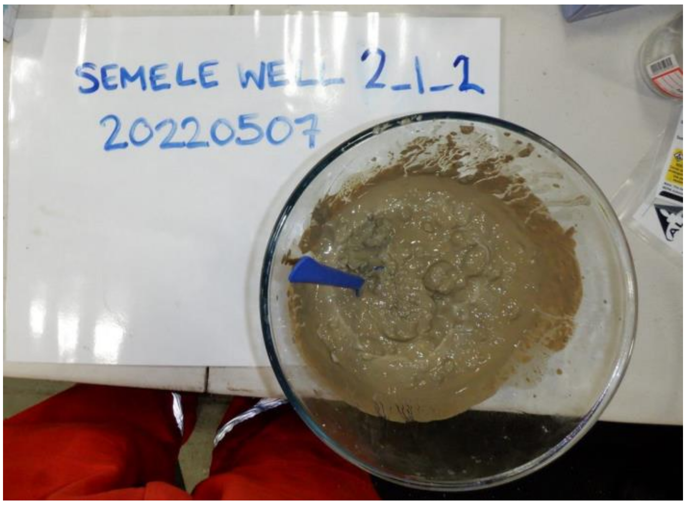
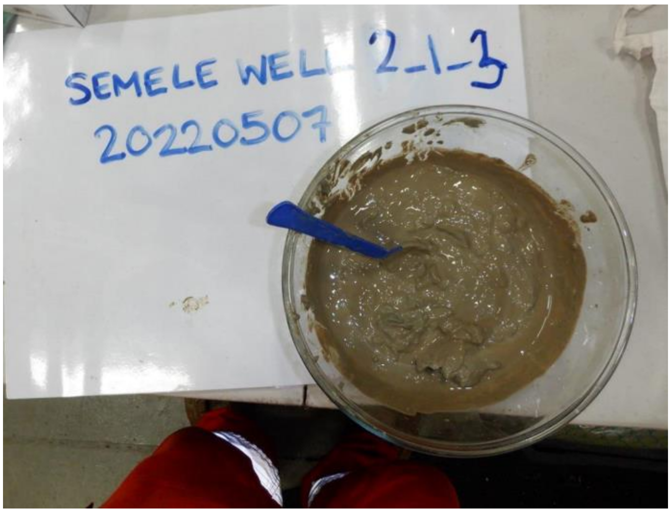
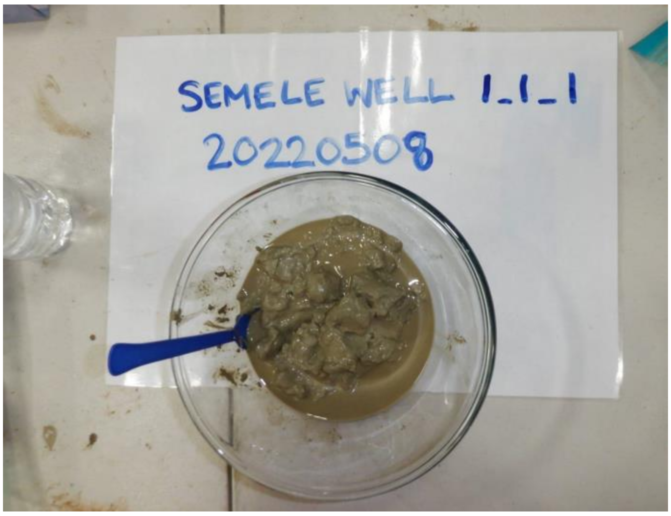
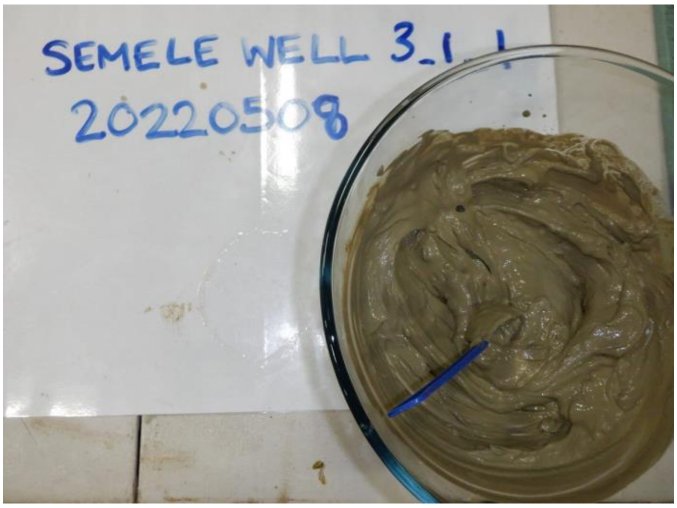
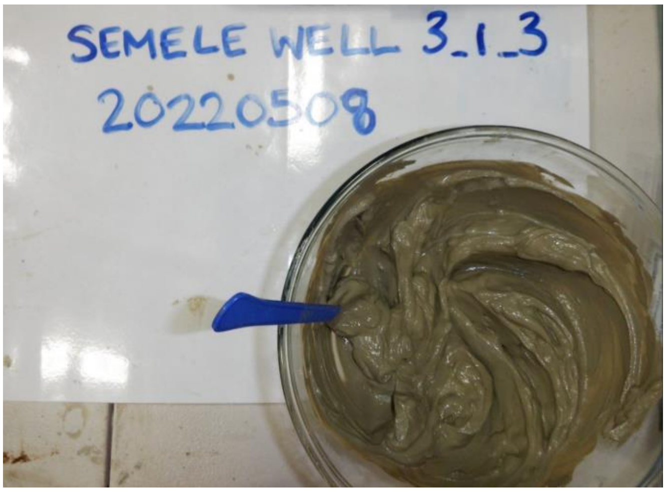
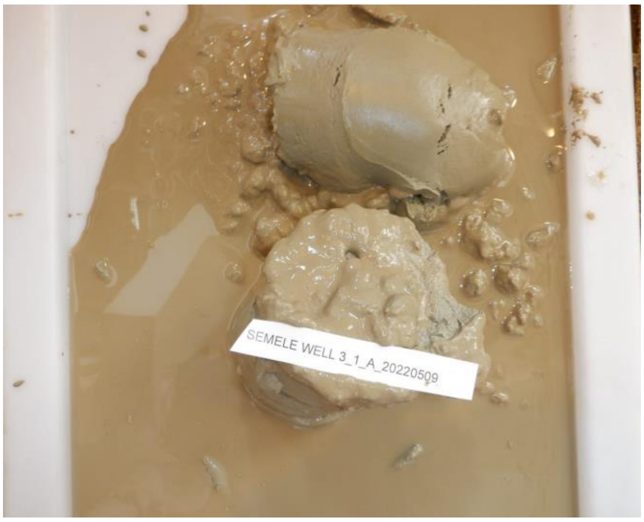
Site/Sample	Photo
NTB3_1_4	
NTB3_1_A	
NTB3_1_B	

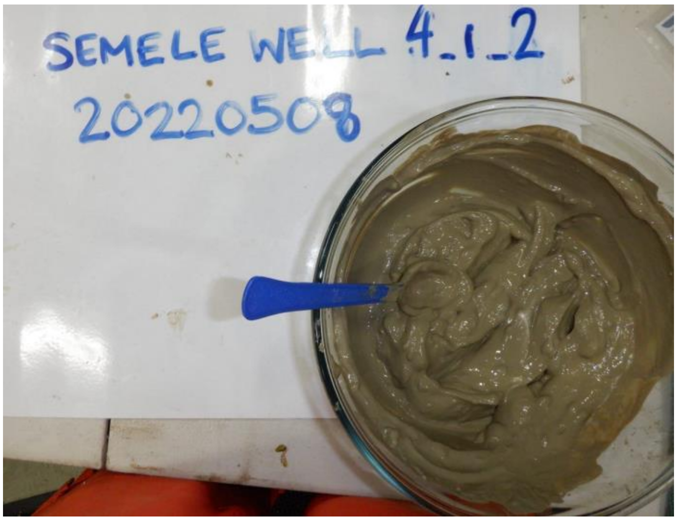
Site/Sample	Photo
GE_DC-1	
GE_DC-3	
GE_DC-2	

Site/Sample	Photo
GE_DC-4	
Chandon DC1_1_1	

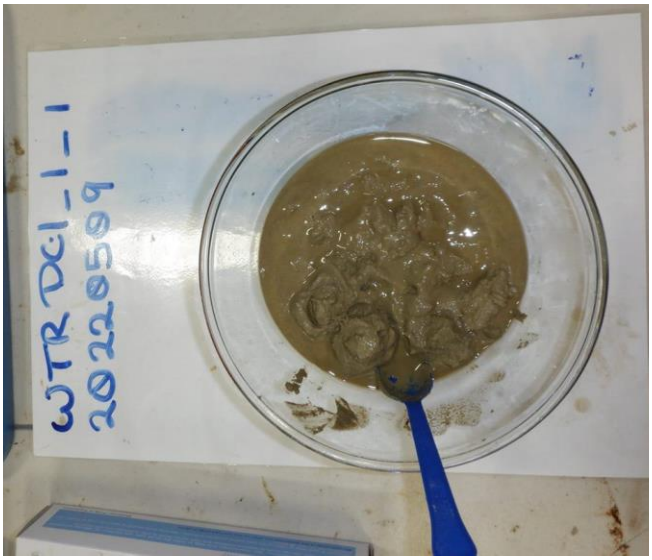
Site/Sample	Photo
Chandon DC1_1_2	
Chandon DC1_1_3	
SEMELE WELL 2_1_1	

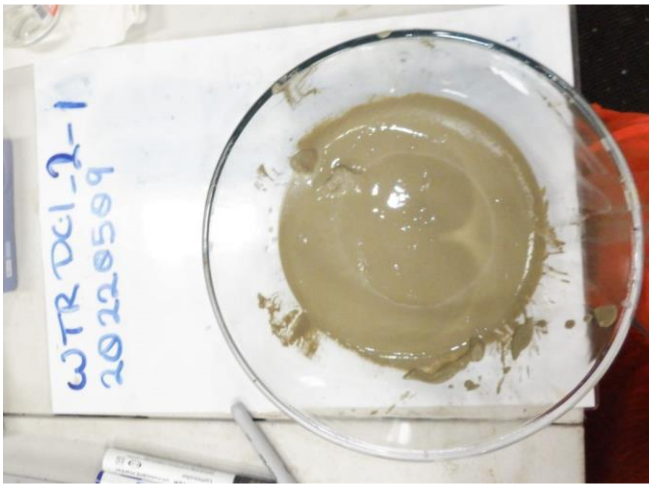
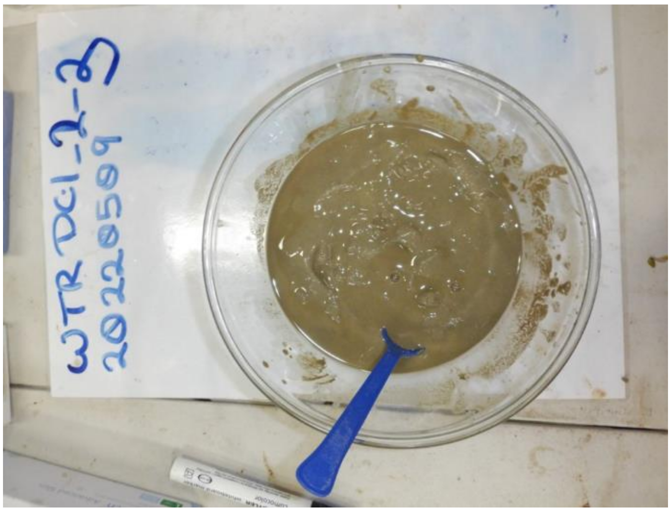
Site/Sample	Photo
SEMELE WELL 2_1_2	
SEMELE WELL 2_1_3	
SEMELE WELL 1_1_1	

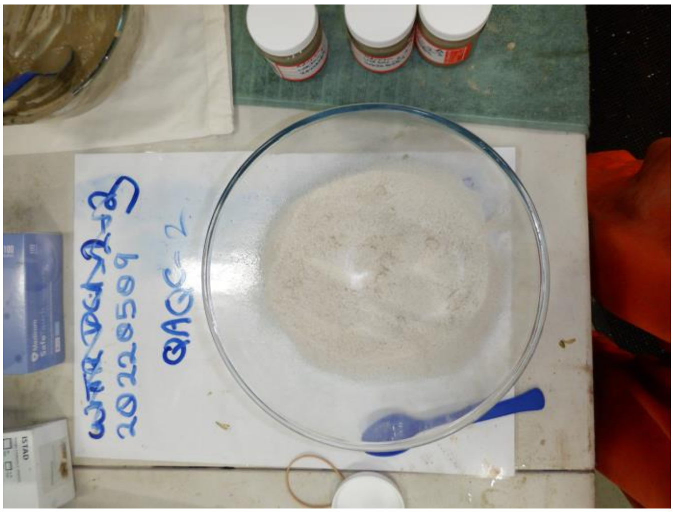
Site/Sample	Photo
SEMELE WELL 3_1_1	
SEMELE WELL 3_1_3	
SEMELE WELL 3_1_A	

Site/Sample	Photo
SEMELE WELL 3_1_B	
SEMELE WELL 4_1_2	

Site/Sample	Photo
SEMELE WELL 4_1_A	
SEMELE WELL 4_2_B	

Site/Sample	Photo
WTR DC1_1_1	
WTR DC1_1_2	
WTR DC1_1_3	

Site/Sample	Photo
WTR DC1_2_1	
WTR DC1_2_2	
WTR DC1_2_3	

Site/Sample	Photo
QAQC-2	

Appendix H Laboratory Reports for Water Samples

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2215199**	Page	: 1 of 4
Client	: **ADVISIAN PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MARK WESTERA	Contact	: Customer Services EB
Address	: LEVEL 4 600 MURRAY STREET WEST PERTH WA, AUSTRALIA	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3243 7222
Project	: Gorgon Benthic Survey 2022	Date Samples Received	: 30-May-2022 13:54
Order number	: 1	Date Analysis Commenced	: 01-Jun-2022
C-O-C number	: ----	Issue Date	: 09-Jun-2022 08:49
Sampler	: Luca Chiaroni, Stephanie Watts		
Site	: ----		
Quote number	: EP/246/22		
No. of samples received	: 2		
No. of samples analysed	: 2		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Matt Frost	Assistant Laboratory Manager	Brisbane Organics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Some samples were diluted due to matrix interference. LOR adjusted accordingly.
- **Metals analysis will be conducted by ALS Sydney, NATA accreditation no. 825, site no 10911.**
- EG093: Samples containing high levels of sulfate may precipitate barium under the acidic conditions of this method and may therefore bias results low.

Analytical Results

Sub-Matrix: WATER
(Matrix: WATER)

Compound	CAS Number	LOR	Unit	WTR DC-1_SURFACE_1	GORGON GMT_SEABED_1	----	----	----
Sampling date / time				09-May-2022 17:09	10-May-2022 17:10	----	----	----
				EB2215199-001	EB2215199-002	--------	--------	--------
				Result	Result	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	----	----	----
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	----	----	----
Arsenic	7440-38-2	0.5	µg/L	**1.5**	**1.4**	----	----	----
Barium	7440-39-3	1	µg/L	**5**	**5**	----	----	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	----	----	----
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	----	----	----
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	----	----	----
Iron	7439-89-6	5	µg/L	<5	<5	----	----	----
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	----	----	----
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	----	----	----
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	----	----	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	----	----	----
Zinc	7440-66-6	5	µg/L	<5	<5	----	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	----	----	----
Arsenic	7440-38-2	0.5	µg/L	**1.8**	**1.5**	----	----	----
Barium	7440-39-3	1	µg/L	**6**	**6**	----	----	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	----	----	----
Iron	7439-89-6	5	µg/L	<5	<5	----	----	----
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	----	----	----
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	----	----	----
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	----	----	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	----	----	----
Zinc	7440-66-6	5	µg/L	<5	<5	----	----	----
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	----	----	----
Copper	7440-50-8	0.2	µg/L	**0.3**	<0.2	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<0.5	<0.5	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	WTR DC-1_SURFACE_1	GORGON GMT_SEABED_1	----	----	----
			Sampling date / time	09-May-2022 17:09	10-May-2022 17:10	----	----	----
Compound	CAS Number	LOR	Unit	EB2215199-001	EB2215199-002	--------	--------	--------
				Result	Result	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	<0.5	<0.5	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.05	<0.05	----	----	----
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	----	1	mg/L	<1	<1	----	----	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	**1**	<1	----	----	----

Inter-Laboratory Testing

Analysis conducted by ALS Sydney, NATA accreditation no. 825, site no. 10911 (Chemistry) 14913 (Biology).

(WATER) EG035T: Total Recoverable Mercury by FIMS

(WATER) EG035F: Dissolved Mercury by FIMS

(WATER) EG093F: Dissolved Metals in Saline Water by ORC-ICPMS

(WATER) EG093T_LL: Total Metals in Saline Water by ORC-ICPMS

(WATER) EG093T: Total Metals in Saline Water by ORC-ICPMS

CERTIFICATE OF ANALYSIS

Work Order	: **EP2205671**	Page	: 1 of 15
Client	: **ADVISIAN PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MARK WESTERA	Contact	: Customer Services EP
Address	: LEVEL 4 600 MURRAY STREET WEST PERTH WA, AUSTRALIA	Address	: 26 Rigali Way Wangara WA Australia 6065
Telephone	: ----	Telephone	: +61-8-9406 1301
Project	: Gorgon Benthic Survey 2022	Date Samples Received	: 10-May-2022 16:20
Order number	: ----	Date Analysis Commenced	: 12-May-2022
C-O-C number	: ----	Issue Date	: 17-May-2022 17:16
Sampler	: Luca Chiaroni, STEPHANIE WATTS		
Site	: ----		
Quote number	: EP/246/22		
No. of samples received	: 20		
No. of samples analysed	: 20		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Inorganics Supervisor	Perth Inorganics, Wangara, WA
Chris Lemaitre	Laboratory Manager (Perth)	Perth Inorganics, Wangara, WA
David Viner	SENIOR LAB TECH	Perth Organics, Wangara, WA
Mark Kinnin	Laboratory Technician	Perth Inorganics, Wangara, WA

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP002, EP005: It has been noted that the result for Dissolved Organic Carbon is greater than the result for Total Organic Carbon for samples #002, 010, 011 & 013-018 however the difference is within the limits of experimental variation.
- EG093 and EG093-LL: It is recognised that some total analyte concentrations are less than dissolved for various samples. However, the difference is within experimental variation of the methods.
- EG093-LL: Dissolved and Total Cu results for sample EP2205671 -018 has been confirmed by re-preparation and re-analysis.
- EK061G/EK067G (TKN/TP): LOR for samples EP2205671-001, -006, -013, -014, -017 and -018 raised due to the high amount of TDS present.
- EG093: Samples containing high levels of sulfate may precipitate barium under the acidic conditions of this method and may therefore bias results low.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	NTB3_SURFACE_1	NTB3_SURFACE_2	NTB3_SEABED_1	NTB3_SEABED_2	G-E DC_SURFACE_1
			Sampling date / time	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	05-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-001	EP2205671-002	EP2205671-003	EP2205671-004	EP2205671-005
				Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**38400**	**38200**	**36900**	**37100**	**38100**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG049G LL-T: Total Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.7**	**1.8**	**1.9**	**1.9**	**1.8**
Barium	7440-39-3	1	µg/L	**5**	**4**	**12**	**12**	**5**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	0.2	µg/L	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	5	µg/L	<5	**7**	<5	<5	<5
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	**0.6**	<0.2
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.7**	**1.7**	**1.8**	**1.8**	**1.7**
Barium	7440-39-3	1	µg/L	**5**	**5**	**12**	**12**	**5**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L	<5	<5	<5	<5	<5

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	NTB3_SURFACE_1	NTB3_SURFACE_2	NTB3_SEABED_1	NTB3_SEABED_2	G-E DC_SURFACE_1
			Sampling date / time	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	05-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-001	EP2205671-002	EP2205671-003	EP2205671-004	EP2205671-005
				Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued								
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	**0.2**	<0.2
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	**0.7**	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	**0.3**	<0.2	**0.2**	**0.4**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	**0.40**	**0.39**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.2**	**0.2**	**0.3**	**0.3**	**0.3**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**0.2**	**0.2**	**0.7**	**0.7**	**0.3**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.02	**0.03**	**0.11**	**0.13**	**0.03**
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	----	1	mg/L	<1	**1**	<1	<1	<1
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	<1	<1	<1	<1	<1
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	NTB3_SURFACE_1	NTB3_SURFACE_2	NTB3_SEABED_1	NTB3_SEABED_2	G-E DC_SURFACE_1
			Sampling date / time	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	04-May-2022 00:00	05-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-001	EP2205671-002	EP2205671-003	EP2205671-004	EP2205671-005
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**92.0**	**91.2**	**92.5**	**91.8**	**88.2**
Toluene-D8	2037-26-5	2	%	**102**	**125**	**124**	**126**	**123**
4-Bromofluorobenzene	460-00-4	2	%	**104**	**104**	**114**	**108**	**98.4**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	G-E DC_SURFACE_2	G-E DC_SEABED_1	G-E DC_SEABED_2	QAQC_1	JANSZ JMT_SURFACE_1
			Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-006	EP2205671-007	EP2205671-008	EP2205671-009	EP2205671-010
				Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**38600**	**37600**	**38500**	**38100**	**38300**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG049G LL-T: Total Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.6**	**1.8**	**1.8**	**1.7**	**1.7**
Barium	7440-39-3	1	µg/L	**5**	**12**	**13**	**13**	**5**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	0.2	µg/L	<0.2	**0.2**	<0.2	<0.2	**0.4**
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	5	µg/L	<5	<5	<5	<5	**8**
Lead	7439-92-1	0.2	µg/L	<0.2	**0.5**	<0.2	**0.5**	<0.2
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	**6**	<5	<5	<5
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.7**	**1.8**	**1.8**	**1.8**	**1.7**
Barium	7440-39-3	1	µg/L	**5**	**13**	**13**	**13**	**5**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	**0.6**	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	G-E DC_SURFACE_2	G-E DC_SEABED_1	G-E DC_SEABED_2	QAQC_1	JANSZ JMT_SURFACE_1
			Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-006	EP2205671-007	EP2205671-008	EP2205671-009	EP2205671-010
				Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued								
Iron	7439-89-6	5	µg/L	<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L	<0.2	**0.5**	<0.2	**0.5**	<0.2
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	**0.2**	**0.2**	<0.2	<0.2	**0.6**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	**0.39**	**0.40**	**0.39**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.2**	**0.3**	**0.3**	**0.2**	**0.3**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ **Total Nitrogen as N**	----	0.1	mg/L	**0.2**	**0.7**	**0.7**	**0.6**	**0.3**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.02	**0.09**	**0.09**	**0.03**	**0.08**
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	----	1	mg/L	<1	<1	<1	<1	**2**
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	<1	<1	<1	<1	<1
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	G-E DC_SURFACE_2	G-E DC_SEABED_1	G-E DC_SEABED_2	QAQC_1	JANSZ JMT_SURFACE_1
			Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00	05-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-006	EP2205671-007	EP2205671-008	EP2205671-009	EP2205671-010
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**90.1**	**90.5**	**92.2**	**93.4**	**90.2**
Toluene-D8	2037-26-5	2	%	**121**	**124**	**123**	**122**	**126**
4-Bromofluorobenzene	460-00-4	2	%	**112**	**106**	**95.6**	**108**	**107**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	JANSZ JMT_SURFACE_2	JANSZ JMT_SEABED_1	BCH28_SURFACE_1	BCH28_SURFACE_2	BCH28_SEABED_1
			Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-011	EP2205671-012	EP2205671-013	EP2205671-014	EP2205671-015
				Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**38700**	**38700**	**38900**	**39200**	**38600**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG049G LL-T: Total Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.6**	**1.7**	**1.6**	**1.5**	**1.6**
Barium	7440-39-3	1	µg/L	**5**	**13**	**5**	**5**	**13**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	**0.3**	**0.3**	<0.2
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	5	µg/L	<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	**6**	<5
Arsenic	7440-38-2	0.5	µg/L	**1.8**	**1.9**	**1.6**	**1.7**	**1.8**
Barium	7440-39-3	1	µg/L	**5**	**13**	**5**	**5**	**13**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	JANSZ JMT_SURFACE_2	JANSZ JMT_SEABED_1	BCH28_SURFACE_1	BCH28_SURFACE_2	BCH28_SEABED_1
			Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-011	EP2205671-012	EP2205671-013	EP2205671-014	EP2205671-015
				Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued								
Iron	7439-89-6	5	µg/L	<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	**0.3**	**0.3**	**0.2**	<0.2
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	**0.40**	<0.01	<0.01	**0.40**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.2**	**0.3**	**0.3**	**0.2**	**0.3**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ **Total Nitrogen as N**	----	0.1	mg/L	**0.2**	**0.7**	**0.3**	**0.2**	**0.7**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.03**	**0.10**	<0.02	<0.02	**0.09**
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	----	1	mg/L	**1**	<1	**1**	**1**	**1**
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	<1	<1	<1	<1	<1
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Sample ID	JANSZ JMT_SURFACE_2	JANSZ JMT_SEABED_1	BCH28_SURFACE_1	BCH28_SURFACE_2	BCH28_SEABED_1
			Sampling date / time	05-May-2022 00:00	05-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00	06-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-011	EP2205671-012	EP2205671-013	EP2205671-014	EP2205671-015
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**89.8**	**91.7**	**90.5**	**89.0**	**93.1**
Toluene-D8	2037-26-5	2	%	**122**	**123**	**123**	**121**	**125**
4-Bromofluorobenzene	460-00-4	2	%	**100**	**105**	**99.5**	**99.4**	**103**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	BCH28_SEABED_2	CHANDON DC-1_SURFACE_1	CHANDON DC-1_SURFACE_2	CHANDON DC-1_SEABED_1	CHANDON DC-1_SEABED_2
			Sampling date / time	06-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-016	EP2205671-017	EP2205671-018	EP2205671-019	EP2205671-020
				Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**39100**	**38200**	**37800**	**38200**	**39000**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG049G LL-T: Total Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.8**	**1.7**	**1.6**	**1.8**	**1.8**
Barium	7440-39-3	1	µg/L	**13**	**5**	**5**	**13**	**13**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	0.2	µg/L	<0.2	**0.3**	**1.6**	<0.2	**0.2**
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	5	µg/L	<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L	**0.2**	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	**0.7**
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	**6**	<5	<5	<5	**9**
Arsenic	7440-38-2	0.5	µg/L	**1.9**	**1.8**	**1.8**	**1.8**	**1.8**
Barium	7440-39-3	1	µg/L	**13**	**7**	**5**	**12**	**12**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	BCH28_SEABED_2	CHANDON DC-1_SURFACE_1	CHANDON DC-1_SURFACE_2	CHANDON DC-1_SEABED_1	CHANDON DC-1_SEABED_2
			Sampling date / time	06-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205671-016	EP2205671-017	EP2205671-018	EP2205671-019	EP2205671-020
				Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued								
Iron	7439-89-6	5	µg/L	<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	**0.3**	**1.4**	<0.2	**0.3**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.40**	<0.01	<0.01	**0.40**	**0.41**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.3**	**0.2**	**0.3**	**0.3**	**0.4**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**0.7**	**0.2**	**0.3**	**0.7**	**0.8**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.08**	<0.02	<0.02	**0.11**	**0.11**
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	----	1	mg/L	**1**	**2**	**1**	<1	<1
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	<1	**1**	**1**	**1**	<1
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	BCH28_SEABED_2	CHANDON DC-1_SURFACE_1	CHANDON DC-1_SURFACE_2	CHANDON DC-1_SEABED_1	CHANDON DC-1_SEABED_2
			Sampling date / time	06-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00	07-May-2022 00:00
Compound	*CAS Number*	*LOR*	*Unit*	EP2205671-016	EP2205671-017	EP2205671-018	EP2205671-019	EP2205671-020
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**90.5**	**97.8**	**94.9**	**93.3**	**90.1**
Toluene-D8	2037-26-5	2	%	**125**	**121**	**122**	**123**	**125**
4-Bromofluorobenzene	460-00-4	2	%	**102**	**99.4**	**101**	**104**	**99.4**

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	Recovery Limits (%) High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	61	141
Toluene-D8	2037-26-5	73	126
4-Bromofluorobenzene	460-00-4	60	125

CERTIFICATE OF ANALYSIS

Work Order	: **EP2205756**	Page	: 1 of 14
Client	: **ADVISIAN PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MARK WESTERA	Contact	: Customer Services EP
Address	: LEVEL 4 600 MURRAY STREET WEST PERTH WA, AUSTRALIA	Address	: 26 Rigali Way Wangara WA Australia 6065
Telephone	: ----	Telephone	: +61-8-9406 1301
Project	: Gorgon Benthic Survey 2022	Date Samples Received	: 12-May-2022 09:00
Order number	: 1	Date Analysis Commenced	: 13-May-2022
C-O-C number	: ----	Issue Date	: 20-May-2022 17:21
Sampler	: Luca Chiaroni, STEPHANIE WATTS		
Site	: ----		
Quote number	: EP/246/22		
No. of samples received	: 12		
No. of samples analysed	: 12		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Inorganics Supervisor	Perth Inorganics, Wangara, WA
Chris Lemaitre	Laboratory Manager (Perth)	Perth Inorganics, Wangara, WA
David Viner	SENIOR LAB TECH	Perth Organics, Wangara, WA
Mark Kinnin	Laboratory Technician	Perth Inorganics, Wangara, WA

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP002, EP005: It is noted that the results for Dissolved Organic Carbon are greater than the results for Total Organic Carbon for samples #002 & 007, however the results are within the limits of experimental variation.
- EG093 and EG093-LL: It is recognised that some total analyte concentrations are less than dissolved for various samples. However, the difference is within experimental variation of the methods.
- EK061G/EK067G (TKN/TP): LOR for samples EP2205756-009, -010, -011 and -012 raised due to the high amount of TDS present.
- EG094: Positive metals results for samples EP2205756-005 to -008 have been confirmed by re-preparation and re-analysis.
- EG094 and EG094-LL: It is recognised that total Cu, Zn concentrations are less than dissolved for samples EP2205756-005 to -008. However, the difference is within experimental variation of the methods.
- EG093: Samples containing high levels of sulfate may precipitate barium under the acidic conditions of this method and may therefore bias results low.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	WTR DC-1_SURFACE_1	WTR DC-1_SURFACE_2	WTR DC-1_SEABED_1	WTR DC-1_SEABED_2	QAQC4
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205756-001	EP2205756-002	EP2205756-003	EP2205756-004	EP2205756-005
				Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**39300**	**40000**	**38400**	**40000**	**166**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	----	----	----	----	<0.001
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
EG049G LL-T: Total Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	----	----	----	----	<0.001
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	----
Arsenic	7440-38-2	0.5	µg/L	**1.9**	**1.9**	**1.9**	**1.8**	----
Barium	7440-39-3	1	µg/L	**5**	**4**	**5**	**5**	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	----
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	----
Copper	7440-50-8	0.2	µg/L	<0.2	**0.5**	<0.2	<0.2	----
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	----
Iron	7439-89-6	5	µg/L	<5	<5	<5	<5	----
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	----
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	----
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	----
Zinc	7440-66-6	5	µg/L	<5	<5	**5**	<5	----
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	----
Arsenic	7440-38-2	0.5	µg/L	**1.8**	**1.9**	**1.9**	**1.8**	----
Barium	7440-39-3	1	µg/L	**6**	**4**	**4**	**5**	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	WTR DC-1_SURFACE_1	WTR DC-1_SURFACE_2	WTR DC-1_SEABED_1	WTR DC-1_SEABED_2	QAQC4
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	*CAS Number*	*LOR*	*Unit*	EP2205756-001	EP2205756-002	EP2205756-003	EP2205756-004	EP2205756-005
				Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued								
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	----
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	**0.7**	----
Iron	7439-89-6	5	µg/L	<5	<5	<5	**7**	----
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	**0.2**	----
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	----
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	----
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	----
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	----
Copper	7440-50-8	0.2	µg/L	<0.2	**0.9**	<0.2	<0.2	----
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	----	----	----	----	<5
Arsenic	7440-38-2	0.2	µg/L	----	----	----	----	<0.2
Barium	7440-39-3	0.5	µg/L	----	----	----	----	**1.1**
Cadmium	7440-43-9	0.05	µg/L	----	----	----	----	<0.05
Chromium	7440-47-3	0.2	µg/L	----	----	----	----	<0.2
Cobalt	7440-48-4	0.02	µg/L	----	----	----	----	<0.02
Copper	7440-50-8	0.05	µg/L	----	----	----	----	**0.33**
Iron	7439-89-6	2	µg/L	----	----	----	----	<2
Lead	7439-92-1	0.1	µg/L	----	----	----	----	<0.1
Manganese	7439-96-5	0.5	µg/L	----	----	----	----	<0.5
Nickel	7440-02-0	0.5	µg/L	----	----	----	----	<0.5
Silver	7440-22-4	0.1	µg/L	----	----	----	----	<0.1
Zinc	7440-66-6	1	µg/L	----	----	----	----	**3**
EG094T: Total metals in Fresh water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	----	----	----	----	<5
Arsenic	7440-38-2	0.2	µg/L	----	----	----	----	<0.2
Barium	7440-39-3	0.5	µg/L	----	----	----	----	**3.4**
Cadmium	7440-43-9	0.05	µg/L	----	----	----	----	<0.05
Chromium	7440-47-3	0.2	µg/L	----	----	----	----	<0.2
Cobalt	7440-48-4	0.02	µg/L	----	----	----	----	<0.02
Copper	7440-50-8	0.05	µg/L	----	----	----	----	**0.35**
Iron	7439-89-6	2	µg/L	----	----	----	----	<2

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	WTR DC-1_SURFACE_1	WTR DC-1_SURFACE_2	WTR DC-1_SEABED_1	WTR DC-1_SEABED_2	QAQC4
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205756-001	EP2205756-002	EP2205756-003	EP2205756-004	EP2205756-005
				Result	Result	Result	Result	Result
EG094T: Total metals in Fresh water by ORC-ICPMS - Continued								
Lead	7439-92-1	0.1	µg/L	----	----	----	----	<0.1
Manganese	7439-96-5	0.5	µg/L	----	----	----	----	<0.5
Nickel	7440-02-0	0.5	µg/L	----	----	----	----	<0.5
Silver	7440-22-4	0.1	µg/L	----	----	----	----	<0.1
Zinc	7440-66-6	1	µg/L	----	----	----	----	**2**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	**0.01**	**0.01**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.2**	**0.4**	**0.3**	**0.2**	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ **Total Nitrogen as N**	----	0.1	mg/L	**0.2**	**0.4**	**0.3**	**0.2**	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.02**	**0.05**	**0.06**	**0.03**	<0.01
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	----	1	mg/L	**1**	**2**	**2**	**2**	**1**
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	**1**	**1**	**2**	**2**	**1**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	**40**
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	**130**
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	**130**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	**40**
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	WTR DC-1_SURFACE_1	WTR DC-1_SURFACE_2	WTR DC-1_SEABED_1	WTR DC-1_SEABED_2	QAQC4
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205756-001	EP2205756-002	EP2205756-003	EP2205756-004	EP2205756-005
				Result	Result	Result	Result	Result
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	**25**
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	**3**
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	**2**
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	**5**
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	**30**
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**111**	**107**	**113**	**106**	**98.1**
Toluene-D8	2037-26-5	2	%	**100**	**100**	**99.9**	**101**	**100**
4-Bromofluorobenzene	460-00-4	2	%	**101**	**101**	**100**	**98.0**	**100.0**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	QAQC5	QAQC6	QAQC7	GORGON GMT_SURFACE_1	GORGON GMT_SURFACE_2
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	10-May-2022 00:00	10-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205756-006	EP2205756-007	EP2205756-008	EP2205756-009	EP2205756-010
				Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	<10	**35**	**160**	**38700**	**38800**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
EG049G LL-F: Dissolved Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Trivalent Chromium	16065-83-1	0.001	mg/L	----	----	----	<0.001	<0.001
EG049G LL-T: Total Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Trivalent Chromium	16065-83-1	0.001	mg/L	----	----	----	<0.001	<0.001
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	----	----	----	<5	<5
Arsenic	7440-38-2	0.5	µg/L	----	----	----	**1.9**	**1.9**
Barium	7440-39-3	1	µg/L	----	----	----	**5**	**4**
Cadmium	7440-43-9	0.2	µg/L	----	----	----	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	----	----	----	<0.5	<0.5
Copper	7440-50-8	0.2	µg/L	----	----	----	**0.3**	**1.7**
Cobalt	7440-48-4	0.05	µg/L	----	----	----	<0.05	<0.05
Iron	7439-89-6	5	µg/L	----	----	----	<5	<5
Lead	7439-92-1	0.2	µg/L	----	----	----	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L	----	----	----	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L	----	----	----	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L	----	----	----	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	----	----	----	<5	<5
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	----	----	----	<5	<5
Arsenic	7440-38-2	0.5	µg/L	----	----	----	**1.9**	**1.9**
Barium	7440-39-3	1	µg/L	----	----	----	**5**	**5**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	QAQC5	QAQC6	QAQC7	GORGON GMT_SURFACE_1	GORGON GMT_SURFACE_2
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	10-May-2022 00:00	10-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205756-006	EP2205756-007	EP2205756-008	EP2205756-009	EP2205756-010
				Result	Result	Result	Result	Result
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued								
Cadmium	7440-43-9	0.2	µg/L	----	----	----	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	----	----	----	<0.5	<0.5
Iron	7439-89-6	5	µg/L	----	----	----	<5	<5
Lead	7439-92-1	0.2	µg/L	----	----	----	**7.4**	<0.2
Manganese	7439-96-5	0.5	µg/L	----	----	----	<0.5	<0.5
Nickel	7440-02-0	0.5	µg/L	----	----	----	<0.5	<0.5
Silver	7440-22-4	0.1	µg/L	----	----	----	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	----	----	----	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	----	----	----	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	----	----	----	**0.3**	**1.2**
EG094F: Dissolved Metals in Fresh Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	----	----
Arsenic	7440-38-2	0.2	µg/L	<0.2	<0.2	<0.2	----	----
Barium	7440-39-3	0.5	µg/L	<0.5	**30.3**	**7.4**	----	----
Cadmium	7440-43-9	0.05	µg/L	<0.05	<0.05	<0.05	----	----
Chromium	7440-47-3	0.2	µg/L	<0.2	<0.2	<0.2	----	----
Cobalt	7440-48-4	0.02	µg/L	<0.02	<0.02	<0.02	----	----
Copper	7440-50-8	0.05	µg/L	**0.31**	**0.14**	**0.34**	----	----
Iron	7439-89-6	2	µg/L	<2	<2	<2	----	----
Lead	7439-92-1	0.1	µg/L	<0.1	<0.1	<0.1	----	----
Manganese	7439-96-5	0.5	µg/L	<0.5	**0.7**	<0.5	----	----
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	----	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	----	----
Zinc	7440-66-6	1	µg/L	**2**	**3**	**2**	----	----
EG094T: Total metals in Fresh water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	**5**	----	----
Arsenic	7440-38-2	0.2	µg/L	<0.2	<0.2	<0.2	----	----
Barium	7440-39-3	0.5	µg/L	<0.5	**37.2**	**34.2**	----	----
Cadmium	7440-43-9	0.05	µg/L	<0.05	<0.05	<0.05	----	----
Chromium	7440-47-3	0.2	µg/L	<0.2	<0.2	<0.2	----	----
Cobalt	7440-48-4	0.02	µg/L	<0.02	<0.02	<0.02	----	----
Copper	7440-50-8	0.05	µg/L	**0.22**	**0.39**	**0.30**	----	----
Iron	7439-89-6	2	µg/L	<2	<2	**5**	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	QAQC5	QAQC6	QAQC7	GORGON GMT_SURFACE_1	GORGON GMT_SURFACE_2
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	10-May-2022 00:00	10-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205756-006	EP2205756-007	EP2205756-008	EP2205756-009	EP2205756-010
				Result	Result	Result	Result	Result
EG094T: Total metals in Fresh water by ORC-ICPMS - Continued								
Lead	7439-92-1	0.1	µg/L	<0.1	<0.1	**0.3**	----	----
Manganese	7439-96-5	0.5	µg/L	<0.5	**0.8**	<0.5	----	----
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	----	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	----	----
Zinc	7440-66-6	1	µg/L	**1**	**2**	**2**	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<0.1	<0.1	<0.1	**0.2**	**0.3**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ **Total Nitrogen as N**	----	0.1	mg/L	<0.1	<0.1	<0.1	**0.2**	**0.3**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.01	<0.01	<0.01	<0.02	<0.02
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	----	1	mg/L	<1	**2**	**3**	**2**	**1**
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	<1	**1**	**4**	**2**	**1**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	**60**	**30**	**30**	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	**130**	**160**	**2160**	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	**1690**	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	**130**	**160**	**3850**	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	**60**	**30**	**40**	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	**100**	**120**	**160**	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	**3730**	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	**220**	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	**100**	**120**	**4110**	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	**100**	**120**	**160**	<100	<100

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	QAQC5	QAQC6	QAQC7	GORGON GMT_SURFACE_1	GORGON GMT_SURFACE_2
			Sampling date / time	09-May-2022 00:00	09-May-2022 00:00	09-May-2022 00:00	10-May-2022 00:00	10-May-2022 00:00
Compound	CAS Number	LOR	Unit	EP2205756-006	EP2205756-007	EP2205756-008	EP2205756-009	EP2205756-010
				Result	Result	Result	Result	Result
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	**40**	**20**	**22**	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	**5**	**2**	**3**	<2	<2
ortho-Xylene	95-47-6	2	µg/L	**4**	<2	**2**	<2	<2
^ **Total Xylenes**	----	2	µg/L	**9**	**2**	**5**	<2	<2
^ **Sum of BTEX**	----	1	µg/L	**49**	**22**	**27**	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**102**	**98.4**	**98.0**	**116**	**106**
Toluene-D8	2037-26-5	2	%	**99.0**	**102**	**102**	**103**	**105**
4-Bromofluorobenzene	460-00-4	2	%	**96.5**	**96.7**	**99.7**	**100**	**106**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	GORGON GMT_SEABED_1	GORGON GMT_SEABED_2	----	----	----
			Sampling date / time	10-May-2022 00:00	10-May-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EP2205756-011	EP2205756-012	--------	--------	--------
				Result	Result	----	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**40000**	**39800**	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	ug/L	<0.1	<0.1	----	----	----
EG049G LL-F: Dissolved Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	----	----	----
EG049G LL-T: Total Trivalent Chromium - Low Level								
Trivalent Chromium	16065-83-1	0.001	mg/L	<0.001	<0.001	----	----	----
EG050G LL-F: Dissolved Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	----	----	----
EG050G LL-T: Total Hexavalent Chromium by Discrete Analyser - Low Level								
Hexavalent Chromium	18540-29-9	0.001	mg/L	<0.001	<0.001	----	----	----
EG093F: Dissolved Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	----	----	----
Arsenic	7440-38-2	0.5	µg/L	**2.0**	**1.9**	----	----	----
Barium	7440-39-3	1	µg/L	**4**	**4**	----	----	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	----	----	----
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	----	----	----
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	----	----	----
Cobalt	7440-48-4	0.05	µg/L	**0.10**	<0.05	----	----	----
Iron	7439-89-6	5	µg/L	<5	<5	----	----	----
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	----	----	----
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	----	----	----
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	----	----	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	----	----	----
Zinc	7440-66-6	5	µg/L	<5	<5	----	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	----	----	----
Arsenic	7440-38-2	0.5	µg/L	**1.9**	**1.9**	----	----	----
Barium	7440-39-3	1	µg/L	**5**	**4**	----	----	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	----	----	----
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	GORGON GMT_SEABED_1	GORGON GMT_SEABED_2	----	----	----
			Sampling date / time	10-May-2022 00:00	10-May-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EP2205756-011	EP2205756-012	--------	--------	--------
				Result	Result	----	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS - Continued								
Iron	7439-89-6	5	µg/L	<5	<5	----	----	----
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	----	----	----
Manganese	7439-96-5	0.5	µg/L	**1.1**	**0.9**	----	----	----
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	----	----	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	----	----	----
Zinc	7440-66-6	5	µg/L	<5	<5	----	----	----
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	----	----	----
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<0.2	<0.2	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	<0.2	<0.2	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.03**	**0.02**	----	----	----
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	----	1	mg/L	**1**	**2**	----	----	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	**2**	**2**	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	----	----	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	----	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	<100	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	GORGON GMT_SEABED_1	GORGON GMT_SEABED_2	----	----	----
			Sampling date / time	10-May-2022 00:00	10-May-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EP2205756-011	EP2205756-012	--------	--------	--------
				Result	Result	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C34 - C40 Fraction	----	100	µg/L	<100	<100	----	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	----	----	----
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	----	----	----
Toluene	108-88-3	2	µg/L	<2	<2	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	<2	----	----	----
^ Total Xylenes	----	2	µg/L	<2	<2	----	----	----
^ Sum of BTEX	----	1	µg/L	<1	<1	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	<5	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**118**	**106**	----	----	----
Toluene-D8	2037-26-5	2	%	**108**	**99.4**	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**106**	**94.3**	----	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	*CAS Number*	***Recovery Limits (%)*** Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	61	141
Toluene-D8	2037-26-5	73	126
4-Bromofluorobenzene	460-00-4	60	125

Appendix I Assessment of Quality Assurance and Quality Control Samples

Appendix I Assessment of QAQC samples

Assessment of Quality Control Samples

Comparisons were made of the laboratory test results for the duplicate samples with the original samples and the Relative Percentage Difference (RPD) calculated as difference/average in order to assess the accuracy of the sampling and laboratory test procedures. The comparisons between the duplicates and the original samples indicate acceptable RPDs when they comply with criteria which are commonly set at:

- Less than 30% for inorganics (metals) and 50% for organics (hydrocarbons and PAHs);
- Less than five times the Laboratory LOR; and,

Where analyte values resulted as < LOR, half the LOR was used to calculate the RPD.

This data validation criteria and process is based off the National Environment Protection Measure (NEPM).

Both water and sediment hydrocarbons (PAH's, BTEXN), values at all sites resulted below the LOR therefore they have all conformed to the above criteria (RPD = 0%), and therefore have not been included or displayed in the tables.

The RPD% for the majority of intra-laboratory and inter-laboratory duplicates had concentrations that complied with the criteria set for acceptable RPDs. Only two exceedances were noted. These included the duplicate sample for (dissolved) iron in water from G-E DC_Seabed (RPD% = 33.33%), and the intra-laboratory samples for (total) manganese in water from Gorgon GMT_Seabed (RPD% = 31.48%).

The RSD% for the majority of replicates had concentrations that complied with the criteria set for acceptable RSDs. Only one exceedance was noted. The replicate samples for cadmium from WTR DC-2 (RSD% = 43.30%) displayed an exceedance.

The RPD/RSD results for the metals were all below 50%. The heterogeneity observed in the duplicate and replicate samples was not deemed significant enough to diminish confidence in the sampling technique or laboratory results. Therefore, it is considered that sampling techniques and laboratory analysis were appropriate.

Table 1 1 Calculated intra-laboratory and replicate RPDs for sediment metal concentrations

Sample Type	Units	Sample ID	Date	Ag (Silver)	Al (Aluminium)	As (Arsenic)	Ba (Barium)	Cd (Cadmium)	Co (Cobalt)	Cr (Chromium)	Cu (Copper)	Fe (Iron)	Mn (Manganese)	Ni (Nickel)	Pb (Lead)	Zn (Zinc)	Hg (Mercury)
Sediment	**mg/kg**	SEMELE WELL-4_1_3	08/05/2022	0.1	4960	1.75	100	0.4	3.2	31.3	13.5	6650	186	19.7	2.8	22.2	0.02
Sediment	**mg/kg**	*SEMELE WELL-4_1_3	08/05/2022	0.1	3300	1.62	80	0.3	3.1	30.3	12.8	5130	173	18.9	2.6	20.6	0.02
		RPD %		0.00	10.05	1.93	5.56	7.14	0.79	0.81	1.33	6.45	1.81	1.04	1.85	1.87	0.00
Sediment	**mg/kg**	SEMELE WELL-4_1_2	08/05/2022	0.1	5140	1.76	110	0.4	3.4	32.6	14.5	6990	221	20.8	2.9	23.9	0.01
Sediment	**mg/kg**	*SEMELE WELL-4_1_2	08/05/2022	0.1	3460	1.63	90	0.3	3.1	30.5	13.2	5380	216	19.1	2.7	20.8	0.02
		RPD %		0.00	9.77	1.92	5.00	7.14	2.31	1.66	2.35	6.51	0.57	2.13	1.79	3.47	16.67
Sediment	**mg/kg**	WTR DC-1-4_1_1	09/05/2022	0.05	2260	1.25	40	0.1	1.4	16.7	3.8	3390	95	7.5	1.5	6.7	0.005
Sediment	**mg/kg**	*WTR DC-1_4_1_1	09/05/2022	0.05	1570	1.27	30	0.1	1.5	17.4	3.7	2800	96	7.5	1.6	6.2	0.005
		RPD %		0.00	9.01	0.40	7.14	0.00	1.72	1.03	0.67	4.77	0.26	0.00	1.61	1.94	0.00
Sediment	**mg/kg**	WTR DC-2_2_3	09/05/2022	0.05	2400	1.29	50	0.2	1.5	17.5	3.9	3610	102	7.8	1.6	6.8	0.005
Sediment	**mg/kg**	*WTR DC-2_2_3	09/05/2022	0.05	1490	1.23	30	0.1	1.4	15.9	3.4	2720	92	7.1	1.5	5.9	0.005
		RPD %		0.00	11.70	1.19	12.50	16.67	1.72	2.40	3.42	7.03	2.58	2.35	1.61	3.54	0.00
Criteria		**RPD <30%**		**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**
		Diff < 5 X LOR Soils and Sediments		**0.5**	**250**	**5**	**50**	**0.5**	**2.5**	**5**	**5**	**250**	**50**	**5**	**5**	**5**	**0.05**

Note:
1. * indicates intra laboratory duplicate
2.. For ease of identification, RPD >30% are shown in bold.

Table 1 2 Calculated intra-laboratory and replicate RPDs for water (dissolved) metal concentrations

Sample Type	Units	Sample ID	Date	Dissolved Metals														
				Ag (Silver)	Al (Aluminium)	As (Arsenic)	Ba (Barium)	Cd (Cadmium)	Co (Cobalt)	Cu (Copper)	Fe (Iron)	Mn (Manganese)	Ni (Nickel)	Pb (Lead)	Zn (Zinc)	Hg (Mercury)	Cr (Chromium) III	Cr (Chromium) VI
Water	**µg/L**	WTR DC-1_SURFACE_1	09/05/2022	0.05	2.5	1.9	5	0.1	0.025	0.1	2.5	0.25	0.25	0.1	2.5	-	-	-
Water	**µg/L**	*WTR DC-1_SURFACE_1_	09/05/2022	0.05	2.5	1.5	5	0.1	0.025	0.1	2.5	0.25	0.25	0.1	2.5	0.05	-	-
		RPD %		0.00	0.00	5.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Water	**µg/L**	GORGON GMT_SEABED_1	10/05/2022	0.05	2.5	2	4	0.1	0.1	0.1	2.5	0.25	0.25	0.1	2.5	0.05	-	-
Water	**µg/L**	*GORGON GMT_SEABED_1	10/05/2022	0.05	2.5	1.4	5	0.1	0.025	0.1	2.5	0.25	0.25	0.1	2.5	0.05	-	-
		RPD %		0.00	0.00	8.82	5.56	0.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Water	**µg/L**	QAQC_1	05/05/2022	0.05	2.5	1.7	13	0.1	0.025	0.25	2.5	0.25	0.25	0.5	2.5	0.05	0.0005	0.0005

Water	**µg/L**	G-E DC_SEABED_2	05/05/2022	0.05	2.5	1.8	13	0.1	0.025	0.25	2.5	0.25	0.25	0.1	2.5	0.05	0.0005	0.0005
		RPD %		0.00	1.43	0.00	0.00	0.00	0.00	0.00	**33.33**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Criteria		**RPD <30%**		**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**
		Diff < 5 X LOR Waters		**0.5**	**25**	**2.5**	**5**	**1**	**0.25**	**1**	**25**	**2.5**	**2.5**	**1**	**25**	**0**	**0.005**	**0.005**

Note:
1. * indicates intra laboratory duplicate
2.. For ease of identification, RPD >30% are shown in bold.

Table 1-3 Calculated intra-laboratory and replicate RPDs for water (total) metal concentrations.

Sample Type	Units	Sample ID	Date	Total Metals														
				Ag (Silver)	Al (Aluminium)	As (Arsenic)	Ba (Barium)	Cd (Cadmium)	Co (Cobalt)	Cu (Copper)	Fe (Iron)	Mn (Manganese)	Ni (Nickel)	Pb (Lead)	Zn (Zinc)	Hg (Mercury)	Cr (Chromium) III	Cr (Chromium) VI
Water	**µg/L**	WTR DC-1_SURFACE_1	09/05/2022	0.05	2.5	1.8	6	0.1	0.025	0.1	2.5	0.25	0.25	0.1	2.5	0.05	-	-
Water	**µg/L**	*WTR DC-1_SURFACE_1	09/05/2022	0.05	2.5	1.8	6	0.1	0.025	0.3	2.5	0.25	0.25	0.1	2.5	0.05	-	-
		RPD %		0.00	0.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Water	**µg/L**	GORGON GMT_SEABED_1	10/05/2022	0.05	2.5	1.9	5	0.1	0.025	0.025	2.5	1.1	0.25	0.1	2.5	0.05	-	-
Water	**µg/L**	*GORGON GMT_SEABED_1	10/05/2022	0.05	2.5	1.5	6	0.1	0.1	0.1	2.5	0.25	0.25	0.1	2.5	0.05	-	-
		RPD %		0.00	0.00	5.88	4.55	0.00	0.00	0.00	0.00	**31.48**	0.00	0.00	0.00	0.00	-	-
Water	**µg/L**	QAQC_1	05/05/2022	0.05	2.5	1.8	13	0.1	0.025	0.1	2.5	0.25	0.25	0.5	2.5	0.05	0.0005	0.0005
Water	**µg/L**	G-E DC_SEABED_2	05/05/2022	0.05	2.5	1.8	13	0.1	0.025	0.1	2.5	0.25	0.25	0.1	2.5	0.05	0.0005	0.0005
		RPD %		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Criteria		**RPD <30%**		**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**
		Diff < 5 X LOR Waters		**0.5**	**25**	**2.5**	**5**	**1**	**0.25**	**1**	**25**	**2.5**	**2.5**	**1**	**25**	**0**	**0.005**	**0.005**

Note:
1. * indicates intra laboratory duplicate
2.. For ease of identification, RPD >30% are shown in bold.

Table 1-4 Calculated intra-laboratory and replicate RPDs for sediment nutrients and other parameters.

Sample Type	Units	Sample ID	Date	Other Parameters: Moisture Content	TOC (Total Organic Carbon)	SPD (Soil Particle Distribution)
Sediment	**mg/kg**	SEMELE WELL-4_1_3	08/05/2022	61.4	-	-
Sediment	**mg/kg**	*SEMELE WELL-4_1_3	08/05/2022	57.6	-	-
		RPD %		1.60	-	-
Sediment	**mg/kg**	SEMELE WELL-4_1_2	08/05/2022	61.3	-	-
Sediment	**mg/kg**	*SEMELE WELL-4_1_2	08/05/2022	58.2	-	-
		RPD %		1.30	-	-
Sediment	**mg/kg**	WTR DC-1-4_1_1	09/05/2022	39.1	-	-
Sediment	**mg/kg**	*WTR DC-1_4_1_1	09/05/2022	35.4	-	-
		RPD %		2.48	-	-
Criteria		**RPD <30%**		**30**	**30**	**30**
		Diff < 5 X LOR Soils and Sediments		**-**	**-**	**-**

Note:
1. * indicates intra laboratory duplicate
2.. For ease of identification, RPD >30% are shown in bold.

Table 1-5 Calculated intra-laboratory and replicate RPDs for water nutrients and other parameters.

Sample Type	Units	Sample ID	Date	Other Parameters: TN (Total Nitrogen)	TP (Total Phosphorus)	DOC (Dissolved Organic Carbon)	TOC (Total Organic Carbon)	TDS (Total Dissolved Solids)
Water	**µg/L**	WTR DC-1_SURFACE_1	09/05/2022	-	-	-	-	-
Water	**µg/L**	*WTR DC-1_SURFACE_1	09/05/2022	0.25	0.025	0.5	1	-
		RPD %		-	-	-	-	-
Water	**µg/L**	GORGON GMT_SEABED_1	10/05/2022	0.1	0.03	1	2	-
Water	**µg/L**	*GORGON GMT_SEABED_1	10/05/2022	0.25	0.025	0.5	0.5	-
		RPD %		21.43	4.55	16.67	30.00	-
Water	**µg/L**	QAQC_1	05/05/2022	0.5	0.03	0.5	0.5	38100
Water	**µg/L**	G-E DC_SEABED_2	05/05/2022	0.7	0.09	0.5	0.5	38500

		RPD %		8.33	25.00	0.00	0.00	0.26
Criteria		**RPD <30%**		**30**	**30**	**30**	**30**	**30**
		Diff < 5 X LOR Waters		**0.5**	**0.05**	**5**	**5**	**-**

Table 1-6 Calculated replicate RSDs for sediment metal concentrations.

Sample Type	Units	Sample ID	Date	Ag (Silver)	Al (Aluminium)	As (Arsenic)	Ba (Barium)	Cd (Cadmium)	Co (Cobalt)	Cr (Chromium)	Cu (Copper)	Fe (Iron)	Mn (Manganese)	Ni (Nickel)	Pb (Lead)	Zn (Zinc)	Hg (Mercury)
Sediment	**mg/kg**	WTR DC-2_1_1	09/05/2022	0.05	2280	1.23	40	0.1	1.5	16.7	3.8	3530	96	7.7	1.6	6.7	0.005
Sediment	**mg/kg**	WTR DC-2_2_2	09/05/2022	0.05	2230	1.3	40	0.1	1.5	16.7	3.8	3510	101	7.3	1.6	6.6	0.005
Sediment	**mg/kg**	WTR DC-2_2_3	09/05/2022	0.05	2400	1.29	50	0.2	1.5	17.5	3.9	3610	102	7.8	1.6	6.8	0.005
		RSD %		0.00	3.79	2.97	13.32	**43.30**	0.00	2.72	1.51	1.49	3.23	3.48	0.00	1.49	0.00
Criteria		**RSD <30%**		**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**
		Diff < 5 X LOR Soils and Sediments		**0.5**	**250**	**5**	**50**	**0.5**	**2.5**	**5**	**5**	**250**	**50**	**5**	**5**	**5**	**0.05**

Table 1-7 Calculated replicate RSDs for sediment nutrients and other parameters.

Sample Type	Units	Sample ID	Date	Other Parameters		
				Moisture Content	TOC (Total Organic Carbon)	SPD (Soil Particle Distribution)
Sediment	**mg/kg**	WTR DC-2_1_1	09/05/2022	40.6	0.47	2.36
Sediment	**mg/kg**	WTR DC-2_2_2	09/05/2022	40.9	0.46	2.42
Sediment	**mg/kg**	WTR DC-2_2_3	09/05/2022	40.4	0.49	2.42
		RSD %		0.62	3.23	1.44
Criteria		**RSD <30%**		**30**	**30**	**30**
		Diff < 5 X LOR Soils and Sediments		**-**	**-**	**-**

Appendix J Benthic Infauna Raw Data

Advisian
Worley Group

Table 1-1 Benthic infauna raw counts per sample.

Phylum	Class/ Order	Family	Morph-sp	CHANDO NDC-1_1_A	CHANDO NDC1_1_B	D1-3_1_A	D1-3_1_B	G_EDC_1_A	GEDC_1_B	NTB3_1_A	NTB3_1_B	BCH42_1_A
Sipuncula	Sipuncula	Sipuncula	Sipuncula sp.1	0	0	0	0	0	0	0	0	1
Annelida	Polychaeta	Capitellidae	*Notomastus sp1*	0	0	0	0	0	0	0	0	0
Annelida	Polychaeta	Orbiniidae	Orbiniidae sp.1	0	0	0	0	0	0	0	0	0
Annelida	Polychaeta	Hartmaniellidae	*Hartmaniella sp1*	0	0	0	0	0	0	0	0	0
Annelida	Polychaeta	Pilargidae	*Sigambra sp1*	0	0	0	0	0	0	0	0	0
Mollusca	Gastropoda	Aplacophora	Aplacophora sp.1	0	0	0	0	0	0	0	0	0

Phylum	Class/ Order	Family	Morph-sp	BCH42_1_B	BCH43_1_A	BCH43_1_B	BCH40_1_A	BCH40_1_B	BCH41_1_A	BCH41_1_B	STB4_1_A	STB4_1_B	WTR DC1_1_A	WTR DC1_1_B	WTR DC1_2_A
Sipuncula	Sipuncula	Sipuncula	Sipuncula sp.1	1	0	1	0	0	0	0	0	0	0	0	1
Annelida	Polychaeta	Capitellidae	*Notomastus sp1*	0	0	0	0	0	0	0	0	0	0	1	1
Annelida	Polychaeta	Orbiniidae	Orbiniidae sp.1	0	0	0	0	0	0	0	0	0	0	0	2
Annelida	Polychaeta	Hartmaniellidae	*Hartmaniella sp1*	0	0	0	0	0	0	0	0	0	0	0	1
Annelida	Polychaeta	Pilargidae	*Sigambra sp1*	0	0	0	0	0	0	0	0	0	0	0	1
Mollusca	Gastropoda	Aplacophora	Aplacophora sp.1	0	0	0	0	1	0	0	0	0	0	0	0

Appendix K ROV depth profiles

Appendix N ROV depth profiles

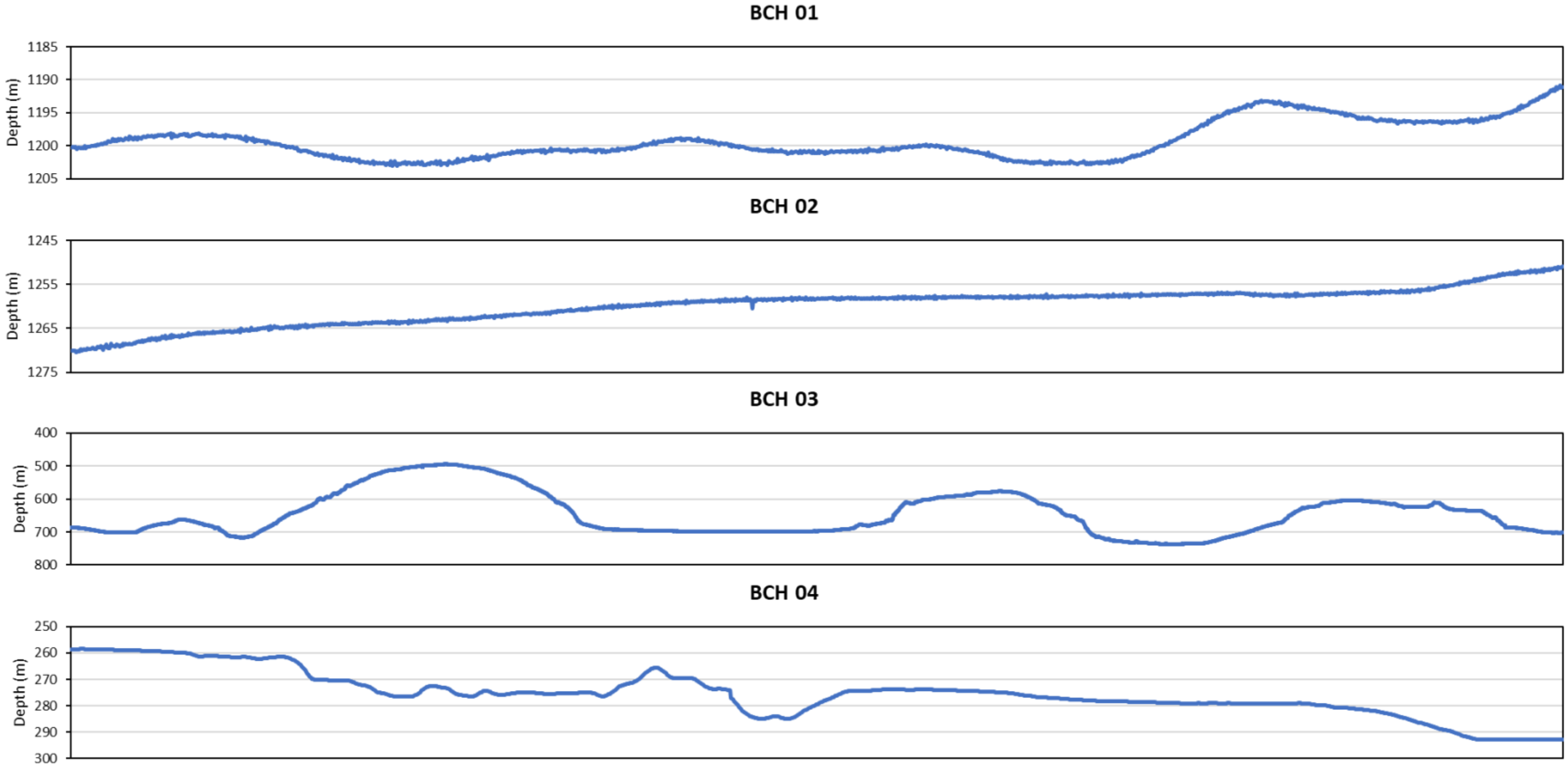


Figure 1.1 ROV depth profiles based on altitude across Gorgon Backfill Fields sites (BCH01, BCH02, BCH03, and BCH04).

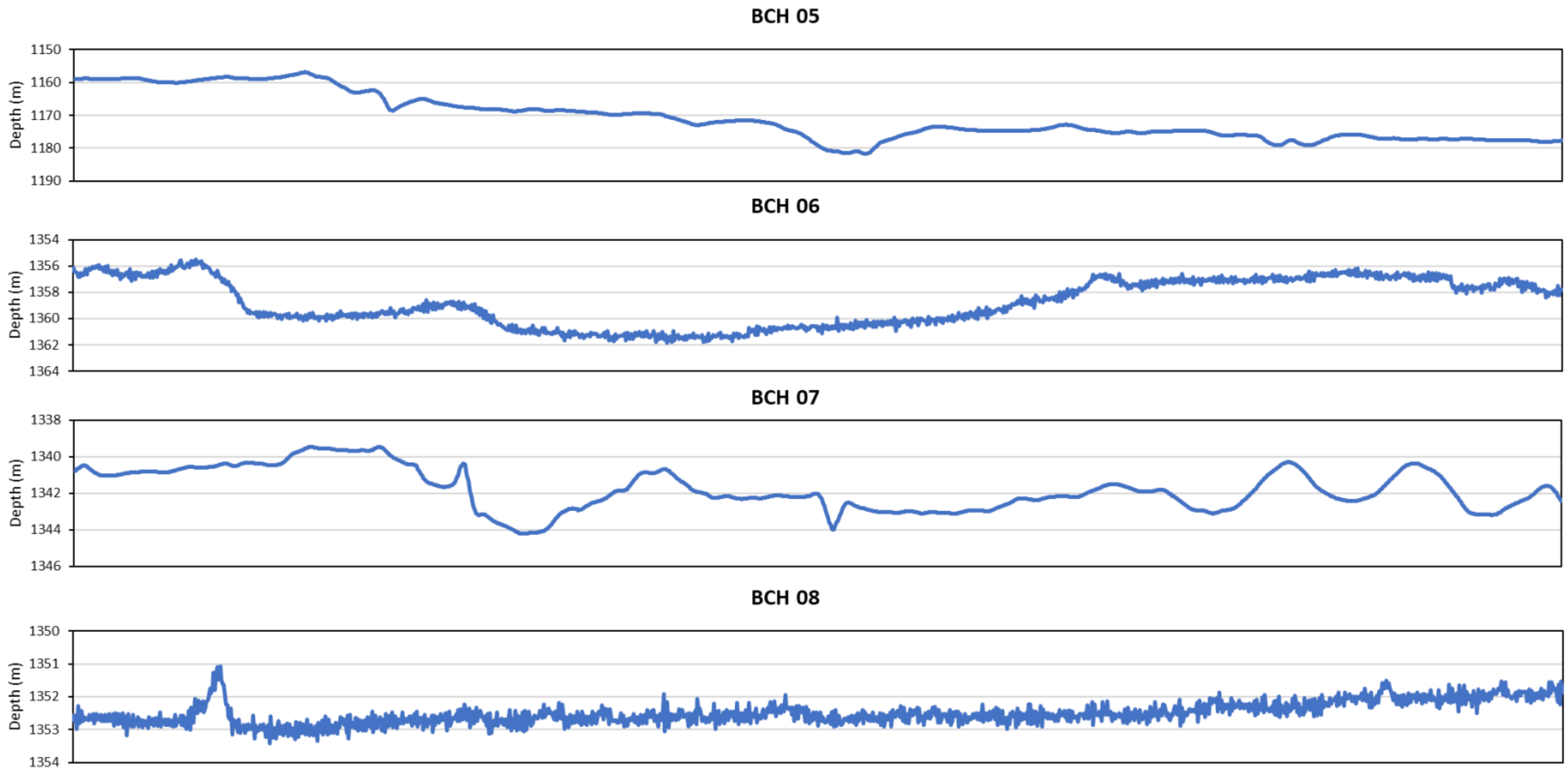


Figure 1-2 ROV depth profiles based on altitude across Gorgon Backfill Fields sites (BCH05, BCH06, BCH07, and BCH08).

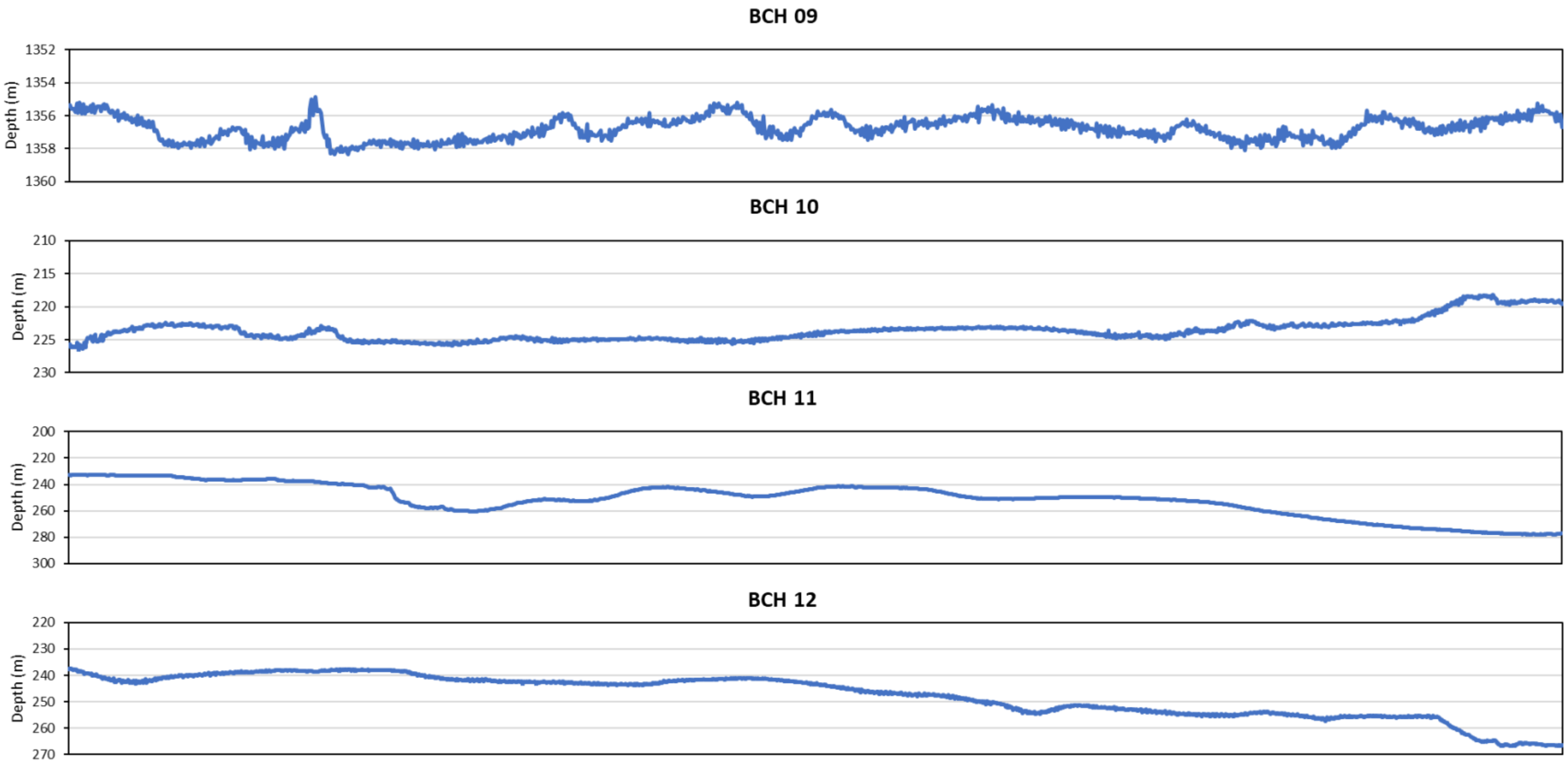


Figure 1-3 ROV depth profiles based on altitude across Gorgon Backfill Fields sites (BCH05, BCH06, BCH07, and BCH08).

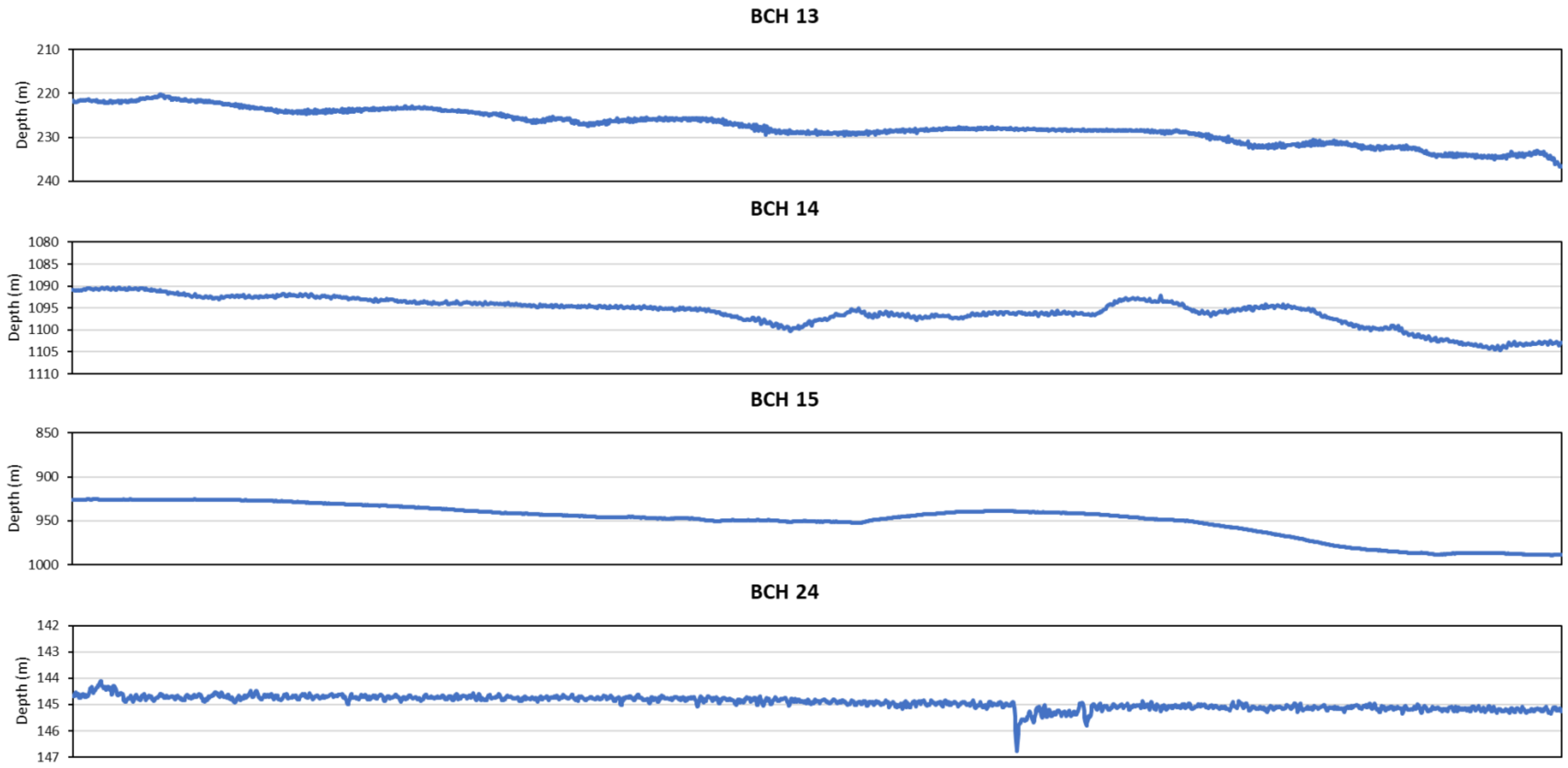


Figure 1-4 ROV depth profiles based on altitude across Gorgon Backfill Fields sites (BCH13, BCH14, BCH15, and BCH24).

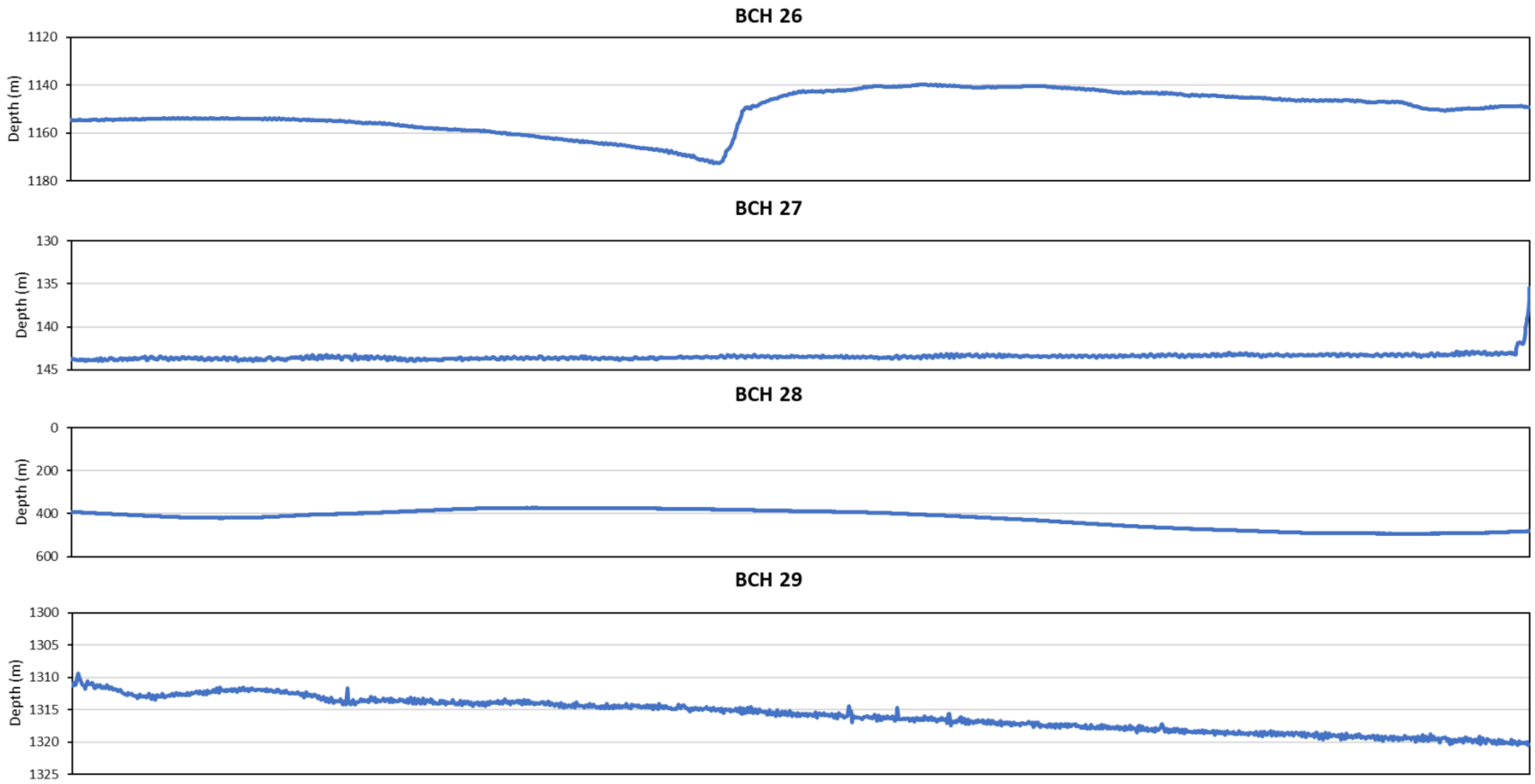


Figure 1-5 ROV depth profiles based on altitude across Gorgon Backfill Fields sites (BCH26, BCH27, BCH28, and BCH29).

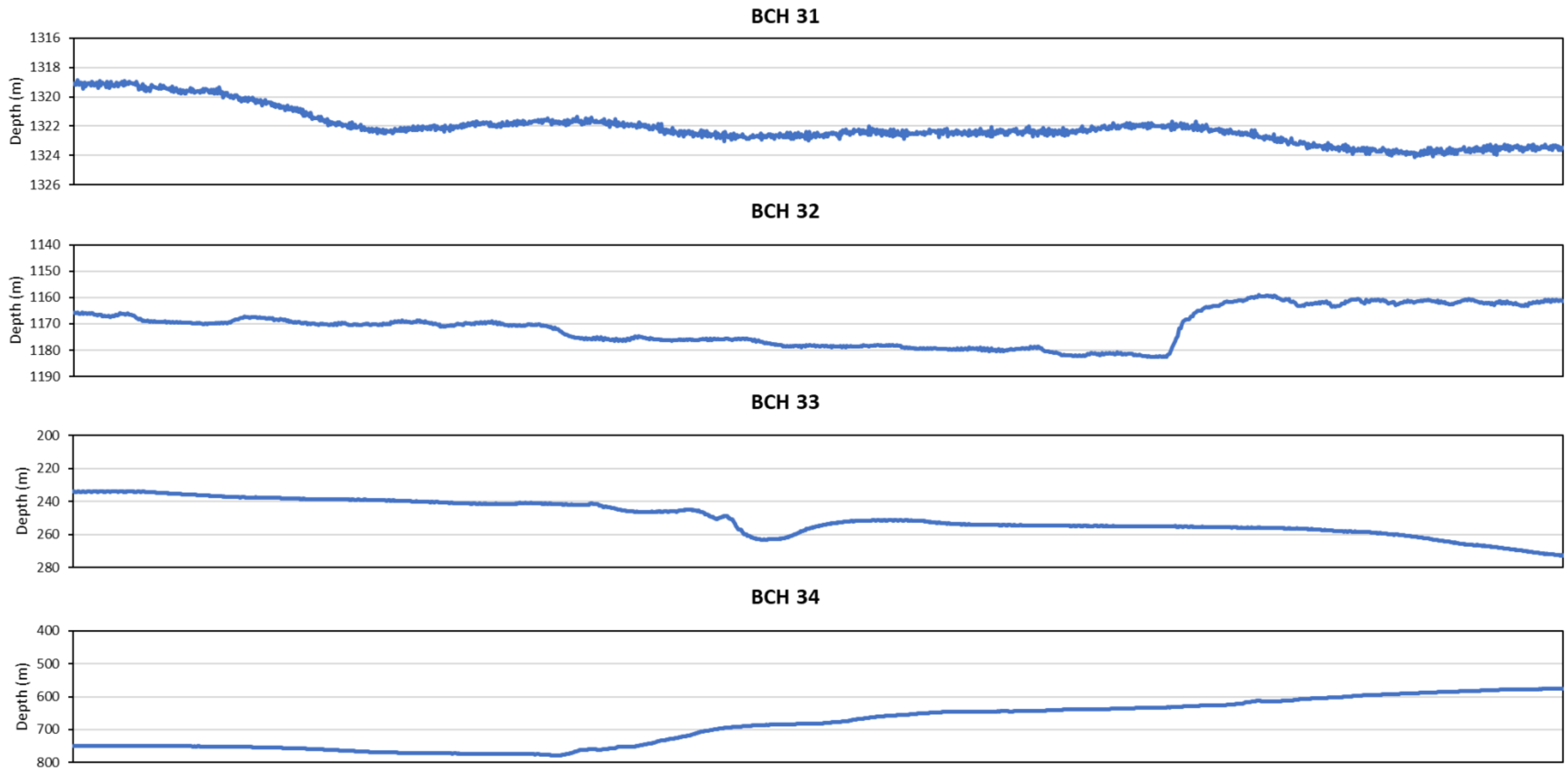


Figure 1-6 ROV depth profiles based on altitude across Gorgon Backfill Fields sites (BCH31, BCH32, BCH33, and BCH34).

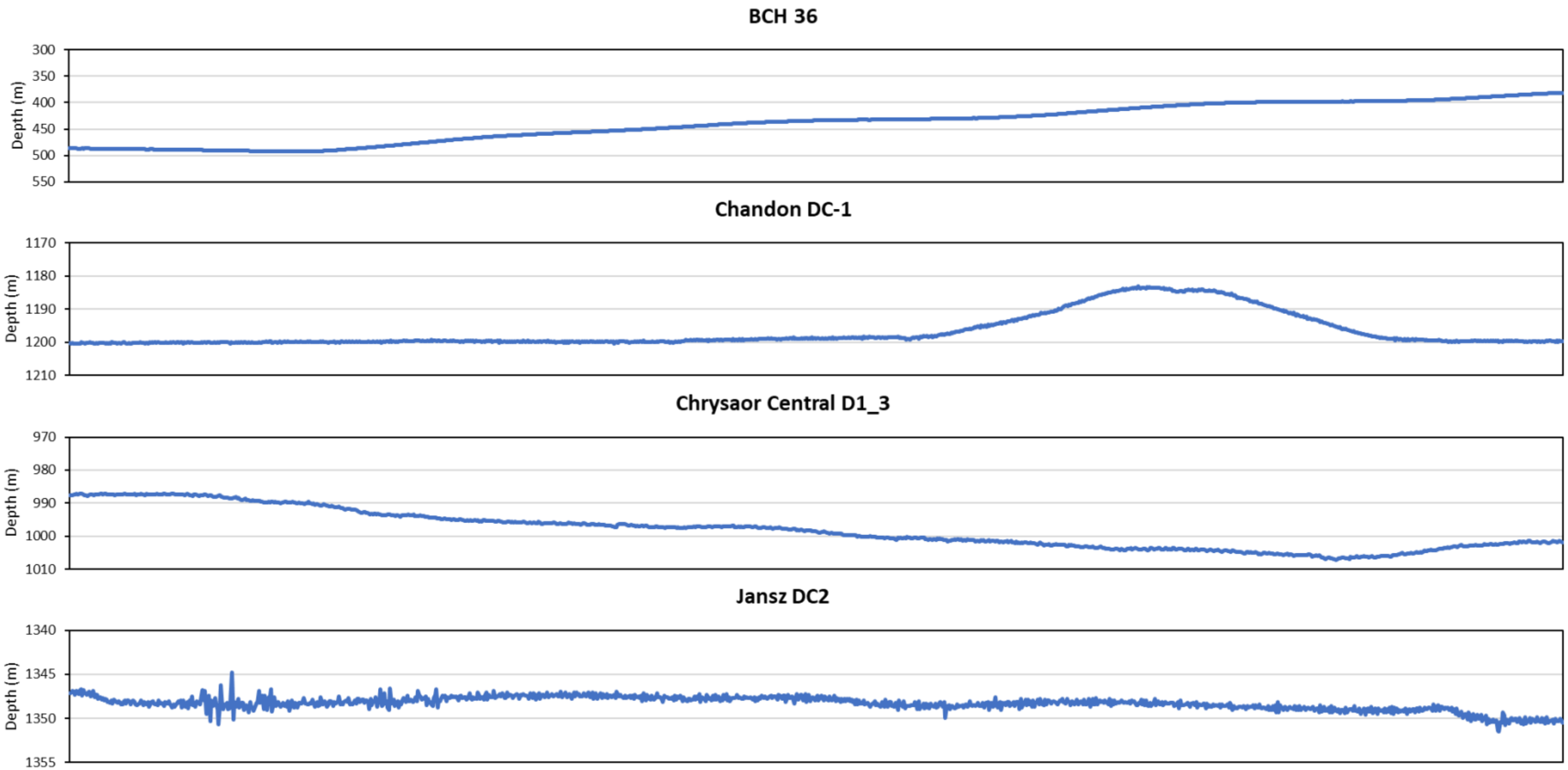


Figure 1-7 ROV depth profiles based on altitude across Gorgon Backfill Fields sites (BCH36, Chandon DC-1, Chrysaor Central D1 3, and Jansz DC2).

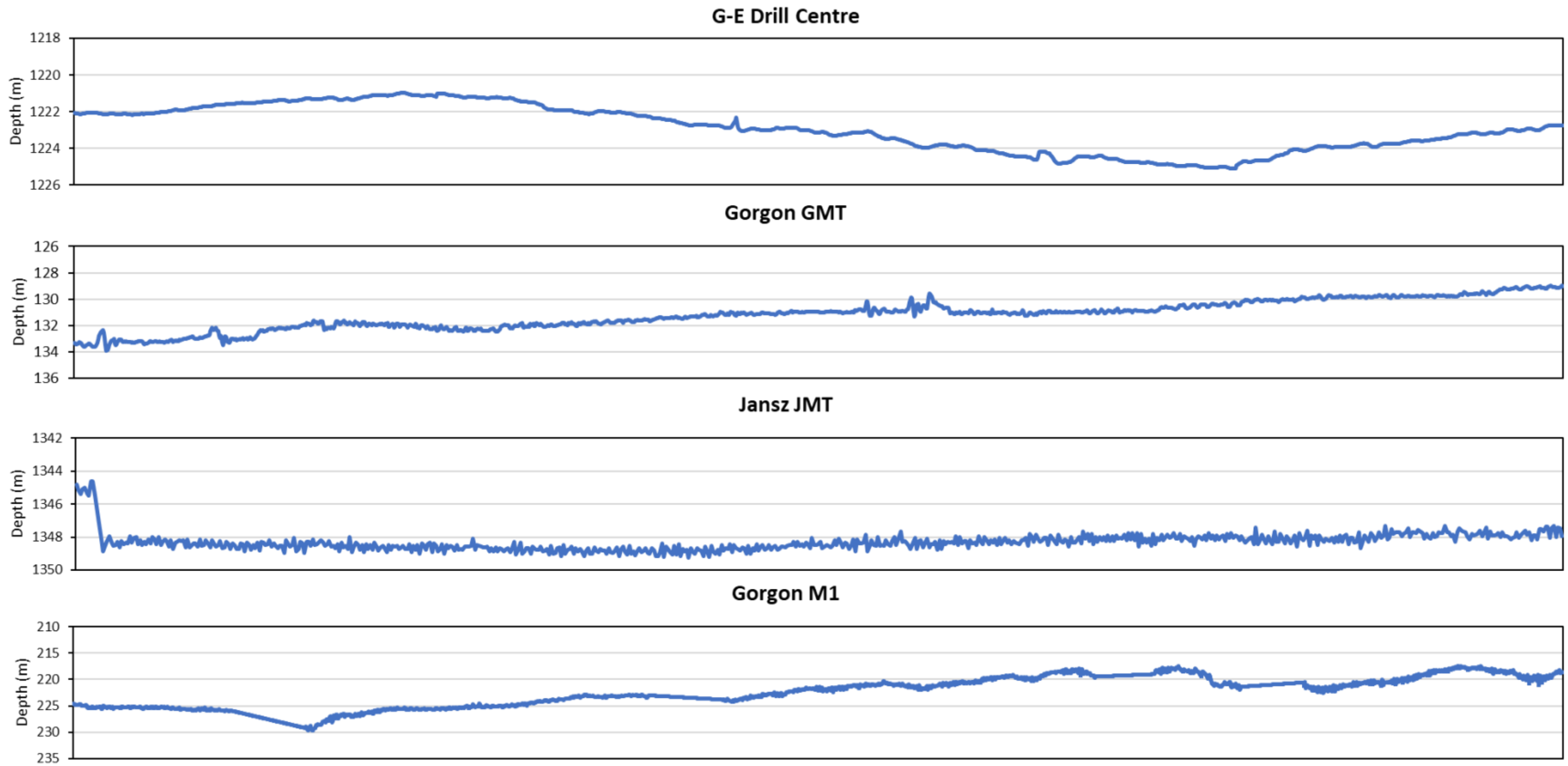


Figure 1-8 ROV depth profiles based on altitude across Gorgon Backfill Fields sites (G-E Drill Centre, Gorgon GMT, Jansz JMT, and Gorgon M1).

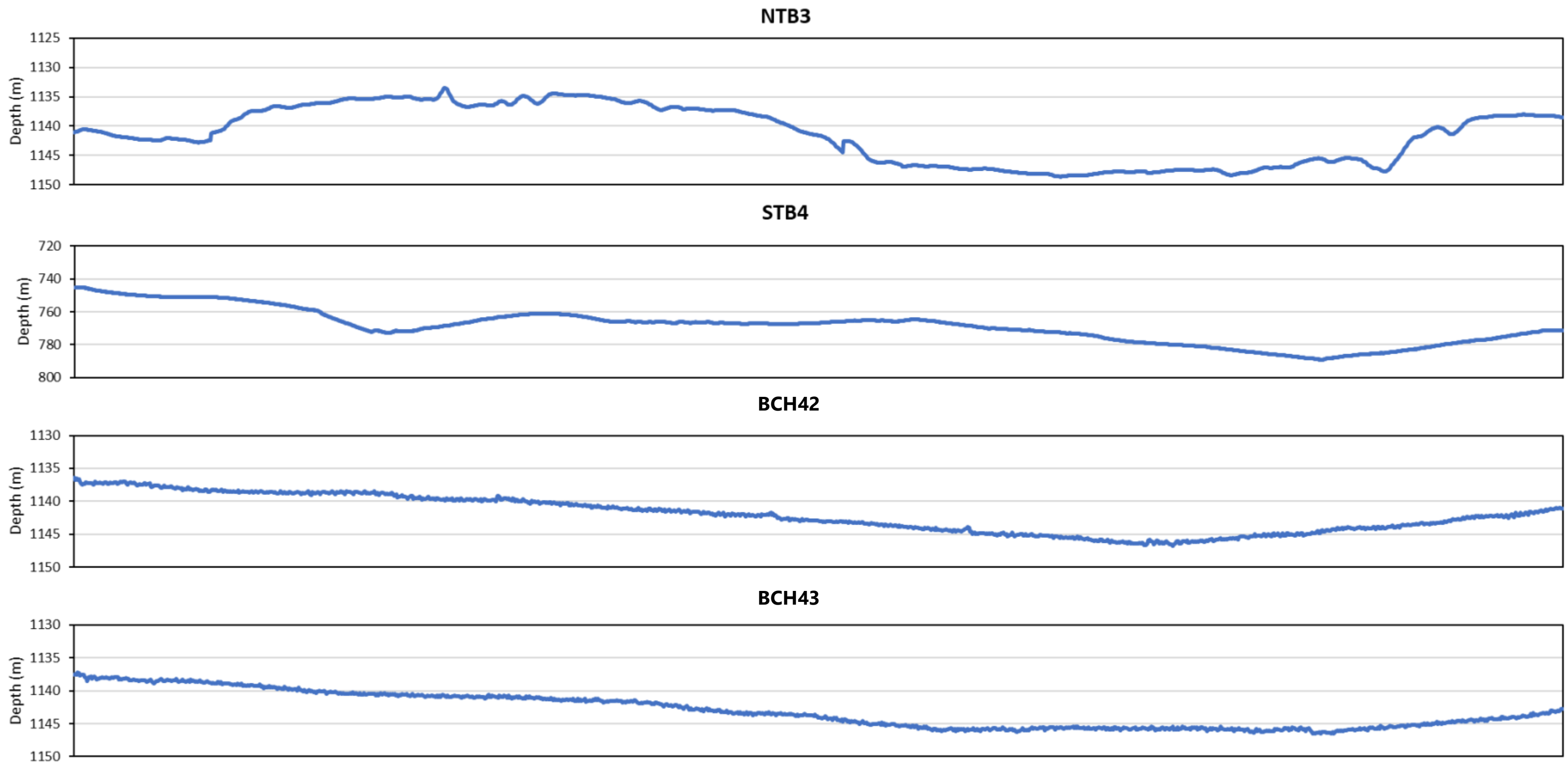


Figure 1-9 ROV depth profiles based on altitude across Gorgon Backfill Fields sites (NTB3, STB4, BCH42, and BCH43).

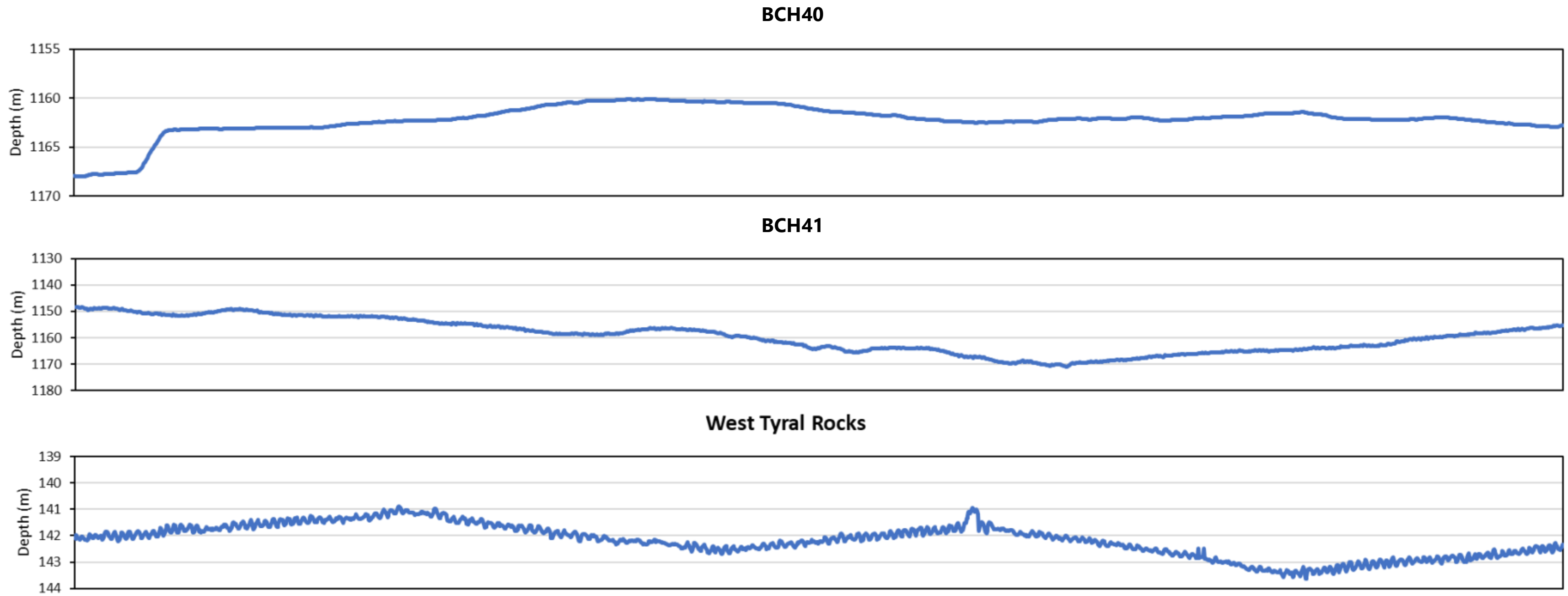


Figure 1-10 ROV depth profiles based on altitude across Gorgon Backfill Fields sites (BCH40, BCH41, and West Tyral Rocks).

Advisian
Worley Group

Chevron

Appendix B Protected Matters Search Reports

Australian Government
Department of Climate Change, Energy, the Environment and Water

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 26-Feb-2024

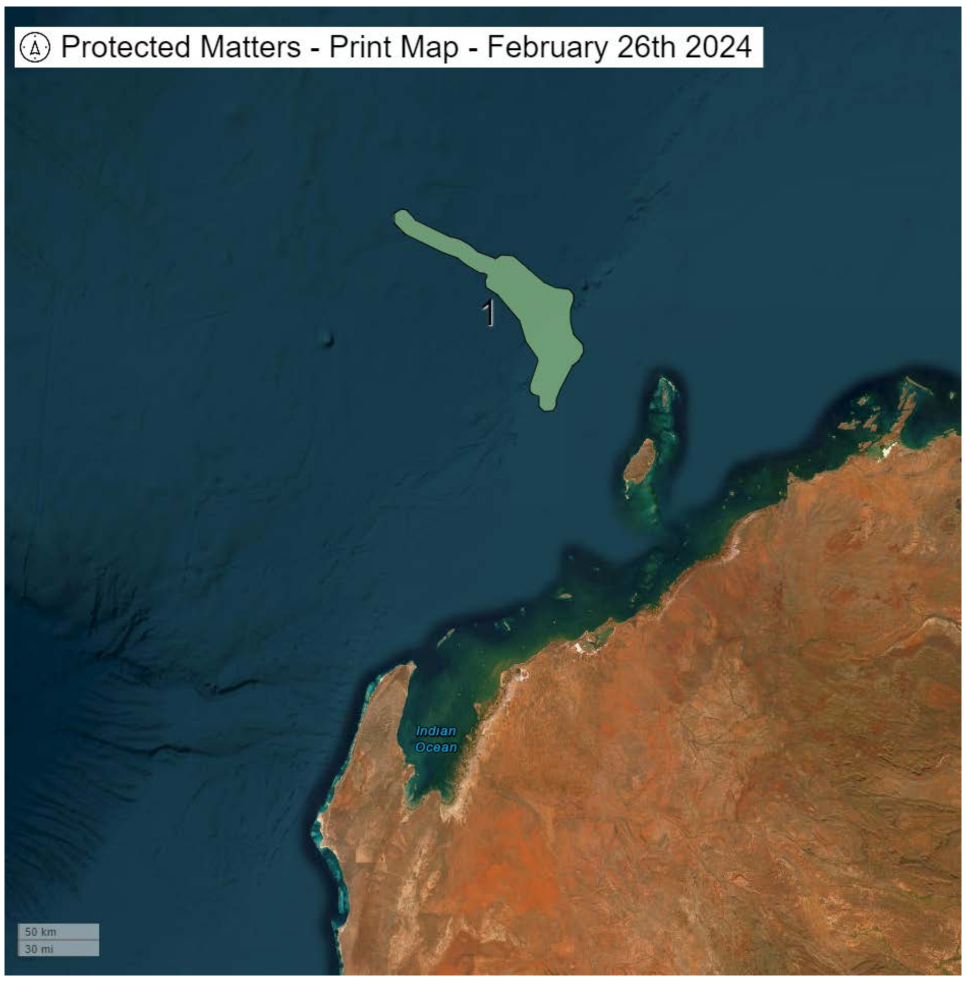


Figure 1. PMST search area (OA for the Development).

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	25
Listed Migratory Species:	38

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	66
Whales and Other Cetaceans:	29
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
Habitat Critical to the Survival of Marine Turtles:	1

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	None
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	45
Key Ecological Features (Marine):	3
Biologically Important Areas:	6
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon rubricauda westralis		
Red-tailed Tropicbird (Indian Ocean), Indian Ocean Red-tailed Tropicbird [91824]	Endangered	Species or species habitat may occur within area
Sternula nereis nereis		
Australian Fairy Tern [82950]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
FISH		
Thunnus maccoyii		
Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
REPTILE		
Aipysurus apraefrontalis		
Short-nosed Sea Snake, Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat may occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
SHARK		
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat likely to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Species or species habitat may occur within area
Calonectris leucomelas		
Streaked Shearwater [1077]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat likely to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Orcinus orca		
Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus		
Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis		
Australian Humpback Dolphin [87942]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area
Calidris canutus		
Red Knot, Knot [855]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat may occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Calonectris leucomelas		
Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Macronectes giganteus		
Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Phaethon lepturus		
White-tailed Tropicbird [1014]		Species or species habitat may occur within area
Phaethon lepturus fulvus		
Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Fish		
Acentronura larsonae		
Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bulbonaricus brauni		
Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus		
Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma		
Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus		
Muiron Island Pipefish [66196]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Micrognathus micronotopterus		
Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri		
Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii		
Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis		
Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus		
Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus		
Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus		
Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris		
Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Reptile		
Aipysurus apraefrontalis		
Short-nosed Sea Snake, Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat may occur within area
Aipysurus duboisii		
Dubois' Sea Snake, Dubois' Seasnake, Reef Shallows Sea Snake [1116]		Species or species habitat may occur within area
Aipysurus laevis		
Olive Sea Snake, Olive-brown Sea Snake [1120]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Aipysurus mosaicus as Aipysurus eydouxii Mosaic Sea Snake [87261]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Emydocephalus annulatus Eastern Turtle-headed Sea Snake [1125]		Species or species habitat may occur within area
Ephalophis greyae as Ephalophis greyi Mangrove Sea Snake [93738]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Hydrophis czeblukovi Fine-spined Sea Snake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Sea Snake, Bar-bellied Sea Snake [1104]		Species or species habitat may occur within area
Hydrophis kingii as Disteira kingii Spectacled Sea Snake [93511]		Species or species habitat may occur within area
Hydrophis major as Disteira major Olive-headed Sea Snake [93512]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hydrophis ornatus Spotted Sea Snake, Ornate Reef Sea Snake [1111]		Species or species habitat may occur within area
Hydrophis peronii as Acalyptophis peronii Horned Sea Snake [93509]		Species or species habitat may occur within area
Hydrophis platurus as Pelamis platurus Yellow-bellied Sea Snake [93517]		Species or species habitat may occur within area
Hydrophis stokesii as Astrotia stokesii Stokes' Sea Snake [93510]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area

Current Scientific Name	Status	Type of Presence
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis Australian Humpback Dolphin [87942]		Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence
Aug - Sep		
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur

Extra Information

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Gorgon Gas Development	2003/1294		Post-Approval
Project Highclere Cable Lay and Operation	2022/09203		Completed
Controlled action			
Construct and operate LNG & domestic gas plant including onshore and offshore facilities - Wheatston	2008/4469	Controlled Action	Post-Approval
Develop Jansz-Io deepwater gas field in Permit Areas WA-18-R, WA-25-R and WA-26-	2005/2184	Controlled Action	Post-Approval
Equus Gas Fields Development Project, Carnarvon Basin	2012/6301	Controlled Action	Completed
Gorgon Gas Development 4th Train Proposal	2011/5942	Controlled Action	Post-Approval
Pluto Gas Project	2005/2258	Controlled Action	Completed
Pluto Gas Project Including Site B	2006/2968	Controlled Action	Post-Approval
Not controlled action			

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Bollinger 2D Seismic Survey 200km North of North West Cape WA	2004/1868	Not Controlled Action	Completed
Construction and operation of an unmanned sea platform and connecting pipeline to Varanus Island for	2004/1703	Not Controlled Action	Completed
Controlled Source Electromagnetic Survey	2007/3262	Not Controlled Action	Completed
Development of Halyard Field off the west coast of WA	2010/5611	Not Controlled Action	Completed
Hess Exploration Drilling Programme	2007/3566	Not Controlled Action	Completed
Jansz-2 and 3 Appraisal Wells	2002/754	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	Not Controlled Action	Completed
Wheatstone 3D seismic survey, 70km north of Barrow Island	2004/1761	Not Controlled Action	Completed
Not controlled action (particular manner)			
"Leanne" offshore 3D seismic exploration, WA-356-P	2005/1938	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey in Permit Areas WA-15-R, WA-18-R, WA-205-P, WA-253-P, WA-267-P and WA-268-P	2003/1271	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic survey over petroleum title WA-268-P	2007/3458	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Surveys - Contos CT-13 & Supertubes CT-13, offshore WA	2013/6901	Not Controlled Action (Particular Manner)	Post-Approval
3D seismic survey	2006/2715	Not Controlled Action (Particular Manner)	Post-Approval
Aperio 3D Marine Seismic Survey, WA	2012/6648	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Babylon 3D Marine Seismic Survey, Commonwealth Waters, nr Exmouth WA	2013/7081	Not Controlled Action (Particular Manner)	Post-Approval
Balnaves Condensate Field Development	2011/6188	Not Controlled Action (Particular Manner)	Post-Approval
CGGVERITAS 2010 2D Seismic Survey	2010/5714	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Drilling Program	2010/5532	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Draeck 3D Marine Seismic Survey, WA-205-P	2006/3067	Not Controlled Action (Particular Manner)	Post-Approval
Drilling 35-40 offshore exploration wells in deep water	2008/4461	Not Controlled Action (Particular Manner)	Post-Approval
Eendracht Multi-Client 3D Marine Seismic Survey	2009/4749	Not Controlled Action (Particular Manner)	Post-Approval
Geco Eagle 3D Marine Seismic Survey	2008/3958	Not Controlled Action (Particular Manner)	Post-Approval
Glencoe 3D Marine Seismic Survey WA-390-P	2007/3684	Not Controlled Action (Particular Manner)	Post-Approval
Harmony 3D Marine Seismic Survey	2012/6699	Not Controlled Action (Particular Manner)	Post-Approval
Huzzas MC3D Marine Seismic Survey (HZ-13) Carnarvon Basin, offshore WA	2013/7003	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
John Ross & Rosella Off Bottom Cable Seismic Exploration Program	2008/3966	Not Controlled Action (Particular Manner)	Post-Approval
Julimar Brunello Gas Development Project	2011/5936	Not Controlled Action (Particular Manner)	Post-Approval
Munmorah 2D seismic survey within permits WA-308/9-P	2003/970	Not Controlled Action (Particular Manner)	Post-Approval
Orcus 3D Marine Seismic Survey in WA-450-P	2010/5723	Not Controlled Action (Particular Manner)	Post-Approval
Osprey and Dionysus Marine Seismic Survey	2011/6215	Not Controlled Action (Particular Manner)	Post-Approval
Pomodoro 3D Marine Seismic Survey in WA-426-P and WA-427-P	2010/5472	Not Controlled Action (Particular Manner)	Post-Approval
Triton 3D Marine Seismic Survey, WA-2-R and WA-3-R	2006/2609	Not Controlled Action (Particular Manner)	Post-Approval
Warramunga Non-Inclusive 3D Seismic Survey	2008/4553	Not Controlled Action (Particular Manner)	Post-Approval
West Anchor 3D Marine Seismic Survey	2008/4507	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
Bianchi 3D Marine Seismic Survey, Carnavon Basin, WA	2013/7078	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence
Marine Turtles		
Natator depressus		
Flatback Turtle [59257]	Internesting buffer	Known to occur
Seabirds		
Ardenna pacifica		
Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Sharks		
Rhincodon typus		
Whale Shark [66680]	Foraging	Known to occur
Whales		
Balaenoptera musculus brevicauda		
Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda		
Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae		
Humpback Whale [38]	Migration (north and south)	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Department of Land and Resource Management, Northern Territory
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Australian Tropical Herbarium, Cairns
- -eBird Australia
- -Australian Government – Australian Antarctic Data Centre
- -Museum and Art Gallery of the Northern Territory
- -Australian Government National Environmental Science Program
- -Australian Institute of Marine Science
- -Reef Life Survey Australia
- -American Museum of Natural History
- -Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
- -Tasmanian Museum and Art Gallery, Hobart, Tasmania
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

Australian Government
Department of Climate Change, Energy, the Environment and Water

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 28-Feb-2024

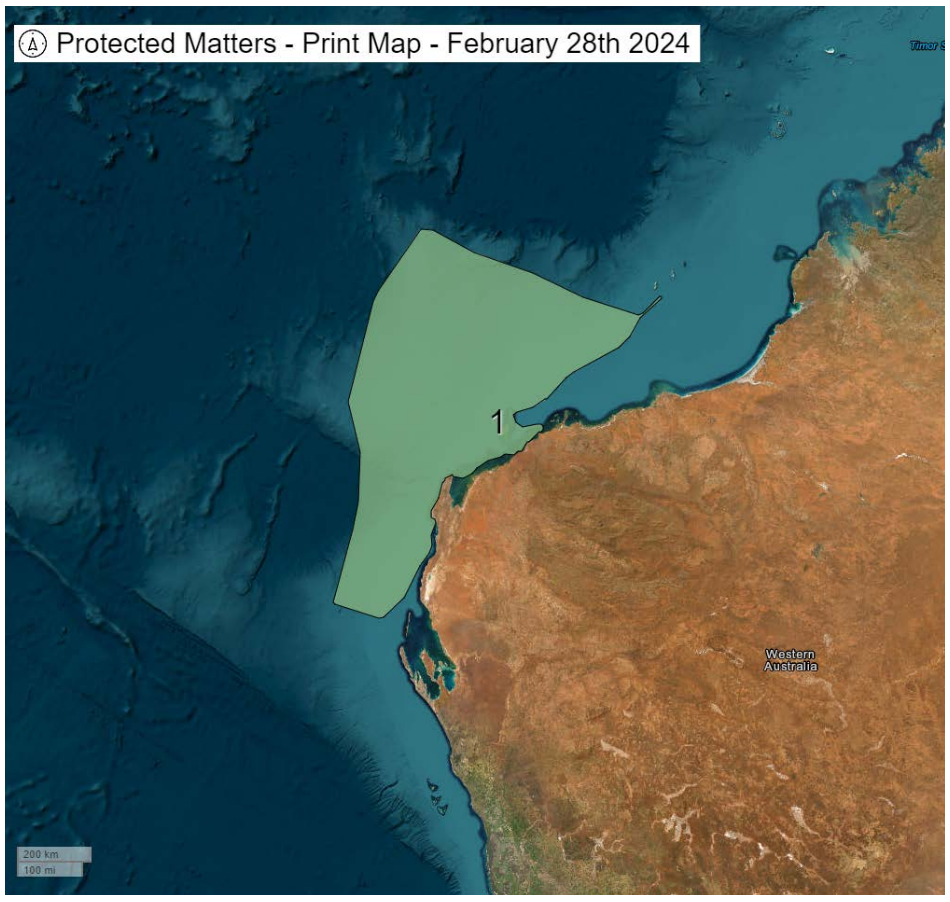


Figure 1: PMST area- Hydrocarbon Ecological EMBA for the Development

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	1
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	4
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	60
Listed Migratory Species:	65

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	5
Commonwealth Heritage Places:	2
Listed Marine Species:	117
Whales and Other Cetaceans:	32
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	13
Habitat Critical to the Survival of Marine Turtles:	4

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	30
Regional Forest Agreements:	None
Nationally Important Wetlands:	1
EPBC Act Referrals:	215
Key Ecological Features (Marine):	7
Biologically Important Areas:	38
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Legal Status
The Ningaloo Coast	WA	Declared property

National Heritage Places [Resource Information]

Name	State	Legal Status
Natural		
The Ningaloo Coast	WA	Listed place

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Aphelocephala leucopsis Southern Whiteface [529]	Vulnerable	Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Endangered	Species or species habitat may occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Endangered	Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Malurus leucopterus edouardi White-winged Fairy-wren (Barrow Island), Barrow Island Black-and-white Fairy-wren [26194]	Vulnerable	Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Phaethon rubricauda westralis Red-tailed Tropicbird (Indian Ocean), Indian Ocean Red-tailed Tropicbird [91824]	Endangered	Species or species habitat known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Tringa nebularia Common Greenshank, Greenshank [832]	Endangered	Species or species habitat likely to occur within area
CRUSTACEAN		

Scientific Name	Threatened Category	Presence Text
Kumonga exleyi Cape Range Remipede [86875]	Vulnerable	Species or species habitat likely to occur within area
FISH		
Milyeringa veritas Cape Range Cave Gudgeon, Blind Gudgeon [66676]	Vulnerable	Species or species habitat known to occur within area
Ophisternon candidum Blind Cave Eel [66678]	Vulnerable	Species or species habitat known to occur within area
Thunnus maccoyii Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia lesueur Barrow and Boodie Islands subspecies Boodie, Burrowing Bettong (Barrow and Boodie Islands) [88021]	Vulnerable	Species or species habitat known to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Isoodon auratus barrowensis		
Golden Bandicoot (Barrow Island) [66666]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes conspicillatus conspicillatus		
Spectacled Hare-wallaby (Barrow Island) [66661]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes hirsutus Central Australian subspecies		
Mala, Rufous Hare-Wallaby (Central Australia) [88019]	Endangered	Translocated population known to occur within area
Macroderma gigas		
Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Osphranter robustus isabellinus		
Barrow Island Wallaroo, Barrow Island Euro [89262]	Vulnerable	Species or species habitat likely to occur within area
Petrogale lateralis lateralis		
Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat known to occur within area
Rhinonicteris aurantia (Pilbara form)		
Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat known to occur within area
PLANT		
Minuria tridens		
Minnie Daisy [13753]	Vulnerable	Species or species habitat known to occur within area
REPTILE		
Aipysurus apraefrontalis		
Short-nosed Sea Snake, Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama		
Leaf-scaled Sea Snake, Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Ctenotus zastictus		
Hamelin Ctenotus [25570]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Liasis olivaceus barroni		
Pilbara Olive Python [66699]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARK		
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Congregation or aggregation known to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Centrophorus uyato		
Little Gulper Shark [68446]	Conservation Dependent	Species or species habitat likely to occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes		
Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area
Ardenna pacifica		
Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas		
Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Hydroprogne caspia		
Caspian Tern [808]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Congregation or aggregation known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Eubalaena australis as Balaena glacialis australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis		
Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Hirundo rustica		
Barn Swallow [662]		Species or species habitat may occur within area
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limnodromus semipalmatus Asian Dowitcher [843]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]	Endangered	Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - EXMOUTH VLF TRANSMITTER STATION [50123]	WA
Defence - EXMOUTH VLF TRANSMITTER STATION [50122]	WA
Defence - LEARMONTH - AIR WEAPONS RANGE [50193]	WA
Defence - LEARMONTH RADAR SITE - VLAMING HEAD EXMOUTH [50001]	WA
Unknown	
Commonwealth Land - [52236]	WA

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Learmonth Air Weapons Range Facility	WA	Listed place
Ningaloo Marine Area - Commonwealth Waters	WA	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Chroicocephalus novaehollandiae as Larus novaehollandiae		
Silver Gull [82326]		Breeding known to occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Glareola maldivarum		
Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area
Haliaeetus leucogaster		
White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Hirundo rustica		
Barn Swallow [662]		Species or species habitat may occur within area overfly marine area
Hydroprogne caspia as Sterna caspia		
Caspian Tern [808]		Breeding known to occur within area
Larus pacificus		
Pacific Gull [811]		Breeding known to occur within area
Limnodromus semipalmatus		
Asian Dowitcher [843]	Vulnerable	Species or species habitat known to occur within area overfly marine area
Limosa lapponica		
Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Macronectes giganteus		
Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Rostratula australis as Rostratula benghalensis (sensu lato)		
Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area
Sterna dougallii		
Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons		
Little Tern [82849]		Congregation or aggregation known to occur within area
Sternula nereis as Sterna nereis		
Fairy Tern [82949]		Breeding known to occur within area
Thalassarche carteri		
Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta		
Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida		
Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris		
Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi		
White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Thalasseus bengalensis as Sterna bengalensis		
Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii		
Greater Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia		
Common Greenshank, Greenshank [832]	Endangered	Species or species habitat likely to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		

Scientific Name	Threatened Category	Presence Text
Dugong dugon Dugong [28]		Breeding known to occur within area
Reptile		
Aipysurus apraefrontalis Short-nosed Sea Snake, Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Sea Snake, Dubois' Seasnake, Reef Shallows Sea Snake [1116]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Sea Snake, Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus laevis Olive Sea Snake, Olive-brown Sea Snake [1120]		Species or species habitat may occur within area
Aipysurus mosaicus as Aipysurus eydouxii Mosaic Sea Snake [87261]		Species or species habitat may occur within area
Aipysurus pooleorum Shark Bay Sea Snake [66061]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Sea Snake, Mjoberg's Sea Snake [1121]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Emydocephalus annulatus Eastern Turtle-headed Sea Snake [1125]		Species or species habitat may occur within area
Ephalophis greyae as Ephalophis greyi Mangrove Sea Snake [93738]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrelaps darwiniensis Port Darwin Sea Snake, Black-ringed Mangrove Sea Snake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Sea Snake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Sea Snake, Bar-bellied Sea Snake [1104]		Species or species habitat may occur within area
Hydrophis kingii as Disteira kingii Spectacled Sea Snake [93511]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli MacDowell's Sea Snake, Small-headed Sea Snake, [75601]		Species or species habitat may occur within area
Hydrophis major as Disteira major Olive-headed Sea Snake [93512]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Sea Snake, Ornate Reef Sea Snake [1111]		Species or species habitat may occur within area
Hydrophis peronii as Acalyptophis peronii Horned Sea Snake [93509]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Hydrophis platurus as Pelamis platurus Yellow-bellied Sea Snake [93517]		Species or species habitat may occur within area
Hydrophis stokesii as Astrotia stokesii Stokes' Sea Snake [93510]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area

Current Scientific Name	Status	Type of Presence
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks

[Resource Information]

Park Name	Zone & IUCN Categories
Carnarvon Canyon	Habitat Protection Zone (IUCN IV)
Gascoyne	Habitat Protection Zone (IUCN IV)
Gascoyne	Habitat Protection Zone (IUCN IV)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Gascoyne	Multiple Use Zone (IUCN VI)
Montebello	Multiple Use Zone (IUCN VI)
Shark Bay	Multiple Use Zone (IUCN VI)
Gascoyne	National Park Zone (IUCN II)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)
Ningaloo	Recreational Use Zone (IUCN IV)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence
Aug - Sep		

Scientific Name	Behaviour	Presence
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
Dec - Jan		
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
Nov-Feb		
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur
Nov - May		
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur

Extra Information

State and Territory Reserves [Resource Information]

Protected Area Name	Reserve Type	State
Airlie Island	Nature Reserve	WA
Barrow Island	Nature Reserve	WA
Barrow Island	Marine Management Area	WA
Barrow Island	Marine Park	WA
Bessieres Island	Nature Reserve	WA
Boodie, Double Middle Islands	Nature Reserve	WA
Bundegi Coastal Park	5(1)(h) Reserve	WA
Cape Range	National Park	WA
Cape Range (South)	National Park	WA
Great Sandy Island	Nature Reserve	WA
Jurabi Coastal Park	5(1)(h) Reserve	WA
Lowendal Islands	Nature Reserve	WA
Montebello Islands	Conservation Park	WA
Montebello Islands	Conservation Park	WA

Protected Area Name	Reserve Type	State
Montebello Islands	Marine Park	WA
Muiron Islands	Nature Reserve	WA
Muiron Islands	Marine Management Area	WA
Ningaloo	Marine Park	WA
North Sandy Island	Nature Reserve	WA
Nyingguulu (Ningaloo) Coastal Reserve	5(1)(h) Reserve	WA
Round Island	Nature Reserve	WA
Rowley Shoals	Marine Park	WA
Serrurier Island	Nature Reserve	WA
Thevenard Island	Nature Reserve	WA
Unnamed WA40322	5(1)(h) Reserve	WA
Unnamed WA40828	5(1)(h) Reserve	WA
Unnamed WA41080	5(1)(h) Reserve	WA
Unnamed WA44665	5(1)(h) Reserve	WA
Unnamed WA44667	5(1)(h) Reserve	WA
Victor Island	Nature Reserve	WA

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Cape Range Subterranean Waterways	WA

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Browse to North West Shelf Development, Indian Ocean, WA	2018/8319		Approval
Gorgon Gas Development	2003/1294		Post-Approval
Ningaloo Lighthouse Development, 17km north west Exmouth, Western Australia	2020/8693		Approval
Optimised Mardie Solar Salt Project	2022/9169		Assessment

Title of referral	Reference	Referral Outcome	Assessment Status
Project Highclere Cable Lay and Operation	2022/09203		Completed
Action clearly unacceptable			
Highlands 3D Marine Seismic Survey	2012/6680	Action Clearly Unacceptable	Completed
Controlled action			
'Van Gogh' Petroleum Field Development	2007/3213	Controlled Action	Post-Approval
Balmoral South Iron Ore Mine	2008/4236	Controlled Action	Post-Approval
Binowee Iron Ore Project	2001/366	Controlled Action	Proposed Decision
Construct and operate LNG & domestic gas plant including onshore and offshore facilities - Wheatston	2008/4469	Controlled Action	Post-Approval
Develop Jansz-Io deepwater gas field in Permit Areas WA-18-R, WA-25-R and WA-26-	2005/2184	Controlled Action	Post-Approval
Development of Angel gas and condensate field, North West Shelf	2004/1805	Controlled Action	Post-Approval
Development of Browse Basin Gas Fields (Upstream)	2008/4111	Controlled Action	Completed
Development of Coniston/Novara fields within the Exmouth Sub-basin	2011/5995	Controlled Action	Post-Approval
Development of Stybarrow petroleum field incl drilling and facility installation	2004/1469	Controlled Action	Post-Approval
Echo-Yodel Production Wells	2000/11	Controlled Action	Post-Approval
Enfield full field development	2001/257	Controlled Action	Post-Approval
Equus Gas Fields Development Project, Carnarvon Basin	2012/6301	Controlled Action	Completed
Eramurra Industrial Salt Project	2021/9027	Controlled Action	Assessment Approach
Eramurra Industrial Salt Project, near Karratha, WA	2019/8448	Controlled Action	Completed
Gorgon Gas Development 4th Train Proposal	2011/5942	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Gorgon Gas Revised Development	2008/4178	Controlled Action	Post-Approval
Greater Enfield (Vincent) Development	2005/2110	Controlled Action	Post-Approval
Greater Gorgon Development - Optical Fibre Cable, Mainland to Barrow Island	2005/2141	Controlled Action	Completed
Light Crude Oil Production	2001/365	Controlled Action	Post-Approval
Mardie Project, 80 km south west of Karratha, WA	2018/8236	Controlled Action	Post-Approval
Mauds Landing Marina	2000/98	Controlled Action	Completed
Pluto Gas Project	2005/2258	Controlled Action	Completed
Pluto Gas Project Including Site B	2006/2968	Controlled Action	Post-Approval
Proposed West Pilbara Iron Ore Project	2009/4706	Controlled Action	Post-Approval
Pyrenees Oil Fields Development	2005/2034	Controlled Action	Post-Approval
Simpson Development	2000/59	Controlled Action	Completed
Simpson Oil Field Development	2001/227	Controlled Action	Post-Approval
The Scarborough Project - FLNG & assoc subsea infrastructure, Carnarvon Basin	2013/6811	Controlled Action	Post-Approval
Vincent Appraisal Well	2000/22	Controlled Action	Post-Approval
Yardie Creek Road Realignment Project	2021/8967	Controlled Action	Assessment Approach
Not controlled action			
'Goodwyn A' Low Pressure Train Project	2003/914	Not Controlled Action	Completed
'Van Gogh' Oil Appraisal Drilling Program, Exploration Permit Area WA-155-P(1)	2006/3148	Not Controlled Action	Completed
Airlie Island soil and groundwater investigations, Exmouth Gulf, offshore Pilbara coast	2014/7250	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Baniyas-1 Exploration Well, EP-424, near Onslow	2007/3282	Not Controlled Action	Completed
Barrow Island 2D Seismic survey	2006/2667	Not Controlled Action	Completed
Bollinger 2D Seismic Survey 200km North of North West Cape WA	2004/1868	Not Controlled Action	Completed
Bultaco-2, Laverda-2, Laverda-3 and Montesa-2 Appraisal Wells	2000/103	Not Controlled Action	Completed
Carnarvon 3D Marine Seismic Survey	2004/1890	Not Controlled Action	Completed
Cazadores 2D seismic survey	2004/1720	Not Controlled Action	Completed
Construction and operation of an unmanned sea platform and connecting pipeline to Varanus Island for	2004/1703	Not Controlled Action	Completed
Controlled Source Electromagnetic Survey	2007/3262	Not Controlled Action	Completed
Development of Halyard Field off the west coast of WA	2010/5611	Not Controlled Action	Completed
Development of Mutineer and Exeter petroleum fields for oil production, Permit	2003/1033	Not Controlled Action	Completed
Drilling of an exploration well Gats-1 in Permit Area WA-261-P	2004/1701	Not Controlled Action	Completed
Eagle-1 Exploration Drilling, North West Shelf, WA	2019/8578	Not Controlled Action	Completed
Echo A Development WA-23-L, WA-24-L	2005/2042	Not Controlled Action	Completed
Expansion of the Sino Iron Ore Mine and export facilities, Cape Preston, WA	2017/7862	Not Controlled Action	Completed
Expansion Proposal, Mineralogy Cape Preston Iron Ore Project, Cape Preston, WA	2009/5010	Not Controlled Action	Completed
Exploration drilling well WA-155-P(1)	2003/971	Not Controlled Action	Completed
Exploration of appraisal wells	2006/3065	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Exploration Well (Taunton-2)	2002/731	Not Controlled Action	Completed
Exploration Well in Permit Area WA-155-P(1)	2002/759	Not Controlled Action	Completed
Exploratory drilling in permit area WA-225-P	2001/490	Not Controlled Action	Completed
Extension of Simpson Oil Platforms & Wells	2002/685	Not Controlled Action	Completed
HCA05X Macedon Experimental Survey	2004/1926	Not Controlled Action	Completed
Hess Exploration Drilling Programme	2007/3566	Not Controlled Action	Completed
Huascaran-1 exploration well (WA-292-P)	2001/539	Not Controlled Action	Completed
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Infill Production Well (Griffin-9)	2001/417	Not Controlled Action	Completed
Jansz-2 and 3 Appraisal Wells	2002/754	Not Controlled Action	Completed
Klammer 2D Seismic Survey	2002/868	Not Controlled Action	Completed
Maia-Gaea Exploration wells	2000/17	Not Controlled Action	Completed
Manaslu - 1 and Huascaran - 1 Offshore Exploration Wells	2001/235	Not Controlled Action	Completed
Mermaid Marine Australia Desalination Project	2011/5916	Not Controlled Action	Completed
Montesa-1 and Bultaco-1 Exploration Wells	2000/102	Not Controlled Action	Completed
North Rankin B gas compression facility	2005/2500	Not Controlled Action	Completed
Pipeline System Modifications Project	2000/3	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Searipple gas and condensate field development	2000/89	Not Controlled Action	Completed
Spool Base Facility	2001/263	Not Controlled Action	Completed
Subsea Gas Pipeline From Stybarrow Field to Griffin Venture Gas Export Pipeline	2005/2033	Not Controlled Action	Completed
sub-sea tieback of Perseus field wells	2004/1326	Not Controlled Action	Completed
Telstra North Rankin Spur Fibre Optic Cable	2016/7836	Not Controlled Action	Completed
Thevenard Island Retirement Project	2015/7423	Not Controlled Action	Completed
To construct and operate an offshore submarine fibre optic cable, WA	2014/7373	Not Controlled Action	Completed
WA-295-P Kerr-McGee Exploration Wells	2001/152	Not Controlled Action	Completed
Wanda Offshore Research Project, 80 km north-east of Exmouth, WA	2018/8293	Not Controlled Action	Completed
Western Flank Gas Development	2005/2464	Not Controlled Action	Completed
Wheatstone 3D seismic survey, 70km north of Barrow Island	2004/1761	Not Controlled Action	Completed
Not controlled action (particular manner)			
'Kate' 3D marine seismic survey, exploration permits WA-320-P and WA-345-P, 60km	2005/2037	Not Controlled Action (Particular Manner)	Post-Approval
'Tourmaline' 2D marine seismic survey, permit areas WA-323-P, WA-330-P and WA-32	2005/2282	Not Controlled Action (Particular Manner)	Post-Approval
"Leanne" offshore 3D seismic exploration, WA-356-P	2005/1938	Not Controlled Action (Particular Manner)	Post-Approval
2D and 3D seismic surveys	2005/2151	Not Controlled Action (Particular Manner)	Post-Approval
2D marine seismic survey	2012/6296	Not Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		(Particular Manner)	
2D seismic survey	2008/4493	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Survey	2005/2146	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Survey Permit Area WA-352-P	2008/4628	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey within permit WA-291	2007/3265	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic survey	2008/4281	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey (WA-482-P, WA-363-P), WA	2013/6761	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey in Permit Areas WA-15-R, WA-18-R, WA-205-P, WA-253-P, WA-267-P and WA-268-P	2003/1271	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey in WA 457-P & WA 458-P, North West Shelf, offshore WA	2013/6862	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic survey over petroleum title WA-268-P	2007/3458	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Surveys - Contos CT-13 & Supertubes CT-13, offshore WA	2013/6901	Not Controlled Action (Particular Manner)	Post-Approval
3D seismic survey	2006/2715	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
3D Seismic Survey, WA	2008/4428	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey in the Carnarvon Bsin on the North West Shelf	2002/778	Not Controlled Action (Particular Manner)	Post-Approval
3D sesmic survey	2006/2781	Not Controlled Action (Particular Manner)	Post-Approval
Acheron Non-Exclusive 2D Seismic Survey	2008/4565	Not Controlled Action (Particular Manner)	Post-Approval
Acheron Non-Exclusive 2D Seismic Survey	2009/4968	Not Controlled Action (Particular Manner)	Post-Approval
Agrippina 3D Seismic Marine Survey	2009/5212	Not Controlled Action (Particular Manner)	Post-Approval
Apache Northwest Shelf Van Gogh Field Appraisal Drilling Program	2007/3495	Not Controlled Action (Particular Manner)	Post-Approval
Aperio 3D Marine Seismic Survey, WA	2012/6648	Not Controlled Action (Particular Manner)	Post-Approval
Artemis-1 Drilling Program (WA-360-P)	2010/5432	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Babylon 3D Marine Seismic Survey, Commonwealth Waters, nr Exmouth WA	2013/7081	Not Controlled Action (Particular Manner)	Post-Approval
Balnaves Condensate Field Development	2011/6188	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Bonaventure 3D seismic survey	2006/2514	Not Controlled Action (Particular Manner)	Post-Approval
Cable Seismic Exploration Permit areas WA-323-P and WA-330-P	2008/4227	Not Controlled Action (Particular Manner)	Post-Approval
Cape Preston East - Iron Ore Export Facilities, Pilbara, WA	2013/6844	Not Controlled Action (Particular Manner)	Post-Approval
Cerberus exploration drilling campaign, Carnarvon Basin, WA	2016/7645	Not Controlled Action (Particular Manner)	Post-Approval
CGGVERITAS 2010 2D Seismic Survey	2010/5714	Not Controlled Action (Particular Manner)	Post-Approval
Charon 3D Marine Seismic Survey	2007/3477	Not Controlled Action (Particular Manner)	Post-Approval
Consturction & operation of the Varanus Island kitchen & mess cyclone refuge building, compression p	2013/6952	Not Controlled Action (Particular Manner)	Post-Approval
Coverack Marine Seismic Survey	2001/399	Not Controlled Action (Particular Manner)	Post-Approval
Cue Seismic Survey within WA-359-P, WA-361-P and WA-360-P	2007/3647	Not Controlled Action (Particular Manner)	Post-Approval
CVG 3D Marine Seismic Survey	2012/6654	Not Controlled Action (Particular Manner)	Post-Approval
DAVROS MC 3D marine seismic survey northwaet of Dampier, WA	2013/7092	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Decommissioning of the Legendre facilities	2010/5681	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Drilling Program	2010/5532	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Demeter 3D Seismic Survey, off Dampier, WA	2002/900	Not Controlled Action (Particular Manner)	Post-Approval
Draeck 3D Marine Seismic Survey, WA-205-P	2006/3067	Not Controlled Action (Particular Manner)	Post-Approval
Drilling 35-40 offshore exploration wells in deep water	2008/4461	Not Controlled Action (Particular Manner)	Post-Approval
Earthworks for kitchen/mess, cyclone refuge building & Compression Plant, Varanus Island	2013/6900	Not Controlled Action (Particular Manner)	Post-Approval
Eendracht Multi-Client 3D Marine Seismic Survey	2009/4749	Not Controlled Action (Particular Manner)	Post-Approval
Enfield M3 & Vincent 4D Marine Seismic Surveys	2008/3981	Not Controlled Action (Particular Manner)	Completed
Enfield M3 4D, Vincent 4D & 4D Line Test Marine Seismic Surveys	2008/4122	Not Controlled Action (Particular Manner)	Post-Approval
Enfield M4 4D Marine Seismic Survey	2008/4558	Not Controlled Action (Particular Manner)	Post-Approval
Enfield oilfield 3D Seismic Survey	2006/3132	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Exmouth West 2D Marine Seismic Survey	2008/4132	Not Controlled Action (Particular Manner)	Post-Approval
Exploration drilling of Zeus-1 well	2008/4351	Not Controlled Action (Particular Manner)	Post-Approval
Fletcher-Finucane Development, WA26-L and WA191-P	2011/6123	Not Controlled Action (Particular Manner)	Post-Approval
Foxhound 3D Non-Exclusive Marine Seismic Survey	2009/4703	Not Controlled Action (Particular Manner)	Post-Approval
Gazelle 3D Marine Seismic Survey in WA-399-P and WA-42-L	2010/5570	Not Controlled Action (Particular Manner)	Post-Approval
Geco Eagle 3D Marine Seismic Survey	2008/3958	Not Controlled Action (Particular Manner)	Post-Approval
Glencoe 3D Marine Seismic Survey WA-390-P	2007/3684	Not Controlled Action (Particular Manner)	Post-Approval
Greater Western Flank Phase 1 gas Development	2011/5980	Not Controlled Action (Particular Manner)	Post-Approval
Grimalkin 3D Seismic Survey	2008/4523	Not Controlled Action (Particular Manner)	Post-Approval
Guacamole 2D Marine Seismic Survey	2008/4381	Not Controlled Action (Particular Manner)	Post-Approval
Harmony 3D Marine Seismic Survey	2012/6699	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Harpy 1 exploration well	2001/183	Not Controlled Action (Particular Manner)	Post-Approval
Honeycombs MC3D Marine Seismic Survey	2012/6368	Not Controlled Action (Particular Manner)	Post-Approval
Huzzas MC3D Marine Seismic Survey (HZ-13) Carnarvon Basin, offshore WA	2013/7003	Not Controlled Action (Particular Manner)	Post-Approval
Huzzas phase 2 marine seismic survey, Exmouth Plateau, Northern Carnarvon Basin, WA	2013/7093	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
John Ross & Rosella Off Bottom Cable Seismic Exploration Program	2008/3966	Not Controlled Action (Particular Manner)	Post-Approval
Judo Marine 3D Seismic Survey within and adjacent to WA-412-P	2008/4630	Not Controlled Action (Particular Manner)	Post-Approval
Judo Marine 3D Seismic Survey within and adjacent to WA-412-P	2009/4801	Not Controlled Action (Particular Manner)	Post-Approval
Julimar Brunello Gas Development Project	2011/5936	Not Controlled Action (Particular Manner)	Post-Approval
Klimt 2D Marine Seismic Survey	2007/3856	Not Controlled Action (Particular Manner)	Post-Approval
Laverda 3D Marine Seismic Survey and Vincent M1 4D Marine Seismic Survey	2010/5415	Not Controlled Action (Particular Manner)	Post-Approval
Leopard 2D marine seismic survey	2005/2290	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Lion 2D Marine Seismic Survey	2007/3777	Not Controlled Action (Particular Manner)	Post-Approval
Macedon Gas Field Development	2008/4605	Not Controlled Action (Particular Manner)	Post-Approval
Marine reconnaissance survey	2008/4466	Not Controlled Action (Particular Manner)	Post-Approval
Moosehead 2D seismic survey within permit WA-192-P	2005/2167	Not Controlled Action (Particular Manner)	Post-Approval
Munmorah 2D seismic survey within permits WA-308/9-P	2003/970	Not Controlled Action (Particular Manner)	Post-Approval
Ocean Bottom Cable Seismic Program, WA-264-P	2007/3844	Not Controlled Action (Particular Manner)	Post-Approval
Ocean Bottom Cable Seismic Survey	2005/2017	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Canning Multi Client 2D Marine Seismic Survey	2010/5393	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Drilling Campaign	2011/5830	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Orcus 3D Marine Seismic Survey in WA-450-P	2010/5723	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Osprey and Dionysus Marine Seismic Survey	2011/6215	Not Controlled Action (Particular Manner)	Post-Approval
Palta-1 exploration well in Petroleum Permit Area WA-384-P	2011/5871	Not Controlled Action (Particular Manner)	Post-Approval
Phoenix 3D Seismic Survey, Bedout Sub-Basin	2010/5360	Not Controlled Action (Particular Manner)	Post-Approval
Pomodoro 3D Marine Seismic Survey in WA-426-P and WA-427-P	2010/5472	Not Controlled Action (Particular Manner)	Post-Approval
Pyrenees 4D Marine Seismic Monitor Survey, HCA12A	2012/6579	Not Controlled Action (Particular Manner)	Post-Approval
Pyrenees-Macedon 3D marine seismic survey	2005/2325	Not Controlled Action (Particular Manner)	Post-Approval
Quiberon 2D Seismic Survey, permit area WA-385P, offshore of Carnarvon	2009/5077	Not Controlled Action (Particular Manner)	Post-Approval
Reindeer gas reservior development, Devil Creek, Carnarvon Basin - WA	2007/3917	Not Controlled Action (Particular Manner)	Post-Approval
Repsol 3d & 2D Marine Seismic Survey	2012/6658	Not Controlled Action (Particular Manner)	Post-Approval
Rose 3D Seismic Program	2008/4239	Not Controlled Action (Particular Manner)	Post-Approval
Rydal-1 Petroleum Exploration Well, WA	2012/6522	Not Controlled Action (Particular Manner)	Post-Approval
Salsa 3D Marine Seismic Survey	2010/5629	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Santos Winchester three dimensional seismic survey - WA-323-P & WA-330-P	2011/6107	Not Controlled Action (Particular Manner)	Post-Approval
Skorpion Marine Seismic Survey WA	2001/416	Not Controlled Action (Particular Manner)	Post-Approval
Sovereign 3D Marine Seismic Survey	2011/5861	Not Controlled Action (Particular Manner)	Post-Approval
Stag 4D & Reindeer MAZ Marine Seismic Surveys, WA	2013/7080	Not Controlled Action (Particular Manner)	Post-Approval
Stag Off-bottom Cable Seismic Survey	2007/3696	Not Controlled Action (Particular Manner)	Post-Approval
Stybarrow 4D Marine Seismic Survey	2011/5810	Not Controlled Action (Particular Manner)	Post-Approval
Stybarrow Baseline 4D marine seismic survey	2008/4530	Not Controlled Action (Particular Manner)	Post-Approval
Tantabiddi Boat Ramp Sand Bypassing	2015/7411	Not Controlled Action (Particular Manner)	Post-Approval
Tidepole Maz 3D Seismic Survey Campaign	2007/3706	Not Controlled Action (Particular Manner)	Post-Approval
Tortilla 2D Seismic Survey, WA	2011/6110	Not Controlled Action (Particular Manner)	Post-Approval
Triton 3D Marine Seismic Survey, WA-2-R and WA-3-R	2006/2609	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Undertake a 3D marine seismic survey	2010/5695	Not Controlled Action (Particular Manner)	Post-Approval
Undertake a three dimensional marine seismic survey	2010/5715	Not Controlled Action (Particular Manner)	Post-Approval
Undertake a three dimensional marine seismic survey	2010/5679	Not Controlled Action (Particular Manner)	Post-Approval
Vincent M1 and Enfield M5 4D Marine Seismic Survey	2010/5720	Not Controlled Action (Particular Manner)	Post-Approval
Warramunga Non-Inclusive 3D Seismic Survey	2008/4553	Not Controlled Action (Particular Manner)	Post-Approval
West Anchor 3D Marine Seismic Survey	2008/4507	Not Controlled Action (Particular Manner)	Post-Approval
West Panaeus 3D seismic survey	2006/3141	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Wheatstone 3D MAZ Marine Seismic Survey	2011/6058	Not Controlled Action (Particular Manner)	Post-Approval
Wheatstone Iago Appraisal Well Drilling	2007/3941	Not Controlled Action (Particular Manner)	Post-Approval
Wheatstone Iago Appraisal Well Drilling	2008/4134	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Marine Seismic Survey in the offshore northwest Carnarvon	2011/6175	Referral Decision	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Referral decision			
Basin			
3D Seismic Survey	2008/4219	Referral Decision	Completed
Bianchi 3D Marine Seismic Survey, Carnavon Basin, WA	2013/7078	Referral Decision	Completed
CVG 3D Marine Seismic Survey	2012/6270	Referral Decision	Completed
Enfield 4D Marine Seismic Surveys, Production Permit WA-28-L	2005/2370	Referral Decision	Completed
Mardie Salt Project, Pilbara region, WA	2018/8183	Referral Decision	Completed
Rose 3D Seismic acquisition survey	2008/4220	Referral Decision	Completed
Stybarrow Baseline 4D Marine Seismic Survey (Permit Areas WA-255-P, WA-32-L, WA-	2008/4165	Referral Decision	Completed
Two Dimensional Transition Zone Seismic Survey - TP/7 (R1)	2010/5507	Referral Decision	Completed
Varanus Island Compression Project	2012/6698	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	North-west
Commonwealth waters adjacent to Ningaloo Reef	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west
Glomar Shoals	North-west
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence

Scientific Name	Behaviour	Presence
Dugong		
Dugong dugon Dugong [28]	Breeding	Known to occur
Dugong dugon Dugong [28]	Calving	Known to occur
Dugong dugon Dugong [28]	Foraging (high density seagrass beds)	Known to occur
Dugong dugon Dugong [28]	Nursing	Known to occur
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Internesting buffer	Known to occur
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur
Chelonia mydas Green Turtle [1765]	Aggregation	Known to occur
Chelonia mydas Green Turtle [1765]	Basking	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Chelonia mydas Green Turtle [1765]	Mating	Known to occur
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur

Scientific Name	Behaviour	Presence
Eretmochelys imbricata Hawksbill Turtle [1766]	Foraging	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Mating	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur
Natator depressus Flatback Turtle [59257]	Aggregation	Known to occur
Natator depressus Flatback Turtle [59257]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting buffer	Known to occur
Natator depressus Flatback Turtle [59257]	Mating	Known to occur
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Resting	Known to occur
Sternula nereis Fairy Tern [82949]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Rhincodon typus Whale Shark [66680]	Foraging (high density prey)	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Resting	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 28-Feb-2024

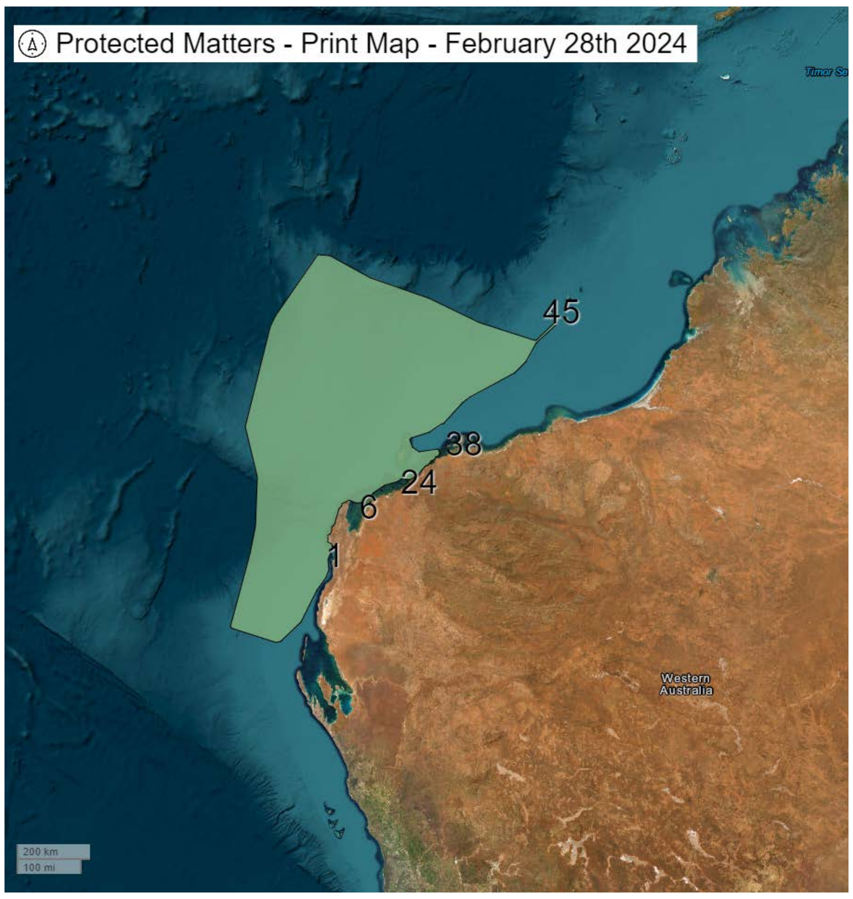


Figure 1. PMST area- Hydrocarbon Social EMBA for the Development

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	1
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	4
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	60
Listed Migratory Species:	65

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	5
Commonwealth Heritage Places:	2
Listed Marine Species:	117
Whales and Other Cetaceans:	32
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	13
Habitat Critical to the Survival of Marine Turtles:	4

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	30
Regional Forest Agreements:	None
Nationally Important Wetlands:	1
EPBC Act Referrals:	215
Key Ecological Features (Marine):	7
Biologically Important Areas:	38
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties		[Resource Information]
Name	State	Legal Status
The Ningaloo Coast	WA	Declared property

National Heritage Places		[Resource Information]
Name	State	Legal Status
Natural		
The Ningaloo Coast	WA	Listed place

Commonwealth Marine Area	[Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)
Commonwealth Marine Areas (EPBC Act)

Listed Threatened Species	[Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Aphelocephala leucopsis Southern Whiteface [529]	Vulnerable	Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Endangered	Species or species habitat may occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Endangered	Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Malurus leucopterus edouardi White-winged Fairy-wren (Barrow Island), Barrow Island Black-and-white Fairy-wren [26194]	Vulnerable	Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Phaethon rubricauda westralis Red-tailed Tropicbird (Indian Ocean), Indian Ocean Red-tailed Tropicbird [91824]	Endangered	Species or species habitat known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Tringa nebularia Common Greenshank, Greenshank [832]	Endangered	Species or species habitat likely to occur within area
CRUSTACEAN		

Scientific Name	Threatened Category	Presence Text
Kumonga exleyi		
Cape Range Remipede [86875]	Vulnerable	Species or species habitat likely to occur within area
FISH		
Milyeringa veritas		
Cape Range Cave Gudgeon, Blind Gudgeon [66676]	Vulnerable	Species or species habitat known to occur within area
Ophisternon candidum		
Blind Cave Eel [66678]	Vulnerable	Species or species habitat known to occur within area
Thunnus maccoyii		
Southern Bluefin Tuna [69402]	Conservation Dependent	Breeding known to occur within area
MAMMAL		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia lesueur Barrow and Boodie Islands subspecies		
Boodie, Burrowing Bettong (Barrow and Boodie Islands) [88021]	Vulnerable	Species or species habitat known to occur within area
Dasyurus hallucatus		
Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Eubalaena australis		
Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Isoodon auratus barrowensis Golden Bandicoot (Barrow Island) [66666]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes conspicillatus conspicillatus Spectacled Hare-wallaby (Barrow Island) [66661]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes hirsutus Central Australian subspecies Mala, Rufous Hare-Wallaby (Central Australia) [88019]	Endangered	Translocated population known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Osphranter robustus isabellinus Barrow Island Wallaroo, Barrow Island Euro [89262]	Vulnerable	Species or species habitat likely to occur within area
Petrogale lateralis lateralis Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat known to occur within area
Rhinonicteris aurantia (Pilbara form) Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat known to occur within area
PLANT		
Minuria tridens Minnie Daisy [13753]	Vulnerable	Species or species habitat known to occur within area
REPTILE		
Aipysurus apraefrontalis Short-nosed Sea Snake, Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama Leaf-scaled Sea Snake, Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Ctenotus zastictus		
Hamelin Ctenotus [25570]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Liasis olivaceus barroni		
Pilbara Olive Python [66699]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARK		
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Congregation or aggregation known to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Centrophorus uyato		
Little Gulper Shark [68446]	Conservation Dependent	Species or species habitat likely to occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sphyrna lewini		
Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes		
Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area
Ardenna pacifica		
Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas		
Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Hydroprogne caspia		
Caspian Tern [808]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Congregation or aggregation known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area

Scientific Name	Threatened Category	Presence Text
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Eubalaena australis as Balaena glacialis australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat likely to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa sahulensis as Sousa chinensis		
Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Hirundo rustica		
Barn Swallow [662]		Species or species habitat may occur within area
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limnodromus semipalmatus Asian Dowitcher [843]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]	Endangered	Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Defence	
Defence - EXMOUTH VLF TRANSMITTER STATION [50123]	WA
Defence - EXMOUTH VLF TRANSMITTER STATION [50122]	WA
Defence - LEARMONTH - AIR WEAPONS RANGE [50193]	WA
Defence - LEARMONTH RADAR SITE - VLAMING HEAD EXMOUTH [50001]	WA
Unknown	
Commonwealth Land - [52236]	WA

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Learmonth Air Weapons Range Facility	WA	Listed place
Ningaloo Marine Area - Commonwealth Waters	WA	Listed place

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area

Scientific Name	Threatened Category	Presence Text
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat known to occur within area overfly marine area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Chroicocephalus novaehollandiae as Larus novaehollandiae		
Silver Gull [82326]		Breeding known to occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Glareola maldivarum		
Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area
Haliaeetus leucogaster		
White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Hirundo rustica		
Barn Swallow [662]		Species or species habitat may occur within area overfly marine area
Hydroprogne caspia as Sterna caspia		
Caspian Tern [808]		Breeding known to occur within area
Larus pacificus		
Pacific Gull [811]		Breeding known to occur within area
Limnodromus semipalmatus		
Asian Dowitcher [843]	Vulnerable	Species or species habitat known to occur within area overfly marine area
Limosa lapponica		
Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Macronectes giganteus		
Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Onychoprion anaethetus as Sterna anaethetus Bridled Tern [82845]		Breeding known to occur within area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Scientific Name	Threatened Category	Presence Text
Rostratula australis as Rostratula benghalensis (sensu lato)		
Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area
Sterna dougallii		
Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons as Sterna albifrons		
Little Tern [82849]		Congregation or aggregation known to occur within area
Sternula nereis as Sterna nereis		
Fairy Tern [82949]		Breeding known to occur within area
Thalassarche carteri		
Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta		
Shy Albatross [89224]	Endangered	Species or species habitat may occur within area
Thalassarche impavida		
Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris		
Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi		
White-capped Albatross [64462]	Vulnerable	Species or species habitat may occur within area
Thalasseus bengalensis as Sterna bengalensis		
Lesser Crested Tern [66546]		Breeding known to occur within area
Thalasseus bergii as Sterna bergii		
Greater Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia		
Common Greenshank, Greenshank [832]	Endangered	Species or species habitat likely to occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammal		

Scientific Name	Threatened Category	Presence Text
Dugong dugon Dugong [28]		Breeding known to occur within area
Reptile		
Aipysurus apraefrontalis Short-nosed Sea Snake, Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Sea Snake, Dubois' Seasnake, Reef Shallows Sea Snake [1116]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Sea Snake, Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus laevis Olive Sea Snake, Olive-brown Sea Snake [1120]		Species or species habitat may occur within area
Aipysurus mosaicus as Aipysurus eydouxii Mosaic Sea Snake [87261]		Species or species habitat may occur within area
Aipysurus pooleorum Shark Bay Sea Snake [66061]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Sea Snake, Mjoberg's Sea Snake [1121]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area

Scientific Name	Threatened Category	Presence Text
Emydocephalus annulatus Eastern Turtle-headed Sea Snake [1125]		Species or species habitat may occur within area
Ephalophis greyae as Ephalophis greyi Mangrove Sea Snake [93738]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrelaps darwiniensis Port Darwin Sea Snake, Black-ringed Mangrove Sea Snake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Sea Snake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Sea Snake, Bar-bellied Sea Snake [1104]		Species or species habitat may occur within area
Hydrophis kingii as Disteira kingii Spectacled Sea Snake [93511]		Species or species habitat may occur within area
Hydrophis macdowelli as Hydrophis mcdowelli MacDowell's Sea Snake, Small-headed Sea Snake, [75601]		Species or species habitat may occur within area
Hydrophis major as Disteira major Olive-headed Sea Snake [93512]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Sea Snake, Ornate Reef Sea Snake [1111]		Species or species habitat may occur within area
Hydrophis peronii as Acalyptophis peronii Horned Sea Snake [93509]		Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
[Hydrophis platurus as Pelamis platurus] Yellow-bellied Sea Snake [93517]		Species or species habitat may occur within area
[Hydrophis stokesii as Astrotia stokesii] Stokes' Sea Snake [93510]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area

Whales and Other Cetaceans [Resource Information]

Current Scientific Name	Status	Type of Presence
Mammal		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia sima Dwarf Sperm Whale [85043]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area

Current Scientific Name	Status	Type of Presence
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa sahulensis Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area

Current Scientific Name	Status	Type of Presence
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str.		
Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris		
Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Park Name	Zone & IUCN Categories
Carnarvon Canyon	Habitat Protection Zone (IUCN IV)
Gascoyne	Habitat Protection Zone (IUCN IV)
Gascoyne	Habitat Protection Zone (IUCN IV)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Gascoyne	Multiple Use Zone (IUCN VI)
Montebello	Multiple Use Zone (IUCN VI)
Shark Bay	Multiple Use Zone (IUCN VI)
Gascoyne	National Park Zone (IUCN II)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)
Ningaloo	Recreational Use Zone (IUCN IV)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence
Aug - Sep		

Scientific Name	Behaviour	Presence
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
Dec - Jan		
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur
Nov-Feb		
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur
Nov - May		
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur

Extra Information

State and Territory Reserves [Resource Information]

Protected Area Name	Reserve Type	State
Airlie Island	Nature Reserve	WA
Barrow Island	Nature Reserve	WA
Barrow Island	Marine Management Area	WA
Barrow Island	Marine Park	WA
Bessieres Island	Nature Reserve	WA
Boodie, Double Middle Islands	Nature Reserve	WA
Bundegi Coastal Park	5(1)(h) Reserve	WA
Cape Range	National Park	WA
Cape Range (South)	National Park	WA
Great Sandy Island	Nature Reserve	WA
Jurabi Coastal Park	5(1)(h) Reserve	WA
Lowendal Islands	Nature Reserve	WA
Montebello Islands	Conservation Park	WA
Montebello Islands	Conservation Park	WA

Protected Area Name	Reserve Type	State
Montebello Islands	Marine Park	WA
Muiron Islands	Nature Reserve	WA
Muiron Islands	Marine Management Area	WA
Ningaloo	Marine Park	WA
North Sandy Island	Nature Reserve	WA
Nyingguulu (Ningaloo) Coastal Reserve	5(1)(h) Reserve	WA
Round Island	Nature Reserve	WA
Rowley Shoals	Marine Park	WA
Serrurier Island	Nature Reserve	WA
Thevenard Island	Nature Reserve	WA
Unnamed WA40322	5(1)(h) Reserve	WA
Unnamed WA40828	5(1)(h) Reserve	WA
Unnamed WA41080	5(1)(h) Reserve	WA
Unnamed WA44665	5(1)(h) Reserve	WA
Unnamed WA44667	5(1)(h) Reserve	WA
Victor Island	Nature Reserve	WA

Nationally Important Wetlands [Resource Information]

Wetland Name	State
Cape Range Subterranean Waterways	WA

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Browse to North West Shelf Development, Indian Ocean, WA	2018/8319		Approval
Gorgon Gas Development	2003/1294		Post-Approval
Ningaloo Lighthouse Development, 17km north west Exmouth, Western Australia	2020/8693		Approval
Optimised Mardie Solar Salt Project	2022/9169		Assessment

Title of referral	Reference	Referral Outcome	Assessment Status
Project Highclere Cable Lay and Operation	2022/09203		Completed
Action clearly unacceptable			
Highlands 3D Marine Seismic Survey	2012/6680	Action Clearly Unacceptable	Completed
Controlled action			
'Van Gogh' Petroleum Field Development	2007/3213	Controlled Action	Post-Approval
Balmoral South Iron Ore Mine	2008/4236	Controlled Action	Post-Approval
Binowee Iron Ore Project	2001/366	Controlled Action	Proposed Decision
Construct and operate LNG & domestic gas plant including onshore and offshore facilities - Wheatston	2008/4469	Controlled Action	Post-Approval
Develop Jansz-Io deepwater gas field in Permit Areas WA-18-R, WA-25-R and WA-26-	2005/2184	Controlled Action	Post-Approval
Development of Angel gas and condensate field, North West Shelf	2004/1805	Controlled Action	Post-Approval
Development of Browse Basin Gas Fields (Upstream)	2008/4111	Controlled Action	Completed
Development of Coniston/Novara fields within the Exmouth Sub-basin	2011/5995	Controlled Action	Post-Approval
Development of Stybarrow petroleum field incl drilling and facility installation	2004/1469	Controlled Action	Post-Approval
Echo-Yodel Production Wells	2000/11	Controlled Action	Post-Approval
Enfield full field development	2001/257	Controlled Action	Post-Approval
Equus Gas Fields Development Project, Carnarvon Basin	2012/6301	Controlled Action	Completed
Eramurra Industrial Salt Project	2021/9027	Controlled Action	Assessment Approach
Eramurra Industrial Salt Project, near Karratha, WA	2019/8448	Controlled Action	Completed
Gorgon Gas Development 4th Train Proposal	2011/5942	Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Controlled action			
Gorgon Gas Revised Development	2008/4178	Controlled Action	Post-Approval
Greater Enfield (Vincent) Development	2005/2110	Controlled Action	Post-Approval
Greater Gorgon Development - Optical Fibre Cable, Mainland to Barrow Island	2005/2141	Controlled Action	Completed
Light Crude Oil Production	2001/365	Controlled Action	Post-Approval
Mardie Project, 80 km south west of Karratha, WA	2018/8236	Controlled Action	Post-Approval
Mauds Landing Marina	2000/98	Controlled Action	Completed
Pluto Gas Project	2005/2258	Controlled Action	Completed
Pluto Gas Project Including Site B	2006/2968	Controlled Action	Post-Approval
Proposed West Pilbara Iron Ore Project	2009/4706	Controlled Action	Post-Approval
Pyrenees Oil Fields Development	2005/2034	Controlled Action	Post-Approval
Simpson Development	2000/59	Controlled Action	Completed
Simpson Oil Field Development	2001/227	Controlled Action	Post-Approval
The Scarborough Project - FLNG & assoc subsea infrastructure, Carnarvon Basin	2013/6811	Controlled Action	Post-Approval
Vincent Appraisal Well	2000/22	Controlled Action	Post-Approval
Yardie Creek Road Realignment Project	2021/8967	Controlled Action	Assessment Approach
Not controlled action			
'Goodwyn A' Low Pressure Train Project	2003/914	Not Controlled Action	Completed
'Van Gogh' Oil Appraisal Drilling Program, Exploration Permit Area WA-155-P(1)	2006/3148	Not Controlled Action	Completed
Airlie Island soil and groundwater investigations, Exmouth Gulf, offshore Pilbara coast	2014/7250	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Baniyas-1 Exploration Well, EP-424, near Onslow	2007/3282	Not Controlled Action	Completed
Barrow Island 2D Seismic survey	2006/2667	Not Controlled Action	Completed
Bollinger 2D Seismic Survey 200km North of North West Cape WA	2004/1868	Not Controlled Action	Completed
Bultaco-2, Laverda-2, Laverda-3 and Montesa-2 Appraisal Wells	2000/103	Not Controlled Action	Completed
Carnarvon 3D Marine Seismic Survey	2004/1890	Not Controlled Action	Completed
Cazadores 2D seismic survey	2004/1720	Not Controlled Action	Completed
Construction and operation of an unmanned sea platform and connecting pipeline to Varanus Island for	2004/1703	Not Controlled Action	Completed
Controlled Source Electromagnetic Survey	2007/3262	Not Controlled Action	Completed
Development of Halyard Field off the west coast of WA	2010/5611	Not Controlled Action	Completed
Development of Mutineer and Exeter petroleum fields for oil production, Permit	2003/1033	Not Controlled Action	Completed
Drilling of an exploration well Gats-1 in Permit Area WA-261-P	2004/1701	Not Controlled Action	Completed
Eagle-1 Exploration Drilling, North West Shelf, WA	2019/8578	Not Controlled Action	Completed
Echo A Development WA-23-L, WA-24-L	2005/2042	Not Controlled Action	Completed
Expansion of the Sino Iron Ore Mine and export facilities, Cape Preston, WA	2017/7862	Not Controlled Action	Completed
Expansion Proposal, Mineralogy Cape Preston Iron Ore Project, Cape Preston, WA	2009/5010	Not Controlled Action	Completed
Exploration drilling well WA-155-P(1)	2003/971	Not Controlled Action	Completed
Exploration of appraisal wells	2006/3065	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Exploration Well (Taunton-2)	2002/731	Not Controlled Action	Completed
Exploration Well in Permit Area WA-155-P(1)	2002/759	Not Controlled Action	Completed
Exploratory drilling in permit area WA-225-P	2001/490	Not Controlled Action	Completed
Extension of Simpson Oil Platforms & Wells	2002/685	Not Controlled Action	Completed
HCA05X Macedon Experimental Survey	2004/1926	Not Controlled Action	Completed
Hess Exploration Drilling Programme	2007/3566	Not Controlled Action	Completed
Huascaran-1 exploration well (WA-292-P)	2001/539	Not Controlled Action	Completed
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed
INDIGO West Submarine Telecommunications Cable, WA	2017/8126	Not Controlled Action	Completed
Infill Production Well (Griffin-9)	2001/417	Not Controlled Action	Completed
Jansz-2 and 3 Appraisal Wells	2002/754	Not Controlled Action	Completed
Klammer 2D Seismic Survey	2002/868	Not Controlled Action	Completed
Maia-Gaea Exploration wells	2000/17	Not Controlled Action	Completed
Manaslu - 1 and Huascaran - 1 Offshore Exploration Wells	2001/235	Not Controlled Action	Completed
Mermaid Marine Australia Desalination Project	2011/5916	Not Controlled Action	Completed
Montesa-1 and Bultaco-1 Exploration Wells	2000/102	Not Controlled Action	Completed
North Rankin B gas compression facility	2005/2500	Not Controlled Action	Completed
Pipeline System Modifications Project	2000/3	Not Controlled Action	Completed
Project Highclere Geophysical Survey	2021/9023	Not Controlled Action	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Searipple gas and condensate field development	2000/89	Not Controlled Action	Completed
Spool Base Facility	2001/263	Not Controlled Action	Completed
Subsea Gas Pipeline From Stybarrow Field to Griffin Venture Gas Export Pipeline	2005/2033	Not Controlled Action	Completed
sub-sea tieback of Perseus field wells	2004/1326	Not Controlled Action	Completed
Telstra North Rankin Spur Fibre Optic Cable	2016/7836	Not Controlled Action	Completed
Thevenard Island Retirement Project	2015/7423	Not Controlled Action	Completed
To construct and operate an offshore submarine fibre optic cable, WA	2014/7373	Not Controlled Action	Completed
WA-295-P Kerr-McGee Exploration Wells	2001/152	Not Controlled Action	Completed
Wanda Offshore Research Project, 80 km north-east of Exmouth, WA	2018/8293	Not Controlled Action	Completed
Western Flank Gas Development	2005/2464	Not Controlled Action	Completed
Wheatstone 3D seismic survey, 70km north of Barrow Island	2004/1761	Not Controlled Action	Completed
Not controlled action (particular manner)			
'Kate' 3D marine seismic survey, exploration permits WA-320-P and WA-345-P, 60km	2005/2037	Not Controlled Action (Particular Manner)	Post-Approval
'Tourmaline' 2D marine seismic survey, permit areas WA-323-P, WA-330-P and WA-32	2005/2282	Not Controlled Action (Particular Manner)	Post-Approval
"Leanne" offshore 3D seismic exploration, WA-356-P	2005/1938	Not Controlled Action (Particular Manner)	Post-Approval
2D and 3D seismic surveys	2005/2151	Not Controlled Action (Particular Manner)	Post-Approval
2D marine seismic survey	2012/6296	Not Controlled Action	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		(Particular Manner)	
2D seismic survey	2008/4493	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Survey	2005/2146	Not Controlled Action (Particular Manner)	Post-Approval
2D Seismic Survey Permit Area WA-352-P	2008/4628	Not Controlled Action (Particular Manner)	Post-Approval
2D seismic survey within permit WA-291	2007/3265	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic survey	2008/4281	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey (WA-482-P, WA-363-P), WA	2013/6761	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey in Permit Areas WA-15-R, WA-18-R, WA-205-P, WA-253-P, WA-267-P and WA-268-P	2003/1271	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Survey in WA 457-P & WA 458-P, North West Shelf, offshore WA	2013/6862	Not Controlled Action (Particular Manner)	Post-Approval
3D marine seismic survey over petroleum title WA-268-P	2007/3458	Not Controlled Action (Particular Manner)	Post-Approval
3D Marine Seismic Surveys - Contos CT-13 & Supertubes CT-13, offshore WA	2013/6901	Not Controlled Action (Particular Manner)	Post-Approval
3D seismic survey	2006/2715	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
3D Seismic Survey, WA	2008/4428	Not Controlled Action (Particular Manner)	Post-Approval
3D Seismic Survey in the Carnarvon Bsin on the North West Shelf	2002/778	Not Controlled Action (Particular Manner)	Post-Approval
3D sesmic survey	2006/2781	Not Controlled Action (Particular Manner)	Post-Approval
Acheron Non-Exclusive 2D Seismic Survey	2008/4565	Not Controlled Action (Particular Manner)	Post-Approval
Acheron Non-Exclusive 2D Seismic Survey	2009/4968	Not Controlled Action (Particular Manner)	Post-Approval
Agrippina 3D Seismic Marine Survey	2009/5212	Not Controlled Action (Particular Manner)	Post-Approval
Apache Northwest Shelf Van Gogh Field Appraisal Drilling Program	2007/3495	Not Controlled Action (Particular Manner)	Post-Approval
Aperio 3D Marine Seismic Survey, WA	2012/6648	Not Controlled Action (Particular Manner)	Post-Approval
Artemis-1 Drilling Program (WA-360-P)	2010/5432	Not Controlled Action (Particular Manner)	Post-Approval
Australia to Singapore Fibre Optic Submarine Cable System	2011/6127	Not Controlled Action (Particular Manner)	Post-Approval
Babylon 3D Marine Seismic Survey, Commonwealth Waters, nr Exmouth WA	2013/7081	Not Controlled Action (Particular Manner)	Post-Approval
Balnaves Condensate Field Development	2011/6188	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Bonaventure 3D seismic survey	2006/2514	Not Controlled Action (Particular Manner)	Post-Approval
Cable Seismic Exploration Permit areas WA-323-P and WA-330-P	2008/4227	Not Controlled Action (Particular Manner)	Post-Approval
Cape Preston East - Iron Ore Export Facilities, Pilbara, WA	2013/6844	Not Controlled Action (Particular Manner)	Post-Approval
Cerberus exploration drilling campaign, Carnarvon Basin, WA	2016/7645	Not Controlled Action (Particular Manner)	Post-Approval
CGGVERITAS 2010 2D Seismic Survey	2010/5714	Not Controlled Action (Particular Manner)	Post-Approval
Charon 3D Marine Seismic Survey	2007/3477	Not Controlled Action (Particular Manner)	Post-Approval
Consturction & operation of the Varanus Island kitchen & mess cyclone refuge building, compression p	2013/6952	Not Controlled Action (Particular Manner)	Post-Approval
Coverack Marine Seismic Survey	2001/399	Not Controlled Action (Particular Manner)	Post-Approval
Cue Seismic Survey within WA-359-P, WA-361-P and WA-360-P	2007/3647	Not Controlled Action (Particular Manner)	Post-Approval
CVG 3D Marine Seismic Survey	2012/6654	Not Controlled Action (Particular Manner)	Post-Approval
DAVROS MC 3D marine seismic survey northwaet of Dampier, WA	2013/7092	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Decommissioning of the Legendre facilities	2010/5681	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Drilling Program	2010/5532	Not Controlled Action (Particular Manner)	Post-Approval
Deep Water Northwest Shelf 2D Seismic Survey	2007/3260	Not Controlled Action (Particular Manner)	Post-Approval
Demeter 3D Seismic Survey, off Dampier, WA	2002/900	Not Controlled Action (Particular Manner)	Post-Approval
Draeck 3D Marine Seismic Survey, WA-205-P	2006/3067	Not Controlled Action (Particular Manner)	Post-Approval
Drilling 35-40 offshore exploration wells in deep water	2008/4461	Not Controlled Action (Particular Manner)	Post-Approval
Earthworks for kitchen/mess, cyclone refuge building & Compression Plant, Varanus Island	2013/6900	Not Controlled Action (Particular Manner)	Post-Approval
Eendracht Multi-Client 3D Marine Seismic Survey	2009/4749	Not Controlled Action (Particular Manner)	Post-Approval
Enfield M3 & Vincent 4D Marine Seismic Surveys	2008/3981	Not Controlled Action (Particular Manner)	Completed
Enfield M3 4D, Vincent 4D & 4D Line Test Marine Seismic Surveys	2008/4122	Not Controlled Action (Particular Manner)	Post-Approval
Enfield M4 4D Marine Seismic Survey	2008/4558	Not Controlled Action (Particular Manner)	Post-Approval
Enfield oilfield 3D Seismic Survey	2006/3132	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Exmouth West 2D Marine Seismic Survey	2008/4132	Not Controlled Action (Particular Manner)	Post-Approval
Exploration drilling of Zeus-1 well	2008/4351	Not Controlled Action (Particular Manner)	Post-Approval
Fletcher-Finucane Development, WA26-L and WA191-P	2011/6123	Not Controlled Action (Particular Manner)	Post-Approval
Foxhound 3D Non-Exclusive Marine Seismic Survey	2009/4703	Not Controlled Action (Particular Manner)	Post-Approval
Gazelle 3D Marine Seismic Survey in WA-399-P and WA-42-L	2010/5570	Not Controlled Action (Particular Manner)	Post-Approval
Geco Eagle 3D Marine Seismic Survey	2008/3958	Not Controlled Action (Particular Manner)	Post-Approval
Glencoe 3D Marine Seismic Survey WA-390-P	2007/3684	Not Controlled Action (Particular Manner)	Post-Approval
Greater Western Flank Phase 1 gas Development	2011/5980	Not Controlled Action (Particular Manner)	Post-Approval
Grimalkin 3D Seismic Survey	2008/4523	Not Controlled Action (Particular Manner)	Post-Approval
Guacamole 2D Marine Seismic Survey	2008/4381	Not Controlled Action (Particular Manner)	Post-Approval
Harmony 3D Marine Seismic Survey	2012/6699	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Harpy 1 exploration well	2001/183	Not Controlled Action (Particular Manner)	Post-Approval
Honeycombs MC3D Marine Seismic Survey	2012/6368	Not Controlled Action (Particular Manner)	Post-Approval
Huzzas MC3D Marine Seismic Survey (HZ-13) Carnarvon Basin, offshore WA	2013/7003	Not Controlled Action (Particular Manner)	Post-Approval
Huzzas phase 2 marine seismic survey, Exmouth Plateau, Northern Carnarvon Basin, WA	2013/7093	Not Controlled Action (Particular Manner)	Post-Approval
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval
John Ross & Rosella Off Bottom Cable Seismic Exploration Program	2008/3966	Not Controlled Action (Particular Manner)	Post-Approval
Judo Marine 3D Seismic Survey within and adjacent to WA-412-P	2008/4630	Not Controlled Action (Particular Manner)	Post-Approval
Judo Marine 3D Seismic Survey within and adjacent to WA-412-P	2009/4801	Not Controlled Action (Particular Manner)	Post-Approval
Julimar Brunello Gas Development Project	2011/5936	Not Controlled Action (Particular Manner)	Post-Approval
Klimt 2D Marine Seismic Survey	2007/3856	Not Controlled Action (Particular Manner)	Post-Approval
Laverda 3D Marine Seismic Survey and Vincent M1 4D Marine Seismic Survey	2010/5415	Not Controlled Action (Particular Manner)	Post-Approval
Leopard 2D marine seismic survey	2005/2290	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Lion 2D Marine Seismic Survey	2007/3777	Not Controlled Action (Particular Manner)	Post-Approval
Macedon Gas Field Development	2008/4605	Not Controlled Action (Particular Manner)	Post-Approval
Marine reconnaissance survey	2008/4466	Not Controlled Action (Particular Manner)	Post-Approval
Moosehead 2D seismic survey within permit WA-192-P	2005/2167	Not Controlled Action (Particular Manner)	Post-Approval
Munmorah 2D seismic survey within permits WA-308/9-P	2003/970	Not Controlled Action (Particular Manner)	Post-Approval
Ocean Bottom Cable Seismic Program, WA-264-P	2007/3844	Not Controlled Action (Particular Manner)	Post-Approval
Ocean Bottom Cable Seismic Survey	2005/2017	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Canning Multi Client 2D Marine Seismic Survey	2010/5393	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Drilling Campaign	2011/5830	Not Controlled Action (Particular Manner)	Post-Approval
Offshore Fibre Optic Cable Network Construction & Operation, Port Hedland WA to Darwin NT	2014/7223	Not Controlled Action (Particular Manner)	Post-Approval
Orcus 3D Marine Seismic Survey in WA-450-P	2010/5723	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Osprey and Dionysus Marine Seismic Survey	2011/6215	Not Controlled Action (Particular Manner)	Post-Approval
Palta-1 exploration well in Petroleum Permit Area WA-384-P	2011/5871	Not Controlled Action (Particular Manner)	Post-Approval
Phoenix 3D Seismic Survey, Bedout Sub-Basin	2010/5360	Not Controlled Action (Particular Manner)	Post-Approval
Pomodoro 3D Marine Seismic Survey in WA-426-P and WA-427-P	2010/5472	Not Controlled Action (Particular Manner)	Post-Approval
Pyrenees 4D Marine Seismic Monitor Survey, HCA12A	2012/6579	Not Controlled Action (Particular Manner)	Post-Approval
Pyrenees-Macedon 3D marine seismic survey	2005/2325	Not Controlled Action (Particular Manner)	Post-Approval
Quiberon 2D Seismic Survey, permit area WA-385P, offshore of Carnarvon	2009/5077	Not Controlled Action (Particular Manner)	Post-Approval
Reindeer gas reservior development, Devil Creek, Carnarvon Basin - WA	2007/3917	Not Controlled Action (Particular Manner)	Post-Approval
Repsol 3d & 2D Marine Seismic Survey	2012/6658	Not Controlled Action (Particular Manner)	Post-Approval
Rose 3D Seismic Program	2008/4239	Not Controlled Action (Particular Manner)	Post-Approval
Rydal-1 Petroleum Exploration Well, WA	2012/6522	Not Controlled Action (Particular Manner)	Post-Approval
Salsa 3D Marine Seismic Survey	2010/5629	Not Controlled Action (Particular	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
		Manner)	
Santos Winchester three dimensional seismic survey - WA-323-P & WA-330-P	2011/6107	Not Controlled Action (Particular Manner)	Post-Approval
Skorpion Marine Seismic Survey WA	2001/416	Not Controlled Action (Particular Manner)	Post-Approval
Sovereign 3D Marine Seismic Survey	2011/5861	Not Controlled Action (Particular Manner)	Post-Approval
Stag 4D & Reindeer MAZ Marine Seismic Surveys, WA	2013/7080	Not Controlled Action (Particular Manner)	Post-Approval
Stag Off-bottom Cable Seismic Survey	2007/3696	Not Controlled Action (Particular Manner)	Post-Approval
Stybarrow 4D Marine Seismic Survey	2011/5810	Not Controlled Action (Particular Manner)	Post-Approval
Stybarrow Baseline 4D marine seismic survey	2008/4530	Not Controlled Action (Particular Manner)	Post-Approval
Tantabiddi Boat Ramp Sand Bypassing	2015/7411	Not Controlled Action (Particular Manner)	Post-Approval
Tidepole Maz 3D Seismic Survey Campaign	2007/3706	Not Controlled Action (Particular Manner)	Post-Approval
Tortilla 2D Seismic Survey, WA	2011/6110	Not Controlled Action (Particular Manner)	Post-Approval
Triton 3D Marine Seismic Survey, WA-2-R and WA-3-R	2006/2609	Not Controlled Action (Particular Manner)	Post-Approval

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action (particular manner)			
Undertake a 3D marine seismic survey	2010/5695	Not Controlled Action (Particular Manner)	Post-Approval
Undertake a three dimensional marine seismic survey	2010/5679	Not Controlled Action (Particular Manner)	Post-Approval
Undertake a three dimensional marine seismic survey	2010/5715	Not Controlled Action (Particular Manner)	Post-Approval
Vincent M1 and Enfield M5 4D Marine Seismic Survey	2010/5720	Not Controlled Action (Particular Manner)	Post-Approval
Warramunga Non-Inclusive 3D Seismic Survey	2008/4553	Not Controlled Action (Particular Manner)	Post-Approval
West Anchor 3D Marine Seismic Survey	2008/4507	Not Controlled Action (Particular Manner)	Post-Approval
West Panaeus 3D seismic survey	2006/3141	Not Controlled Action (Particular Manner)	Post-Approval
Westralia SPAN Marine Seismic Survey, WA & NT	2012/6463	Not Controlled Action (Particular Manner)	Post-Approval
Wheatstone 3D MAZ Marine Seismic Survey	2011/6058	Not Controlled Action (Particular Manner)	Post-Approval
Wheatstone Iago Appraisal Well Drilling	2007/3941	Not Controlled Action (Particular Manner)	Post-Approval
Wheatstone Iago Appraisal Well Drilling	2008/4134	Not Controlled Action (Particular Manner)	Post-Approval
Referral decision			
3D Marine Seismic Survey in the offshore northwest Carnarvon	2011/6175	Referral Decision	Completed

Title of referral	Reference	Referral Outcome	Assessment Status
Referral decision			
Basin			
3D Seismic Survey	2008/4219	Referral Decision	Completed
Bianchi 3D Marine Seismic Survey, Carnavon Basin, WA	2013/7078	Referral Decision	Completed
CVG 3D Marine Seismic Survey	2012/6270	Referral Decision	Completed
Enfield 4D Marine Seismic Surveys, Production Permit WA-28-L	2005/2370	Referral Decision	Completed
Mardie Salt Project, Pilbara region, WA	2018/8183	Referral Decision	Completed
Rose 3D Seismic acquisition survey	2008/4220	Referral Decision	Completed
Stybarrow Baseline 4D Marine Seismic Survey (Permit Areas WA-255-P, WA-32-L, WA-	2008/4165	Referral Decision	Completed
Two Dimensional Transition Zone Seismic Survey - TP/7 (R1)	2010/5507	Referral Decision	Completed
Varanus Island Compression Project	2012/6698	Referral Decision	Completed

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	North-west
Commonwealth waters adjacent to Ningaloo Reef	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west
Glomar Shoals	North-west
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	North-west

Biologically Important Areas

Scientific Name	Behaviour	Presence

Scientific Name	Behaviour	Presence
Dugong		
Dugong dugon Dugong [28]	Breeding	Known to occur
Dugong dugon Dugong [28]	Calving	Known to occur
Dugong dugon Dugong [28]	Foraging (high density seagrass beds)	Known to occur
Dugong dugon Dugong [28]	Nursing	Known to occur
Marine Turtles		
Caretta caretta Loggerhead Turtle [1763]	Internesting buffer	Known to occur
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur
Chelonia mydas Green Turtle [1765]	Aggregation	Known to occur
Chelonia mydas Green Turtle [1765]	Basking	Known to occur
Chelonia mydas Green Turtle [1765]	Foraging	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting	Known to occur
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur
Chelonia mydas Green Turtle [1765]	Mating	Known to occur
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur

Scientific Name	Behaviour	Presence
Eretmochelys imbricata Hawksbill Turtle [1766]	Foraging	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Mating	Known to occur
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur
Natator depressus Flatback Turtle [59257]	Aggregation	Known to occur
Natator depressus Flatback Turtle [59257]	Foraging	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting	Known to occur
Natator depressus Flatback Turtle [59257]	Internesting buffer	Known to occur
Natator depressus Flatback Turtle [59257]	Mating	Known to occur
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur
Seabirds		
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur
Fregata ariel Lesser Frigatebird [1012]	Breeding	Known to occur
Phaethon lepturus White-tailed Tropicbird [1014]	Breeding	Known to occur

Scientific Name	Behaviour	Presence
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur
Sternula albifrons sinensis Little Tern [82850]	Resting	Known to occur
Sternula nereis Fairy Tern [82949]	Breeding	Known to occur
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur
Sharks		
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur
Rhincodon typus Whale Shark [66680]	Foraging (high density prey)	Known to occur
Whales		
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging	Known to occur
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Migration	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur
Megaptera novaeangliae Humpback Whale [38]	Resting	Known to occur

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Department of Land and Resource Management, Northern Territory
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Australian Tropical Herbarium, Cairns
- -eBird Australia
- -Australian Government – Australian Antarctic Data Centre
- -Museum and Art Gallery of the Northern Territory
- -Australian Government National Environmental Science Program
- -Australian Institute of Marine Science
- -Reef Life Survey Australia
- -American Museum of Natural History
- -Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
- -Tasmanian Museum and Art Gallery, Hobart, Tasmania
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

Appendix C Spill modelling

a. West Tryal Rocks Oil Spill Modelling - Vessel Collision (Ref. 496)
b. West Tryal Rocks Oil Spill Modelling (Ref. 496)
c. Geryon-Eurytion Oil Spill Modelling (Ref. 534)
d. Chrysaor-Dionysis Oil Spill Modelling (Ref. 535)
e. Semele Oil Spill Modelling (Ref. 536)
f. Chandon Oil Spill Modelling (Ref. 537)

GREATER GORGON – WEST TRYAL ROCKS

Oil Spill Modelling

Report relevant to the vessel collision scenario only

MAQ1162J
West Tryal Rocks Oil Spill
Modelling
Rev 3
5 December 2022

www.rpsgroup.com/mst

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
Rev A	Draft issued for internal review	Dr. Ryan Dunn Jeremie Bernard	Dr. Sasha Zigic Jeremie Bernard		17 August 2022
Rev 0	Draft issued for client review			Dr. Sasha Zigic	17 August 2022
Rev 1	Updated deterministic scenarios	Nathan Benfer	Dr. Sasha Zigic	Dr. Sasha Zigic	27 September 2022
Rev 2	Final report	Jeremie Bernard	Dr. Sasha Zigic	Dr. Sasha Zigic	3 November 2022
Rev 3	Small amendments to final report	Jeremie Bernard	Dr. Sasha Zigic	Dr. Sasha Zigic	5 December 2022

Approval for issue

Dr. Sasha Zigic   5 December 2022

Prepared by:

RPS

Jeremie Bernard
Senior Coastal Engineer

Lakeside Corporate Space, Suite 425
Level 2, 34-38 Glenferrie Drive
Robina, QLD, 4226, Australia

T +61 7 5553 6900
E Jeremie.Bernard@rpsgroup.com

Prepared for:

Xodus

Naomi Kerp
Principal Environmental Consultant

Level 1, 1 William Street
Perth, WA, 6000, Australia

T +61 8 6555 5652
E naomi.kerp@xodusgroup.com

Contents

Tables

Figures

TERMS AND ABBREVIATIONS

°	Degrees
‘	Minutes
“	Seconds
µm	Micrometre (unit of length; 1 µm = 0.001 mm)
Actionable oil	Oil which is thick enough for the effective use of mitigation strategies
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute gravity. A measure of how heavy or light a petroleum liquid is compared to water.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m3)
bbl/d	Barrels per day
Bonn Agreement	An agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983, includes: Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
cP	Centipoise (unit of dynamic viscosity)
Decay	The process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions.
Dynamic viscosity	The dynamic viscosity of a fluid expresses its resistance to shearing flows, where adjacent layers move parallel to each other with different speeds.
Floating oil exposure	Contact by floating oil on the sea surface at concentrations equal to or exceeding defined threshold concentrations. The consequence will vary depending on the threshold and the receptors
g/m^2	Grams per square meter (unit of surface area density)
GODAE	Global Ocean Data Assimilation Experiment
HYCOM	Hybrid Coordinate Ocean Model. A data-assimilative, three-dimensional ocean model
HYDROMAP	Advanced ocean/coastal tidal model used to predict tidal water levels, current speed and current direction.
IAA	Impact Assessment Area
IBRA	Interim Biogeographic Regionalisation for Australia

IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
Shoreline contact	Arrival of oil at or near shorelines at on-water concentrations equal to or exceeding defined threshold concentrations. Shoreline contact is judged for floating oil arriving within a 2 km buffer zone from any shoreline as a conservative measure
SIMAP	Spill Impact Model Application Package. SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for surface or subsea releases
Single Oil spill modelling	Oil spill modelling involving a computer simulation of a single hypothetical oil spill event subject to a single sequence of wind, current and other sea conditions over time. Single oil spill modelling, also referred to as “deterministic modelling” provides a simulation of one possible outcome of a given spill scenario, subject to the metocean conditions that are imposed. Single oil spill modelling is commonly used to consider the fate and effects of ‘worst-case’ oil spill scenarios that are carefully selected in consideration of the nature and scale of the offshore petroleum activity and the local environment (NOPSEMA, 2017). Because the outcomes of a single oil spill simulation can only represent the outcome of that scenario under one sequence of metocean conditions, worst-case conditions are often identified from stochastic modelling. It is impossible to calculate the likelihood of any outcome from a single oil spill simulation. Single oil spill modelling is generally used for response planning, preparedness planning and for supporting oil spill response operations in the event of an actual spill

SRTM	Shuttle Radar Topography Mission
Stochastic oil spill modelling	Stochastic oil spill modelling is created by overlaying and statistically analysing the outcomes of many single oil-spill simulations of a defined spill scenario, where each simulation was subject to a different sequence of metocean conditions, selected objectively (typically by random selection) from a long sequence of historic conditions for the study area. Analysis of this larger set of simulations provides a more accurate indication of the environment that maybe affected (EMBA) and indicates which locations are more likely to be affected (as well as other statistics). Stochastic oil spill modelling avoids biases that affect single oil spill modelling (due to the reliance on only one possible sequence of conditions). However, when interpreting stochastic modelling, which is based on a wide range of potential conditions that might happen to occur, it is essential to understand that calculations will encompass a much larger area than could be affected in any single spill event, where a more limited set of conditions will occur. Consequently, it is misleading to imply that the region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) Stochastic modelling is generally used for risk assessment and preparedness planning by indicating locations that could be exposed and may require response or subsequent impact assessment
TOPEX/Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed, quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the West Tryal Rocks (WTR) field situated within the Northern Carnarvon Basin in Permit area WA-5-R northwest of Barrow Island off the north-west coast of Western Australia. RPS was commissioned via Xodus on behalf of Chevron to undertake an oil spill modelling to support environmental approvals.

The oil spill modelling study was conducted to assess the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following two hypothetical scenario:

- **Scenario 1:** A 4,302 stb/day (684.0 m^3/day) subsea release of condensate over 77 days (totalling 331,254 stb or 52,665.2 m^3) resulting from a loss of well control (LOWC); and

- **Scenario 2:** A 1,500 m^3 surface release of marine diesel oil (MDO) over 24 hours resulting from a containment loss following a vessel collision.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

Methodology

The modelling study was carried out in stages. Firstly, a ten-year current dataset (2010–2019) that includes the combined influence of large-scale ocean and nearshore tidal currents was developed. Secondly, the currents, local winds and detailed hydrocarbon characteristics were used as inputs in the three-dimensional oil spill model (SIMAP) to simulate the drift, spread, weathering and fate of the spilled oil.

As spills can occur during any set of wind and current conditions, modelling was conducted using a stochastic (or probabilistic) approach, which involved running per scenario 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Hydrocarbon Properties

Condensate Properties

West Tryal Rocks condensate has an API of 41.2, a density of 817 kg/m^3 (at 15ºC) and a low viscosity value of 5.9 cP. When exposed to the atmosphere at local temperatures, about 31.1% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 29.9% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~19.4%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 19.6% of the condensate is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation. The process of evaporation will be greater than under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity for the mixture to take up water to form water-in-oil emulsion over the weathering cycle. The soluble aromatic hydrocarbons contribute approximately 3.2% by mass of the whole oil, which is contained in the volatile fractions, which are highly soluble.

Marine Diesel Oil Properties

The MDO has an API of 37.60, a density of 829 kg/m^3 (at 25ºC) and a low viscosity value of 4.0 cP. When exposed to the atmosphere at local temperatures, about 6.0% of the MDO volatile components should evaporate within the first 12 hours (BP < 180°C); a further 34.6% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (54.4%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 5.0% of the MDO is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation.

Key Findings

Loss of Well Control

- The maximum distance from the release location to the low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) threshold for floating condensate was 174.7 north (transitional), 42.1 km northeast (summer and transitional) and 4.6 km west-southwest (winter), respectively.

- Other than the receptors that the release location resides within (Offshore Area Impact Assessment Area (IAA), Flatback Turtle - Internesting Buffer, Pygmy Blue Whale – Distribution, Wedge-tailed Shearwater - Breeding, Whale Shark – Foraging Biologically Important Areas (BIA), Pilbara (offshore) Integrated Marine and Coastal Regionalisation of Australia (IMCRA), and the Ancient coastline at 125 m depth contour Key Ecological Feature (KEF), the Flatback Turtle - Nesting and Humpback Whale - Migration BIAs were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. Accordingly, the probabilities for the low and moderate thresholds was 100% for all seasons for the receptors that the release location resides within. The probabilities of low and moderate exposure at the Flatback Turtle - Nesting ranged between 79–92% and 17–26%, whilst the probabilities of low and moderate exposure at Humpback Whale - Migration ranged between 94–100% and 8–19%, respectively. The minimum times before low exposure for the Flatback Turtle - Nesting BIA and Humpback Whale - Migration BIA were 0.96 days and 0.71 days during summer conditions, respectively.

- The probability of condensate accumulating on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 53%, while the minimum time before shoreline accumulation was 7.08 days and the maximum volume of oil ashore above the low threshold was 105.0 m^3. No high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

- In the 0-10 m depth layer, a total of 19, 8, and 10 BIAs were predicted to be exposed to dissolved hydrocarbons at, or above, the low threshold (≥ 10 ppb) during summer, transitional and winter, respectively. Excluding the 4 BIAs that the release location resides within, the highest probabilities of exposure to low dissolved hydrocarbons were predicted as 9% for Humpback Whale - Migration during summer, 5% for Flatback Turtle - Nesting and Humpback Whale - Migration during transitional, and 5% for Humpback Whale - Migration during winter conditions.

- In the 0-10 m depth layer, a total of 36 BIAs were predicted to be exposed at, or above, the low threshold during all 3 seasons. Excluding the 4 BIAs that the release location resides within, the highest probabilities of exposure to low entrained hydrocarbons (≥ 10 ppb) were predicted for the Flatback Turtle - Internesting Buffer (97% during summer and 100% during transitional and winter) and Humpback Whale - Migration BIAs (100% during all seasons).

- During all 3 seasons, 6 Australian Marine Parks (AMPs) were predicted to be exposed at the low entrained hydrocarbon threshold, with the highest probabilities predicted at the Gascoyne AMP (95% summer, 98% transitional and 94% winter). Furthermore, Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold (≥ 100 ppb).

Vessel Collision

- The maximum distance from the release location to the low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) threshold for floating condensate was 167.0 northeast (summer), 59.6 km south-southwest (winter) and 17.6 km north-northeast (summer), respectively.

- Excluding the receptors that the release location resides within, the Humpback Whale - Migration BIA and Continental Slope Demersal Fish Communities KEF were the only receptors predicted to be exposed during all three seasons at the low and moderate floating oil thresholds. The probabilities of low and moderate exposure at the Humpback Whale - Migration BIA ranged between 16–22% and 3–4%,whilst the probabilities of low and moderate exposure to the Continental Slope Demersal Fish Communities KEF ranged between 35–54% and 4–13%, respectively. The minimum times before exposure at the low threshold for the Humpback Whale - Migration BIA and Continental Slope Demersal Fish Communities KEF were 0.54 days (winter) and 0.38 days (transitional), respectively.

- The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during winter at 9%, while the minimum time before shoreline accumulation was 6.50 days and the maximum volume of oil ashore above the low threshold was 35.1 m3. No high (≥ 1,000 g/m2) shoreline threshold accumulation was predicted in the modelling results.

- In the surface (0-10 m) depth layer, a total of 14, 12, and 14 BIAs were predicted to be exposed to dissolved hydrocarbons at, or above, the low threshold during summer, transitional and winter, respectively. Excluding the 4 BIAs, the highest probabilities of exposure for the low threshold during summer, transitional and winter were predicted as 6%, 6% and 14%, respectively for the Humpback Whale - Migration BIA.

- In the surface (0-10 m) depth layer, a total of 29 BIAs were predicted to be exposed at, or above, the low threshold during all 3 seasons. Excluding the 4 BIAs (that the release location resides within, the highest probabilities of exposure for the low threshold were predicted for the Humpback Whale - Migration during all seasons (42%, 59% and 71% for summer, transitional and winter, respectively).

- During all 3 seasons, 3 AMPs were predicted to be exposed at the low entrained hydrocarbon threshold, with the highest probabilities predicted at the Gascoyne AMP (21% summer, 22% transitional and 37% winter). Furthermore, during seasonal conditions the Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold.

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the West Tryal Rocks (WTR) field situated within the Northern Carnarvon Basin in Permit area WA-5-R northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the WTR field, Xodus on behalf of Chevron had commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the two following hypothetical scenarios:

- **Scenario 1:** A 4,302 stb/day (684.0 m^3/day) subsea release of condensate over 77 days (totalling 331,254 stb or 52,665.2 m^3) resulting from a loss of well control (LOWC); and

- **Scenario 2:** A 1,500 m^3 surface release of marine diesel oil (MDO) over 24 hours resulting from a containment loss following a vessel collision.

The release location used for both Scenario 1 and Scenario 2 is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis Program (SIMAP). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, RPS warrants that this work meets and exceeds the American Society for Testing and Materials (ASTM) Standard F2067-13 "*Standard Practice for Development and Use of Oil Spill Models*".

Table 1.1 Coordinates of the West Tryal Rocks release location.

Location	Latitude	Longitude	Depth (mLAT)
WTR Well 5	20.23666° S	115.04357° E	150

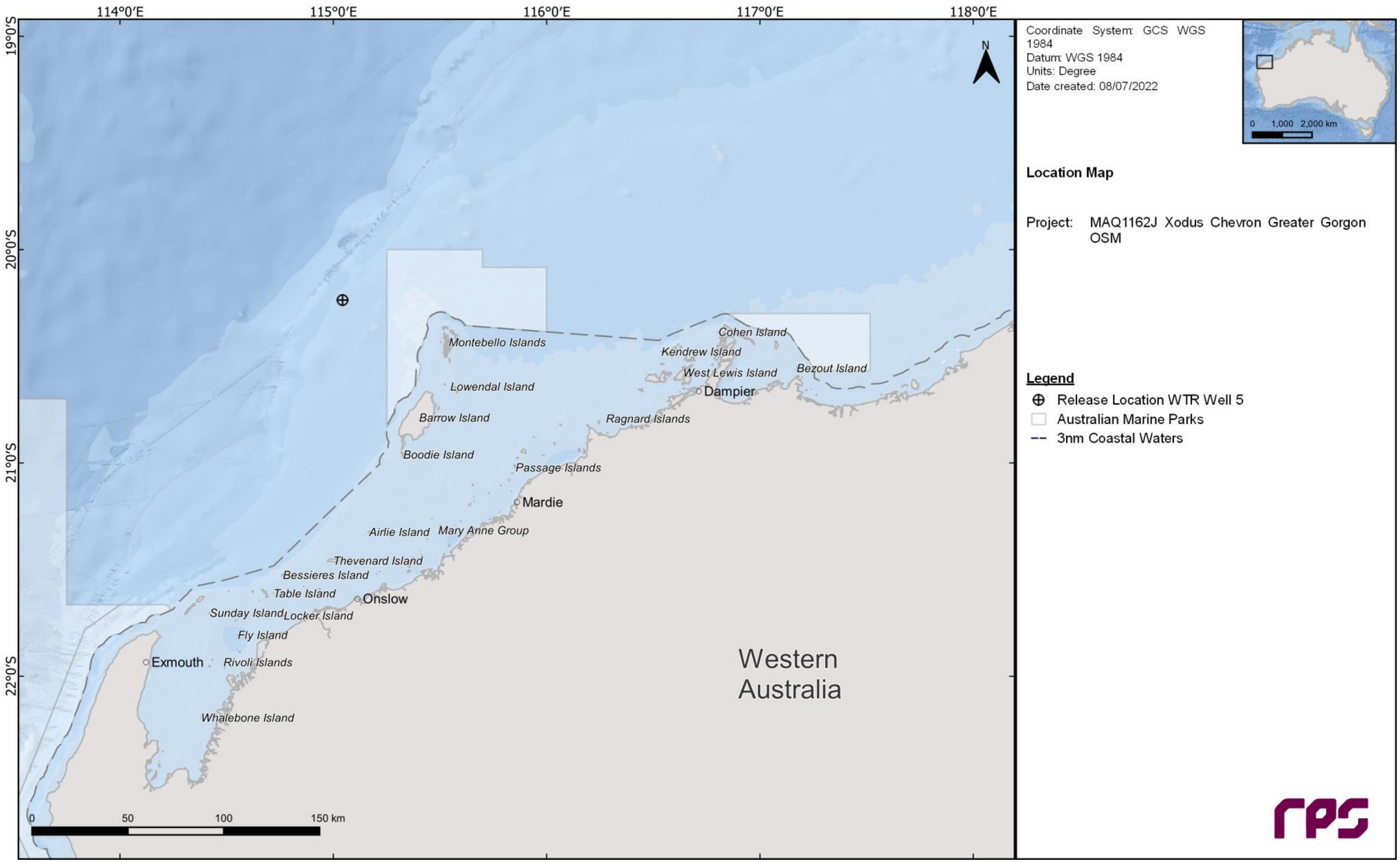


Figure 1.1 West Tryal Rocks hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate ten years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. For each scenario run 100 simulations per season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds for each scenario; and

5. From the 300 simulations modelled per scenario, identify and present the “worst case” deterministic runs, which can be used to inform response planning based on the following criteria:

   a. Largest swept area of floating hydrocarbon above 10 g/m^2

   b. Largest swept area of floating hydrocarbon above 50 g/m^2

   c. Largest volume of oil ashore

   d. Longest length of shoreline with accumulation above 100 g/m^2

   e. Largest area of entrained hydrocarbons above 100 ppb

   f. Largest area of dissolved hydrocarbons above 50 ppb

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

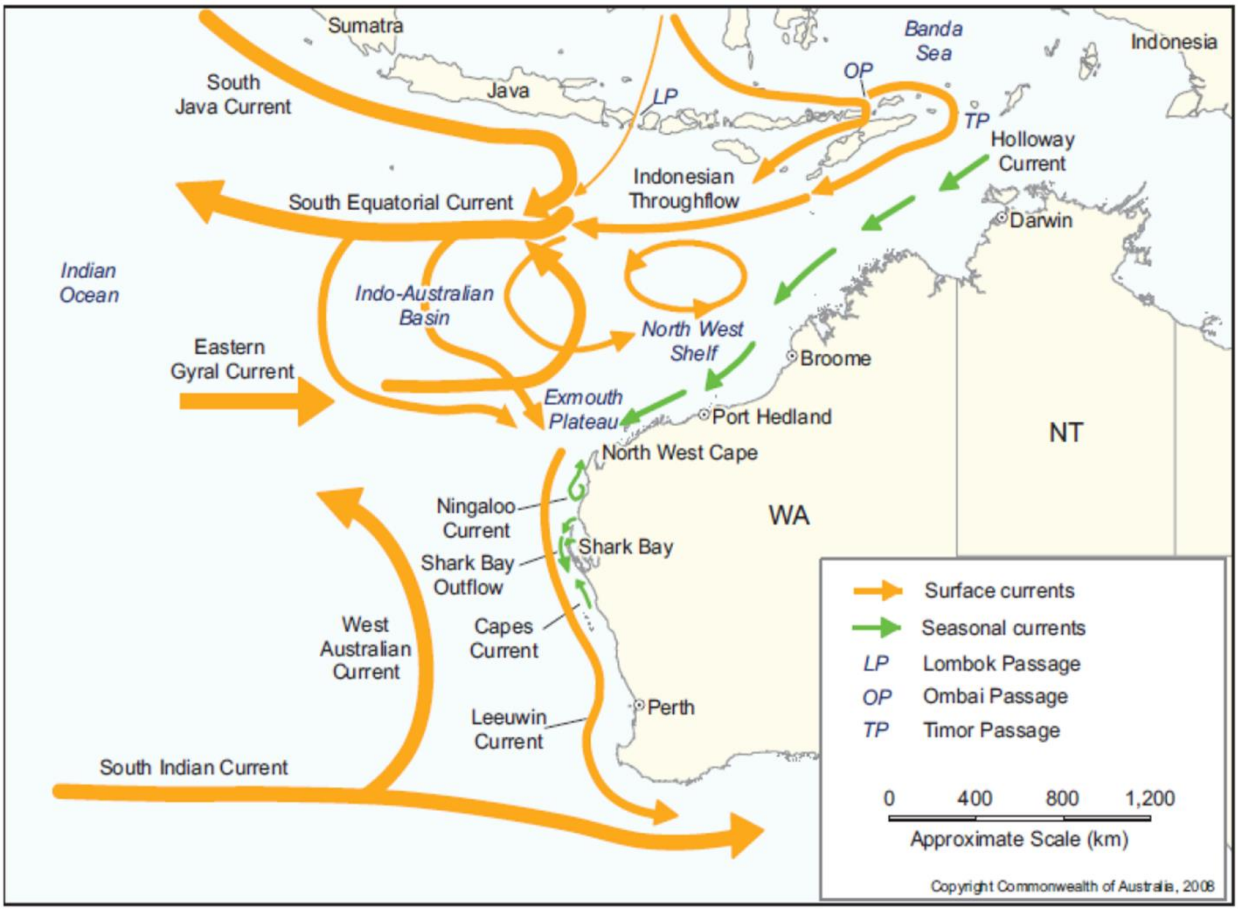


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

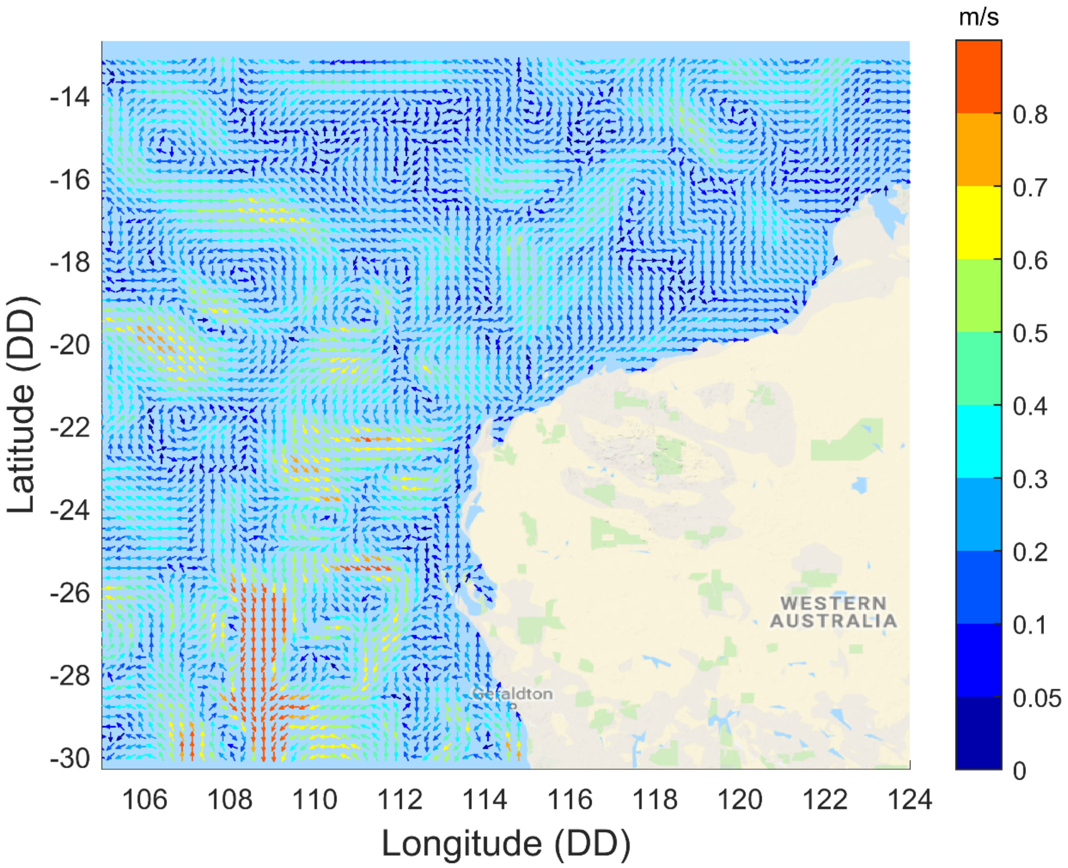


Figure 3.2 Typical ocean current circulation pattern during the summer months.

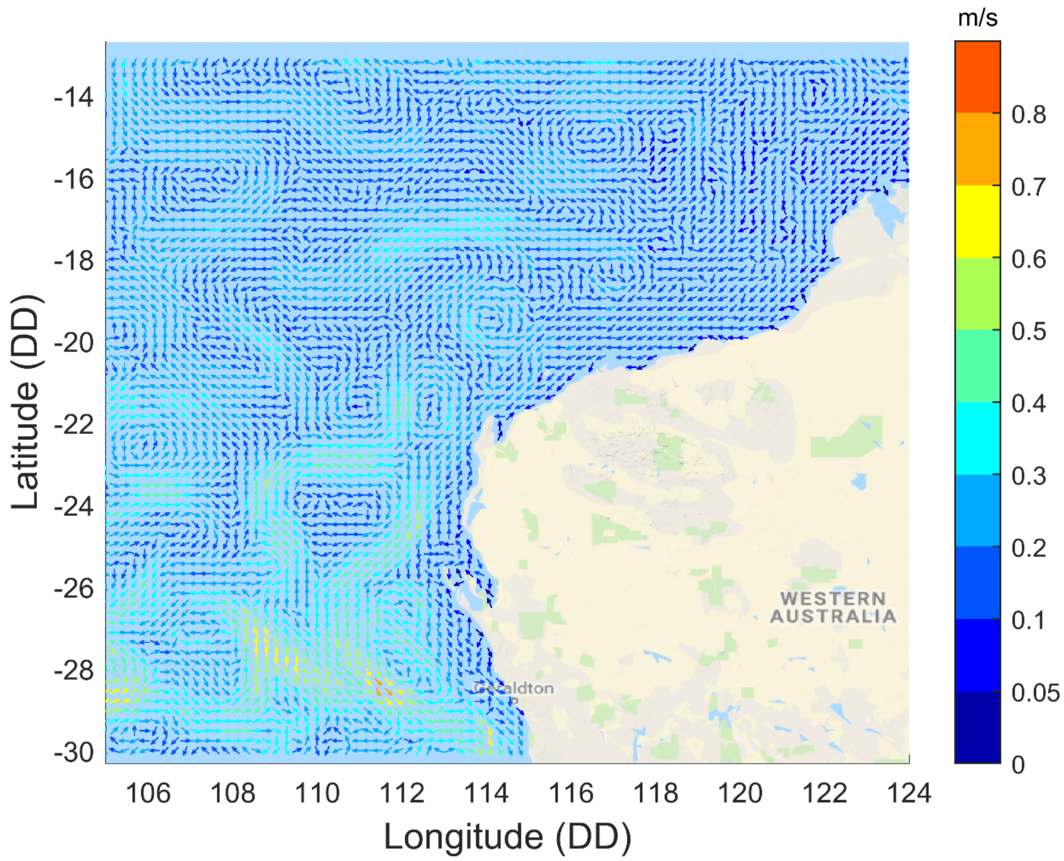


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grids were allocated in a step-wise fashion to resolve flows more accurately along the coastline, around islands and over regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

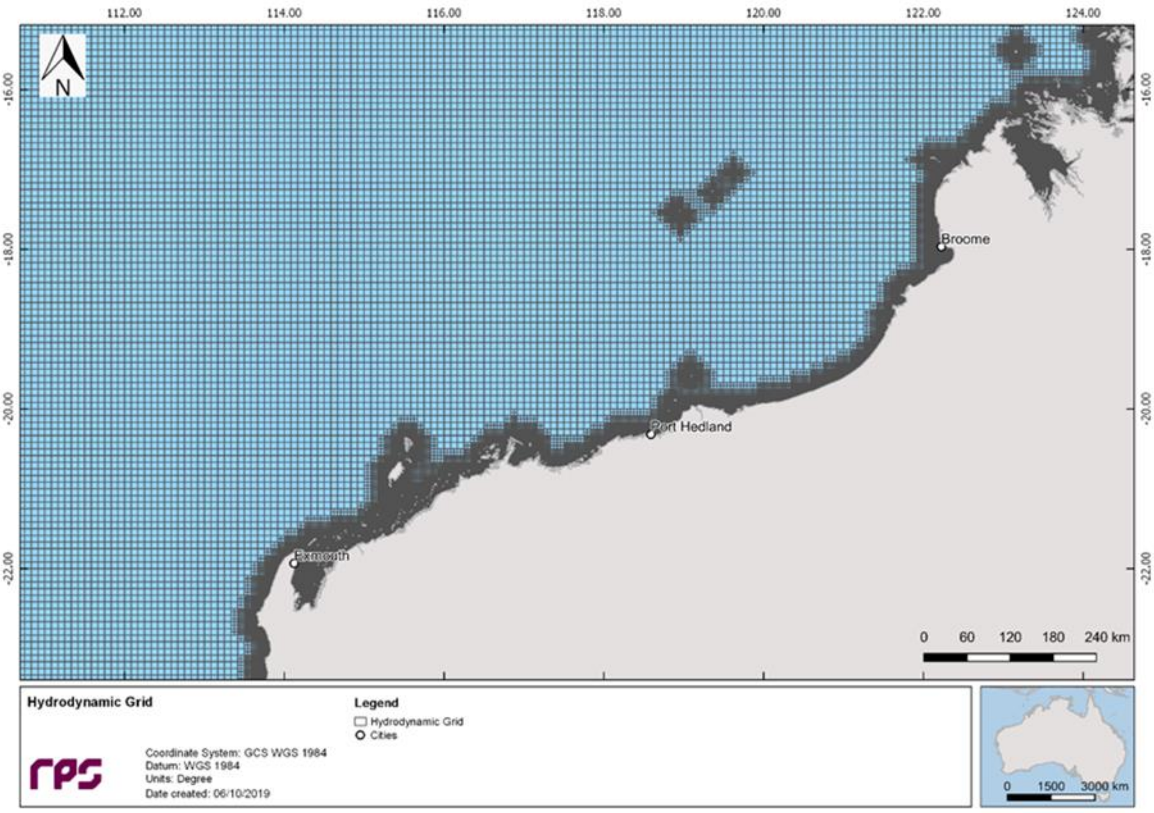


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

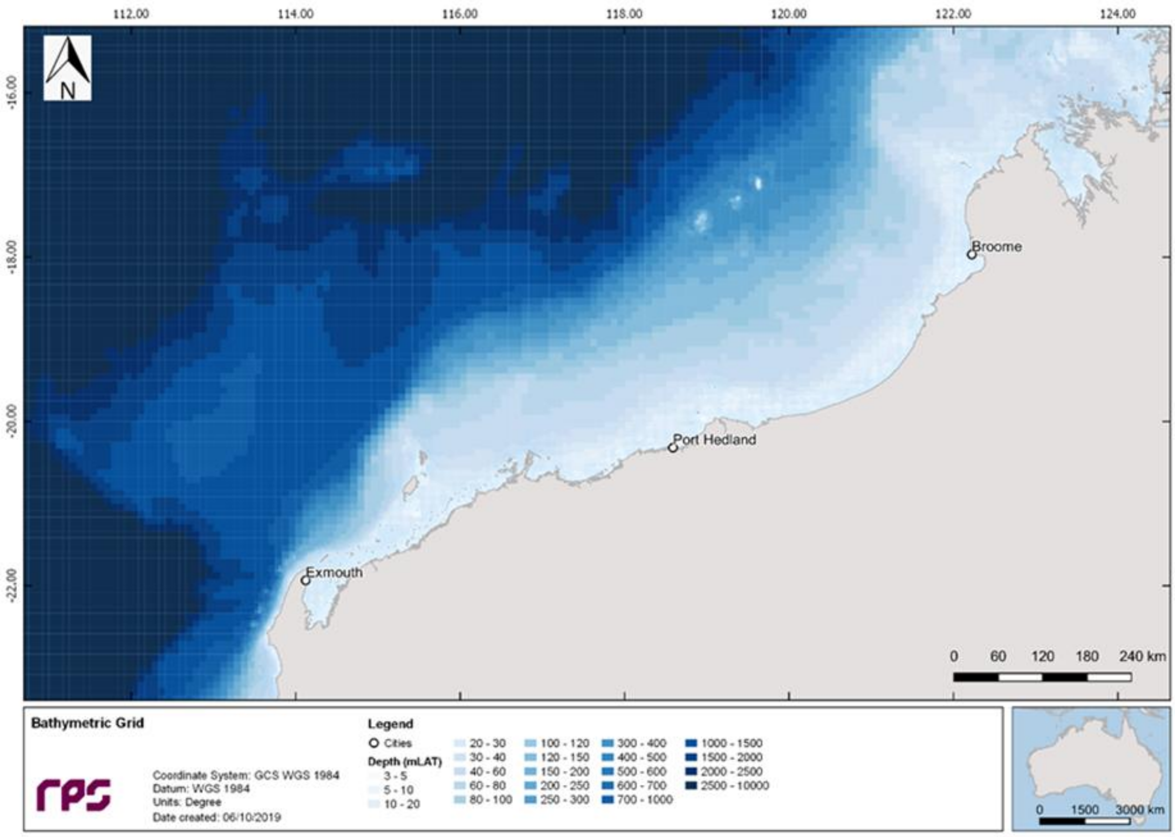


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.16 m/s (November) and 0.26 m/s (May). Additionally, the maximums ranged between 0.54 m/s (November) and 2.18 m/s (March). The general current directions were towards the southwest. Figure 3.6 and Figure 3.7 present the monthly and total current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.23	1.93	Northeast and Southwest
	February	0.21	1.07	Northeast and Southwest
	March	0.22	2.18	Southwest
Transitional	April	0.24	1.20	Southwest
Winter	May	0.26	0.95	Southwest
	June	0.26	0.90	Southwest
	July	0.21	1.08	Southwest
Transitional	August	0.19	0.78	Southwest
Summer	September	0.19	1.03	Northeast and Southwest
	October	0.18	0.63	Northeast and Southwest
	November	0.16	0.54	Variable
	December	0.20	0.80	Southwest
Minimum		**0.16**	**0.54**	
Maximum		**0.26**	**2.18**	

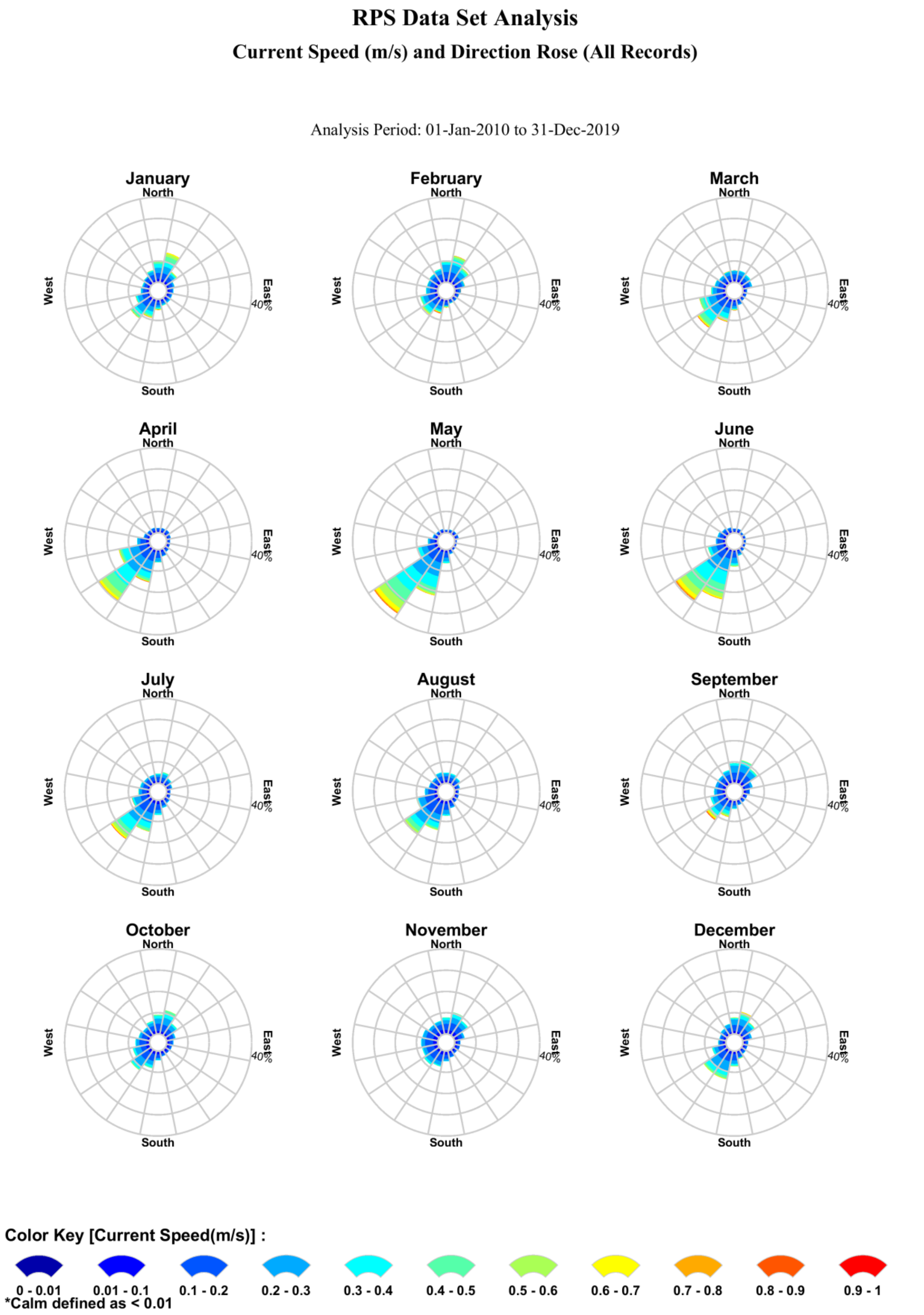


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

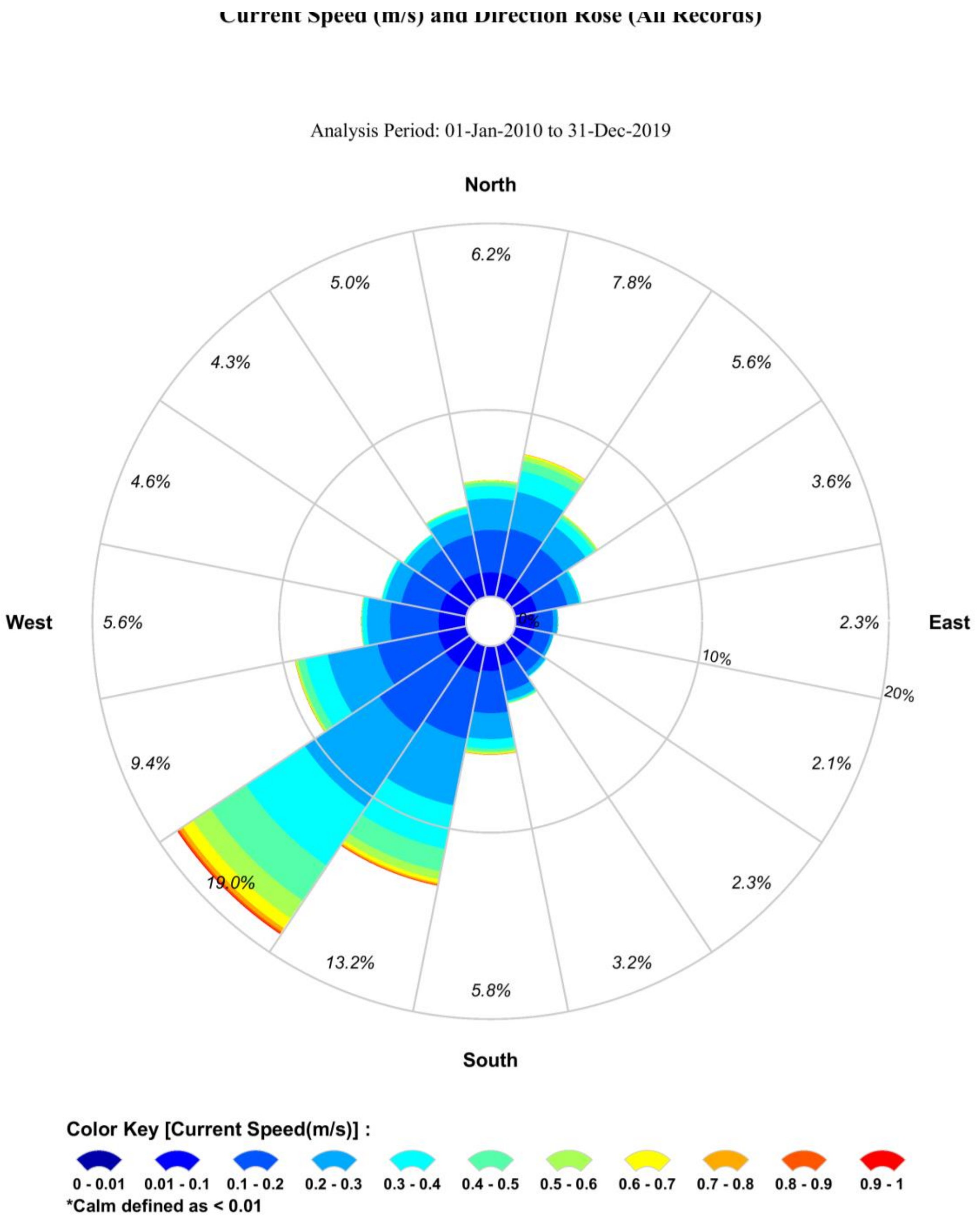


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 49 knots (July). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

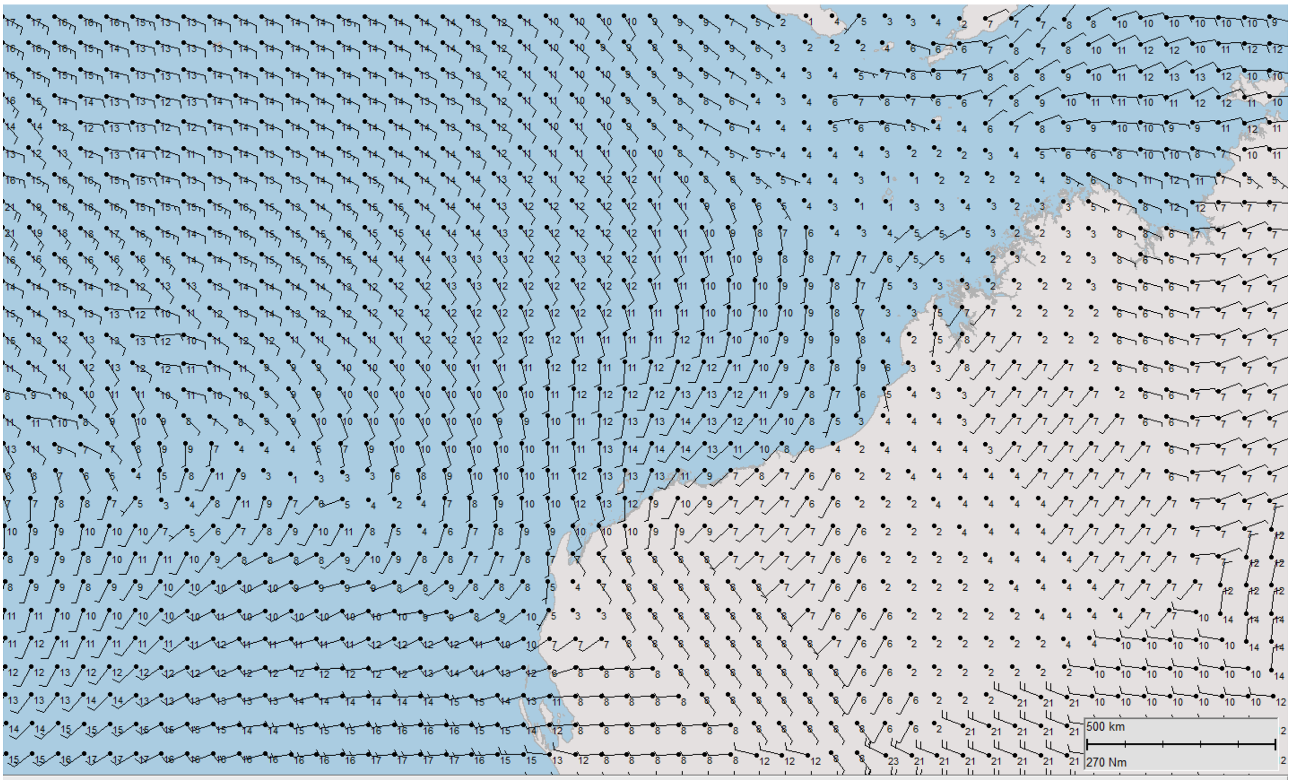


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	41	Southwest
	February	11	46	Southwest
	March	10	35	Southwest
Transitional	April	10	38	Variable
Winter	May	12	40	East
	June	14	31	East
	July	13	49	East to South
Transitional	August	11	31	South
Summer	September	12	27	South-Southwest
	October	13	28	Southwest
	November	13	25	Southwest
	December	12	29	Southwest
Minimum		**10**	**25**	
Maximum		**14**	**49**	

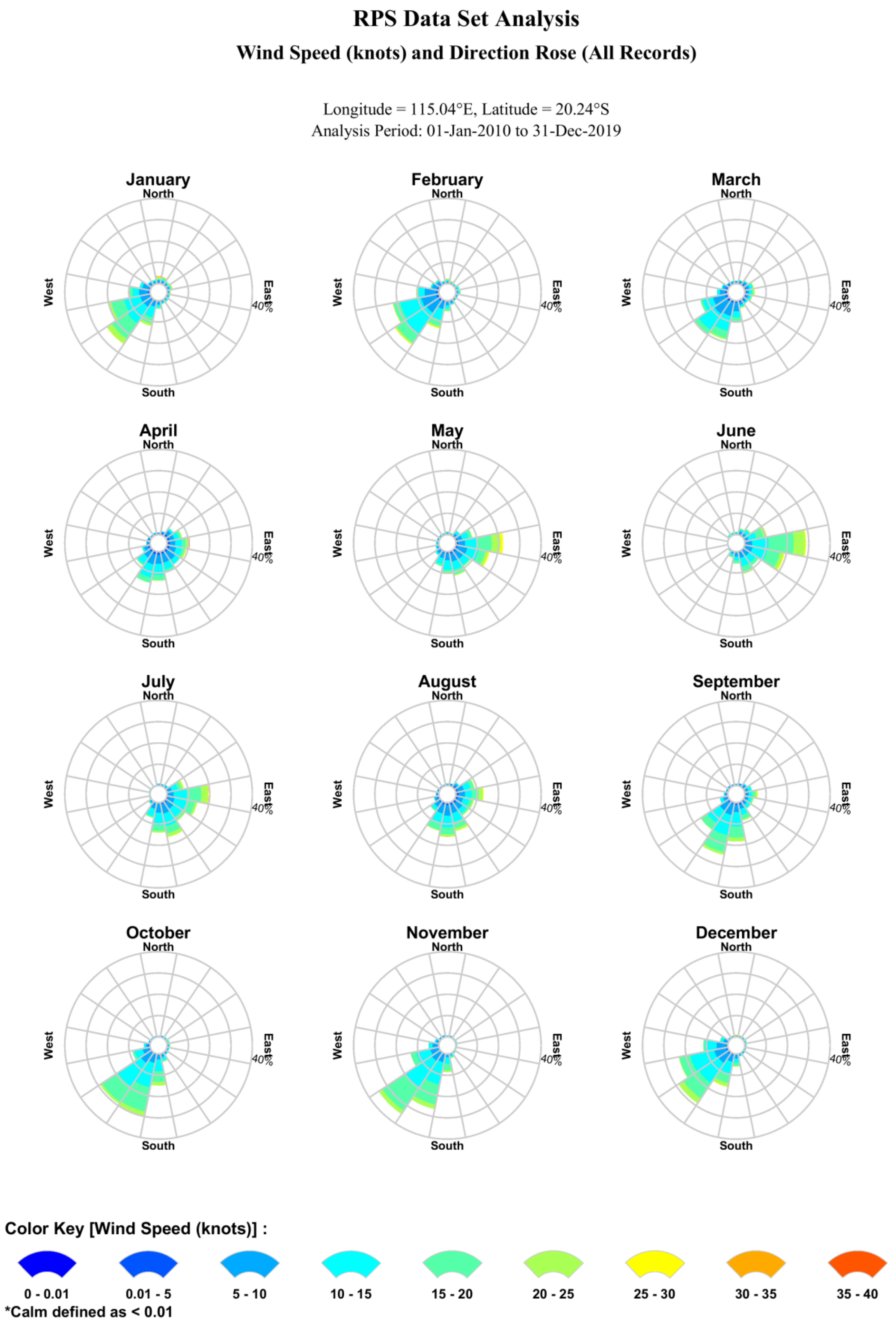


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

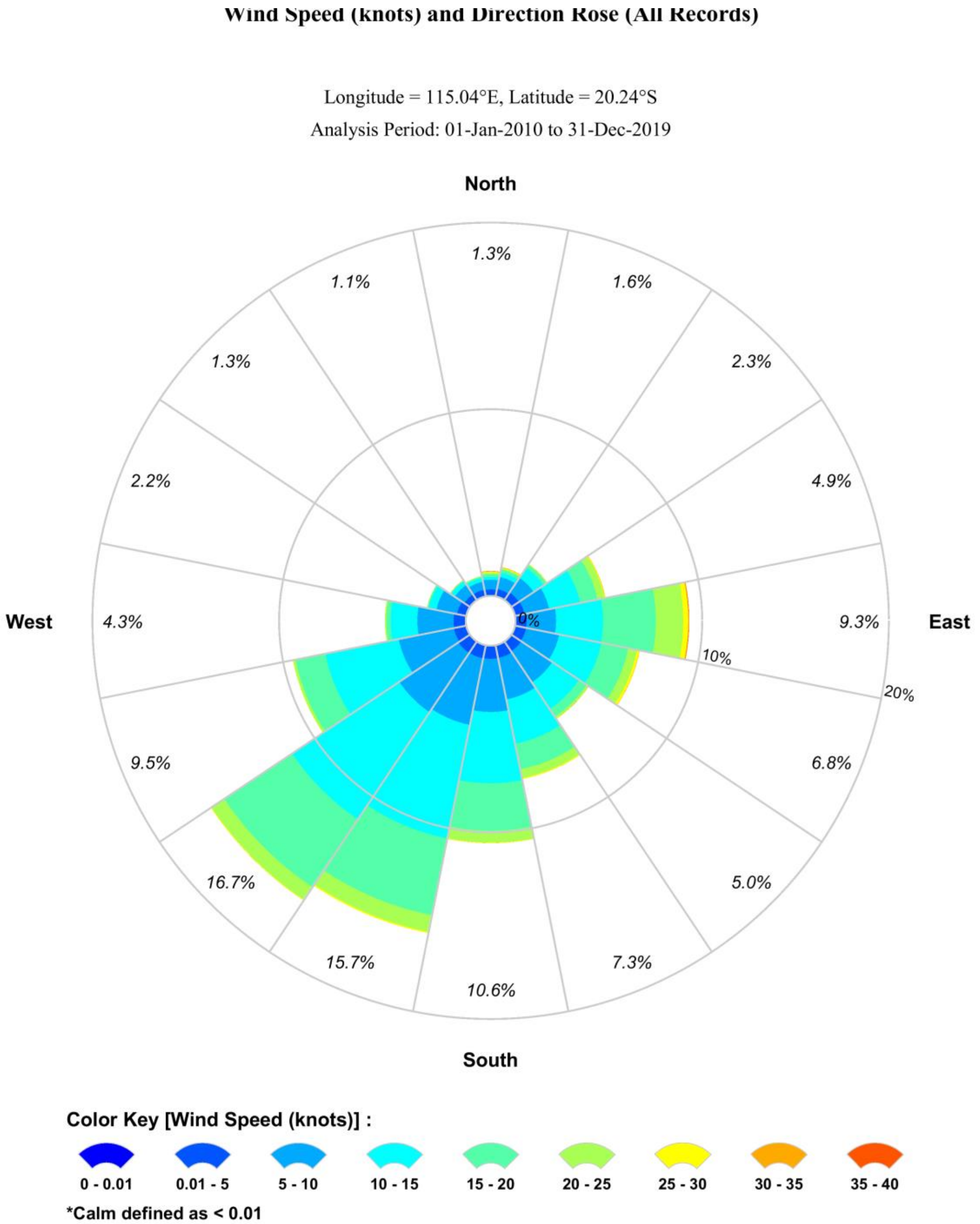


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from the HYbrid Coordinate Ocean Model (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.2°C (September) to 29.6°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.6–35.3 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	27.8	28.6	29.6	28.7	27.9	27.0	25.3	24.5	24.2	25.0	27.3	27.0
Salinity (psu)	35.1	34.9	35.0	35.1	35.2	35.3	34.9	34.8	34.9	34.9	34.6	34.9

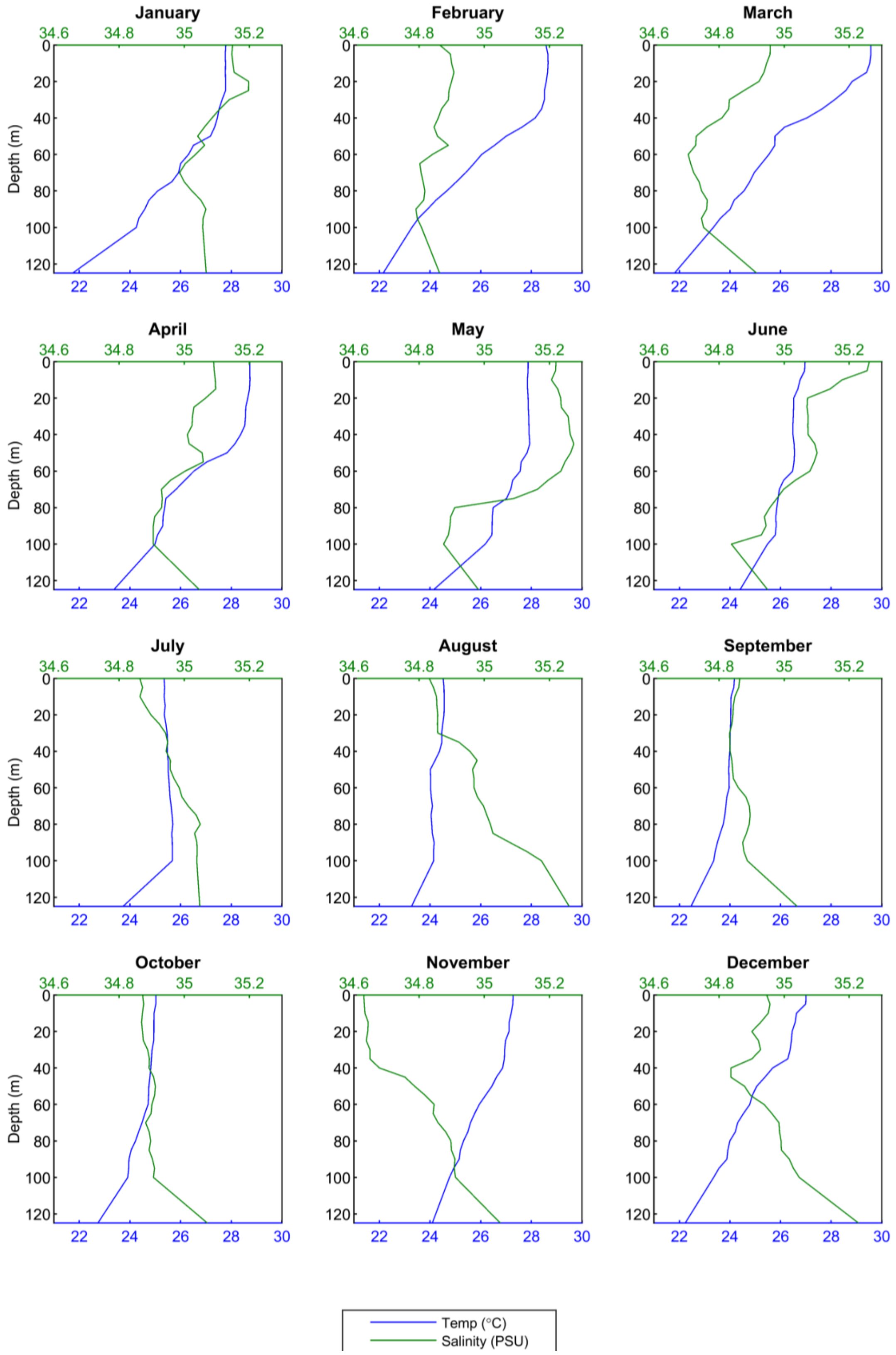


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 SUBSEA PLUME MODEL – OILMAP DEEP

The LOWC scenario is a high-pressure release of mostly gas and condensate and where gas is released with condensate, the buoyancy of the expanding gas cloud will entrain ambient seawater and propel the droplets towards the surface at a faster rate than would occur from the relative buoyancy of the condensate alone. Furthermore, the turbulence generated by such an intense discharge will tend to break the condensate up into droplets of various sizes.

To define the near-field plume dynamics, the subsea blowout model, OILMAP-DEEP, was applied. The model simulates the plume rise dynamics in two phases, the initial jet phase and the buoyant plume phase. The initial jet phase governs the plume dynamics directly above the subsurface release location and is predominately driven by the exit velocity. During this phase, the condensate droplet size and distribution is calculated. Next, the rise dynamics are dominated by the buoyant nature of the plume until the termination of the plume phase (known as the trapping depth). At this point, the results from OILMAP-DEEP (including plume trapping depth, plume diameter and droplet size distribution) are integrated into the far-field model SIMAP to simulate the rise and dispersion of the condensate droplets.

More details on the OILMAP-DEEP model, can be found in Spaulding et al. (2015). The model has been validated against observations from Deepwater Horizon as well as small and large-scale laboratory studies on subsurface oil releases (Brandvik et al., 2013, 2014; Belore, 2014; Spaulding et al., 2015; Li et al., 2017).

Table 6.1 presents the input parameters for the OILMAP-DEEP model and key results related to the near-field plume dynamics. The results indicated that the mixture of gas and condensate rose through the water column (whilst gradually losing momentum) to a trapping depth of less than 1 m below mean sea level. The modelling predicted droplets ranging in size from 175 to 756 μm.

Figure 6.1 illustrates the various stages of an example blowout plume.

Table 6.1 Input data and key results for the subsea plume modelling.

Input Variable	Value
Scenario	Loss of Well Control
Well name	WTR Well 5
Water depth (m)	150
Tubing diameter (inch) [m]	7 5/8 [0.194]
Condensate rate (stb/day)	4,302
Gas rate (MMscf/day)	310
Gas to condensate ratio (scf/bbl)	72,060
Formation water flow rate (stb/day)	0
Operating pressure (psia)	6,220
Key results	
Plume execution depth (m BMSL)	<1
Droplet sizes (μm)	175 to 756

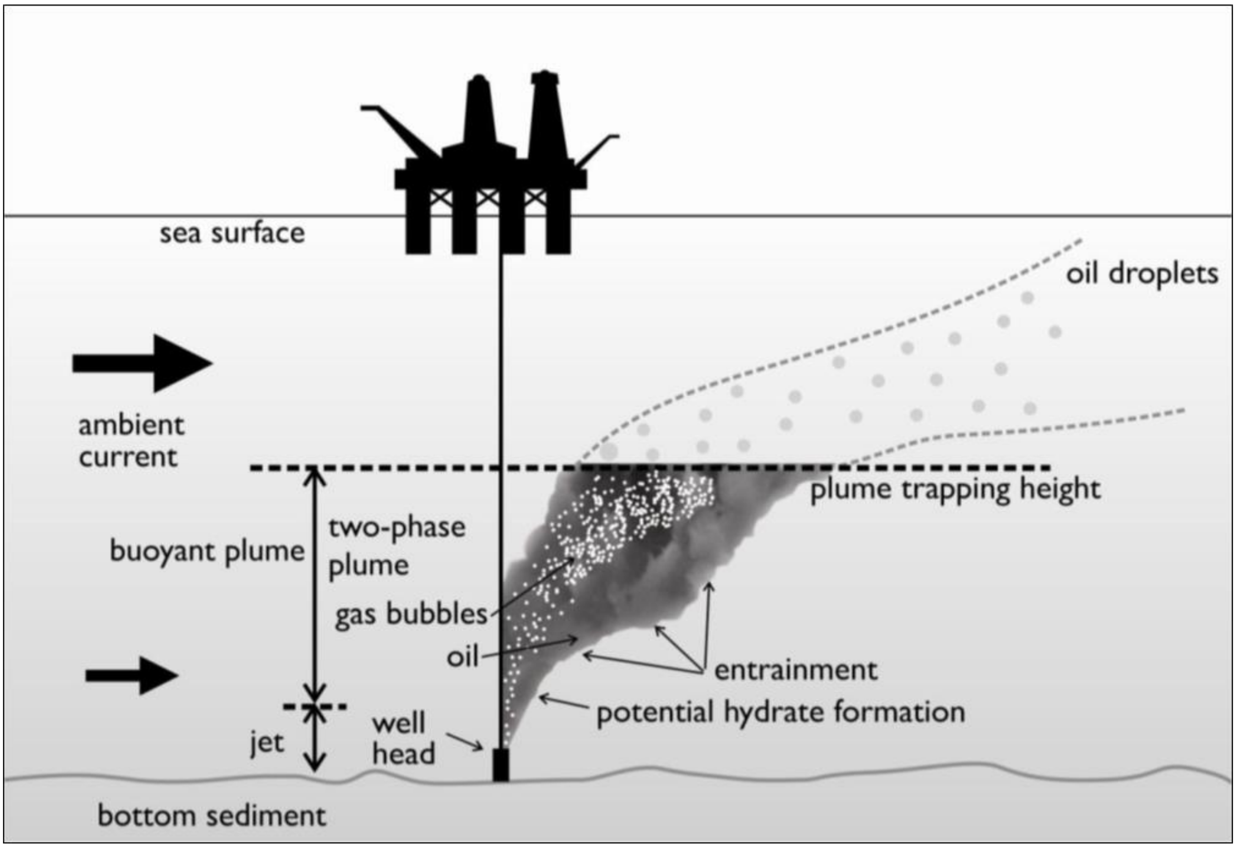


Figure 6.1 Example of a subsea plume and the various stages of the plume in the water column (Source: ASA, 2011).

7 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application.

The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

7.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 7.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and

- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

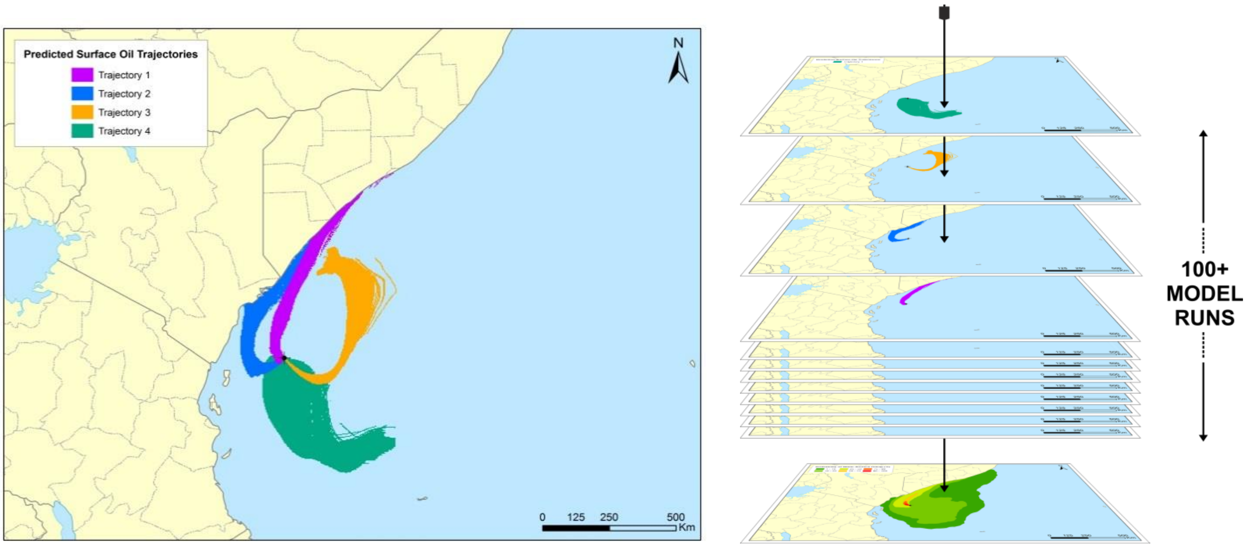


Figure 7.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

7.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 7.2.1 to 7.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

7.2.1 Floating Oil Exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating oil exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil exposure, was 1 g/m^2, which equates approximately to an average thickness of 1 μm, referred to as visible oil. Oil of this thickness is described as rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement, 2009; AMSA, 2014) (see Table 7.1). Figure 7.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. This threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to its visibility on the sea surface and potential to trigger temporary closures of areas (i.e. fishing grounds) as a precautionary measure. Table 7.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil exposure.

Ecological impact has been estimated to occur at 10 g/m^2 (a film thickness of approximately 10 μm or 0.01 mm) according to French et al. (1996) and French-McCay (2009) as this level of fresh oiling has been observed to mortally impact some birds through adhesion of oil to their feathers, exposing them to secondary effects such as hypothermia. The appearance of oil at this average thickness has been described as a metallic sheen (Bonn Agreement, 2009). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at oil concentrations on the sea surface of 25 g/m^2 (or greater), would be harmful for all birds that have landed in an oil film due to potential contamination of their feathers, with secondary effects such as loss of temperature regulation and ingestion of oil through preening. The appearance of oil at this thickness is also described as metallic sheen (Bonn Agreement, 2009). For this study the high exposure threshold was set to 50 g/m^2 and above based on NOPSEMA (2019). This threshold can also be used to inform response planning.

Table 7.2 defines the thresholds used to classify the zones of floating oil exposure reported herein.

Table 7.1 The Bonn Agreement Oil Appearance Code.

Code	Description Appearance	Layer Thickness Interval (g/m^2 or µm)	Litres per km^2
1	Sheen (silvery/grey)	0.04 – 0.30	40 – 300
2	Rainbow	0.30 – 5.0	300 – 5,000
3	Metallic	5.0 – 50	5,000 – 50,000
4	Discontinuous True Oil Colour	50 – 200	50,000 – 200,000
5	Continuous True Oil Colour	≥ 200	≥ 200,000

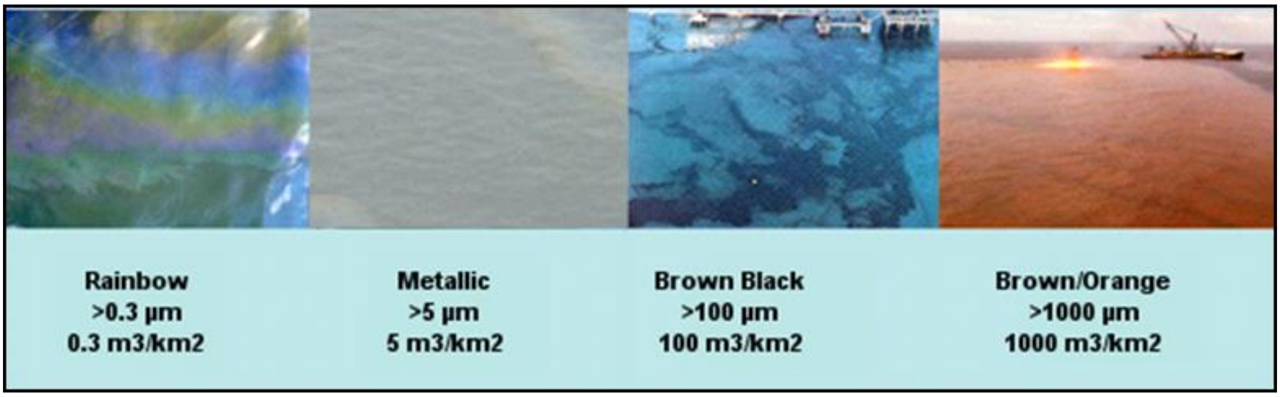


Figure 7.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 7.2 Floating oil exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (g/m^2)	Description
Low	1	Approximates range of socioeconomic effects and establishes planning area for scientific monitoring
Moderate	10	Approximates lower limit for harmful exposures to birds and marine mammals
High	50*	Approximates surface oil slick and informs response planning

* 50 g/m^2 also used to define the threshold for actionable floating oil.

7.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential “low shoreline accumulation”.

French et al. (1996) and French-McCay (2009) define a shoreline oil accumulation threshold of 100 g/m^2, or above, would potentially harm shorebirds and wildlife (furbearing aquatic mammals and marine reptiles on or along the shore) based on studies for sub-lethal and lethal impacts. This threshold has been used in previous environmental risk assessment studies (see French-McCay, 2003; French-McCay et al., 2004, French-McCay et al., 2011; 2012; NOAA, 2013). Additionally, a shoreline concentration of 100 g/m^2, or above, is the minimum limit that the oil can be effectively cleaned according to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential “moderate shoreline accumulation”.

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential “high shoreline accumulation”. It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 7.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 7.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	10	Predicts potential for some socio-economic impact
Moderate	100*	Loading predicts area likely to require clean-up effort
High	> 1,000	Loading predicts area likely to require intensive clean-up effort

* 100 g/m^2 also used to define the threshold for actionable shoreline oil.

7.2.3 In-water Exposure Thresholds

Oil is a mixture of thousands of hydrocarbons of varying physical, chemical, and toxicological characteristics, and therefore, demonstrate varying fates and impacts on organisms. As such, for in-water exposure, the SIMAP model provides separate outputs for dissolved and entrained hydrocarbons from oil droplets. The consequences of exposure to dissolved and entrained components will differ because they have different modes and magnitudes of effect.

Entrained hydrocarbon concentrations were calculated based on oil droplets that are suspended in the water column, though not dissolved. The composition of this oil would vary with the state of weathering (oil age) and may contain soluble hydrocarbons when the oil is fresh. Calculations for dissolved hydrocarbons specifically calculates oil components which are dissolved in water, which are known to be the primary source of toxicity exerted by oil.

7.2.3.1 Dissolved Hydrocarbons

Laboratory studies have shown that dissolved hydrocarbons exert most of the toxic effects of oil on aquatic biota (Carls et al., 2008; Nordtug et al., 2011; Redman, 2015). The mode of action is a narcotic effect, which is positively related to the concentration of soluble hydrocarbons in the body tissues of organisms (French-McCay, 2002). Dissolved hydrocarbons are taken up by organisms directly from the water column by absorption through external surfaces and gills, as well as through the digestive tract. Thus, soluble hydrocarbons are termed “bioavailable”.

Hydrocarbon compounds vary in water-solubility and the toxicity exerted by individual compounds is inversely related to solubility, however bioavailability will be modified by the volatility of individual compounds (Nirmalakhandan & Speece, 1988; Blum & Speece, 1990; McCarty, 1986; McCarty et al., 1992a, 1992b; Mackay et al., 1992; McCarty & Mackay, 1993; Verhaar et al., 1992, 1999; Swartz et al., 1995; French-McCay, 2002; McGrath & Di Toro, 2009). Of the soluble compounds, the greatest contributor to toxicity for water-column and benthic organisms are the lower-molecular-weight aromatic compounds, which are both volatile and soluble in water. Although they are not the most water-soluble hydrocarbons within most oil types, the polynuclear aromatic hydrocarbons (PAHs) containing 2-3 aromatic ring structures typically exert the largest narcotic effects because they are semi-soluble and not highly volatile, so they persist in the environment long enough for significant accumulation to occur (Anderson et al., 1974, 1987; Neff & Anderson, 1981; Malins & Hodgins, 1981; McAuliffe, 1987; NRC, 2003). The monoaromatic hydrocarbons (MAHs), including the BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), and the soluble alkanes (straight chain hydrocarbons) also contribute to toxicity, but these compounds are highly volatile, so that their contribution will be low when oil is exposed to evaporation and higher when oil is discharged at depth where volatilisation does not occur (French-McCay, 2002).

French-McCay (2002) reviewed available toxicity data, where marine biota was exposed to dissolved hydrocarbons prepared from oil mixtures, finding that 95% of species and life stages exhibited 50% population mortality (LC_{50}) between 6 and 400 ppb total PAH concentration after 96 hrs exposure, with an average of 50 ppb. Hence, concentrations lower than 6 ppb total PAH value should be protective of 97.5% of species and life stages even with exposure periods of days (at least 96 hours). Early life-history stages of fish appear to be more sensitive than older fish stages and invertebrates.

Exceedances of 10, 50 or 400 ppb over a 1 hour timestep (see Table 7.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on NOPSEMA (2019).

7.2.3.2 Entrained Hydrocarbons

Entrained hydrocarbons consist of oil droplets that are suspended in the water column and insoluble. As such, insoluble compounds in oil cannot be absorbed from the water column by aquatic organisms, hence are not bioavailable through absorption of compounds from the water. Exposure to these compounds would require routes of uptake other than absorption of soluble compounds. The route of exposure of organisms to whole oil alone include direct contact with tissues of organisms and uptake of oil by direct consumption, with potential for biomagnification through the food chain (NRC, 2003).

The 10 ppb threshold represents the very lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the ANZECC & ARMCANZ (2000) water quality guidelines. Due to the requirement for relatively long exposure times (> 24 hours) for these concentrations to be significant, they are likely to be more meaningful for juvenile fish, larvae and planktonic organisms that might be entrained (or otherwise moving) within the entrained plumes, or when entrained hydrocarbons adhere to organisms or trapped against a shoreline for periods of several days or more.

This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the entrained hydrocarbon at this level.

Thresholds of 10 ppb and 100 ppb were applied over a 1 hour time exposure (Table 7.4), to cover the range of thresholds outlined in the ANZECC & ARMCANZ (2000) water quality guidelines, the incremental change for greater potential effect and is per NOPSEMA (2019).

A complicating factor that should be considered when assessing the consequence of dissolved and entrained oil distributions is that there will be some areas where both physically entrained oil droplets and dissolved hydrocarbons co-exist. Higher concentrations of each will tend to occur close to the source where sea conditions can force mixing of relatively unweathered oil into the water column, resulting in more rapid dissolution of soluble compounds.

Table 7.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

8 HYDROCARBON PROPERTIES

8.1 Condensate Properties

West Tryal Rocks condensate physical properties and boiling point distributions were provided by Chevron and are presented in Table 8.1 and Table 8.2, respectively.

West Tryal Rocks condensate has an API of 41.2, a density of 789 kg/m^3 (at 15ºC) and a low viscosity value of 5.9 cP. When exposed to the atmosphere at local temperatures, about 31.1% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 29.9% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~19.4%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 19.6% of the condensate is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity for the mixture to take up water to form water-in-oil emulsion.

Soluble, aromatic hydrocarbons contribute approximately 3.2% by mass of the whole oil, which is contained in the volatile fractions, which are highly soluble. The process of evaporation will be greater under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

The actual fate will depend greatly on the amount that reaches the surface, either through the initial release or by resurfacing.

Table 8.1 Physical properties of West Tryal Rocks condensate.

Characteristic	West Tryal Rocks Condensate
Density (kg/m^3)	817 (at 15°C)
API	41.2
Dynamic viscosity (cP)	5.9 (at 15°C)
Pour point (°C)	0
Surface tension (dyne/cm)	23
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light-persistent

Table 8.2 Boiling point ranges of West Tryal Rocks condensate.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 >C_{20}
West Tryal Rocks Condensate	% of total	31.1	29.9	19.4	19.6
	% of aromatics	3.2	0.0	0.0	0.0

8.2 Condensate Weathering Characteristics

8.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this condensate when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.
- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the condensate reaches the surface.

8.2.2 Results

The mass balance forecast for the calm-wind case (Figure 8.1) shows that 61.1% of the condensate is predicted to evaporate within 24 hours. Majority of the remaining condensate on the water surface will weather at a slower rate due to the low volatile components. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.2), where the winds are of greater strength on average, entrainment of West Tryal Rocks condensate into the water column is predicted to increase. Approximately 24 hours after the spill, 51.6% of the condensate mass is forecast to have entrained and a further 45.1% is forecast to have evaporated, leaving only a small proportion of the condensate floating on the water surface (1.5%). The residual compounds will tend to remain entrained beneath the surface under conditions that generate wind waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case will result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and condensate droplets in the water column occurs at an approximate rate of 1.66% per day with an accumulated total of 11.6% after 7 days, in comparison to a rate of 0.22% per day and an accumulated total of 1.59% after 7 days in the constant-wind case. Given the proportion of entrained condensate and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

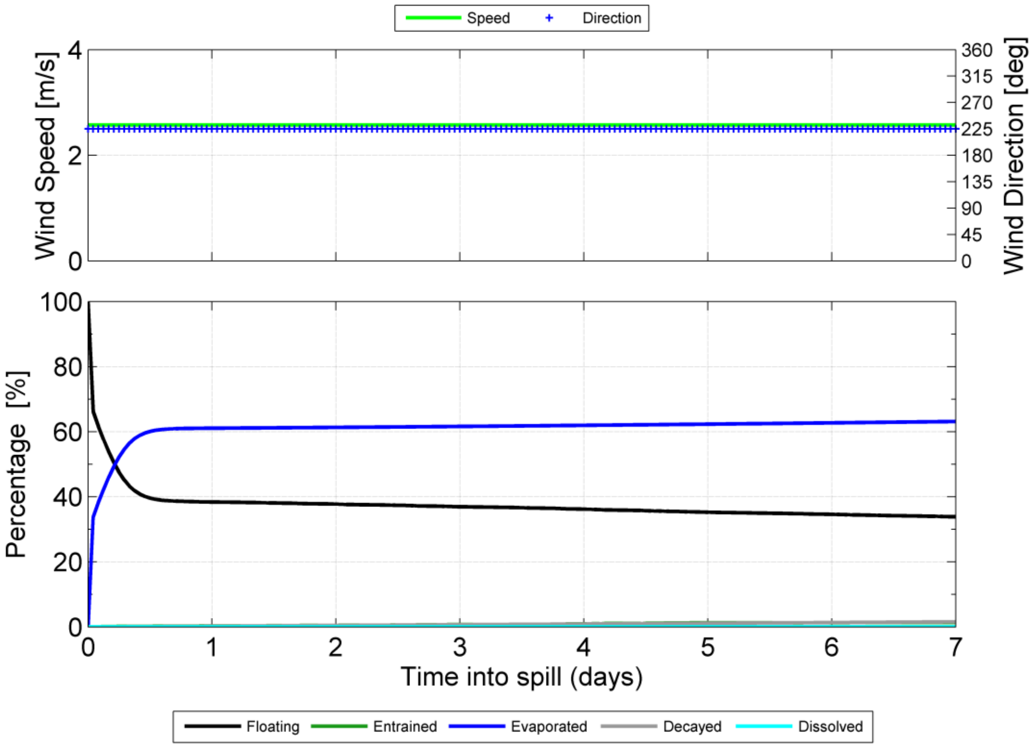


Figure 8.1 Proportional mass balance plot representing the weathering of West Tryal Rocks condensate spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature.

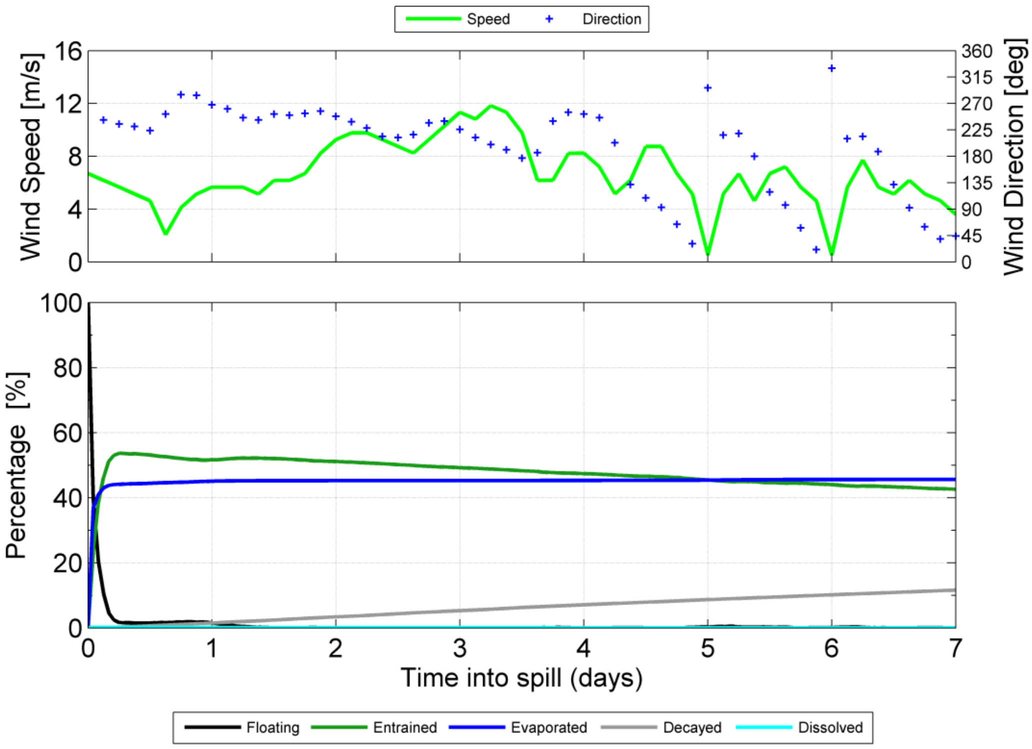


Figure 8.2 Proportional mass balance plot representing the weathering of West Tryal Rocks condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature.

8.3 Marine Diesel Oil Properties

The marine diesel oil (MDO) physical properties and boiling point distributions are presented in Table 8.3 and Table 8.4, respectively.

The MDO has an API of 37.60, a density of 829 kg/m^3 (at 25ºC) and a low viscosity value of 4.0 cP. When exposed to the atmosphere at local temperatures, about 6.0% of the MDO volatile components should evaporate within the first 12 hours (BP < 180°C); a further 34.6% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (54.4%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 5.0% of the MDO is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation.

The oil is categorised as a group II oil (light-persistent) based on categorisation and classification derived from AMSA (2015) guidelines. The classification is based on the specific gravity of hydrocarbons in combination with relevant boiling point ranges.

The actual fate of released oil in the marine environment will depend greatly on the amount of oil that remains on the surface or is entrained in the water column.

Table 8.3 Physical properties of marine diesel oil.

Characteristic	Marine Diesel Oil
Density (kg/m^3)	829 (at 25°C)
API	37.60
Dynamic viscosity (cP)	4.0 (at 25°C)
Pour point (°C)	-14
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light-persistent

Table 8.4 Boiling point ranges of marine diesel oil.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 >C_{20}
Marine Diesel Oil	% of total	6.0	34.6	54.4	5.0

8.4 Marine Diesel Oil Weathering Characteristics

8.4.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this diesel when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.
- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the diesel reaches the surface.

8.4.2 Results

The mass balance forecast for the calm-wind case (Figure 8.3) shows that 36.1% of the diesel is predicted to evaporate within 24 hours. Majority of the remaining diesel on the water surface will weather at a slower rate due to being comprised of the longer-chain compounds with higher boiling points. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.4), where the winds are of greater strength on average, entrainment of diesel into the water column is predicted to increase. Approximately 24 hours after the spill, 80.5% of the diesel is forecast to have entrained and a further 15.0% is forecast to have evaporated, leaving only a small proportion floating on the water surface (<1%). The residual compounds will tend to remain entrained beneath the surface under conditions that generate wind waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case will result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and diesel droplets in the water column occurs at an approximate rate of 2.90% per day with an accumulated total of 20.3% after 7 days, in comparison to a rate of 0.37% per day and an accumulated total of 2.60% after 7 days in the constant-wind case. Given the proportion of entrained MDO and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

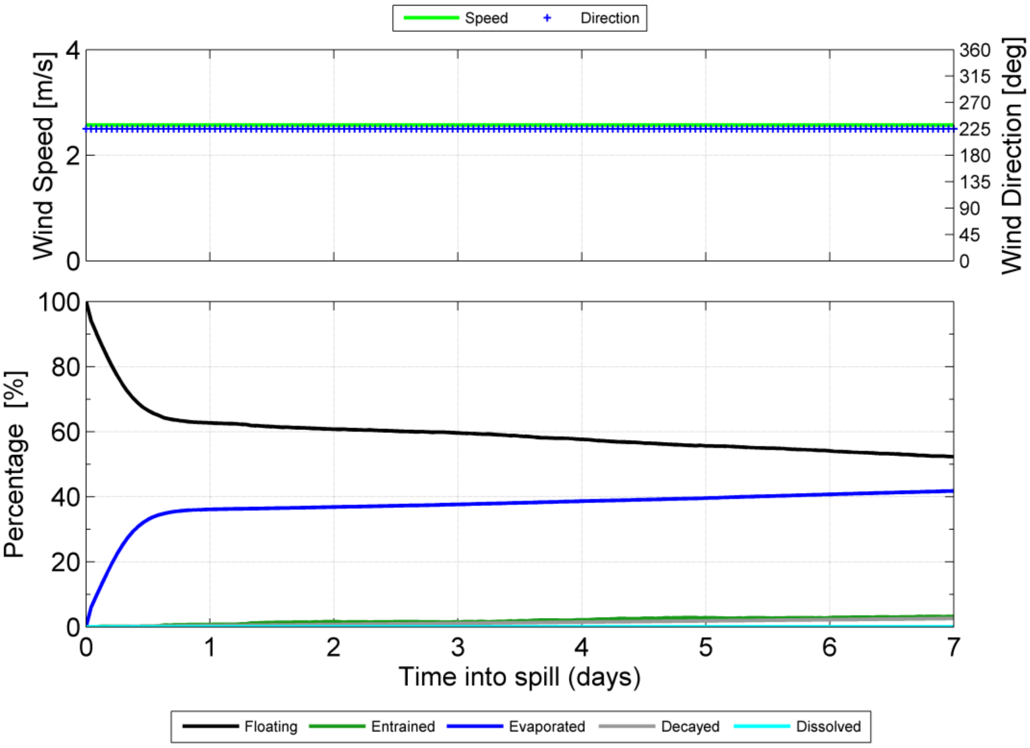


Figure 8.3 Proportional mass balance plot representing the weathering of marine diesel oil spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature.

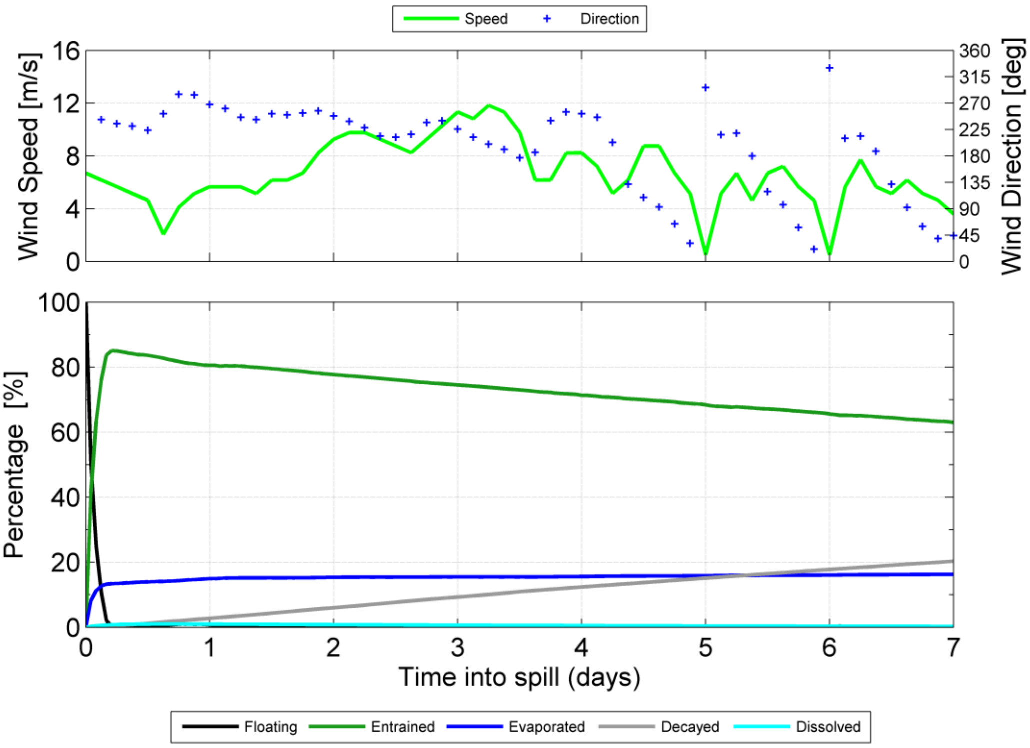


Figure 8.4 Proportional mass balance plot representing the weathering of marine diesel oil spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature.

9 MODEL SETTINGS

Table 9.1 provides a summary of the oil spill model settings.

Table 9.1 Summary of the oil spill model settings used in this assessment.

	Scenario 1	Scenario 2
Location	WTR Well 5	
Number of spill simulations with randomly selected start times	100 per season (300 total)	
Spill volume (m^3) [bbl]	52,665.2 [331,254]	1,500 [238.5]
Condensate type	West Tryal Rocks condensate	MDO
Release type (depth)	Subsea (150 m)	Surface
Release duration (days)	77	1
Simulation length (days)	104	60
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)	
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure	
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure	
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure	
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour, high exposure	

10 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

10.1 Stochastic Analysis

10.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***probability of oil exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***minimum time before oil exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

10.2 Deterministic Trajectories

The deterministic results for both scenarios are based on the following criteria:

a. Largest volume of oil ashore;

b. Minimum time before shoreline accumulation above 10 g/m^2;

c. Longest length of shoreline accumulation above 10 g/m^2;

d. Largest swept area of floating oil above 1 g/m2;

e. Largest area of entrained hydrocarbons above 10 ppb; and

f. Largest area of dissolved hydrocarbons above 10 ppb.

10.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 10.1 to Figure 10.11). Receptor categories (see Table 10.1) include sections of shorelines and offshore islands. All other sensitive receptors other than submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

Table 10.2 summarises the receptors that the location resides within.

Table 10.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	×
Biologically Important Area	BIA	✓	✓	×
Marine Park	MP	✓	✓	×
Marine Management Area	MMA	✓	✓	×
Nature Reserve	NR	✓	✓	×
Integrated Marine and Coastal Regionalisation of Australia	IMCRA	✓	✓	×
Interim Biogeographic Regionalisation of Australia	IBRA	✓	✓	×
Reefs, Shoals and Banks	RSB	✓	✓	×
Key Ecological Feature	KEF	✓	✓	×
Ramsar Sites	Ramsar	✓	✓	×
State Waters	State Waters	✓	✓	×
Impact Assessment Area	IAA	✓	✓	✓
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 10.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Flatback Turtle - Internesting Buffer	BIA	✓
Pygmy Blue Whale - Distribution	BIA	✓
Wedge-tailed Shearwater - Breeding	BIA	✓
Whale Shark - Foraging	BIA	✓
Offshore Area	IAA	✓
Pilbara (offshore)	IMCRA	✓
Ancient coastline at 125 m depth contour	KEF	✓

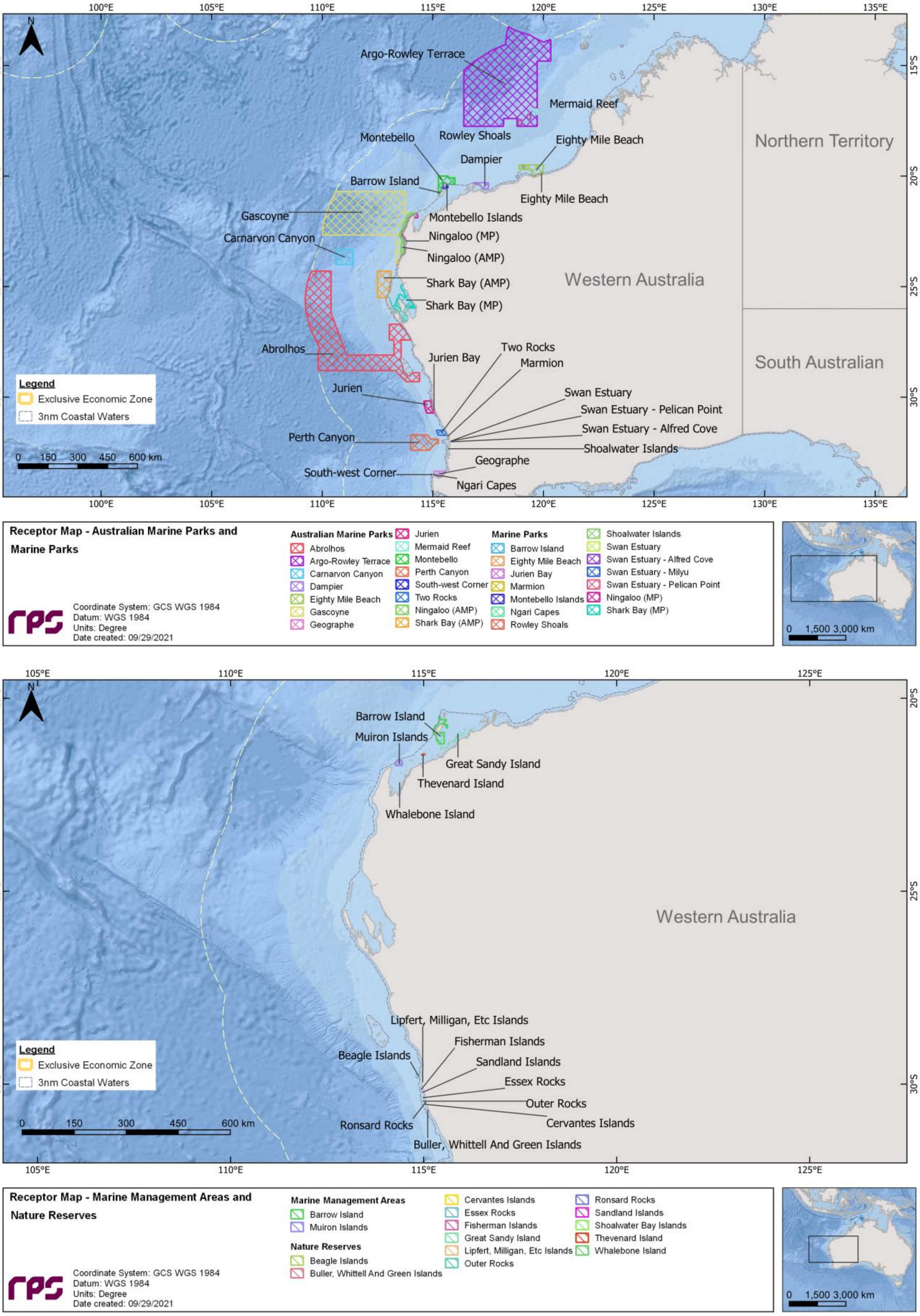
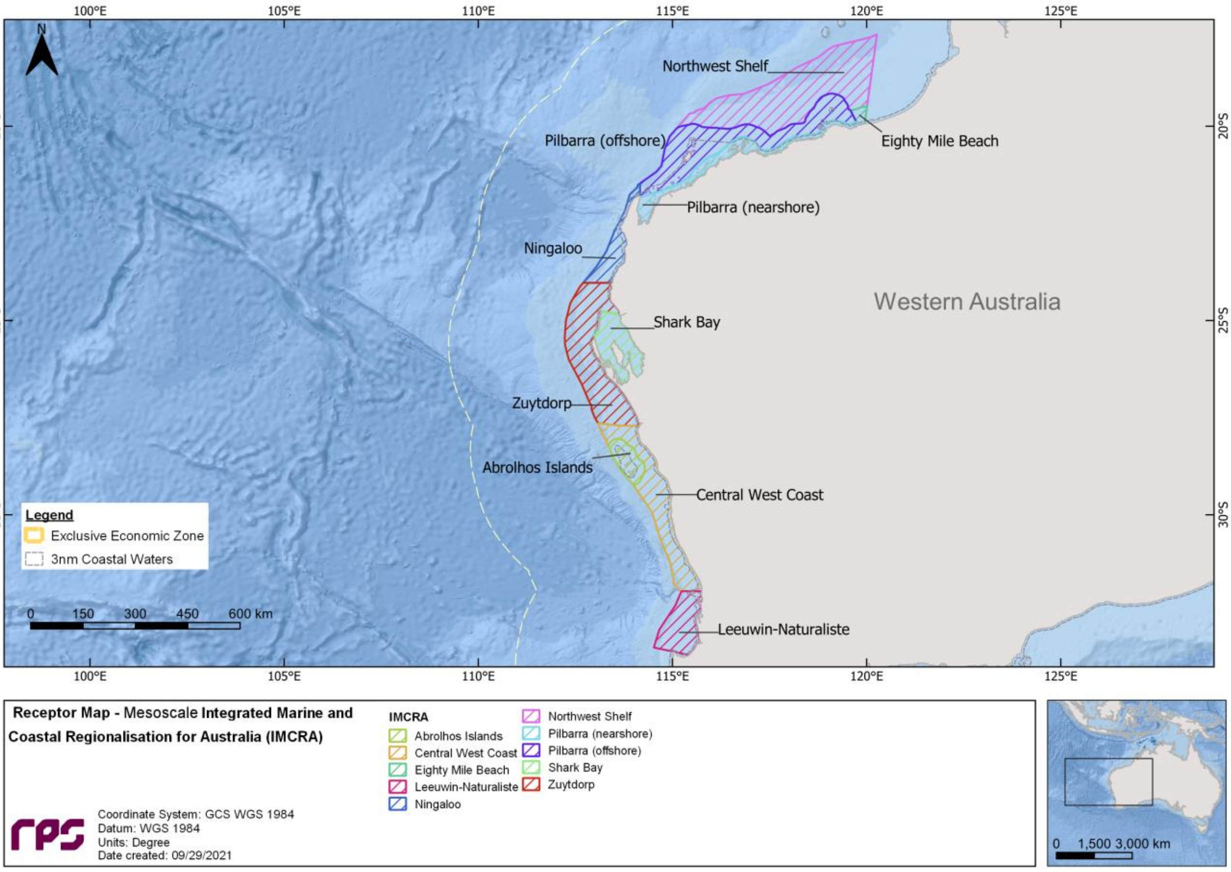


Figure 10.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).



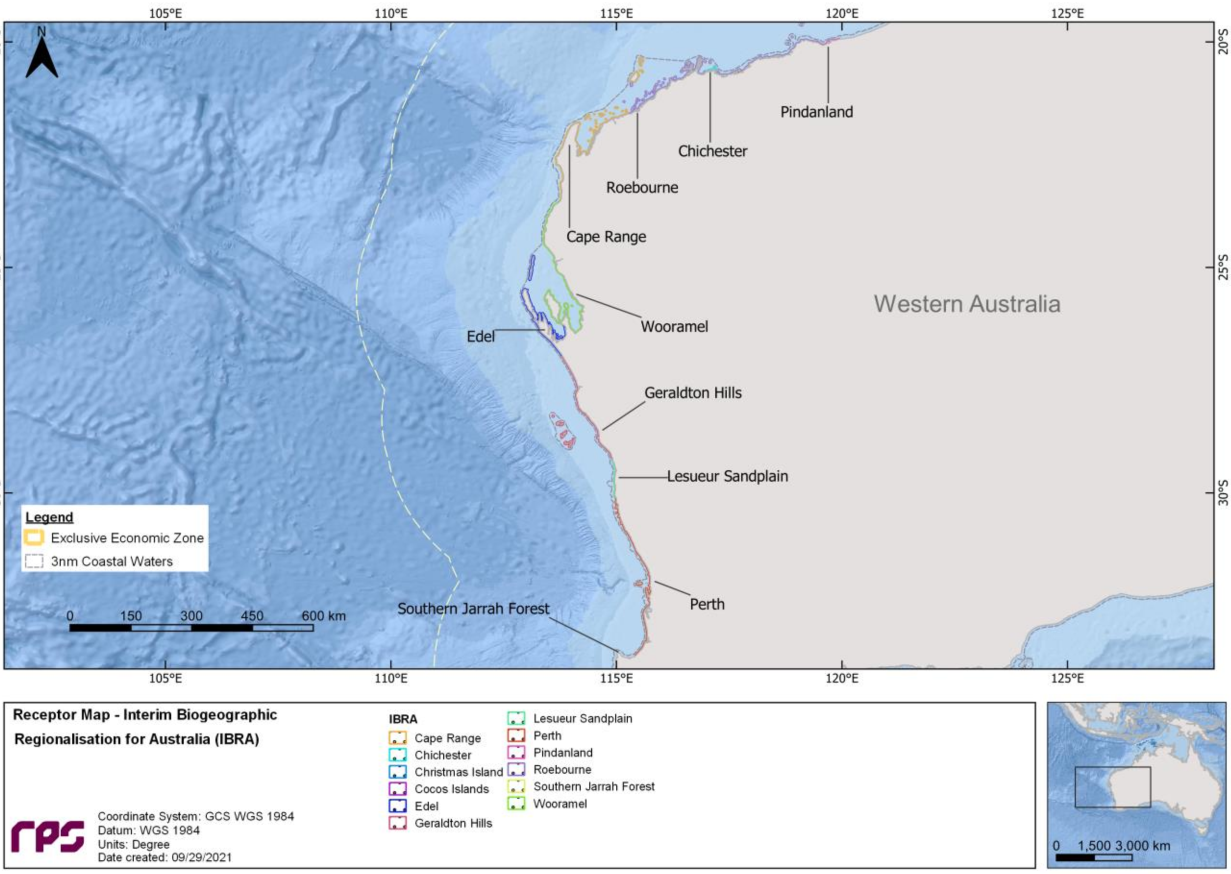
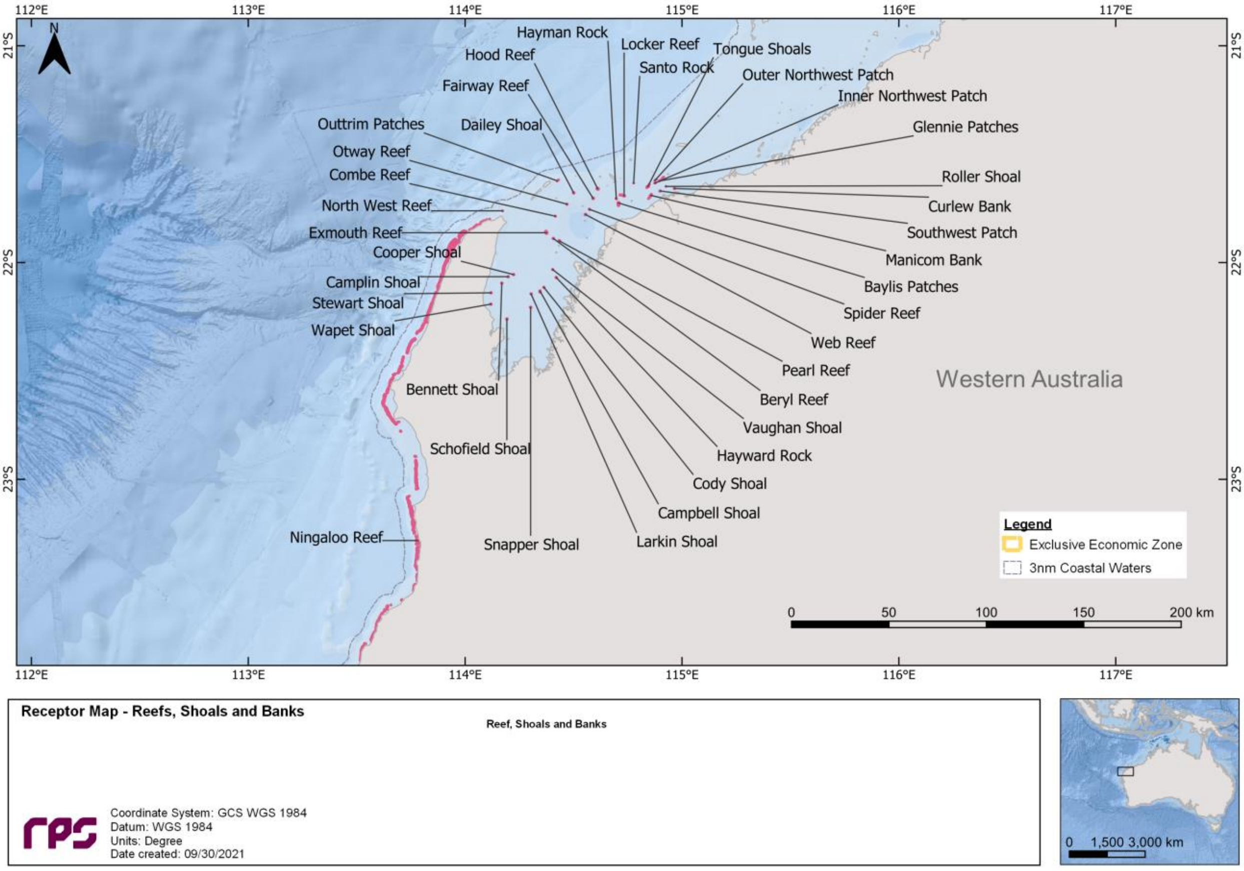


Figure 10.2 Receptor maps for Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).



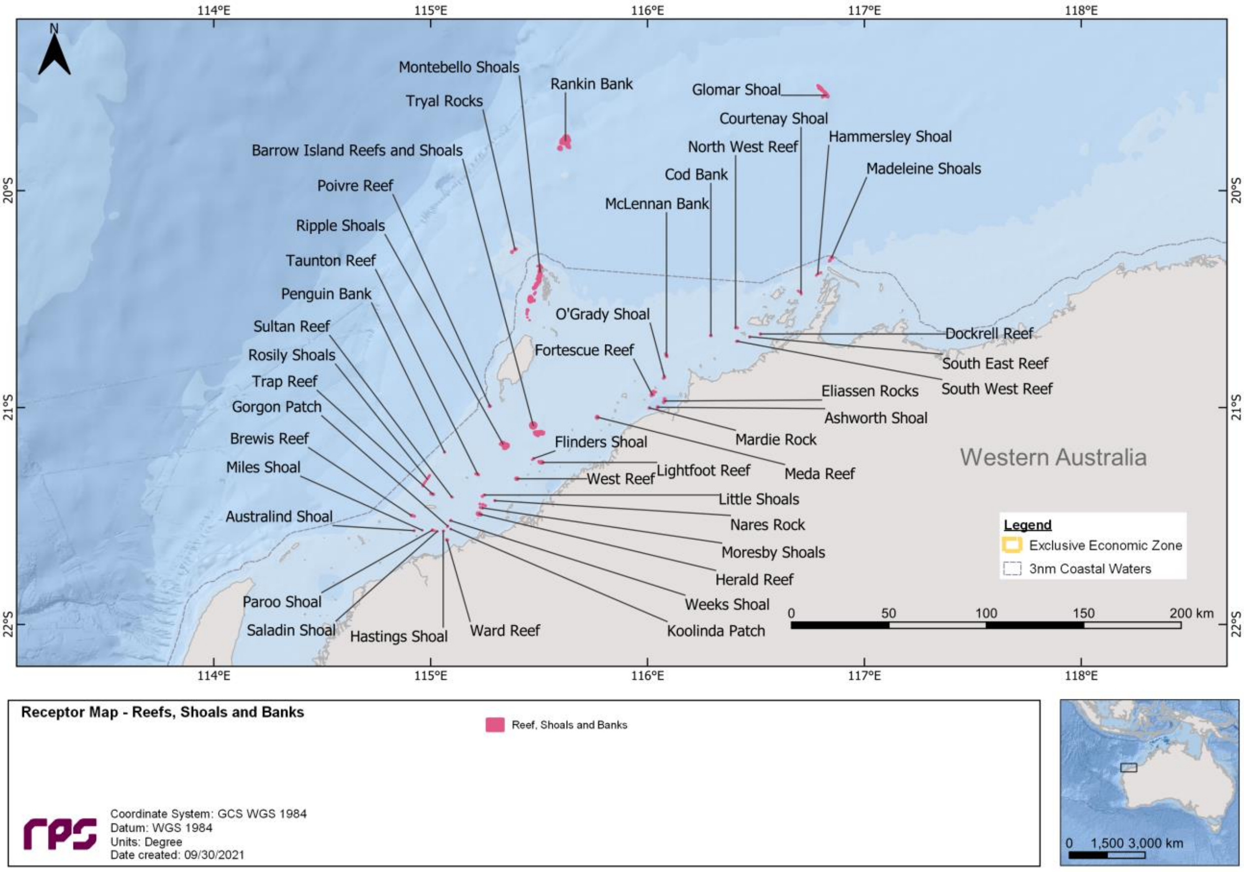


Figure 10.3 Receptor maps for Reefs, Shoals and Banks (RSB).

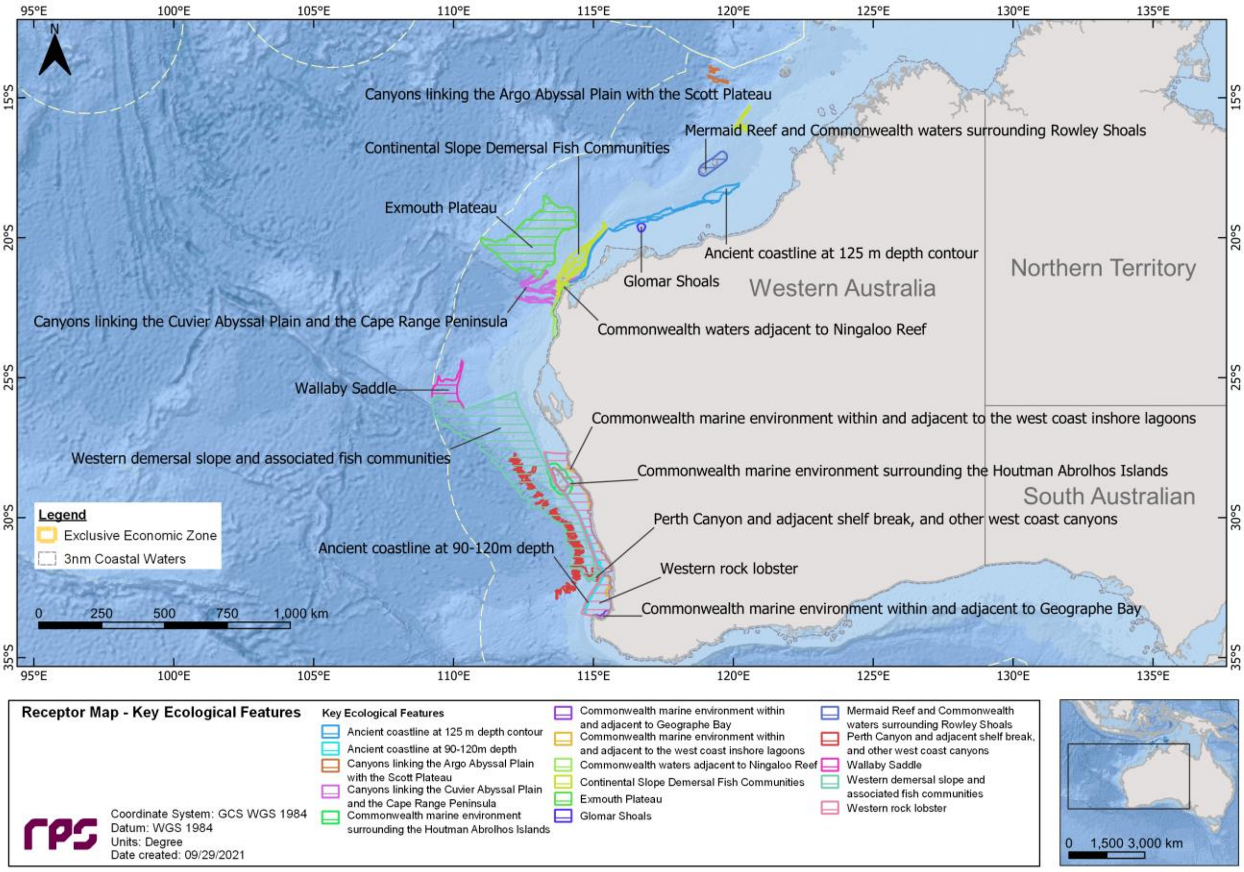


Figure 10.4 Receptor maps for Key Ecological Features (KEFs).

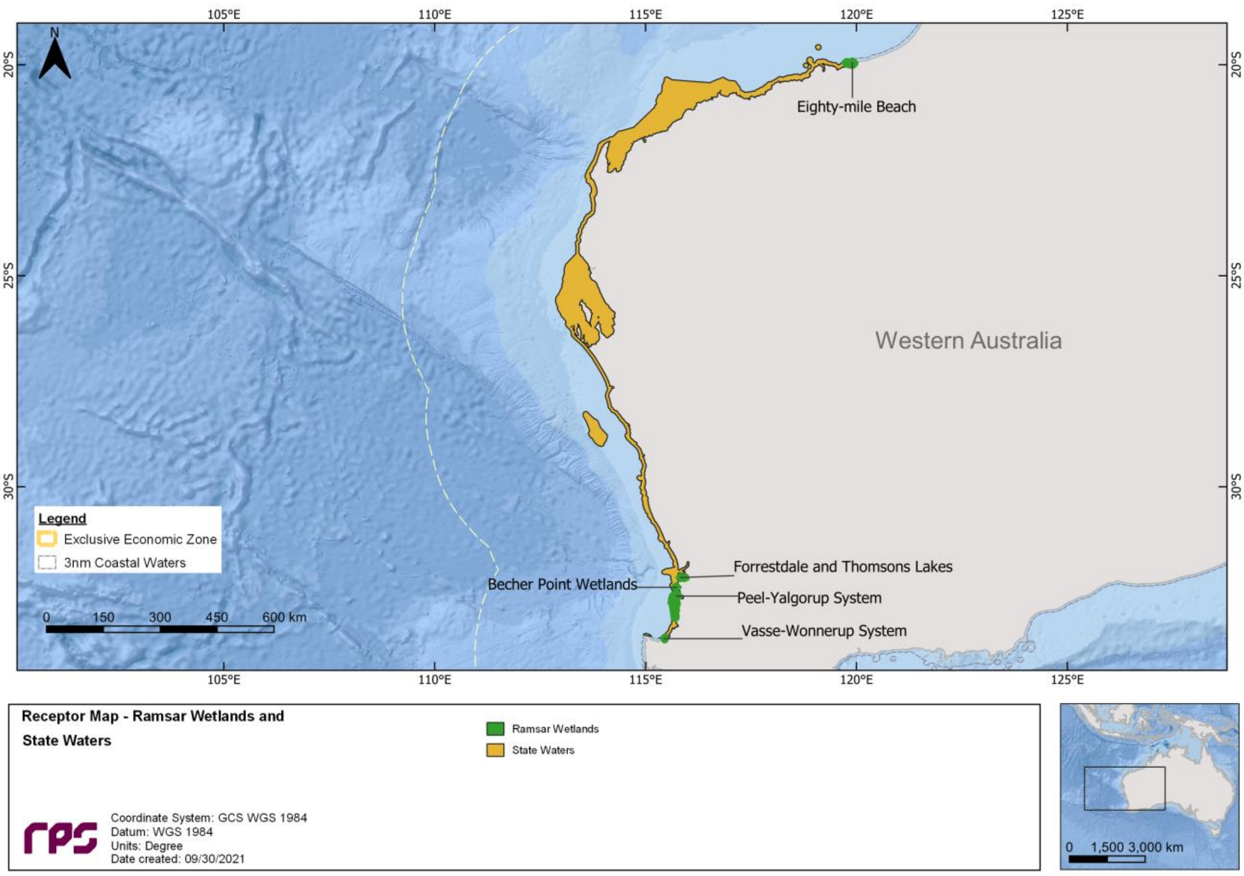
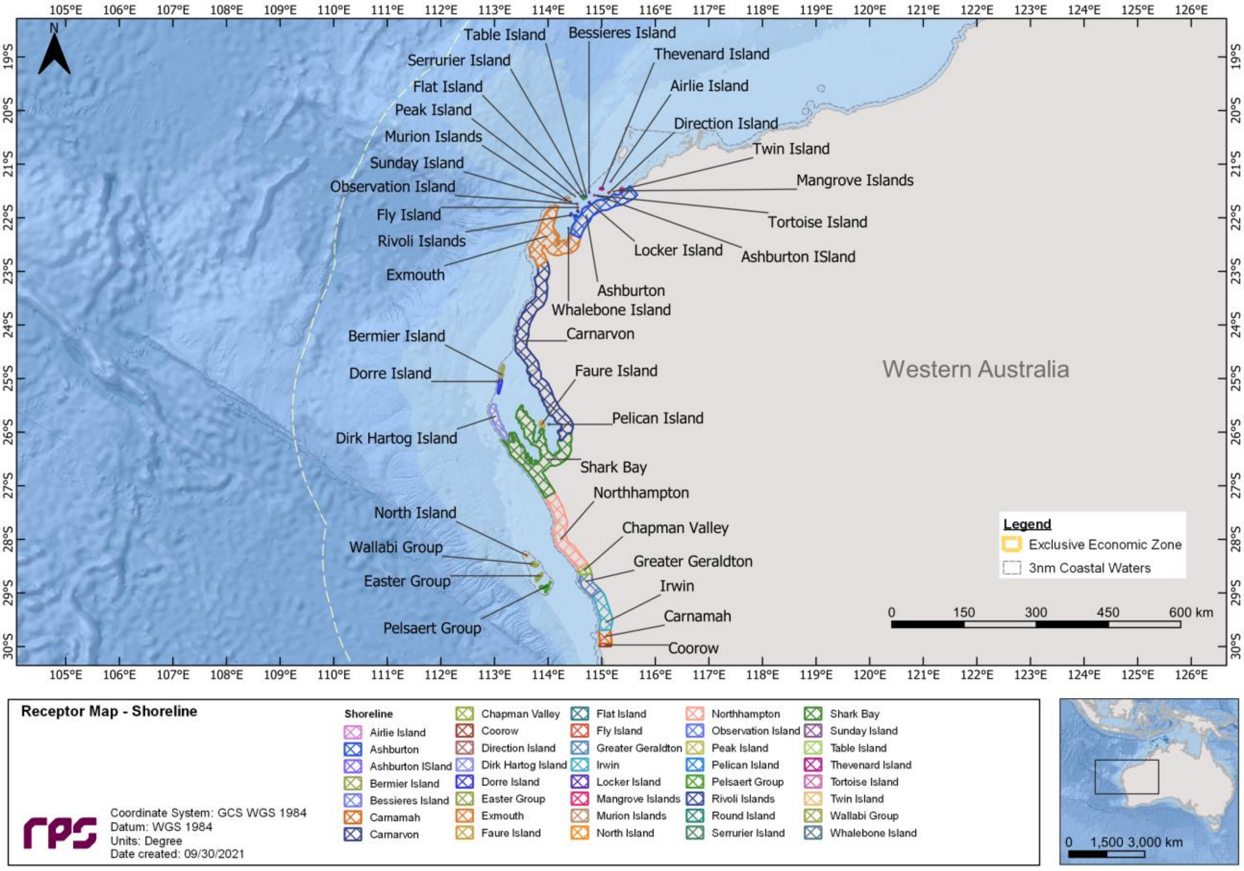


Figure 10.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.



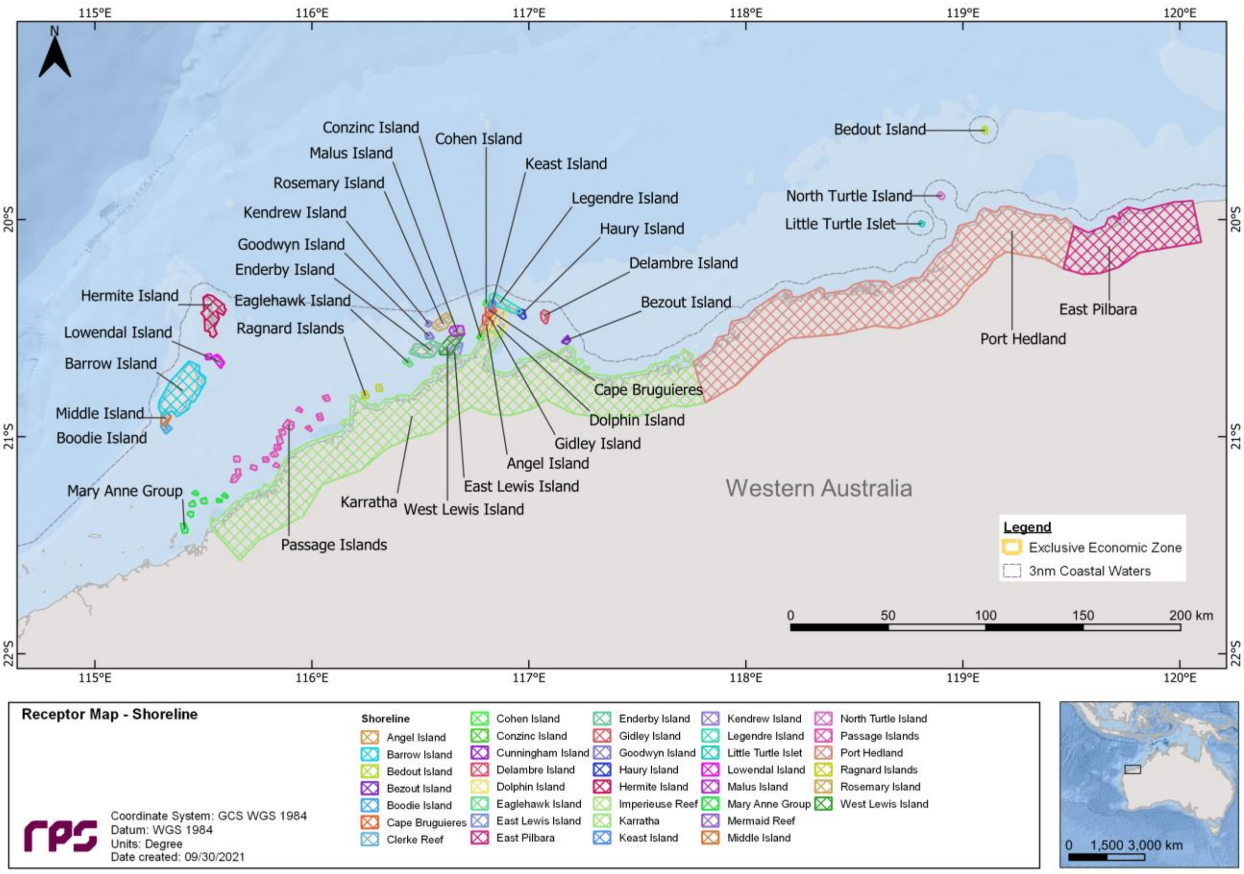


Figure 10.6 Receptor maps for Shorelines (1 of 2).

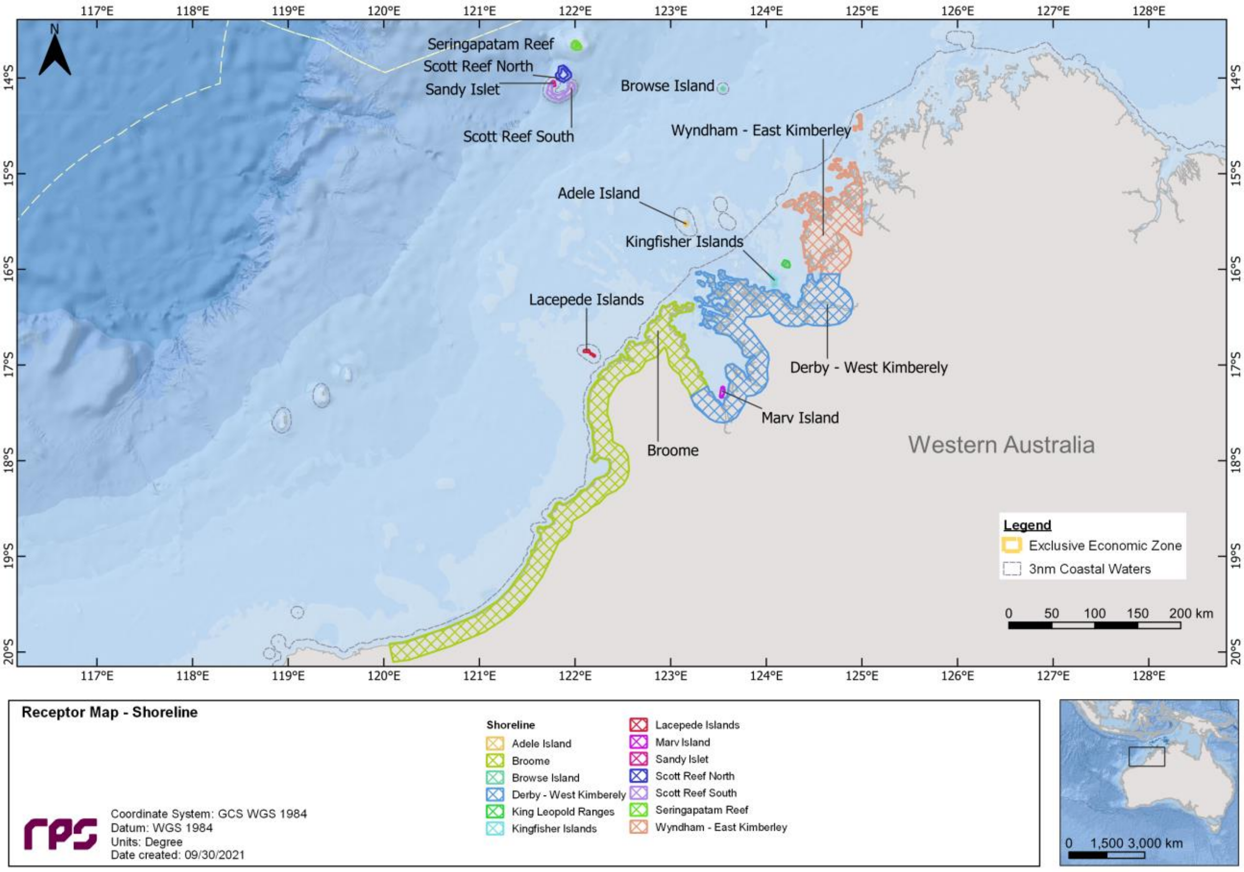


Figure 10.7 Receptor maps for Shorelines (2 of 2).

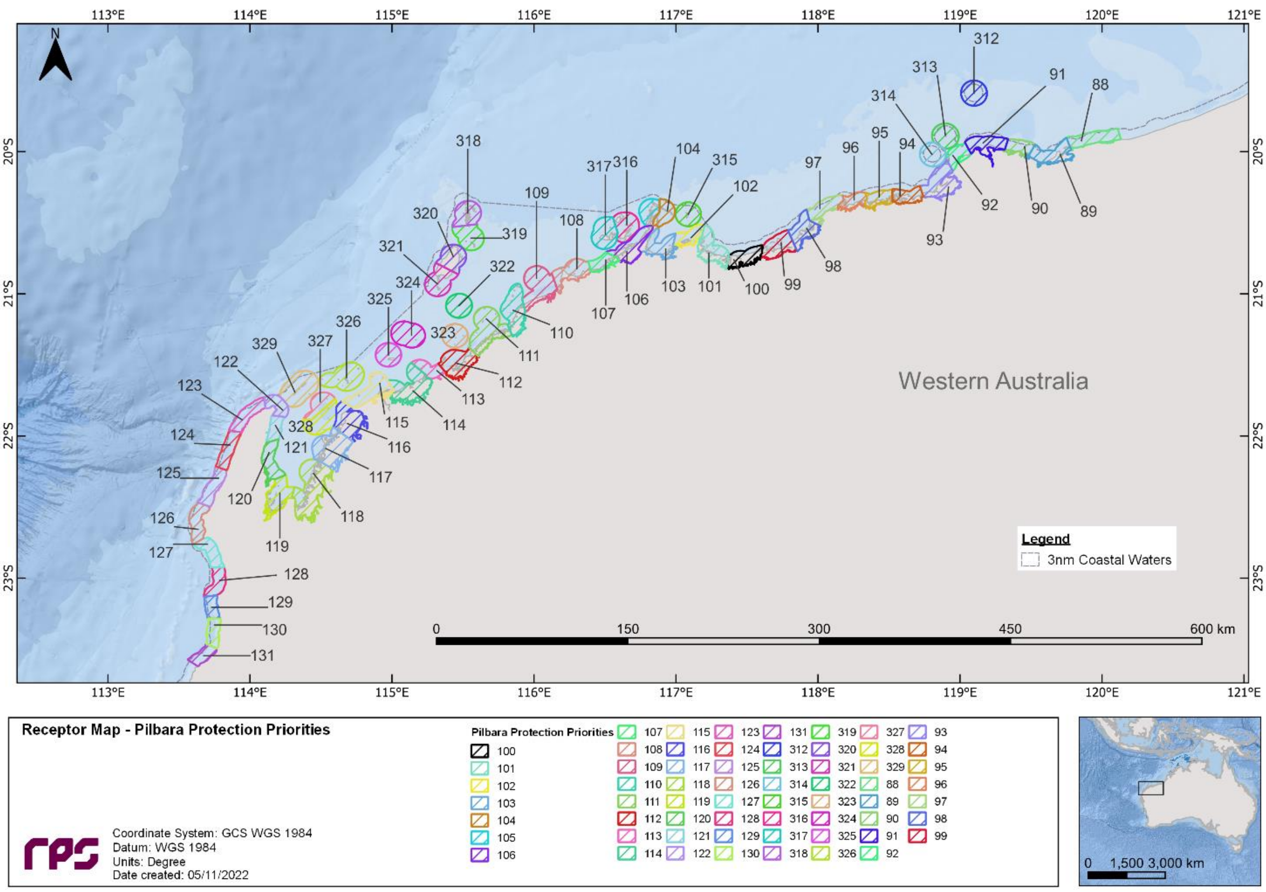


Figure 10.8 Receptor maps for Pilbara Protection Priorities Shorelines.

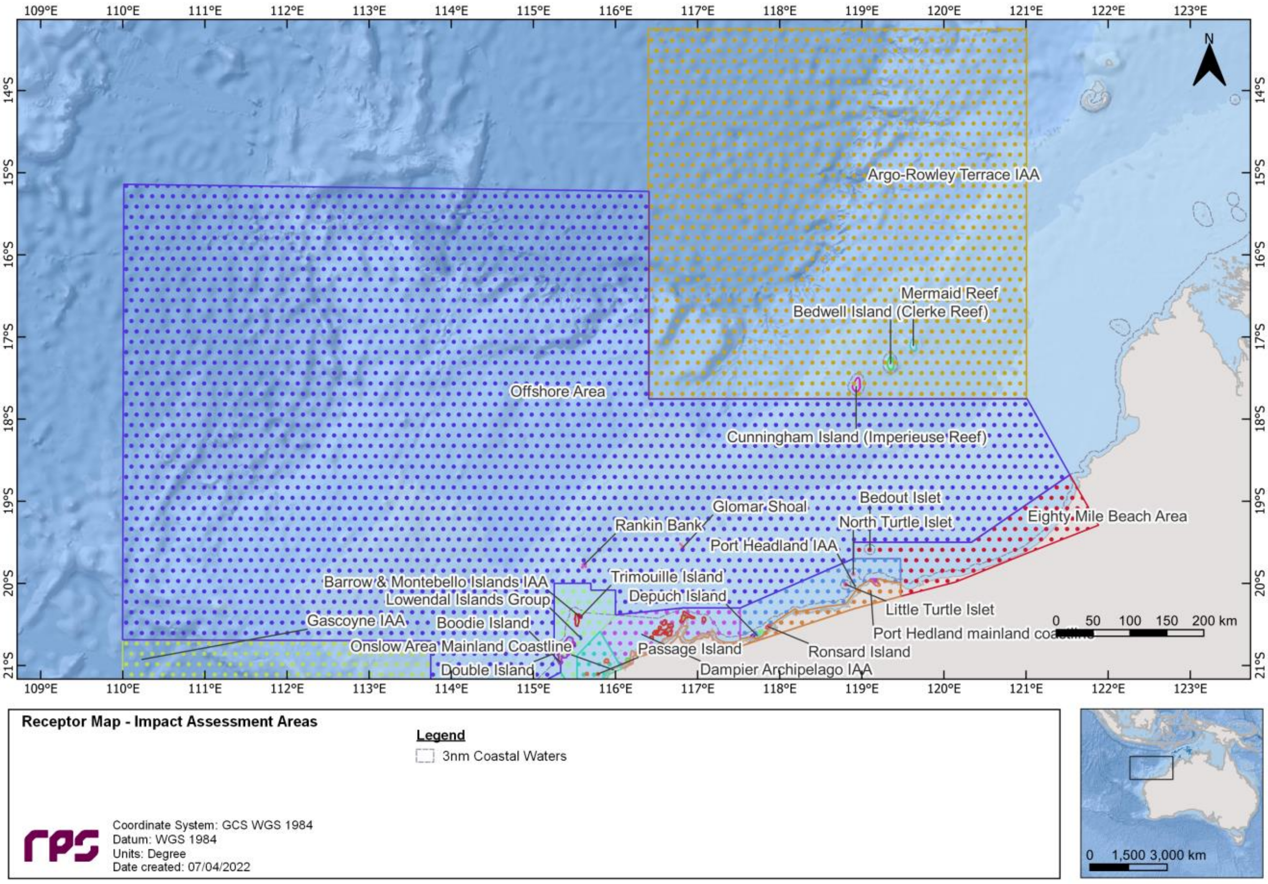


Figure 10.9 Receptor maps for Impact Assessment Areas (1 of 3).

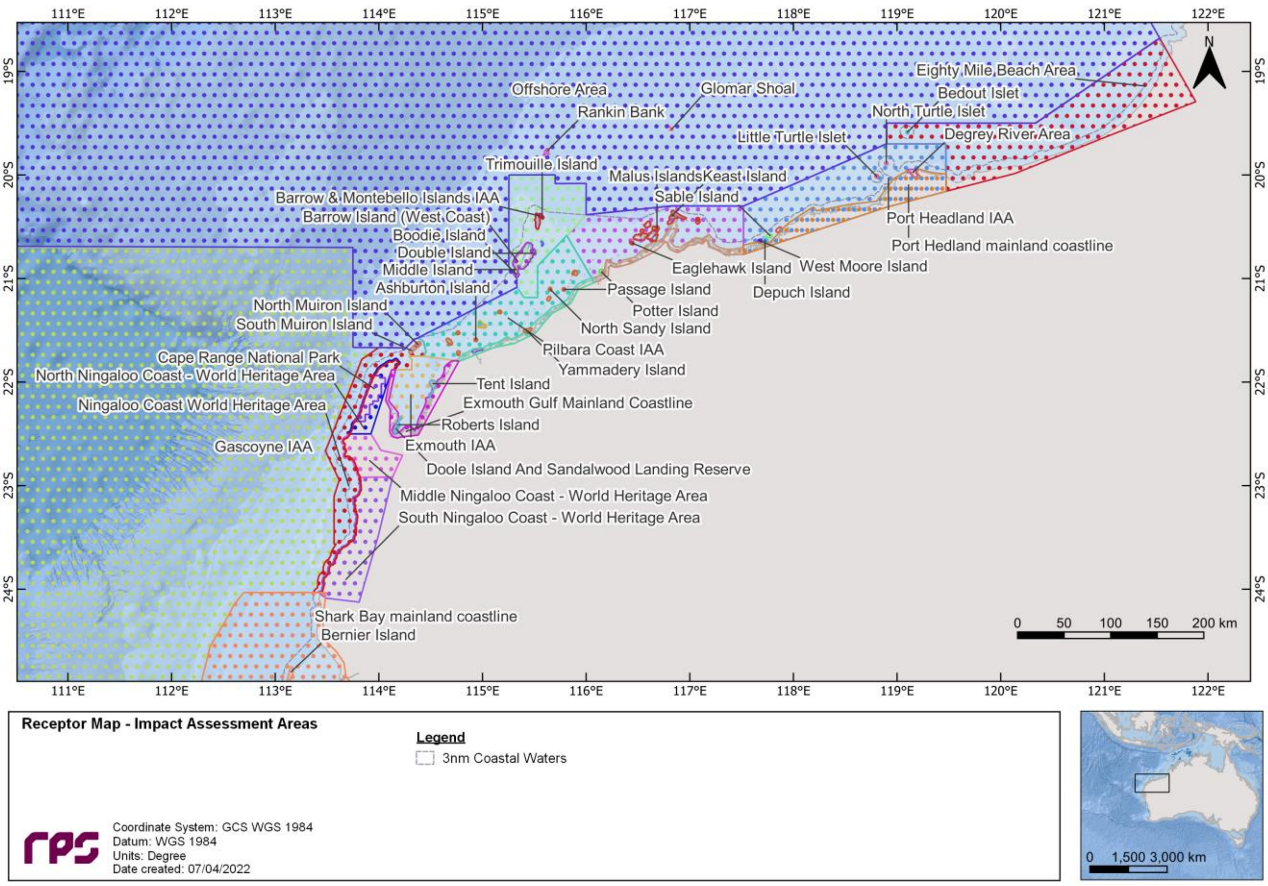


Figure 10.10 Receptor maps for Impact Assessment Areas (2 of 3).

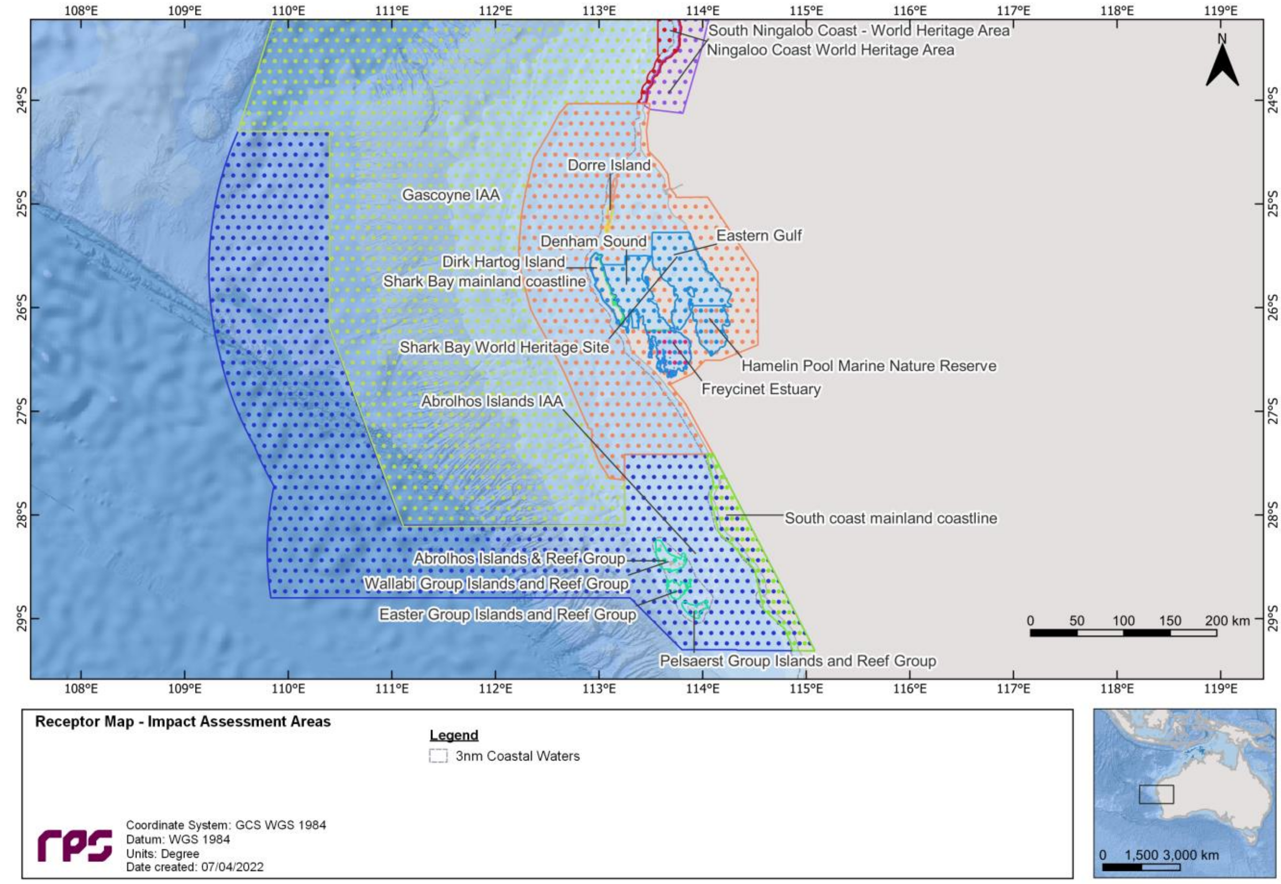


Figure 10.11 Receptor maps for Impact Assessment Areas (3 of 3).

11 RESULTS: WEST TRYAL ROCKS LOSS OF WELL CONTROL

This scenario examined a 331,254 bbl (or 52,665.2 m^3) subsea release of condensate over 77 days, from a LOWC. A total of 300 spill simulations were run for each of the three seasons (i.e. 100 spills per season) and tracked for 104 days.

Section 11.1 presents the seasonal (or stochastic) analysis results, while Section 11.2 presents the deterministic results.

11.1 Stochastic Analysis

11.1.1 Floating Condensate Exposure

Table 11.1 summarises the maximum distances from the release location to floating condensate exposure zones for each season.

The maximum distance from the release location to the low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) threshold was 174.7 north (transitional), 42.1 km northeast (summer and transitional) and 4.6 km west-southwest (winter), respectively.

Table 11.2 summarises the potential floating condensate exposure to individual receptors during each season.

The Offshore Area IAA, Flatback Turtle - Internesting Buffer, Pygmy Blue Whale – Distribution, Wedge-tailed Shearwater - Breeding, Whale Shark – Foraging BIAs, Pilbara (offshore) IMCRA, and the Ancient coastline at 125 m depth contour KEF, which the release location resides within (see Section 10.3), and the Flatback Turtle - Nesting and Humpback Whale - Migration BIAs were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. With the exception of Flatback Turtle - Nesting and Humpback Whale - Migration BIAs, the probabilities for the low and moderate thresholds was 100% for all seasons for these receptors. The probabilities of low and moderate exposure at the Flatback Turtle - Nesting ranged between 79–92% and 17–26%, whilst the probabilities of low and moderate exposure at the Humpback Whale - Migration ranged between 94–100% and 8–19%, respectively. The minimum times before low exposure for the Flatback Turtle - Nesting BIA and Humpback Whale - Migration BIA were 0.96 days and 0.71 days during summer conditions, respectively. Furthermore, the probability of exposure at the low threshold for the Montebello AMP and Continental Slope Demersal Fish Communities KEF was 73%, 41% and 43% during summer, transitional and winter conditions and 100%, 100% and 100% during summer, transitional and winter conditions, respectively. The corresponding minimum time before low exposure Montebello AMP and Continental Slope Demersal Fish Communities KEF was 1.46 days (winter) and 0.38 days (summer).

Figure 11.1 to Figure 11.3 present the zones of floating condensate exposure for each season.

Table 11.1 Maximum distances and directions travelled from the release location to floating condensate exposure for each season and threshold, following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating condensate exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	165.5	42.1	3.8
	Max. distance from release site (km) (99th percentile)	121.4	35.5	3.8
	Direction	Southwest	Northeast	North
Transitional	Max. distance from release site (km)	174.7	42.1	4.4
	Max. distance from release site (km) (99th percentile)	116.6	37.8	4.4
	Direction	North	Northeast	Northeast
Winter	Max. distance from release site (km)	162.8	39.9	4.6
	Max. distance from release site (km) (99th percentile)	116.5	35.4	4.6
	Direction	North	Northeast	West-southwest

Table 11.2 Summary of the potential floating oil exposure to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
AMP	Montebello	73	12	-	1.58	6.5	-	41	17	-	1.71	6.63	-	43	9	-	1.46	48.79	-
BIA	Fairy Tern - Breeding	1	-	-	71.54	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flatback Turtle - Internesting Buffer*	100	100	98	0.04	0.04	0.29	100	100	93	0.04	0.04	0.21	100	100	98	0.04	0.04	0.33
	Flatback Turtle - Nesting	90	22	-	0.96	5.63	-	92	26	-	1.92	2	-	79	17	-	2.54	28.58	-
	Green Turtle - Foraging	1	-	-	71.54	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Green Turtle - Internesting	1	-	-	71.54	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Green Turtle - Internesting Buffer	31	-	-	6.04	-	-	23	-	-	6.46	-	-	13	-	-	10.5	-	-
	Green Turtle - Mating	1	-	-	71.54	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Green Turtle - Nesting	19	-	-	6.79	-	-	8	-	-	41.08	-	-	2	-	-	77.79	-	-
	Hawksbill Turtle - Internesting Buffer	19	-	-	6.04	-	-	24	-	-	6.58	-	-	13	-	-	33.33	-	-
	Hawksbill Turtle - Nesting	19	-	-	6.79	-	-	8	-	-	41.08	-	-	2	-	-	77.83	-	-
	Humpback Whale - Migration	94	11	-	0.71	12.92	-	100	19	-	0.92	23.63	-	100	8	-	0.75	3.13	-
	Lesser Crested Tern - Breeding	3	-	-	6.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Loggerhead Turtle - Internesting Buffer	6	-	-	7.42	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pygmy Blue Whale - Distribution*	100	100	98	0.04	0.04	0.29	100	100	93	0.04	0.04	0.21	100	100	98	0.04	0.04	0.33
	Roseate Tern - Breeding	4	-	-	11.21	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Wedge-tailed Shearwater – Breeding*	100	100	98	0.04	0.04	0.29	100	100	93	0.04	0.04	0.21	100	100	98	0.04	0.04	0.33
	Whale Shark - Foraging*	100	100	98	0.04	0.04	0.29	100	100	93	0.04	0.04	0.21	100	100	98	0.04	0.04	0.33
IAA	Rankin Bank	-	-	-	-	-	-	3	-	-	74.33	-	-	7	-	-	22.42	-	-
	Barrow & Montebello Islands	73	12	-	1.58	6.5	-	41	17	-	1.71	6.63	-	43	9	-	1.46	48.79	-
	Offshore Area*	100	100	98	0.04	0.04	0.29	100	100	93	0.04	0.04	0.21	100	100	98	0.04	0.04	0.33
IMCRA	Northwest Shelf	74	8	-	1.21	3.83	-	66	12	-	3.42	4.67	-	77	15	-	1.21	2.42	-
	Pilbara (offshore)*	100	100	98	0.04	0.04	0.29	100	100	93	0.04	0.04	0.21	100	100	98	0.04	0.04	0.33
KEF	Ancient coastline at 125 m depth contour*	100	100	98	0.04	0.04	0.29	100	100	93	0.04	0.04	0.21	100	100	98	0.04	0.04	0.33
	Continental Slope Demersal Fish Communities	100	60	-	0.38	2.38	-	100	57	-	0.58	2.46	-	100	68	-	0.46	2.75	-
	Exmouth Plateau	2	-	-	39.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MP	Montebello Islands	1	-	-	71.54	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RSB	Rankin Bank	-	-	-	-	-	-	4	-	-	74.29	-	-	7	-	-	22.42	-	-
	Tryal Rocks	3	-	-	49.17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
State Waters	Western Australia State Waters	1	-	-	71.54	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*The release location resides within the receptor boundaries.

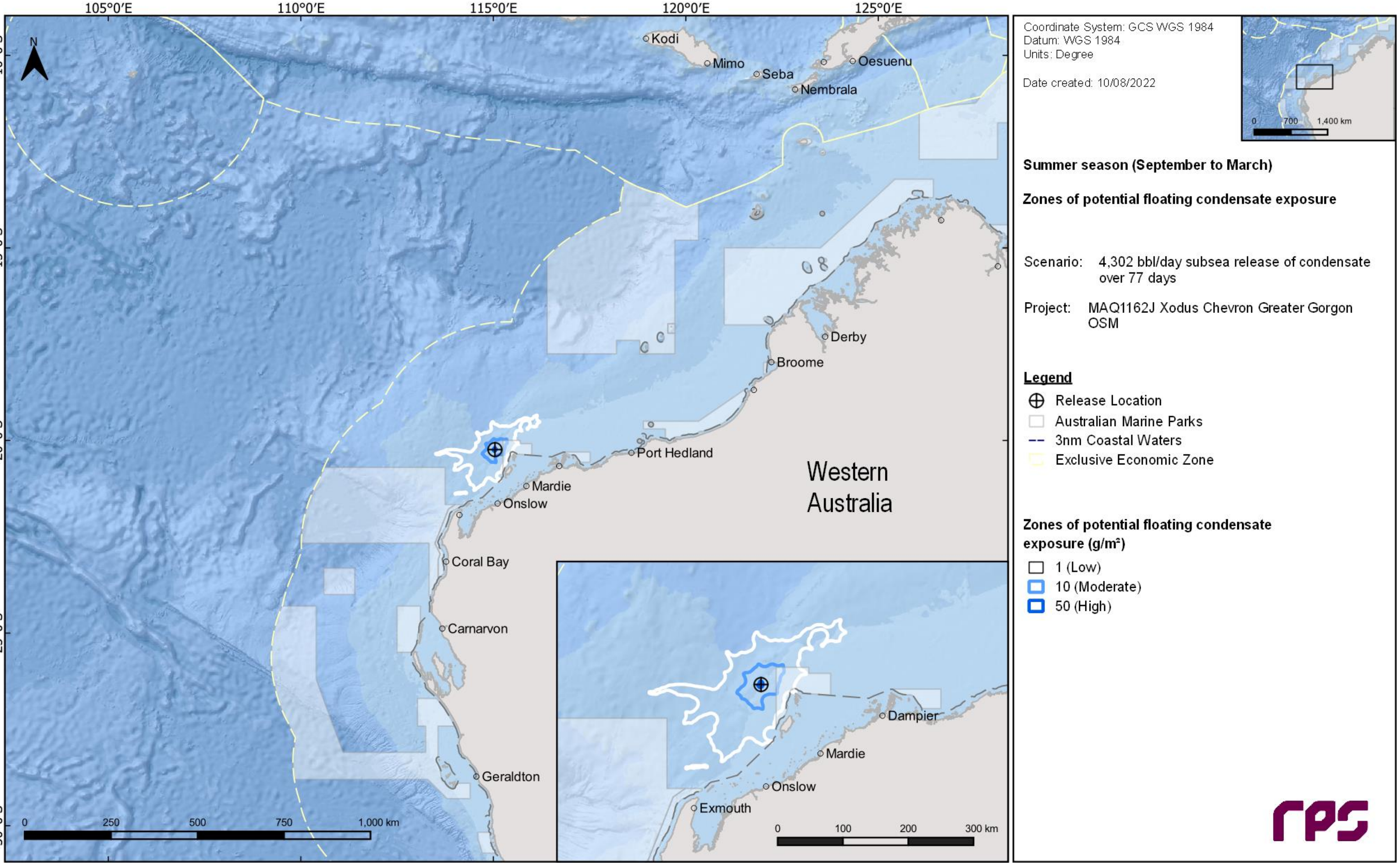


Figure 11.1 Zones of potential floating oil exposure following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

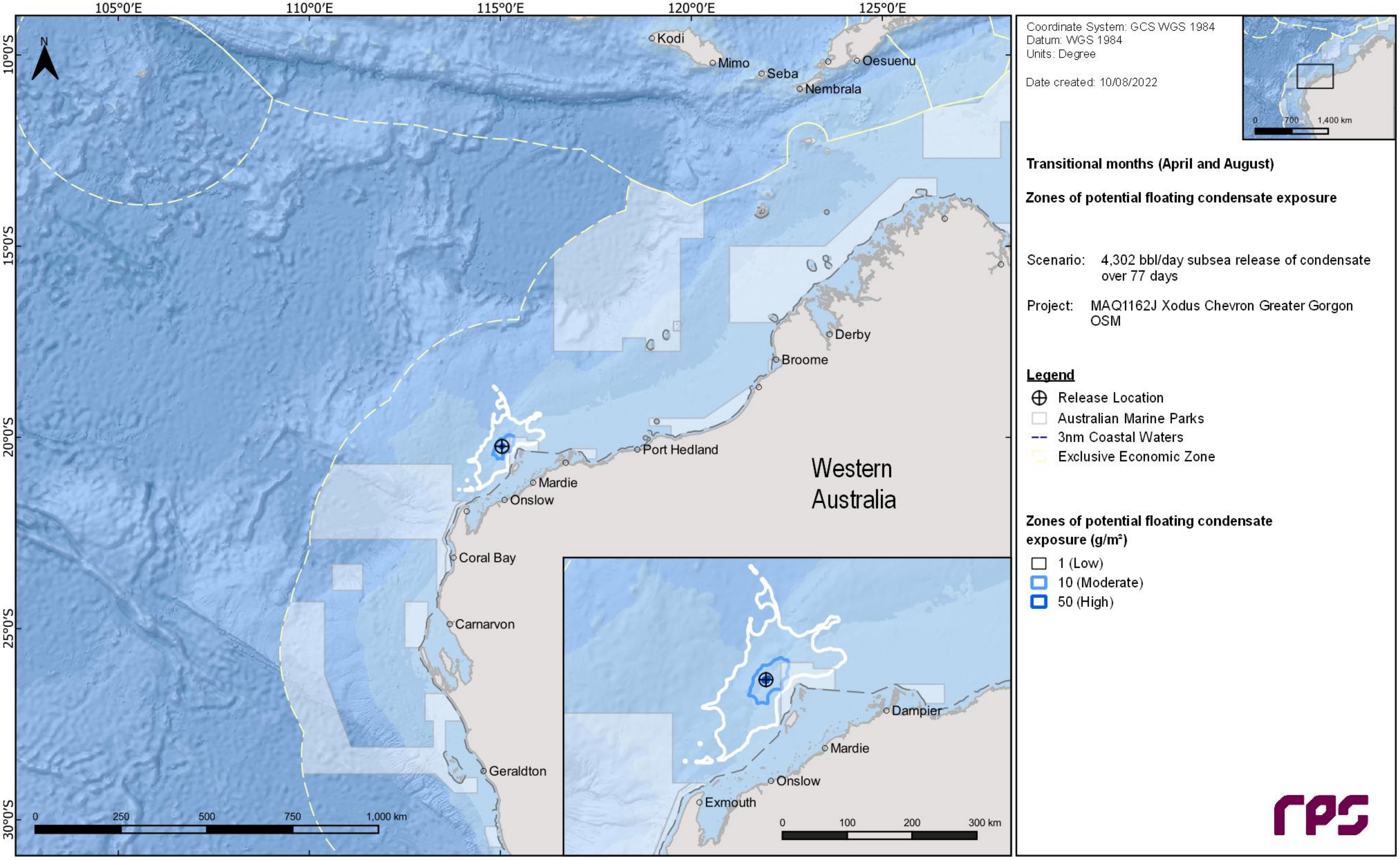


Figure 11.2 Zones of potential floating oil exposure following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

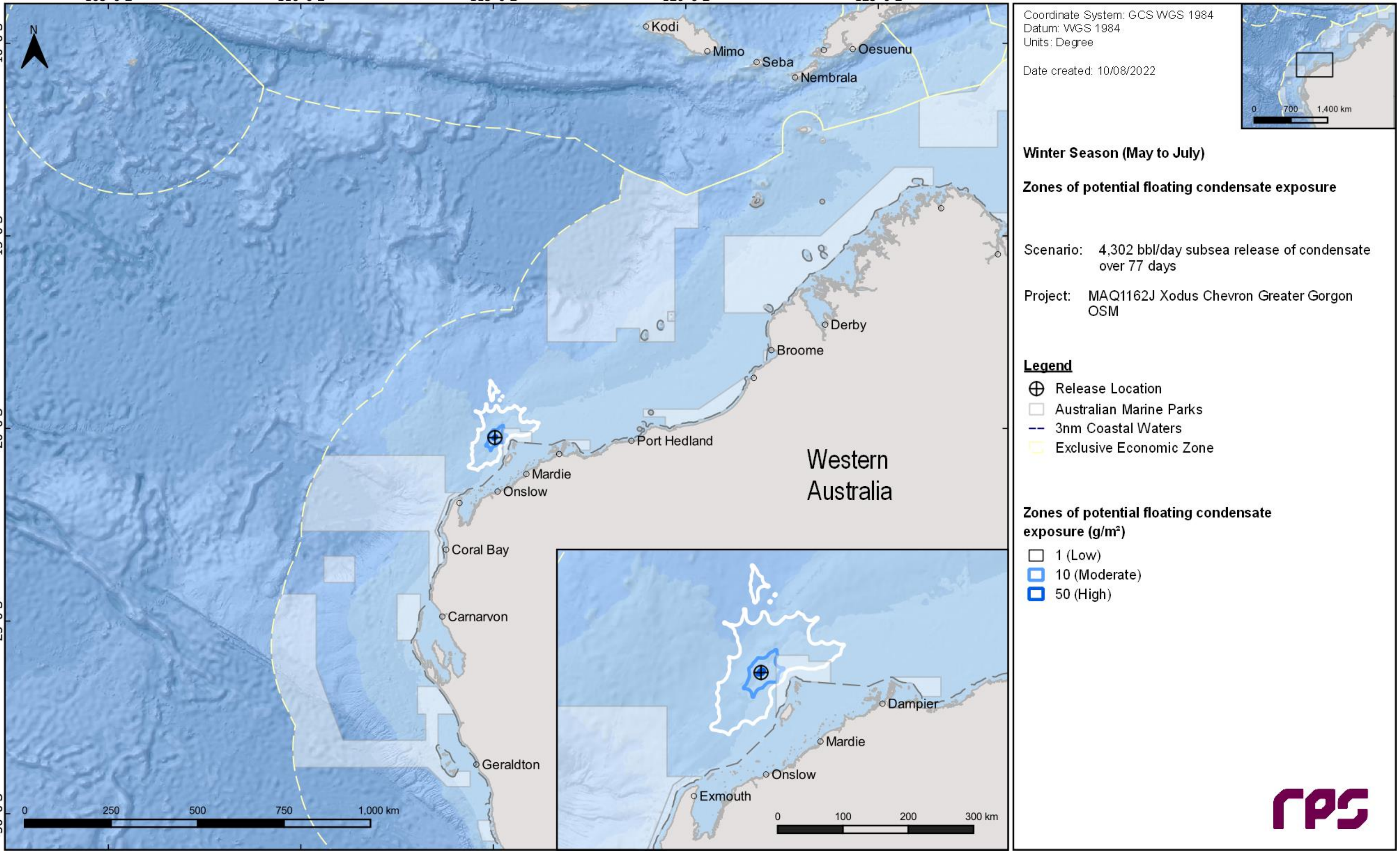


Figure 11.3 Zones of potential floating oil exposure following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.2 Shoreline Accumulation

Table 11.3 presents a summary of the predicted shoreline accumulation during summer, transitional and winter seasons. The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 53%, while the minimum time before shoreline accumulation was 7.08 days and the maximum volume of oil ashore was 105.0 m^3.

No high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

Table 11.4 to Table 11.6 summarises the shoreline accumulation on individual receptors for each season.

During summer conditions, 75 shoreline receptors were predicted to record condensate accumulation at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA (36%). In comparison, during transitional and winter conditions, 35 and 39 shoreline receptors, respectively, were predicted to record accumulation, with the greatest probability at the Ningaloo Coast World Heritage Area IAA occurring during both seasons (31% during transitional and 32% during winter).

The maximum potential shoreline accumulation is presented for each season in Figure 11.4 to Figure 11.6.

Table 11.3 Summary of oil accumulation across all shorelines for each season and threshold, following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of accumulation on any shoreline (%)	53	33	46
Absolute minimum time for visible oil to shore (days)	7.08	10.00	9.88
Maximum volume of hydrocarbons ashore (m^3) above the low threshold	105.0	21.4	1.5
Average volume of hydrocarbons ashore (m^3) above the low threshold	12.6	1.8	0.5
Maximum length of the shoreline at **10 g/m^2** (km)	143	42	15
Average shoreline length (km) at **10 g/m^2** (km)	44.9	7.4	4.6
Maximum length of the shoreline at **100 g/m^2** (km)	31	9	-
Average shoreline length (km) at **100 g/m^2** (km)	11.1	4.7	-
Maximum length of the shoreline at **1,000 g/m^2** (km)	-	-	-
Average shoreline length (km) at **1,000 g/m^2** (km)	-	-	-

Table 11.4 Summary of shoreline oil accumulation to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories days during summer (September to the following March) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	28	12	-	7.58	8.71	-	28	318	2	30.2	14.8	7.9	-	29.8	16.4	-
	South Muiron Island	22	1	-	9.46	80.04	-	10	153	0.1	4.7	2.3	1.9	-	7.7	1.9	-
	Thevenard Island	11	-	-	11.42	-	-	8	36	< 0.1	0.6	1.9	-	-	3.8	-	-
	Serrurier Island	21	-	-	10.42	-	-	11	64	0.1	1.4	3.8	-	-	7.7	-	-
	Bessieres Island	11	-	-	10.58	-	-	9	49	< 0.1	0.3	1.2	-	-	1.9	-	-
	Locker Island	1	-	-	37.67	-	-	24	24	0.1	0.1	1	-	-	1	-	-
	Airlie Island	10	1	-	11.38	81.67	-	15	115	< 0.1	1.9	1.5	1	-	2.9	1	-
	Ashburton Island	2	-	-	33.58	-	-	7	14	< 0.1	< 0.1	1	-	-	1	-	-
	North Muiron Island	29	-	-	9.08	-	-	12	69	0.1	1.9	2.6	-	-	5.8	-	-
	Great Sandy Island	8	1	-	13.46	92.54	-	13	114	< 0.1	2.7	1.4	1	-	2.9	1	-
	North Sandy Island	9	-	-	13.17	-	-	18	78	< 0.1	0.6	1.7	-	-	1.9	-	-
	Passage Island	4	-	-	28.25	-	-	11	23	< 0.1	0.2	1	-	-	1	-	-
	Sholl Island	9	-	-	14	-	-	11	57	< 0.1	1.2	3.3	-	-	4.8	-	-
	Boodie Island	19	10	-	7.17	9.96	-	63	346	0.5	7.4	3.9	2.7	-	6.7	3.8	-
	Middle Island	21	10	-	7.08	9.33	-	73	532	0.9	13	5.5	4.1	-	7.7	5.8	-
	Double Island	2	-	-	34.5	-	-	7	13	< 0.1	0.1	1	-	-	1	-	-
	Bedwell Island (Clerke Reef)	3	-	-	31.42	-	-	6	15	< 0.1	0.2	1.3	-	-	1.9	-	-
	Cunningham Island (Imperieuse Reef)	3	-	-	32.29	-	-	5	15	< 0.1	0.2	1.3	-	-	1.9	-	-
	Middle Ningaloo Coast - World Heritage Area	15	-	-	10.54	-	-	7	35	< 0.1	1	5.5	-	-	11.5	-	-
	North Ningaloo Coast - World Heritage Area	22	-	-	9.38	-	-	10	77	0.3	4	9.4	-	-	27.9	-	-
	Cape Range National Park	23	3	-	9.42	10.96	-	11	127	0.4	12.7	11.6	1.9	-	42.3	3.8	-
	Ningaloo Coast World Heritage Area	31	3	-	9.08	11.04	-	12	153	0.8	11.2	16.4	1.3	-	51	1.9	-
	Argo-Rowley Terrace	3	-	-	31.42	-	-	5	15	< 0.1	0.3	2.6	-	-	2.9	-	-
	Dampier Archipelago	11	-	-	17.08	-	-	8	55	< 0.1	0.8	2.6	-	-	4.8	-	-
	Abutilon Island	6	-	-	37.13	-	-	14	31	< 0.1	0.2	1	-	-	1	-	-
	Varanus Island	12	-	-	8.88	-	-	12	63	< 0.1	0.7	1.8	-	-	3.8	-	-
	Trimouille Island	9	2	-	14.25	14.71	-	11	131	< 0.1	2	2.9	1	-	7.7	1	-
	Hermite Island	31	6	-	7.17	32.54	-	19	194	0.8	10.2	9.3	2.1	-	17.3	2.9	-
	Barrow Island (East Coast)	1	-	-	36.04	-	-	11	11	< 0.1	< 0.1	1	-	-	1	-	-
	Barrow & Montebello Islands	36	14	-	7.08	8.71	-	22	532	4.9	64	33.3	13.5	-	78.9	29.8	-
	Pilbara Coast	28	1	-	9.29	81.67	-	11	167	0.6	14.3	12.3	4.8	-	33.7	4.8	-
	Exmouth	6	-	-	31.5	-	-	5	21	< 0.1	0.2	1.4	-	-	1.9	-	-
	Onslow Area Mainland Coastline	2	-	-	28.71	-	-	4	23	< 0.1	0.9	3.4	-	-	5.8	-	-
	Dampier mainland coastline	1	-	-	90.5	-	-	13	13	0.2	0.2	1.9	-	-	1.9	-	-
	Lowendal Islands Group	12	-	-	8.88	-	-	11	63	< 0.1	0.9	2.3	-	-	4.8	-	-
	Montebello Islands Group	31	8	-	7.17	14.71	-	18	194	0.9	10.3	10.1	1.8	-	20.2	2.9	-
	Barrow Island Group	28	14	-	7.08	8.71	-	34	532	3.3	48.6	21.7	11.6	-	42.3	25	-
	Pilbara Mainland Coast	2	-	-	28.71	-	-	4	23	< 0.1	0.9	3.4	-	-	5.8	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Pilbara Coast Islands Group	24	1	-	10.42	81.67	-	12	115	0.3	5.5	7.2	1.9	-	17.3	1.9	-
	Exmouth Gulf Mainland Coastline	2	-	-	31.5	-	-	5	14	< 0.1	0.1	1	-	-	1	-	-
	Muiron Islands	30	1	-	9.08	80.04	-	11	153	0.2	6.5	4.2	1.9	-	12.5	1.9	-
Shoreline	Airlie Island	10	1	-	11.38	81.67	-	15	115	< 0.1	1.9	1.5	1	-	2.9	1	-
	Ashburton	5	-	-	28.71	-	-	5	15	< 0.1	0.1	1	-	-	1	-	-
	Ashburton Island	2	-	-	33.58	-	-	7	14	< 0.1	< 0.1	1	-	-	1	-	-
	Barrow Island	28	12	-	7.58	8.71	-	29	318	2.2	32.1	16	8.5	-	31.7	17.3	-
	Bessieres Island	11	-	-	10.58	-	-	9	49	< 0.1	0.3	1.2	-	-	1.9	-	-
	Boodie Island	20	10	-	7.08	9.38	-	72	532	0.7	11.3	4.6	3.7	-	7.7	4.8	-
	Clerke Reef	3	-	-	31.42	-	-	6	15	< 0.1	0.2	1.3	-	-	1.9	-	-
	Cunningham Island	2	-	-	32.29	-	-	4	14	< 0.1	0.2	1.4	-	-	1.9	-	-
	Direction Island	3	-	-	58.21	-	-	8	13	< 0.1	0.1	1	-	-	1	-	-
	Exmouth	23	3	-	9.38	10.96	-	9	127	0.8	17.1	24.2	1.9	-	77	3.8	-
	Flat Island	11	-	-	10.63	-	-	11	46	< 0.1	0.8	2	-	-	3.8	-	-
	Fly Island	4	-	-	37.63	-	-	8	21	< 0.1	0.2	1	-	-	1	-	-
	Imperieuse Reef	1	-	-	84.5	-	-	15	15	0.2	0.2	1	-	-	1	-	-
	Karratha	2	-	-	32.33	-	-	5	23	< 0.1	1.2	4.3	-	-	7.7	-	-
	Kendrew Island	2	-	-	35.29	-	-	8	11	< 0.1	< 0.1	1	-	-	1	-	-
	Locker Island	1	-	-	37.67	-	-	24	24	0.1	0.1	1	-	-	1	-	-
	Lowendal Island	18	2	-	7.58	33.25	-	16	115	0.3	3	6	1	-	10.6	1	-
	Mangrove Islands	2	-	-	34.33	-	-	6	16	< 0.1	0.1	1	-	-	1	-	-
	Mary Anne Group	11	1	-	12.17	83.17	-	11	167	< 0.1	5.2	2	2.9	-	6.7	2.9	-
	Middle Island	22	10	-	7.08	9.33	-	73	532	1.1	15.6	6.6	5.6	-	9.6	7.7	-
	Montebello Islands	33	8	-	7.17	14.58	-	16	215	1.3	12.5	14.7	3.1	-	31.7	3.8	-
	Murion Islands	30	1	-	9.08	80.04	-	11	153	0.2	6.5	4.2	1.9	-	12.5	1.9	-
	Observation Island	12	-	-	11.67	-	-	12	33	< 0.1	0.3	1.4	-	-	1.9	-	-
	Passage Islands	13	1	-	13.17	92.54	-	10	114	0.3	6.6	10.6	1	-	19.2	1	-
	Peak Island	12	-	-	9.29	-	-	14	57	< 0.1	0.5	1	-	-	1	-	-
	Ragnard Islands	1	-	-	88.29	-	-	10	10	0.1	0.1	1	-	-	1	-	-
	Rivoli Islands	1	-	-	82.75	-	-	12	12	0.1	0.1	1	-	-	1	-	-
	Rosemary Island	1	-	-	42.33	-	-	11	11	0.1	0.1	1	-	-	1	-	-
	Round Island	4	-	-	10.38	-	-	8	15	< 0.1	0.1	1	-	-	1	-	-
	Serrurier Island	21	-	-	10.42	-	-	11	64	0.1	1.4	3.8	-	-	7.7	-	-
	Sunday Island	15	-	-	10.67	-	-	10	43	< 0.1	0.4	1.3	-	-	1.9	-	-
	Table Island	7	-	-	26.92	-	-	14	37	< 0.1	0.4	1	-	-	1	-	-
	Thevenard Island	11	-	-	11.42	-	-	8	36	< 0.1	0.6	1.9	-	-	3.8	-	-
	Tortoise Island	3	-	-	12.13	-	-	8	21	< 0.1	0.1	1	-	-	1	-	-

Table 11.5 Summary of shoreline oil accumulation to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories days during transitional (April and August) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	2	1	-	77.71	80.67	-	14	132	< 0.1	5.3	8.2	1.9	-	9.6	1.9	-
	South Muiron Island	19	-	-	26.08	-	-	9	32	< 0.1	0.5	1.8	-	-	2.9	-	-
	Thevenard Island	6	-	-	18	-	-	7	23	< 0.1	0.2	1.1	-	-	1.9	-	-
	Serrurier Island	2	-	-	23.71	-	-	7	19	< 0.1	0.1	1	-	-	1	-	-
	Bessieres Island	4	1	-	10	24.21	-	20	102	< 0.1	1	2.2	1	-	3.8	1	-
	Locker Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Airlie Island	1	-	-	64.79	-	-	11	11	< 0.1	< 0.1	1	-	-	1	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	25	-	-	25.21	-	-	10	58	< 0.1	0.8	2.4	-	-	5.8	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passage Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	2	1	-	77.42	77.75	-	43	177	< 0.1	4.5	4.8	2.9	-	4.8	2.9	-
	Middle Island	2	2	-	77.58	77.83	-	94	177	0.1	6.5	6.7	3.8	-	6.7	3.8	-
	Double Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bedwell Island (Clerke Reef)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island (Imperieuse Reef)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	10	-	-	43.46	-	-	9	33	< 0.1	0.2	1.6	-	-	2.9	-	-
	Cape Range National Park	5	-	-	44.21	-	-	6	19	< 0.1	0.2	1.2	-	-	1.9	-	-
	Ningaloo Coast World Heritage Area	31	-	-	25.21	-	-	10	58	0.2	1	3.8	-	-	6.7	-	-
	Argo-Rowley Terrace	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Abutilon Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Varanus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	1	-	-	87.58	-	-	14	14	0.1	0.1	1	-	-	1	-	-
	Hermite Island	3	-	-	79.88	-	-	8	67	< 0.1	3.8	8.7	-	-	12.5	-	-
	Barrow Island (East Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands	3	2	-	77.42	77.75	-	9	177	0.4	21.4	26.6	6.3	-	40.4	8.7	-
	Pilbara Coast	19	1	-	10	24.21	-	11	102	< 0.1	1.1	1.7	1	-	4.8	1	-
	Exmouth	1	-	-	76.13	-	-	14	14	0.1	0.1	1	-	-	1	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	3	-	-	79.88	-	-	8	67	< 0.1	3.9	9	-	-	13.5	-	-
	Barrow Island Group	2	2	-	77.42	77.75	-	20	177	0.3	16.2	19.7	6.3	-	21.2	8.7	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Pilbara Coast Islands Group	6	1	-	10	24.21	-	14	102	< 0.1	1	1.9	1	-	3.8	1	-
	Exmouth Gulf Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	30	-	-	25.21	-	-	10	58	0.1	1	3.1	-	-	6.7	-	-
Shoreline	Airlie Island	1	-	-	64.79	-	-	11	11	< 0.1	< 0.1	1	-	-	1	-	-
	Ashburton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	2	2	-	77.58	78.75	-	17	177	0.1	8	10.1	2.4	-	11.5	3.8	-
	Bessieres Island	4	1	-	10	24.21	-	20	102	< 0.1	1	2.2	1	-	3.8	1	-
	Boodie Island	2	2	-	77.42	77.75	-	49	177	0.1	5.9	5.8	2.4	-	5.8	3.8	-
	Clerke Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Direction Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	10	-	-	43.46	-	-	7	33	< 0.1	0.4	2.2	-	-	3.8	-	-
	Flat Island	1	-	-	56.33	-	-	13	13	< 0.1	< 0.1	1	-	-	1	-	-
	Fly Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Imperieuse Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Kendrew Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Locker Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mangrove Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	2	2	-	77.58	77.75	-	65	177	0.2	8.7	8.7	4.3	-	8.7	4.8	-
	Montebello Islands	3	-	-	79.88	-	-	7	67	0.1	5.5	13.5	-	-	20.2	-	-
	Murion Islands	30	-	-	25.21	-	-	10	58	0.1	1	3.1	-	-	6.7	-	-
	Observation Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Peak Island	13	-	-	25.08	-	-	18	57	< 0.1	0.4	1	-	-	1	-	-
	Ragnard Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rivoli Islands	1	-	-	76.13	-	-	14	14	0.1	0.1	1	-	-	1	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	2	-	-	23.71	-	-	7	19	< 0.1	0.1	1	-	-	1	-	-
	Sunday Island	6	-	-	52.21	-	-	10	23	< 0.1	0.2	1	-	-	1	-	-
	Table Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	6	-	-	18	-	-	7	23	< 0.1	0.2	1.1	-	-	1.9	-	-
	Tortoise Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 11.6 Summary of shoreline oil accumulation to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories days during winter (May to July) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	16	-	-	20.54	-	-	8	23	< 0.1	0.7	1.7	-	-	5.8	-	-
	Thevenard Island	4	-	-	30.63	-	-	6	17	< 0.1	0.1	1	-	-	1	-	-
	Serrurier Island	9	-	-	18.5	-	-	9	39	< 0.1	0.6	2.7	-	-	3.8	-	-
	Bessieres Island	6	-	-	18.46	-	-	8	25	< 0.1	0.2	1.3	-	-	1.9	-	-
	Locker Island	1	-	-	59.54	-	-	10	10	< 0.1	< 0.1	1	-	-	1	-	-
	Airlie Island	3	-	-	39.88	-	-	8	16	< 0.1	0.2	1	-	-	1	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	24	-	-	9.88	-	-	9	37	< 0.1	0.5	1.6	-	-	3.8	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passage Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	2	-	-	96.21	-	-	7	15	< 0.1	0.2	1	-	-	1	-	-
	Double Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bedwell Island (Clerke Reef)	4	-	-	77.38	-	-	6	22	< 0.1	0.2	1	-	-	1	-	-
	Cunningham Island (Imperieuse Reef)	8	-	-	55.5	-	-	7	25	< 0.1	0.7	2	-	-	3.8	-	-
	Middle Ningaloo Coast - World Heritage Area	5	-	-	30.71	-	-	6	20	< 0.1	0.3	1.5	-	-	2.9	-	-
	North Ningaloo Coast - World Heritage Area	7	-	-	18.58	-	-	6	23	< 0.1	0.2	1.2	-	-	1.9	-	-
	Cape Range National Park	4	-	-	19.08	-	-	6	19	< 0.1	0.3	2.2	-	-	3.8	-	-
	Ningaloo Coast World Heritage Area	32	-	-	9.88	-	-	8	37	< 0.1	1.3	2.8	-	-	12.5	-	-
	Argo-Rowley Terrace	8	-	-	55.5	-	-	7	25	< 0.1	0.7	2.5	-	-	3.8	-	-
	Dampier Archipelago	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Abutilon Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Varanus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island (East Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands	2	-	-	96.21	-	-	6	15	< 0.1	0.2	1	-	-	1	-	-
	Pilbara Coast	18	-	-	18.46	-	-	9	56	0.1	1.2	4.8	-	-	10.6	-	-
	Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	2	-	-	96.21	-	-	7	15	< 0.1	0.2	1	-	-	1	-	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Pilbara Coast Islands Group	13	-	-	18.46	-	-	8	39	< 0.1	0.7	2.7	-	-	5.8	-	-
	Exmouth Gulf Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	29	-	-	9.88	-	-	8	37	< 0.1	1	2.2	-	-	8.7	-	-
Shoreline	Airlie Island	3	-	-	39.88	-	-	8	16	< 0.1	0.2	1	-	-	1	-	-
	Ashburton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	6	-	-	18.46	-	-	8	25	< 0.1	0.2	1.3	-	-	1.9	-	-
	Boodie Island	1	-	-	102.79	-	-	12	12	0.1	0.1	1	-	-	1	-	-
	Clerke Reef	4	-	-	77.38	-	-	6	22	< 0.1	0.2	1	-	-	1	-	-
	Cunningham Island	4	-	-	74.42	-	-	7	22	< 0.1	0.2	1	-	-	1	-	-
	Direction Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	14	-	-	18.58	-	-	6	23	< 0.1	0.4	1.8	-	-	4.8	-	-
	Flat Island	11	-	-	18.88	-	-	12	38	< 0.1	0.4	1.9	-	-	3.8	-	-
	Fly Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Imperieuse Reef	8	-	-	55.5	-	-	7	25	< 0.1	0.5	1.7	-	-	2.9	-	-
	Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Kendrew Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Locker Island	1	-	-	59.54	-	-	10	10	< 0.1	< 0.1	1	-	-	1	-	-
	Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mangrove Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	2	-	-	96.21	-	-	6	15	< 0.1	0.2	1	-	-	1	-	-
	Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Murion Islands	29	-	-	9.88	-	-	8	37	< 0.1	1	2.2	-	-	8.7	-	-
	Observation Island	4	-	-	33.67	-	-	10	24	< 0.1	0.3	1.2	-	-	1.9	-	-
	Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Peak Island	14	-	-	19.21	-	-	17	56	< 0.1	0.4	1	-	-	1	-	-
	Ragnard Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rivoli Islands	-	-	-	-	-	-	6	8	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Round Island	4	-	-	29.58	-	-	10	26	< 0.1	0.2	1	-	-	1	-	-
	Serrurier Island	9	-	-	18.5	-	-	9	39	< 0.1	0.6	2.7	-	-	3.8	-	-
	Sunday Island	5	-	-	13.17	-	-	8	18	< 0.1	0.1	1	-	-	1	-	-
	Table Island	2	-	-	21.71	-	-	8	13	< 0.1	< 0.1	1	-	-	1	-	-
	Thevenard Island	4	-	-	30.63	-	-	6	17	< 0.1	0.1	1	-	-	1	-	-
	Tortoise Island	2	-	-	49.38	-	-	8	16	< 0.1	0.1	1	-	-	1	-	-

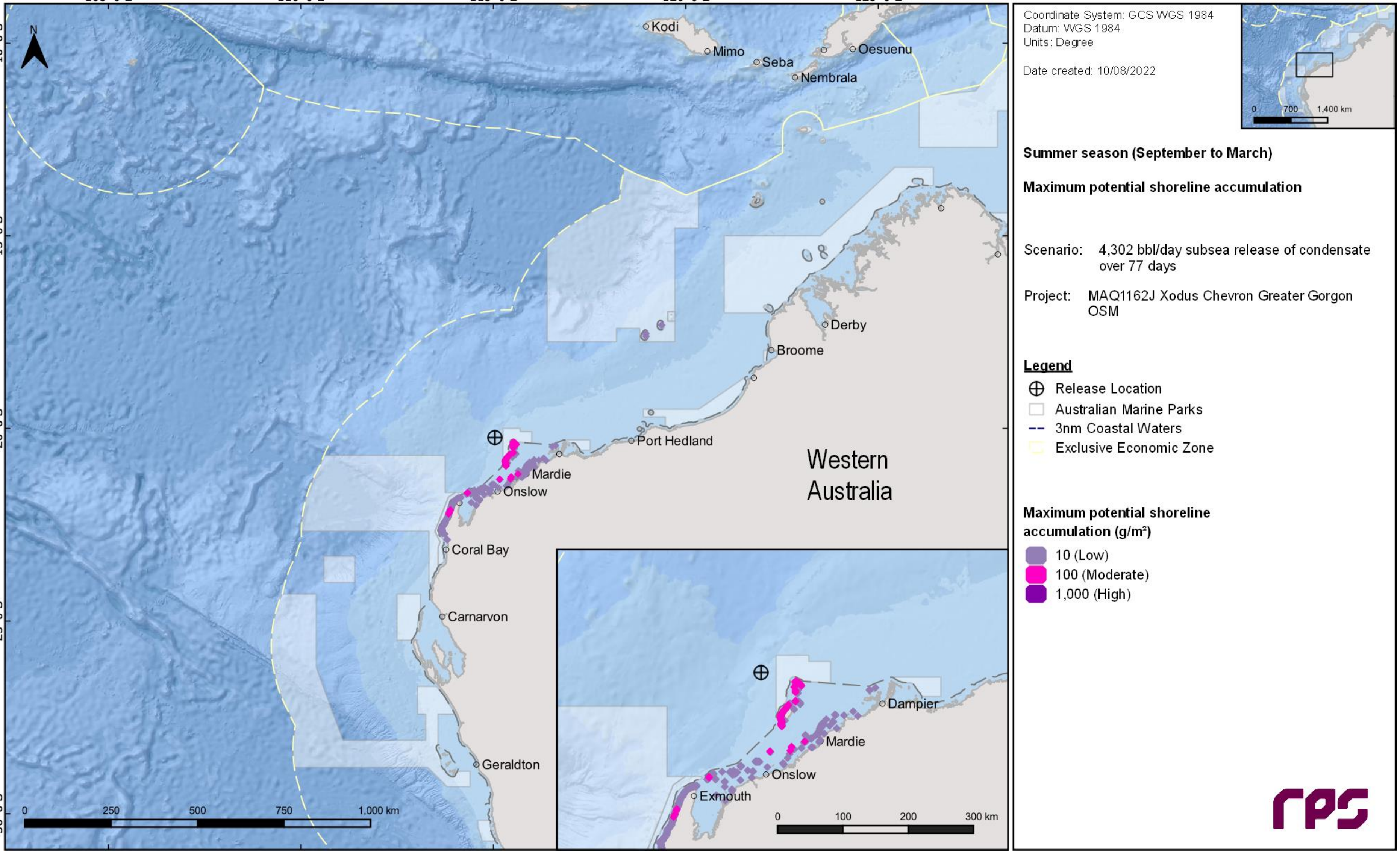


Figure 11.4 Maximum potential shoreline accumulation following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

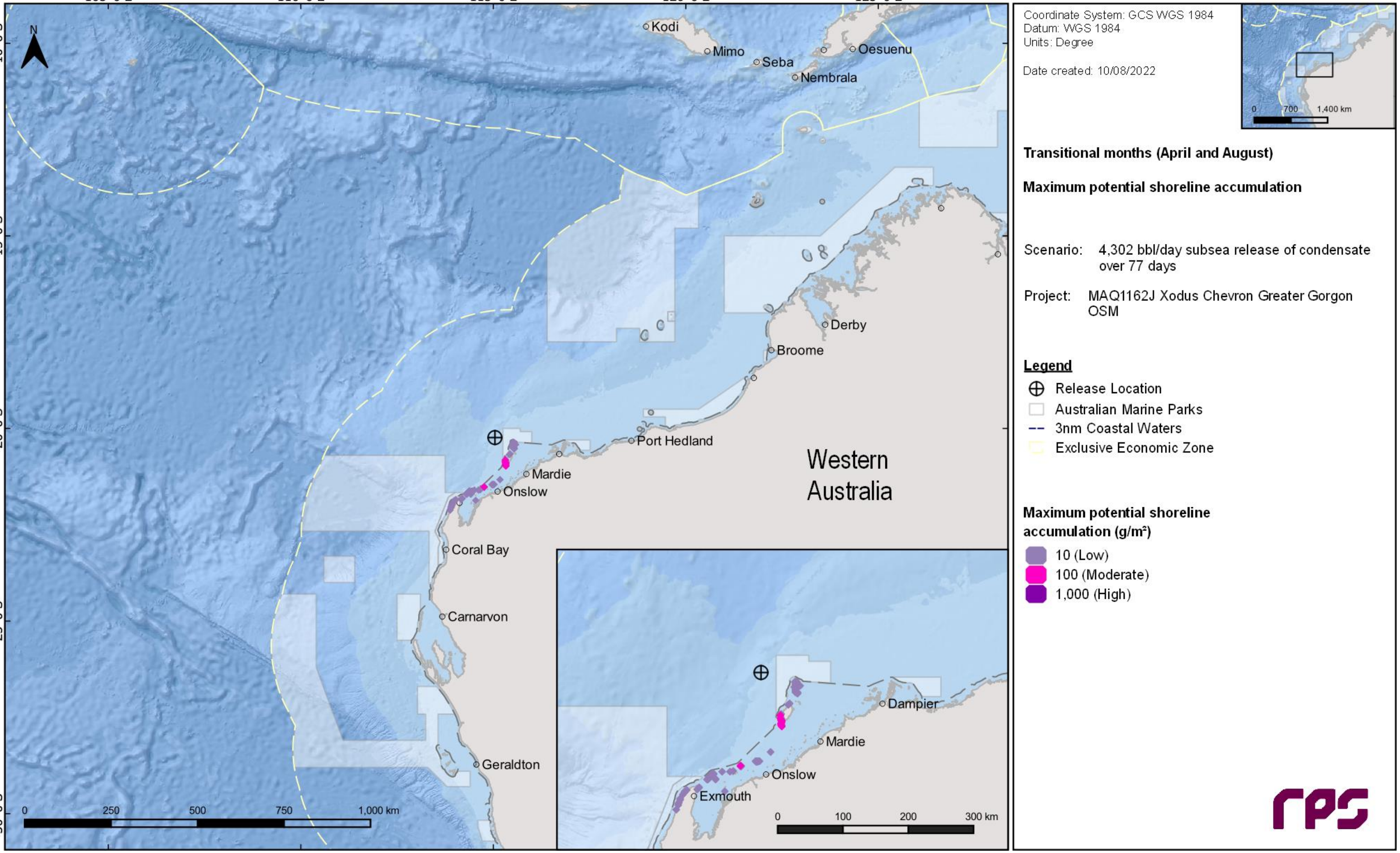


Figure 11.5 Maximum potential shoreline accumulation following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

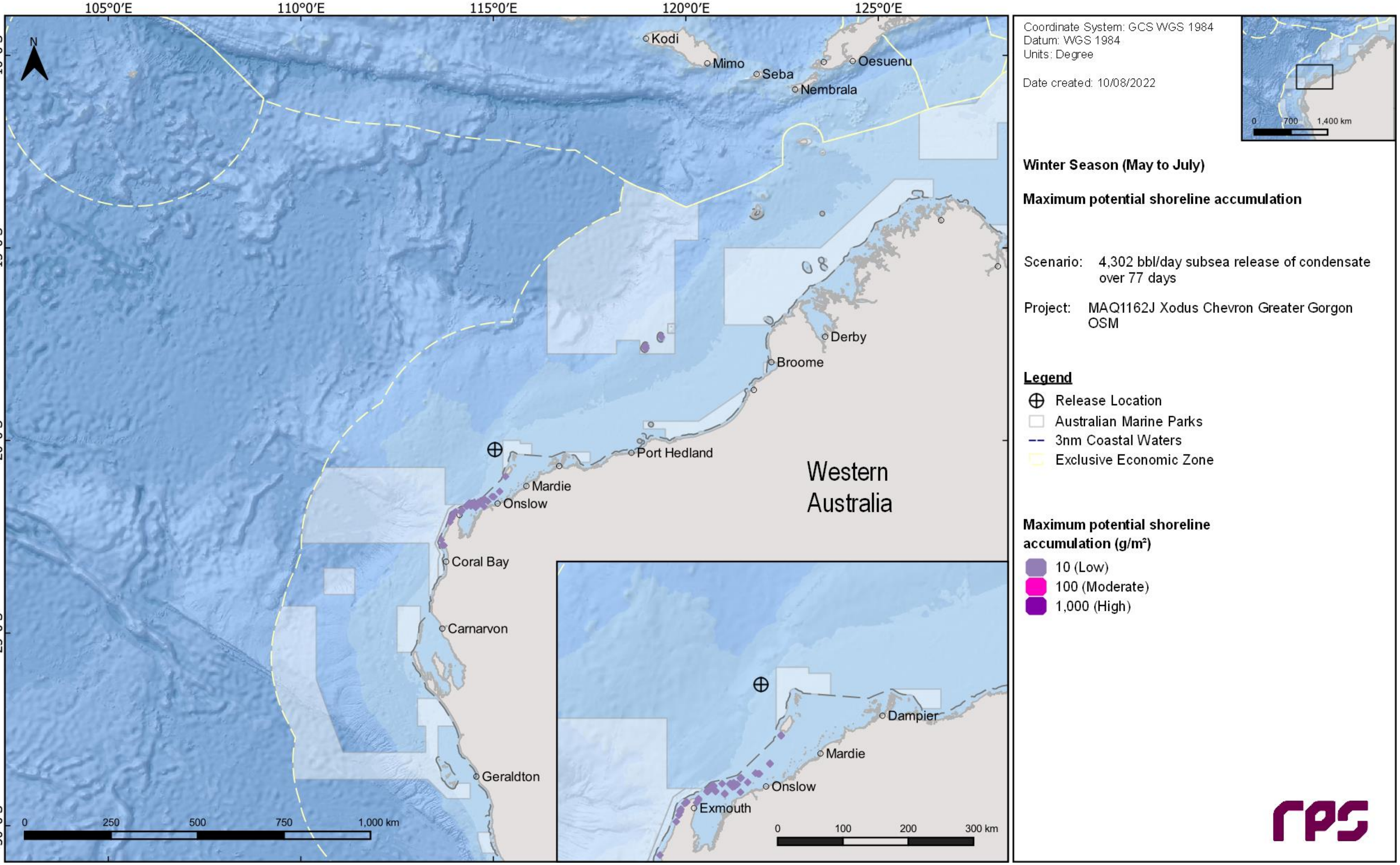


Figure 11.6 Maximum potential shoreline accumulation following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3 Water Column Exposure

11.1.3.1 Dissolved Hydrocarbons

Table 11.7 summarises the seasonal probability of exposure to individual receptors from dissolved hydrocarbons in the 0-10 m depth layer, at the low (≥ 10 ppb), moderate (≥ 50 ppb) and high (≥ 400 ppb) exposure thresholds.

In the surface (0-10 m) depth layer, a total of 19, 8, and 10 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter, respectively. Excluding the 4 BIAs that the release location resides within (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging) (see Section 10.3), the highest probabilities of exposure to low dissolved hydrocarbons were predicted as 9% for Humpback Whale - Migration during summer, 5% for Flatback Turtle - Nesting and Humpback Whale - Migration during transitional, and 5% for Humpback Whale - Migration during winter conditions.

A total of 3, 2 and 1 AMPs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold during summer, transitional and winter, respectively with the highest probability predicted at the Montebello AMP (3%) during winter.

Additionally, 6, 3 and 2 IAAs and 3, 2 and 2 IMCRAs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold during summer, transitional and winter, respectively.

Furthermore, 4 (summer) and 2 (transitional and winter) KEFs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold.

Figure 11.7 to Figure 11.9 presents the zones of potential instantaneous dissolved hydrocarbon exposure for the 0-10 m depth layer for the summer, transitional and winter periods, respectively.

Table 11.7 Predicted probability and maximum dissolved hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer				Transitional				Winter			
		Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)			Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)			Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)		
			Low	Moderate	High		Low	Moderate	High		Low	Moderate	High
AMP	Gascoyne	34	2	-	-	12	1	-	-	5	-	-	-
	Montebello	15	1	-	-	20	2	-	-	17	3	-	-
	Ningaloo	14	1	-	-	7	-	-	-	7	-	-	-
BIA	Dugong - Breeding	20	1	-	-	4	-	-	-	8	-	-	-
	Dugong - Calving	20	1	-	-	4	-	-	-	8	-	-	-
	Dugong - Foraging	20	1	-	-	4	-	-	-	8	-	-	-
	Dugong - Nursing	20	1	-	-	4	-	-	-	8	-	-	-
	Fairy Tern - Breeding	15	1	-	-	-	-	-	-	-	-	-	-
	Flatback Turtle - Internesting Buffer*	52	100	1	-	45	100	-	-	39	100	-	-
	Flatback Turtle - Nesting	19	2	-	-	24	5	-	-	20	4	-	-
	Green Turtle - Internesting Buffer	18	1	-	-	14	1	-	-	12	1	-	-
	Green Turtle - Nesting	20	1	-	-	-	-	-	-	13	1	-	-
	Hawksbill Turtle - Internesting Buffer	27	1	-	-	-	-	-	-	12	1	-	-
	Humpback Whale - Migration	51	9	1	-	46	5	-	-	40	5	-	-
	Loggerhead Turtle - Internesting Buffer	27	1	-	-	-	-	-	-	-	-	-	-
	Loggerhead Turtle - Nesting	20	1	-	-	-	-	-	-	-	-	-	-
	Pygmy Blue Whale - Distribution*	57	100	1	-	49	100	-	-	58	100	1	-
	Pygmy Blue Whale - Foraging	34	2	-	-	10	1	-	-	-	-	-	-
	Roseate Tern - Breeding	27	2	-	-	-	-	-	-	-	-	-	-
	Wedge-tailed Shearwater - Breeding*	57	100	1	-	49	100	-	-	40	100	-	-
	Whale Shark - Foraging*	52	100	1	-	46	100	-	-	39	100	-	-
IAA	North Ningaloo Coast - World Heritage Area	18	1	-	-	3	-	-	-	4	-	-	-
	Cape Range National Park	13	1	-	-	2	-	-	-	6	-	-	-
	Gascoyne	34	2	-	-	12	1	-	-	5	-	-	-
	Ningaloo Coast World Heritage Area	20	1	-	-	8	-	-	-	8	-	-	-
	Barrow & Montebello Islands	15	1	-	-	20	2	-	-	17	3	-0	-
	Offshore Area*	57	100	1	-	49	100	-	-	58	100	1	-
IBRA	Cape Range	18	1	-	-	-	-	-	-	-	-	-	-
IMCRA	Ningaloo	20	1	-	-	-	-	-	-	-	-	-	-
	Northwest Shelf	38	4	-	-	17	3	-	-	21	2	-	-
	Pilbara (offshore)*	52	100	1	-	46	100	-	-	39	100	-	-
KEF	Ancient coastline at 125 m depth contour*	52	100	1	-	45	100	-	-	36	100	-	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	27	2	-	-	-	-	-	-	-	-	-	-
	Commonwealth waters adjacent to Ningaloo Reef	14	1	-	-	-	-	-	-	-	-	-	-
	Continental Slope Demersal Fish Communities	48	12	-	-	46	10	-	-	40	14	-	-
MP	Ningaloo	20	1	-	-	-	-	-	-	-	-	-	-
RSB	Ningaloo Reef	18	1	-	-	-	-	-	-	-	-	-	-

Receptor		Summer				Transitional				Winter			
		Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)			Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)			Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)		
			Low	Moderate	High		Low	Moderate	High		Low	Moderate	High
Nearshore Waters	Exmouth	18	1	-	-	-	-	-	-	-	-	-	-

*The release location resides within the receptor boundaries.

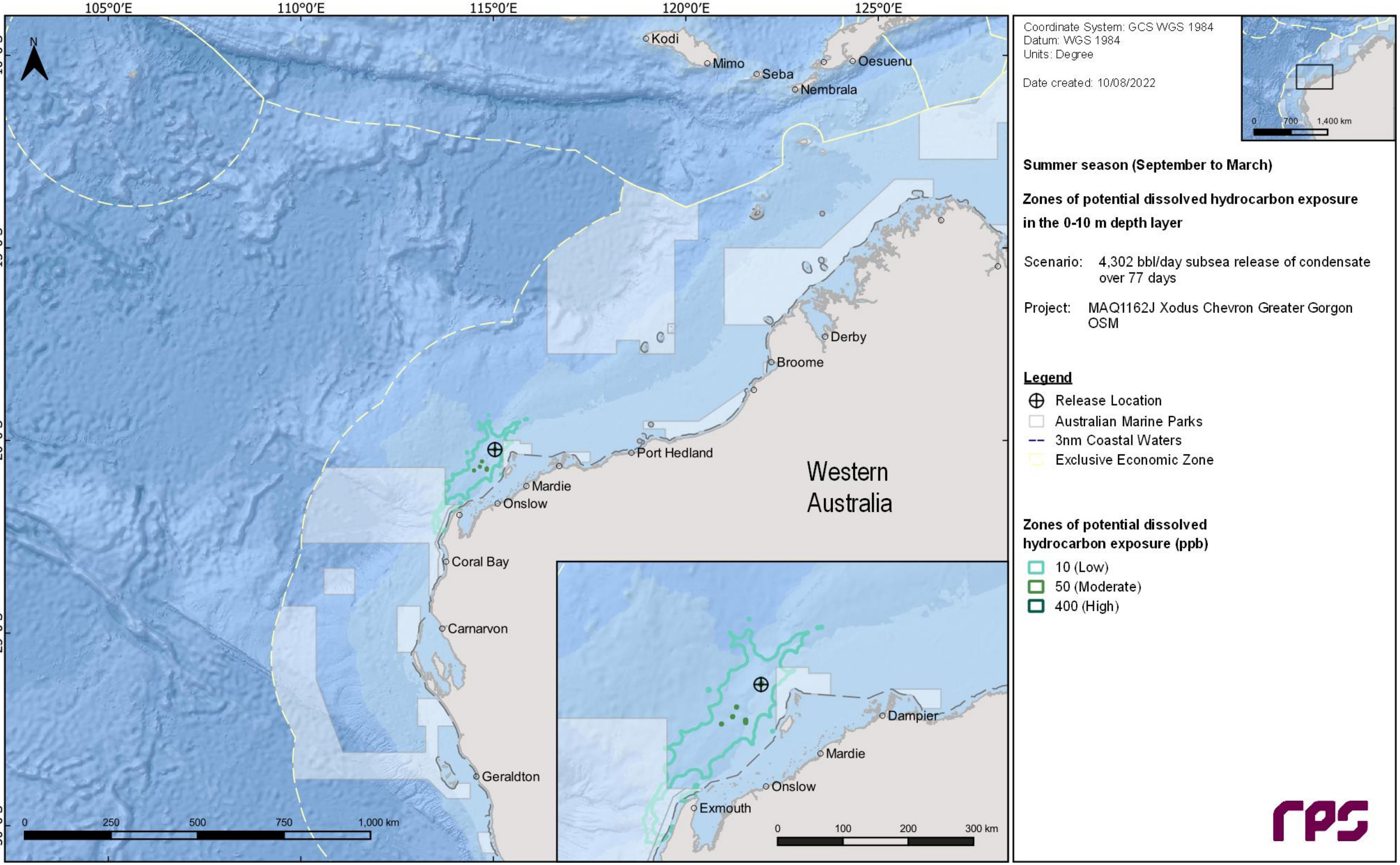


Figure 11.7 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

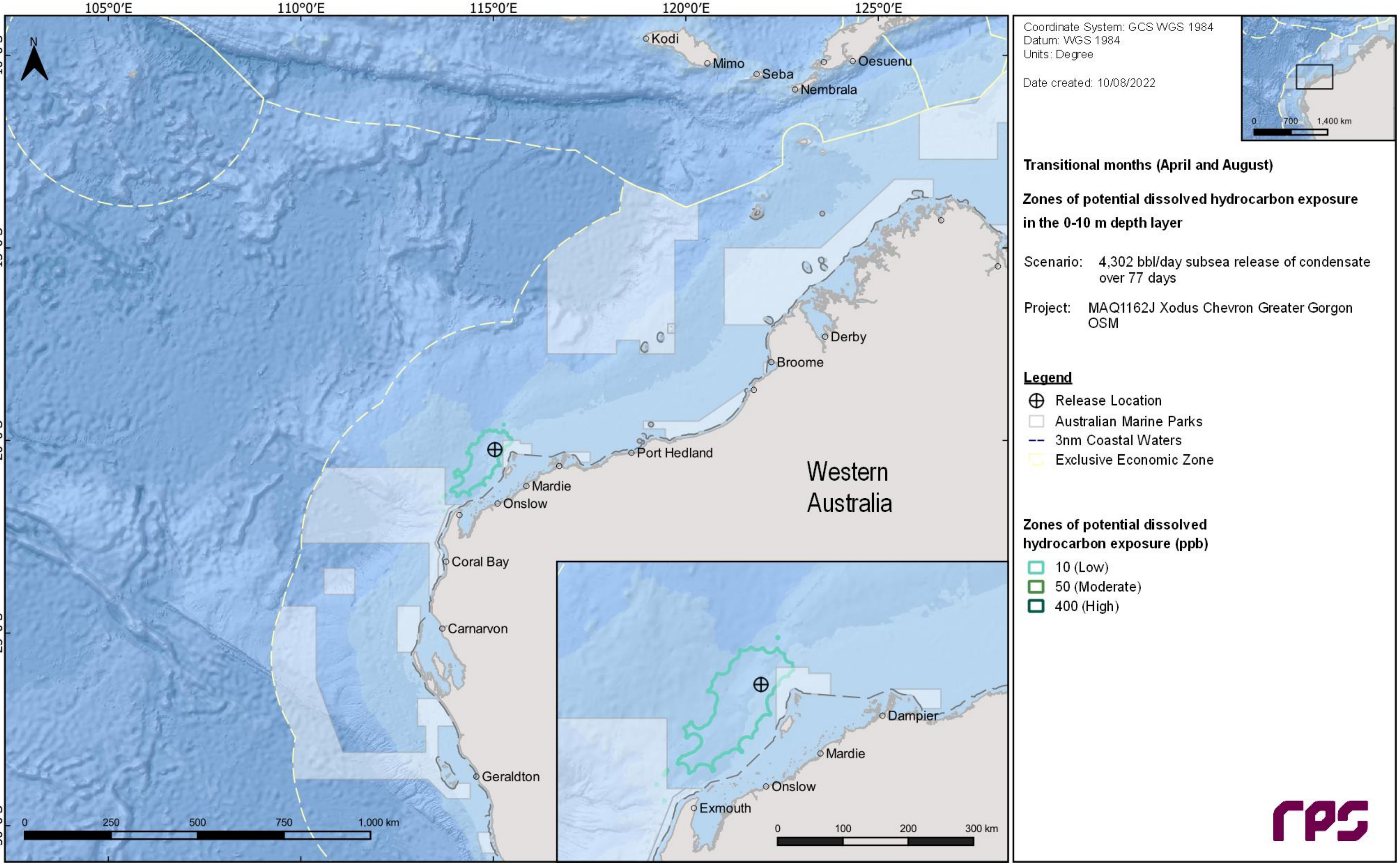


Figure 11.8 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

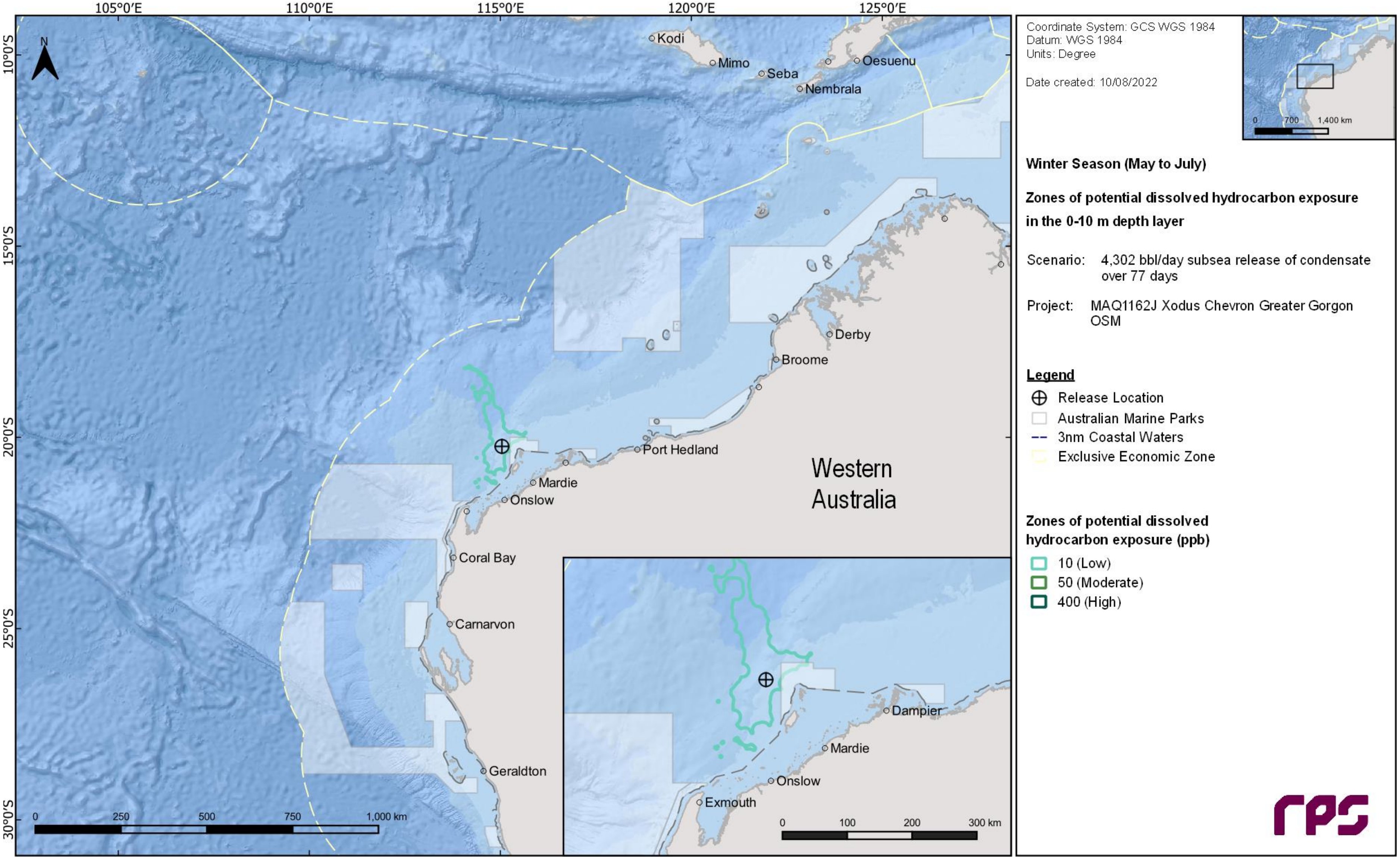


Figure 11.9 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3.2 Entrained Hydrocarbons

Table 11.8 summarises the probability and minimum time before exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

In the surface (0-10 m) depth layer, a total of 36 BIAs were predicted to be exposed at, or above, the low threshold during all 3 seasons. Excluding the 4 BIAs (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging) that the release location resides within (see Section 10.3), the highest probabilities of exposure to low entrained hydrocarbons were predicted for the Flatback Turtle - Internesting Buffer (97% during summer and 100% during transitional and winter) and Humpback Whale - Migration BIAs (100% during all seasons).

During all 3 seasons, 6 AMPs were predicted to be exposed at the low threshold, with the highest probabilities predicted at the Gascoyne AMP (95% summer, 98% transitional and 94% winter). Furthermore, during seasonal conditions the Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold.

During summer, transitional and winter conditions, 9, 10 and 11 KEFs were predicted to be exposed by entrained hydrocarbons at the low threshold, respectively. Probabilities of exposure ranged between 8–100%, 4–100% and 2–100%, for summer, transitional and winter, respectively. Excluding the KEF that the release location resides within (Ancient coastline at 125 m depth contour), the KEF with the greatest probability of low exposure for each season was the Continental Slope Demersal Fish Communities KEF (100% during all seasons).

Additionally, 58, 32 and 33 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold. Excluding the Offshore IAA, the probabilities for each season ranged between 2–95%, 2–98% and 1–94% under summer, transitional and winter conditions, respectively, with the maximum probabilities occurring at the Gascoyne IAA during all seasons.

Furthermore, 70, 29 and 32 RBS receptors were predicted to be exposed to entrained hydrocarbons at the low threshold during summer, transitional and winter, respectively. The maximum probabilities for low threshold exposure during summer, transitional and winter were predicted for Rankin Bank (73%), Outtrim Patches (52%) and Penguin Banks and Rosliy Shoals (70%), respectively.

Figure 11.10 to Figure 11.12 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

Table 11.8 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer					Transitional					Winter				
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
IAA	Barrow Island (West Coast)	219	24	13	6.75	8.54	38	3	-	29.63	-	32	17	-	14.83	-
	South Muiron Island	181	40	15	7.38	39.75	162	54	12	13.75	28.58	207	73	15	5.88	17.25
	Thevenard Island	761	31	3	10.42	79.04	114	35	3	10.92	19.08	49	39	-	10.42	-
	Serrurier Island	143	39	13	8.79	30.00	199	55	4	9.83	17.88	58	69	-	6.96	-
	Bessieres Island	103	38	1	8.88	48.92	354	53	4	8.46	9.50	64	64	-	11.88	-
	Locker Island	28	16	-	32.50	-	19	3	-	27.92	-	7	-	-	-	-
	Airlie Island	778	21	3	11.29	79.08	32	20	-	52.17	-	33	38	-	8.96	-
	Ashburton Island	50	13	-	15.08	-	7	-	-	-	-	14	7	-	33.21	-
	North Muiron Island	202	43	14	7.00	38.92	179	57	10	13.08	21.88	358	73	19	5.71	17.04
	Great Sandy Island	237	10	1	31.50	84.21	1	-	-	-	-	7	-	-	-	-
	North Sandy Island	172	13	1	19.79	86.75	1	-	-	-	-	7	-	-	-	-
	Passage Island	50	9	-	21.96	-	1	-	-	-	-	1	-	-	-	-
	Sholl Island	152	11	1	18.29	89.33	1	-	-	-	-	1	-	-	-	-
	Eaglehawk Island	24	10	-	32.38	-	1	-	-	-	-	1	-	-	-	-
	Enderby Island	25	10	-	33.38	-	1	-	-	-	-	1	-	-	-	-
	Rosemary Island	31	10	-	35.88	-	1	-	-	-	-	2	-	-	-	-
	Goodwyn Island	28	10	-	35.21	-	1	-	-	-	-	1	-	-	-	-
	Malus Islands	23	9	-	37.33	-	1	-	-	-	-	1	-	-	-	-
	West Lewis Island	19	8	-	37.38	-	1	-	-	-	-	1	-	-	-	-
	Legendre Island	12	2	-	39.96	-	1	-	-	-	-	2	-	-	-	-
	Boodie Island	214	25	11	6.75	7.88	16	2	-	78.04	-	40	18	-	13.08	-
	Middle Island	226	25	13	6.79	8.33	14	2	-	24.38	-	32	13	-	13.29	-
	Double Island	17	5	-	36.92	-	2	-	-	-	-	5	-	-	-	-
	Bedwell Island (Clerke Reef)	14	4	-	31.21	-	1	-	-	-	-	6	-	-	-	-
	Dirk Hartog Island	14	5	-	81.13	-	13	5	-	57.75	-	7	-	-	-	-
	Potter Island	68	8	-	58.46	-	-	-	-	-	-	-	-	-	-	-
	Yammadery Island	44	3	-	66.92	-	1	-	-	-	-	3	-	-	-	-
	Cunningham Island (Imperieuse Reef)	69	9	-	27.33	-	2	-	-	-	-	59	8	-	59.88	-
	Rankin Bank	324	72	57	3.29	5.21	417	51	28	7.88	23.42	400	63	37	3.75	13.63
	Glomar Shoal	123	8	2	12.63	13.21	9	-	-	-	-	2	-	-	-	-
	South Ningaloo Coast - World Heritage Area	41	14	-	14.63	-	21	5	-	50.83	-	24	11	-	29.58	-
	Middle Ningaloo Coast - World Heritage Area	157	32	9	8.96	12.08	77	36	-	26.42	-	50	27	-	19.75	-
	North Ningaloo Coast - World Heritage Area	223	42	9	8.25	10.88	235	44	9	15.50	42.50	230	56	16	10.54	17.13
	Cape Range National Park	219	34	8	8.29	8.88	132	42	10	15.00	42.67	376	53	16	11.63	17.46
	Abrolhos Islands IAA	82	11	-	22.83	-	34	13	-	30.13	-	33	8	-	31.63	-
	Gascoyne IAA	475	95	33	4.83	6.63	464	98	45	5.17	7.67	287	94	32	5.17	8.38

Receptor		Summer					Transitional					Winter				
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Ningaloo Coast World Heritage Area	341	60	29	6.29	7.00	270	76	27	5.88	9.75	534	92	36	5.42	10.13
	Argo-Rowley Terrace IAA	91	29	-	24.00	-	94	33	-	19.58	-	96	42	-	31.38	-
	Dampier Archipelago IAA	145	14	1	15.29	89.63	7	-	-	-	-	4	-	-	-	-
	Abutilon Island	19	8	-	36.88	-	3	-	-	-	-	7	-	-	-	-
	Trimouille Island	33	16	-	15.71	-	15	2	-	81.00	-	8	-	-	-	-
	Hermite Island	68	17	-	12.38	-	67	2	-	79.96	-	10	1	-	56.42	-
	Barrow Island (East Coast)	111	20	3	8.38	33.04	7	-	-	-	-	19	8	-	17.33	-
	Barrow & Montebello Islands IAA	886	90	77	0.88	1.33	545	73	60	1.71	2.46	556	94	77	1.42	1.50
	Pilbara Coast IAA	1,092	48	15	6.00	10.25	475	74	25	4.46	7.75	508	84	25	5.17	8.63
	Exmouth IAA	132	38	8	7.83	40.29	143	37	4	15.54	28.50	99	57	-	6.38	-
	Shark Bay mainland coastline	139	25	2	29.79	51.08	30	38	-	16.88	-	28	13	-	20.00	-
	Offshore Area	6,522	100	100	0.04	0.04	3,865	100	100	0.04	0.04	3,826	100	100	0.04	0.04
	Onslow Area Mainland Coastline	105	7	1	36.00	96.21	5	-	-	-	-	3	-	-	-	-
	Dampier mainland coastline	82	10	-	41.46	-	-	-	-	-	-	1	-	-	-	-
	Dampier Archipelago Island Group	31	10	-	32.38	-	1	-	-	-	-	2	-	-	-	-
	Lowendal Islands Group	19	8	-	36.88	-	3	-	-	-	-	7	-	-	-	-
	Montebello Islands Group	68	17	-	12.38	-	67	2	-	79.96	-	10	1	-	56.42	-
	Barrow Island Group	226	25	13	6.75	7.88	38	3	-	24.38	-	40	18	-	13.08	-
	Pilbara Mainland Coast	105	7	1	36.00	96.21	5	-	-	-	-	3	-	-	-	-
	Pilbara Coast Islands Group	778	39	13	8.79	30.00	354	55	4	8.46	9.50	64	69	-	6.96	-
	Exmouth Gulf Mainland Coastline	24	14	-	11.46	-	16	16	-	28.88	-	14	14	-	25.92	-
	Muiron Islands	202	43	15	7.00	38.92	179	57	12	13.08	21.88	358	73	19	5.71	17.04
	Shark Bay World Heritage Site	14	5	-	81.13	-	13	5	-	57.75	-	7	-	-	-	-
AMP	Abrolhos	82	11	-	22.83	-	34	13	-	30.04	-	33	8	-	31.63	-
	Argo-Rowley Terrace	91	29	-	24.00	-	94	33	-	19.58	-	96	42	-	31.38	-
	Carnarvon Canyon	49	22	-	25.54	-	45	18	-	16.63	-	41	11	-	18.04	-
	Dampier	25	1	-	38.54	-	1	-	-	-	-	2	-	-	-	-
	Gascoyne	475	95	33	4.83	6.63	464	98	45	5.17	7.67	287	94	32	5.17	8.38
	Mermaid Reef	10	1	-	68.88	-	1	-	-	-	-	3	-	-	-	-
	Montebello	886	90	77	0.88	1.33	545	73	60	1.71	2.46	556	94	77	1.42	1.50
	Ningaloo	341	60	29	6.29	7.00	270	76	27	5.88	9.75	499	92	36	5.75	10.13
	Shark Bay	139	24	2	30.42	51.58	25	33	-	17.54	-	25	12	-	20.25	-
BIA	Australian Lesser Noddy - Foraging	11	1	-	93.29	-	9	-	-	-	-	7	-	-	-	-
	Bridled Tern - Foraging	38	17	-	30.96	-	28	19	-	44.42	-	28	7	-	23.04	-
	Common Noddy - Foraging	11	1	-	94.38	-	9	-	-	-	-	7	-	-	-	-
	Dugong - Breeding	265	47	18	7.17	7.67	270	59	21	7.38	22.75	534	75	32	6.21	10.38
	Dugong - Calving	265	47	18	7.17	7.67	270	59	21	7.38	22.75	534	75	32	6.21	10.38
	Dugong - Foraging	265	47	18	7.17	7.67	270	59	21	7.38	22.75	534	75	32	6.21	10.38

Receptor	Summer					Transitional					Winter				
	Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)	
		Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
Dugong - Nursing	265	47	18	7.17	7.67	270	59	21	7.38	22.75	534	75	32	6.21	10.38
Fairy Tern - Breeding	1,078	50	27	4.92	5.21	302	69	23	5.46	9.88	534	91	36	5.33	10.38
Flatback Turtle - Aggregation	114	22	5	12.04	32.08	98	2	-	79.29	-	11	1	-	38.04	-
Flatback Turtle - Foraging	410	25	13	6.13	7.88	98	3	-	24.38	-	41	19	-	13.08	-
Flatback Turtle - Internesting	114	22	5	12.04	32.08	98	2	-	79.29	-	11	1	-	38.04	-
Flatback Turtle - Internesting Buffer	6,522	100	100	0.04	0.04	3,865	100	100	0.04	0.04	3,826	100	100	0.04	0.04
Flatback Turtle - Mating	251	25	13	6.13	7.88	98	3	-	24.38	-	41	19	-	13.08	-
Flatback Turtle - Migration	23	10	-	33.29	-	1	-	-	-	-	1	-	-	-	-
Flatback Turtle - Nesting	1,108	97	81	0.96	1.13	886	100	95	1.13	1.50	861	100	97	0.88	1.46
Green Turtle - Aggregation	114	22	5	12.04	32.08	98	2	-	79.29	-	11	1	-	38.04	-
Green Turtle - Basking	251	25	13	6.08	7.83	60	3	-	23.50	-	45	21	-	13.04	-
Green Turtle - Foraging	410	30	13	6.13	7.88	121	7	2	23.67	80.79	41	19	-	13.08	-
Green Turtle - Internesting	251	30	13	6.13	7.88	121	7	2	23.67	80.79	41	19	-	13.08	-
Green Turtle - Internesting Buffer	1,031	69	45	2.92	4.13	482	91	35	3.50	5.58	508	97	42	2.58	5.25
Green Turtle - Mating	251	30	13	6.08	7.83	121	7	2	23.50	80.79	45	21	-	13.04	-
Green Turtle - Migration	23	10	-	33.29	-	1	-	-	-	-	1	-	-	-	-
Green Turtle - Nesting	1,108	66	32	3.29	4.63	533	85	34	3.50	7.46	534	92	36	2.88	5.25
Hawksbill Turtle - Foraging	410	25	13	6.13	7.88	86	3	-	24.38	-	41	19	-	13.08	-
Hawksbill Turtle - Internesting	54	16	-	12.33	-	9	-	-	-	-	8	-	-	-	-
Hawksbill Turtle - Internesting Buffer	1,092	70	37	2.96	4.33	482	91	31	4.00	5.50	534	97	45	2.63	5.21
Hawksbill Turtle - Mating	251	25	13	6.13	7.88	86	3	-	24.38	-	41	19	-	13.08	-
Hawksbill Turtle - Migration	23	10	-	33.29	-	1	-	-	-	-	1	-	-	-	-
Hawksbill Turtle - Nesting	1,108	66	32	3.29	4.63	533	85	34	3.50	7.46	508	92	34	2.88	5.25
Humpback Whale - Migration	1,244	100	100	0.38	0.79	902	100	100	0.67	0.79	855	100	100	0.63	0.75
Humpback Whale - Resting	88	37	-	8.38	-	113	36	3	18.79	30.00	83	49	-	7.38	-
Lesser Crested Tern - Breeding	1,092	53	24	4.21	4.63	372	76	30	5.00	8.46	349	85	23	4.79	5.25
Little Shearwater - Foraging	15	3	-	87.58	-	20	5	-	54.08	-	22	3	-	39.17	-
Little Tern - Resting	94	10	-	23.63	-	4	-	-	-	-	60	8	-	58.71	-
Loggerhead Turtle - Internesting Buffer	429	68	33	4.21	5.25	270	85	35	3.58	7.63	534	92	41	4.63	9.17
Loggerhead Turtle - Nesting	388	60	29	6.17	6.88	270	77	27	5.63	9.75	534	92	36	5.71	10.13
Pygmy Blue Whale - Distribution	6,522	100	100	0.04	0.04	3,865	100	100	0.04	0.04	3,826	100	100	0.04	0.04
Pygmy Blue Whale - Foraging	396	84	31	6.42	6.96	247	82	23	5.25	7.75	380	93	36	5.58	10.63
Roseate Tern - Breeding	1,108	66	25	4.08	6.25	329	86	26	6.54	18.04	326	90	32	3.46	4.25
Sooty Tern - Foraging	38	22	-	31.08	-	34	20	-	25.25	-	33	11	-	23.21	-
Wedge-tailed Shearwater - Breeding	6,522	100	100	0.04	0.04	3,865	100	100	0.04	0.04	3,826	100	100	0.04	0.04
Wedge-tailed Shearwater - Foraging	38	23	-	30.96	-	28	19	-	25.04	-	28	8	-	23.04	-
Whale Shark - Foraging	6,522	100	100	0.04	0.04	3,865	100	100	0.04	0.04	3,826	100	100	0.04	0.04
White-faced Storm-petrel - Foraging	15	4	-	77.08	-	20	5	-	54.00	-	22	4	-	37.58	-

Receptor		Summer					Transitional					Winter				
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	White-tailed Tropicbird - Breeding	108	26	2	19.71	21.00	50	12	-	31.96	-	83	17	-	54.92	-
CP	Montebello Islands (CP	67	17	-	12.88	-	69	2	-	80.00	-	10	1	-	101.42	-
EEZ	Australian Exclusive Economic Zone	6,522	100	100	0.04	0.04	3,865	100	100	0.04	0.04	3,826	100	100	0.04	0.04
	Christmas Island Exclusive Economic Zone	12	2	-	38.63	-	15	1	-	57.75	-	18	4	-	81.46	-
	Indonesian Exclusive Economic Zone	15	3	-	37.00	-	20	7	-	50.29	-	23	7	-	55.29	-
IBRA	Cape Range	365	43	15	6.75	8.54	354	57	12	5.38	9.71	387	73	19	5.71	17.04
	Edel	14	5	-	81.13	-	13	5	-	56.71	-	7	-	-	-	-
	Roebourne	778	25	13	6.79	7.88	29	20	-	24.38	-	39	34	-	9.25	-
	Wooramel	13	4	-	35.21	-	6	-	-	-	-	5	-	-	-	-
IMCRA	Ningaloo	442	69	31	5.67	5.96	264	85	32	4.58	8.67	534	95	36	4.92	9.54
	Northwest Shelf	3,852	95	89	0.58	0.63	1,134	86	78	1.29	1.42	1,049	98	93	0.67	0.71
	Pilbara (nearshore)	518	38	7	7.92	40.25	159	44	4	18.04	27.46	94	54	-	7.38	-
	Pilbara (offshore)	6,522	100	100	0.04	0.04	3,865	100	100	0.04	0.04	3,826	100	100	0.04	0.04
	Zuytdorp	139	25	2	29.46	51.08	30	38	-	16.88	-	28	13	-	20.00	-
KEF	Ancient coastline at 125 m depth contour	6,522	100	100	0.04	0.04	3,865	100	100	0.04	0.04	3,826	100	100	0.04	0.04
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	5	-	-	-	-	19	7	-	47.96	-	17	5	-	89.92	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	442	93	37	4.92	5.92	385	90	50	3.42	6.92	468	100	41	4.33	4.67
	Commonwealth waters adjacent to Ningaloo Reef	341	60	29	6.29	7.00	270	76	27	5.88	9.75	499	92	36	5.75	10.13
	Continental Slope Demersal Fish Communities	3,284	100	100	0.38	0.42	1,456	100	100	0.33	0.42	1,407	100	100	0.42	0.50
	Exmouth Plateau	445	88	23	6.42	9.46	424	100	20	7.21	9.63	378	90	24	6.58	6.83
	Glomar Shoals	318	22	6	11.17	11.63	25	8	-	52.54	-	13	2	-	73.46	-
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	91	10	-	23.63	-	3	-	-	-	-	60	8	-	58.46	-
	Perth Canyon and adjacent shelf break, and other west coast canyons	9	-	-	-	-	15	4	-	55.08	-	15	3	-	41.29	-
	Wallaby Saddle	78	8	-	23.50	-	16	5	-	65.79	-	16	4	-	36.46	-
	Western demersal slope and associated fish communities	38	23	-	30.96	-	28	19	-	25.04	-	28	11	-	23.04	-
MMA	Barrow Island	604	35	16	5.21	6.04	127	19	2	15.17	78.50	51	39	-	11.04	-
	Muiron Islands	202	45	15	6.83	26.42	188	60	21	8.58	21.75	480	73	28	5.42	15.54
MP	Barrow Island	147	27	10	5.33	8.88	93	13	-	46.75	-	23	33	-	17.88	-
	Montebello Islands	171	31	6	7.92	9.96	130	10	2	12.58	80.46	17	16	-	20.58	-
	Ningaloo	260	46	17	7.38	7.88	264	50	19	9.75	22.88	534	67	31	6.29	14.92
	Rowley Shoals	81	10	-	26.17	-	2	-	-	-	-	60	8	-	59.04	-
NR	Great Sandy Island	436	17	2	11.83	83.08	2	-	-	-	-	13	5	-	42.79	-
	Thevenard Island	337	21	1	11.38	79.46	56	26	-	16.96	-	40	36	-	10.79	-
RSB	Ashworth Shoal	81	2	-	90.92	-	-	-	-	-	-	-	-	-	-	-
	Australind Shoal	51	16	-	15.00	-	11	4	-	53.25	-	21	9	-	27.92	-

Receptor	Summer: Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Summer: Probability of instantaneous exposure to entrained hydrocarbons (%)		Summer: Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Transitional: Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Transitional: Probability of instantaneous exposure to entrained hydrocarbons (%)		Transitional: Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Winter: Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Winter: Probability of instantaneous exposure to entrained hydrocarbons (%)		Winter: Minimum time before instantaneous exposure to entrained hydrocarbons (Days)	
		Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
Barrow Island Reefs and Shoals	477	19	2	11.33	82.71	2	-	-	-	-	16	7	-	42.17	-
Baylis Patches	28	18	-	30.50	-	33	4	-	20.88	-	7	-	-	-	-
Beryl Reef	32	14	-	29.29	-	37	7	-	29.88	-	13	5	-	29.79	-
Brewis Reef	85	21	-	10.88	-	101	25	1	9.96	32.08	51	34	-	13.21	-
Clerke Reef	14	4	-	31.21	-	1	-	-	-	-	6	-	-	-	-
Cod Bank	70	10	-	27.38	-	1	-	-	-	-	2	-	-	-	-
Combe Reef	90	35	-	9.46	-	114	26	3	20.79	30.00	32	39	-	18.75	-
Courtenay Shoal	16	10	-	38.25	-	1	-	-	-	-	1	-	-	-	-
Curlew Bank	20	1	-	96.63	-	1	-	-	-	-	3	-	-	-	-
Dailey Shoal	166	39	7	8.88	38.21	180	45	4	19.29	27.54	48	65	-	12.67	-
Dockrell Reef	12	1	-	45.50	-	-	-	-	-	-	1	-	-	-	-
Eliassen Rocks	73	6	-	48.79	-	-	-	-	-	-	-	-	-	-	-
Exmouth Reef	41	33	-	9.92	-	64	23	-	21.88	-	21	28	-	19.71	-
Fairway Reef	66	34	-	11.00	-	150	38	3	19.29	27.42	22	42	-	13.58	-
Flinders Shoal	408	17	1	17.17	82.71	2	-	-	-	-	12	4	-	44.75	-
Fortescue Reef	107	10	1	48.38	94.13	1	-	-	-	-	1	-	-	-	-
Glennie Patches	33	14	-	35.25	-	6	-	-	-	-	10	1	-	41.50	-
Glomar Shoal	136	8	2	12.63	13.17	9	-	-	-	-	2	-	-	-	-
Gorgon Patch	122	6	1	46.58	96.58	3	-	-	-	-	6	-	-	-	-
Hammersley Shoal	15	3	-	83.13	-	1	-	-	-	-	1	-	-	-	-
Hastings Shoal	92	3	-	81.67	-	2	-	-	-	-	5	-	-	-	-
Hayman Rock	34	19	-	20.38	-	47	4	-	19.92	-	7	-	-	-	-
Herald Reef	101	10	1	42.25	95.17	3	-	-	-	-	5	-	-	-	-
Hood Reef	133	35	7	9.38	38.17	172	44	4	18.71	27.29	28	56	-	12.63	-
Imperieuse Reef	69	9	-	27.33	-	2	-	-	-	-	60	8	-	59.88	-
Inner Northwest Patch	27	14	-	35.38	-	6	-	-	-	-	7	-	-	-	-
Koolinda Patch	114	3	1	82.13	97.13	2	-	-	-	-	4	-	-	-	-
Lightfoot Reef	265	13	1	19.38	83.17	2	-	-	-	-	10	1	-	101.46	-
Little Shoals	136	15	1	31.33	81.13	3	-	-	-	-	9	-	-	-	-
Locker Reef	41	19	-	15.46	-	40	4	-	19.88	-	9	-	-	-	-
Madeleine Shoals	23	1	-	38.54	-	1	-	-	-	-	2	-	-	-	-
Manicom Bank	21	13	-	18.25	-	3	-	-	-	-	6	-	-	-	-
Mardie Rock	89	3	-	84.96	-	-	-	-	-	-	-	-	-	-	-
McLennan Bank	122	11	1	25.38	91.04	1	-	-	-	-	2	-	-	-	-
Meda Reef	127	11	1	20.38	88.33	1	-	-	-	-	1	-	-	-	-
Miles Shoal	58	15	-	29.08	-	7	-	-	-	-	13	6	-	34.33	-
Montebello Shoals	107	24	1	8.33	40.25	107	3	1	79.33	82.33	12	3	-	49.50	-
Moresby Shoals	112	13	1	33.88	94.75	2	-	-	-	-	6	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Nares Rock	103	12	1	35.96	94.67	2	-	-	-	-	5	-	-	-	-
	Ningaloo Reef	232	42	12	7.96	8.50	243	44	11	14.42	42.38	399	57	17	10.38	17.04
	North West Reef	28	10	-	30.75	-	1	-	-	-	-	1	-	-	-	-
	North West Reef	140	39	6	8.29	40.88	149	38	9	15.58	44.42	148	56	6	9.83	19.08
	O'Grady Shoal	116	11	1	47.25	91.46	1	-	-	-	-	1	-	-	-	-
	Otway Reef	134	38	7	9.42	40.21	156	38	4	19.75	28.42	26	56	-	13.29	-
	Outtrim Patches	189	42	10	7.29	38.63	174	52	4	13.38	27.67	219	68	10	5.88	17.04
	Paroo Shoal	83	9	-	36.50	-	4	-	-	-	-	8	-	-	-	-
	Pearl Reef	28	9	-	29.33	-	24	7	-	29.88	-	12	2	-	32.79	-
	Penguin Bank	1,053	38	2	7.17	78.25	135	40	9	14.79	52.25	123	70	6	7.08	26.92
	Poivre Reef	204	32	15	6.75	6.83	24	4	-	23.67	-	59	33	-	12.79	-
	Rankin Bank	333	73	58	3.25	3.83	417	51	28	7.88	12.29	405	63	40	3.75	13.63
	Ripple Shoals	523	21	8	8.38	21.63	9	-	-	-	-	39	16	-	11.17	-
	Roller Shoal	22	4	-	51.21	-	3	-	-	-	-	3	-	-	-	-
	Rosily Shoals	974	38	3	6.25	78.58	187	49	6	10.25	18.08	109	70	3	8.79	27.46
	Saladin Shoal	83	5	-	60.17	-	2	-	-	-	-	8	-	-	-	-
	Santo Rock	47	20	-	23.17	-	42	11	-	18.04	-	19	12	-	14.25	-
	South East Reef	18	8	-	34.29	-	-	-	-	-	-	1	-	-	-	-
	South West Reef	25	9	-	32.29	-	-	-	-	-	-	1	-	-	-	-
	Southwest Patch	15	7	-	36.67	-	2	-	-	-	-	3	-	-	-	-
	Spider Reef	52	29	-	12.29	-	93	13	-	19.71	-	23	9	-	22.00	-
	Sultan Reef	560	20	1	13.08	79.67	19	8	-	53.29	-	21	11	-	9.38	-
	Taunton Reef	677	19	2	11.42	80.00	20	9	-	52.25	-	19	14	-	9.46	-
	Tongue Shoals	32	17	-	17.29	-	11	1	-	40.92	-	9	-	-	-	-
	Trap Reef	793	22	3	10.42	78.96	78	27	-	17.04	-	42	38	-	10.71	-
	Tryal Rocks	430	52	17	7.33	10.04	146	30	3	7.04	81.42	132	46	7	10.08	20.29
	Ward Reef	58	2	-	95.42	-	2	-	-	-	-	3	-	-	-	-
	Web Reef	40	29	-	12.33	-	97	12	-	19.88	-	21	9	-	22.92	-
	Weeks Shoal	119	9	1	40.71	95.67	2	-	-	-	-	7	-	-	-	-
	West Reef	159	14	1	30.13	82.67	2	-	-	-	-	8	-	-	-	-
Nearshore Waters	Airlie Island	778	21	3	11.29	79.08	32	20	-	52.17	-	33	38	-	8.96	-
	Ashburton	67	7	-	13.54	-	21	3	-	28.88	-	9	-	-	-	-
	Ashburton Island	50	12	-	15.13	-	6	-	-	-	-	13	4	-	34.38	-
	Barrow Island	219	24	13	6.75	8.54	33	3	-	29.63	-	32	17	-	14.83	-
	Bessieres Island	103	38	1	8.88	48.92	354	53	4	8.46	9.50	64	64	-	11.88	-
	Boodie Island	214	25	10	6.79	7.88	16	2	-	78.33	-	39	18	-	13.13	-
	Cape Bruguieres	10	1	-	93.08	-	1	-	-	-	-	1	-	-	-	-
	Carnarvon	38	14	-	14.13	-	19	5	-	50.50	-	26	10	-	29.54	-

Receptor	Summer: Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Summer: Probability of instantaneous exposure to entrained hydrocarbons (%)		Summer: Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Transitional: Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Transitional: Probability of instantaneous exposure to entrained hydrocarbons (%)		Transitional: Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Winter: Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Winter: Probability of instantaneous exposure to entrained hydrocarbons (%)		Winter: Minimum time before instantaneous exposure to entrained hydrocarbons (Days)	
		Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
Clerke Reef	12	1	-	72.00	-	1	-	-	-	-	5	-	-	-	-
Cohen Island	15	2	-	92.96	-	1	-	-	-	-	1	-	-	-	-
Cunningham Island	62	8	-	27.71	-	1	-	-	-	-	55	8	-	60.50	-
Direction Island	132	9	1	41.25	95.67	2	-	-	-	-	5	-	-	-	-
Dirk Hartog Island	14	5	-	81.13	-	13	5	-	57.54	-	7	-	-	-	-
Eaglehawk Island	24	10	-	32.33	-	1	-	-	-	-	1	-	-	-	-
East Lewis Island	10	1	-	83.17	-	1	-	-	-	-	1	-	-	-	-
Enderby Island	25	10	-	33.21	-	1	-	-	-	-	1	-	-	-	-
Exmouth	223	42	12	8.25	8.88	235	44	10	15.00	42.50	387	56	16	10.54	17.13
Flat Island	177	40	11	8.71	30.00	221	56	4	13.58	23.54	60	72	-	9.21	-
Fly Island	32	28	-	12.42	-	88	11	-	20.38	-	19	7	-	23.00	-
Goodwyn Island	28	10	-	35.21	-	1	-	-	-	-	1	-	-	-	-
Imperieuse Reef	69	8	-	27.33	-	2	-	-	-	-	58	8	-	60.13	-
Karratha	97	10	-	32.17	-	1	-	-	-	-	3	-	-	-	-
Keast Island	11	1	-	92.96	-	1	-	-	-	-	1	-	-	-	-
Kendrew Island	34	11	-	35.25	-	1	-	-	-	-	2	-	-	-	-
Legendre Island	12	2	-	39.92	-	1	-	-	-	-	2	-	-	-	-
Locker Island	28	16	-	32.50	-	19	3	-	27.92	-	7	-	-	-	-
Lowendal Island	32	16	-	12.33	-	6	-	-	-	-	7	-	-	-	-
Malus Island	23	9	-	37.25	-	1	-	-	-	-	1	-	-	-	-
Mangrove Islands	66	4	-	64.50	-	1	-	-	-	-	5	-	-	-	-
Mary Anne Group	328	14	1	19.42	83.13	2	-	-	-	-	13	2	-	42.71	-
Middle Island	226	25	13	6.79	8.29	14	2	-	24.38	-	38	16	-	13.29	-
Montebello Islands	93	23	-	8.33	-	93	2	-	79.88	-	11	2	-	49.50	-
Murion Islands	202	43	15	7.00	38.92	179	57	12	13.08	21.88	358	73	19	5.71	17.04
Observation Island	87	33	-	10.42	-	127	41	3	19.42	27.88	26	43	-	13.63	-
Passage Islands	237	13	1	18.29	84.21	1	-	-	-	-	7	-	-	-	-
Peak Island	214	42	10	7.71	37.79	221	53	4	5.38	27.17	114	68	9	7.29	16.92
Ragnard Islands	80	10	-	30.75	-	1	-	-	-	-	1	-	-	-	-
Rivoli Islands	25	9	-	13.96	-	40	8	-	21.96	-	14	2	-	31.71	-
Rosemary Island	32	11	-	35.88	-	1	-	-	-	-	2	-	-	-	-
Round Island	109	34	3	9.38	48.92	143	44	3	17.75	26.79	38	57	-	12.67	-
Serrurier Island	143	39	13	8.79	30.00	197	55	4	9.88	17.88	58	69	-	6.96	-
Sunday Island	172	39	12	7.88	39.17	177	46	4	15.50	28.38	59	66	-	7.79	-
Table Island	89	33	-	9.38	-	145	46	3	10.08	23.42	50	53	-	13.79	-
Thevenard Island	365	21	1	11.33	79.42	50	26	-	17.54	-	36	36	-	10.88	-
Tortoise Island	59	21	-	10.46	-	46	16	-	17.58	-	26	21	-	13.75	-
Twin Island	99	9	-	44.83	-	2	-	-	-	-	5	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Minimum time before instantaneous exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	West Lewis Island	19	8	-	37.38	-	1	-	-	-	-	1	-	-	-	-
State Waters	Western Australia State Waters	1,108	47	18	5.21	5.92	381	63	21	4.71	8.63	534	81	31	4.79	7.63

*The release location resides within the receptor boundaries.

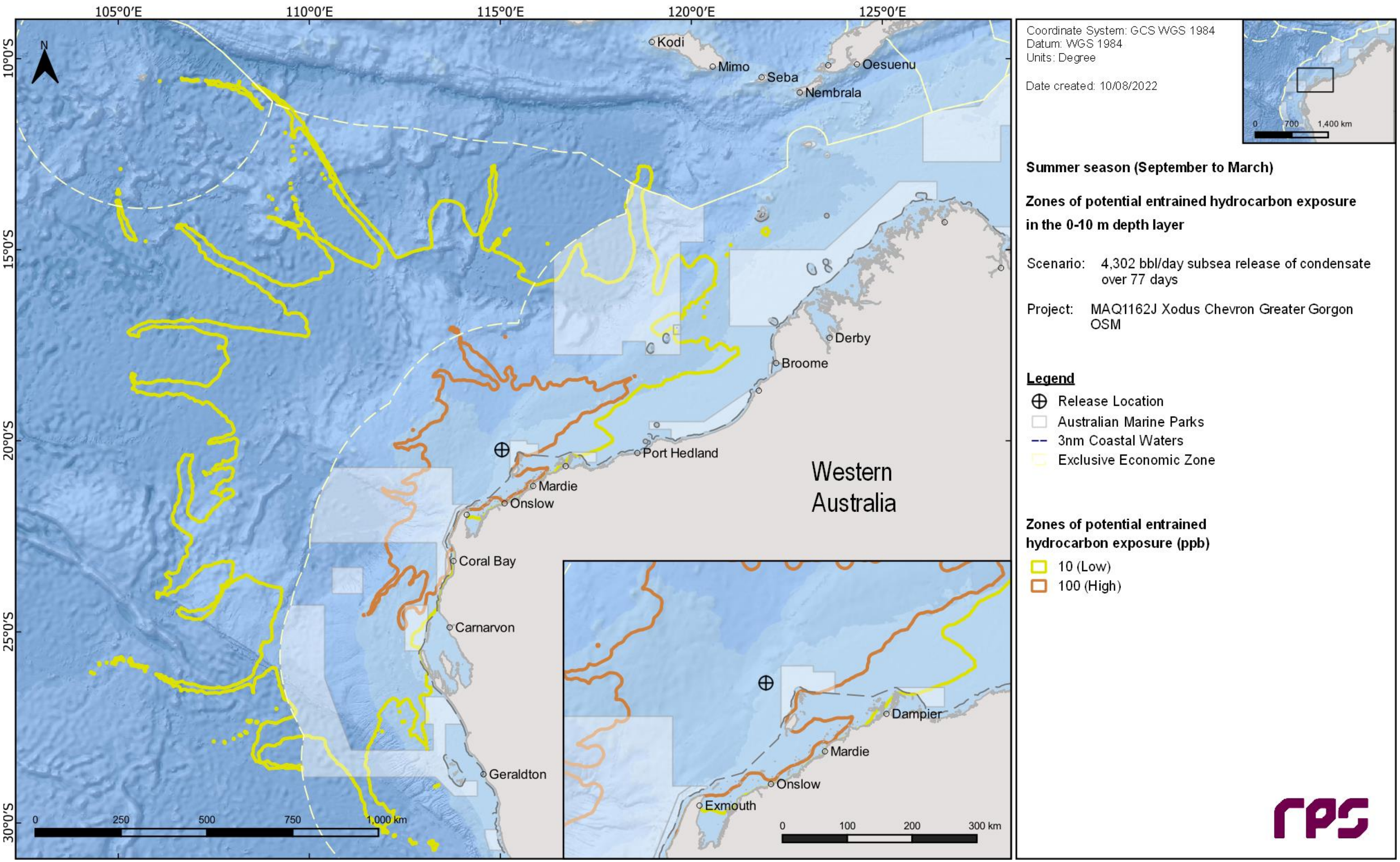


Figure 11.10 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

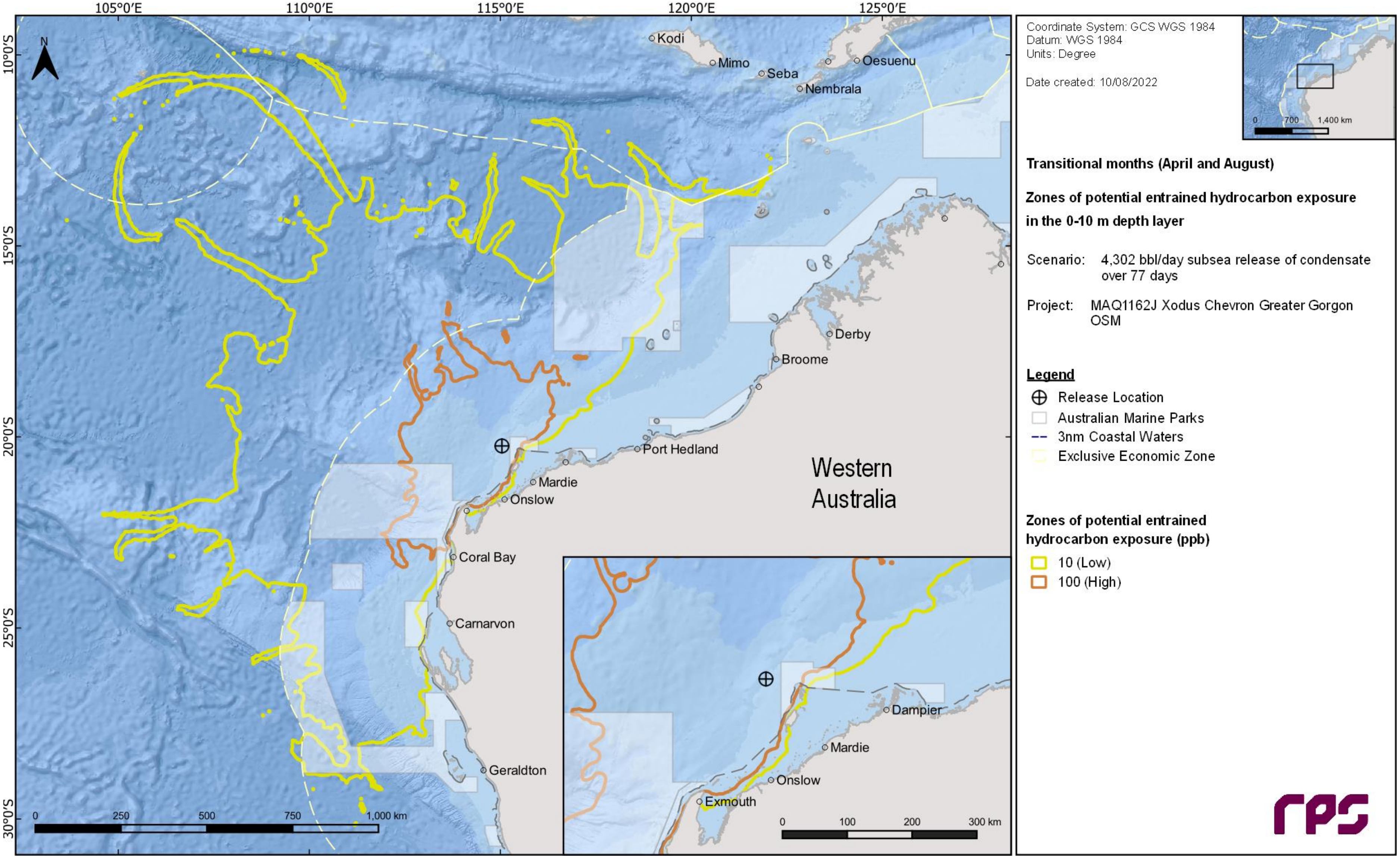


Figure 11.11 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

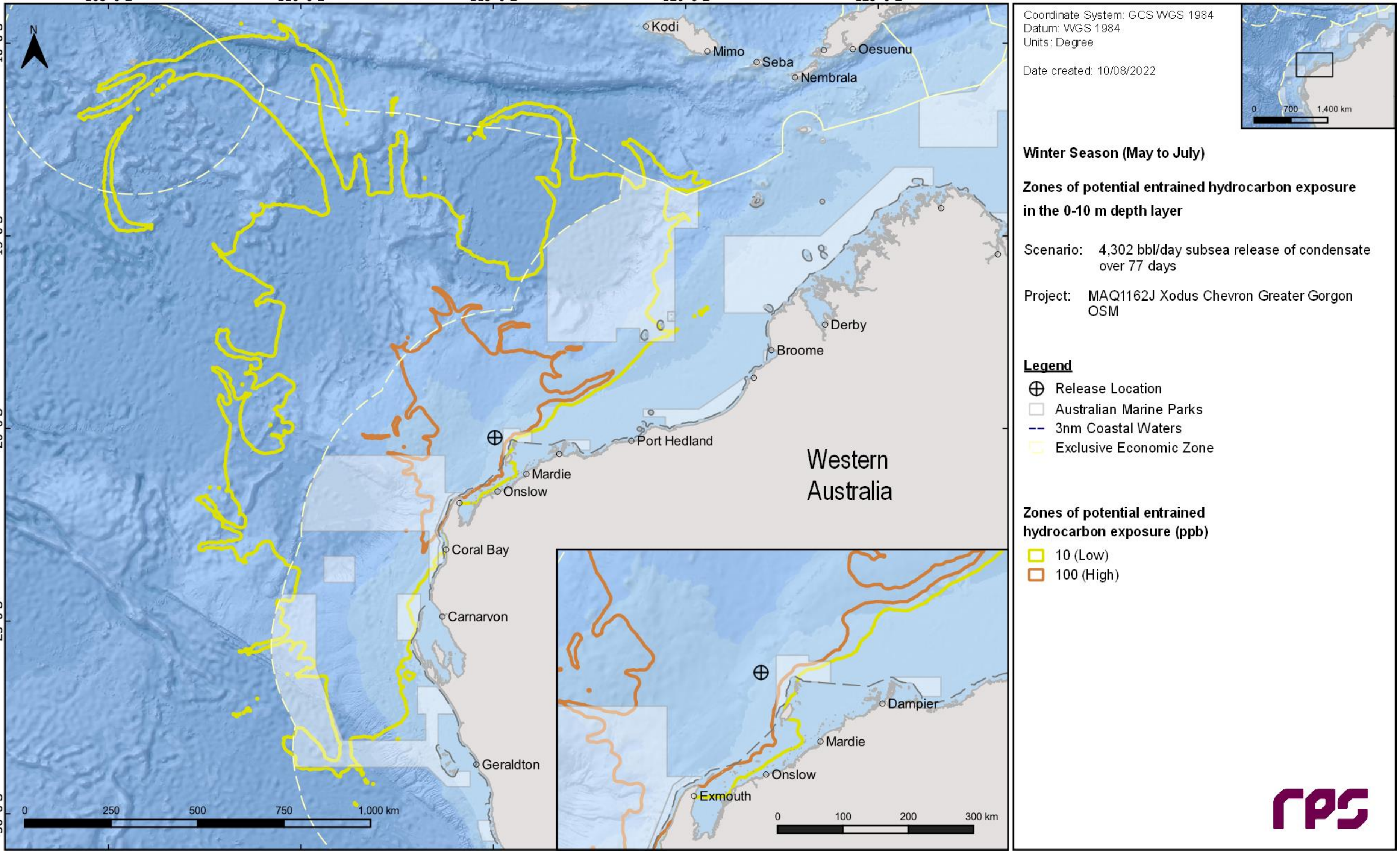


Figure 11.12 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating condensate above 10 g/m^2 (see Section 11.2.1), the largest swept area of floating condensate above 50 g/m^2 (see Section 11.2.2), largest volume of oil ashore (see Section 11.2.3), longest length of shoreline accumulation above 100 g/m^2 (see Section 11.2.4), the largest area of entrained hydrocarbons above 100 ppb (see Section 11.2.5), and the largest area of dissolved hydrocarbons above 50 ppb (see Section 11.2.6).

Table 11.9 presents a summary of all deterministic analysis criteria and the corresponding floating condensate, shoreline accumulation, entrained and dissolved hydrocarbon values at the assessed thresholds.

Table 11.9 Summary of the deterministic analysis following a subsea LOWC at WTR Well 5.

Variable	Threshold	Deterministic Analysis Criteria					
		Largest swept area of floating condensate above 10 g/m^2	Largest swept area of floating condensate above 50 g/m^2	Largest volume of oil ashore	Longest length of shoreline accumulation above 100 g/m^2	Largest area of entrained hydrocarbons above 100 ppb	Largest area of dissolved hydrocarbons above 50 ppb
Season		Summer	Summer	Summer	Summer	Summer	Summer
Run Number		31	42	70	90	60	36
Floating Oil (km^2)	1 g/m^2	3,460	2,498	3,361	3,390	2,381	838
	10 g/m^2	**556**	325	375	387	279	79
	50 g/m^2	8	**13**	3	3	2	0
Shoreline Length (km)	10 g/m^2	4	0	143	142	19	0
	100 g/m^2	0	0	24	**30**	0	0
	1,000 g/m^2	0	0	0	0	0	0
Minimum Time (days)		57.5	0	35	35.3	41.1	0
Maximum Volume (m^3)		1	0	**105**	102	7	0
Entrained Area (km^2)	10 ppb	196,460	187,494	202,026	199,548	279,463	204,204
	100 ppb	24,791	24,018	24,996	24,943	**44,630**	18,515
Dissolved Area (km^2)	10 ppb	127	155	131	122	107	703
	50 ppb	0	0	0	0	0	**3**
	400 ppb	0	0	0	0	0	0
Start Date		28 January 2014	25 February 2012	8 December 2011	8 December 2011	31 January 2015	30 October 2018

11.2.1 Deterministic Case: Largest swept area of floating condensate above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 was identified as run number 31 during the summer period.

Figure 11.13 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.14 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.15 presents the fates and weathering for the corresponding simulation and Table 11.10 summarises peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.10 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	891	60	0
Entrained (m^3)	9,033	77	5,133
Dissolved (m^3)	3	57	0
Evaporation (m^3)	34,803	96	34,803
Decay (m^3)	12,691	104	12,691
Ashore (m^3)	2	61	1

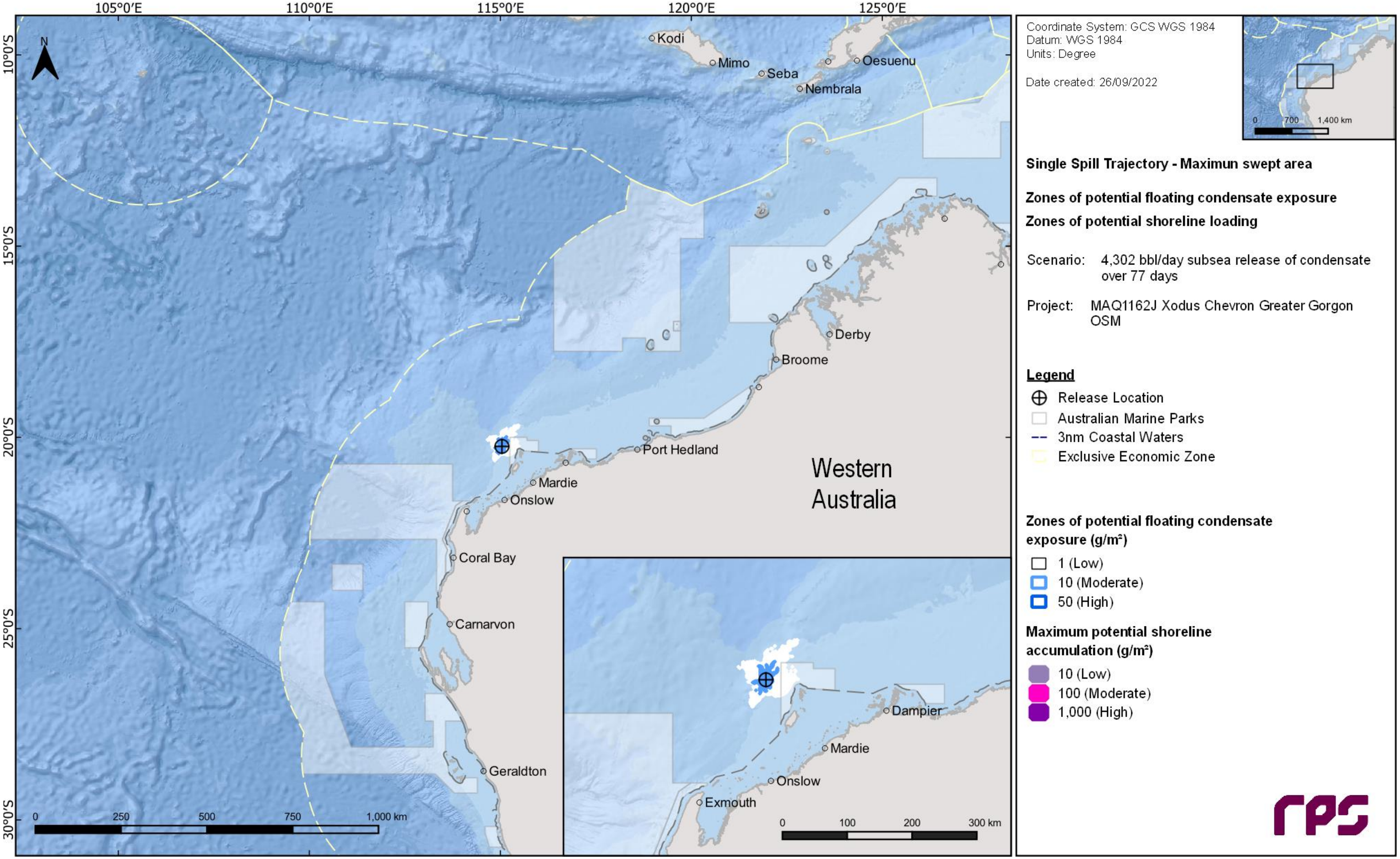


Figure 11.13 Zones of potential floating oil exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at WTR Well 5.

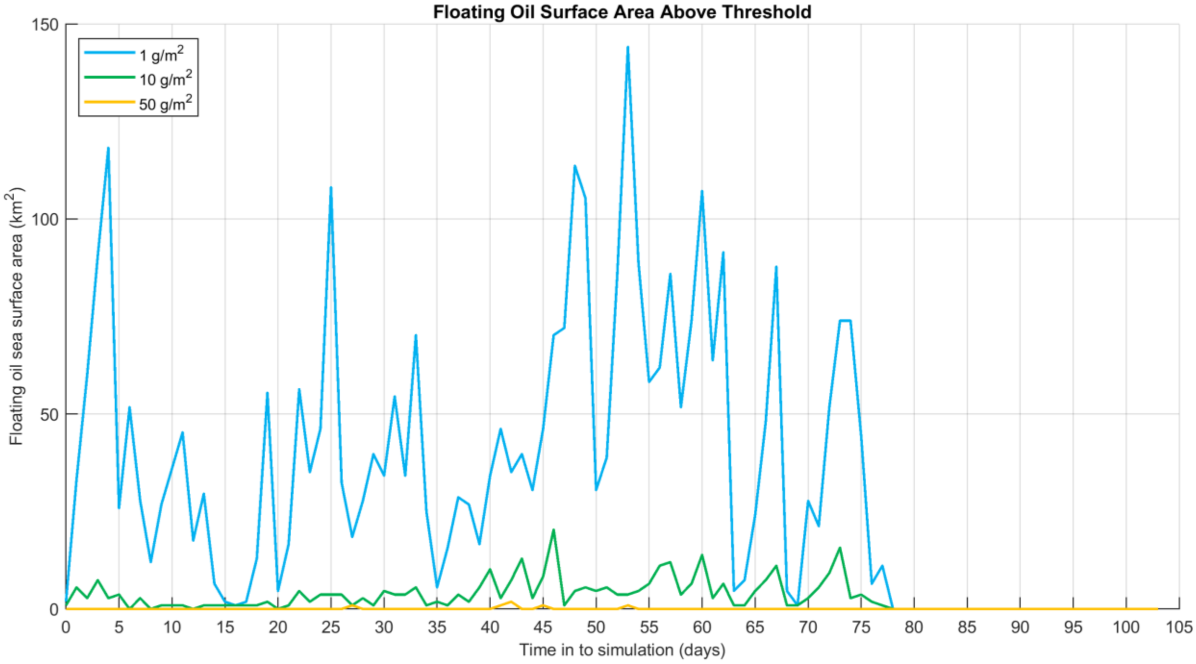


Figure 11.14 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at WTR Well 5.

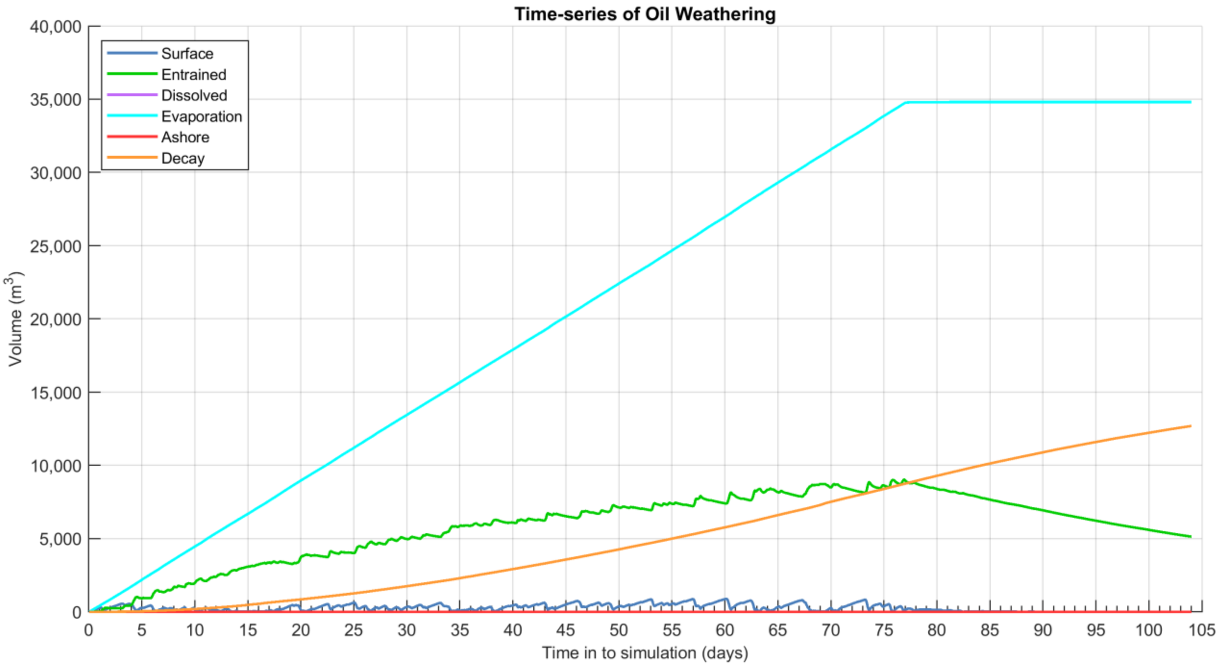


Figure 11.15 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at WTR Well 5.

11.2.2 Deterministic Case: Largest swept area of floating condensate above 50 g/m²

The deterministic simulation that resulted in the largest swept area of floating condensate above 50 g/m² was identified as run number 42 during the summer period.

Figure 11.13 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.14 displays the time series of the swept area of low (≥ 1 g/m²), moderate (≥ 10 g/m²) and high (≥ 50 g/m²) floating condensate over the 104-day simulation.

Figure 11.15 presents the fates and weathering for the corresponding simulation and Table 11.10 summarises peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.11 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 50 g/m² following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	970	36	0
Entrained (m^3)	8,806	73	4,944
Dissolved (m^3)	3	37	0
Evaporation (m^3)	34,596	97	34,596
Decay (m^3)	13,085	104	13,085
Ashore (m^3)	0	0	0

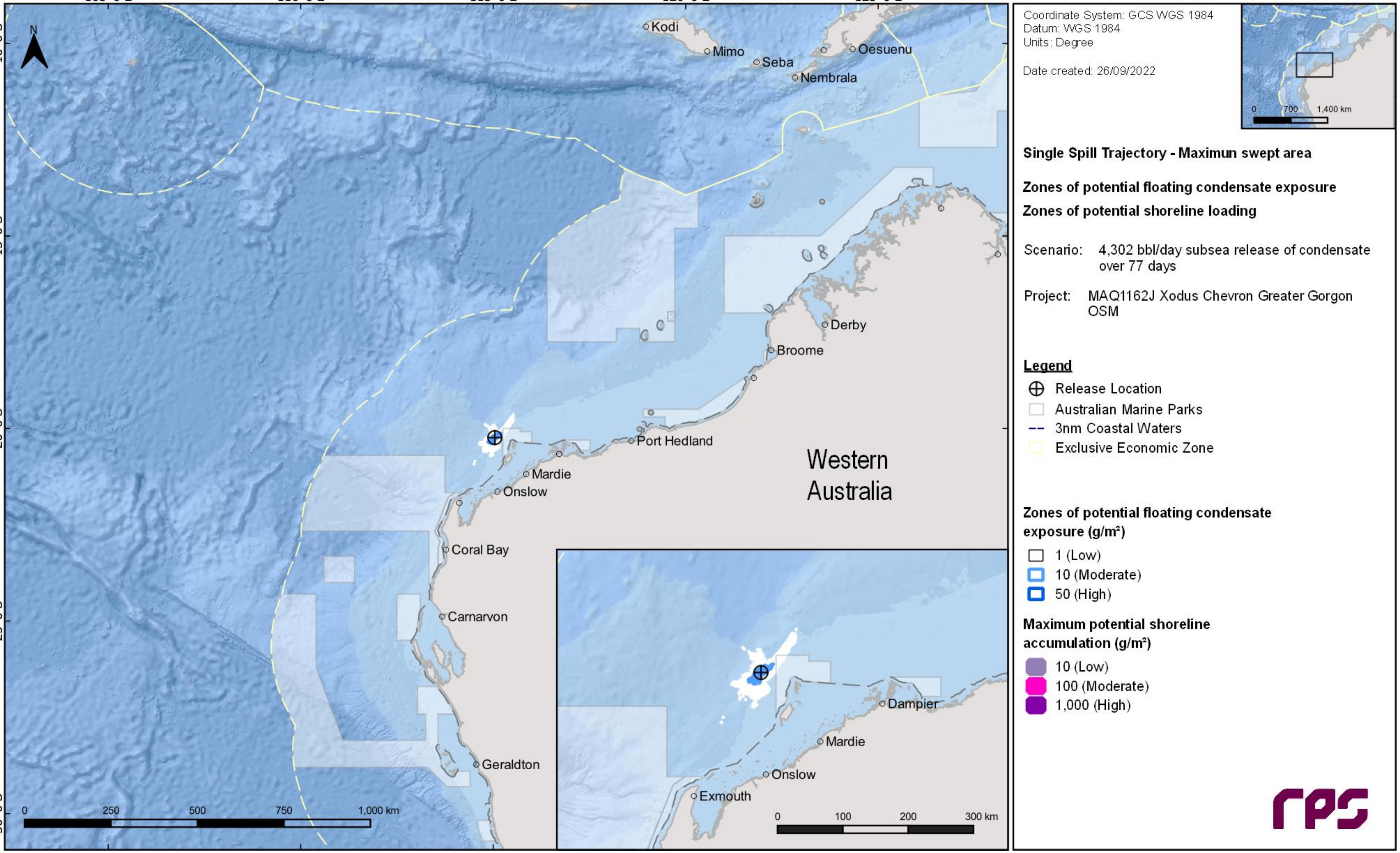


Figure 11.16 Zones of potential floating oil exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 50 g/m^2 following a subsea LOWC at WTR Well 5.

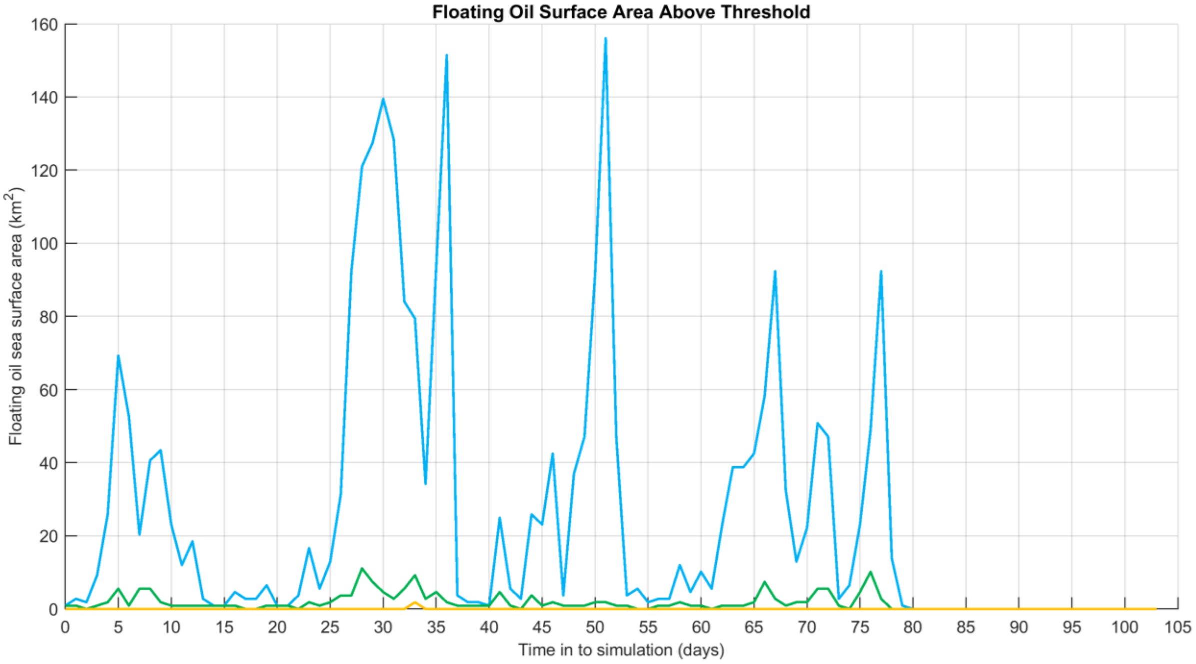


Figure 11.17 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating condensate above 50 g/m^2 following a subsea LOWC at WTR Well 5.

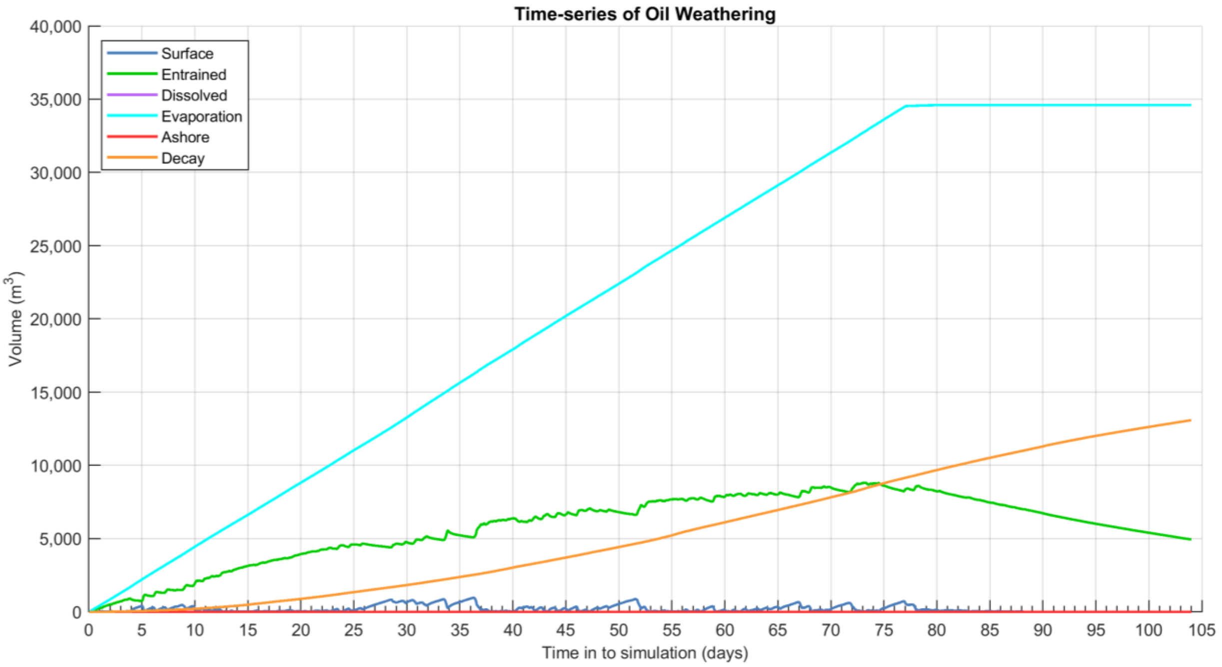


Figure 11.18 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 50 g/m^2 following a subsea LOWC at WTR Well 5.

11.2.3 Deterministic Case: Largest volume of oil ashore

The deterministic simulation that resulted in the largest volume of oil ashore was identified as run number 70 during the summer period.

Figure 11.19 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.20 displays the time series of the volume of oil accumulating on shorelines at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.21 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.12 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.12 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest volume of oil ashore following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	1217	41	1
Entrained (m^3)	8,515	75	4,932
Dissolved (m^3)	3	41	-
Evaporation (m^3)	34,695	104	34,718
Decay (m^3)	12,938	104	12,946
Ashore (m^3)	105	60	68

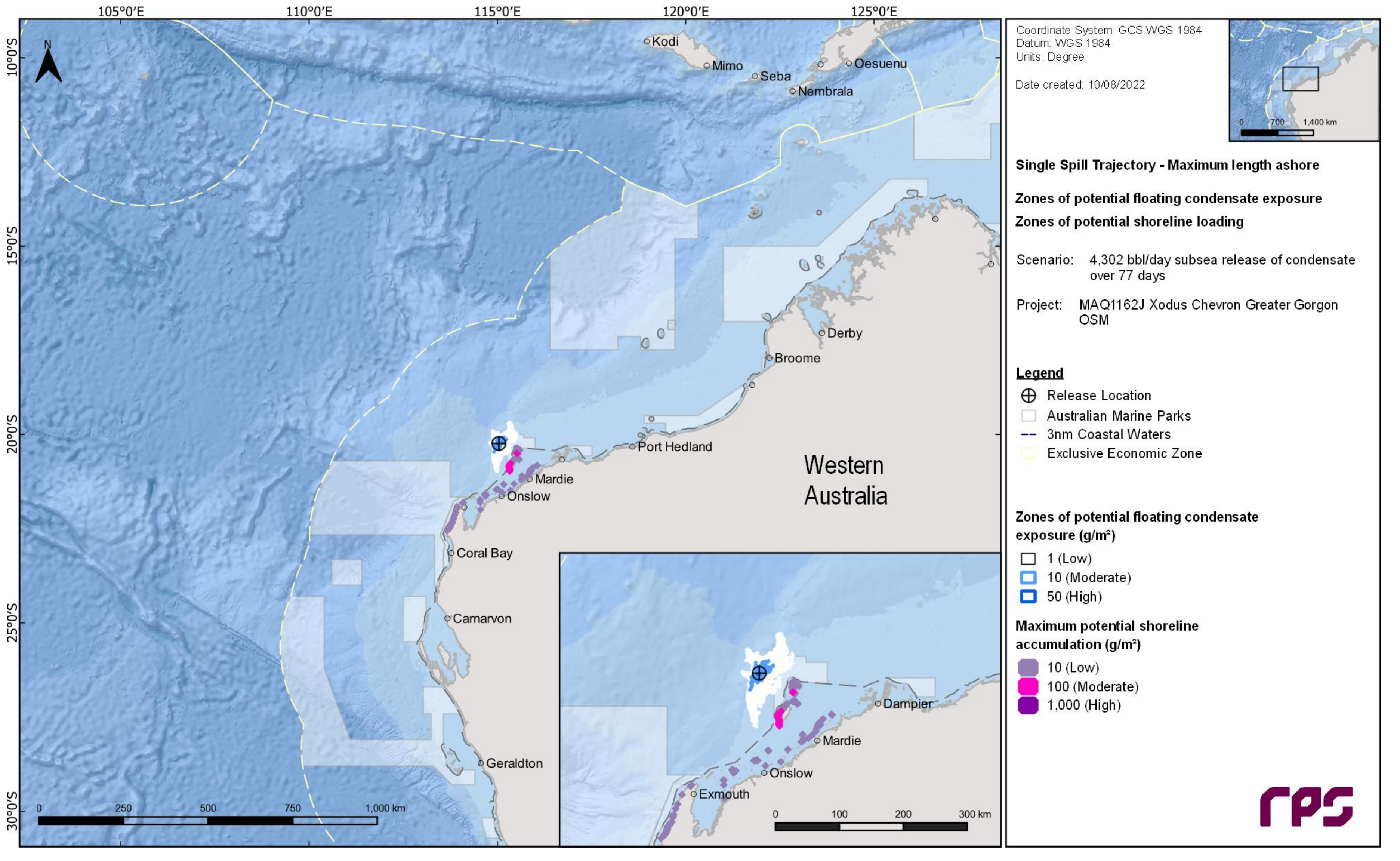


Figure 11.19 Zones of potential floating oil and shoreline exposure over the entire 104 days, for the simulation with the largest volume of oil ashore following a subsea LOWC at WTR Well 5.

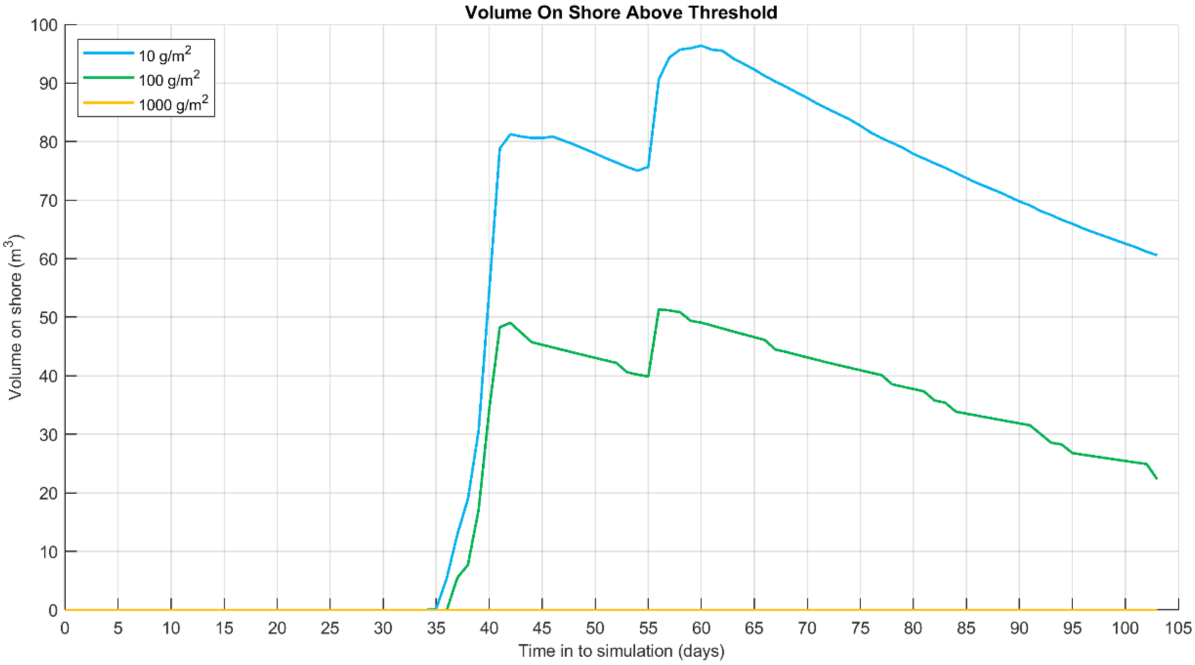


Figure 11.20 Time series of the volume of oil ashore at each threshold for the simulations with the largest volume ashore following a subsea LOWC at WTR Well 5.

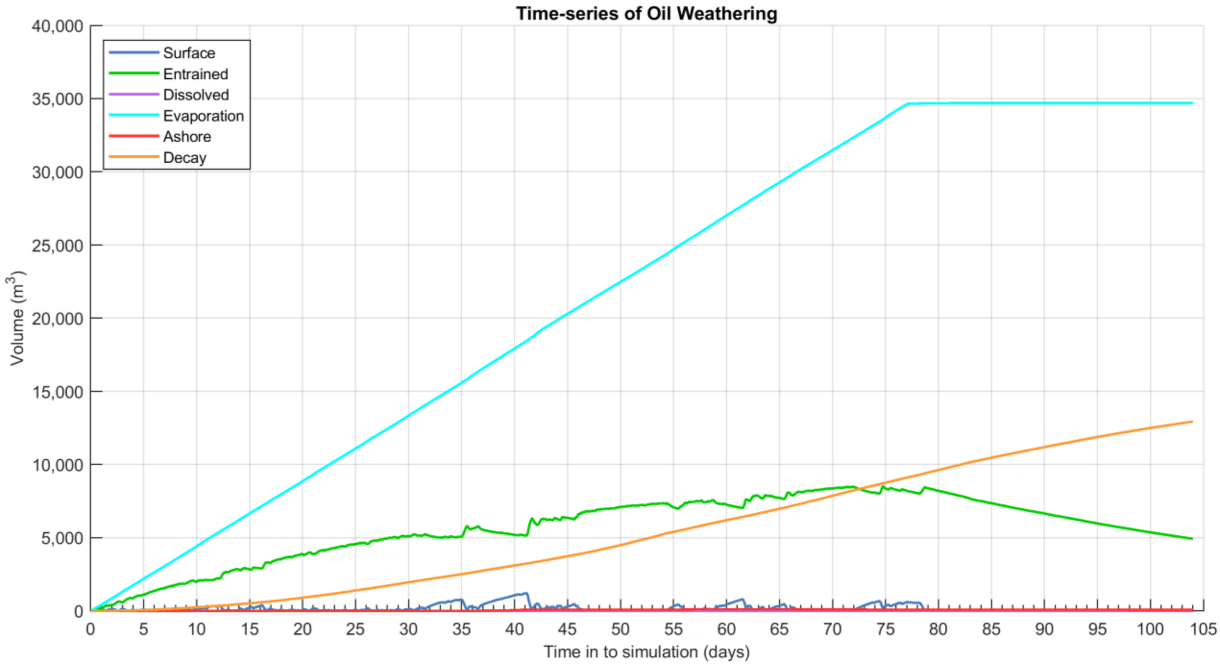


Figure 11.21 Predicted weathering and fates for the simulation with largest volume of oil ashore following a subsea LOWC at WTR Well 5.

11.2.4 Deterministic Case: Longest length of shoreline with accumulation above 100 g/m^2

The deterministic simulation that resulted in the longest length of shoreline with accumulation above 100 g/m^2 (moderate threshold) was identified as run number 90 during the summer period.

Figure 11.22 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.23 displays the time series of the length of shoreline with accumulation above the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.24 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.13 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.13 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the longest length of shoreline accumulation above 100 g/m^2 following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	1,223	41	0
Entrained (m^3)	8,487	75	4,929
Dissolved (m^3)	3	42	0
Evaporation (m^3)	34,724	104	34,724
Decay (m^3)	12,906	104	12,906
Ashore (m^3)	102	61	65

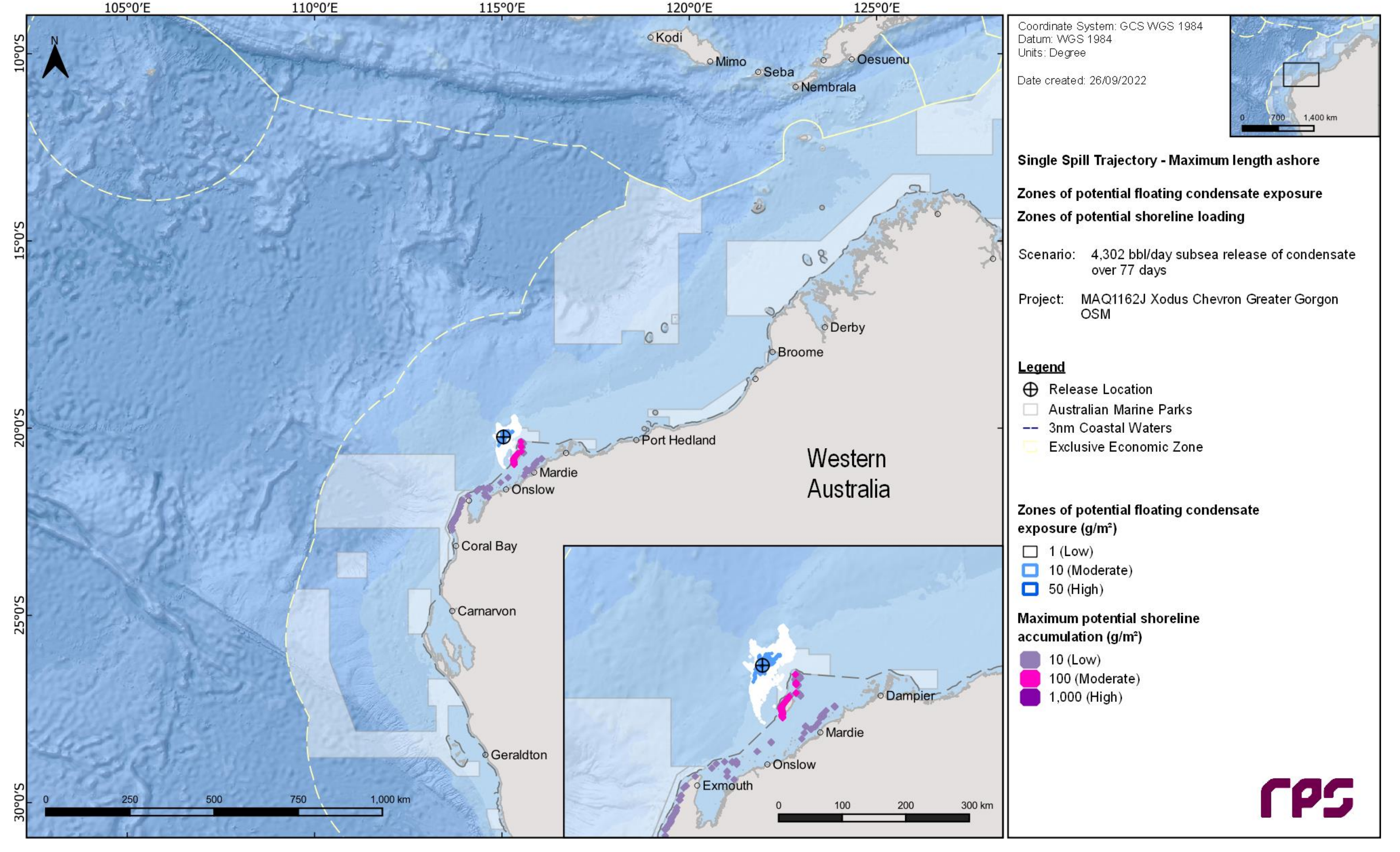


Figure 11.22 Zones of potential floating oil and shoreline exposure over the entire 104 days, for the simulation with the longest length of shoreline accumulation above 100 g/m^2 following a subsea LOWC at WTR Well 5.

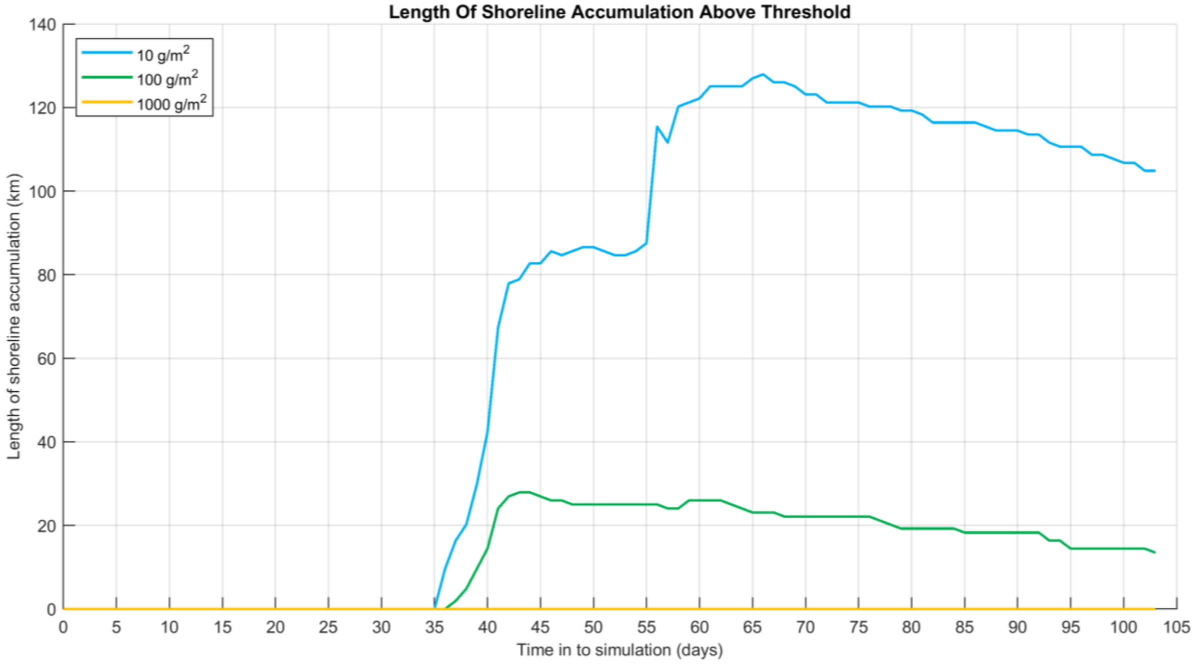


Figure 11.23 Time series of the length of shoreline at each threshold for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a subsea LOWC at WTR Well 5.

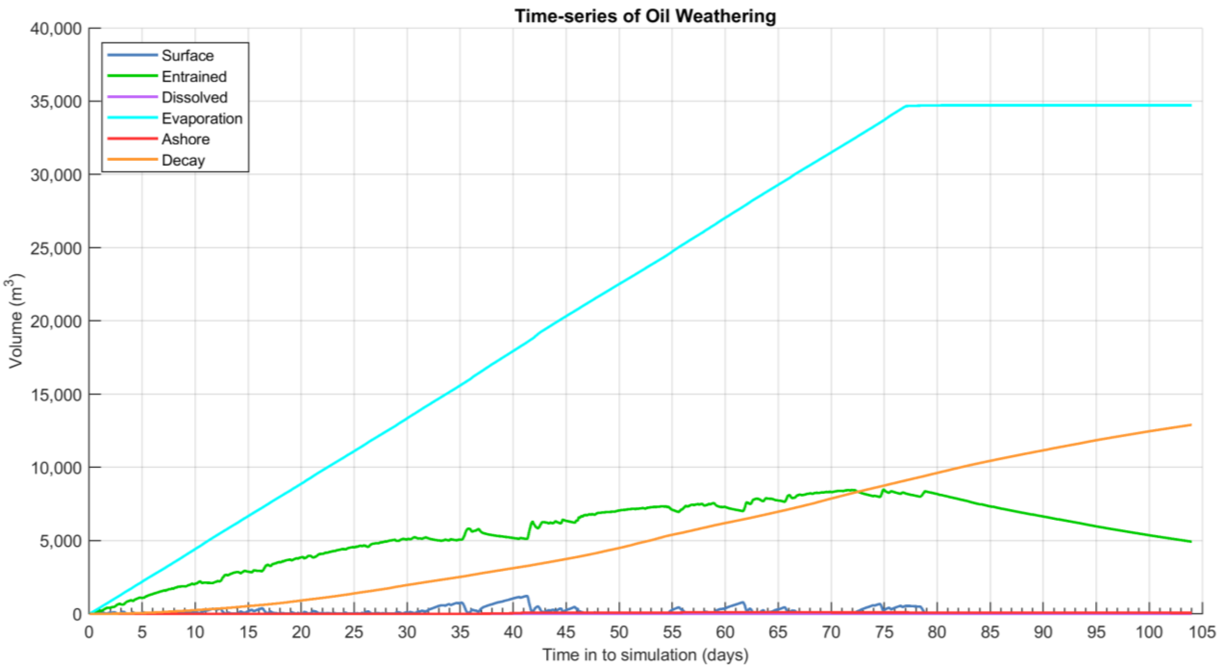


Figure 11.24 Predicted weathering and fates for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a subsea LOWC at WTR Well 5.

11.2.5 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (high threshold) was identified as run number 60 during the summer period.

Figure 11.25 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.26 displays the time series of the area of entrained hydrocarbons at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds over the 104-day simulation.

Figure 11.27 presents the fates and weathering for the corresponding single spill trajectory and Table 11.14 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.14 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the trajectory with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	788	69	0
Entrained (m^3)	9,062	77	4,804
Dissolved (m^3)	3	76	0
Evaporation (m^3)	34,451	102	34,451
Decay (m^3)	13,369	104	13,369
Ashore (m^3)	7	47	4

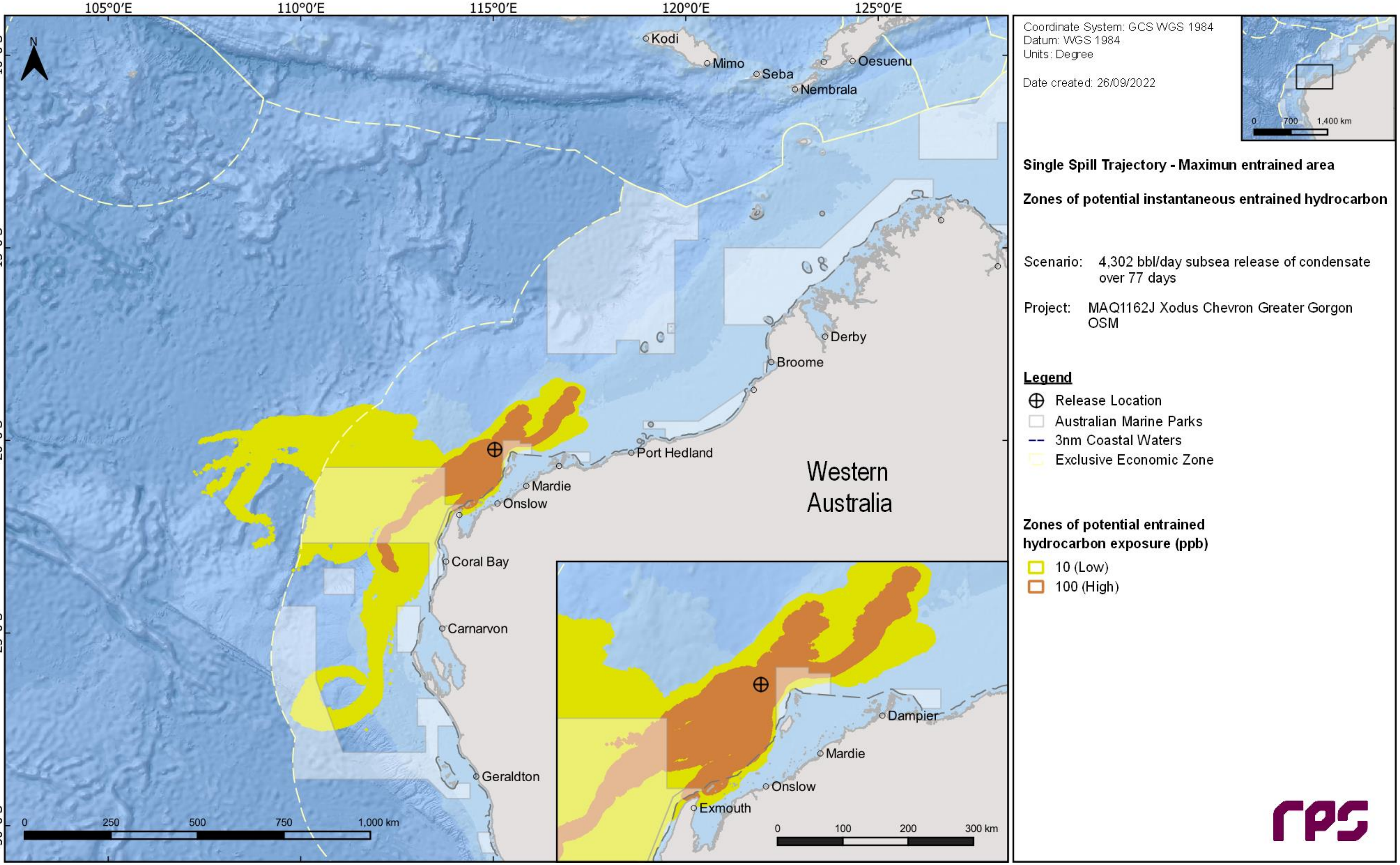


Figure 11.25 Zones of potential entrained hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

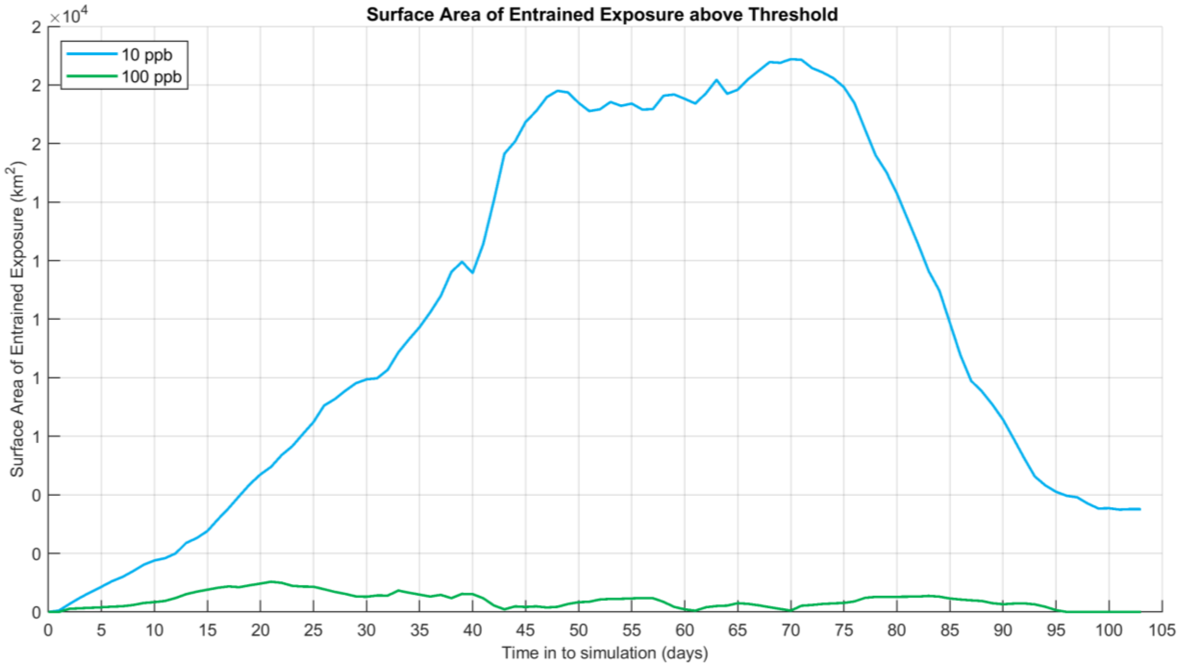


Figure 11.26 Time series of the area of entrained hydrocarbons for each threshold, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

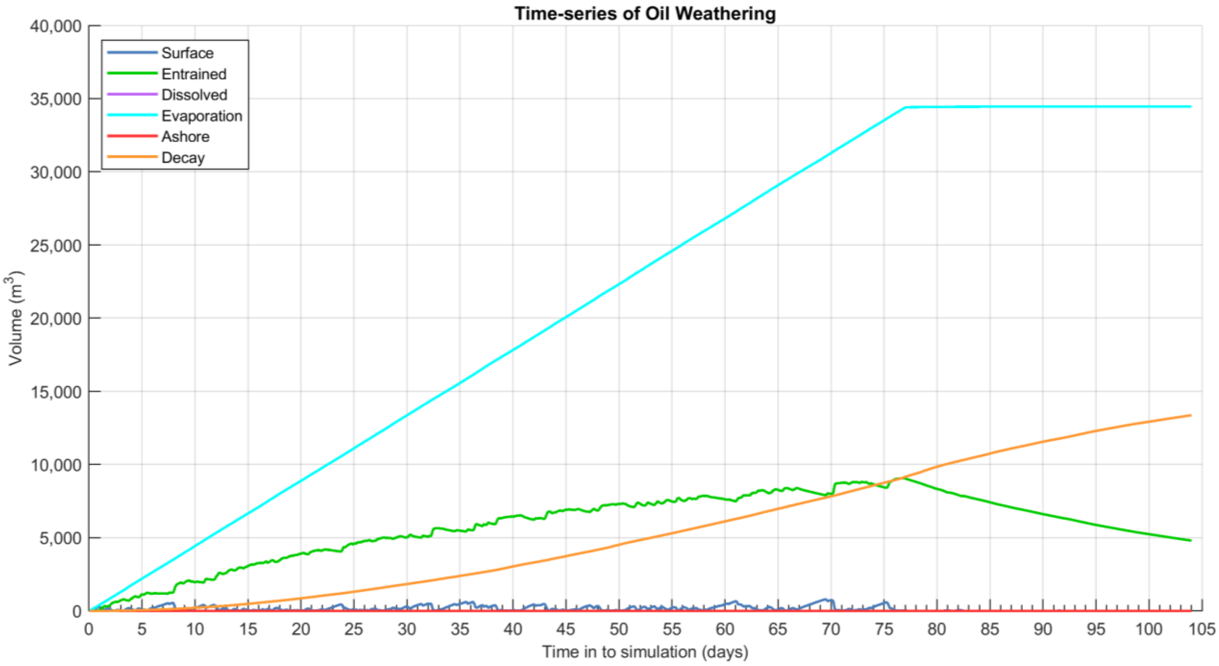


Figure 11.27 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

11.2.6 Deterministic Case: Largest area of dissolved hydrocarbons above 50 ppb

The deterministic simulation that resulted in the largest area of dissolved hydrocarbons above 50 ppb (moderate threshold) was identified as run number 36 during the summer period.

Figure 11.28 presents the extent of the predicted dissolved hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.29 displays the time series of the area of dissolved hydrocarbons at the low (≥ 10 ppb), moderate (≥ 50 ppb) and high (≥400 ppb) thresholds over the 104-day simulation.

Figure 11.30 presents the fates and weathering for the corresponding single spill trajectory and Table 11.15 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.15 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the trajectory with the largest area of dissolved hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	453	15	0
Entrained (m^3)	8,495	76	4,623
Dissolved (m^3)	3	69	0
Evaporation (m^3)	34,362	93	34,362
Decay (m^3)	13,651	104	13,651
Ashore (m^3)	0	0	0

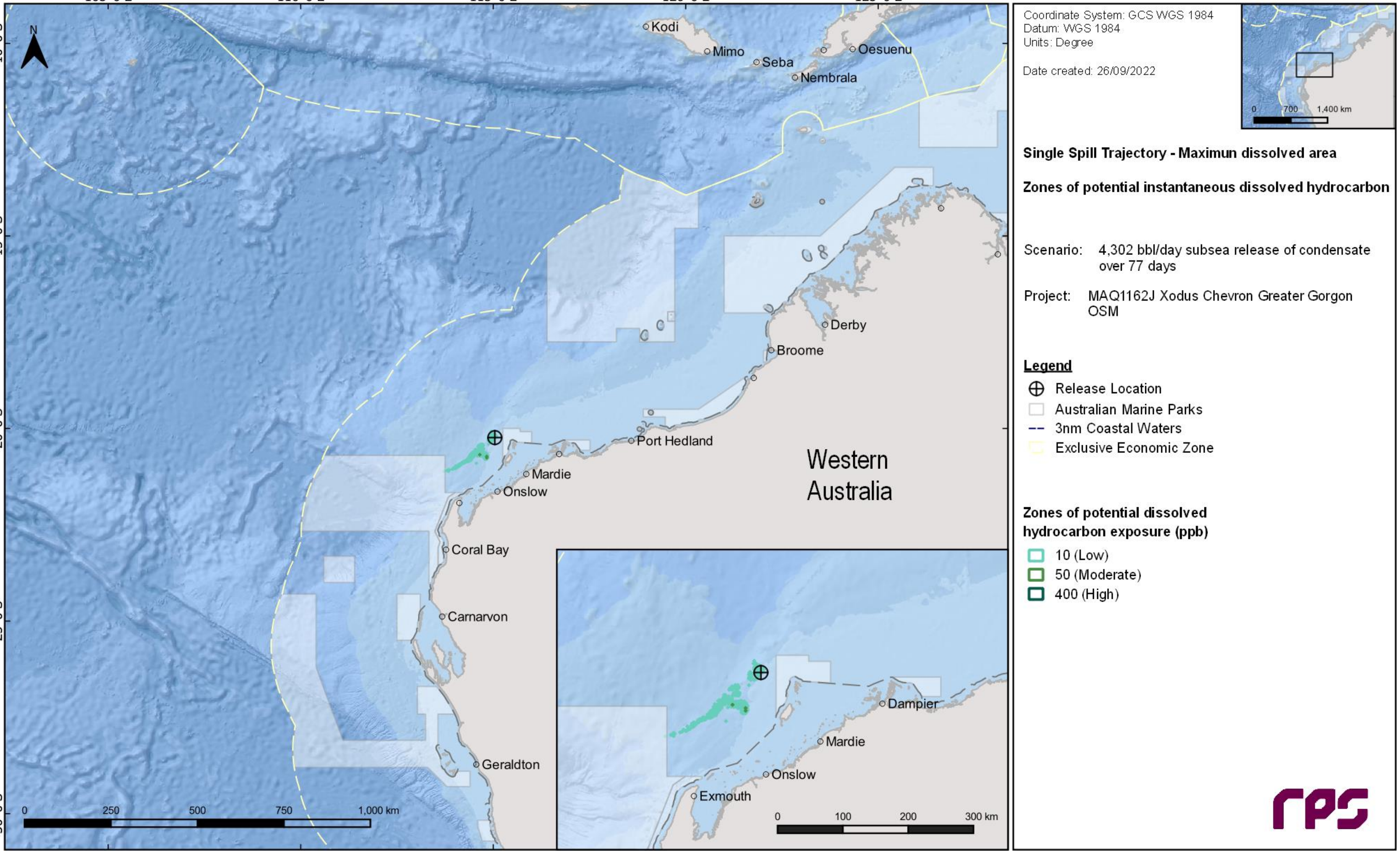


Figure 11.28 Zones of potential dissolved hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of dissolvede hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

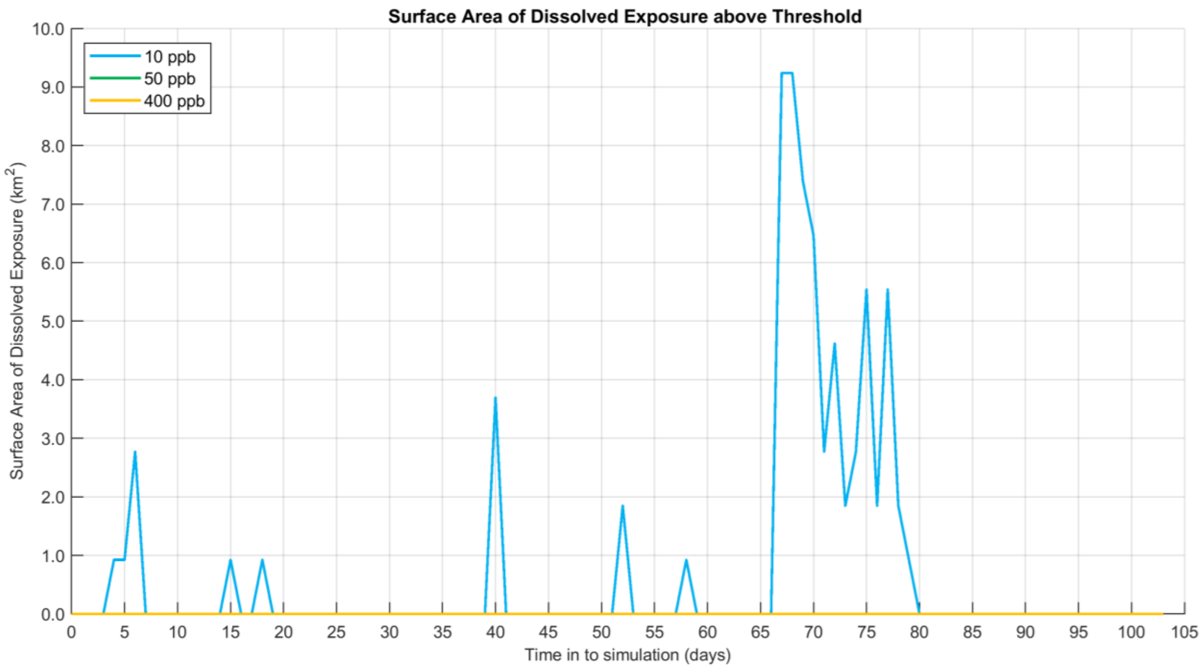


Figure 11.29 Time series of the area of dissolved hydrocarbons for each threshold, for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

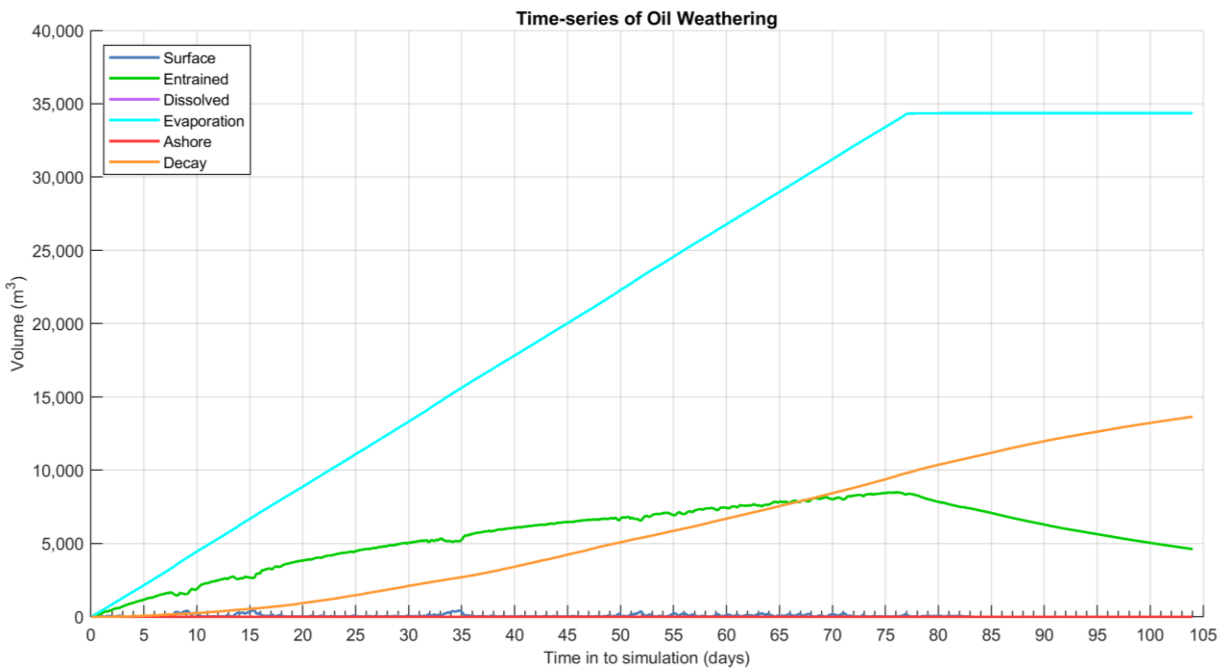


Figure 11.30 Predicted weathering and fates graph for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

12 RESULTS: WEST TRYAL ROCKS VESSEL COLLISION

This scenario examined a 1,500 m^3 surface release of MDO over 24 hours, from a vessel collision. A total of 300 spill simulations were run for each of the three seasons (i.e. 100 spills per season) and tracked for 60 days.

Section 12.1 presents the seasonal (or stochastic) analysis results, while Section 12.2 presents the deterministic results.

12.1 Stochastic Analysis

12.1.1 Floating MDO Exposure

Table 12.1 summarises the maximum distances from the release location to floating oil exposure zones for each season.

The maximum distance from the release location to the low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) threshold was 167.0 northeast (summer), 59.6 km south-southwest (winter) and 17.6 km north-northeast (summer), respectively.

Table 12.2 summarises the potential floating oil exposure to individual receptors during each season.

The Offshore Area IAA, Flatback Turtle - Internesting Buffer, Pygmy Blue Whale – Distribution, Wedge-tailed Shearwater - Breeding, Whale Shark – Foraging BIAs, Pilbara (offshore) IMCRA, and the Ancient coastline at 125 m depth contour KEF, which the release location resides within (see Section 10.3), and the Humpback Whale - Migration BIA and Continental Slope Demersal Fish Communities KEF were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. With the exception of the Humpback Whale - Migration BIA and Continental Slope Demersal Fish Communities KEF, the probabilities for the low and moderate thresholds was 100% for all seasons for these receptors. The probabilities of low and moderate exposure at the Humpback Whale - Migration BIA ranged between 16–22% and 3–4%, whilst the probabilities of low and moderate exposure to the Continental Slope Demersal Fish Communities KEF ranged between 35–54% and 4–13%, respectively. The minimum times before low exposure for the Humpback Whale - Migration BIA and Continental Slope Demersal Fish Communities KEF were 0.54 days (winter) and 0.38 days (transitional), respectively.

Figure 12.1 to Figure 12.3 present the zones of floating oil exposure for each season.

Table 12.1 Maximum distances and directions travelled from the release location to floating oil exposure for each season and threshold, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating oil exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	167.0	52.1	17.6
	Max. distance from release site (km) (99th percentile)	154.0	43.4	17.1
	Direction	Northeast	South	North-northeast
Transitional	Max. distance from release site (km)	134.4	46.6	17.3
	Max. distance from release site (km) (99th percentile)	91.6	43.7	16.7
	Direction	West-northwest	South-southwest	South-southwest
Winter	Max. distance from release site (km)	158.6	59.6	9.8
	Max. distance from release site (km) (99th percentile)	86.3	53.3	9.5
	Direction	South-southwest	South-southwest	North

Table 12.2 Summary of the potential floating oil exposure to individual receptors, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
AMP	Montebello	3	-	-	1.96	-	-	4	-	-	3.33	-	-	1	-	-	4.88	-	-
BIA	Flatback Turtle - Internesting Buffer*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
	Flatback Turtle - Nesting	10	2	-	1.08	1.5	-	8	-	-	0.71	-	-	14	-	-	1.17	-	-
	Green Turtle - Internesting Buffer	1	-	-	3.08	-	-	-	-	-	-	-	-	4	-	-	2.58	-	-
	Hawksbill Turtle - Internesting Buffer	1	-	-	3.04	-	-	-	-	-	-	-	-	2	-	-	2.58	-	-
	Humpback Whale - Migration	16	3	-	0.71	0.79	-	19	4	-	0.83	0.88	-	22	3	-	0.54	0.88	-
	Loggerhead Turtle - Internesting Buffer	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	6.92	-	-
	Pygmy Blue Whale - Distribution*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
	Wedge-tailed Shearwater - Breeding*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
	Whale Shark - Foraging*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
IAA	Barrow & Montebello Islands	3	-	-	1.96	-	-	4	-	-	3.33	-	-	1	-	-	4.88	-	-
	Offshore Area*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
IMCRA	Northwest Shelf	9	1	-	1.04	1.58	-	8	-	-	1.25	-	-	-	-	-	-	-	-
	Pilbara (offshore)	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
KEF	Ancient coastline at 125 m depth contour*	100	100	59	0.04	0.04	0.04	100	100	82	0.04	0.04	0.04	100	100	57	0.04	0.04	0.04
	Continental Slope Demersal Fish Communities	35	4	-	0.79	0.88	-	54	13	2	0.38	0.58	1.75	37	6	-	0.71	1.58	-
	Exmouth Plateau	-	-	-	-	-	-	1	-	-	7.04	-	-	-	-	-	-	-	-

*The release location resides within the receptor boundaries.

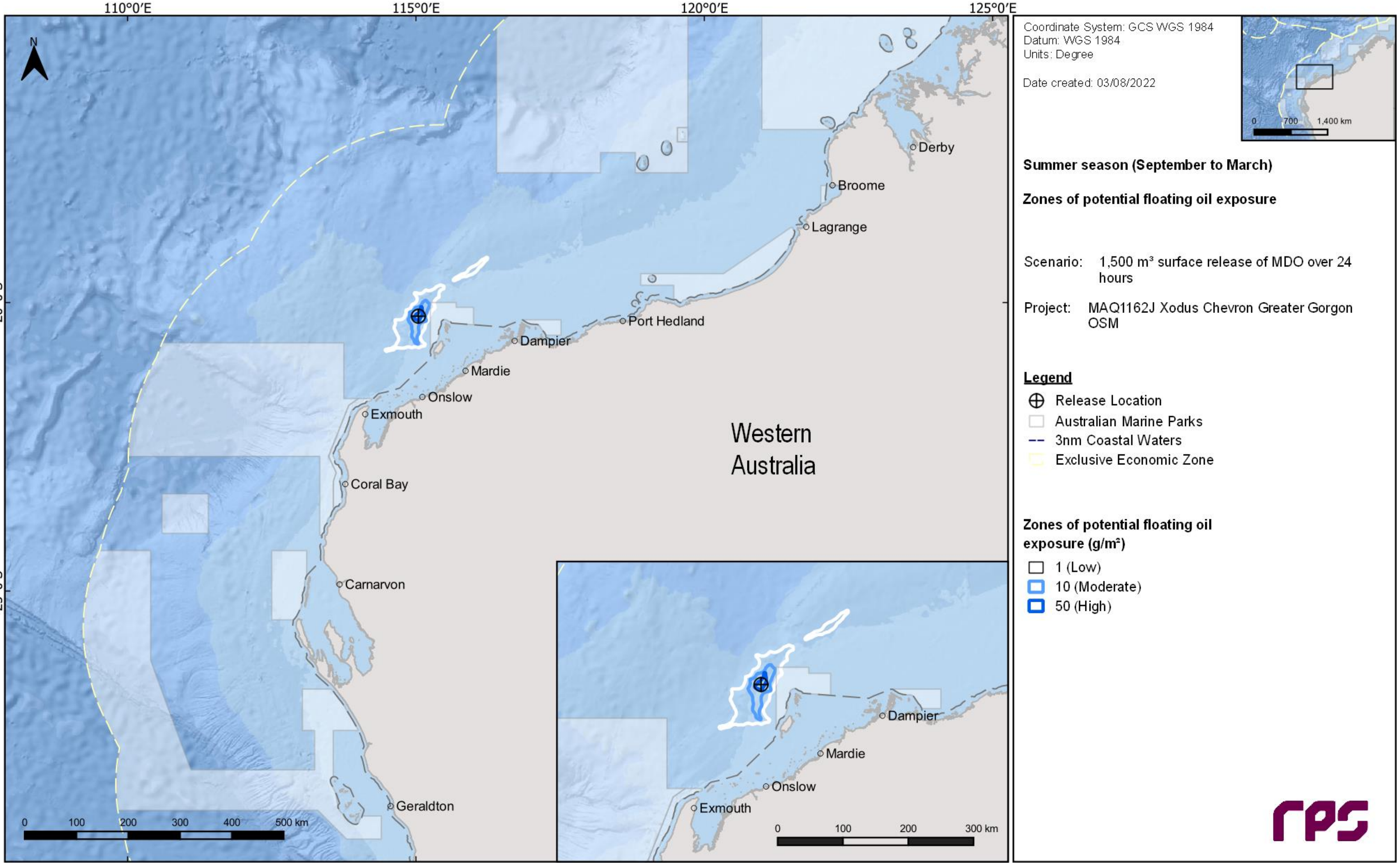


Figure 12.1 Zones of potential floating oil exposure following a vessel collision at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

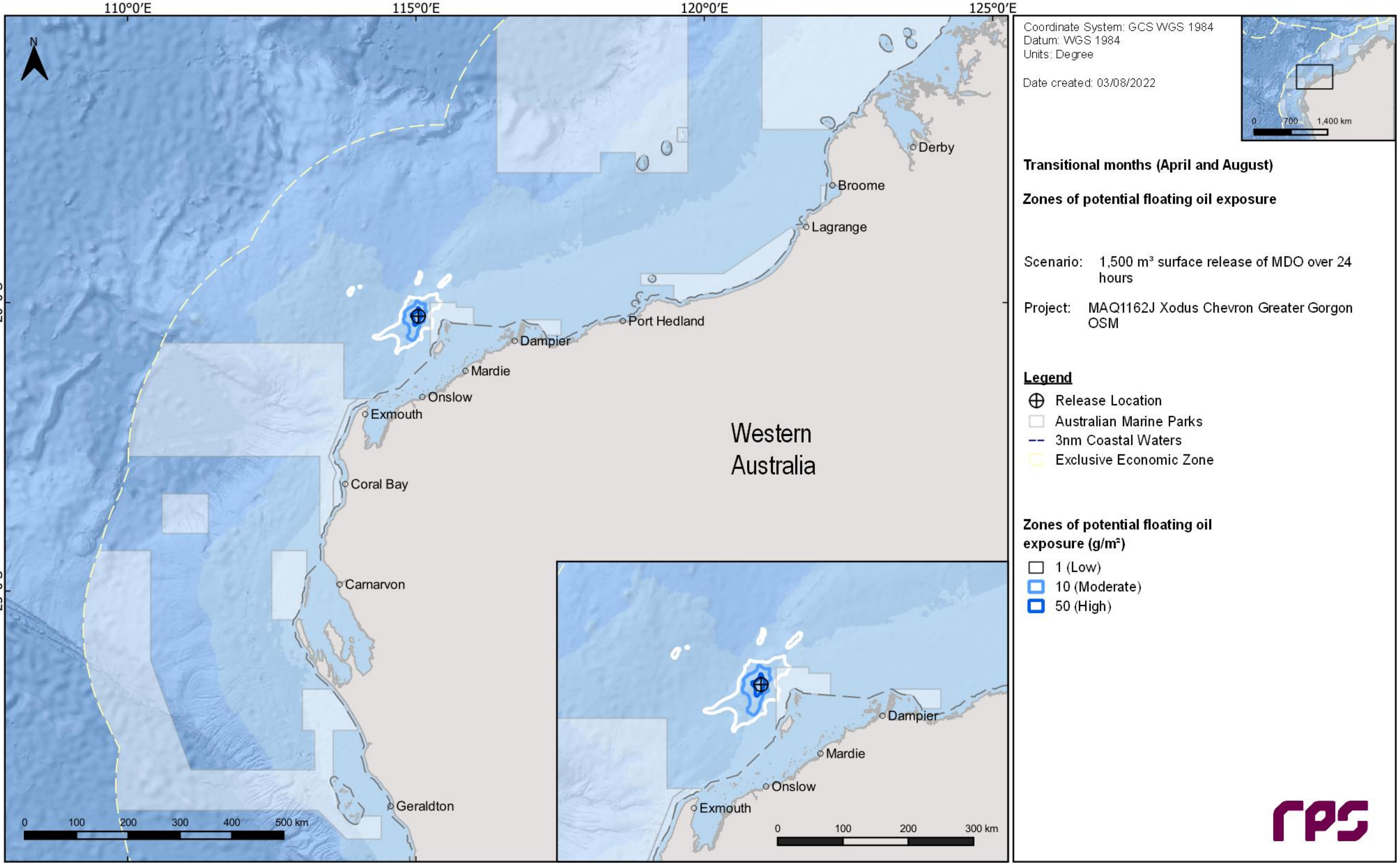


Figure 12.2 Zones of potential floating oil exposure following a vessel collision at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

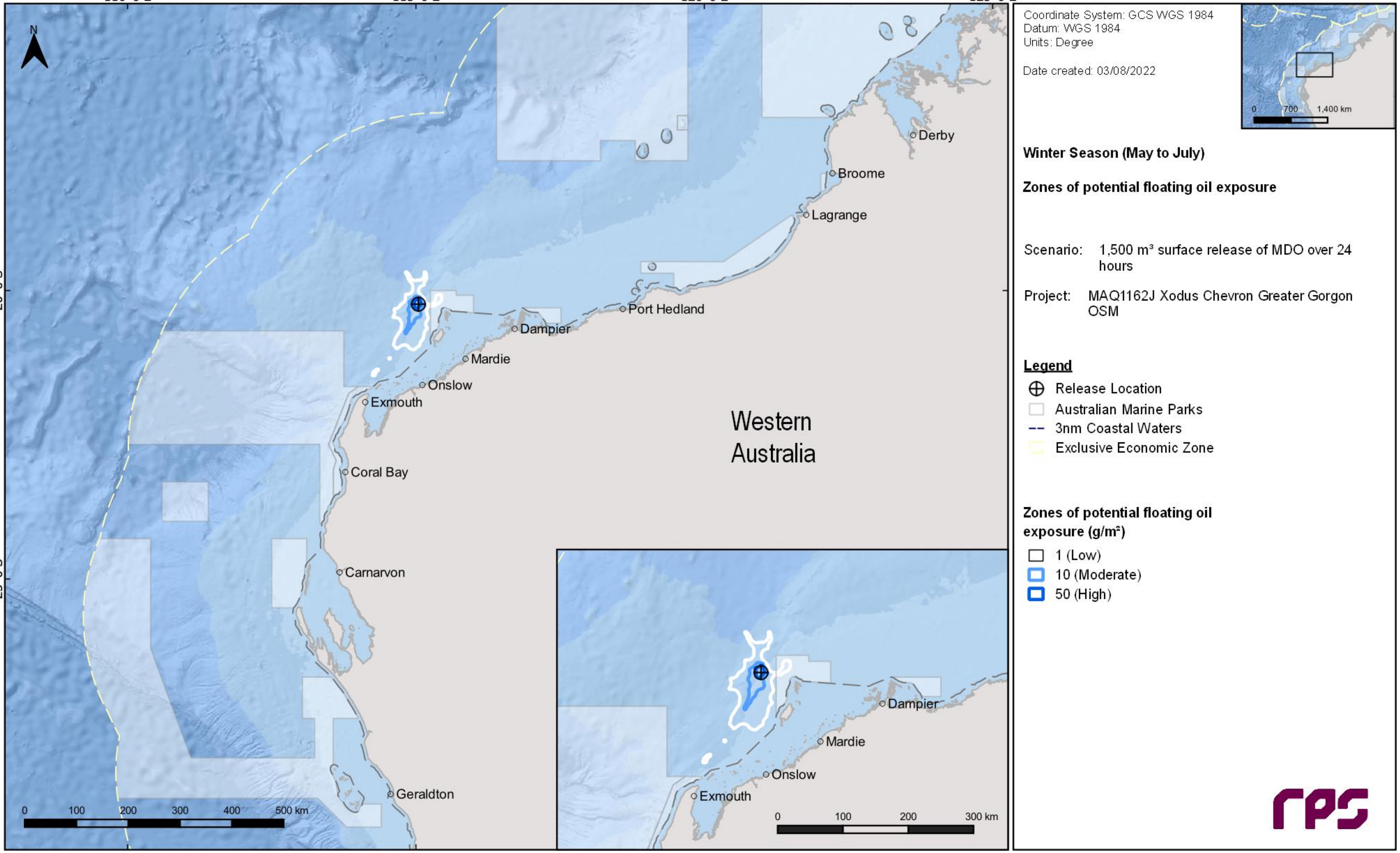


Figure 12.3 Zones of potential floating oil exposure following a vessel collision at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

12.1.2 Shoreline Accumulation

Table 12.3 presents a summary of the predicted shoreline accumulation during summer, transitional and winter seasons. The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during winter at 9%, while the minimum time before shoreline accumulation was 6.50 days and the maximum volume of oil ashore was 35.1 m^3.

No high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

Table 12.4 to Table 12.6summarises the shoreline accumulation on individual receptors for each season.

During summer conditions, 23 shoreline receptors were predicted to record oil accumulation at, or above, the low threshold with the greatest probability predicted for Ningaloo Coast World Heritage Area IAA (4%). In comparison, during transitional and winter conditions, 9 and 22 shoreline receptors, respectively, were predicted to record accumulation. During transitional conditions the greatest probability for low threshold accumulation was 3% predicted for South Muiron Island and Ningaloo Coast World Heritage Area IAA, and the Muiron Islands IAA and shoreline. Additionally, during the winter conditions the greatest probability for low threshold accumulation was 7% and was predicted for the Ningaloo Coast World Heritage Area IAA.

The maximum potential shoreline accumulation is presented for each season in Figure 12.4 to Figure 12.6.

Table 12.3 Summary of oil accumulation across all shorelines for each season and threshold, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of accumulation on any shoreline (%)	6	4	9
Absolute minimum time for visible oil to shore (days)	8.04	16.33	6.50
Maximum volume of hydrocarbons ashore (m^3) above the low threshold	35.1	1.7	7.2
Average volume of hydrocarbons ashore (m^3) above the low threshold	1.9	< 0.1	0.2
Maximum length of the shoreline at **10 g/m^2** (km)	51.0	6	14
Average shoreline length (km) at **10 g/m^2** (km)	21.7	4.3	6.2
Maximum length of the shoreline at **100 g/m^2** (km)	24	-	2
Average shoreline length (km) at **100 g/m^2** (km)	6.5	-	2
Maximum length of the shoreline at **1,000 g/m^2** (km)	-	-	-
Average shoreline length (km) at **1,000 g/m^2** (km)	-	-	-

Table 12.4 Summary of shoreline oil accumulation to individual receptors, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories days during summer (September to the following March) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	2	2	-	10.92	14.29	-	17	177	< 0.1	1.5	14.4	1.4	-	15.4	1.9	-
	South Muiron Island	2	1	-	9.08	12.92	-	6	224	< 0.1	0.6	4.8	1	-	6.7	1	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	2	-	-	19.71	-	-	2	14	< 0.1	< 0.1	1	-	-	1	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	3	-	-	8.54	-	-	9	69	< 0.1	0.5	3.5	-	-	5.8	-	-
	Boodie Island	2	-	-	9	-	-	25	73	< 0.1	0.4	3.4	-	-	3.8	-	-
	Middle Island	2	2	-	8.04	12.42	-	85	348	< 0.1	2.5	6.7	4.8	-	6.7	5.8	-
	Middle Ningaloo Coast - World Heritage Area	1	1	-	10.38	12.46	-	271	271	1.2	1.2	23.1	3.8	-	23.1	3.8	-
	North Ningaloo Coast - World Heritage Area	1	1	-	10.25	14.38	-	280	280	1.5	1.5	14.4	7.7	-	14.4	7.7	-
	Cape Range National Park	1	-	-	10.58	-	-	67	67	0.4	0.4	13.5	-	-	13.5	-	-
	Ningaloo Coast World Heritage Area	4	2	-	8.54	12.46	-	11	280	< 0.1	2	13	3.8	-	29.8	6.7	-
	Barrow & Montebello Islands IAA	2	2	-	8.04	12.42	-	11	348	< 0.1	4.3	24.5	6.3	-	25	7.7	-
	Pilbara Coast IAA	2	-	-	13.17	-	-	2	15	< 0.1	< 0.1	1.4	-	-	1.9	-	-
	Barrow Island Group	2	2	-	8.04	12.42	-	28	348	< 0.1	4.3	24.5	6.3	-	25	7.7	-
	Pilbara Coast Islands Group	2	-	-	19.71	-	-	2	14	< 0.1	< 0.1	1	-	-	1	-	-
	Muiron Islands	3	1	-	8.54	12.92	-	7	224	< 0.1	1.1	6.7	1	-	12.5	1	-
Shoreline	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	2	2	-	10.63	12.42	-	19	242	< 0.1	1.9	16.4	2.4	-	17.3	2.9	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	2	1	-	8.04	17.42	-	34	147	< 0.1	0.7	4.3	1	-	4.8	1	-
	Exmouth	1	1	-	10.25	12.46	-	280	280	35	35	51	24	-	51	24	-
	Flat Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	2	2	-	8.04	12.42	-	77	348	< 0.1	2.7	8.7	4.8	-	8.7	5.8	-
	Murion Islands	3	1	-	8.54	12.92	-	7	224	< 0.1	1.1	6.7	1	-	12.5	1	-
	Peak Island	1	-	-	13.17	-	-	15	15	< 0.1	< 0.1	1	-	-	1	-	-
	Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	2	-	-	19.71	-	-	2	14	< 0.1	< 0.1	1	-	-	1	-	-
	Sunday Island	1	-	-	13.92	-	-	15	15	< 0.1	< 0.1	1.9	-	-	1.9	-	-
	Table Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 12.5 Summary of shoreline oil accumulation to individual receptors, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories days during transitional (April and August) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	3	-	-	18.54	-	-	3	19	< 0.1	< 0.1	1.3	-	-	1.9	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	2	-	-	17.54	-	-	4	21	< 0.1	< 0.1	3.4	-	-	3.8	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	3	-	-	17.54	-	-	3	21	< 0.1	0.1	3.8	-	-	5.8	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	2	-	-	16.33	-	-	3	34	< 0.1	0.1	2.4	-	-	3.8	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	3	-	-	17.54	-	-	3	21	< 0.1	0.1	3.5	-	-	5.8	-	-
Shoreline	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flat Island	2	-	-	16.33	-	-	7	34	< 0.1	< 0.1	1.9	-	-	2.9	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Murion Islands	3	-	-	17.54	-	-	3	21	< 0.1	0.1	3.5	-	-	5.8	-	-
	Peak Island	1	-	-	16.71	-	-	14	14	< 0.1	< 0.1	1	-	-	1	-	-
	Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sunday Island	1	-	-	17.71	-	-	16	16	< 0.1	< 0.1	1	-	-	1	-	-
	Table Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 12.6 Summary of shoreline oil accumulation to individual receptors, following a vessel collision at WTR Well 5. The results were calculated from 100 spill trajectories days during winter (May to July) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	1	1	-	9.42	12.5	-	185	185	0.4	0.4	5.8	1	-	5.8	1	-
	Thevenard Island	1	-	-	11.08	-	-	20	20	< 0.1	< 0.1	1	-	-	1	-	-
	Serrurier Island	2	-	-	9.58	-	-	4	71	< 0.1	0.2	2.9	-	-	3.8	-	-
	Bessieres Island	1	-	-	8.92	-	-	44	44	< 0.1	0.1	2.9	-	-	2.9	-	-
	Airlie Island	1	-	-	10.54	-	-	35	35	< 0.1	0.1	2.9	-	-	2.9	-	-
	North Muiron Island	4	1	-	6.5	14.04	-	4	106	< 0.1	0.2	2.4	1	-	3.8	1	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	3	-	-	12.29	-	-	3	27	< 0.1	0.2	5.8	-	-	12.5	-	-
	Ningaloo Coast World Heritage Area	7	1	-	6.5	12.5	-	4	185	< 0.1	0.7	4.3	1.9	-	11.5	1.9	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	2	-	-	8.92	-	-	3	71	< 0.1	0.5	9.6	-	-	13.5	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	2	-	-	8.92	-	-	4	71	< 0.1	0.3	5.8	-	-	6.7	-	-
	Muiron Islands	4	1	-	6.5	12.5	-	4	185	< 0.1	0.7	3.8	1.9	-	9.6	1.9	-
Shoreline	Airlie Island	1	-	-	10.54	-	-	35	35	0.1	0.1	2.9	-	-	2.9	-	-
	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	1	-	-	8.92	-	-	44	44	0.1	0.1	2.9	-	-	2.9	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	3	-	-	12.29	-	-	3	27	< 0.1	0.2	5.8	-	-	12.5	-	-
	Flat Island	1	-	-	9.5	-	-	32	32	0.1	0.1	3.8	-	-	3.8	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Murion Islands	4	1	-	6.5	12.5	-	4	185	< 0.1	0.7	3.8	1.9	-	9.6	1.9	-
	Peak Island	1	-	-	12.08	-	-	11	11	< 0.1	< 0.1	1	-	-	1	-	-
	Round Island	1	-	-	12.04	-	-	13	13	< 0.1	< 0.1	1	-	-	1	-	-
	Serrurier Island	2	-	-	9.58	-	-	4	71	< 0.1	0.2	2.9	-	-	3.8	-	-
	Sunday Island	1	-	-	11.88	-	-	20	20	< 0.1	1.9	1.9	-	-	1.9	-	-
	Table Island	1	-	-	11.46	-	-	11	11	< 0.1	< 0.1	1	-	-	1	-	-
	Thevenard Island	1	-	-	11.08	-	-	20	20	< 0.1	< 0.1	1	-	-	1	-	-

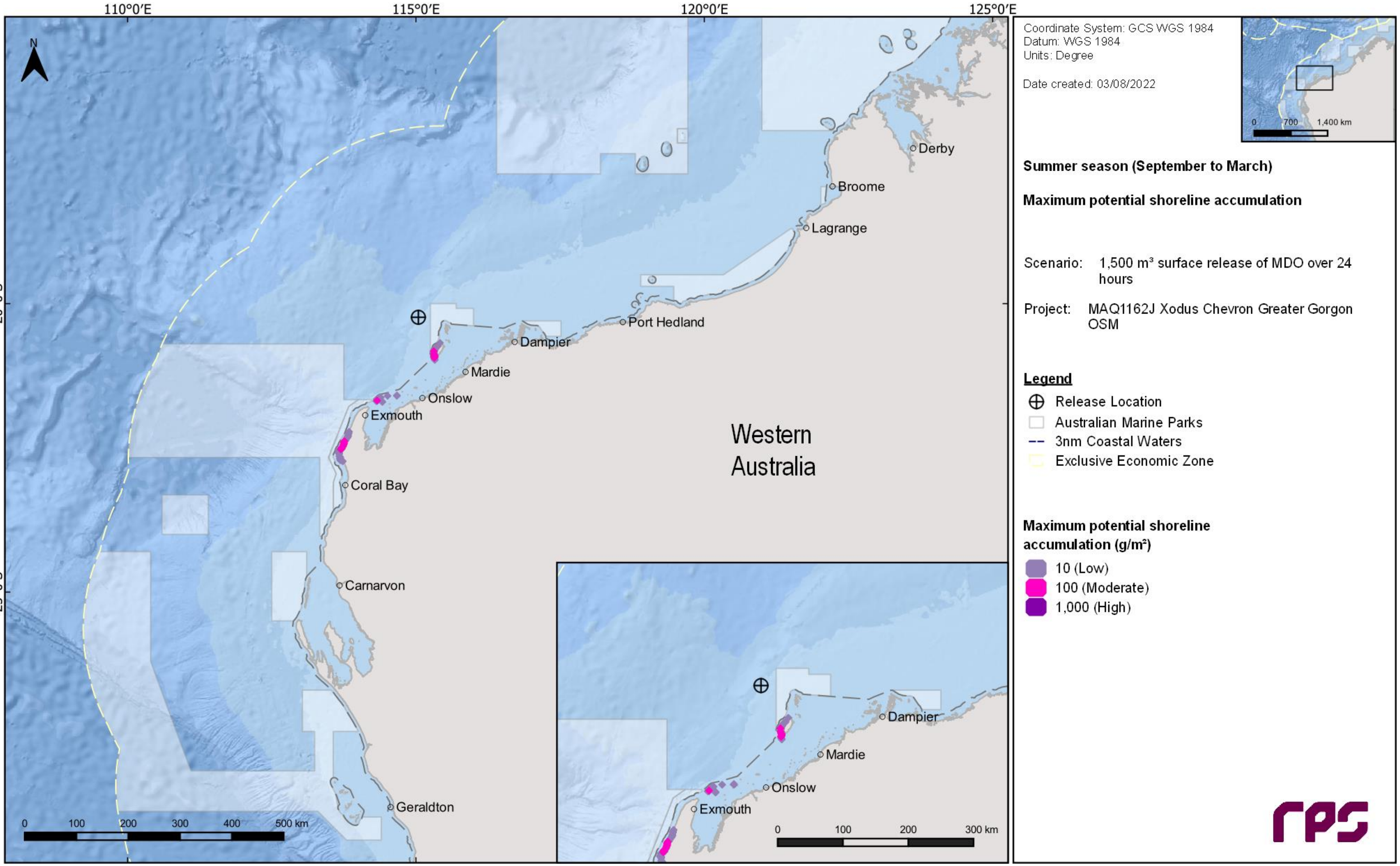


Figure 12.4 Maximum potential shoreline accumulation following a vessel collision at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

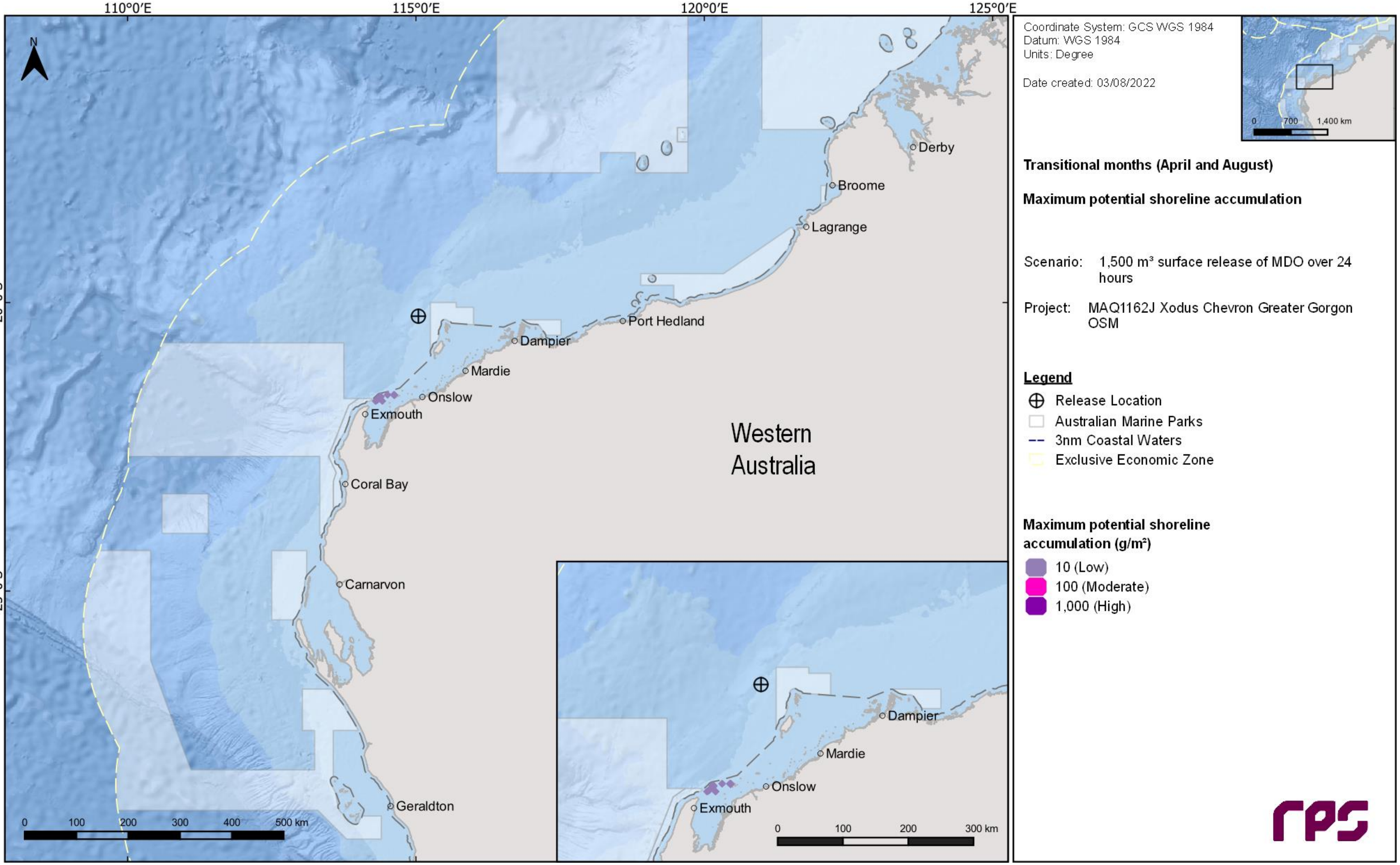


Figure 12.5 Maximum potential shoreline accumulation following a vessel collision at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

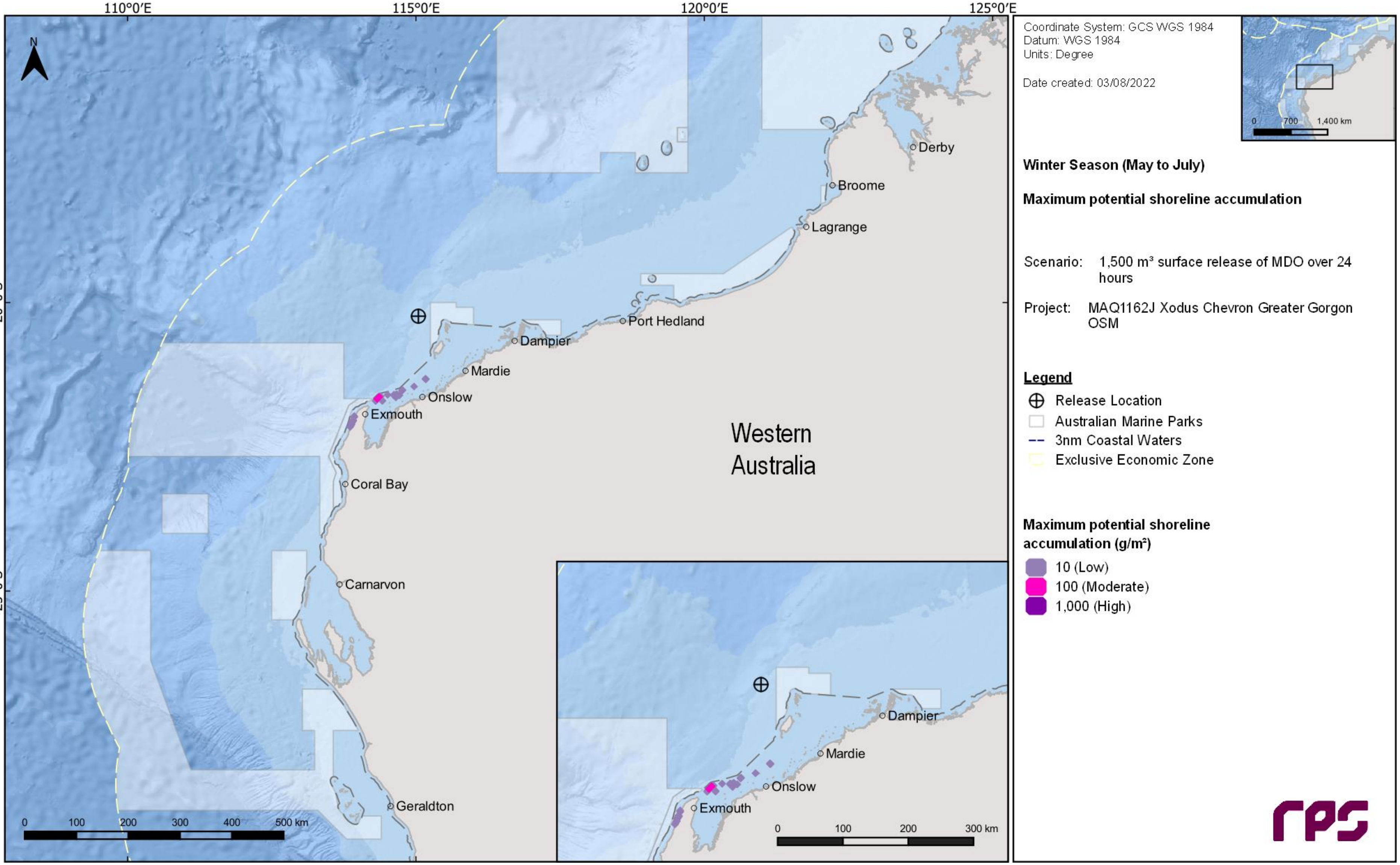


Figure 12.6 Maximum potential shoreline accumulation following a vessel collision at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

12.1.3 Water Column Exposure

12.1.3.1 Dissolved Hydrocarbons

Table 12.7 summarises the seasonal probability of exposure to individual receptors from dissolved hydrocarbons in the 0-10 m depth layer, at the low (≥ 10 ppb), moderate (≥ 50 ppb) and high (≥ 400 ppb) exposure thresholds.

In the surface (0-10 m) depth layer, a total of 14, 12, and 14 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter, respectively. Excluding the 4 BIAs that the release location resides within (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging) , the highest probabilities of exposure for the low threshold during summer, transitional and winter were predicted as 6%, 6% and 14%, respectively for the Humpback Whale - Migration BIA.

A total of 3, 2 and 2 AMPs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold during summer, transitional and winter, respectively with the highest probability predicted at the Montebello AMP of 3% during summer and transitional.

Additionally, 4, 3 and 4 IAAs and 2, 3 and 3 IMCRAs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold during summer, transitional and winter, respectively.

Furthermore, 4 (summer) and 3 (transitional) and 5 (winter) KEFs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold.

Figure 12.7 to Figure 12.9 presents the zones of potential instantaneous dissolved hydrocarbon exposure for the 0-10 m depth layer for the summer, transitional and winter periods, respectively.

Table 12.7 Predicted probability and maximum dissolved hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a vessel collision at WTR Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer				Transitional				Winter			
		Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)			Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)			Maximum instantaneous exposure to dissolved hydrocarbons (ppb)	Probability of instantaneous exposure to dissolved hydrocarbons (%)		
			Low	Moderate	High		Low	Moderate	High		Low	Moderate	High
AMP	Gascoyne	16	1	-	-	14	1	-	-	17	1	-	-
	Montebello	31	3	-	-	53	3	1	-	8	-	-	-
	Ningaloo	4	-	-	-	5	-	-	-	12	1	-	-
BIA	Fairy Tern - Breeding	11	1	-	-	5	-	-	-	9	-	-	-
	Flatback Turtle - Internesting Buffer*	144	71	35	-	132	75	25	-	138	84	29	-
	Flatback Turtle - Nesting	50	2	1	-	32	2	-	-	43	3	-	-
	Green Turtle - Internesting Buffer	44	1	-	-	32	1	-	-	26	1	-	-
	Green Turtle - Nesting	44	1	-	-	32	1	-	-	26	1	-	-
	Hawksbill Turtle - Internesting Buffer	44	1	-	-	32	1	-	-	26	1	-	-
	Hawksbill Turtle - Nesting	44	1	-	-	32	1	-	-	26	1	-	-
	Humpback Whale - Migration	55	6	1	-	52	6	1	-	82	14	1	-
	Lesser Crested Tern - Breeding	20	1	-	-	6	-	-	-	9	-	-	-
	Loggerhead Turtle - Internesting Buffer	6	-	-	-	14	1	-	-	13	1	-	-
	Loggerhead Turtle - Nesting	5	-	-	-	14	1	-	-	12	1	-	-
	Pygmy Blue Whale - Distribution*	144	71	35	-	132	75	25	-	138	84	29	-
	Pygmy Blue Whale - Foraging	12	1	-	-	10	-	-	-	11	1	-	-
	Roseate Tern - Breeding	34	1	-	-	5	-	-	-	17	1	-	-
	Wedge-tailed Shearwater - Breeding*	144	71	35	-	132	75	25	-	138	84	29	-
	Whale Shark - Foraging*	144	71	35	-	132	75	25	-	138	84	29	-
IAA	Gascoyne	16	1	-	-	14	1	-	-	17	1	-	-
	Ningaloo Coast World Heritage Area	4	-	-	-	5	-	-	-	12	1	-	-
	Barrow & Montebello Islands	31	3	-	-	53	3	1	-	8	-	-	-
	Pilbara Coast	16	1	-	-	5	-	-	-	14	1	-	-
	Offshore Area*	144	71	35	-	132	75	25	-	138	84	29	-
IMCRA	Ningaloo	8	-	-	-	10	1	-	-	12	1	-	-
	Northwest Shelf	45	4	-	-	44	2	-	-	19	2	-	-
	Pilbara (offshore)*	144	71	35	-	132	75	25	-	138	84	29	-
KEF	Ancient coastline at 125 m depth contour*	144	71	35	-	132	75	25	-	138	84	29	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	16	1	-	-	13	1	-	-	14	1	-	-
	Commonwealth waters adjacent to Ningaloo Reef	4	-	-	-	5	-	-	-	12	1	-	-
	Continental Slope Demersal Fish Communities	64	9	1	-	60	9	1	-	97	9	1	-
State waters	Western Australia	20	1	-	-	5	-	-	-	12	1	-	-

*The release location resides within the receptor boundaries.

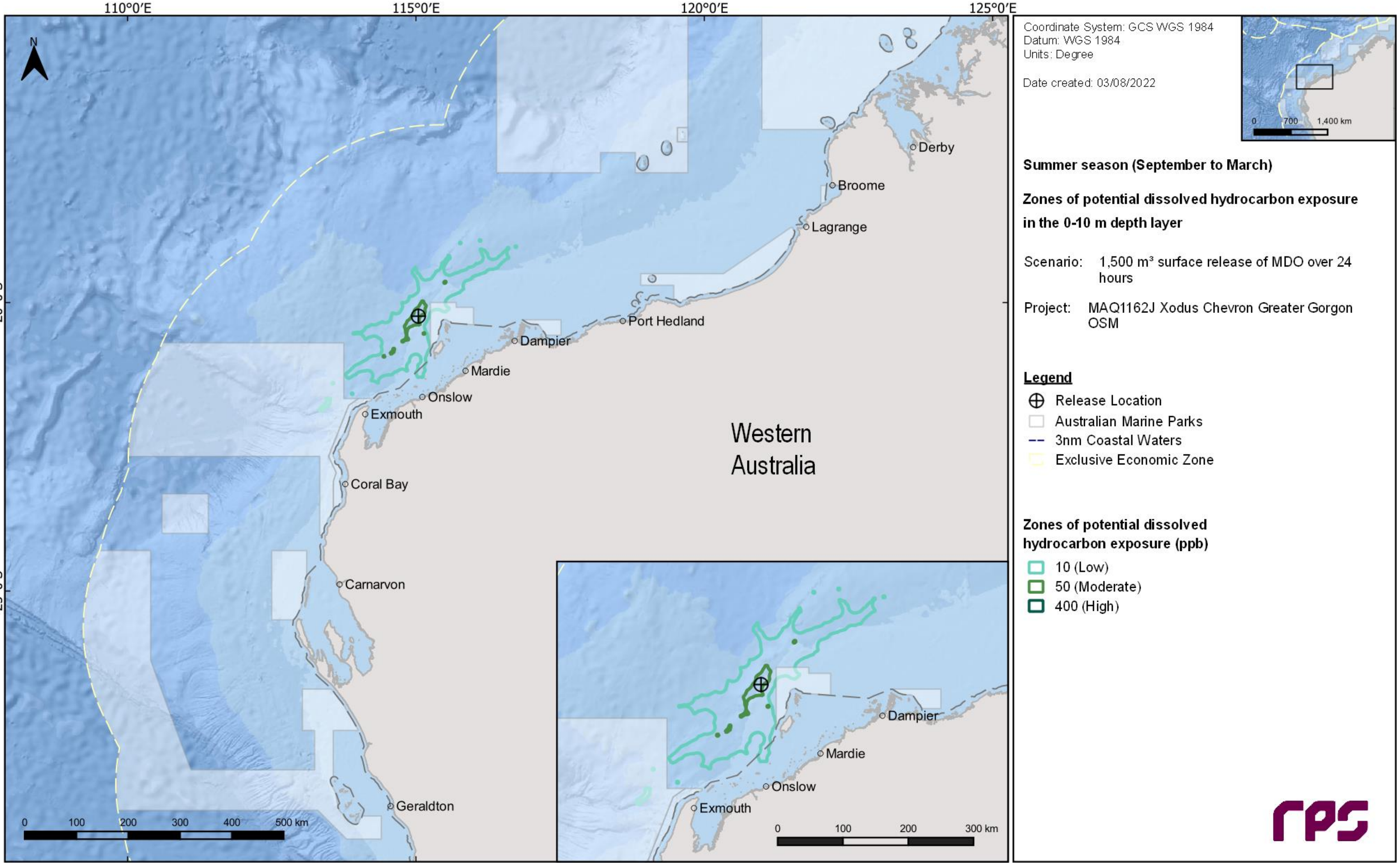


Figure 12.7 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

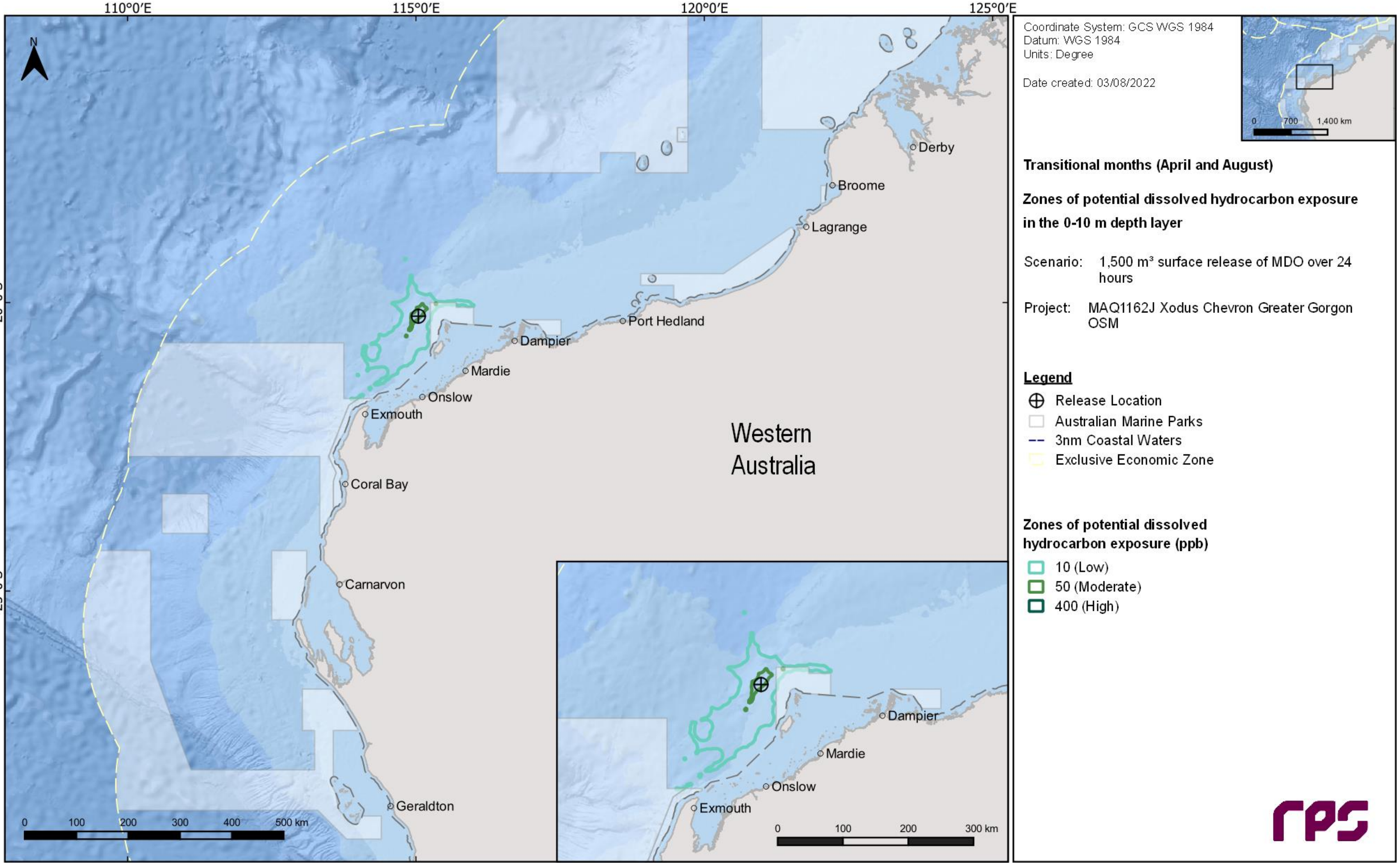


Figure 12.8 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

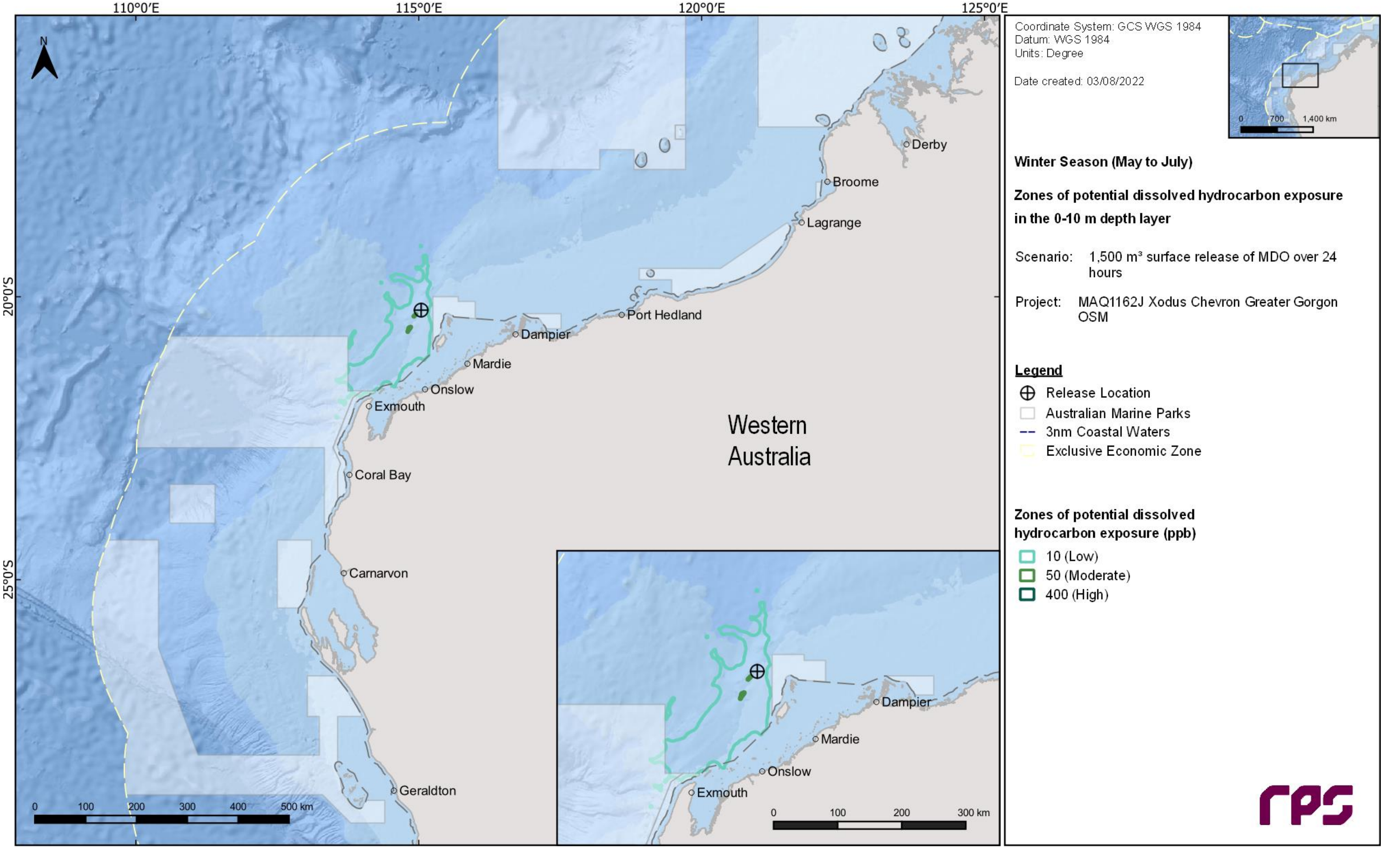


Figure 12.9 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

12.1.3.2 Entrained Hydrocarbons

Table 12.8 summarises the probability and minimum time before exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

In the surface (0-10 m) depth layer, a total of 29 BIAs were predicted to be exposed at, or above, the low threshold during all 3 seasons. Excluding the 4 BIAs that the release location resides within (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging) , the highest probabilities of exposure to low entrained hydrocarbons were predicted for the Humpback Whale - Migration during all seasons (42%, 59% and 71% for summer, transitional and winter, respectively).

During all 3 seasons, 3 AMPs were predicted to be exposed at the low threshold, with the highest probabilities predicted at the Gascoyne AMP (21% summer, 22% transitional and 37% winter). Furthermore, during seasonal conditions the Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold.

During summer, transitional and winter conditions, 8, 5 and 6 KEFs were predicted to be exposed by entrained hydrocarbons at the low threshold, respectively. Probabilities of exposure ranged between 1–100%, 13–95% and 12–100%, for summer, transitional and winter, respectively. Excluding the KEF that the release location resides within (Ancient coastline at 125 m depth contour), the KEF with the greatest probability of low exposure for each season was the Continental Slope Demersal Fish Communities KEF (58%, 54% and 68% for summer, transitional and winter, respectively).

Additionally, 24, 22 and 24 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold. Excluding the Offshore IAA, the probabilities for each season ranged between 1–21%, 1–22% and 1–37% under summer, transitional and winter conditions, respectively, with the maximum probabilities occurring at the Gascoyne IAA during all seasons.

Furthermore, 17, 22 and 23 RBS receptors were predicted to be exposed to entrained hydrocarbons at the low threshold during summer, transitional and winter, respectively. The maximum probabilities for low threshold exposure during summer, transitional and winter were predicted for Rankin Bank (17%), Rankin Bank (8%) and Outtrim Patches (13%), respectively.

Figure 12.10 to Figure 12.12 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

Table 12.8 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a vessel collision at WTR Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer			Transitional			Winter		
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)	
			Low	High		Low	High		Low	High
AMP	Abrolhos	17	1	-	-	-	-	13	2	-
	Argo-Rowley Terrace	13	1	-	17	1	-	-	-	-
	Carnarvon Canyon	-	-	-	10	1	-	31	3	-
	Gascoyne	324	21	3	384	22	5	283	37	8
	Montebello	1,171	19	11	611	11	7	645	8	2
	Ningaloo	329	6	2	87	13	-	311	29	6
	Shark Bay	-	-	-	-	-	-	34	4	-
BIA	Bridled Tern - Foraging	-	-	-	-	-	-	20	2	-
	Dugong - Breeding	209	3	1	72	10	-	225	22	2
	Dugong - Calving	209	3	1	72	10	-	225	22	2
	Dugong - Foraging	209	3	1	72	10	-	225	22	2
	Dugong - Nursing	209	3	1	72	10	-	225	22	2
	Fairy Tern - Breeding	219	5	1	251	11	2	187	26	3
	Flatback Turtle - Aggregation	21	1	-	-	-	-	-	-	-
	Flatback Turtle - Foraging	102	2	1	26	1	-	13	1	-
	Flatback Turtle - Internesting	21	1	-	-	-	-	-	-	-
	Flatback Turtle - Internesting Buffer*	19,061	100	97	13,629	95	90	13,131	100	97
	Flatback Turtle - Mating	102	2	1	26	1	-	13	1	-
	Flatback Turtle - Nesting	1,242	22	13	1,334	33	17	1,613	58	17
	Green Turtle - Aggregation	21	1	-	-	-	-	-	-	-
	Green Turtle - Basking	102	2	1	30	1	-	17	2	-
	Green Turtle - Foraging	102	2	1	26	1	-	14	1	-
	Green Turtle - Internesting	102	2	1	26	1	-	14	1	-
	Green Turtle - Internesting Buffer	511	12	5	445	20	3	818	29	10
	Green Turtle - Mating	102	2	1	30	1	-	14	2	-
	Green Turtle - Nesting	332	11	4	310	15	2	690	31	9
	Hawksbill Turtle - Foraging	102	2	1	26	1	-	17	1	-
	Hawksbill Turtle - Mating	102	2	1	26	1	-	13	1	-
	Hawksbill Turtle - Nesting	274	11	4	306	15	2	690	27	9
	Humpback Whale - Migration	1,819	42	24	1,607	59	39	2,117	71	42
	Humpback Whale - Resting	35	2	-	32	6	-	17	4	-
	Lesser Crested Tern - Breeding	223	8	3	275	11	2	216	17	4
	Little Tern - Resting	11	1	-	-	-	-	-	-	-
	Loggerhead Turtle - Internesting Buffer	366	9	5	229	19	2	360	32	9
	Loggerhead Turtle - Nesting	333	7	2	95	14	-	311	31	6
	Pygmy Blue Whale - Distribution*	19,061	100	97	13,629	95	90	13,131	100	97
	Pygmy Blue Whale - Foraging	219	9	3	195	18	3	226	33	8
	Roseate Tern - Breeding	277	11	1	191	11	2	331	17	8

Receptor		Summer			Transitional			Winter		
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)	
			Low	High		Low	High		Low	High
	Sooty Tern - Foraging	-	-	-	-	-	-	22	3	-
	Wedge-tailed Shearwater - Breeding*	19,061	100	97	13,629	95	90	13,131	100	97
	Wedge-tailed Shearwater - Foraging	-	-	-	-	-	-	21	2	-
	Whale Shark - Foraging*	19,061	100	97	13,629	95	90	13,131	100	97
	White-tailed Tropicbird - Breeding	30	1	-	12	1	-	-	-	-
IAA	Barrow Island (West Coast)	93	2	-	19	1	-	11	1	-
	South Muiron Island	139	4	1	47	6	-	80	12	-
	Thevenard Island	-	-	-	22	2	-	46	2	-
	Serrurier Island	23	2	-	64	6	-	69	4	-
	Bessieres Island	15	2	-	55	6	-	128	4	1
	Airlie Island	-	-	-	31	1	-	23	1	-
	Ashburton Island	-	-	-	-	-	-	10	1	-
	North Muiron Island	175	3	1	57	6	-	130	16	1
	Boodie Island	83	2	-	25	1	-	11	1	-
	Middle Island	99	2	-	18	1	-	-	-	-
	Rankin Bank	425	17	5	79	8	-	208	2	1
	Glomar Shoal	11	1	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	156	2	1	-	-	-	43	2	-
	North Ningaloo Coast - World Heritage Area	160	1	1	22	5	-	53	8	-
	Cape Range National Park	128	1	1	23	4	-	113	7	1
	Abrolhos Islands	17	1	-	4	-	-	13	2	-
	Gascoyne	324	21	3	384	22	5	283	37	8
	Ningaloo Coast World Heritage Area	329	6	2	87	13	-	311	29	6
	Argo-Rowley Terrace	16	1	-	17	1	-	-	-	-
	Barrow Island (East Coast)	46	2	-	-	-	-	-	-	-
	Barrow & Montebello Islands	1,171	19	11	611	11	7	645	8	2
	Pilbara Coast	158	6	2	254	10	2	181	19	2
	Exmouth	69	3	-	45	6	-	46	5	-
	Shark Bay mainland coastline	-	-	-	-	-	-	43	4	-
	Offshore Area*	19,061	100	97	13,629	95	90	13,131	100	97
	Barrow Island Group	99	2	-	25	1	-	11	1	-
	Pilbara Coast Islands Group	23	2	-	64	6	-	128	4	1
	Muiron Islands	175	4	1	57	6	-	130	16	1
IBRA	Cape Range	175	4	1	74	6	-	130	16	1
	Roebourne	99	2	-	29	1	-	22	1	-
IMCRA	Ningaloo	365	7	3	182	19	4	311	37	8
	Northwest Shelf	1,255	34	23	1,187	16	10	707	12	5
	Pilbara (nearshore)	50	2	-	36	6	-	37	4	-
	Pilbara (offshore)*	19,061	100	97	13,629	95	90	13,131	100	97
	Zuytdorp	-	-	-	-	-	-	43	4	-

Receptor		Summer			Transitional			Winter		
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)	
			Low	High		Low	High		Low	High
KEF	Ancient coastline at 125 m depth contour*	19,061	100	97	13,629	95	90	13,131	100	97
KEF	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	365	14	5	303	26	7	356	45	13
KEF	Commonwealth waters adjacent to Ningaloo Reef	329	6	2	87	13	-	311	29	6
KEF	Continental Slope Demersal Fish Communities	2,828	58	39	3,732	54	36	2,964	68	44
KEF	Exmouth Plateau	239	13	3	214	14	3	203	12	3
KEF	Glomar Shoals	51	4	-	-	-	-	-	-	-
KEF	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	12	1	-	-	-	-	-	-	-
KEF	Wallaby Saddle	16	1	-	-	-	-	-	-	-
KEF	Western demersal slope and associated fish communities	-	-	-	-	-	-	22	3	-
MMA	Barrow Island	119	3	1	36	2	-	67	3	-
MMA	Muiron Islands	175	6	2	60	9	-	185	21	2
MP	Barrow Island	34	2	-	22	2	-	48	3	-
MP	Montebello Islands	118	3	1	28	1	-	15	1	-
MP	Ningaloo	196	3	1	67	9	-	141	16	2
NR	Great Sandy Island	18	1	-	-	-	-	-	-	-
NR	Thevenard Island	-	-	-	-	-	-	31	2	-
RSB	Australind Shoal	-	-	-	-	-	-	19	2	-
RSB	Barrow Island Reefs and Shoals	22	1	-	-	-	-	-	-	-
RSB	Brewis Reef	-	-	-	-	-	-	47	2	-
RSB	Combe Reef	31	2	-	25	4	-	14	1	-
RSB	Dailey Shoal	53	3	-	52	6	-	22	4	-
RSB	Exmouth Reef	-	-	-	13	1	-	-	-	-
RSB	Fairway Reef	11	1	-	37	3	-	11	1	-
RSB	Glennie Patches	-	-	-	-	-	-	10	1	-
RSB	Glomar Shoal	11	1	-	-	-	-	-	-	-
RSB	Hayman Rock	-	-	-	14	1	-	-	-	-
RSB	Hood Reef	17	2	-	46	6	-	15	2	-
RSB	Locker Reef	-	-	-	13	1	-	-	-	-
RSB	Miles Shoal	-	-	-	-	-	-	13	1	-
RSB	Montebello Shoals	27	1	-	-	-	-	11	1	-
RSB	Ningaloo Reef	160	2	1	37	6	-	122	10	1
RSB	North West Reef	27	1	-	16	2	-	60	7	-
RSB	Otway Reef	32	2	-	34	5	-	21	3	-
RSB	Outtrim Patches	140	3	1	59	6	-	79	13	-
RSB	Penguin Bank	48	3	-	82	3	-	86	9	-
RSB	Poivre Reef	94	2	-	37	1	-	15	3	-
RSB	Rankin Bank	451	17	5	79	8	-	212	2	1
RSB	Ripple Shoals	19	1	-	18	1	-	-	-	-
RSB	Rosily Shoals	25	2	-	92	4	-	68	8	-

Receptor		Summer			Transitional			Winter		
		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)		Maximum instantaneous exposure to entrained hydrocarbons (ppb)	Probability of instantaneous exposure to entrained hydrocarbons (%)	
			Low	High		Low	High		Low	High
	Santo Rock	-	-	-	13	1	-	41	1	-
	Spider Reef	-	-	-	22	2	-	-	-	-
	Sultan Reef	-	-	-	-	-	-	21	1	-
	Taunton Reef	-	-	-	15	1	-	17	1	-
	Tongue Shoals	-	-	-	-	-	-	12	1	-
	Trap Reef	-	-	-	11	1	-	46	2	-
	Tryal Rocks	130	6	2	73	2	-	242	1	1
	Web Reef	-	-	-	19	2	-	-	-	-
Nearshore Waters	Airlie Island	-	-	-	31	1	-	23	1	-
	Barrow Island	93	2	-	19	1	-	11	1	-
	Bessieres Island	15	2	-	55	6	-	128	4	1
	Boodie Island	80	2	-	24	1	-	11	1	-
	Exmouth	160	2	1	25	5	-	111	8	1
	Flat Island	34	2	-	74	6	-	35	6	-
	Fly Island	-	-	-	18	1	-	-	-	-
	Middle Island	99	2	-	19	1	-	-	-	-
	Montebello Islands	14	1	-	-	-	-	-	-	-
	Murion Islands	175	4	1	57	6	-	130	16	1
	Observation Island	13	1	-	30	3	-	-	-	-
	Peak Island	89	3	-	62	6	-	72	11	-
	Round Island	11	1	-	50	5	-	32	3	-
	Serrurier Island	23	2	-	64	6	-	69	4	-
	Sunday Island	75	3	-	54	6	-	43	9	-
	Table Island	-	-	-	46	4	-	73	3	-
	Thevenard Island	-	-	-	-	-	-	29	2	-
	Tortoise Island	-	-	-	-	-	-	59	2	-
State Waters	Western Australia State Waters	196	6	2	251	10	2	192	21	3

*The release location resides within the receptor boundaries.

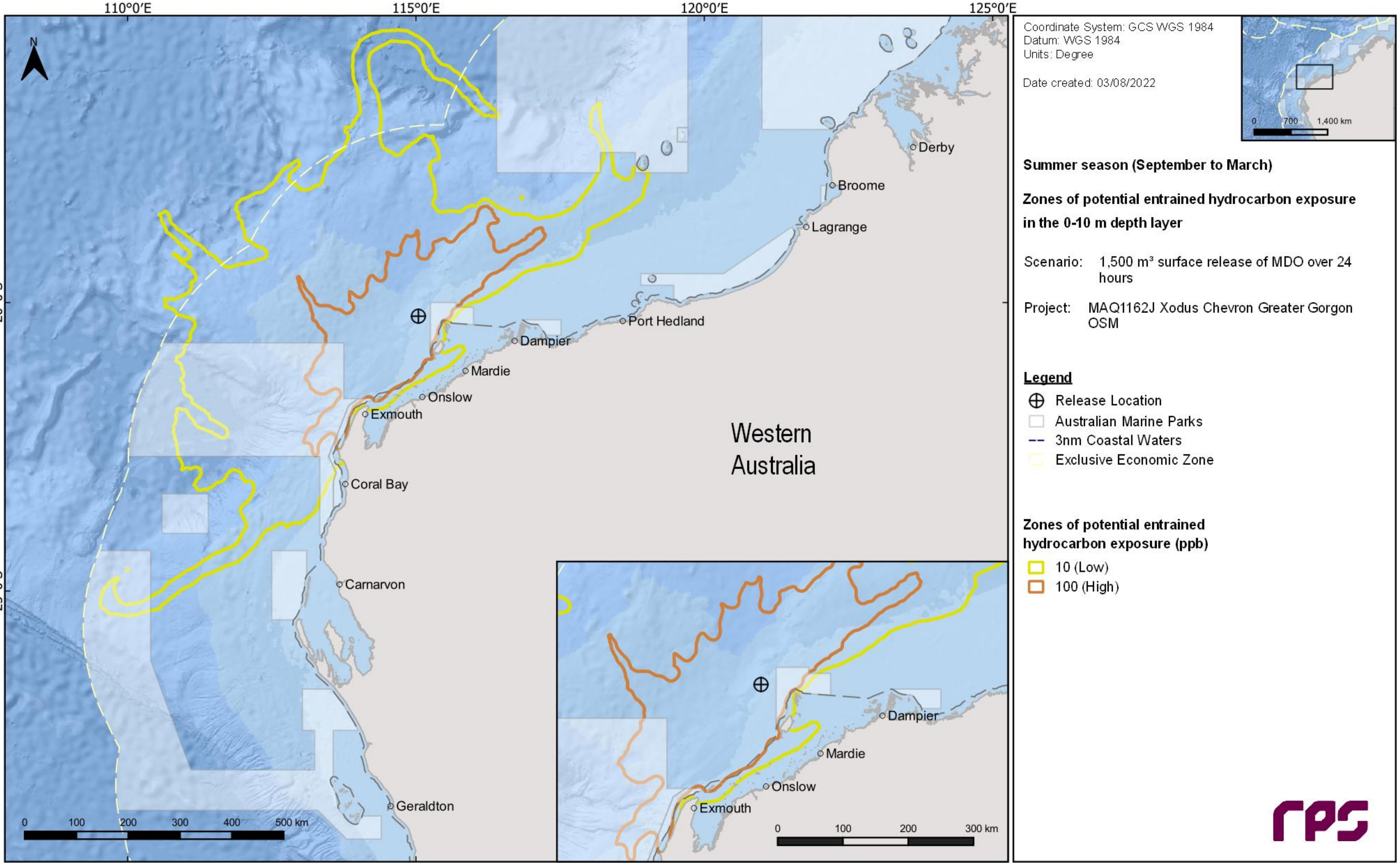


Figure 12.10 Zones of potential entrained hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

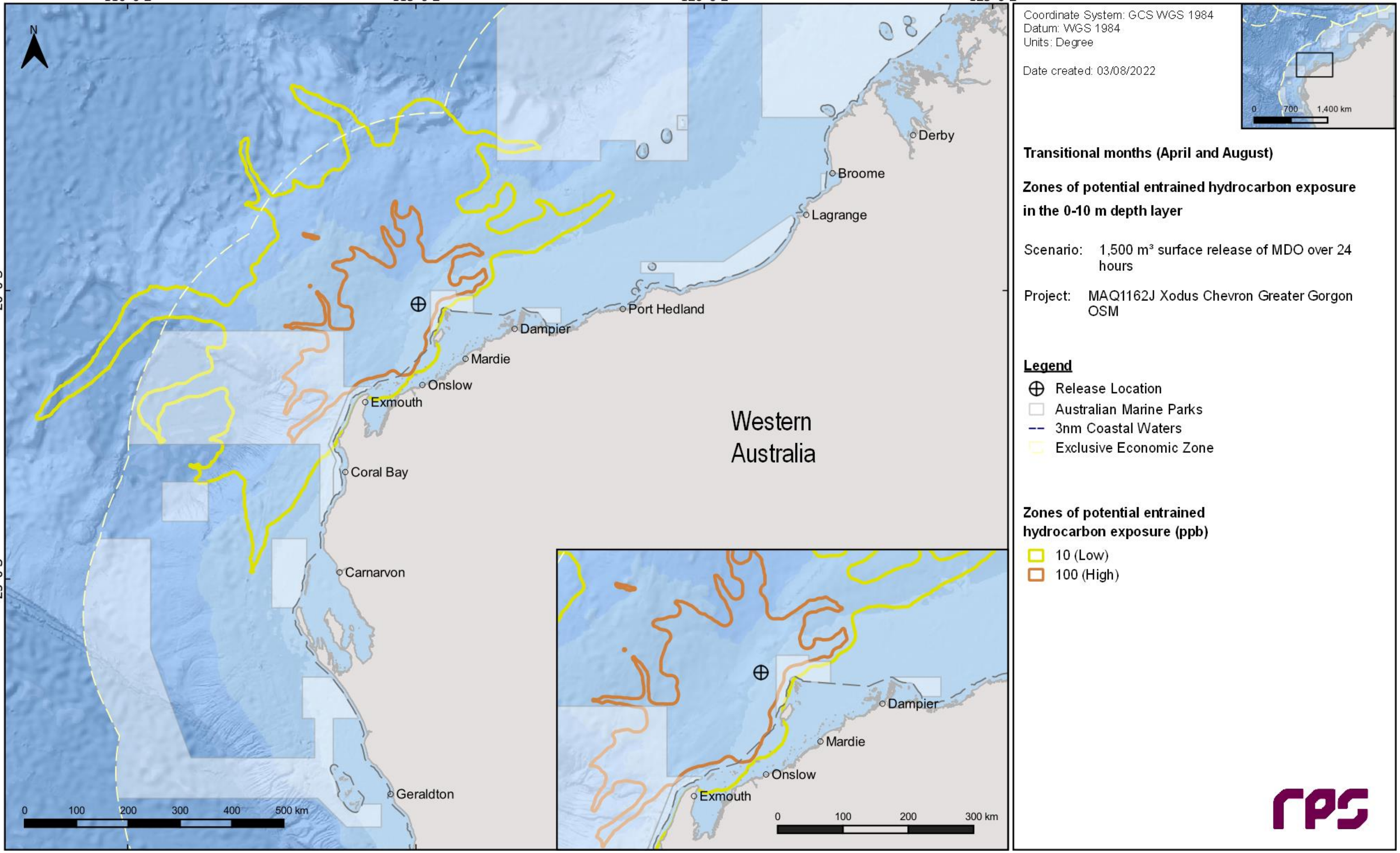


Figure 12.11 Zones of potential entrained hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

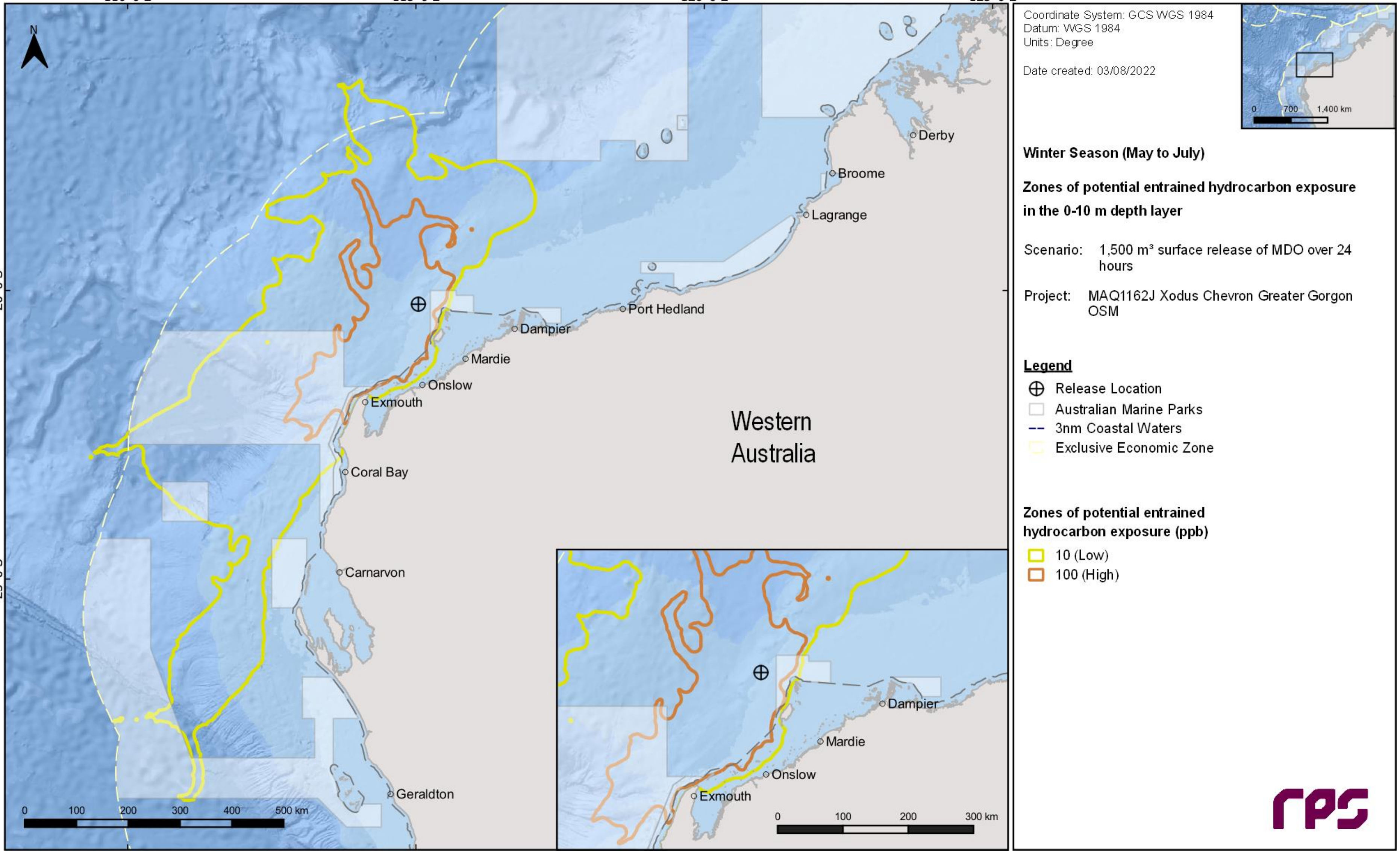


Figure 12.12 Zones of potential entrained hydrocarbon exposure at 0-10 m following a vessel collision at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

12.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating MDO above 10 g/m^2 (see Section 12.2.1), largest swept area of floating MDO above 50 g/m^2 (see Section 12.2.2), largest volume of oil ashore and longest length of shoreline accumulation above 100 g/m^2 (see Section 12.2.3), the largest area of entrained hydrocarbons above 100 ppb (see Section 12.2.4), and the largest area of dissolved hydrocarbons above 50 ppb (see Section 12.2.5).

Table 12.9 presents a summary of all deterministic analysis criteria and the corresponding floating oil, shoreline accumulation, entrained and dissolved hydrocarbon values at the assessed thresholds.

Table 12.9 Summary of the deterministic analysis following a vessel collision at WTR Well 5.

Variable	Threshold	Deterministic Analysis Criteria: Largest swept area of floating MDO above 10 g/m²	Largest swept area of floating MDO above 50 g/m²	Largest volume of oil ashore	Longest length of shoreline accumulation above 100 g/m²	Largest area of entrained hydrocarbons above 100 ppb	Largest area of dissolved hydrocarbons above 50 ppb
Season		Winter	Transitional	Summer	Summer	Transitional	Winter
Run Number		60	64	41	41	31	96
Floating Oil (km²)	1 g/m²	912	181	122	122	36	54
	10 g/m²	**256**	96	61	61	15	3
	50 g/m²	8	**38**	14	14	4	0
Shoreline Length (km)	10 g/m²	0	0	51	51	0	0
	100 g/m²	0	0	24	**24**	0	0
	1,000 g/m²	0	0	0	0	0	0
Minimum Time (days)		0	0	10.25	10.25	0	0
Maximum Volume (m³)		0	0	**35**	35	0	0
Entrained Area (km²)	10 ppb	15,905	22,528	7,741	7,741	23,157	10,363
	100 ppb	1,181	2,749	4,150	4,150	**6,049**	1,792
Dissolved Area (km²)	10 ppb	0	0	0	0	204	413
	50 ppb	0	0	0	0	2	**60**
	400 ppb	0	0	0	0	0	0
Start Date		31 May 20111	28 August 2019	21 January 2012	21 January 2012	16 April 2015	20 May 2011

12.2.1 Deterministic Case: Largest swept area of floating oil above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating oil above 10 g/m^2 (moderate threshold) was identified as run number 60 during the winter period.

Figure 12.13 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 60-day simulation.

Figure 12.14 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating oil over the 60-day simulation.

Figure 12.15 presents the fates and weathering for the corresponding simulation and Table 12.10 summarises peak volumes and times of occurrence for each oil phase and volumes at the end of the 60-day simulation.

Table 12.10 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 60), for the simulation with the largest swept area of floating oil above 10 g/m^2 following a vessel collision at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 60
Surface (m^3)	900	1	0
Entrained (m^3)	488	4	62
Dissolved (m^3)	1	4	0
Evaporation (m^3)	1,057	58	1,057
Decay (m^3)	371	60	371
Ashore (m^3)	0	0	0

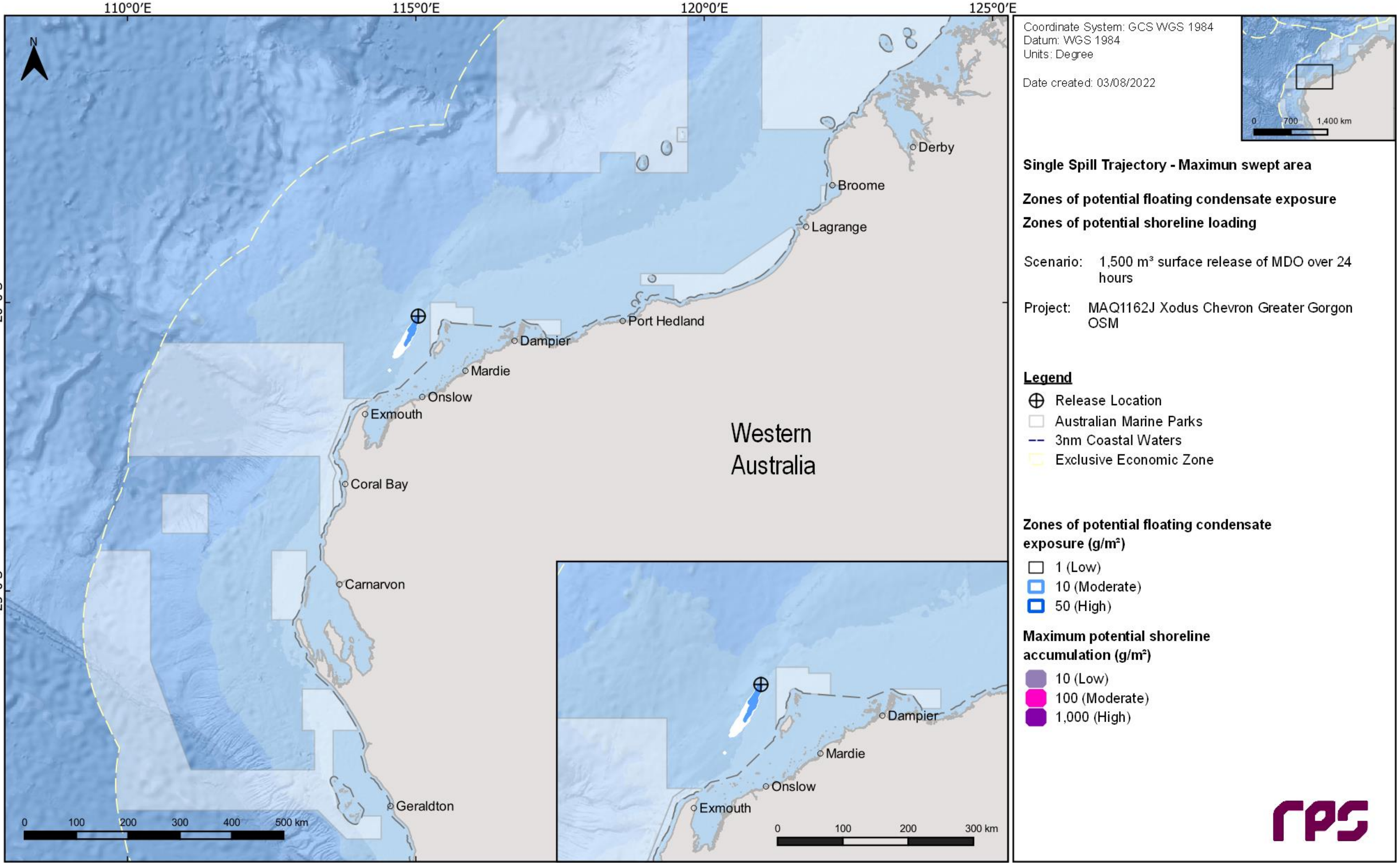


Figure 12.13 Zones of potential floating oil exposure and shoreline accumulation over the entire 60 days, for the simulation with the largest swept area of floating oil above 10 g/m² following a vessel collision at WTR Well 5.

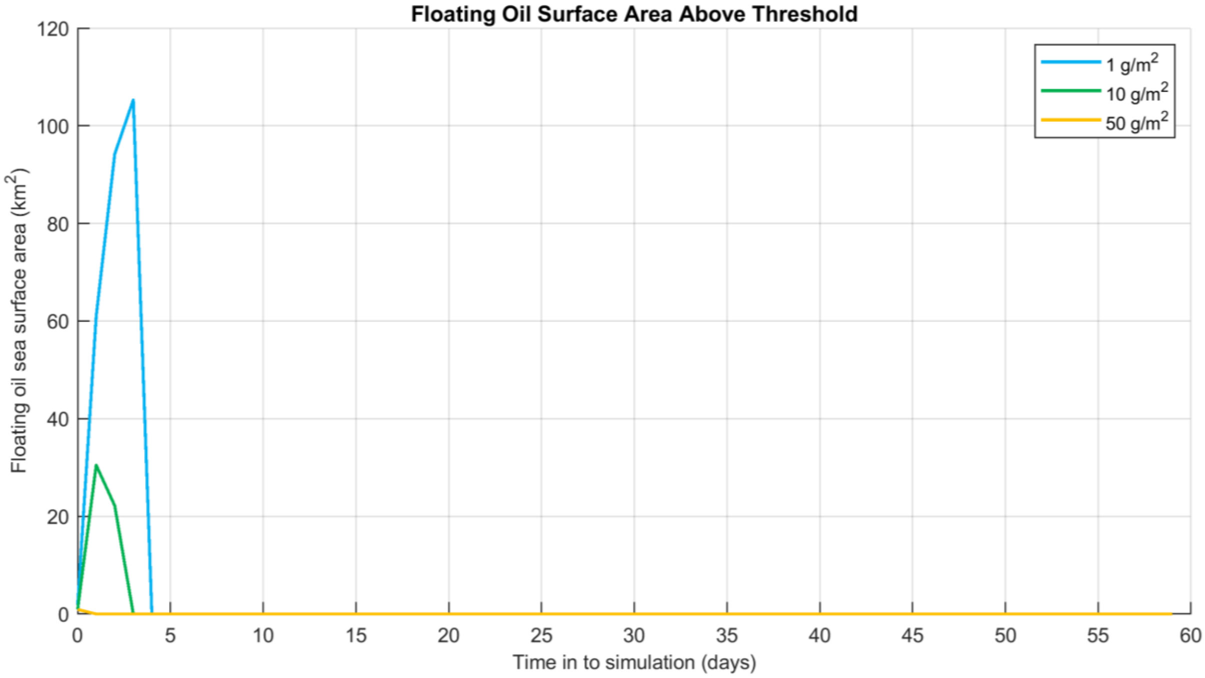


Figure 12.14 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating oil above 10 g/m^2 following a LOWC at WTR Well 5.

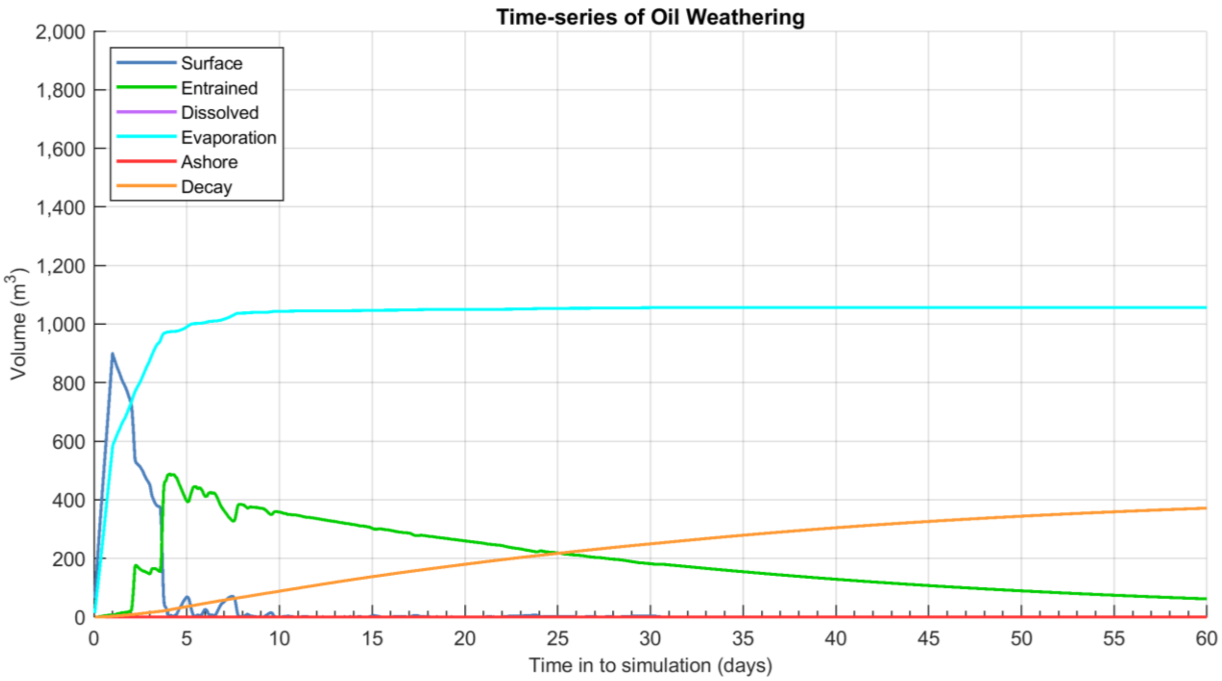


Figure 12.15 Predicted weathering and fates for the simulation with the largest swept area of floating oil above 10 g/m^2 following a vessel collision at WTR Well 5.

12.2.2 Deterministic Case: Largest swept area of floating oil above 50 g/m^2

The deterministic simulation that resulted in the largest swept area of floating oil above 50 g/m^2 (high threshold) was identified as run number 64 during the transitional period.

Figure 12.16 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 60-day simulation.

Figure 12.17 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating oil over the 60-day simulation.

Figure 12.18 presents the fates and weathering for the corresponding simulation and Table 12.11 summarises peak volumes and times of occurrence for each oil phase and volumes at the end of the 60-day simulation.

Table 12.11 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 60), for the simulation with the largest swept area of floating oil above 50 g/m^2 following a vessel collision at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 60
Surface (m^3)	932	1	0
Entrained (m^3)	745	3	83
Dissolved (m^3)	1	5	0
Evaporation (m^3)	866	59	866
Decay (m^3)	553	60	553
Ashore (m^3)	0	0	0

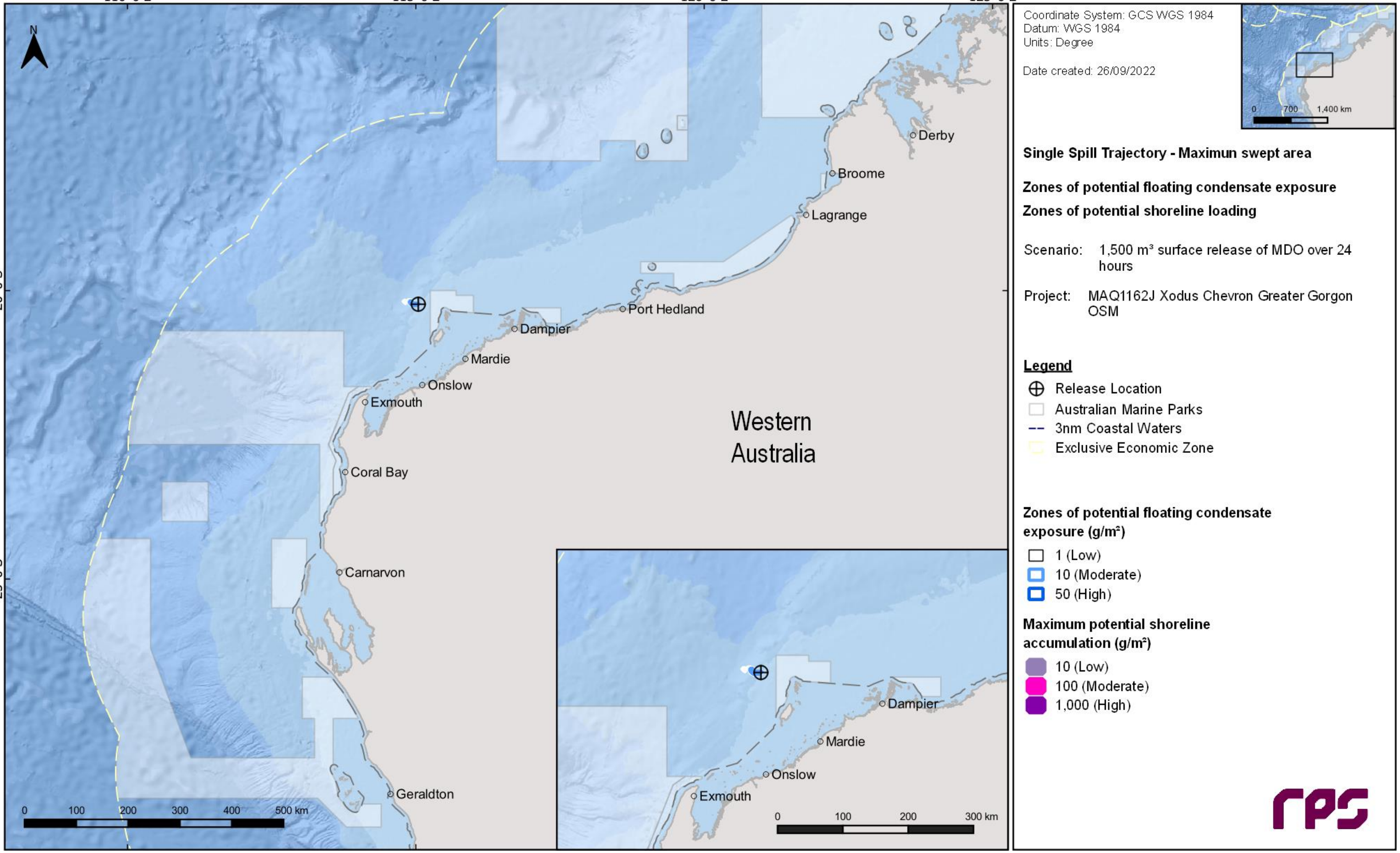


Figure 12.16 Zones of potential floating oil exposure and shoreline accumulation over the entire 60 days, for the simulation with the largest swept area of floating oil above 50 g/m^2 following a vessel collision at WTR Well 5.

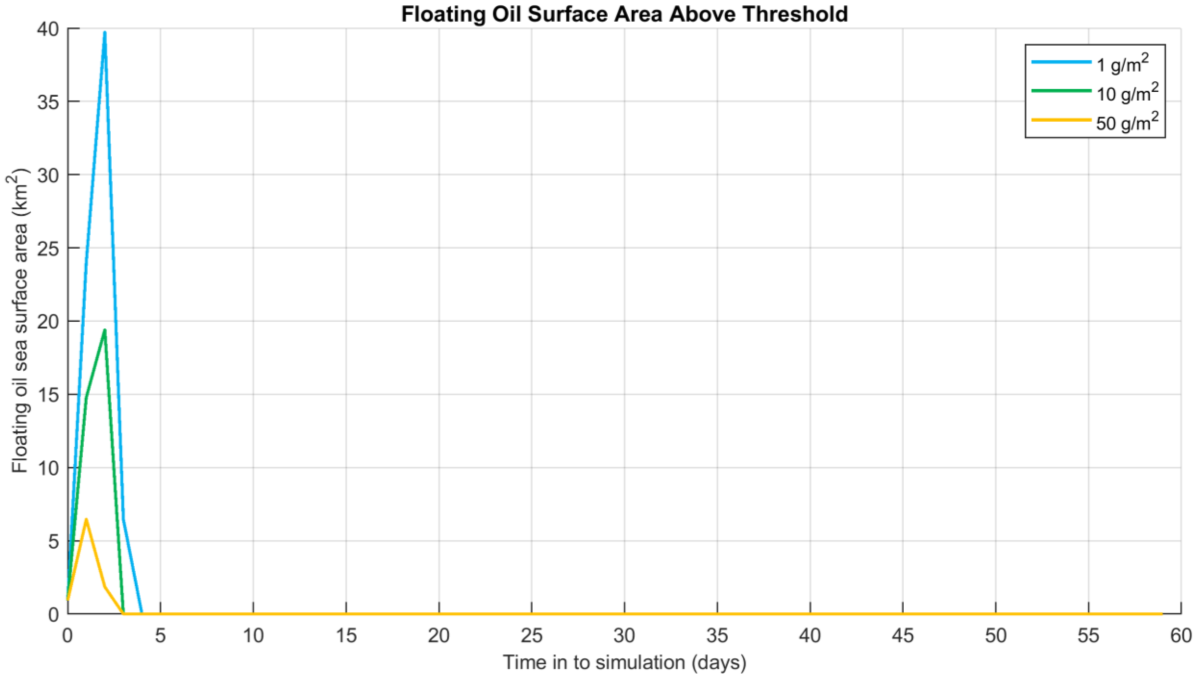


Figure 12.17 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating oil above 50 g/m² following a LOWC at WTR Well 5.

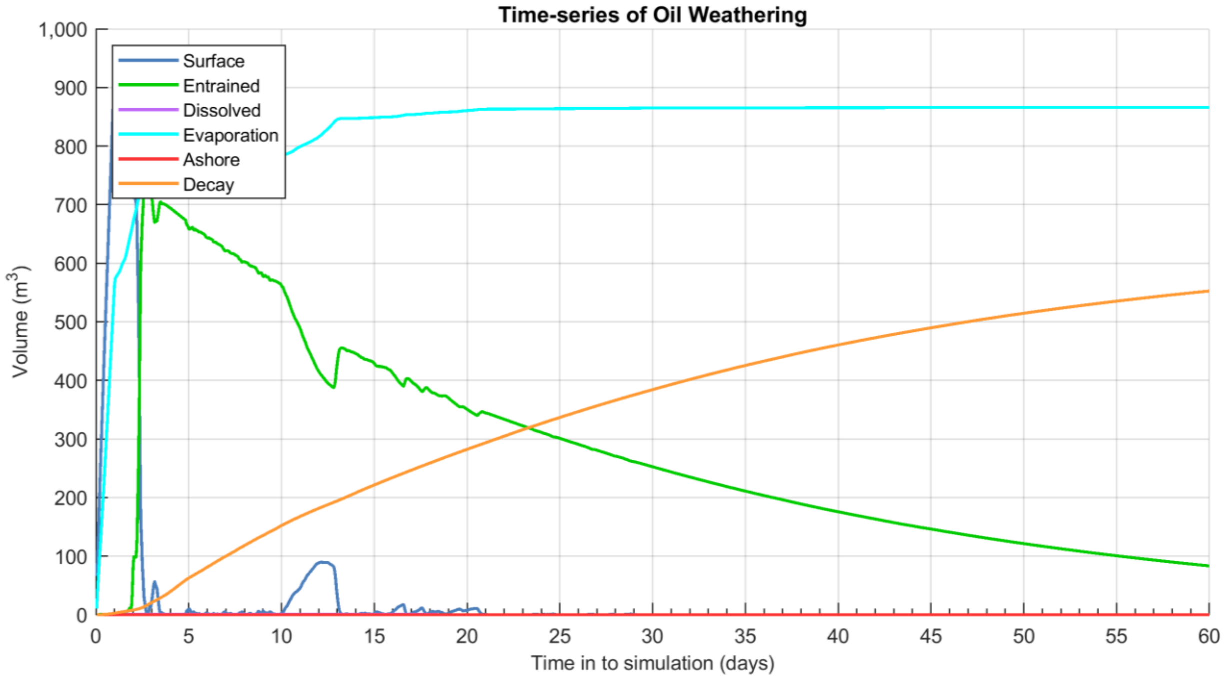


Figure 12.18 Predicted weathering and fates for the simulation with the largest swept area of floating oil above 50 g/m² following a vessel collision at WTR Well 5.

12.2.3 Deterministic Case: Largest volume of oil ashore and longest length of shoreline accumulation above 100 g/m^2

The deterministic simulation that resulted in the largest volume of oil ashore and the longest length of shoreline accumulation above 100 g/m^2 (moderate threshold) was identified as run number 41 during the summer period.

Figure 12.19 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 60-day simulation.

Figure 12.20 displays the time series of the volume of oil accumulating on shorelines at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 60-day simulation

Figure 12.21 displays the time series of length of shoreline oil accumulation at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 60-day simulation.

Figure 12.22 presents the fates and weathering graph for the corresponding single spill trajectory and Table 12.12 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 12.12 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 60), for the simulation that resulted in the largest volume of oil ashore and the longest length of shoreline accumulation above 100 g/m^2 following a vessel collision at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 60
Surface (m^3)	738	1	<1
Entrained (m^3)	854	2	106
Dissolved (m^3)	1	5	-
Evaporation (m^3)	703	60	706
Decay (m^3)	679	60	684
Ashore (m^3)	35	17	3

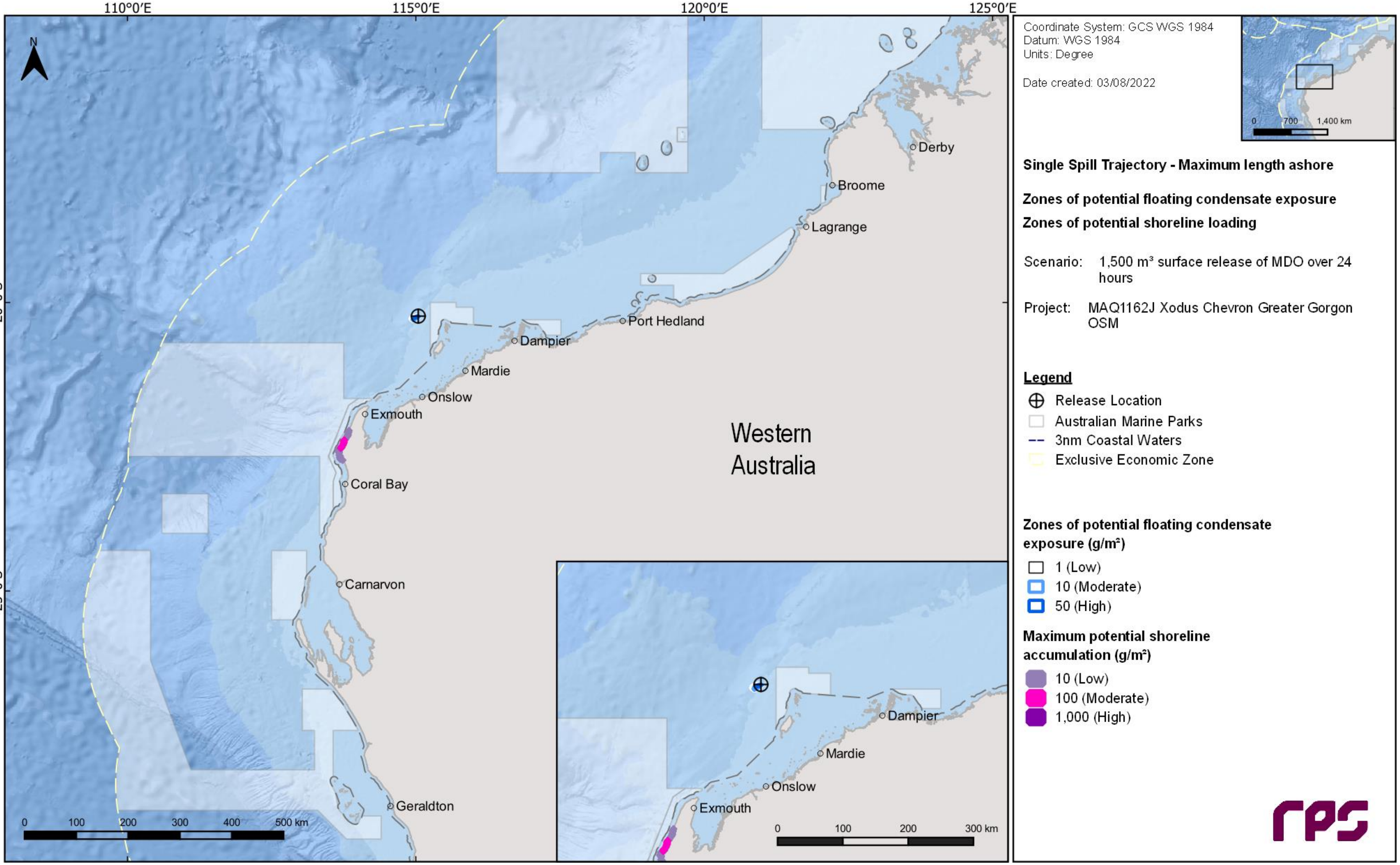


Figure 12.19 Zones of potential floating oil exposure over the entire 60 days, for the simulation with the largest volume of oil ashore and the longest length of shoreline with accumulation above 100 g/m^2 following a vessel collision at WTR Well 5.

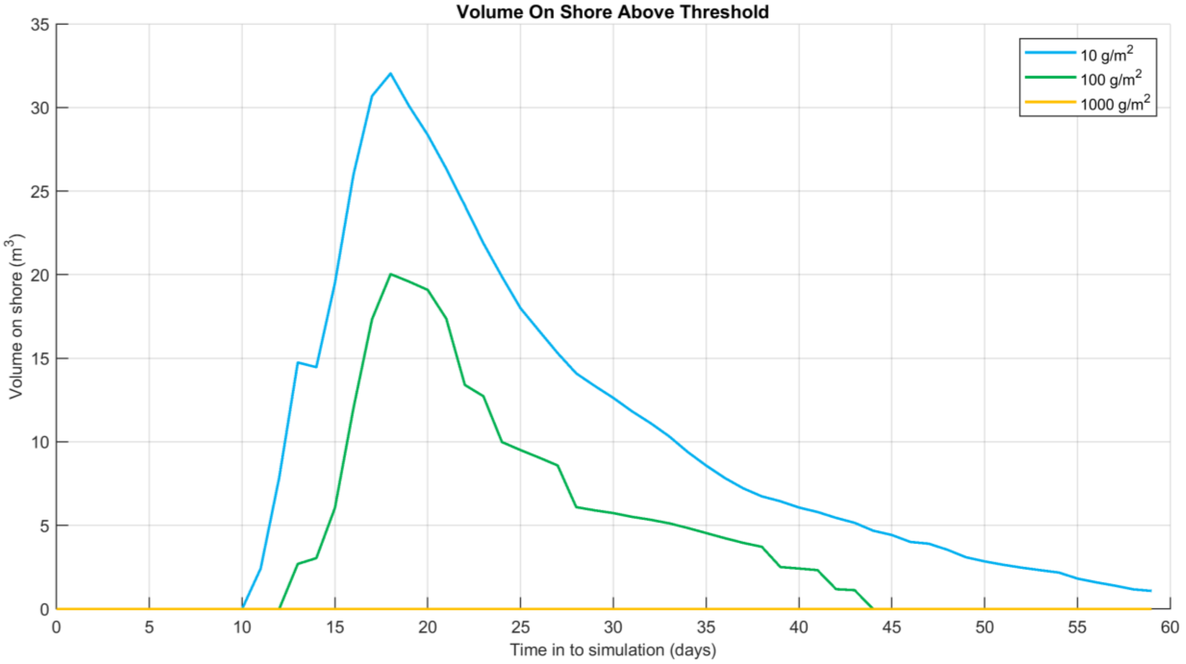


Figure 12.20 Time series of the volume of oil ashore at each threshold for the simulation with the largest volume ashore and the longest length of shoreline with accumulation above 100 g/m² following a vessel collision at WTR Well 5.

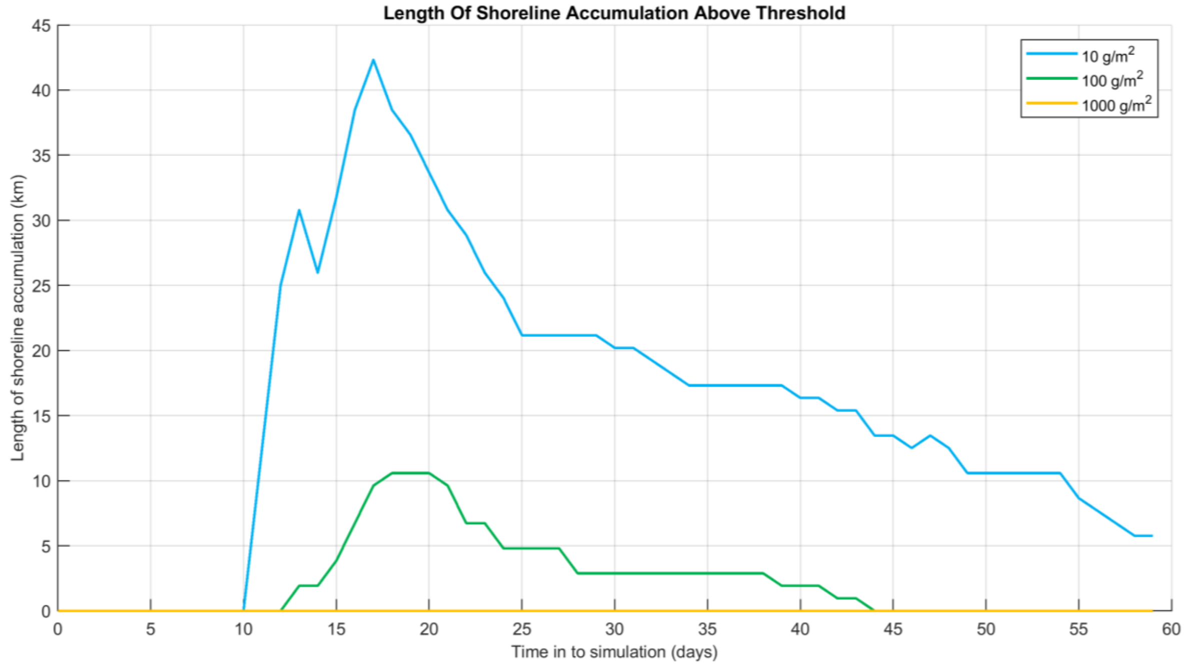


Figure 12.21 Time series of the length of shoreline at each thresholds for the simulation with the largest volume of oil ashore and the longest length of shoreline with accumulation above 100 g/m² following a vessel collision at WTR Well 5.

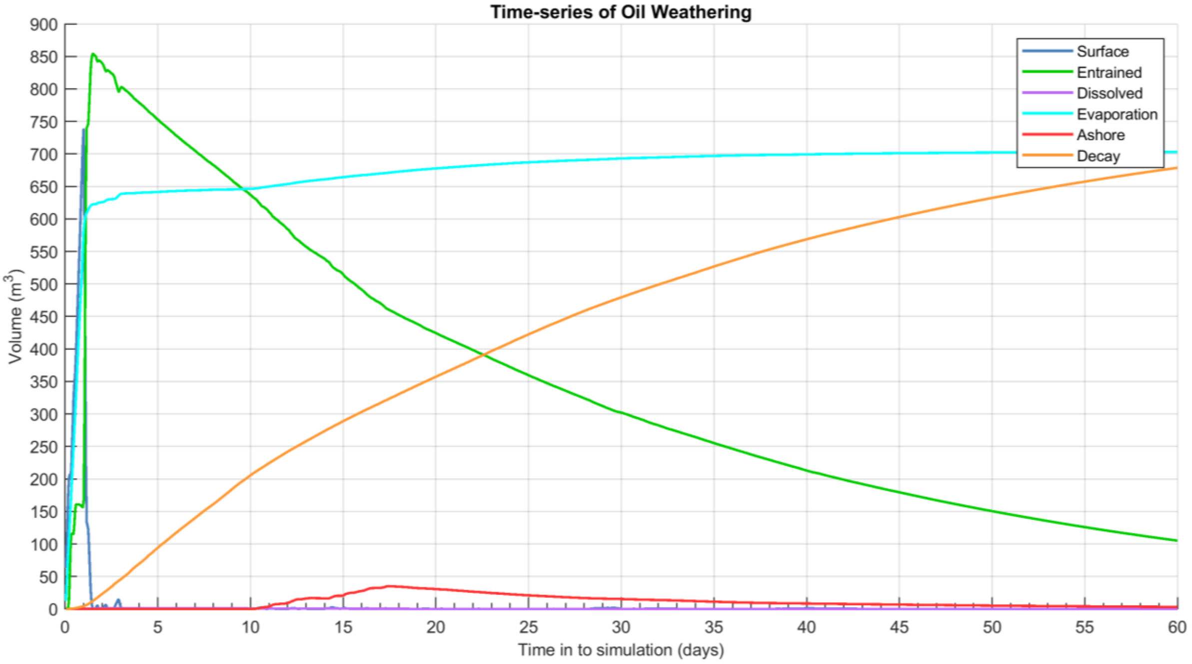


Figure 12.22 Predicted weathering and fates for the simulation that resulted largest volume of oil ashore and the longest length of shoreline with accumulation above 100 g/m^2 following a vessel collision at WTR Well 5.

12.2.4 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (high threshold) was identified as run number 31 during transitional period.

Figure 12.23 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 60-day simulation.

Figure 12.24 displays the time series of the area of entrained hydrocarbons at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds over the 60-day simulation.

Figure 12.25 presents the fates and weathering for the corresponding single spill trajectory and Table 12.13 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 12.13 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 60), for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a vessel collision at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 60
Surface (m^3)	247	0	0
Entrained (m^3)	954	1	104
Dissolved (m^3)	3	2	0
Evaporation (m^3)	656	60	656
Decay (m^3)	727	60	727
Ashore (m^3)	0	0	0

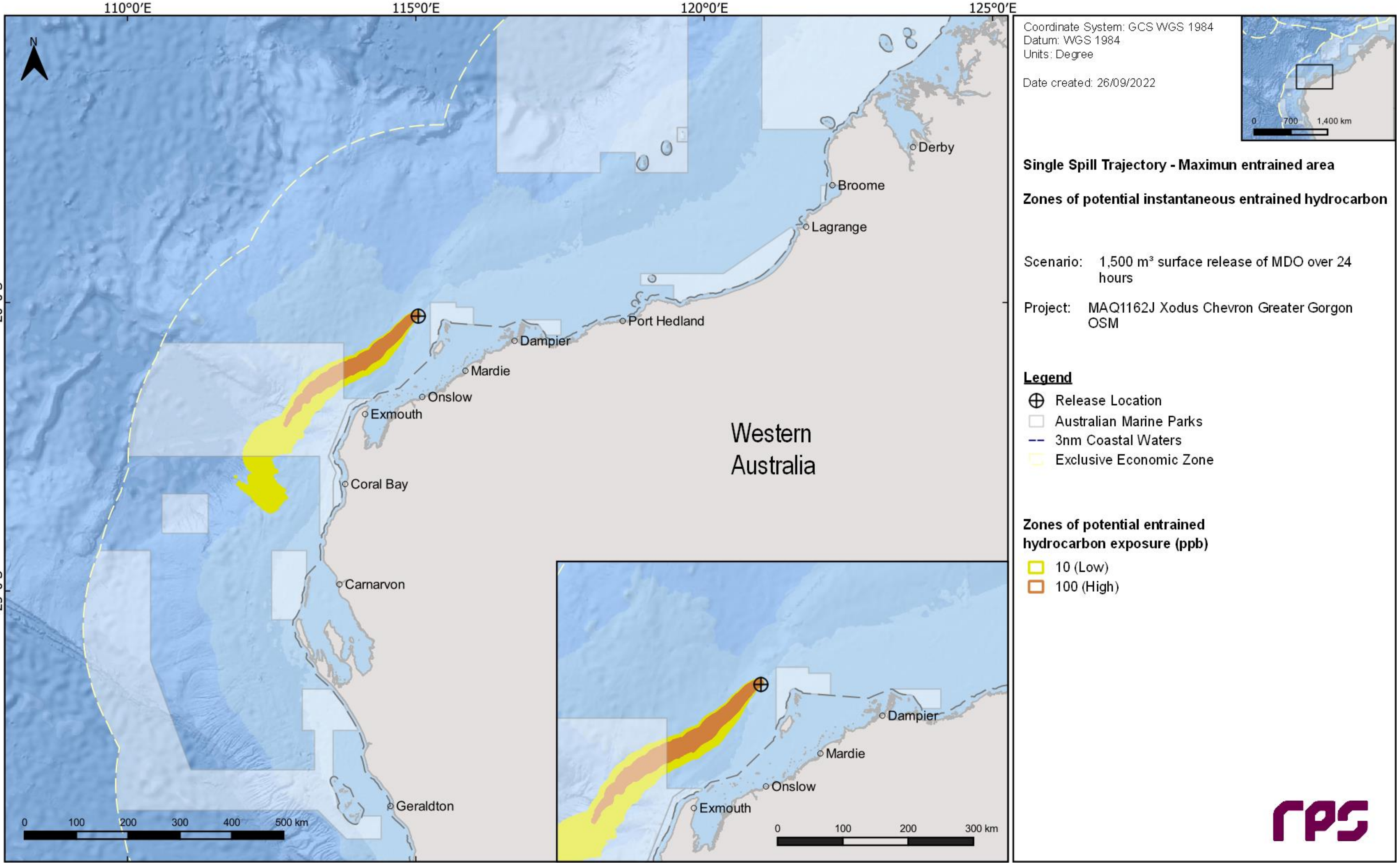


Figure 12.23 Zones of potential entrained hydrocarbon exposure over the entire 60 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a vessel collision at WTR Well 5.

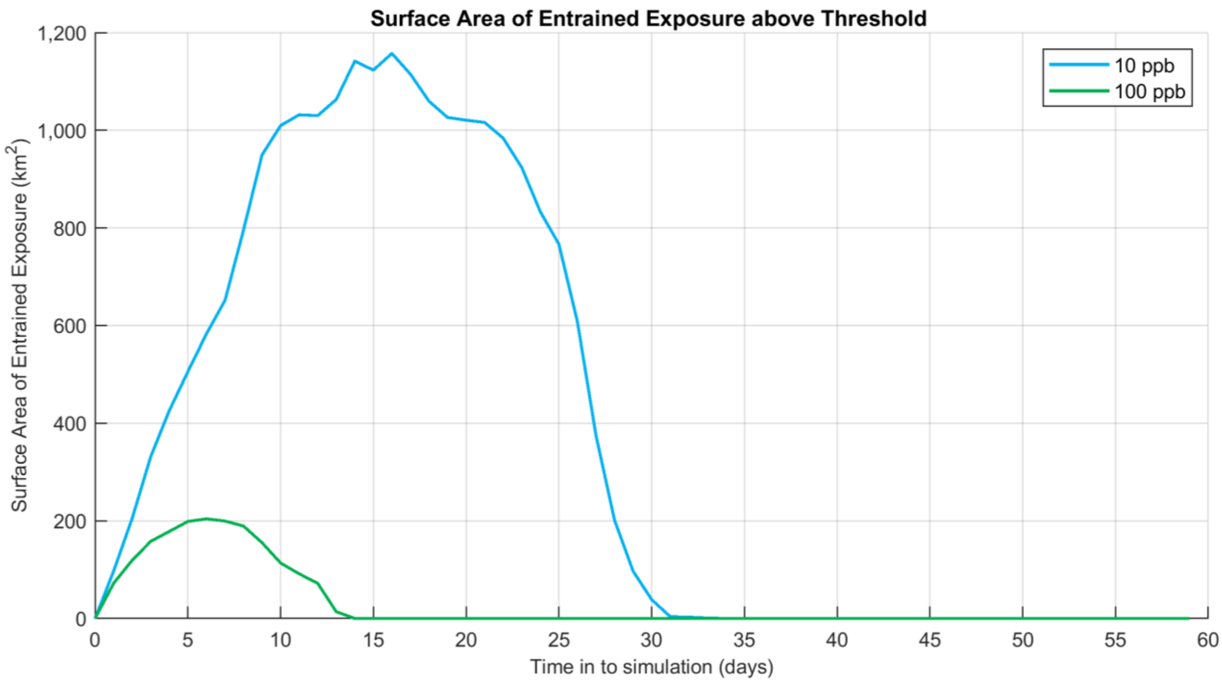


Figure 12.24 Time series of the area of entrained hydrocarbons for each threshold, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a vessel collision at WTR Well 5.

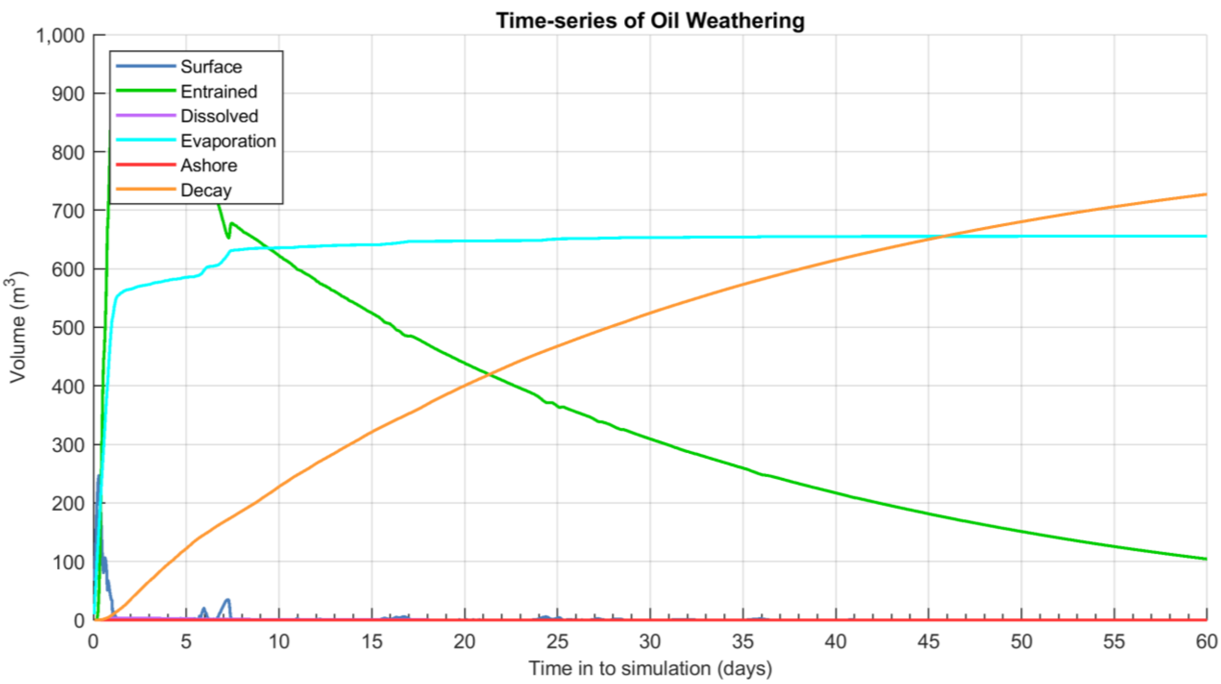


Figure 12.25 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a vessel collision at WTR Well 5.

12.2.5 Deterministic Case: Largest area of dissolved hydrocarbons above 50 ppb

The deterministic simulation that resulted in the largest area of dissolved hydrocarbons above 50 ppb (moderate threshold) was identified as run number 96 during the winter period.

Figure 12.26 presents the extent of the predicted dissolved hydrocarbon exposure zones over the entire 60-day simulation.

Figure 12.27 displays the time series of the area of dissolved hydrocarbons at the low (≥ 10 ppb), moderate (≥50 ppb) and high (≥ 100 ppb) thresholds over the 60-day simulation.

Figure 12.28 presents the fates and weathering for the corresponding single spill trajectory and Table 12.14 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 12.14 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 60), for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a vessel collision at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 60
Surface (m^3)	78	0	0
Entrained (m^3)	1,049	1	84
Dissolved (m^3)	8	1	0
Evaporation (m^3)	789	51	789
Decay (m^3)	617	60	617
Ashore (m^3)	0	0	0

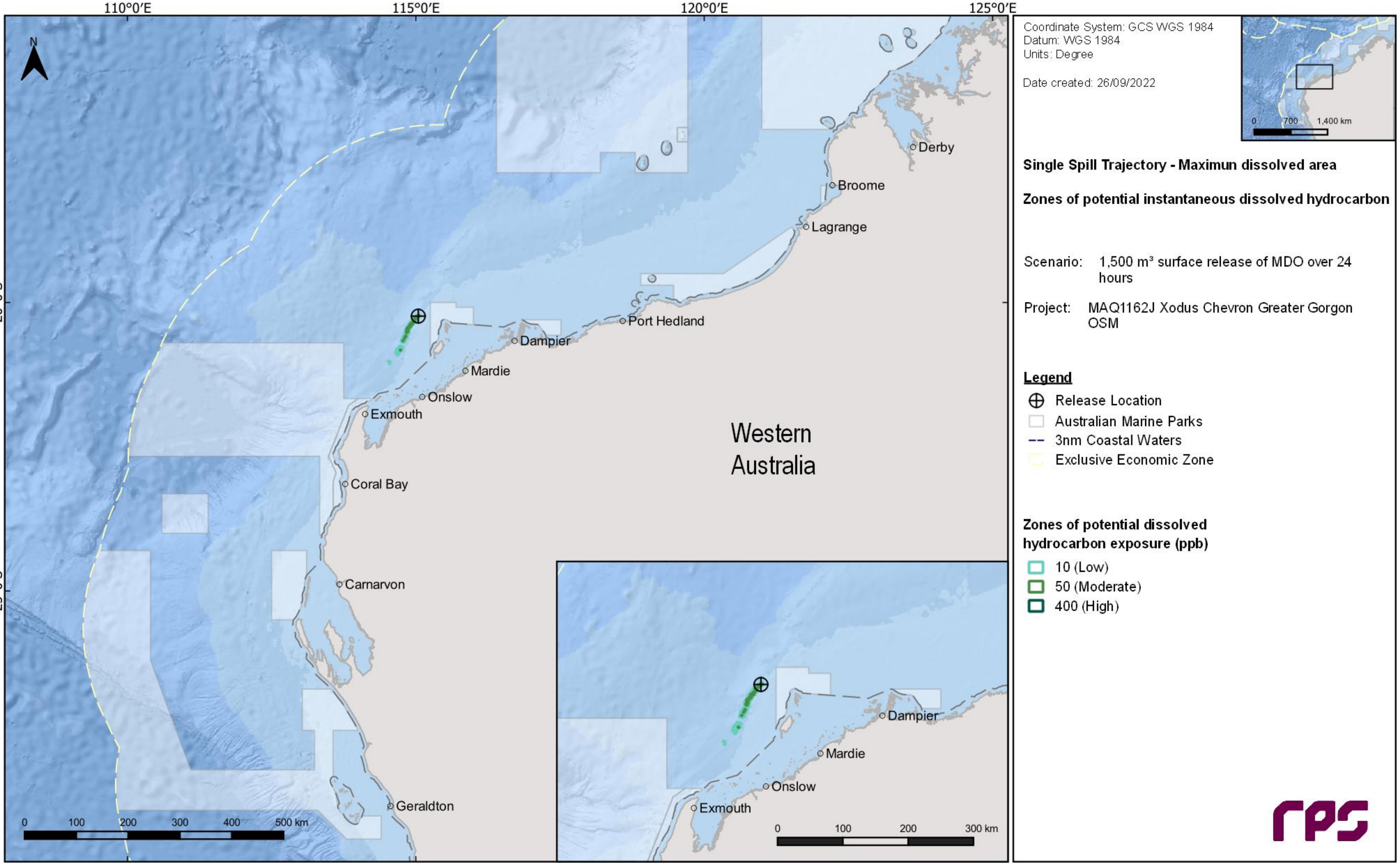


Figure 12.26 Zones of potential dissolved hydrocarbon exposure over the entire 60 days, for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a vessel collision at WTR Well 5.

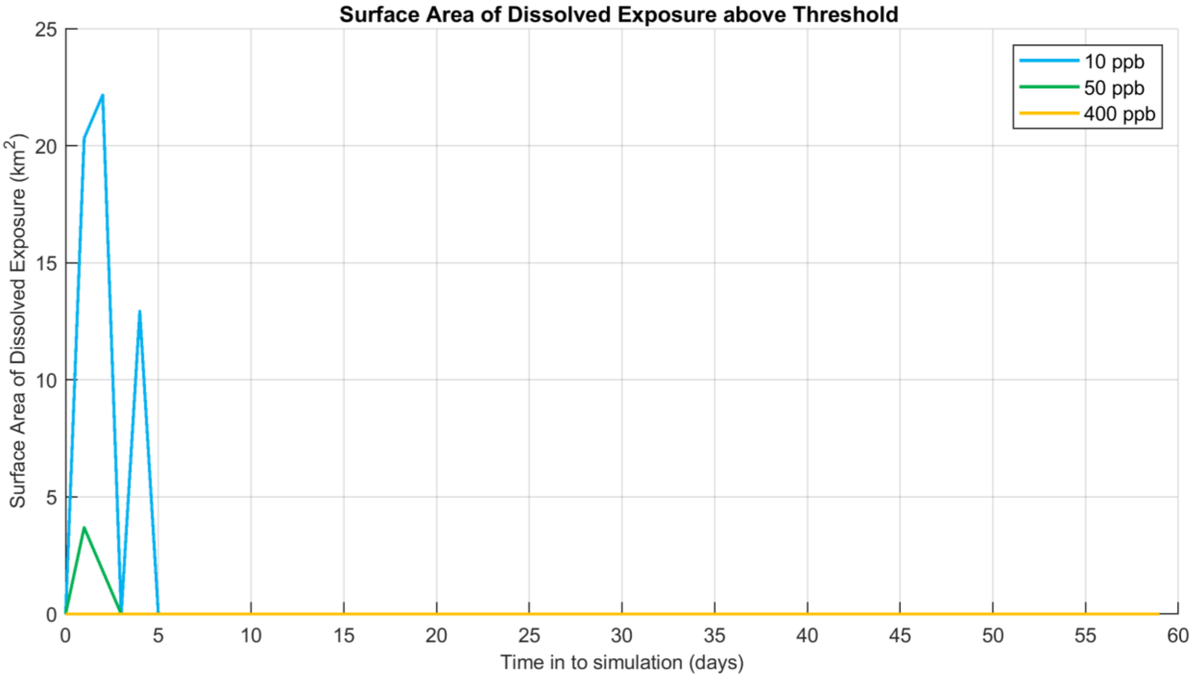


Figure 12.27 Time series of the area of dissolved hydrocarbons for each threshold, for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a vessel collision at WTR Well 5.

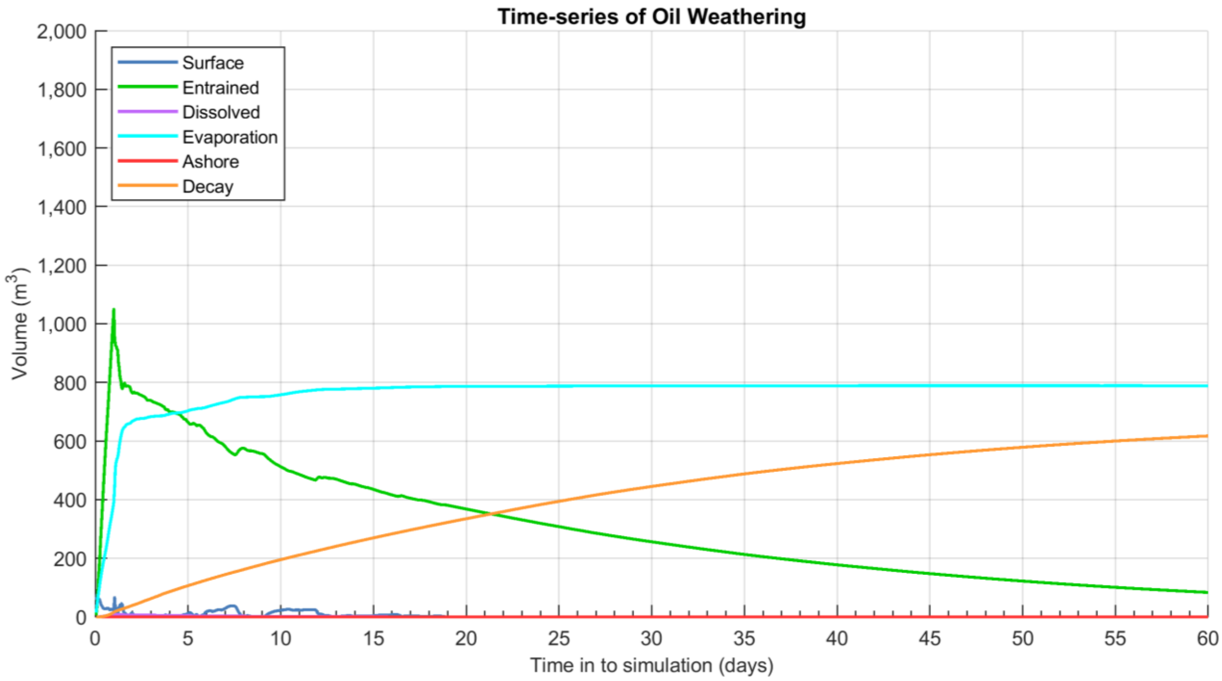


Figure 12.28 Predicted weathering and fates graph for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a vessel collision at WTR Well 5.

13 REFERENCES

American Society for Testing and Materials (ASTM) 2013, 'F2067-13 Standard Practice for Development and Use of Oil-Spill Trajectory Models', ASTM International, West Conshohocken (PA).

Andersen, OB 1995, 'Global ocean tides from ERS 1 and TOPEX/POSEIDON altimetry', *Journal of Geophysical Research: Oceans*, vol. 100, no. C12, pp. 25249–25259.

Anderson JW, Neff JM, Cox BA, Tatem HE & Hightower GM 1974, 'Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish', *Marine Biology*, vol. 27, no. 1, pp. 75–88.

Anderson JW, Riley R, Kiesser S & Gurtisen J 1987, 'Toxicity of dispersed and undispersed Prudhoe Bay crude oil fractions to shrimp and fish', Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 235–240.

Applied Science Associates (ASA) 2011, OILMAP-DEEP: Blowout Plume Model Technical Manual, Applied Science Associates Inc, South Kingstown, USA.

Asia-Pacific ASA 2010, 'Montara well release monitoring study S7.2. Oil fate and effects assessment: modelling of chemical dispersant operation', Prepared for PTTEP Australasia.

Australian Maritime Safety Authority (AMSA) 2014, 'Identification of oil on water: Aerial observations and identification guide', viewed 4 June 2020, https://www.amsa.gov.au/sites/default/files/2014-01-mp-amsa22-identification-oil-on-water.pdf

Australian Maritime Safety Authority (AMSA) 2015, 'Australian Maritime Safety Authority Technical Guideline for the Preparation of Marine Pollution Contingency Plans for Marine and Coastal Facilities Australian Maritime Safety Authority', viewed 20 June 2017, https://www.amsa.gov.au/forms-and-publications/Publications/AMSA413_Contingency_Planning_Guidelines.pdf

Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, 'Australian and New Zealand Guidelines for Fresh and Marine Water', Australian & New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Becker, JJ, Sandwell, DT, Smith, WHF, Braud, J, Binder, B, Depner, J, Fabre, D, Factor, J, Ingalls, S, Kim, S-H, Ladner, R, Marks, K, Nelson, S, Pharaoh, A, Trimmer, R, Von Rosenberg, J, Wallace, G & Weatherall, P 2009, 'Global bathymetry and evaluation data at 30 arc seconds resolution: SRTM30_PLUS', *Marine Geodesy*, vol. 32, no. 4, pp. 355–371.

Belore, UC 2014, Subsea chemical dispersant research. Proceedings of the 37th AMOP Technical Seminar on Environmental Contamination and Response, Environmental Canada, Canmore, Alberta, Canada pp 618–650.

Bonn Agreement 2009, 'Bonn Agreement aerial operations handbook, 2009 - Publication of the Bonn Agreement', London, viewed 13 January 2015, http://www.bonnagreement.org/site/assets/files/3947/ba-aoh_revision_2_april_2012.pdf.

Brandvik, PJ, Johansen, O, Leirvik, F, Farooq, U & Daling PS 2013, 'Droplet Breakup in subsurface oil releases – Part 1: Experimental study of droplet breakup and effectiveness of dispersant injection', *Marine Pollution Bulletin*, vol. 73, no. 1, pp 319–326.

Brandvik, PJ, Johansen, O, Farooq, U, Angell, G & Leirvik F 2014, 'Sub-surface oil releases – Experimental study of droplet distributions and different dispersant injection techniques- version 2', A scaled experimental approach using the SINTEF Tower basin. SINTEF report no: A25122. Trondheim Norway 2014. ISBN: 9788214057393

Carls, MG, Holland, L, Larsen, M, Collier, TK, Scholz, NL & Incardona, JP 2008, 'Fish embryos are damaged by dissolved PAHs, not oil particles', *Aquatic toxicology*, 88(2), pp.121–127.

Chassignet, EP, Hurlburt, HE, Smedstad, OM, Halliwell, GR, Hogan, PJ, Wallcraft, AJ, Baraille, R & Bleck, R 2007, 'The HYCOM (hybrid coordinate ocean model) data assimilative system', *Journal of Marine Systems*, vol. 65, no. 1, pp. 60–83.

Chassignet, E, Hurlburt, H, Metzger, E, Smedstad, O, Cummings, J & Halliwell, G 2009, 'U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)', *Oceanography*, vol. 22, no. 2, pp. 64–75.

Condie, SA., & Andrewartha, JR 2008, 'Circulation and connectivity on the Australian Northwest Shelf', *Continental Shelf Research*, 28, 1724–1739.

Davies, AM 1977a, 'The numerical solutions of the three-dimensional hydrodynamic equations using a B-spline representation of the vertical current profile', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 1–25.

Davies, AM 1977b, 'Three-dimensional model with depth-varying eddy viscosity', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 27–48.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2007, 'Characterisation of the marine environment in the north marine region', Marine Division, Department of the environment, water heritage and the arts.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2008, 'The North-West Marine Bioregional Plan - Bioregional Profile', Retrieved February 12, 2013, from Australian Government Department of Environment, Water, Heritage and the Arts: http://www.environment.gov.au/coasts/mbp/publications/north-west/pubs/bioregional-profile.pdf

French, D, Reed, M, Jayko, K., Feng, S, Rines, H & Pavignano, S 1996, 'The CERCLA Type A Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME), Technical Documentation, Vol. I - Model Description', Office of Environmental Policy and Compliance, U.S. Department of the Interior. Washington, D.C.: Contract No. 14-0001-91-C-11.

French, D, Schuttenberg, H & Isaji, T 1999, 'Probabilities of oil exceeding thresholds of concern: examples from an evaluation for Florida Power and Light', Proceedings of the 22nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Alberta, pp. 243–270.

French-McCay, DP 2002, 'Development and application of an oil toxicity and exposure model, OilToxEx', *Environmental Toxicology and Chemistry*, vol. 21, no. 10, pp. 2080–2094.

French-McCay, DP 2003, 'Development and application of damage assessment modelling: example assessment for the North Cape oil spill', *Marine Pollution Bulletin*, vol. 47, no. 9, pp. 9–12.

French-McCay, DP 2004, 'Spill impact modelling: development and validation', *Environmental Toxicology and Chemistry*, vol. 23, no.10, pp. 2441–2456.

French-McCay, DP 2009, 'State-of-the-art and research needs for oil spill impact assessment modelling', Proceedings of the 32nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 601–653.

French-McCay, D, Rowe, JJ, Whittier, N, Sankaranarayanan, S, & Etkin, DS 2004, 'Estimate of potential impacts and natural resource damages of oil', *Journal of Hazardous Materials*, vol. 107, no. 1, pp. 11–25.

French-McCay, D, Whittier, N, Dalton, C, Rowe, J, Sankaranarayanan, S & Aurand, D 2005a, 'Modeling the fates of hypothetical oil spills in Delaware, Florida, Texas, California, and Alaska waters, varying

response options including use of dispersants', Proceedings of the International Oil Spill Conference 2005, American Petroleum Institute, Washington DC, paper 399.

French-McCay, D, Whittier, N, Rowe, J, Sankaranarayanan, S, Kim, H-S & Aurand, D 2005b, 'Use of probabilistic trajectory and impact modeling to assess consequences of oil spills with various response strategies,' Proceedings of the 28th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 253–271.

French-McCay, D, Reich, D, Rowe, J, Schroeder, M & Graham, E 2011, 'Oil spill modeling input to the offshore environmental cost model (OECM) for US-BOEMRE's spill risk and costs evaluations', Proceedings of the 34th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Reich, D, Michel, J, Etkin, DS, Symons, L, Helton, D, & Wagner J 2012, 'Oil spill consequence analysis of potentially-polluting shipwrecks', Proceedings of the 35th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Jayko, K, Li, Z, Horn, M, Kim, Y, Isaji, T, Crowley, D, Spaulding, M, Decker, L, Turner, C, Zamorski, S, Fontenault, J, Schmmkler, R & Rowe, J 2015, 'Technical Reports for Deepwater Horizon Water Column Injury Assessment: WC_TR.14: Modeling Oil Fate and Exposure Concentrations in the Deepwater Plume and Rising Oil Resulting from the Deepwater Horizon Oil Spill', RPS ASA, South Kingston, Rhode Island.

Gordon, R 1982, 'Wind driven circulation in Narragansett Bay' PhD thesis, Department of Ocean Engineering, University of Rhode Island.

Grant, DL, Clarke, PJ & Allaway, WG 1993, 'The response of grey mangrove (*Avicennia marina* (Forsk.) Vierh) seedlings to spills of crude oil,' *The Journal of Experimental Marine Biological Ecology*, vol. 171, no. 2, pp. 273–295.

Isaji, T & Spaulding, M 1984, 'A model of the tidally induced residual circulation in the Gulf of Maine and Georges Bank', *Journal of Physical Oceanography*, vol. 14, no. 6, pp. 1119–1126.

Isaji, T, Howlett, E, Dalton C, & Anderson, E 2001, 'Stepwise-continuous-variable-rectangular grid hydrodynamics model', Proceedings of the 24th Arctic and Marine Oil spill Program (AMOP) Technical Seminar (including 18th TSOCS and 3rd PHYTO), Environment Canada, Edmonton, pp. 597–610.

Koops, W, Jak, RG & van der Veen, DPC 2004, 'Use of dispersants in oil spill response to minimise environmental damage to birds and aquatic organisms', Proceedings of the Interspill 2004: Conference and Exhibition on Oil Spill Technology, Trondheim, presentation 429.

Kostianoy, AG, Ginzburg, AI, Lebedev, SA, Frankignoulle, M & Delille, B 2003, 'Fronts and mesoscale variability in the southern Indian Ocean as inferred from the TOPEX/POSEIDON and ERS-2 Altimetry data', *Oceanology*, vol. 43, no. 5, pp. 632–642.

Li, Z, Spaulding, M, French-McCay, D, Crowley, D & Payne JR 2017, 'Development of a unified oil droplet size distribution model with application to surface breaking waves and subsea blowout releases considering dispersant effects', *Marine Pollution Bulletin*, vol. 114, no. 1, pp 247–257.

Lin, Q & Mendelssohn, IA 1996, 'A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish and Salt Marshes', *Marine Pollution Bulletin*, vol. 32, no. 2, pp. 202–209.

Ludicone, D, Santoleri, R, Marullo, S & Gerosa, P 1998, 'Sea level variability and surface eddy statistics in the Mediterranean Sea from TOPEX/POSEIDON data', *Journal of Geophysical Research I*, vol. 103, no. C2, pp. 2995–3011.

Mackay D, Puig H & McCarty LS 1992, 'An equation describing the time course and variability in uptake and toxicity of narcotic chemicals to fish', *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, p.941–951.

Malins DC & Hodgins HO 1981, 'Petroleum and marine fishes: a review of uptake, disposition, and effects', *Environmental Science & Technology*, vol. 15, no. 11, pp.1272–1280.

Matsumoto, K, Takanezawa, T & Ooe, M 2000, 'Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan', *Journal of Oceanography*, vol. 56, no.5, pp. 567–581.

McAuliffe CD 1987, 'Organism exposure to volatile/soluble hydrocarbons from crude oil spills – a field and laboratory comparison', Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 275–288.

McCarty LS 1986, 'The relationship between aquatic toxicity QSARs and bioconcentration for some organic chemicals', *Environmental Toxicology and Chemistry*, vol. 5, no. 12, pp. 1071–1080.

McCarty LS & Mackay D 1993, 'Enhancing ecotoxicological modelling and assessment. Body residues and modes of toxic action', *Environmental Science & Technology*, vol. 27, no. 9, pp. 1718–1728.

McCarty LS, Dixon DG, MacKay D, Smith AD & Ozburn GW 1992a, 'Residue-based interpretation of toxicity and bioconcentration QSARs from aquatic bioassays: Neutral narcotic organics', *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, pp.917–930.

McCarty LP, Flannagan DC, Randall SA & Johnson KA 1992b, 'Acute toxicity in rats of chlorinated hydrocarbons given via the intratracheal route', *Human & Experimental Toxicology*, vol. 11, no. 3, pp.173–117.

McGrath JA, & Di Toro DM 2009, 'Validation of the target lipid model for toxicity assessment of residual petroleum constituents: monocyclic and polycyclic aromatic hydrocarbons', *Environmental Toxicology and Chemistry*, vol. 28, no. 6, pp. 1130–1148.

National Oceanic and Atmospheric Administration (NOAA) 2013, 'Screening level risk assessment package Gulf state', Office of National Marine Sanctuaries & Office of Response and Restoration, Washington DC.x

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2018, 'At a glance: Oil spill modelling', viewed 15 November 2018, https://www.nopsema.gov.au/assets/Publications/A626200.pdf

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2019, 'NOPSEMA Bulletin #1: Oil spill modelling', viewed April 2019, https://www.nopsema.gov.au/assets/Bulletins/A652993.pdf

National Research Council (NRC) 2003, 'Oil in the sea III: Inputs, fates and effects', The National Academic Press, Washington D.C.

Neff JM, Anderson JW 1981, 'Response of marine animals to petroleum and specific petroleum hydrocarbons' United States Department of Energy, United States.

Nirmalakhandan N & Speece RE 1998, 'Quantitative techniques for predicting the behaviour of chemicals in the ecosystem', *Environmental Science & Technology*, vol. 22, no. 6, pp. 606–615.

Nordtug, T, Olsen, AJ, Altin, D, Overrein, I, Storøy, W, Hansen, BH & De Laender, F 2011, 'Oil droplets do not affect assimilation and survival probability of first feeding larvae of North-East Arctic cod', *Science of the Total Environment*, 412, pp.148–153.

Oil Spill Solutions 2015, 'Evaluation - The Theory of Oil Slick Appearances', viewed 6 January 2015, http://www.oilspillsolutions.org/evaluation.htm

Owen, A 1980, 'A three-dimensional model of the Bristol Channel', *Journal of Physical Oceanography*, vol. 10, no. 8, pp. 1290–1302.

Qiu, B & Chen, S 2010, ‘Eddy-mean flow interaction in the decadally modulating Kuroshio Extension system’, *Deep-Sea Research II*, vol. 57, no. 13, pp. 1098–1110.

Redman AD 2015, ‘Role of entrained droplet oil on the bioavailability of petroleum substances in aqueous exposures’, *Marine Pollution Bulletin*, vol. 97, no. (1–2), pp. 342–348.

Saha, S, Moorthi, S, Pan, H-L, Wu, X, Wang, J & Nadiga, S 2010, ‘The NCEP Climate Forecast System Reanalysis’, *Bulletin of the American Meteorological Society*, vol. 91, no. 8, pp. 1015–1057.

Scholten, MCTh, Kaag, NHBM, Dokkum, HP van, Jak, R.G., Schobben, HPM & Slob, W 1996, Toxische effecten van olie in het aquatische milieu, TNO report TNO-MEP – R96/230, Den Helder.

Spaulding, ML., Kolluru, VS, Anderson, E & Howlett, E 1994, ‘Application of three-dimensional oil spill model (WOSM/OILMAP) to hindcast the Braer Spill’, *Spill Science and Technology Bulletin*, vol. 1, no. 1, pp. 23–35.

Spaulding, MS, Mendelsohn, D, Crowley, D, Li, Z, and Bird A, 2015. Technical Reports for Deepwater Horizon Water Column Injury Assessment- WC_TR.13: Application of OILMAP DEEP to the Deepwater Horizon Blowout. RPS APASA, 55 Village Square Drive, South Kingstown, RE 02879.

Suprayogi, B & Murray, F 1999, ‘A field experiment of the physical and chemical effects of two oils on mangroves’, *Environmental and Experimental Botany*, vol. 42, no. 3, pp. 221–229.

Swartz RC, Schults DW, Ozretich RJ, Lamberson JO, Cole FA, Ferraro SP, Dewitt TH & Redmond MS 1995, ‘ΣPAH: A Model to predict the toxicity of polynuclear aromatic hydrocarbon mixtures in field-collected sediments’, *Environmental Toxicology and Chemistry*, vol. 14, no. 11, pp. 1977–1187.

Verhaar HJM, Van Leeuwen CJ & Hermens JLM 1992, ‘Classifying environmental pollutants’, *Chemosphere*, vol. 24, no. 4, pp. 471–491.

Verhaar HJM, de Jongh J & Hermens JLM 1999, ‘Modelling the bioconcentration of organic compounds by fish: A novel approach’, *Environmental Science & Technology*, vol. 33, no. 22, pp. 4069–4072.

Yaremchuk, M & Tangdong, Q 2004, ‘Seasonal variability of the large-scale currents near the coast of the Philippines’, *Journal of Physical Oceanography*, vol. 34, no., 4, pp. 844–855.

Zigic, S, Zapata, M, Isaji, T, King, B, & Lemckert, C 2003, ‘Modelling of Moreton Bay using an ocean/coastal circulation model’, Proceedings of the 16th Australasian Coastal and Ocean Engineering Conference, the 9th Australasian Port and Harbour Conference and the Annual New Zealand Coastal Society Conference, Institution of Engineers Australia, Auckland, paper 170.

GREATER GORGON – WEST TRYAL ROCKS

Oil Spill Modelling

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Prepared by:

RPS

Jeremie Bernard
Senior Coastal Engineer

Lakeside Corporate Space, Suite 425
Level 2, 34-38 Glenferrie Drive
Robina, QLD, 4226, Australia

T +61 7 5553 6900
E Jeremie.Bernard@rpsgroup.com

Prepared for:

CHEVRON AUSTRALIA PTY LTD

Mike Daly
HSE Specialist - Environment

Level 13, 250 St Georges Tce
Perth WA 6000 Australia

T +61 418 488 728
E mike.daly@chevron.com

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TERMS AND ABBREVIATIONS

°	Degrees
'	Minutes
"	Seconds
µm	Micrometre (unit of length; 1 µm = 0.001 mm)
Actionable oil	Oil which is thick enough for the effective use of mitigation strategies
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute gravity. A measure of how heavy or light a petroleum liquid is compared to water.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m3)
bbl/d	Barrels per day
Bonn Agreement	An agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983, includes: Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
cP	Centipoise (unit of dynamic viscosity)
Decay	The process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions.
Dynamic viscosity	The dynamic viscosity of a fluid expresses its resistance to shearing flows, where adjacent layers move parallel to each other with different speeds.
Floating oil exposure	Contact by floating oil on the sea surface at concentrations equal to or exceeding defined threshold concentrations. The consequence will vary depending on the threshold and the receptors
g/m^2	Grams per square meter (unit of surface area density)
GODAE	Global Ocean Data Assimilation Experiment
HYCOM	Hybrid Coordinate Ocean Model. A data-assimilative, three-dimensional ocean model
HYDROMAP	Advanced ocean/coastal tidal model used to predict tidal water levels, current speed and current direction.
IAA	Impact Assessment Area
IBRA	Interim Biogeographic Regionalisation for Australia

IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
Shoreline contact	Arrival of oil at or near shorelines at on-water concentrations equal to or exceeding defined threshold concentrations. Shoreline contact is judged for floating oil arriving within a 2 km buffer zone from any shoreline as a conservative measure
SIMAP	Spill Impact Model Application Package. SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for surface or subsea releases
Single Oil spill modelling	Oil spill modelling involving a computer simulation of a single hypothetical oil spill event subject to a single sequence of wind, current and other sea conditions over time. Single oil spill modelling, also referred to as “deterministic modelling” provides a simulation of one possible outcome of a given spill scenario, subject to the metocean conditions that are imposed. Single oil spill modelling is commonly used to consider the fate and effects of ‘worst-case’ oil spill scenarios that are carefully selected in consideration of the nature and scale of the offshore petroleum activity and the local environment (NOPSEMA, 2017). Because the outcomes of a single oil spill simulation can only represent the outcome of that scenario under one sequence of metocean conditions, worst-case conditions are often identified from stochastic modelling. It is impossible to calculate the likelihood of any outcome from a single oil spill simulation. Single oil spill modelling is generally used for response planning, preparedness planning and for supporting oil spill response operations in the event of an actual spill

SRTM	Shuttle Radar Topography Mission
Stochastic oil spill modelling	Stochastic oil spill modelling is created by overlaying and statistically analysing the outcomes of many single oil-spill simulations of a defined spill scenario, where each simulation was subject to a different sequence of metocean conditions, selected objectively (typically by random selection) from a long sequence of historic conditions for the study area. Analysis of this larger set of simulations provides a more accurate indication of the environment that maybe affected (EMBA) and indicates which locations are more likely to be affected (as well as other statistics). Stochastic oil spill modelling avoids biases that affect single oil spill modelling (due to the reliance on only one possible sequence of conditions). However, when interpreting stochastic modelling, which is based on a wide range of potential conditions that might happen to occur, it is essential to understand that calculations will encompass a much larger area than could be affected in any single spill event, where a more limited set of conditions will occur. Consequently, it is misleading to imply that the region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) Stochastic modelling is generally used for risk assessment and preparedness planning by indicating locations that could be exposed and may require response or subsequent impact assessment
TOPEX/Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed, quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the West Tryal Rocks (WTR) field situated within the Northern Carnarvon Basin in Permit area WA-5-R northwest of Barrow Island off the north-west coast of Western Australia. RPS was commissioned to undertake an oil spill modelling to support environmental approvals.

The oil spill modelling study was conducted to assess the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following two hypothetical scenario:

- **Scenario 1:** A 4,302 stb/day (684.0 m^3/day) subsea release of condensate over 90 days (totalling 387,180 stb or 61,555 m^3) resulting from a loss of well control (LOWC);

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the ‘outer boundaries’ of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

Methodology

The modelling study was carried out in stages. Firstly, a ten-year current dataset (2010–2019) that includes the combined influence of large-scale ocean and nearshore tidal currents was developed. Secondly, the currents, local winds and detailed hydrocarbon characteristics were used as inputs in the three-dimensional oil spill model (SIMAP) to simulate the drift, spread, weathering and fate of the spilled oil.

As spills can occur during any set of wind and current conditions, modelling was conducted using a stochastic (or probabilistic) approach, which involved running per scenario 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Hydrocarbon Properties

Condensate Properties

West Tryal Rocks condensate has an API of 41.2, a density of 817 kg/m^3 (at 15ºC) and a low viscosity value of 5.9 cP. When exposed to the atmosphere at local temperatures, about 31.1% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 29.9% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~19.4%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 19.6% of the condensate is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation. The process of evaporation will be greater than under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity for the mixture to take up water to form water-in-oil emulsion over the weathering cycle. The soluble aromatic hydrocarbons contribute approximately 3.2% by mass of the whole oil, which is contained in the volatile fractions, which are highly soluble.

Key Findings

Loss of Well Control

- The maximum distance from the release location to the low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) threshold was 251.7 West-southwest (summer), 45.9 km North-northwest (transitional) and 5.2 km West-northwest (transitional) and West-southwest (winter), respectively.

- Other than the receptors that the release location resides within (Section 10.3), the Montebello AMP, Flatback Turtle - Nesting and Humpback Whale - Migration BIAs, Barrow & Montebello Islands IAA and the Continental Slope Demersal Fish Communities KEF were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. Accordingly, the probabilities for the low and moderate thresholds was 100% for all seasons for the receptors that the release location resides within. The probabilities of low and moderate exposure at the Flatback Turtle - Nesting ranged between 91–95% and 17–25%, whilst the probabilities of low and moderate exposure at Humpback Whale - Migration ranged between 97–100% and 6–32%, respectively. The minimum times before low exposure for the Flatback Turtle - Nesting BIA and Humpback Whale - Migration BIA were 1.08 days and 0.71 days during summer conditions, respectively.

- The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 59%, while the minimum time before shoreline accumulation was 6.5 days and the maximum volume of oil ashore was 128 m^3. No high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

- During summer conditions, 82 shoreline receptors were predicted to record condensate accumulation at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA (38%). In comparison, during transitional and winter conditions, 40 and 42 shoreline receptors, respectively, were predicted to record accumulation, with the greatest probability during transitional season occurring at the Ningaloo Coast World Heritage Area IAA and the Muiron Islands (30%) and at the Ningaloo Coast World Heritage Area IAA only during winter (30%).

- In the surface (0-10 m) depth layer, a total of 14, 20, and 10 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter, respectively. Excluding the 4 BIAs that the release location resides within (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging), the highest probabilities of exposure to low dissolved hydrocarbons were predicted as 7% for Humpback Whale - Migration during summer, 12% Humpback Whale - Migration during transitional, and 4% for Flatback Turtle – Nesting and Humpback Whale - Migration during winter conditions.

- In the surface (0-10 m) depth layer, a total of 44, 39 and 40 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter respectively. Excluding the 4 BIAs that the release location resides within, the highest probabilities of exposure to low entrained hydrocarbons were predicted for the Flatback Turtle - Nesting (98% during summer and 100% during transitional and winter) and Humpback Whale - Migration BIAs (100% during all seasons).

- During summer, 9 AMPs were predicted to be exposed at the low threshold, compared to 7 AMPs during transitional and winter periods. The highest probabilities predicted were at the Gascoyne AMP (96% summer, 100% transitional and 98% winter). Furthermore, during seasonal conditions the Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the West Tryal Rocks (WTR) field situated within the Northern Carnarvon Basin in Permit area WA-5-R northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the WTR field, Chevron commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the two following hypothetical scenarios:

- **Scenario 1:** A 4,302 stb/day (684.0 m^3/day) subsea release of condensate over 90 days (totalling 387,180 stb or 61,555 m^3) resulting from a loss of well control (LOWC);

The release location is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the ‘outer boundaries’ of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis Program (SIMAP). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, RPS warrants that this work meets and exceeds the American Society for Testing and Materials (ASTM) Standard F2067-13 “*Standard Practice for Development and Use of Oil Spill Models*”.

Table 1.1 Coordinates of the West Tryal Rocks release location.

Location	Latitude	Longitude	Depth (mLAT)
WTR Well 5	20.23666° S	115.04357° E	150

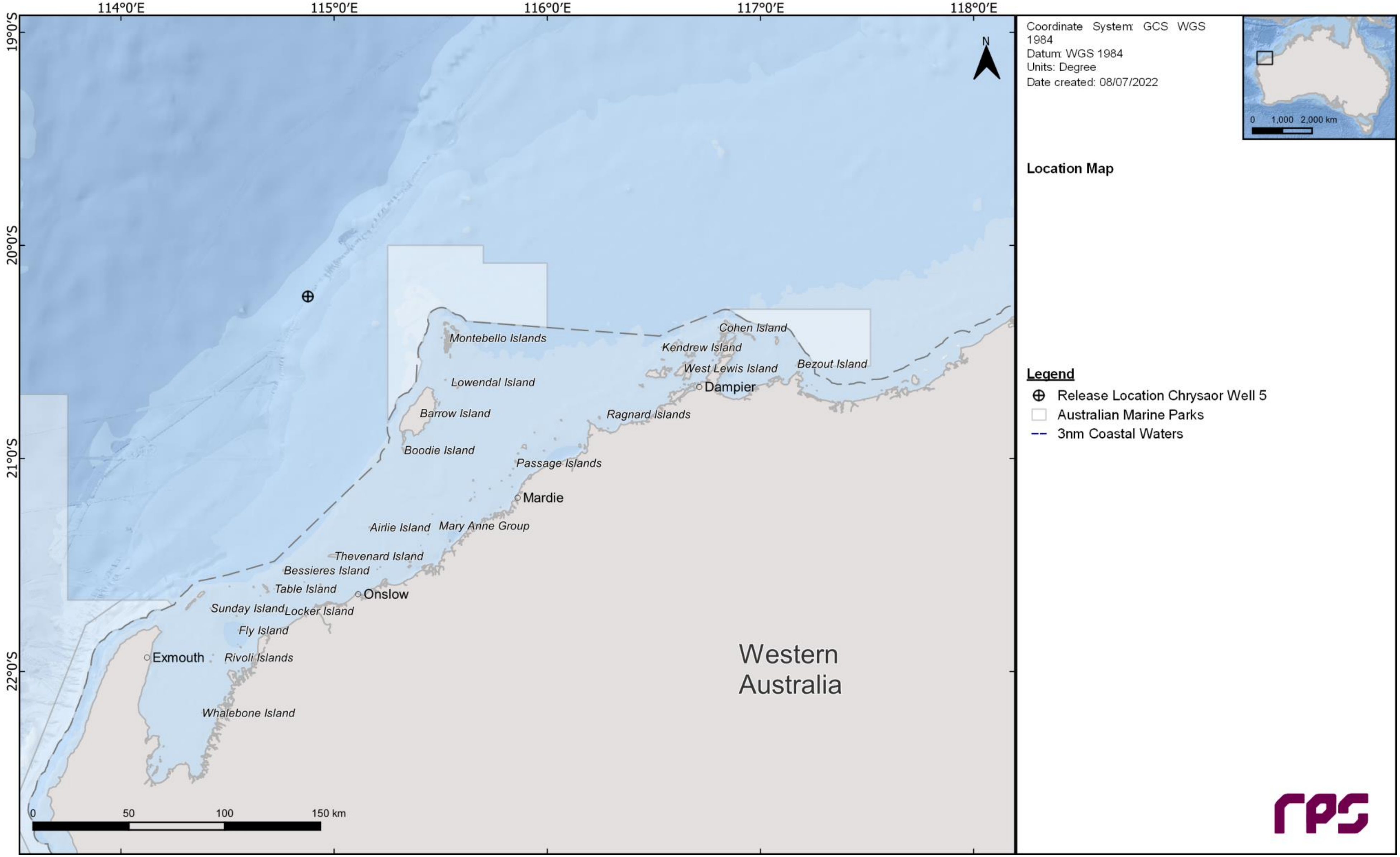


Figure 1.1 West Tryal Rocks hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate ten years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. For each scenario run 100 simulations per season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds for each scenario; and

5. From the 300 simulations modelled per scenario, identify and present the “worst case” deterministic runs, which can be used to inform response planning based on the following criteria:

    a. Largest swept area of floating hydrocarbon above 10 g/m^2

    b. Largest swept area of floating hydrocarbon above 50 g/m^2

    c. Largest volume of oil ashore

    d. Longest length of shoreline with accumulation above 100 g/m^2

    e. Largest area of entrained hydrocarbons above 100 ppb

    f. Largest area of dissolved hydrocarbons above 50 ppb

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

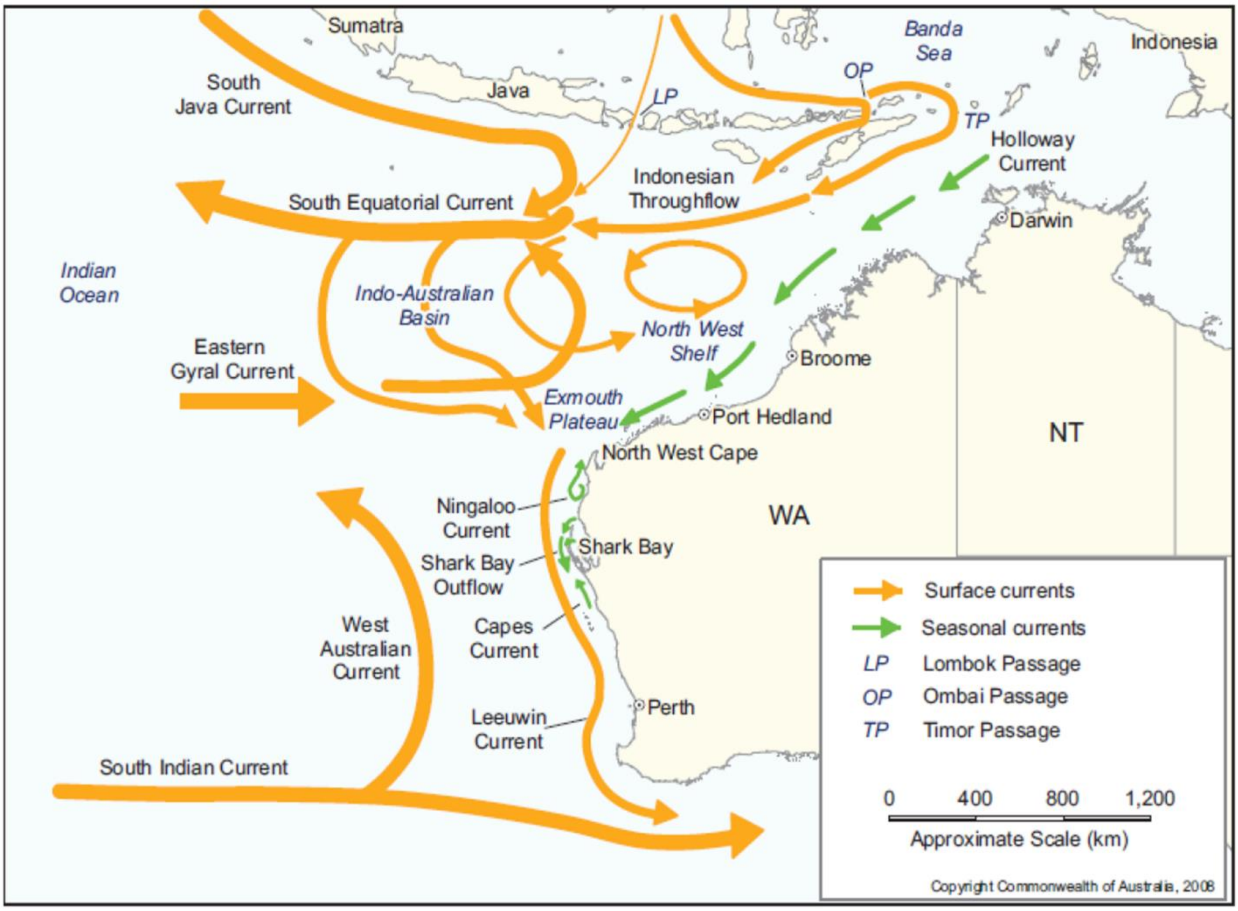


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

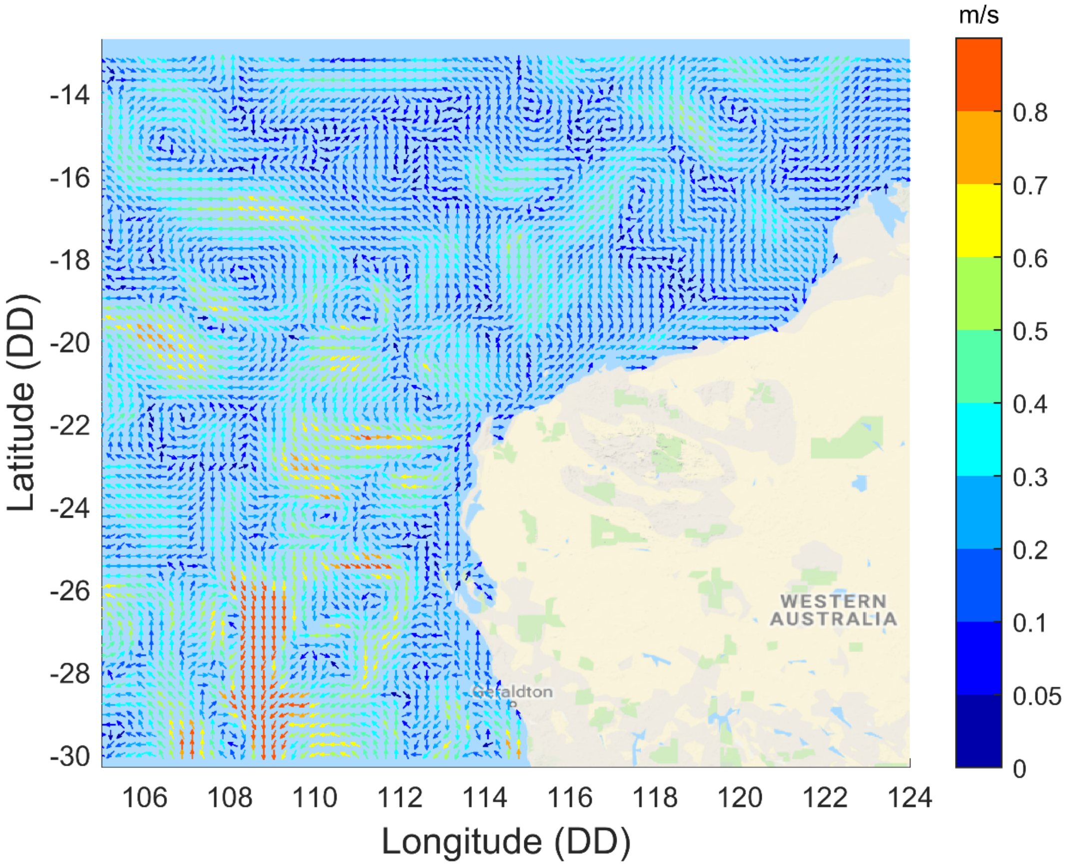


Figure 3.2 Typical ocean current circulation pattern during the summer months.

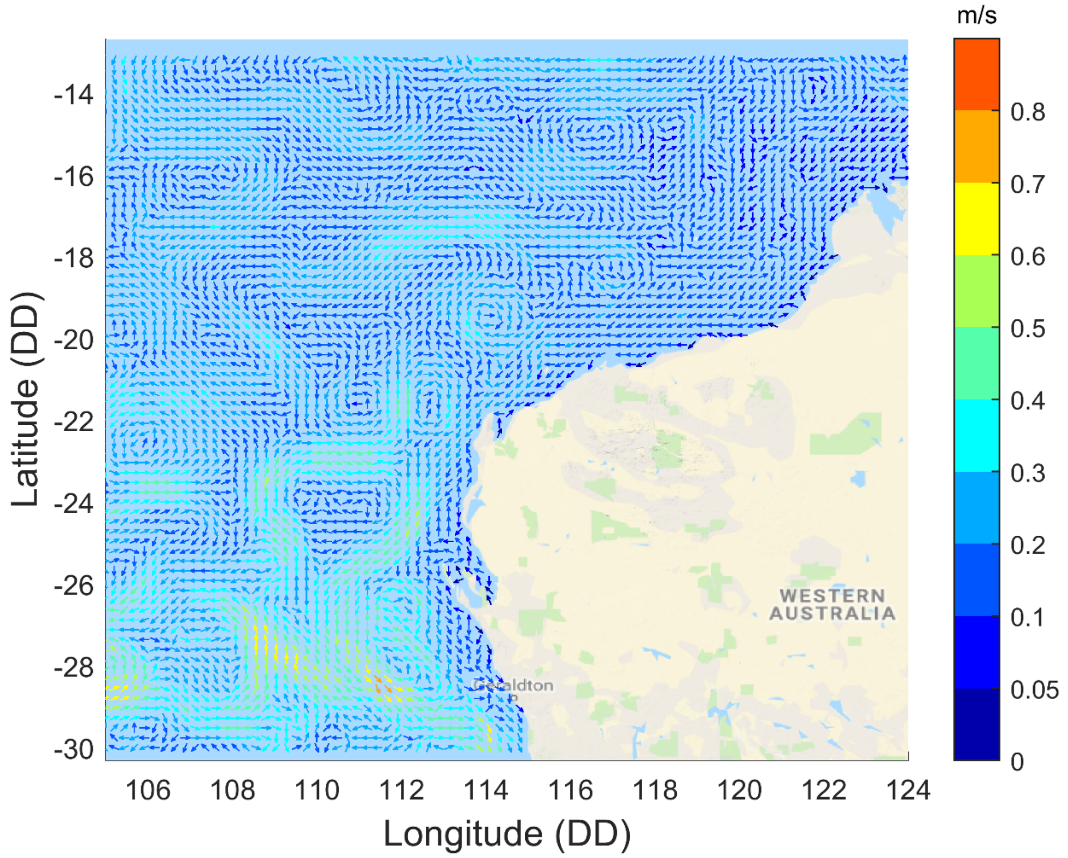


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grids were allocated in a step-wise fashion to resolve flows more accurately along the coastline, around islands and over regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

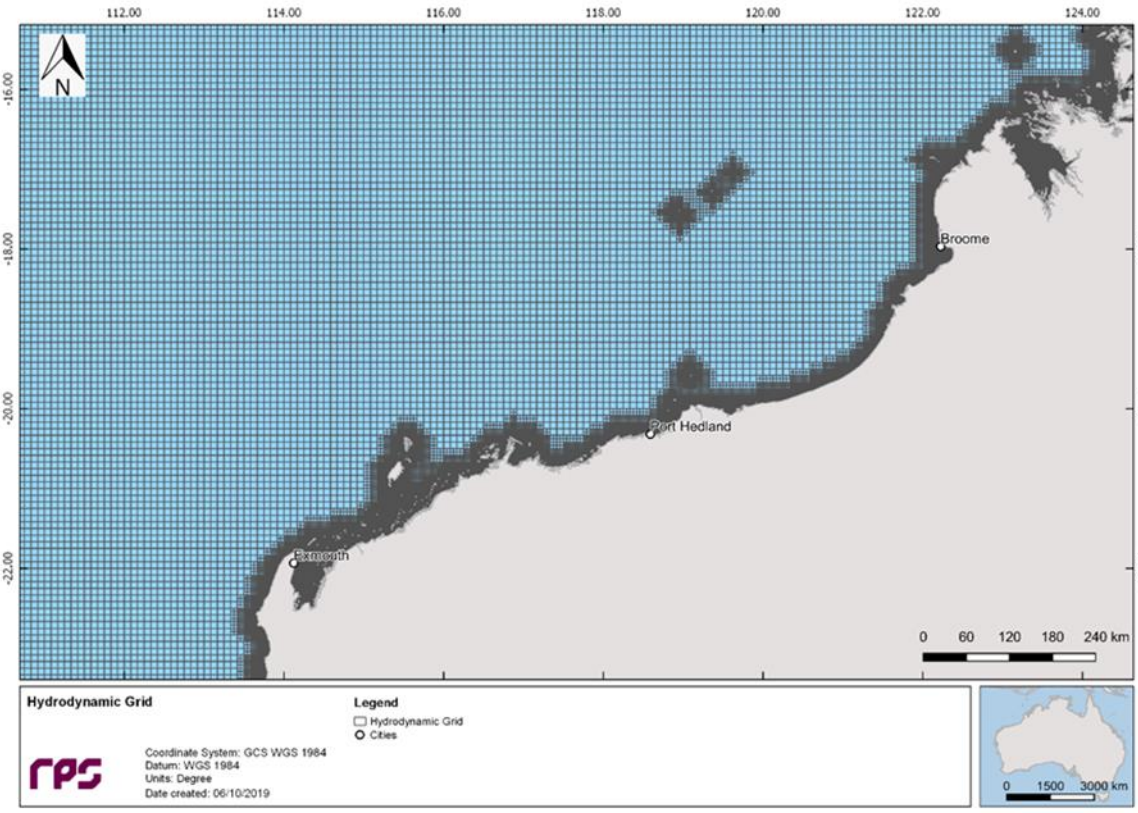


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

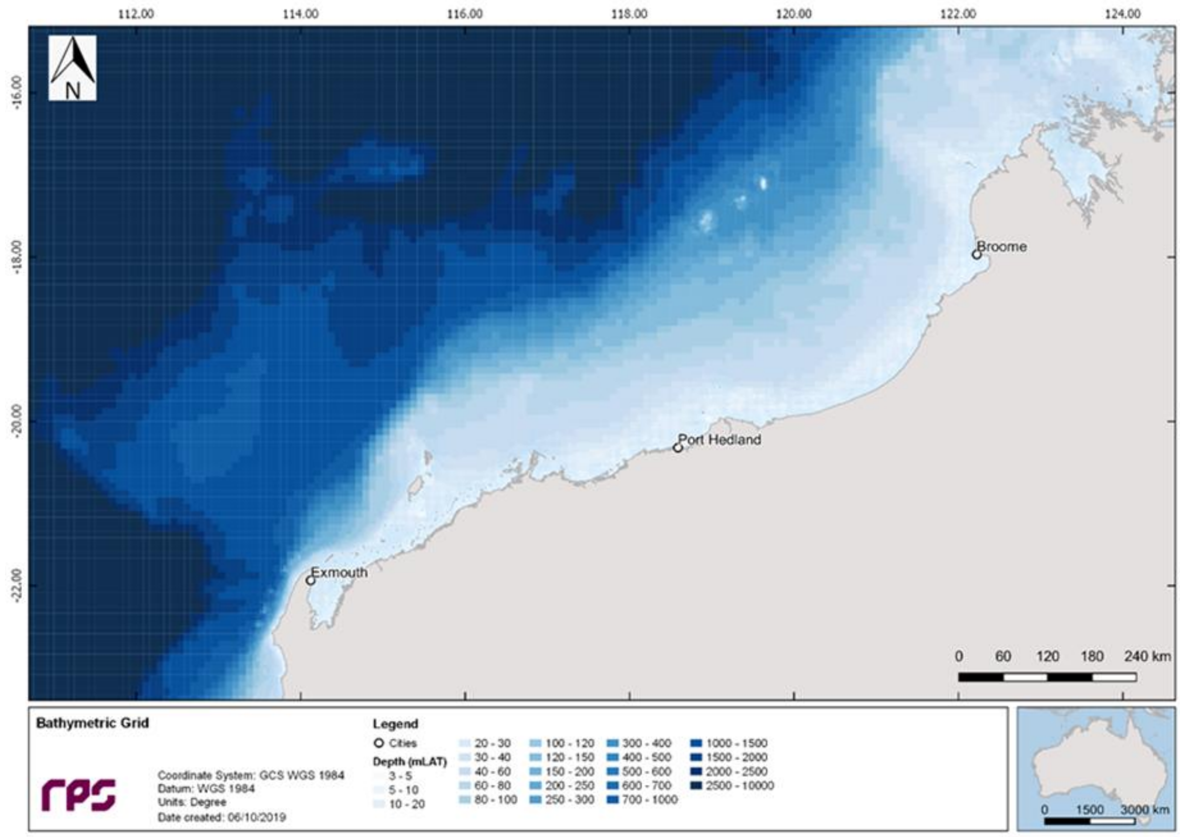


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.16 m/s (November) and 0.26 m/s (May). Additionally, the maximums ranged between 0.54 m/s (November) and 2.18 m/s (March). The general current directions were towards the southwest. Figure 3.6 and Figure 3.7 present the monthly and total current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.23	1.93	Northeast and Southwest
	February	0.21	1.07	Northeast and Southwest
	March	0.22	2.18	Southwest
Transitional	April	0.24	1.20	Southwest
Winter	May	0.26	0.95	Southwest
	June	0.26	0.90	Southwest
	July	0.21	1.08	Southwest
Transitional	August	0.19	0.78	Southwest
Summer	September	0.19	1.03	Northeast and Southwest
	October	0.18	0.63	Northeast and Southwest
	November	0.16	0.54	Variable
	December	0.20	0.80	Southwest
Minimum		**0.16**	**0.54**	
Maximum		**0.26**	**2.18**	

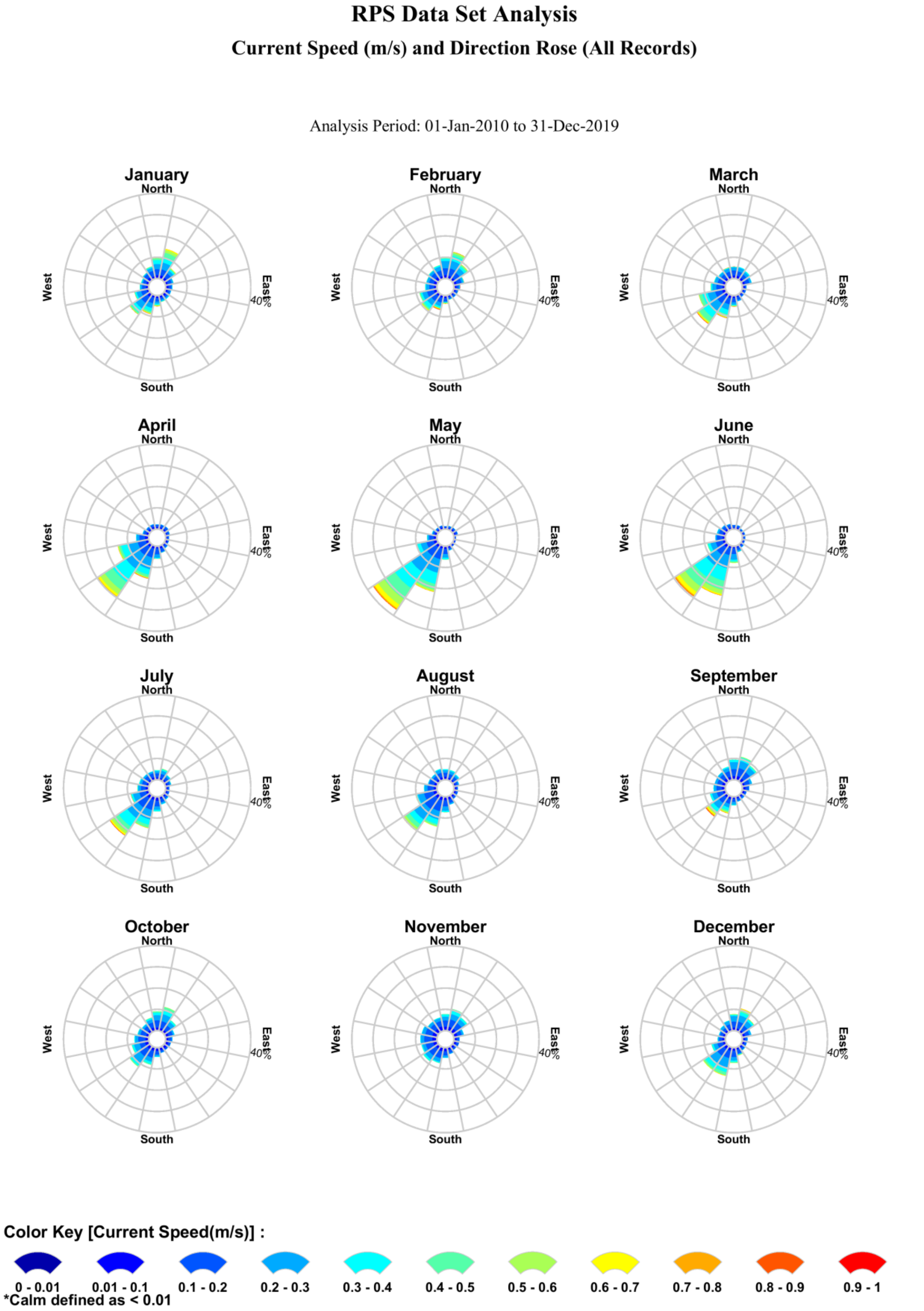


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

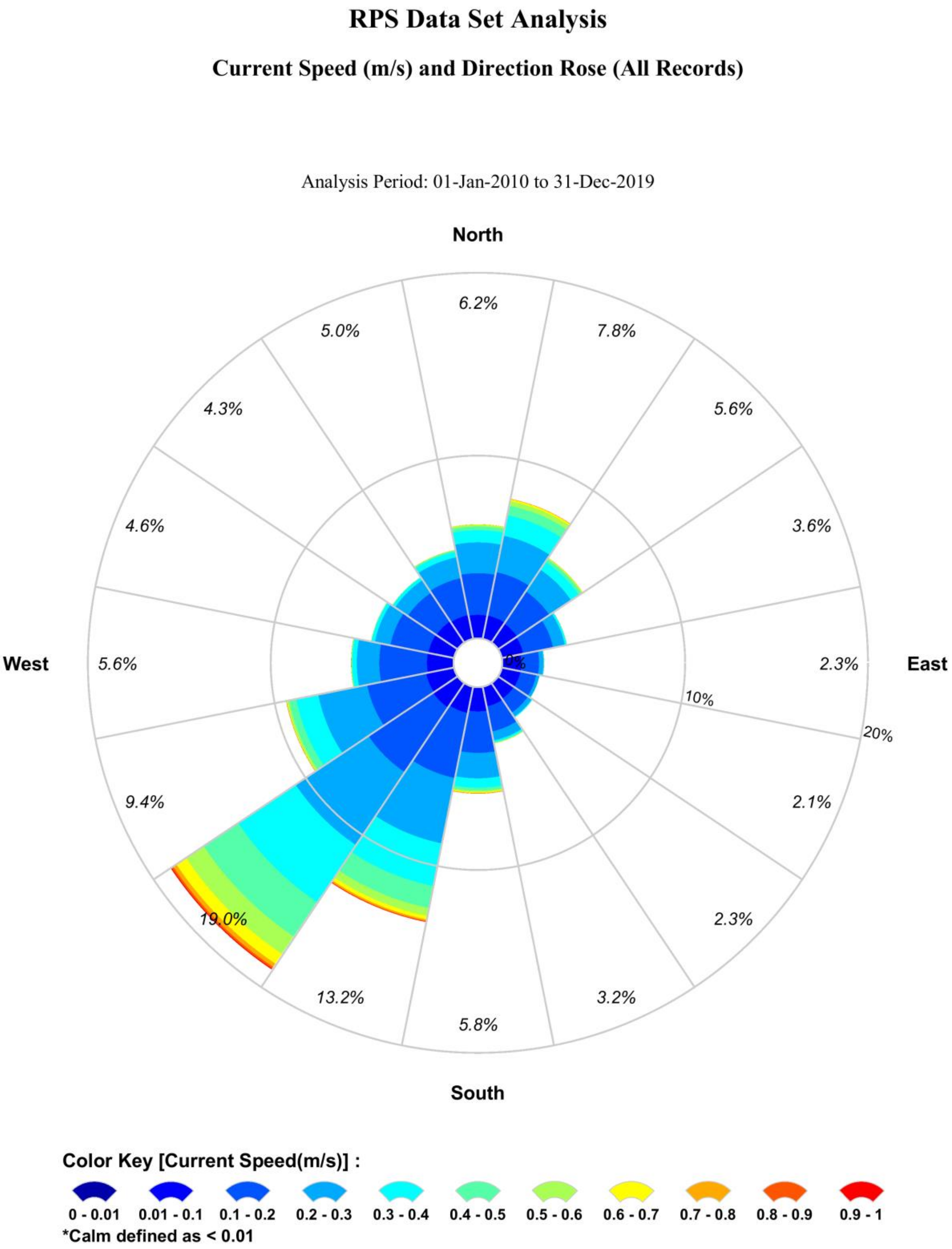


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 49 knots (July). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

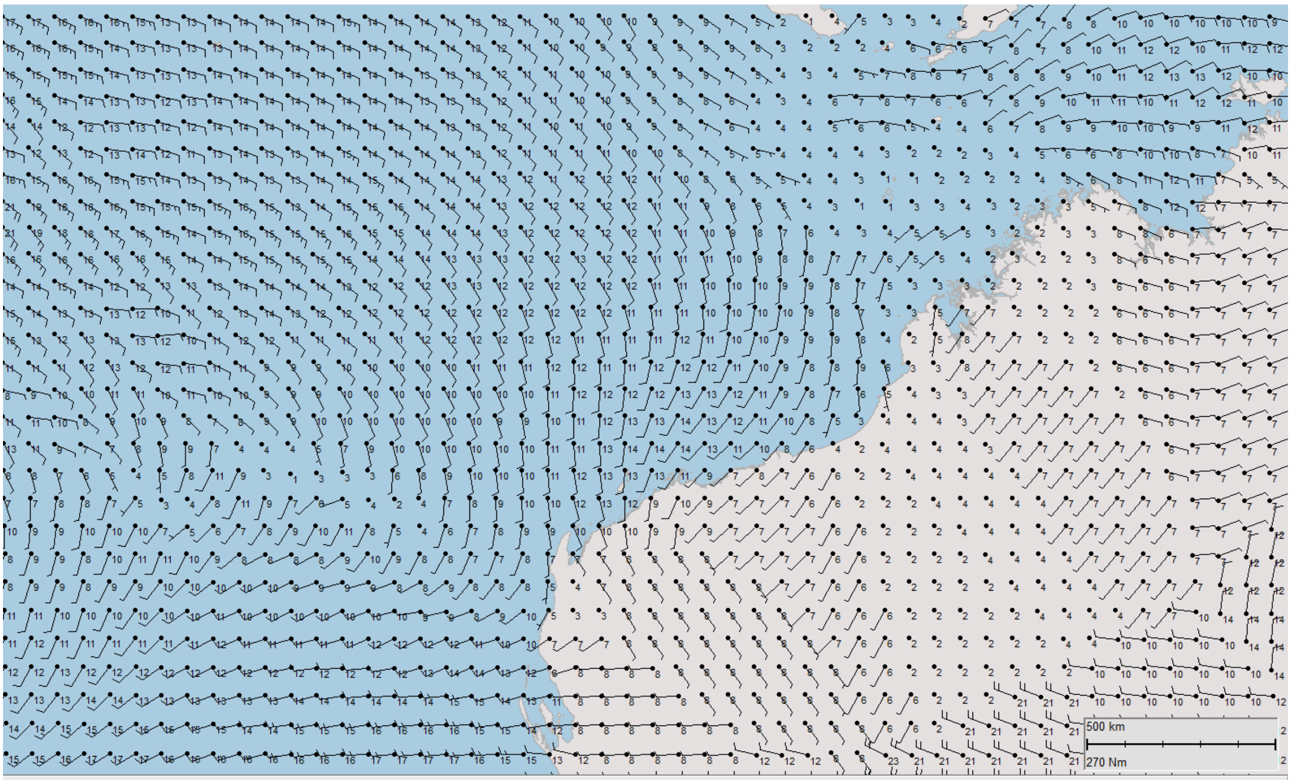


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	41	Southwest
	February	11	46	Southwest
	March	10	35	Southwest
Transitional	April	10	38	Variable
Winter	May	12	40	East
	June	14	31	East
	July	13	49	East to South
Transitional	August	11	31	South
Summer	September	12	27	South-Southwest
	October	13	28	Southwest
	November	13	25	Southwest
	December	12	29	Southwest
Minimum		**10**	**25**	
Maximum		**14**	**49**	

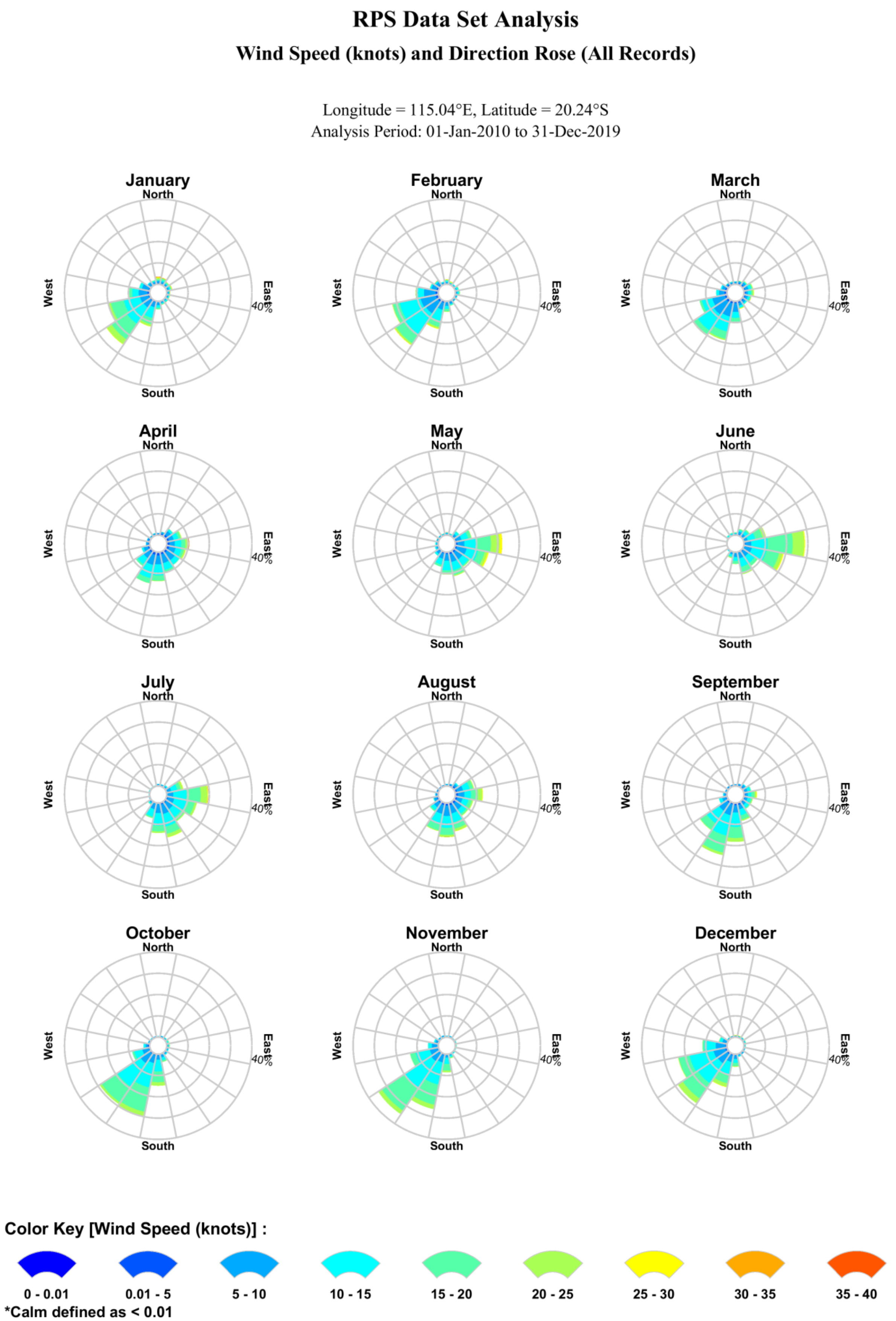


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

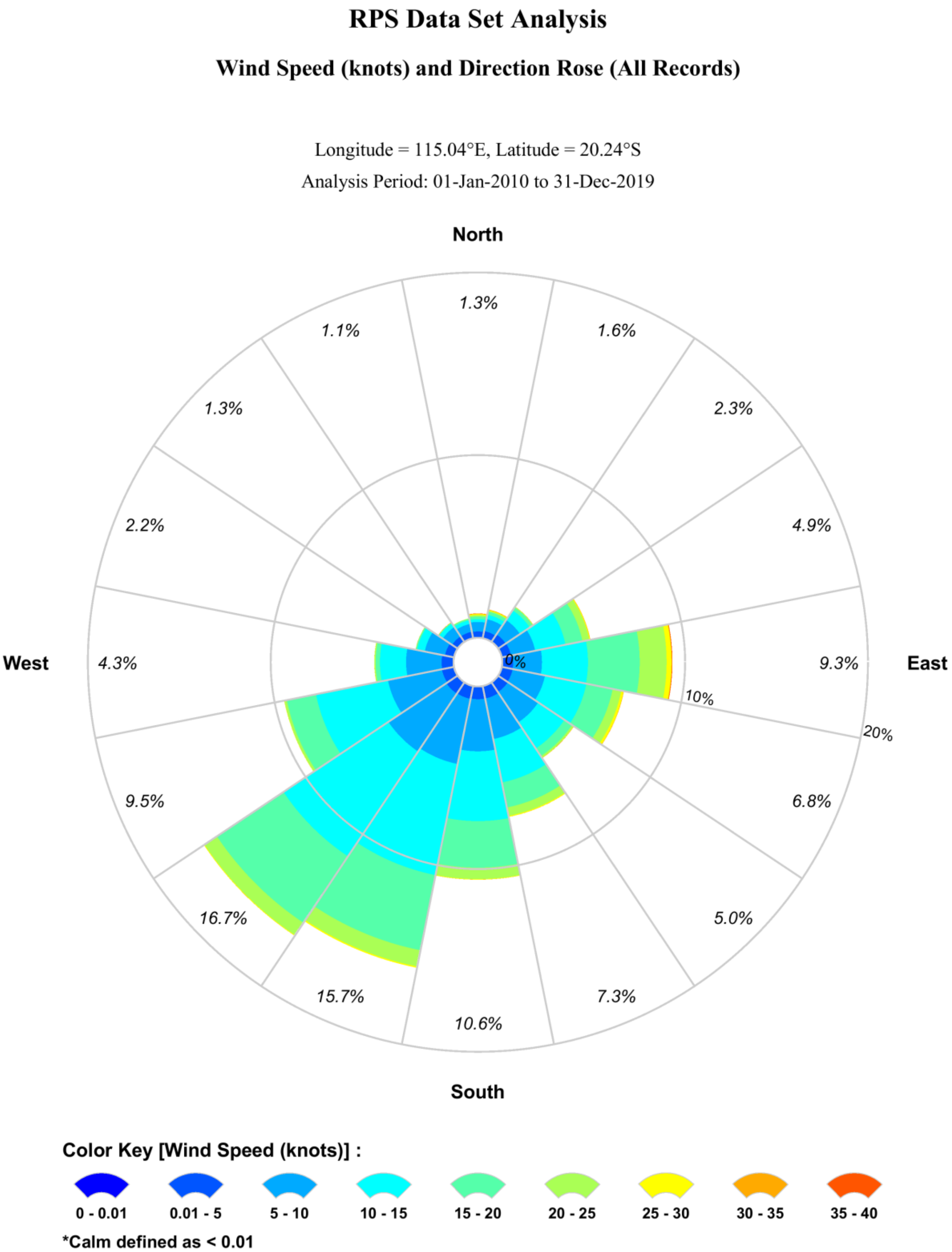


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from the HYbrid Coordinate Ocean Model (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.2°C (September) to 29.6°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.6–35.3 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	27.8	28.6	29.6	28.7	27.9	27.0	25.3	24.5	24.2	25.0	27.3	27.0
Salinity (psu)	35.1	34.9	35.0	35.1	35.2	35.3	34.9	34.8	34.9	34.9	34.6	34.9

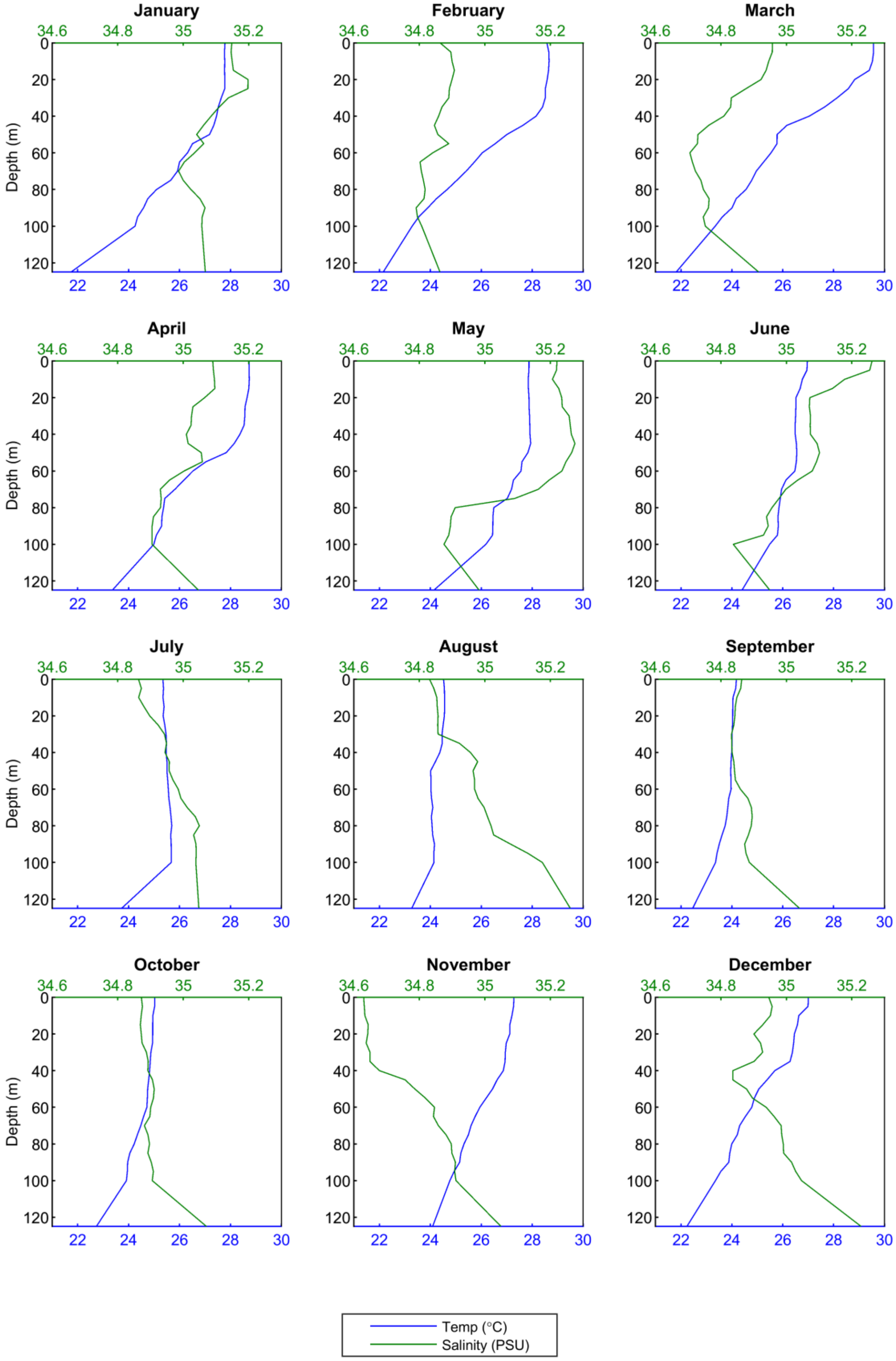


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 SUBSEA PLUME MODEL – OILMAP DEEP

The LOWC scenario is a high-pressure release of mostly gas and condensate and where gas is released with condensate, the buoyancy of the expanding gas cloud will entrain ambient seawater and propel the droplets towards the surface at a faster rate than would occur from the relative buoyancy of the condensate alone. Furthermore, the turbulence generated by such an intense discharge will tend to break the condensate up into droplets of various sizes.

To define the near-field plume dynamics, the subsea blowout model, OILMAP-DEEP, was applied. The model simulates the plume rise dynamics in two phases, the initial jet phase and the buoyant plume phase. The initial jet phase governs the plume dynamics directly above the subsurface release location and is predominately driven by the exit velocity. During this phase, the condensate droplet size and distribution is calculated. Next, the rise dynamics are dominated by the buoyant nature of the plume until the termination of the plume phase (known as the trapping depth). At this point, the results from OILMAP-DEEP (including plume trapping depth, plume diameter and droplet size distribution) are integrated into the far-field model SIMAP to simulate the rise and dispersion of the condensate droplets.

More details on the OILMAP-DEEP model, can be found in Spaulding et al. (2015). The model has been validated against observations from Deepwater Horizon as well as small and large-scale laboratory studies on subsurface oil releases (Brandvik et al., 2013, 2014; Belore, 2014; Spaulding et al., 2015; Li et al., 2017).

Table 6.1 presents the input parameters for the OILMAP-DEEP model and key results related to the near-field plume dynamics. The results indicated that the mixture of gas and condensate rose through the water column (whilst gradually losing momentum) to a trapping depth of less than 1 m below mean sea level. The modelling predicted droplets ranging in size from 175 to 756 µm.

Figure 6.1 illustrates the various stages of an example blowout plume.

Table 6.1 Input data and key results for the subsea plume modelling.

Input Variable	Value
Scenario	Loss of Well Control
Well name	WTR Well 5
Water depth (m)	150
Tubing diameter (inch) [m]	7 5/8 [0.194]
Condensate rate (stb/day)	4,302
Gas rate (MMscf/day)	310
Gas to condensate ratio (scf/bbl)	72,060
Formation water flow rate (stb/day)	0
Operating pressure (psia)	6,220
Key results	
Plume execution depth (m BMSL)	<1
Droplet sizes (µm)	175 to 756

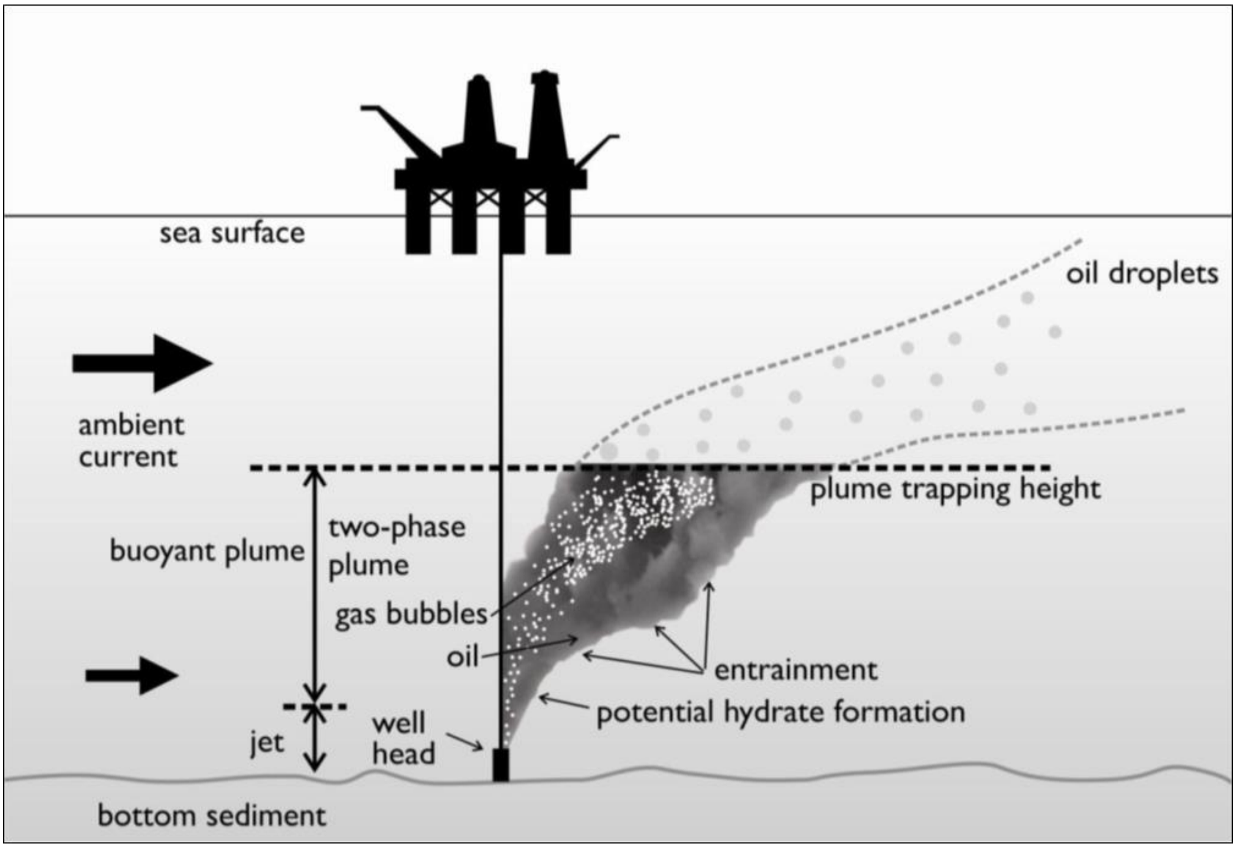


Figure 6.1 Example of a subsea plume and the various stages of the plume in the water column (Source: ASA, 2011).

7 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application.

The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

7.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 7.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and

- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

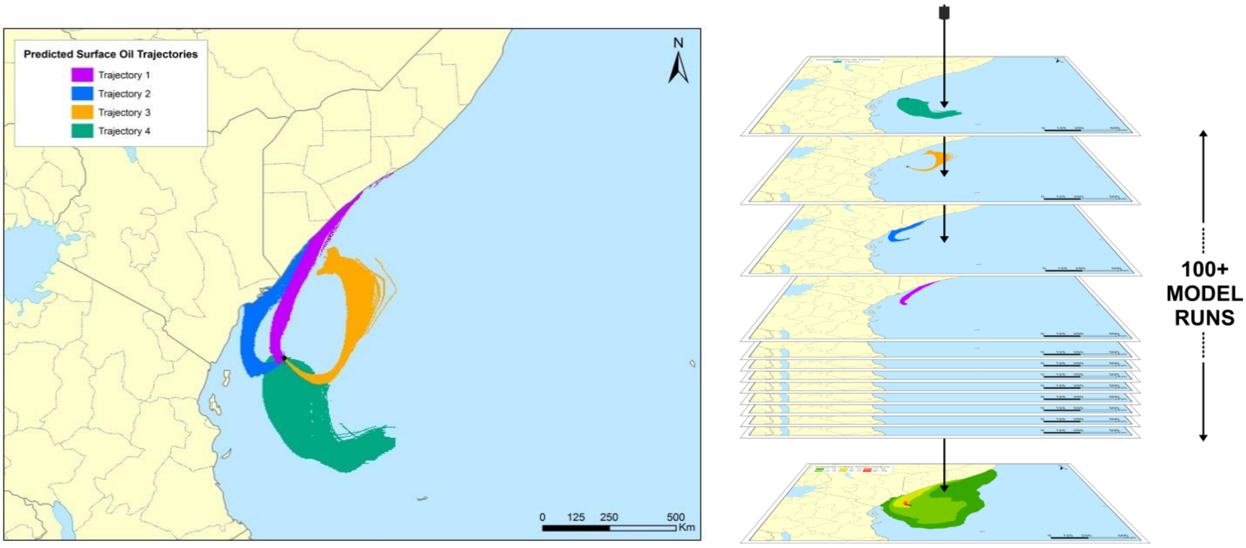


Figure 7.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

7.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 7.2.1 to 7.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

7.2.1 Floating Oil Exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating oil exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil exposure, was 1 g/m^2, which equates approximately to an average thickness of 1 µm, referred to as visible oil. Oil of this thickness is described as rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement, 2009; AMSA, 2014) (see Table 7.1). Figure 7.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. This threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to its visibility on the sea surface and potential to trigger temporary closures of areas (i.e. fishing grounds) as a precautionary measure. Table 7.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil exposure.

Ecological impact has been estimated to occur at 10 g/m^2 (a film thickness of approximately 10 µm or 0.01 mm) according to French et al. (1996) and French-McCay (2009) as this level of fresh oiling has been observed to mortally impact some birds through adhesion of oil to their feathers, exposing them to secondary effects such as hypothermia. The appearance of oil at this average thickness has been described as a metallic sheen (Bonn Agreement, 2009). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at oil concentrations on the sea surface of 25 g/m^2 (or greater), would be harmful for all birds that have landed in an oil film due to potential contamination of their feathers, with secondary effects such as loss of temperature regulation and ingestion of oil through preening. The appearance of oil at this thickness is also described as metallic sheen (Bonn Agreement, 2009). For this study the high exposure threshold was set to 50 g/m^2 and above based on NOPSEMA (2019). This threshold can also be used to inform response planning.

Table 7.2 defines the thresholds used to classify the zones of floating oil exposure reported herein.

Table 7.1 The Bonn Agreement Oil Appearance Code.

Code	Description Appearance	Layer Thickness Interval (g/m^2 or µm)	Litres per km^2
1	Sheen (silvery/grey)	0.04 – 0.30	40 – 300
2	Rainbow	0.30 – 5.0	300 – 5,000
3	Metallic	5.0 – 50	5,000 – 50,000
4	Discontinuous True Oil Colour	50 – 200	50,000 – 200,000
5	Continuous True Oil Colour	≥ 200	≥ 200,000

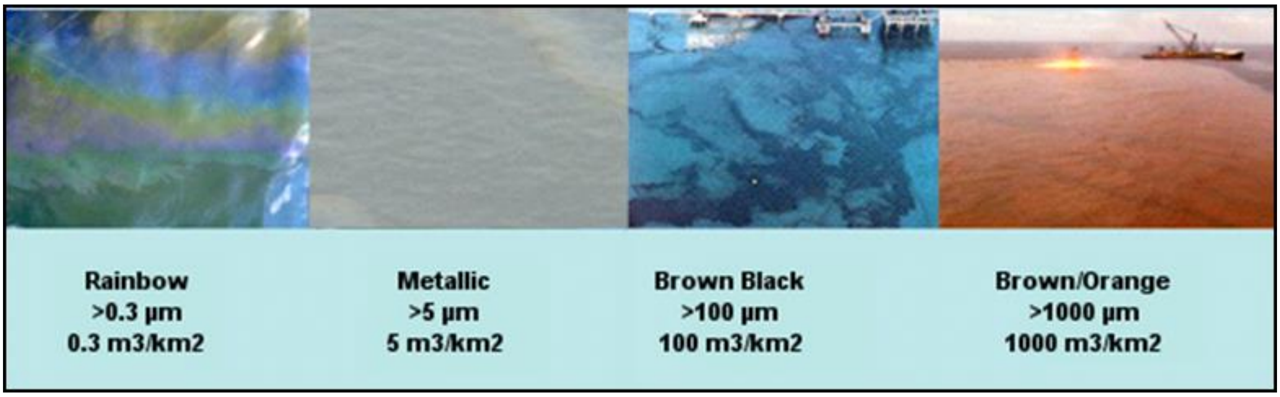


Figure 7.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 7.2 Floating oil exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (g/m^2)	Description
Low	1	Approximates range of socioeconomic effects and establishes planning area for scientific monitoring
Moderate	10	Approximates lower limit for harmful exposures to birds and marine mammals
High	50*	Approximates surface oil slick and informs response planning

* 50 g/m^2 also used to define the threshold for actionable floating oil.

7.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential “low shoreline accumulation”.

French et al. (1996) and French-McCay (2009) define a shoreline oil accumulation threshold of 100 g/m^2, or above, would potentially harm shorebirds and wildlife (furbearing aquatic mammals and marine reptiles on or along the shore) based on studies for sub-lethal and lethal impacts. This threshold has been used in previous environmental risk assessment studies (see French-McCay, 2003; French-McCay et al., 2004, French-McCay et al., 2011; 2012; NOAA, 2013). Additionally, a shoreline concentration of 100 g/m^2, or above, is the minimum limit that the oil can be effectively cleaned according to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential “moderate shoreline accumulation”.

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential “high shoreline accumulation”. It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 7.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 7.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	10	Predicts potential for some socio-economic impact
Moderate	100*	Loading predicts area likely to require clean-up effort
High	> 1,000	Loading predicts area likely to require intensive clean-up effort

* 100 g/m^2 also used to define the threshold for actionable shoreline oil.

7.2.3 In-water Exposure Thresholds

Oil is a mixture of thousands of hydrocarbons of varying physical, chemical, and toxicological characteristics, and therefore, demonstrate varying fates and impacts on organisms. As such, for in-water exposure, the SIMAP model provides separate outputs for dissolved and entrained hydrocarbons from oil droplets. The consequences of exposure to dissolved and entrained components will differ because they have different modes and magnitudes of effect.

Entrained hydrocarbon concentrations were calculated based on oil droplets that are suspended in the water column, though not dissolved. The composition of this oil would vary with the state of weathering (oil age) and may contain soluble hydrocarbons when the oil is fresh. Calculations for dissolved hydrocarbons specifically calculates oil components which are dissolved in water, which are known to be the primary source of toxicity exerted by oil.

7.2.3.1 Dissolved Hydrocarbons

Laboratory studies have shown that dissolved hydrocarbons exert most of the toxic effects of oil on aquatic biota (Carls et al., 2008; Nordtug et al., 2011; Redman, 2015). The mode of action is a narcotic effect, which is positively related to the concentration of soluble hydrocarbons in the body tissues of organisms (French-McCay, 2002). Dissolved hydrocarbons are taken up by organisms directly from the water column by absorption through external surfaces and gills, as well as through the digestive tract. Thus, soluble hydrocarbons are termed “bioavailable”.

Hydrocarbon compounds vary in water-solubility and the toxicity exerted by individual compounds is inversely related to solubility, however bioavailability will be modified by the volatility of individual compounds (Nirmalakhandan & Speece, 1988; Blum & Speece, 1990; McCarty, 1986; McCarty et al., 1992a, 1992b; Mackay et al., 1992; McCarty & Mackay, 1993; Verhaar et al., 1992, 1999; Swartz et al., 1995; French-McCay, 2002; McGrath & Di Toro, 2009). Of the soluble compounds, the greatest contributor to toxicity for water-column and benthic organisms are the lower-molecular-weight aromatic compounds, which are both volatile and soluble in water. Although they are not the most water-soluble hydrocarbons within most oil types, the polynuclear aromatic hydrocarbons (PAHs) containing 2-3 aromatic ring structures typically exert the largest narcotic effects because they are semi-soluble and not highly volatile, so they persist in the environment long enough for significant accumulation to occur (Anderson et al., 1974, 1987; Neff & Anderson, 1981; Malins & Hodgins, 1981; McAuliffe, 1987; NRC, 2003). The monoaromatic hydrocarbons (MAHs), including the BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), and the soluble alkanes (straight chain hydrocarbons) also contribute to toxicity, but these compounds are highly volatile, so that their contribution will be low when oil is exposed to evaporation and higher when oil is discharged at depth where volatilisation does not occur (French-McCay, 2002).

French-McCay (2002) reviewed available toxicity data, where marine biota was exposed to dissolved hydrocarbons prepared from oil mixtures, finding that 95% of species and life stages exhibited 50% population mortality (LC_{50}) between 6 and 400 ppb total PAH concentration after 96 hrs exposure, with an average of 50 ppb. Hence, concentrations lower than 6 ppb total PAH value should be protective of 97.5% of species and life stages even with exposure periods of days (at least 96 hours). Early life-history stages of fish appear to be more sensitive than older fish stages and invertebrates.

Exceedances of 10, 50 or 400 ppb over a 1 hour timestep (see Table 7.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on NOPSEMA (2019).

7.2.3.2 Entrained Hydrocarbons

Entrained hydrocarbons consist of oil droplets that are suspended in the water column and insoluble. As such, insoluble compounds in oil cannot be absorbed from the water column by aquatic organisms, hence are not bioavailable through absorption of compounds from the water. Exposure to these compounds would require routes of uptake other than absorption of soluble compounds. The route of exposure of organisms to whole oil alone include direct contact with tissues of organisms and uptake of oil by direct consumption, with potential for biomagnification through the food chain (NRC, 2003).

The 10 ppb threshold represents the very lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the ANZECC & ARMCANZ (2000) water quality guidelines. Due to the requirement for relatively long exposure times (> 24 hours) for these concentrations to be significant, they are likely to be more meaningful for juvenile fish, larvae and planktonic organisms that might be entrained (or otherwise moving) within the entrained plumes, or when entrained hydrocarbons adhere to organisms or trapped against a shoreline for periods of several days or more.

This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the entrained hydrocarbon at this level.

Thresholds of 10 ppb and 100 ppb were applied over a 1 hour time exposure (Table 7.4), to cover the range of thresholds outlined in the ANZECC & ARMCANZ (2000) water quality guidelines, the incremental change for greater potential effect and is per NOPSEMA (2019).

A complicating factor that should be considered when assessing the consequence of dissolved and entrained oil distributions is that there will be some areas where both physically entrained oil droplets and dissolved hydrocarbons co-exist. Higher concentrations of each will tend to occur close to the source where sea conditions can force mixing of relatively unweathered oil into the water column, resulting in more rapid dissolution of soluble compounds.

Table 7.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

8 HYDROCARBON PROPERTIES

8.1 Condensate Properties

West Tryal Rocks condensate physical properties and boiling point distributions were provided by Chevron and are presented in Table 8.1 and Table 8.2, respectively.

West Tryal Rocks condensate has an API of 41.2, a density of 789 kg/m^3 (at 15ºC) and a low viscosity value of 5.9 cP. When exposed to the atmosphere at local temperatures, about 31.1% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 29.9% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~19.4%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 19.6% of the condensate is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity for the mixture to take up water to form water-in-oil emulsion.

Soluble, aromatic hydrocarbons contribute approximately 3.2% by mass of the whole oil, which is contained in the volatile fractions, which are highly soluble. The process of evaporation will be greater under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

The actual fate will depend greatly on the amount that reaches the surface, either through the initial release or by resurfacing.

Table 8.1 Physical properties of West Tryal Rocks condensate.

Characteristic	West Tryal Rocks Condensate
Density (kg/m^3)	817 (at 15°C)
API	41.2
Dynamic viscosity (cP)	5.9 (at 15°C)
Pour point (°C)	0
Surface tension (dyne/cm)	23
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light-persistent

Table 8.2 Boiling point ranges of West Tryal Rocks condensate.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 >C_{20}
West Tryal Rocks Condensate	% of total	31.1	29.9	19.4	19.6
	% of aromatics	3.2	0.0	0.0	0.0

8.2 Condensate Weathering Characteristics

8.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this condensate when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.

- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the condensate reaches the surface.

8.2.2 Results

The mass balance forecast for the calm-wind case (Figure 8.1) shows that 61.1% of the condensate is predicted to evaporate within 24 hours. Majority of the remaining condensate on the water surface will weather at a slower rate due to the low volatile components. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.2), where the winds are of greater strength on average, entrainment of West Tryal Rocks condensate into the water column is predicted to increase. Approximately 24 hours after the spill, 51.6% of the condensate mass is forecast to have entrained and a further 45.1% is forecast to have evaporated, leaving only a small proportion of the condensate floating on the water surface (1.5%). The residual compounds will tend to remain entrained beneath the surface under conditions that generate wind waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case will result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and condensate droplets in the water column occurs at an approximate rate of 1.66% per day with an accumulated total of 11.6% after 7 days, in comparison to a rate of 0.22% per day and an accumulated total of 1.59% after 7 days in the constant-wind case. Given the proportion of entrained condensate and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

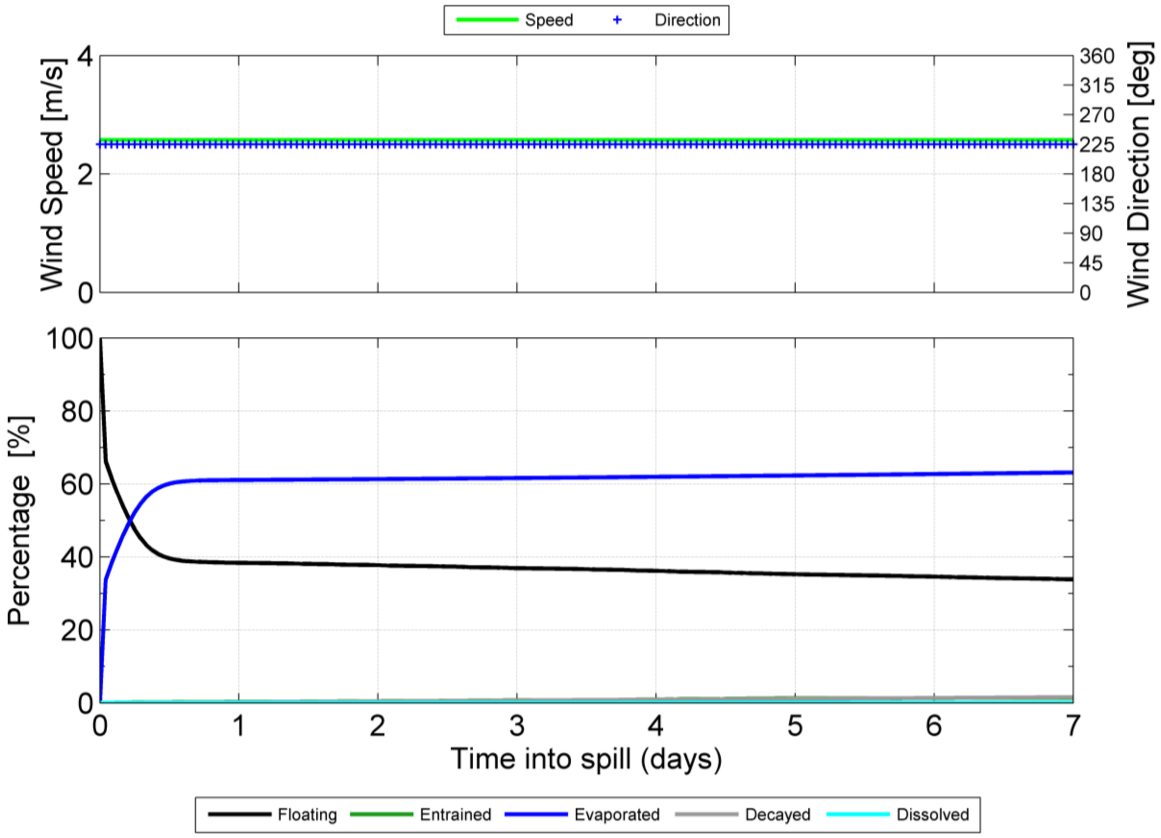


Figure 8.1 Proportional mass balance plot representing the weathering of West Tryal Rocks condensate spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature.

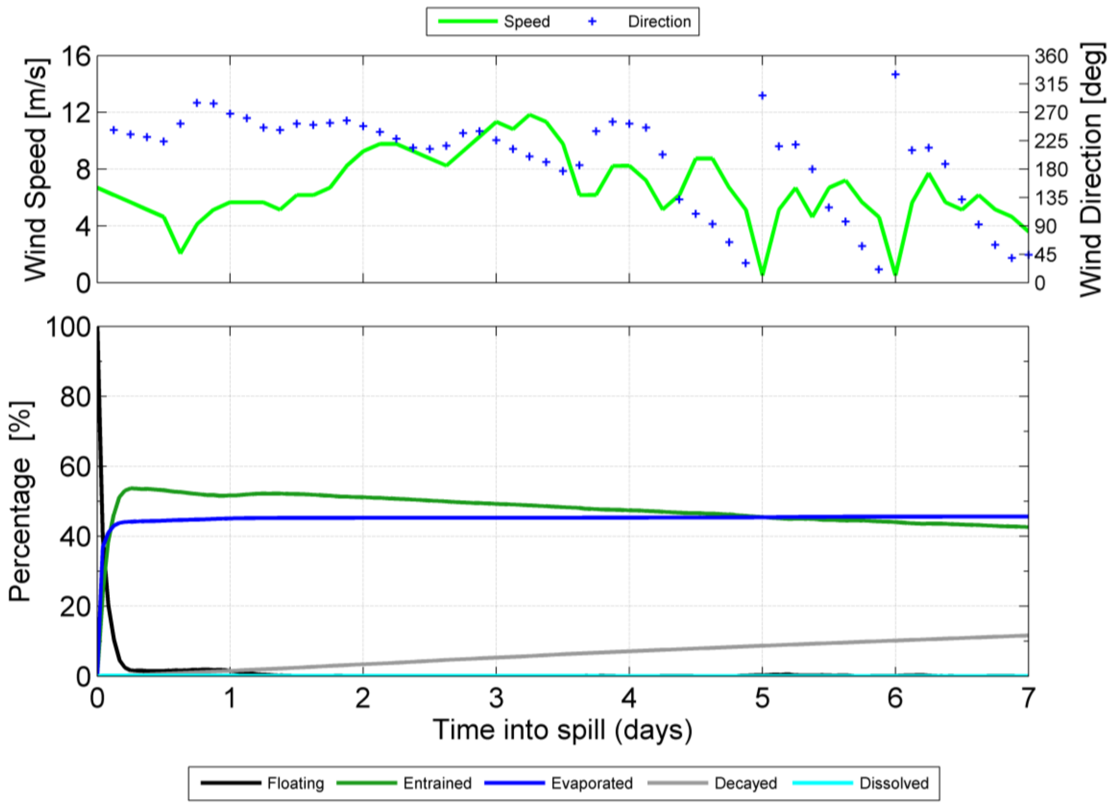


Figure 8.2 Proportional mass balance plot representing the weathering of West Tryal Rocks condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature.

9 MODEL SETTINGS

Table 9.1 provides a summary of the oil spill model settings.

Table 9.1 Summary of the oil spill model settings used in this assessment.

	Scenario 1
Location	WTR Well 5
Number of spill simulations with randomly selected start times	100 per season (300 total)
Spill volume (m^3) [bbl]	61,555 [387,180]
Condensate type	West Tryal Rocks condensate
Release type (depth)	Subsea (150 m)
Release duration (days)	90
Simulation length (days)	104
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour, high exposure

10 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

10.1 Stochastic Analysis

10.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***probability of oil exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***minimum time before oil exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

10.2 Deterministic Trajectories

The deterministic results for both scenarios are based on the following criteria:

a. Largest swept area of floating hydrocarbon above 10 g/m^2

b. Largest swept area of floating hydrocarbon above 50 g/m^2

c. Largest volume of oil ashore

d. Longest length of shoreline with accumulation above 100 g/m^2

e. Largest area of entrained hydrocarbons above 100 ppb

f. Largest area of dissolved hydrocarbons above 50 ppb

10.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 10.1 to Figure 10.11). Receptor categories (see Table 10.1) include sections of shorelines and offshore islands. All other sensitive receptors other than submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

Table 10.2 summarises the receptors that the location resides within.

Table 10.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	×
Biologically Important Area	BIA	✓	✓	×
Marine Park	MP	✓	✓	×
Marine Management Area	MMA	✓	✓	×
Nature Reserve	NR	✓	✓	×
Integrated Marine and Coastal Regionalisation of Australia	IMCRA	✓	✓	×
Interim Biogeographic Regionalisation of Australia	IBRA	✓	✓	×
Reefs, Shoals and Banks	RSB	✓	✓	×
Key Ecological Feature	KEF	✓	✓	×
Ramsar Sites	Ramsar	✓	✓	×
State Waters	State Waters	✓	✓	×
Impact Assessment Area	IAA	✓	✓	✓
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 10.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Flatback Turtle - Internesting Buffer	BIA	✓
Pygmy Blue Whale - Distribution	BIA	✓
Wedge-tailed Shearwater - Breeding	BIA	✓
Whale Shark - Foraging	BIA	✓
Offshore Area	IAA	✓
Pilbara (offshore)	IMCRA	✓
Ancient coastline at 125 m depth contour	KEF	✓

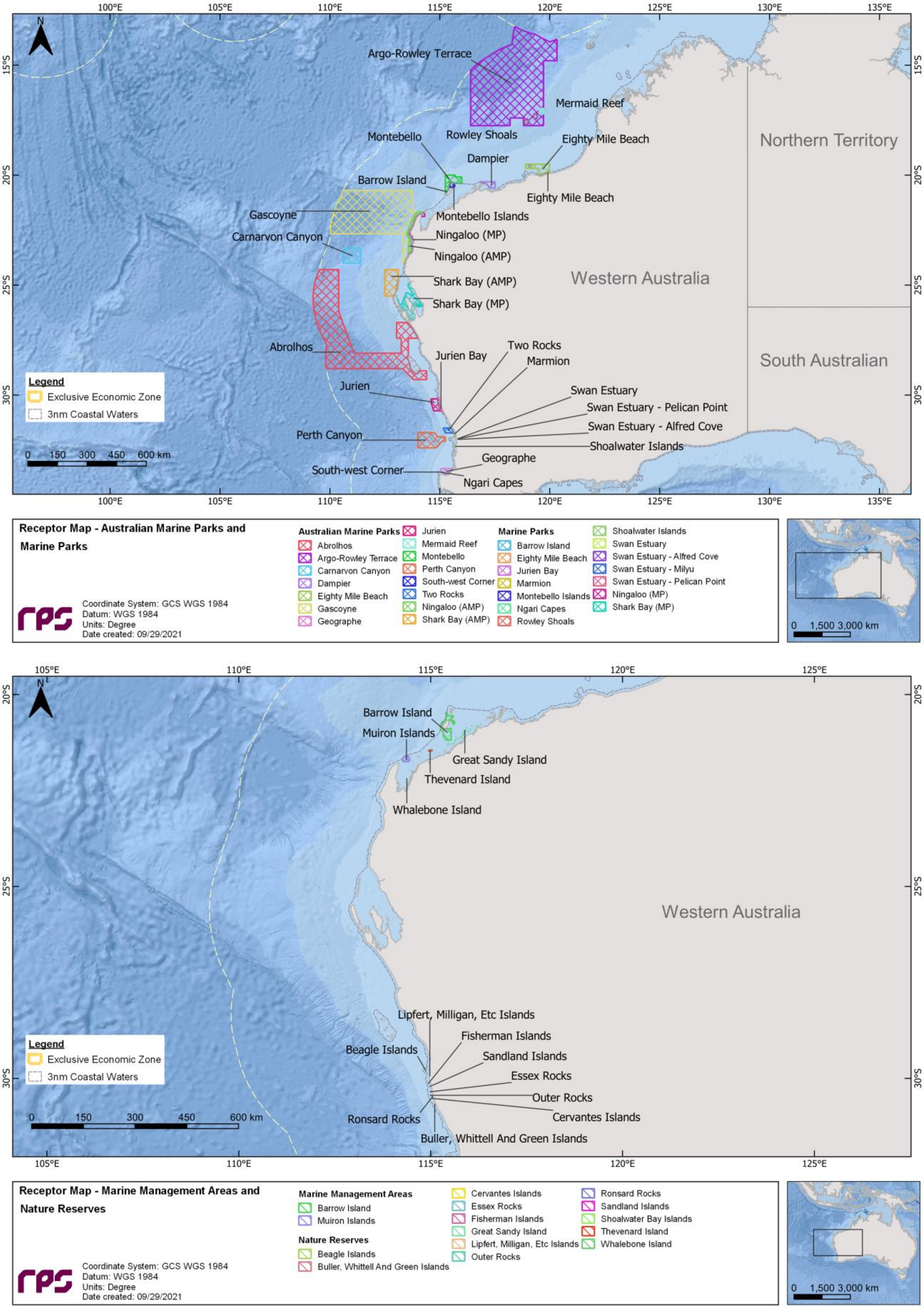


Figure 10.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).

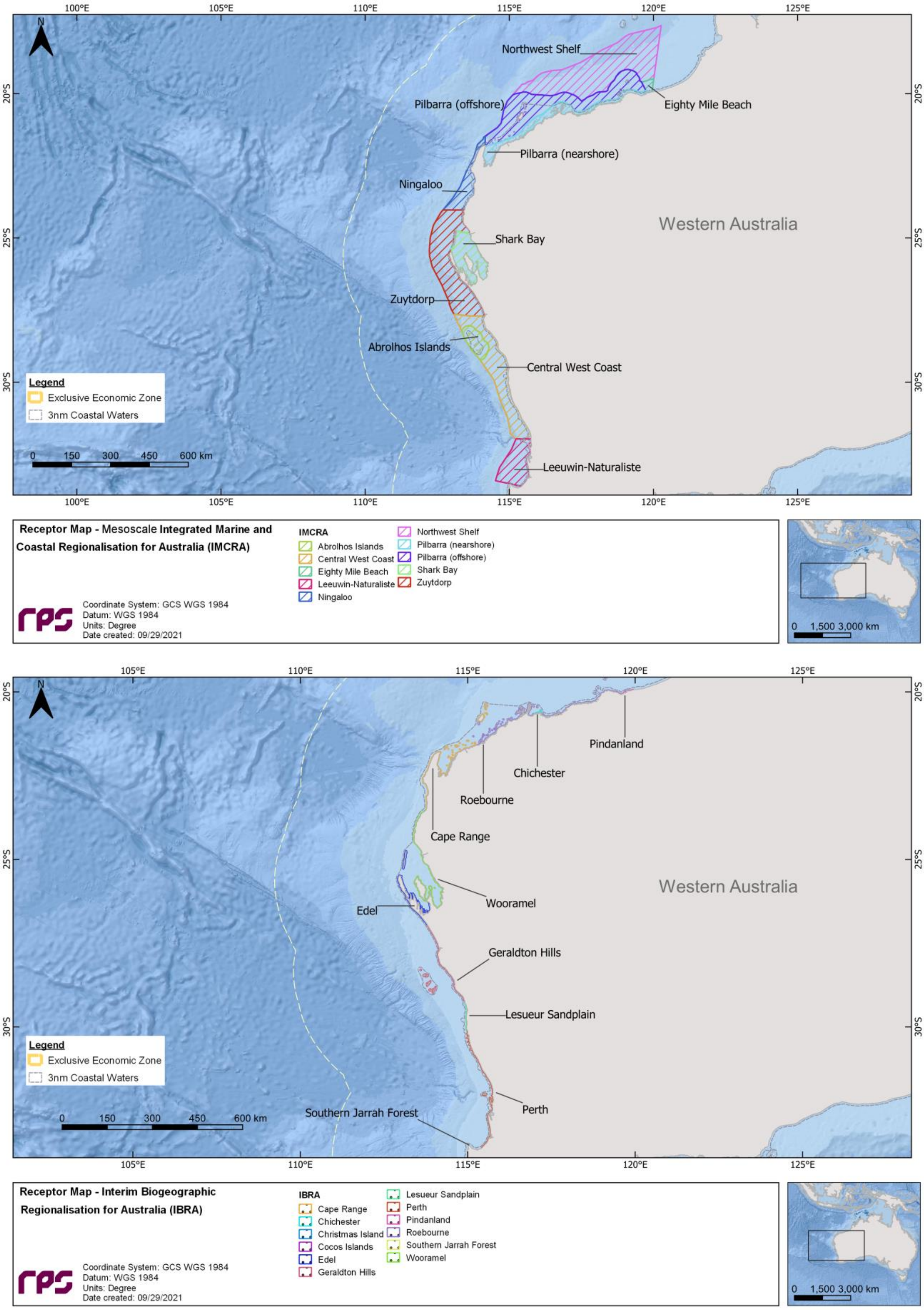
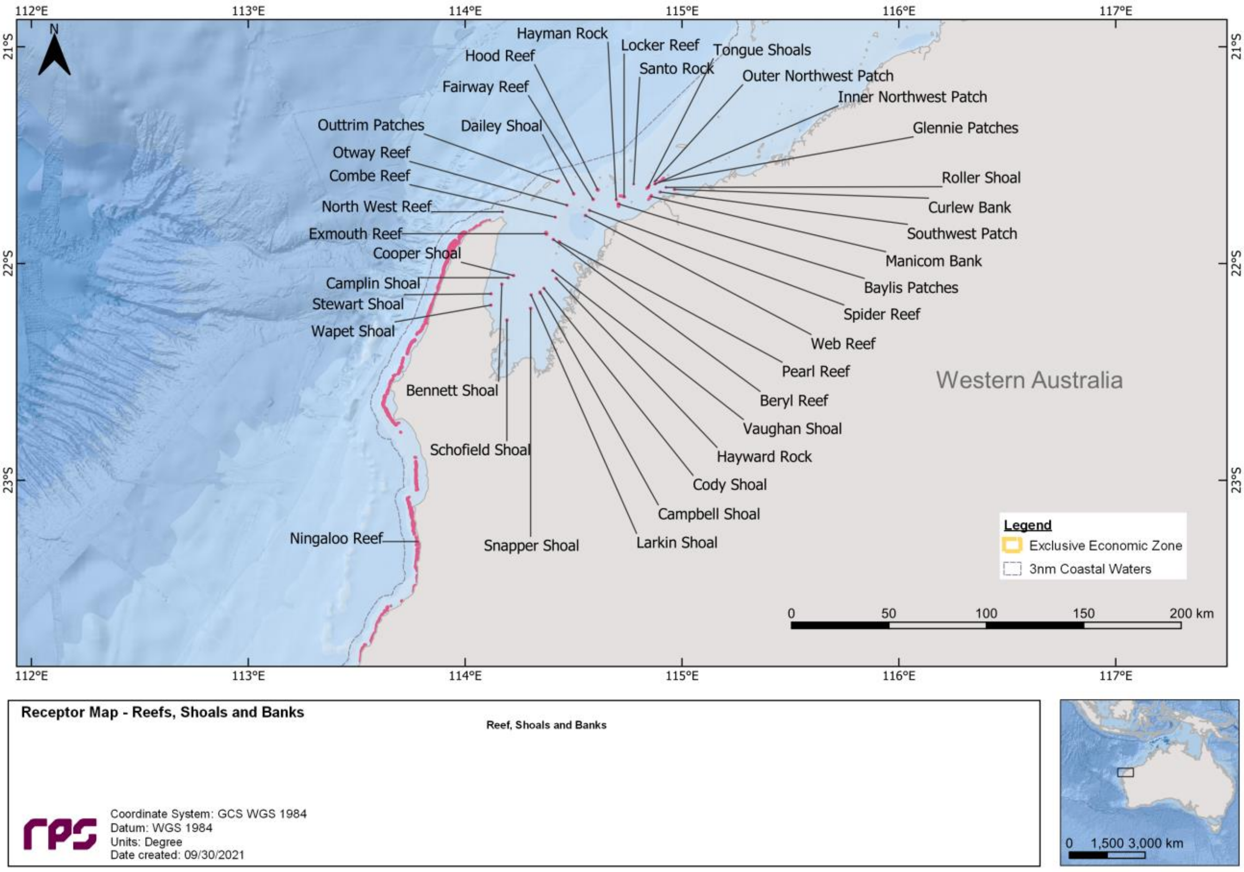


Figure 10.2 Receptor maps for Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).



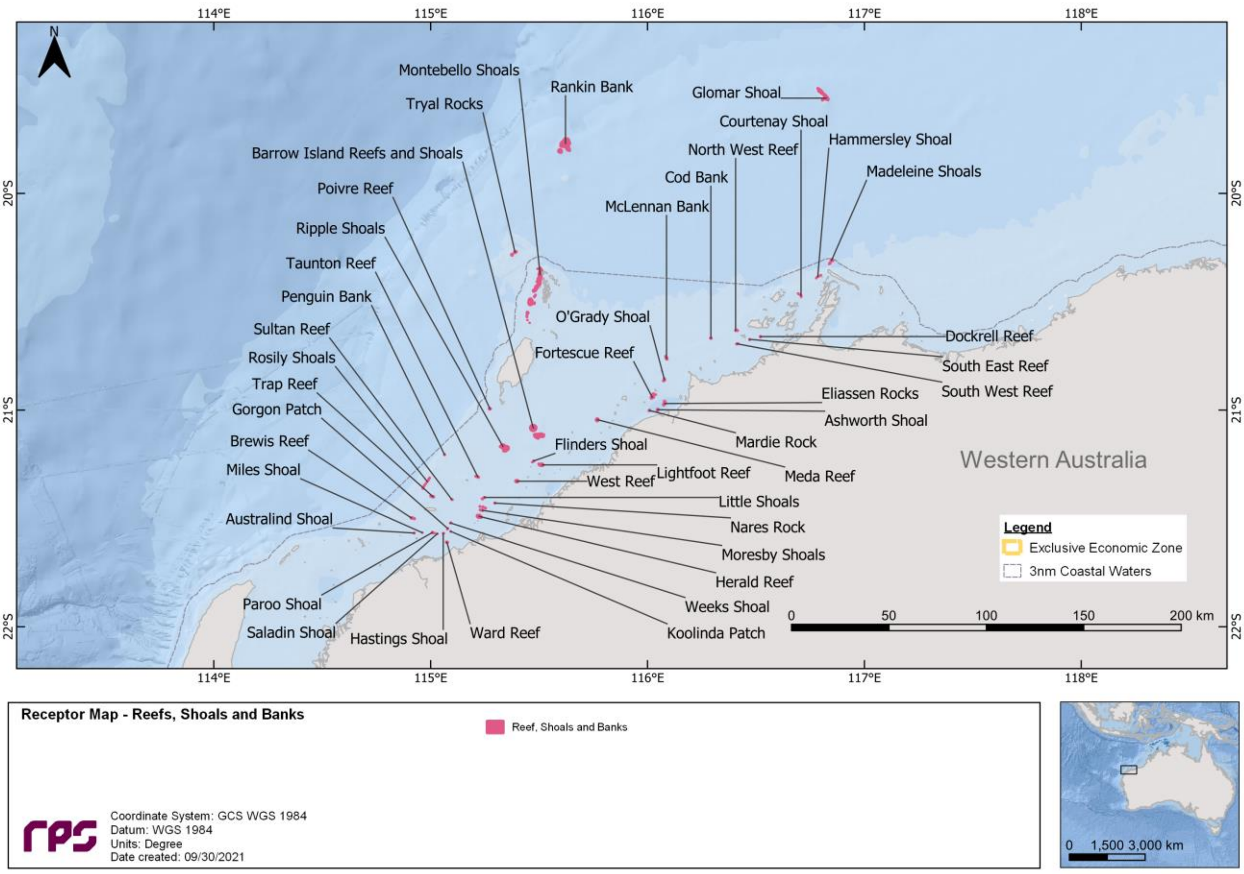


Figure 10.3 Receptor maps for Reefs, Shoals and Banks (RSB).

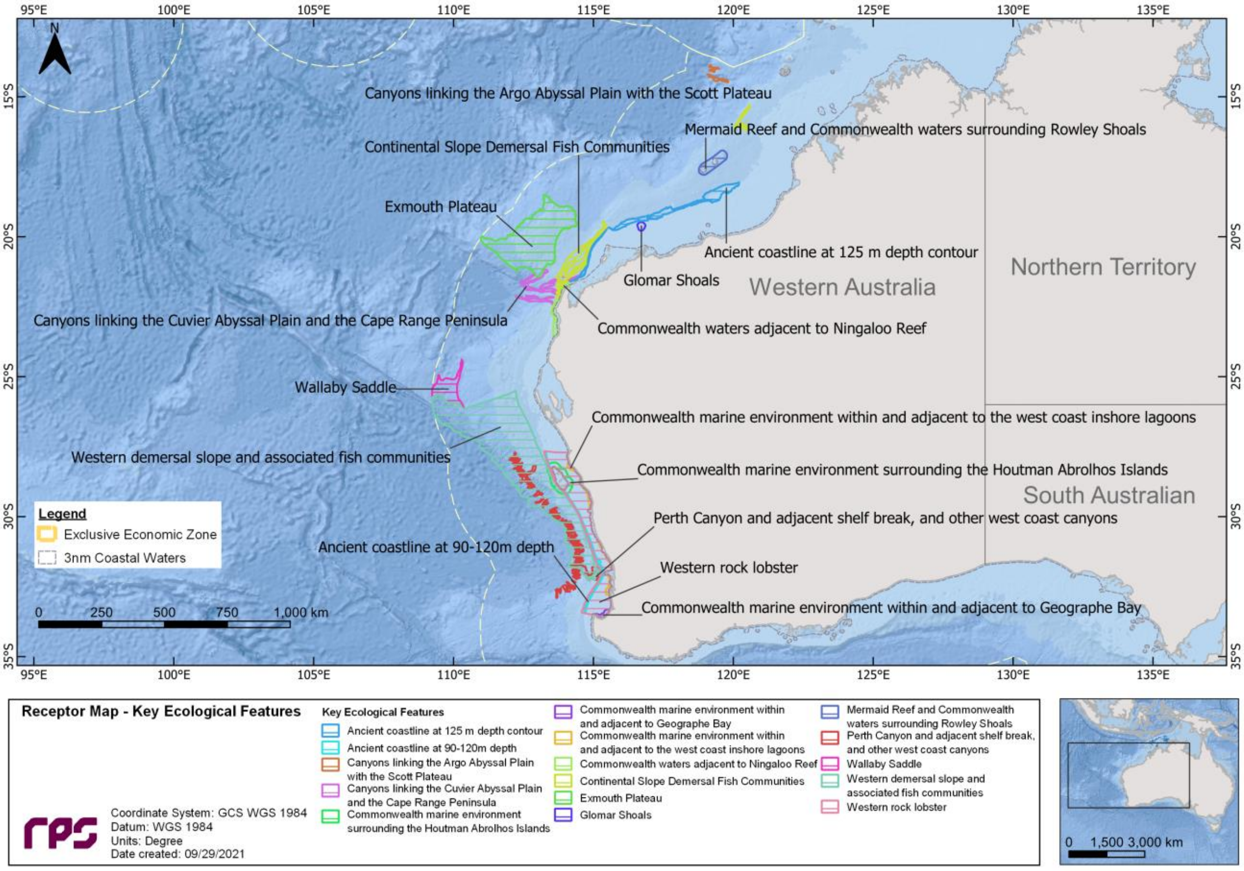


Figure 10.4 Receptor maps for Key Ecological Features (KEFs).

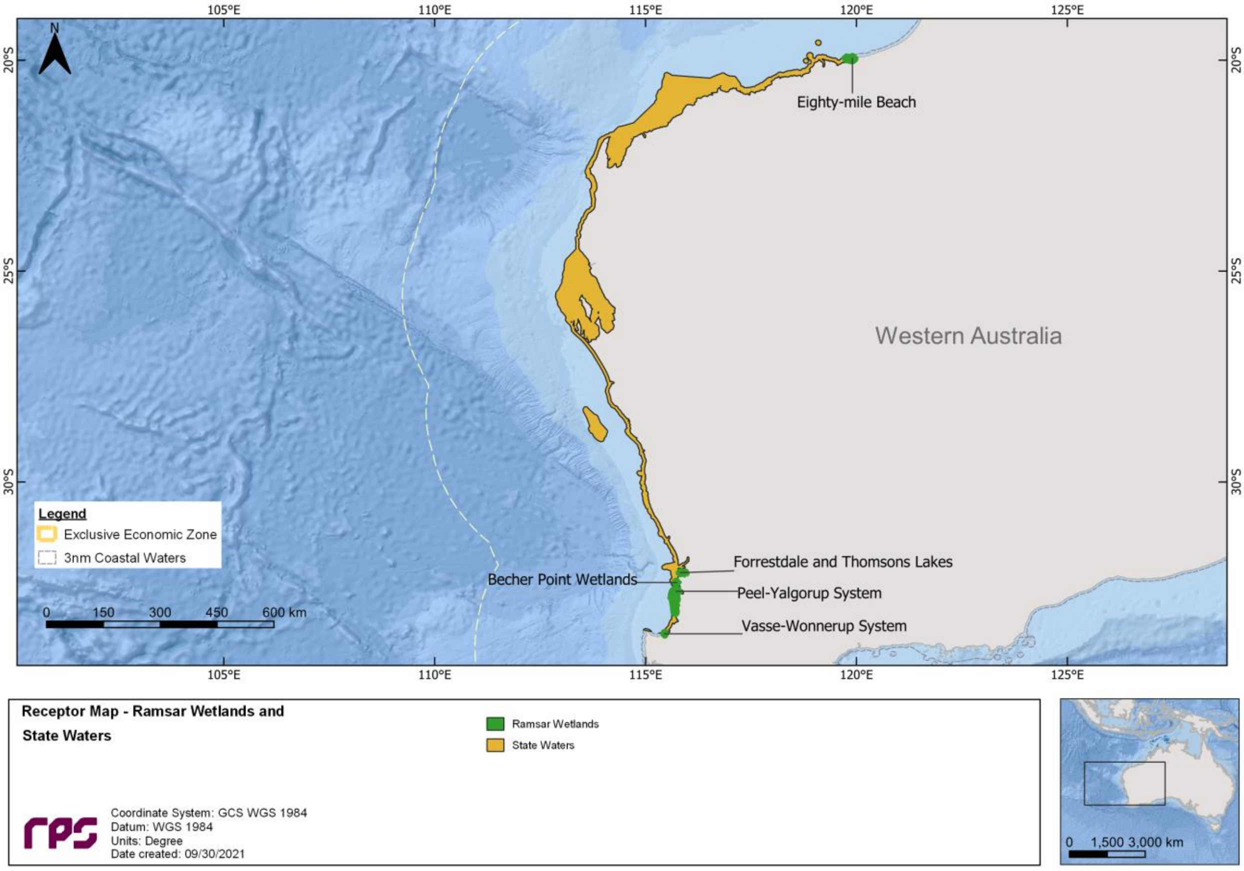


Figure 10.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.

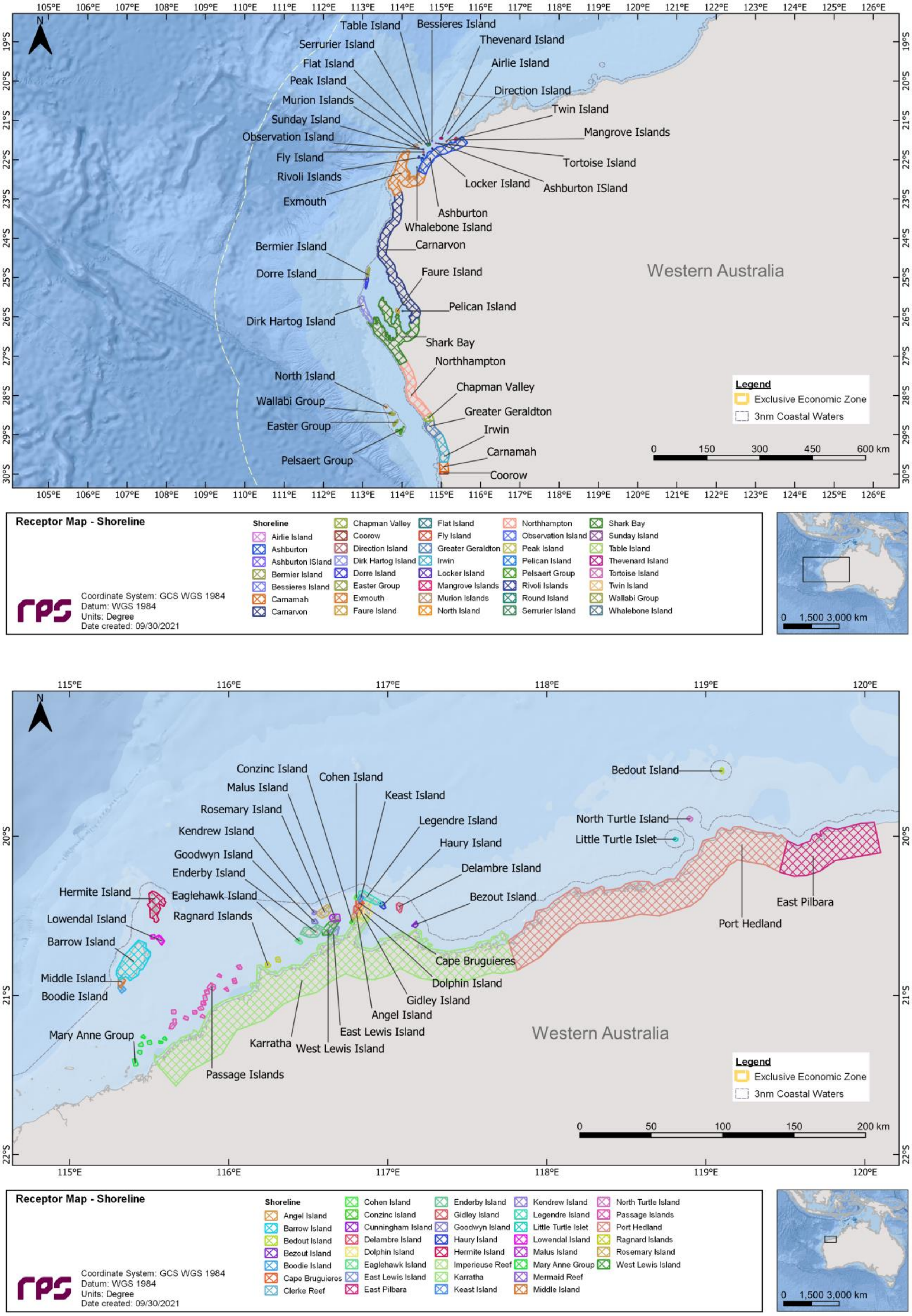


Figure 10.6 Receptor maps for Shorelines (1 of 2).

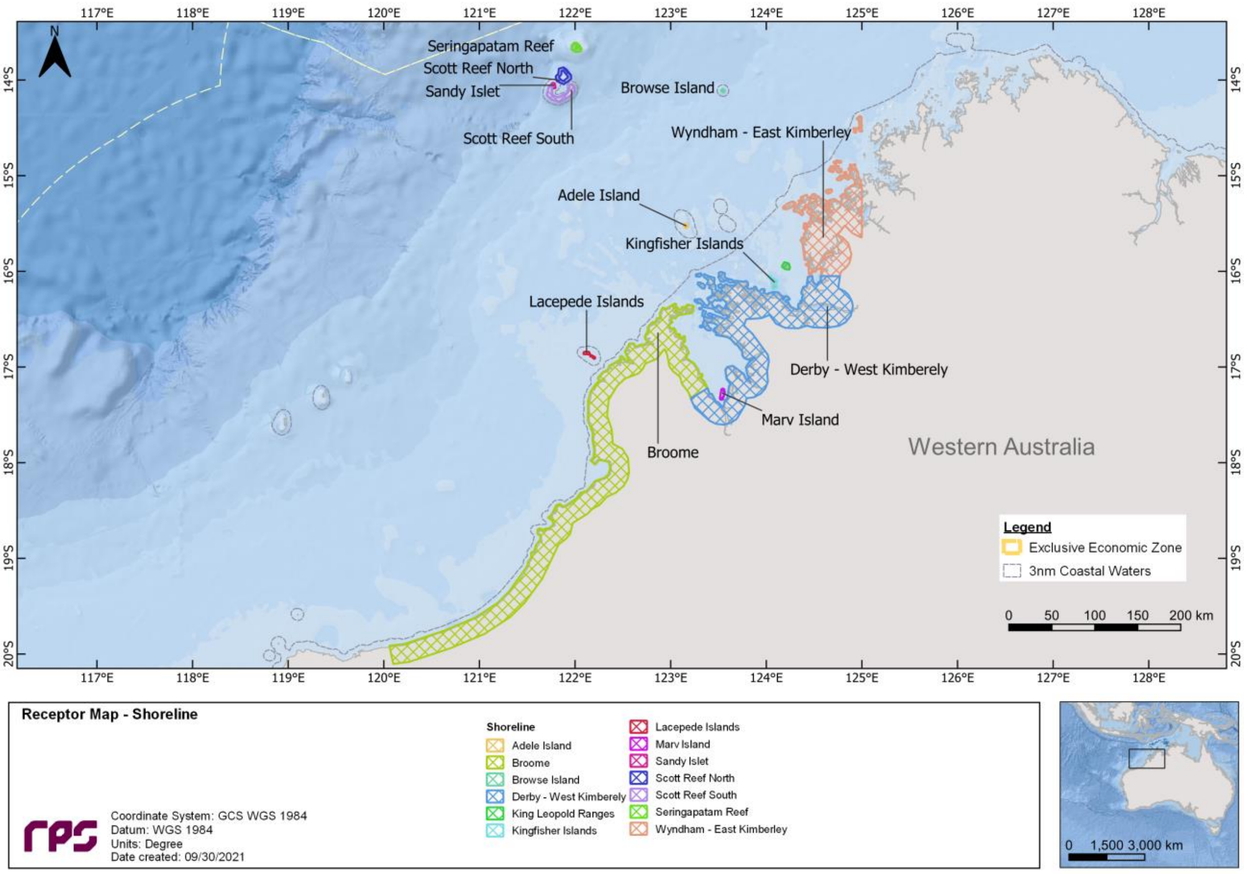


Figure 10.7 Receptor maps for Shorelines (2 of 2).

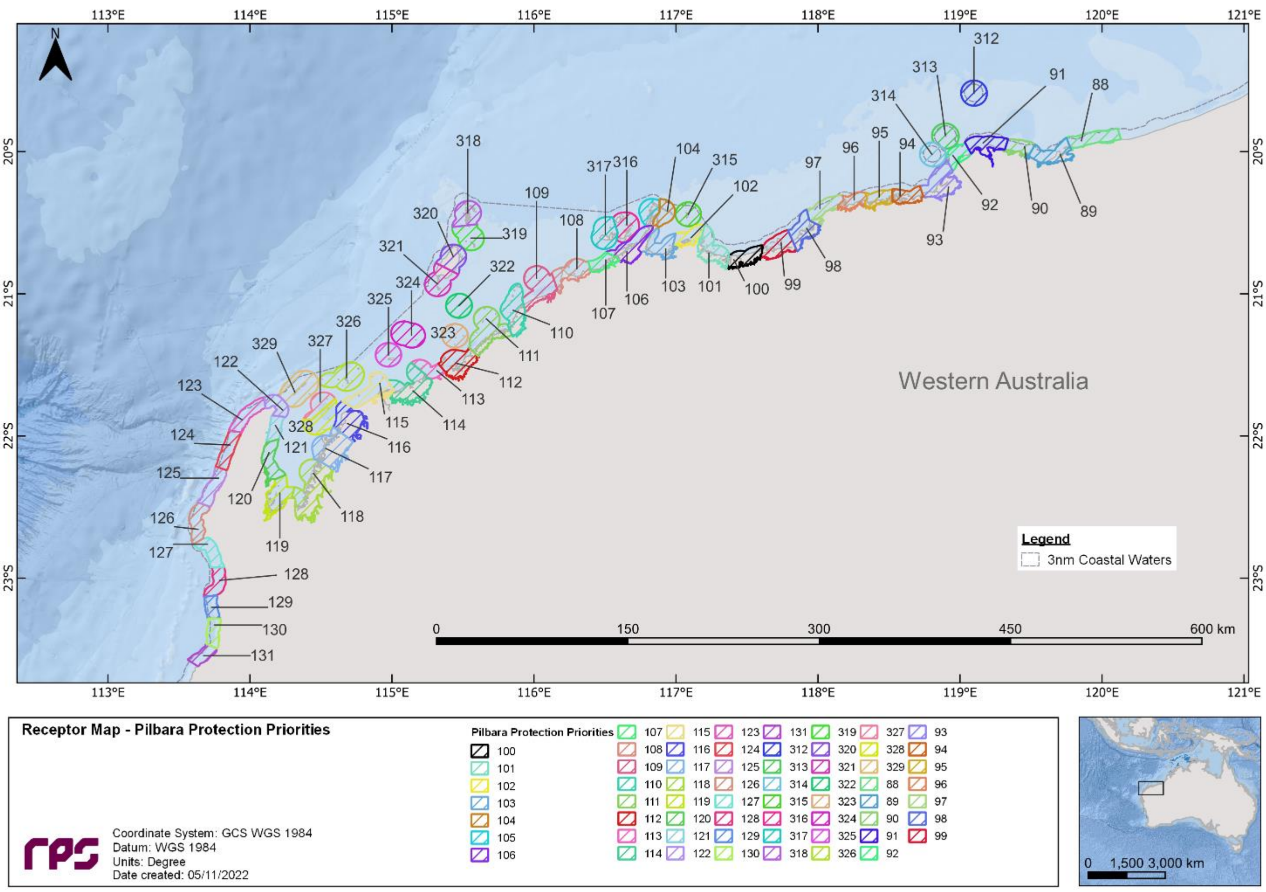


Figure 10.8 Receptor maps for Pilbara Protection Priorities Shorelines.

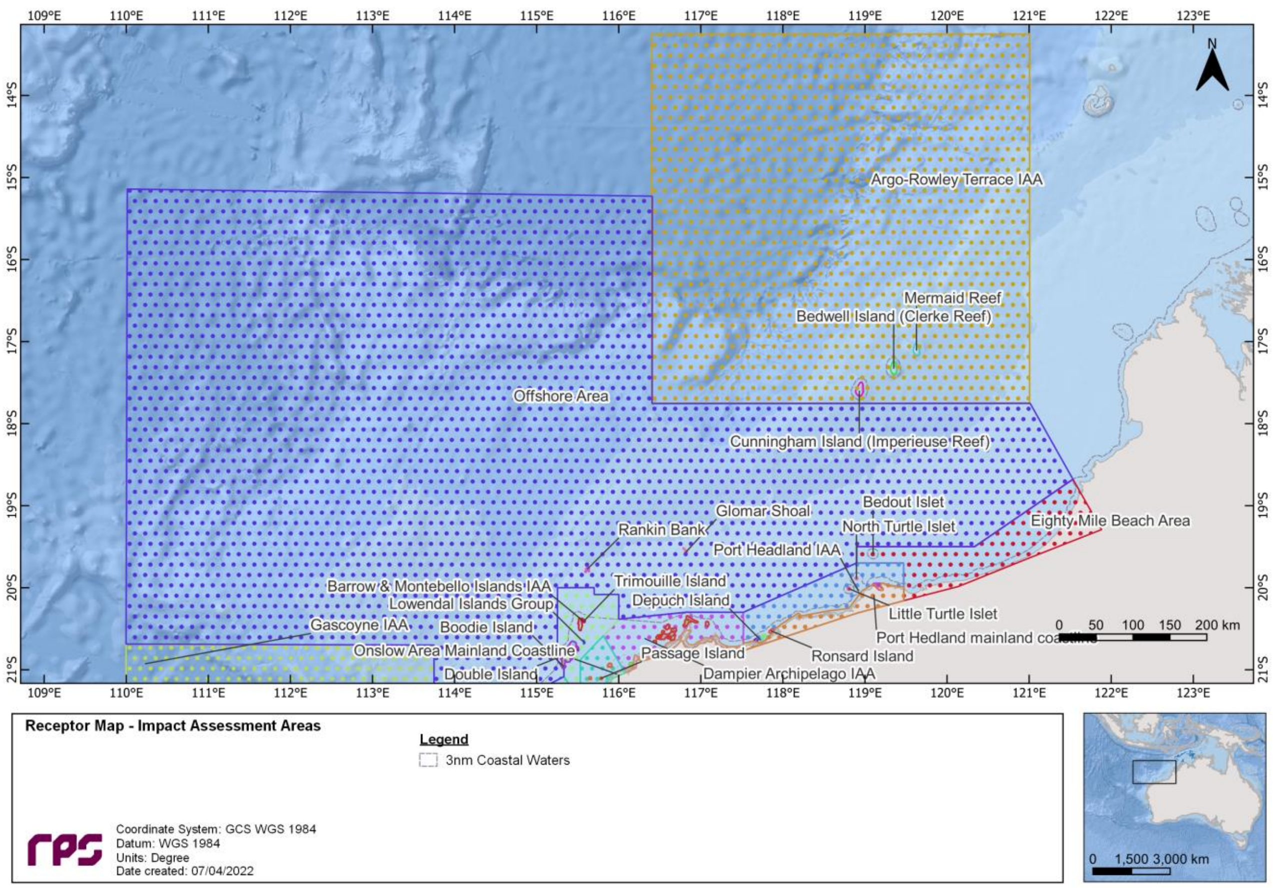


Figure 10.9 Receptor maps for Impact Assessment Areas (1 of 3).

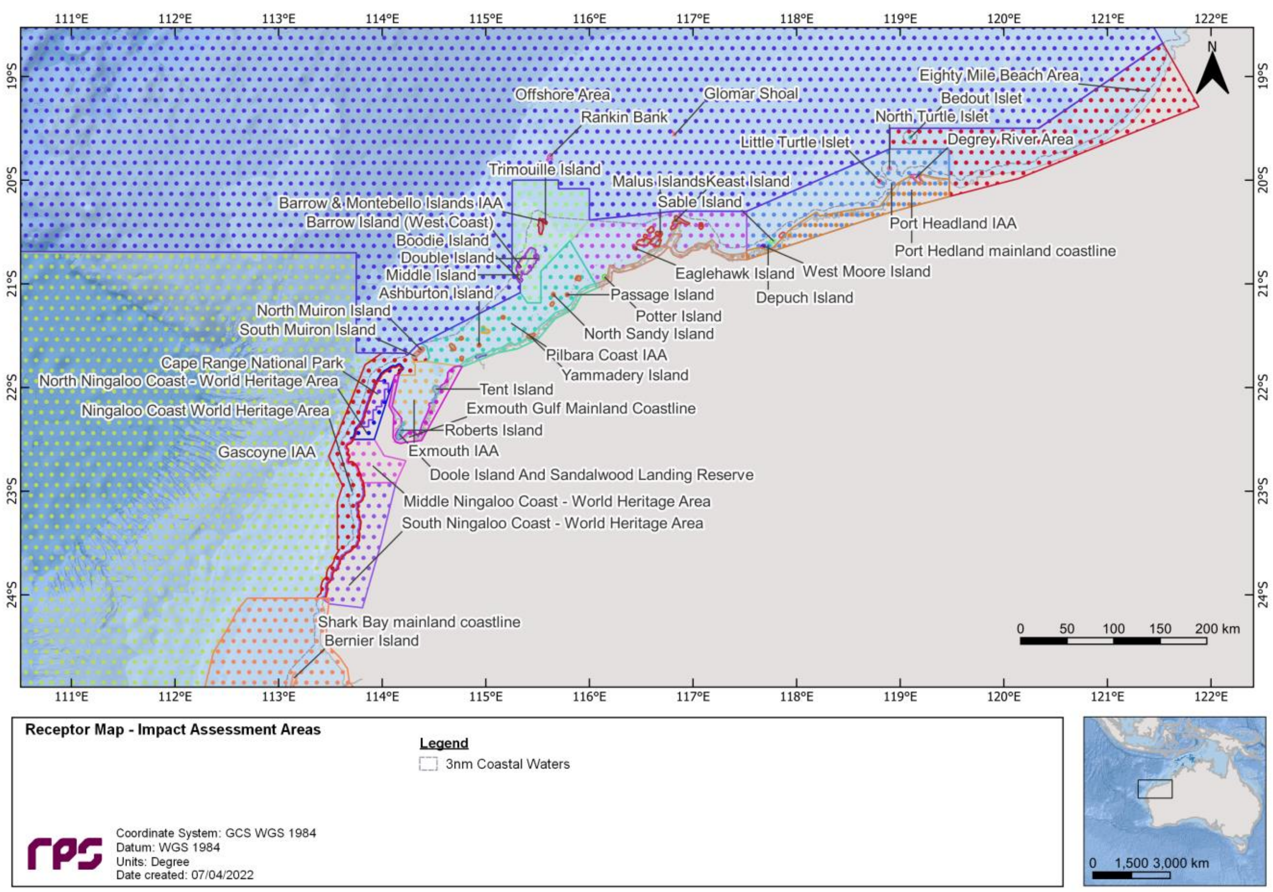


Figure 10.10 Receptor maps for Impact Assessment Areas (2 of 3).

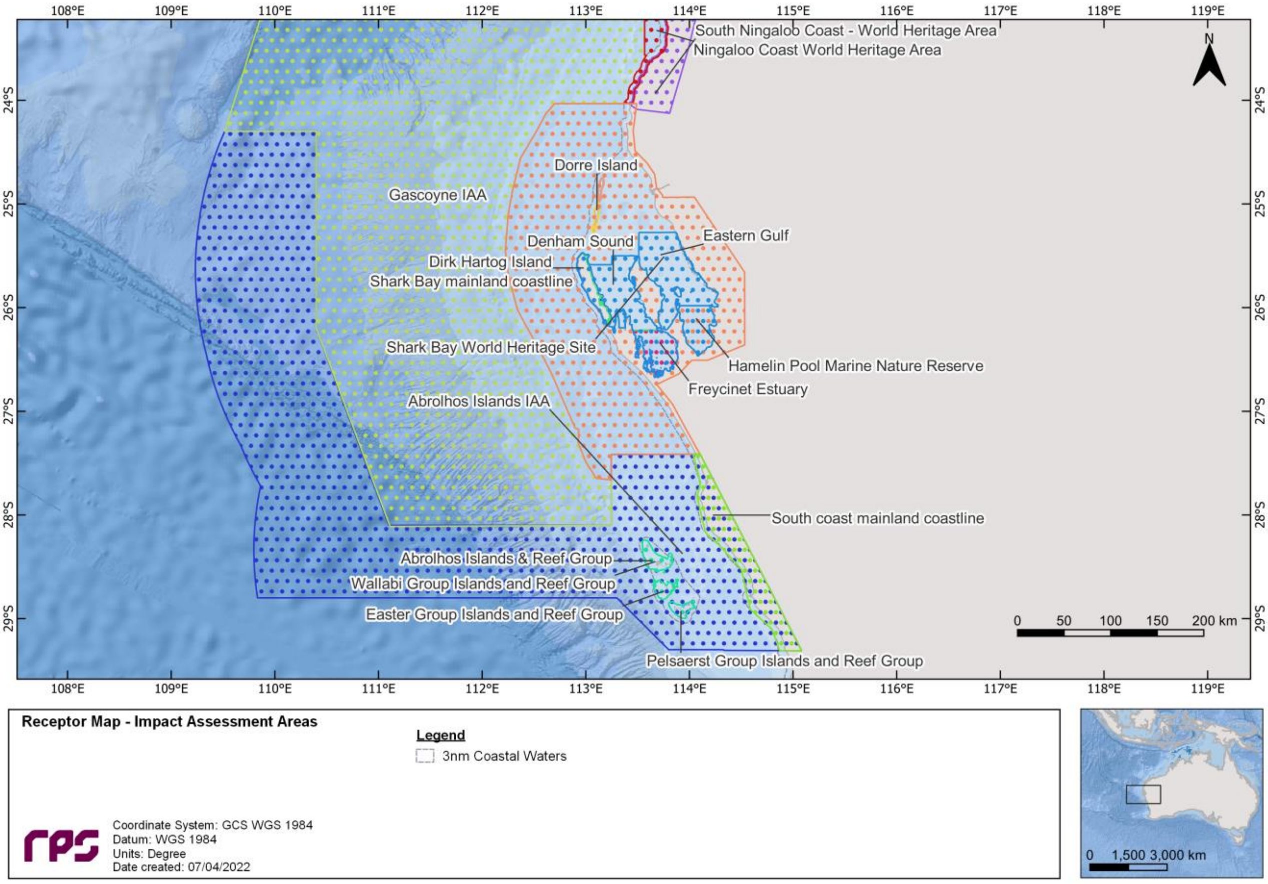


Figure 10.11 Receptor maps for Impact Assessment Areas (3 of 3).

11 RESULTS: WEST TRYAL ROCKS LOSS OF WELL CONTROL

This scenario examined a 387,180 bbl (or 61,555 m^3) subsea release of condensate over 90 days, from a LOWC. A total of 300 spill simulations were run for each of the three seasons (i.e. 100 spills per season) and tracked for 104 days.

Section 11.1 presents the seasonal (or stochastic) analysis results, while Section 11.2 presents the deterministic results.

11.1 Stochastic Analysis

11.1.1 Floating Condensate Exposure

Table 11.1 summarises the maximum distances from the release location to floating condensate exposure zones for each season.

The maximum distance from the release location to the low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) threshold was 251.7 West-southwest (summer), 45.9 km North-northwest (transitional) and 5.2 km West-northwest (transitional) and West-southwest (winter), respectively.

Table 11.2 summarises the potential floating condensate exposure to individual receptors during each season.

The Offshore Area IAA, Flatback Turtle - Internesting Buffer, Pygmy Blue Whale – Distribution, Wedge-tailed Shearwater - Breeding, Whale Shark – Foraging BIAs, Pilbara (offshore) IMCRA, and the Ancient coastline at 125 m depth contour KEF, which the release location resides within (see Section 10.3), and the Montebello AMP, Flatback Turtle - Nesting and Humpback Whale - Migration BIAs, Barrow & Montebello Islands IAA and the Continental Slope Demersal Fish Communities KEF were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low and moderate thresholds was 100% for all seasons for the receptors which the release location resides within. The probabilities of low and moderate exposure at the Flatback Turtle - Nesting BIA ranged between 91–95% and 17–25%, whilst the probabilities of low and moderate exposure at the Humpback Whale - Migration BIA ranged between 97–100% and 6–32%, respectively. The minimum times before low exposure for the Flatback Turtle - Nesting BIA and Humpback Whale - Migration BIA were 1.08 days and 0.71 days during summer conditions, respectively. Furthermore, the probability of exposure at the low threshold for the Montebello AMP and Continental Slope Demersal Fish Communities KEF was 77%, 60% and 59% during summer, transitional and winter conditions and 100%, 100% and 100% during summer, transitional and winter conditions, respectively. The corresponding minimum time before low exposure Montebello AMP and Continental Slope Demersal Fish Communities KEF was 1.21 days (winter) and 0.46 days (transitional and winter).

Figure 11.1 to Figure 11.3 present the zones of floating condensate exposure for each season.

Table 11.1 Maximum distances and directions travelled from the release location to floating condensate exposure for each season and threshold, following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating condensate exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	251.7	45.9	4.9
	Max. distance from release site (km) (99th percentile)	107.5	39.1	4.9
	Direction	West-southwest	North-northwest	North
Transitional	Max. distance from release site (km)	177.1	42.8	5.2
	Max. distance from release site (km) (99th percentile)	127.7	37.5	5.2
	Direction	North	Northeast	West-northwest
Winter	Max. distance from release site (km)	169.7	43.5	5.2
	Max. distance from release site (km) (99th percentile)	114	37.1	5.2
	Direction	Northeast	Northeast	West-southwest

Table 11.2 Summary of the potential floating condensate exposure to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
AMP	Montebello	77	11	-	1.63	6.67	-	60	11	-	2.17	53.33	-	59	13	-	1.21	22.21	-
BIA	Dugong - Breeding	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dugong - Calving	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dugong - Foraging	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dugong - Nursing	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Fairy Tern - Breeding	12	-	-	7.25	-	-	1	-	-	79.21	-	-	-	-	-	-	-	-
	Flatback Turtle - Aggregation	4	-	-	7.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flatback Turtle - Foraging	6	-	-	7.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flatback Turtle - Internesting	4	-	-	7.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flatback Turtle - Internesting Buffer*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
	Flatback Turtle - Mating	6	-	-	7.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Flatback Turtle - Nesting	91	25	-	1.08	6.54	-	95	17	-	2	3	-	91	22	-	1.71	20.75	-
	Green Turtle - Aggregation	4	-	-	7.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Green Turtle - Foraging	8	-	-	7.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Green Turtle - Internesting	8	-	-	7.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Green Turtle - Internesting Buffer	31	-	-	4.08	-	-	35	-	-	6.5	-	-	21	-	-	5.29	-	-
	Green Turtle - Mating	7	-	-	7.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Green Turtle - Nesting	24	-	-	4.08	-	-	13	-	-	41.08	-	-	6	-	-	38.96	-	-
	Hawksbill Turtle - Foraging	2	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hawksbill Turtle - Internesting Buffer	30	-	-	4.08	-	-	33	-	-	7.13	-	-	21	-	-	5.29	-	-
	Hawksbill Turtle - Mating	2	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hawksbill Turtle - Nesting	24	-	-	4.08	-	-	13	-	-	41.08	-	-	6	-	-	38.96	-	-
	Humpback Whale - Migration	97	32	-	0.71	5.96	-	100	18	-	0.79	14.21	-	100	6	-	0.83	17.25	-
	Lesser Crested Tern - Breeding	11	-	-	5.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Loggerhead Turtle - Internesting Buffer	16	-	-	5.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Loggerhead Turtle - Nesting	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pygmy Blue Whale – Distribution*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
	Roseate Tern - Breeding	8	-	-	7.25	-	-	2	-	-	76.75	-	-	-	-	-	-	-	-
	Wedge-tailed Shearwater – Breeding*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
	Whale Shark – Foraging*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
EEZ	Australian Exclusive Economic Zone *	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
IAA	Airlie Island	2	-	-	90.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	77	11	-	1.63	6.67	-	60	11	-	2.17	53.33	-	59	13	-	1.21	22.21	-
	Barrow Island Group	1	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	1	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Offshore Area*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5

Receptor		Summer						Transitional						Winter					
		Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)			Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
	Pilbara Coast IAA	2	-	-	90.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	2	-	-	90.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rankin Bank	2	-	-	48.96	-	-	5	-	-	75.13	-	-	6	-	-	42.29	-	-
IBRA	Cape Range	2	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Roebourne	3	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IMCRA	Ningaloo	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Northwest Shelf	75	7	-	0.92	7.5	-	69	13	-	1.83	5.17	-	83	10	-	1.25	2.71	-
	Pilbara (offshore)*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
KEF	Ancient coastline at 125 m depth contour*	100	100	92	0.04	0.04	0.5	100	100	98	0.04	0.04	0.29	100	100	99	0.04	0.04	0.5
	Continental Slope Demersal Fish Communities	100	53	-	0.67	2.83	-	100	46	-	0.46	3	-	100	61	-	0.46	3.04	-
MMA	Barrow Island	1	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MP	Montebello Islands	7	-	-	7.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RSB	Montebello Shoals	5	-	-	33.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Reef	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rankin Bank	2	-	-	48.96	-	-	5	-	-	75.13	-	-	6	-	-	42.29	-	-
	Tryal Rocks	5	-	-	48.83	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nearshore Waters	Airlie Island	2	-	-	90.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	1	-	-	67.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	1	-	-	10.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands	1	-	-	92.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
State Waters	Western Australia State Waters	9	-	-	7.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*The release location resides within the receptor boundaries.

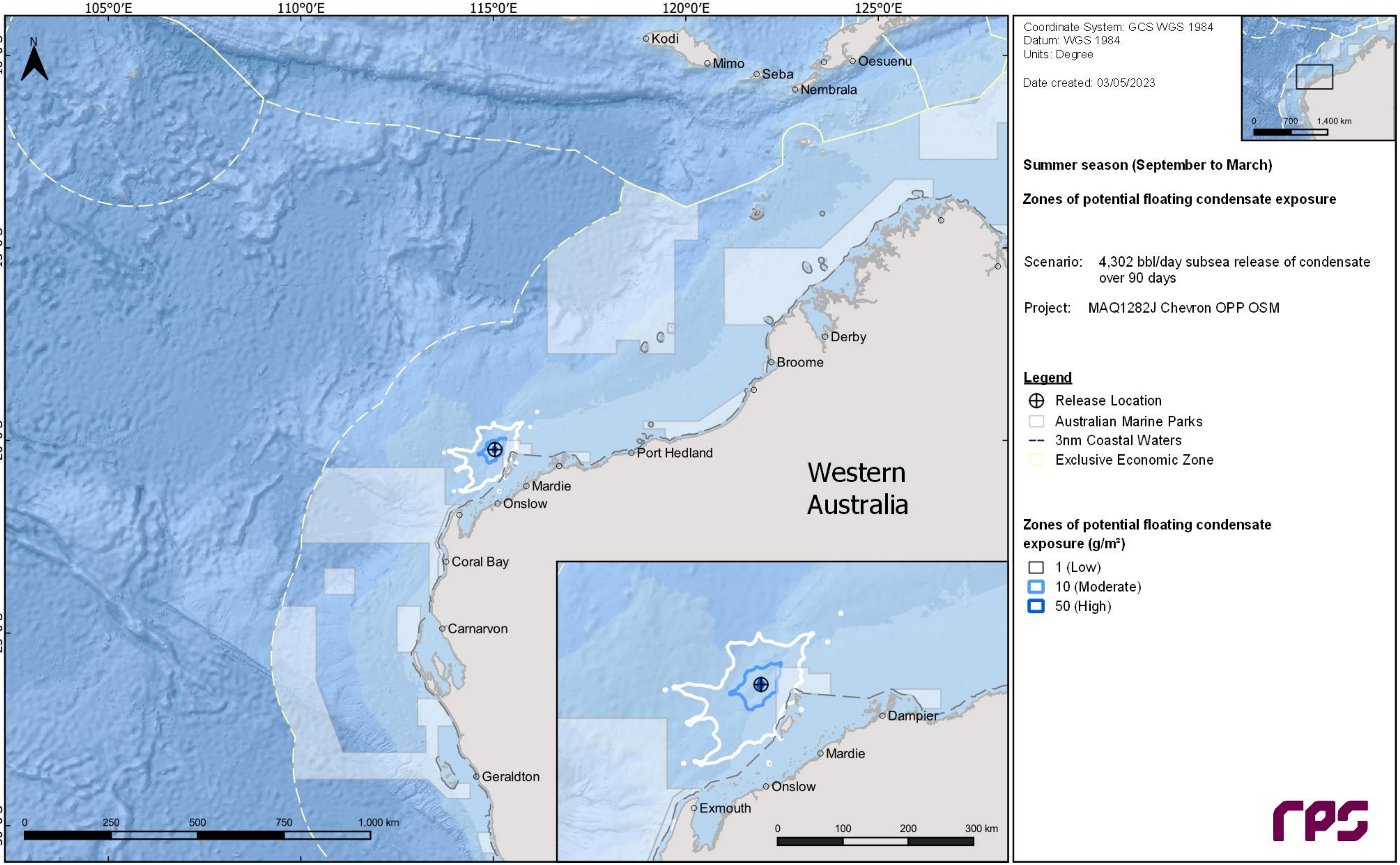


Figure 11.1 Zones of potential floating condensate exposure following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

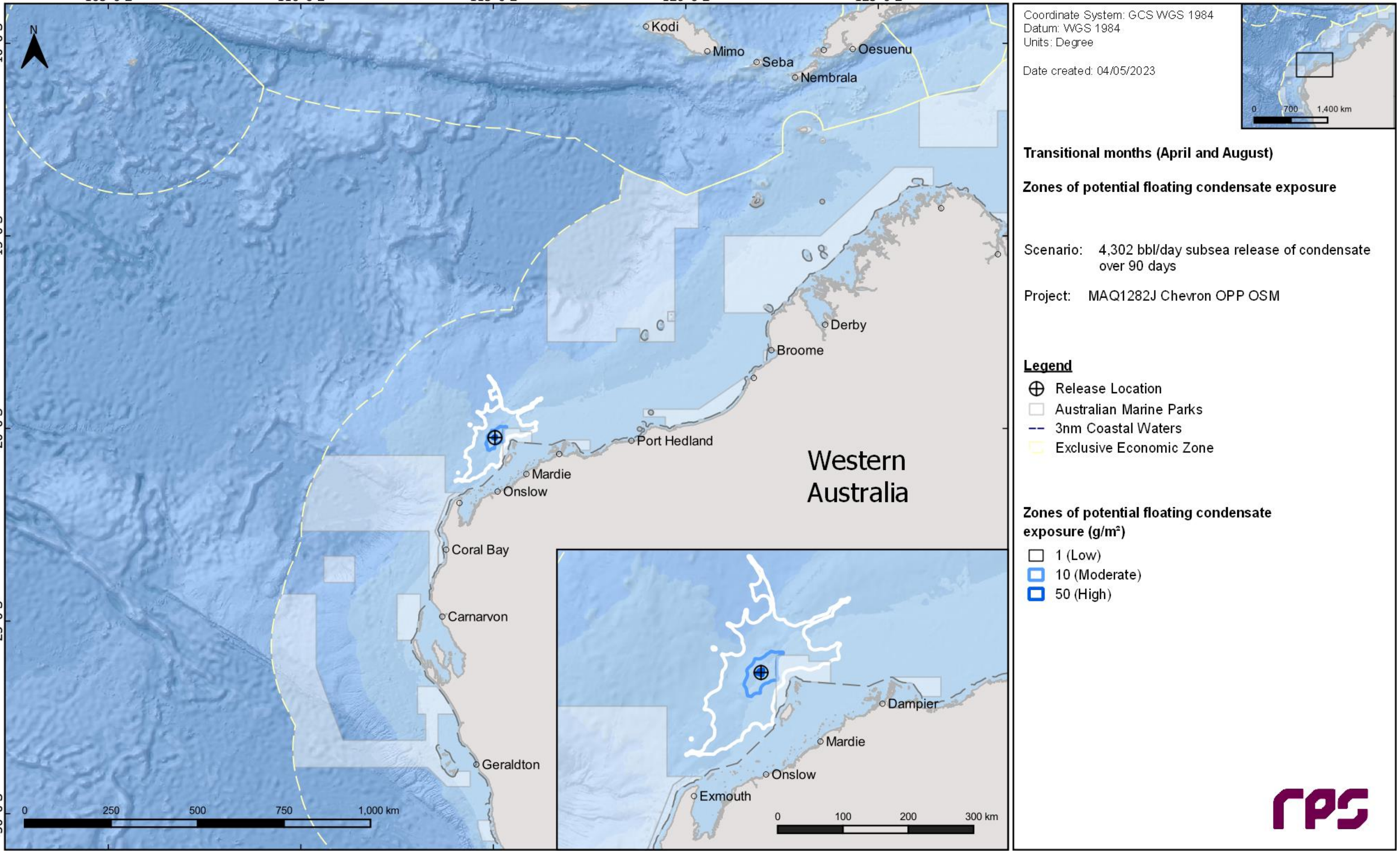


Figure 11.2 Zones of potential floating condensate exposure following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

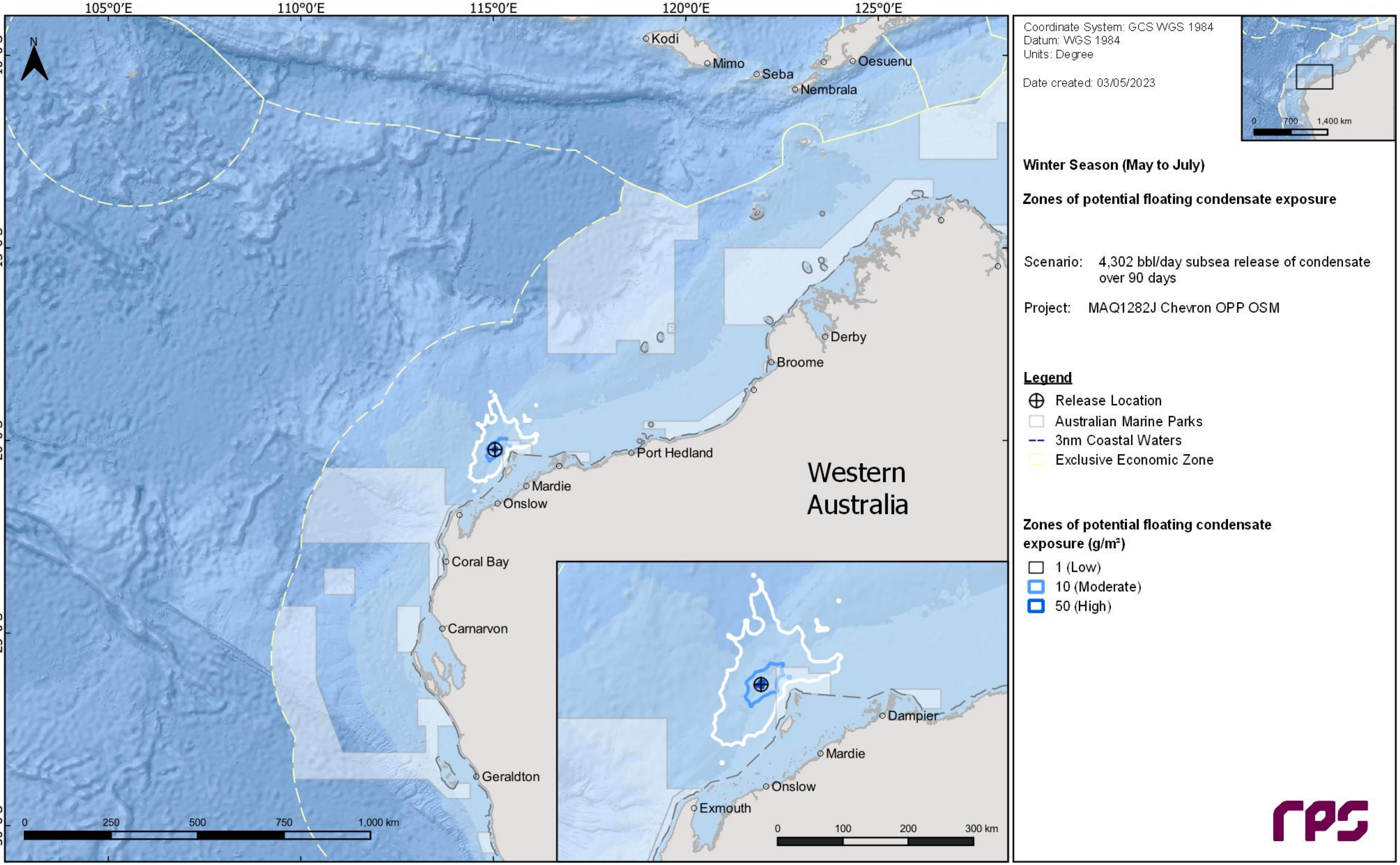


Figure 11.3 Zones of potential floating condensate exposure following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.2 Shoreline Accumulation

Table 11.3 presents a summary of the predicted shoreline accumulation during summer, transitional and winter seasons. The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 59%, while the minimum time before shoreline accumulation was 6.5 days and the maximum volume of oil ashore was 128 m^3.

No high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

Table 11.4 to Table 11.6 summarises the shoreline accumulation on individual receptors for each season.

During summer conditions, 82 shoreline receptors were predicted to record condensate accumulation at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA (38%). In comparison, during transitional and winter conditions, 40 and 42 shoreline receptors, respectively, were predicted to record accumulation, with the greatest probability during transitional season occurring at the Ningaloo Coast World Heritage Area IAA and the Muiron Islands (30%) and at the Ningaloo Coast World Heritage Area IAA only during winter (30%).

The maximum potential shoreline accumulation is presented for each season in Figure 11.4 to Figure 11.6.

Table 11.3 Summary of oil accumulation across all shorelines for each season and threshold, following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill trajectories per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of accumulation on any shoreline (%)	59	38	45
Absolute minimum time for visible oil to shore (days)	6.5	7.75	10.79
Maximum volume of hydrocarbons ashore (m^3) above the low threshold	128	27.5	4.8
Average volume of hydrocarbons ashore (m^3) above the low threshold	27.1	3.2	1.6
Maximum length of the shoreline at **10 g/m^2** (km)	155	39	13
Average shoreline length (km) at **10 g/m^2** (km)	47.2	9.2	4.9
Maximum length of the shoreline at **100 g/m^2** (km)	38	7	-
Average shoreline length (km) at **100 g/m^2** (km)	12.6	4.7	-
Maximum length of the shoreline at **1,000 g/m^2** (km)	-	-	-
Average shoreline length (km) at **1,000 g/m^2** (km)	-	-	-

Table 11.4 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories days during summer (September to the following March) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	26	15	-	7.63	8.5	-	35	507	14.4	53	18.8	7.8	-	31.7	19.2	-
	South Muiron Island	23	-	-	26.58	-	-	9	95	0.8	5.9	2.6	-	-	10.6	-	-
	Thevenard Island	13	-	-	11.54	-	-	9	32	0.6	1.6	2.4	-	-	5.8	-	-
	Serrurier Island	23	-	-	10.13	-	-	11	62	1.1	2.9	4.7	-	-	9.6	-	-
	Bessieres Island	13	-	-	15.17	-	-	11	56	0.4	1.7	1.5	-	-	3.8	-	-
	Locker Island	2	-	-	16.08	-	-	8	19	0.1	0.3	1	-	-	1	-	-
	Airlie Island	13	3	-	11.79	81.04	-	57	402	2	9.3	2.1	1.9	-	2.9	1.9	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	23	-	-	9	-	-	10	62	0.7	2.6	2.6	-	-	5.8	-	-
	Great Sandy Island	12	-	-	17.63	-	-	16	77	0.7	2.7	2	-	-	3.8	-	-
	North Sandy Island	9	-	-	13	-	-	17	50	0.4	1	1.5	-	-	1.9	-	-
	Passage Island	3	-	-	33.88	-	-	11	39	0.1	0.5	1	-	-	1	-	-
	Sholl Island	11	-	-	14.67	-	-	11	45	0.8	1.4	3.1	-	-	5.8	-	-
	Eaglehawk Island	2	-	-	92.46	-	-	8	13	0.1	0.2	1	-	-	1	-	-
	Enderby Island	2	-	-	92.79	-	-	5	13	0.2	0.5	1.4	-	-	1.9	-	-
	Rosemary Island	3	-	-	90.04	-	-	7	19	0.3	1	1.9	-	-	2.9	-	-
	Goodwyn Island	1	-	-	34.79	-	-	6	11	< 0.1	0.1	1	-	-	1	-	-
	Malus Islands	2	-	-	91.33	-	-	7	14	0.2	0.5	1	-	-	1	-	-
	Boodie Island	21	10	-	7.04	9.88	-	75	853	5.8	18.7	3.9	2.9	-	6.7	3.8	-
	Middle Island	23	11	-	7.13	8.17	-	86	706	8.3	23.4	6.1	3.8	-	7.7	5.8	-
	Double Island	2	-	-	67.08	-	-	7	17	0.1	0.4	1	-	-	1	-	-
	Bedwell Island (Clerke Reef)	2	-	-	82.5	-	-	10	13	0.2	0.2	1	-	-	1	-	-
	Cunningham Island (Imperieuse Reef)	2	-	-	88.29	-	-	4	14	0.2	0.6	1	-	-	1	-	-
	South Ningaloo Coast - World Heritage Area	1	-	-	68.25	-	-	6	16	0.4	0.8	1	-	-	1	-	-
	Middle Ningaloo Coast - World Heritage Area	16	-	-	11	-	-	8	60	2	5.2	6.7	-	-	14.4	-	-
	North Ningaloo Coast - World Heritage Area	25	4	-	10.33	11.08	-	10	172	2.7	9.4	9.2	1	-	26	1	-
	Cape Range National Park	21	3	-	10.25	10.54	-	11	256	4.7	36.5	12.1	4.2	-	44.2	6.7	-
	Ningaloo Coast World Heritage Area	35	6	-	9	10.54	-	12	256	5.8	29.9	14.1	2.4	-	39.4	5.8	-
	Argo-Rowley Terrace IAA	3	-	-	82.5	-	-	4	14	0.3	0.9	1.3	-	-	1.9	-	-
	Dampier Archipelago IAA	10	-	-	16.08	-	-	6	27	1.3	5.1	3.7	-	-	13.5	-	-
	Abutilon Island	4	-	-	32.33	-	-	12	37	0.1	0.4	1	-	-	1	-	-
	Varanus Island	14	-	-	9.33	-	-	11	44	0.4	0.9	1.6	-	-	2.9	-	-
	Trimouille Island	14	2	-	14.71	15.21	-	11	168	0.8	6.1	2.5	1.4	-	7.7	1.9	-
	Hermite Island	34	8	-	6.5	24.29	-	23	178	4.8	15.1	10	2.3	-	17.3	3.8	-
	Barrow & Montebello Islands IAA	38	17	-	6.5	7.67	-	27	853	27.8	124.6	37.4	14.3	-	83.7	36.6	-
	Pilbara Coast IAA	32	3	-	9.17	81.04	-	12	402	5.4	26.4	15	2.6	-	43.3	2.9	-
	Exmouth IAA	9	-	-	15.13	-	-	6	29	0.4	1	1	-	-	1	-	-
	Onslow Area Mainland Coastline	9	-	-	26.17	-	-	6	40	1.2	4.6	5	-	-	13.5	-	-
	Dampier mainland coastline	3	-	-	89.5	-	-	6	27	0.4	1.8	2.6	-	-	4.8	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Dampier Archipelago Island Group	4	-	-	34.79	-	-	6	19	0.6	2	3.4	-	-	5.8	-	-
	Lowendal Islands Group	15	-	-	9.33	-	-	11	44	0.4	1.3	1.7	-	-	3.8	-	-
	Montebello Islands Group	34	10	-	6.5	15.21	-	20	178	5.3	16	11	2.1	-	22.1	3.8	-
	Barrow Island Group	28	16	-	7.04	8.17	-	43	853	24.7	94.3	25.5	11.8	-	45.2	28.9	-
	Pilbara Mainland Coast	9	-	-	26.17	-	-	6	40	1.2	4.6	5	-	-	13.5	-	-
	Pilbara Coast Islands Group	27	3	-	10.13	81.04	-	15	402	3.2	13.2	8.6	1.9	-	22.1	1.9	-
	Exmouth Gulf Mainland Coastline	5	-	-	15.13	-	-	6	29	0.3	0.7	1	-	-	1	-	-
	Muiron Islands	29	-	-	9	-	-	9	95	1.4	8.5	4.1	-	-	15.4	-	-
	Airlie Island	13	3	-	11.79	81.04	-	57	402	2	9.3	2.1	1.9	-	2.9	1.9	-
	Ashburton	7	-	-	15.13	-	-	6	29	0.4	0.8	1	-	-	1	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	26	15	-	7.63	8.5	-	37	706	16.4	61.8	20.1	8.3	-	33.7	20.2	-
	Bessieres Island	13	-	-	15.17	-	-	11	56	0.4	1.7	1.5	-	-	3.8	-	-
	Boodie Island	22	11	-	7.04	8.63	-	78	853	7	22.6	4.6	3.3	-	7.7	4.8	-
	Carnarvon	1	-	-	68.25	-	-	6	16	0.4	0.8	1	-	-	1	-	-
	Clerke Reef	2	-	-	82.5	-	-	10	13	0.2	0.2	1	-	-	1	-	-
	Cunningham Island	1	-	-	88.29	-	-	4	10	0.2	0.4	1	-	-	1	-	-
	Direction Island	3	-	-	32.58	-	-	13	32	0.2	0.4	1	-	-	1	-	-
	Eaglehawk Island	2	-	-	92.46	-	-	8	13	0.1	0.2	1	-	-	1	-	-
	Enderby Island	2	-	-	92.79	-	-	5	13	0.2	0.5	1.4	-	-	1.9	-	-
	Exmouth	26	6	-	10.25	10.54	-	10	256	7.5	46.4	22.7	2.7	-	63.5	7.7	-
	Flat Island	18	-	-	10.42	-	-	12	45	0.4	1.3	2	-	-	2.9	-	-
	Fly Island	3	-	-	24.25	-	-	7	14	0.1	0.3	1	-	-	1	-	-
	Goodwyn Island	1	-	-	34.79	-	-	6	11	< 0.1	0.1	1	-	-	1	-	-
Shoreline	Imperieuse Reef	1	-	-	90.88	-	-	5	14	0.2	0.5	1	-	-	1	-	-
	Karratha	7	-	-	26.17	-	-	6	40	1.4	6.7	7.8	-	-	20.2	-	-
	Kendrew Island	1	-	-	92.13	-	-	8	13	< 0.1	0.2	1	-	-	1	-	-
	Locker Island	2	-	-	16.08	-	-	8	19	0.1	0.3	1	-	-	1	-	-
	Lowendal Island	20	8	-	7.63	32.13	-	19	224	2.3	7	5.4	1.3	-	9.6	1.9	-
	Malus Island	2	-	-	91.33	-	-	7	14	0.2	0.5	1	-	-	1	-	-
	Mary Anne Group	9	2	-	15.5	92.17	-	14	130	0.9	4.7	2.7	1	-	6.7	1	-
	Middle Island	24	11	-	7.08	8.17	-	86	706	10.4	32.6	7.4	5.1	-	9.6	7.7	-
	Montebello Islands	36	13	-	6.5	7.67	-	20	192	8.2	24.9	16.6	3.3	-	31.7	6.7	-
	Muiron Islands	29	-	-	9	-	-	9	95	1.4	8.5	4.1	-	-	15.4	-	-
	Observation Island	6	-	-	12.75	-	-	11	41	0.2	0.8	1.4	-	-	1.9	-	-
	Passage Islands	14	-	-	13	-	-	11	86	3.6	8.2	10.9	-	-	21.2	-	-
	Peak Island	14	-	-	9.17	-	-	13	40	0.2	0.5	1	-	-	1	-	-
	Rivoli Islands	1	-	-	66.83	-	-	6	17	0.1	0.2	1	-	-	1	-	-
	Rosemary Island	3	-	-	90.04	-	-	6	19	0.3	1	1.9	-	-	2.9	-	-
	Round Island	6	-	-	28.67	-	-	11	25	0.1	0.3	1	-	-	1	-	-
	Serrurier Island	23	-	-	10.13	-	-	11	62	1.1	2.9	4.7	-	-	9.6	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Sunday Island	14	-	-	18	-	-	12	49	0.2	1	1.2	-	-	1.9	-	-
	Table Island	7	-	-	22.04	-	-	11	27	0.1	0.3	1	-	-	1	-	-
	Thevenard Island	13	-	-	11.54	-	-	9	32	0.6	1.6	2.4	-	-	5.8	-	-
	Tortoise Island	6	-	-	10.96	-	-	10	18	0.1	0.2	1	-	-	1	-	-

Table 11.5 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories days during transitional (April and August) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	5	3	-	78.54	80.67	-	20	158	2.5	6.5	7.1	1.6	-	8.7	1.9	-
	South Muiron Island	19	-	-	7.75	-	-	8	42	0.5	1.1	1.8	-	-	3.8	-	-
	Thevenard Island	9	-	-	21.04	-	-	7	22	0.3	0.6	1.1	-	-	1.9	-	-
	Serrurier Island	6	-	-	24.58	-	-	8	24	0.3	0.8	1.4	-	-	1.9	-	-
	Bessieres Island	4	1	-	11.13	23.75	-	13	121	0.5	2.3	2.4	1	-	2.9	1	-
	Locker Island	1	-	-	96.46	-	-	6	10	< 0.1	0.1	1	-	-	1	-	-
	Airlie Island	1	-	-	59.13	-	-	8	13	0.2	0.2	1	-	-	1	-	-
	Ashburton Island	1	-	-	97.13	-	-	9	14	0.1	0.2	1	-	-	1	-	-
	North Muiron Island	27	-	-	8.08	-	-	9	38	0.5	1.1	1.8	-	-	3.8	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passage Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Goodwyn Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Malus Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	5	5	-	77.71	78.75	-	68	176	5	7.4	5.2	2.5	-	5.8	3.8	-
	Middle Island	5	5	-	77.79	78.63	-	61	221	5.1	8.3	6.7	1.7	-	6.7	1.9	-
	Double Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bedwell Island (Clerke Reef)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island (Imperieuse Reef)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	10	-	-	43.96	-	-	8	35	0.7	1.3	2.6	-	-	3.8	-	-
	Cape Range National Park	7	-	-	43.79	-	-	6	41	0.4	0.9	1.4	-	-	1.9	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Ningaloo Coast World Heritage Area	30	-	-	7.75	-	-	8	42	1.1	2.5	3.6	-	-	8.7	-	-
	Argo-Rowley Terrace IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Abutilon Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Varanus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	5	-	-	80.75	-	-	8	58	1	3.8	9	-	-	11.5	-	-
	Barrow & Montebello Islands IAA	6	5	-	77.71	78.63	-	12	221	4.9	27.5	25.7	5.2	-	37.5	6.7	-
	Pilbara Coast IAA	19	1	-	11.13	23.75	-	9	121	0.9	3.1	3.3	1	-	6.7	1	-
	Exmouth IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	5	-	-	80.75	-	-	8	58	1	3.9	9	-	-	11.5	-	-
	Barrow Island Group	5	5	-	77.71	78.63	-	28	221	7.8	22.2	19	5.2	-	20.2	6.7	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	11	1	-	11.13	23.75	-	11	121	0.6	2.5	1.9	1	-	3.8	1	-
	Exmouth Gulf Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	30	-	-	7.75	-	-	8	42	0.9	2.2	2.8	-	-	6.7	-	-
Shoreline	Airlie Island	1	-	-	59.13	-	-	8	13	0.2	0.2	1	-	-	1	-	-
	Ashburton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	1	-	-	97.13	-	-	9	14	0.1	0.2	1	-	-	1	-	-
	Barrow Island	5	5	-	77.79	78.63	-	24	221	3.7	10.4	9	2.5	-	10.6	3.8	-
	Bessieres Island	4	1	-	11.13	23.75	-	13	121	0.5	2.3	2.4	1	-	2.9	1	-
	Boodie Island	5	5	-	77.71	78.75	-	69	176	5.9	9.1	6.2	2.7	-	6.7	4.8	-
	Carnarvon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Clerke Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Direction Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	10	-	-	43.79	-	-	7	41	0.7	2	3.6	-	-	5.8	-	-
	Flat Island	9	-	-	28.42	-	-	8	25	0.3	0.7	1.5	-	-	2.9	-	-
	Fly Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Goodwyn Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Imperieuse Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Kendrew Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Locker Island	1	-	-	96.46	-	-	6	10	< 0.1	0.1	1	-	-	1	-	-
	Lowendal Island	2	-	-	85.38	-	-	5	15	0.1	0.3	1	-	-	1	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Malus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	5	5	-	77.75	78.63	-	58	221	6.3	11	8.7	2.1	-	8.7	2.9	-
	Montebello Islands	6	-	-	80.75	-	-	8	58	1.1	5	9.5	-	-	16.4	-	-
	Muiron Islands	30	-	-	7.75	-	-	8	42	0.9	2.2	2.8	-	-	6.7	-	-
	Observation Island	2	-	-	91.17	-	-	8	14	0.1	0.3	1	-	-	1	-	-
	Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Peak Island	12	-	-	29.29	-	-	15	34	0.2	0.4	1	-	-	1	-	-
	Rivoli Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Round Island	4	-	-	85.33	-	-	21	40	0.3	0.5	1	-	-	1	-	-
	Serrurier Island	6	-	-	24.58	-	-	8	24	0.3	0.8	1.4	-	-	1.9	-	-
	Sunday Island	3	-	-	31.88	-	-	7	19	0.1	0.3	1	-	-	1	-	-
	Table Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	9	-	-	21.04	-	-	7	22	0.3	0.6	1.1	-	-	1.9	-	-
	Tortoise Island	1	-	-	96.13	-	-	7	11	< 0.1	0.1	1	-	-	1	-	-

Table 11.6 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at WTR Well 5. The results were calculated from 100 spill trajectories days during winter (May to July) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Barrow Island (West Coast)	2	-	-	31.96	-	-	6	15	0.1	0.2	1	-	-	1	-	-
	South Muiron Island	17	-	-	16.08	-	-	7	26	0.4	1.2	2	-	-	3.8	-	-
	Thevenard Island	8	-	-	19.42	-	-	7	18	0.3	0.7	1.3	-	-	1.9	-	-
	Serrurier Island	10	-	-	19.29	-	-	7	38	0.3	1.1	1.6	-	-	2.9	-	-
	Bessieres Island	4	-	-	28.38	-	-	7	20	0.1	0.4	1	-	-	1	-	-
	Locker Island	1	-	-	59.92	-	-	8	12	< 0.1	0.1	1	-	-	1	-	-
	Airlie Island	1	-	-	40.33	-	-	7	17	0.1	0.2	1	-	-	1	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	25	-	-	10.79	-	-	9	32	0.4	1.4	1.8	-	-	4.8	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passage Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Goodwyn Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Malus Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	3	-	-	39.96	-	-	9	27	0.2	0.3	1	-	-	1	-	-
	Middle Island	2	-	-	51.71	-	-	6	12	0.1	0.2	1	-	-	1	-	-
	Double Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bedwell Island (Clerke Reef)	1	-	-	98.71	-	-	5	10	0.1	0.2	1	-	-	1	-	-
	Cunningham Island (Imperieuse Reef)	5	-	-	72.13	-	-	6	19	0.5	0.9	1.5	-	-	2.9	-	-
	South Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	11	-	-	33.54	-	-	6	23	0.6	1.2	1.9	-	-	3.8	-	-
	North Ningaloo Coast - World Heritage Area	7	-	-	18.79	-	-	8	34	0.6	1.6	2.6	-	-	3.8	-	-
	Cape Range National Park	5	-	-	18.5	-	-	6	20	0.3	1.2	1.3	-	-	1.9	-	-
	Ningaloo Coast World Heritage Area	30	-	-	10.79	-	-	7	34	0.9	3.2	3.8	-	-	9.6	-	-
	Argo-Rowley Terrace IAA	5	-	-	72.13	-	-	6	19	0.6	1	1.7	-	-	2.9	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Abutilon Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Varanus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	6	-	-	31.96	-	-	7	27	0.3	0.7	1.1	-	-	1.9	-	-
	Pilbara Coast IAA	17	-	-	19.29	-	-	7	43	0.7	2.7	3.9	-	-	10.6	-	-
	Exmouth IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	6	-	-	31.96	-	-	7	27	0.3	0.7	1.1	-	-	1.9	-	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	11	-	-	19.29	-	-	7	38	0.4	1.5	2	-	-	3.8	-	-
	Exmouth Gulf Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	29	-	-	10.79	-	-	8	32	0.6	2	2.8	-	-	5.8	-	-
Shoreline	Airlie Island	1	-	-	40.33	-	-	7	17	0.1	0.2	1	-	-	1	-	-
	Ashburton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	3	-	-	31.96	-	-	6	15	0.2	0.3	1	-	-	1	-	-
	Bessieres Island	4	-	-	28.38	-	-	7	20	0.1	0.4	1	-	-	1	-	-
	Boodie Island	3	-	-	39.96	-	-	9	27	0.2	0.3	1	-	-	1	-	-
	Carnarvon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Clerke Reef	1	-	-	98.71	-	-	5	10	0.1	0.2	1	-	-	1	-	-
	Cunningham Island	1	-	-	95.58	-	-	5	11	0.2	0.3	1	-	-	1	-	-
	Direction Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exmouth	17	-	-	18.5	-	-	6	34	0.8	2.5	2.7	-	-	4.8	-	-
Flat Island	8	-	-	21.29	-	-	9	25	0.3	0.7	1.4	-	-	2.9	-	-
Fly Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goodwyn Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imperieuse Reef	5	-	-	72.13	-	-	7	19	0.4	0.8	1.5	-	-	2.9	-	-
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kendrew Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Locker Island	1	-	-	59.92	-	-	8	12	< 0.1	0.1	1	-	-	1	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Island	2	-	-	51.71	-	-	6	12	0.1	0.2	1	-	-	1	-	-
Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Muiron Islands	29	-	-	10.79	-	-	8	32	0.6	2	2.8	-	-	5.8	-	-
Observation Island	2	-	-	37.04	-	-	8	16	0.1	0.2	1	-	-	1	-	-
Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	13	-	-	20.08	-	-	13	43	0.2	0.5	1	-	-	1	-	-
Rivoli Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round Island	4	-	-	21.67	-	-	8	18	0.1	0.2	1	-	-	1	-	-
Serrurier Island	10	-	-	19.29	-	-	7	38	0.3	1.1	1.6	-	-	2.9	-	-
Sunday Island	4	-	-	22.83	-	-	8	18	0.1	0.3	1	-	-	1	-	-
Table Island	3	-	-	35.08	-	-	10	22	0.1	0.3	1	-	-	1	-	-
Thevenard Island	8	-	-	19.42	-	-	7	18	0.3	0.7	1.3	-	-	1.9	-	-
Tortoise Island	1	-	-	37.08	-	-	10	19	0.1	0.2	1	-	-	1	-	-

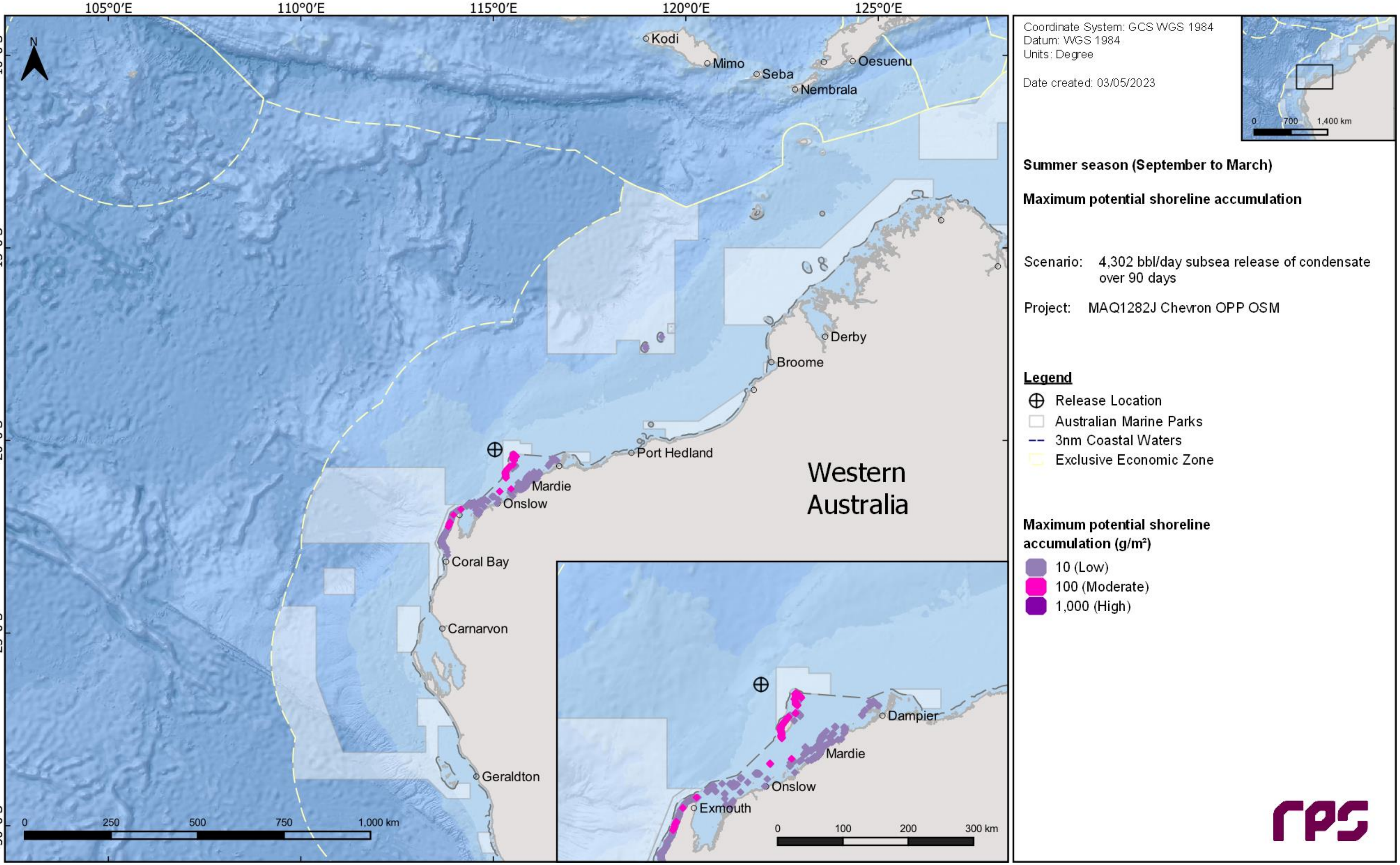


Figure 11.4 Maximum potential shoreline accumulation following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

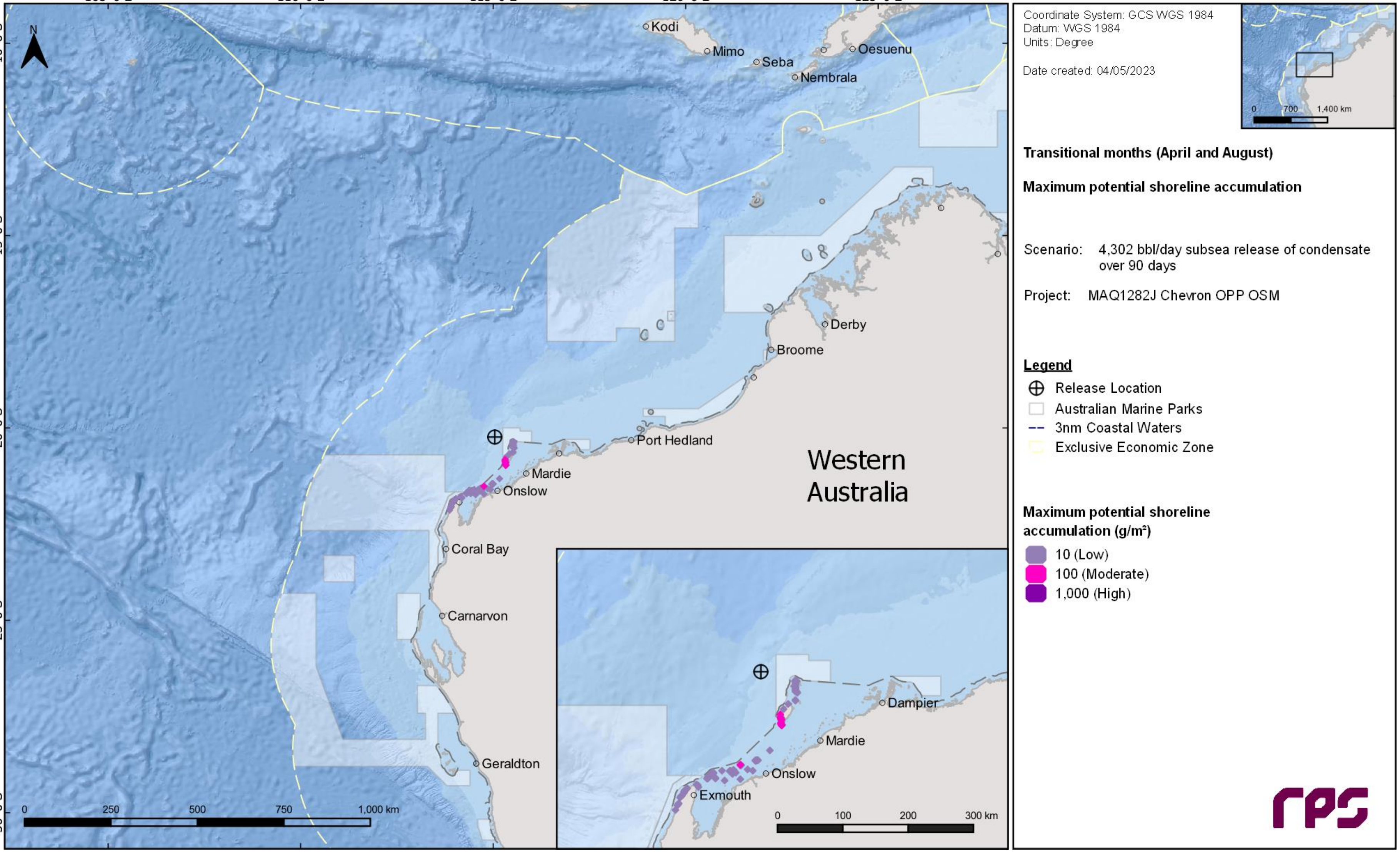


Figure 11.5 Maximum potential shoreline accumulation following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

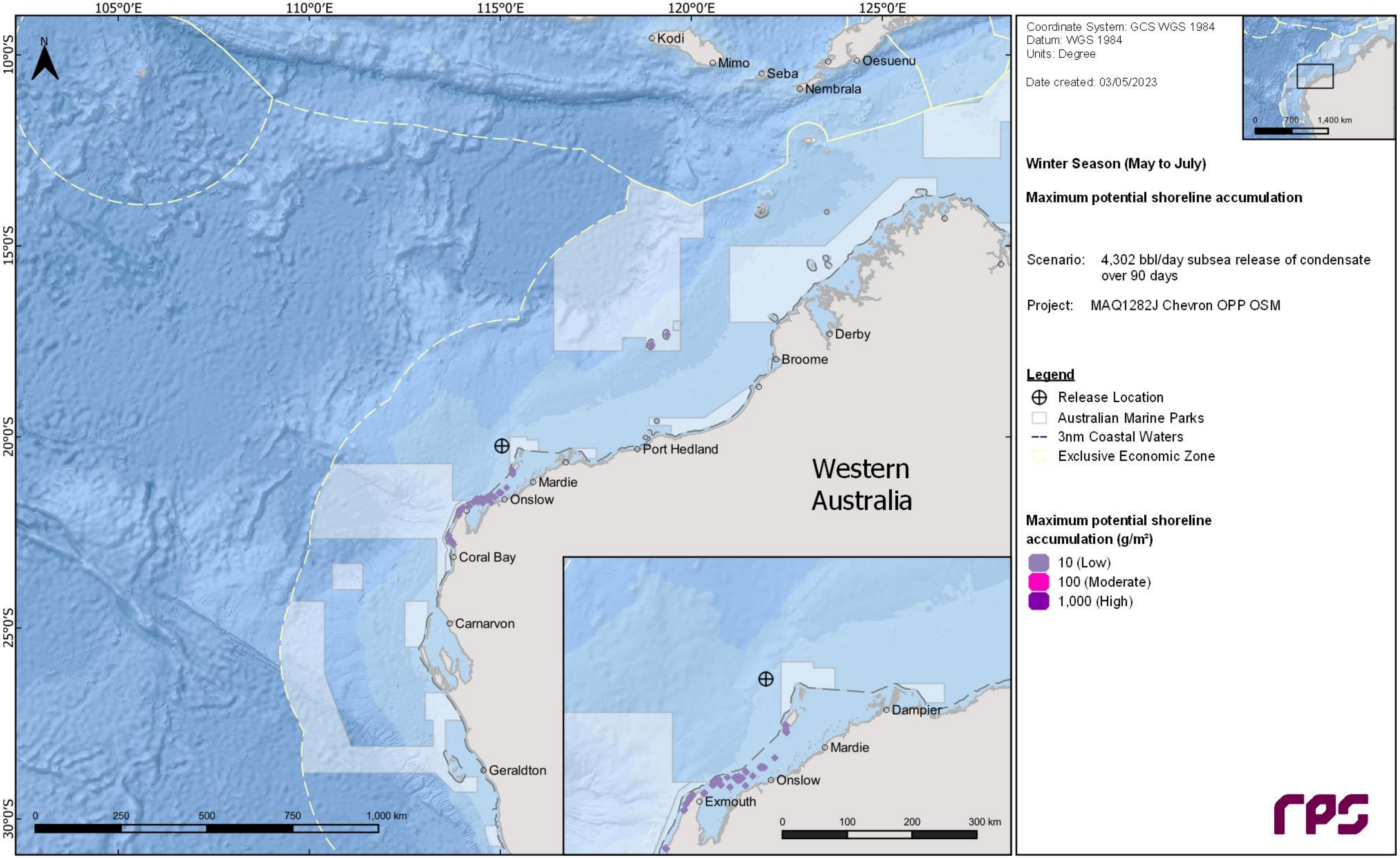


Figure 11.6 Maximum potential shoreline accumulation following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3 Water Column Exposure

11.1.3.1 Dissolved Hydrocarbons

Table 11.7 summarises the seasonal probability of exposure to individual receptors from dissolved hydrocarbons in the 0-10 m depth layer, at the low (≥ 10 ppb), moderate (≥ 50 ppb) and high (≥ 400 ppb) exposure thresholds.

In the surface (0-10 m) depth layer, a total of 14, 20, and 10 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter, respectively. Excluding the 4 BIAs that the release location resides within (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging) (see Section 10.3), the highest probabilities of exposure to low dissolved hydrocarbons were predicted as 7% for Humpback Whale - Migration during summer, 12% Humpback Whale - Migration during transitional, and 4% for Flatback Turtle – Nesting and Humpback Whale - Migration during winter conditions.

A total of 2, 3 and 1 AMPs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold during summer, transitional and winter, respectively with the highest probability predicted at the Montebello AMP (3%) during transitional and winter.

Additionally, 3, 4 and 2 IAAs and 3, 3 and 2 IMCRAs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold during summer, transitional and winter, respectively.

Furthermore, 3 (summer), 4 (transitional) and 2 (winter) KEFs were predicted to be exposed to dissolved hydrocarbons at, or above the low threshold.

Figure 11.7 to Figure 11.9 presents the zones of potential instantaneous dissolved hydrocarbon exposure for the 0-10 m depth layer for the summer, transitional and winter periods, respectively.

The same maps for the 10-20 m depth layer are presented in Figure 11.10 to Figure 11.12.

Table 11.7 Predicted probability and maximum dissolved hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill simulations per season.

	Receptor	Summer							Transitional							Winter						
		Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)		
			Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High
AMP	Gascoyne	17.9	2	-	-	17.38	-	-	12.4	1	-	-	33.54	-	-	6.7	-	-	-	-	-	-
	Montebello	13.7	1	-	-	22.67	-	-	18	3	-	-	7.75	-	-	15.3	3	-	-	22.58	-	-
	Ningaloo	9.8	-	-	-	-	-	-	17.8	1	-	-	51.83	-	-	6.4	-	-	-	-	-	-
BIA	Dugong - Breeding	6.4	-	-	-	-	-	-	12.3	1	-	-	66.04	-	-	5.4	-	-	-	-	-	-
	Dugong - Calving	6.4	-	-	-	-	-	-	12.3	1	-	-	66.04	-	-	5.4	-	-	-	-	-	-
	Dugong - Foraging	6.4	-	-	-	-	-	-	12.3	1	-	-	66.04	-	-	5.4	-	-	-	-	-	-
	Dugong - Nursing	6.4	-	-	-	-	-	-	12.3	1	-	-	66.04	-	-	5.4	-	-	-	-	-	-
	Fairy Tern - Breeding	7.7	-	-	-	-	-	-	16.7	1	-	-	65.83	-	-	6.2	-	-	-	-	-	-
	Flatback Turtle - Internesting Buffer*	44.4	100	-	-	0.29	-	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
	Flatback Turtle - Nesting	32.2	5	-	-	4.71	-	-	32.9	5	-	-	5.67	-	-	23.1	4	-	-	5.71	-	-
	Green Turtle - Internesting Buffer	20.1	1	-	-	5.25	-	-	17.6	1	-	-	51.17	-	-	10.5	1	-	-	81.71	-	-
	Green Turtle - Nesting	20.1	1	-	-	5.5	-	-	17.8	1	-	-	51.75	-	-	10.5	1	-	-	81.71	-	-
	Hawksbill Turtle - Internesting Buffer	20.3	1	-	-	5.25	-	-	17.8	2	-	-	41.46	-	-	10.5	1	-	-	81.71	-	-
	Hawksbill Turtle - Nesting	20.1	1	-	-	5.5	-	-	12.3	1	-	-	66.33	-	-	10.5	1	-	-	81.71	-	-
	Humpback Whale - Migration	56.3	7	1	-	4.71	68.42	-	54.5	12	1	-	2.63	68.46	-	42.3	4	-	-	3.79	-	-
	Lesser Crested Tern - Breeding	11.6	1	-	-	79.33	-	-	15.9	1	-	-	84.29	-	-	7.1	-	-	-	-	-	-
	Loggerhead Turtle - Internesting Buffer	10.9	1	-	-	37.54	-	-	17.8	2	-	-	41.46	-	-	7.5	-	-	-	-	-	-
	Loggerhead Turtle - Nesting	9.8	-	-	-	-	-	-	17.8	1	-	-	51.75	-	-	7.4	-	-	-	-	-	-
	Pygmy Blue Whale – Distribution*	56.3	100	1	-	0.29	68.42	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
	Pygmy Blue Whale - Foraging	17.9	2	-	-	40.67	-	-	10.2	1	-	-	33.67	-	-	6.4	-	-	-	-	-	-
	Roseate Tern - Breeding	12.5	1	-	-	78.71	-	-	10.2	1	-	-	41.46	-	-	9.4	-	-	-	-	-	-
	Wedge-tailed Shearwater – Breeding*	56.3	100	1	-	0.29	68.42	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
	Whale Shark – Foraging*	44.4	100	-	-	0.29	-	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
EEZ	Australian Exclusive Economic Zone*	56.3	100	1	-	0.29	68.42	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
IAA	Barrow & Montebello Islands IAA	13.7	1	-	-	22.67	-	-	18	3	-	-	7.75	-	-	15.3	3	-	-	22.58	-	-
	Gascoyne IAA	17.9	2	-	-	17.38	-	-	12.4	1	-	-	33.54	-	-	6.7	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	9.8	-	-	-	-	-	-	17.8	1	-	-	51.83	-	-	6.4	-	-	-	-	-	-
	Offshore Area*	56.3	100	1	-	0.29	68.42	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
IMCRA	Ningaloo	10.8	1	-	-	26.17	-	-	20	1	-	-	51.25	-	-	7.4	-	-	-	-	-	-
	Northwest Shelf	16.2	2	-	-	3.46	-	-	22.1	3	-	-	31.17	-	-	14.3	1	-	-	18.5	-	-
	Pilbara (offshore)*	44.4	100	-	-	0.29	-	-	54.5	100	1	-	0.33	68.46	-	44.8	100	-	-	0.29	-	-
KEF	Ancient coastline at 125 m depth contour*	37.8	100	-	-	0.29	-	-	42.9	100	-	-	0.33	-	-	42.3	100	-	-	0.29	-	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	17.3	2	-	-	25.79	-	-	20	1	-	-	22.42	-	-	9	-	-	-	-	-	-

	Receptor	Summer							Transitional							Winter						
		Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)		
			Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High
	Commonwealth waters adjacent to Ningaloo Reef	9.8	-	-	-	-	-	-	17.8	1	-	-	51.83	-	-	6.4	-	-	-	-	-	-
	Continental Slope Demersal Fish Communities	45.8	11	-	-	1.75	68.42	-	49.2	14	-	-	2.5	-	-	40.4	21	-	-	3.79	-	-
MP	Ningaloo	5.2	-	-	-	-	-	-	12.3	1	-	-	66.29	-	-	5.4	-	-	-	-	-	-
State Waters	Western Australia State Waters	12.5	1	-	-	79	-	-	12.3	1	-	-	66.29	-	-	6.5	-	-	-	-	-	-

*The release location resides within the receptor boundaries.

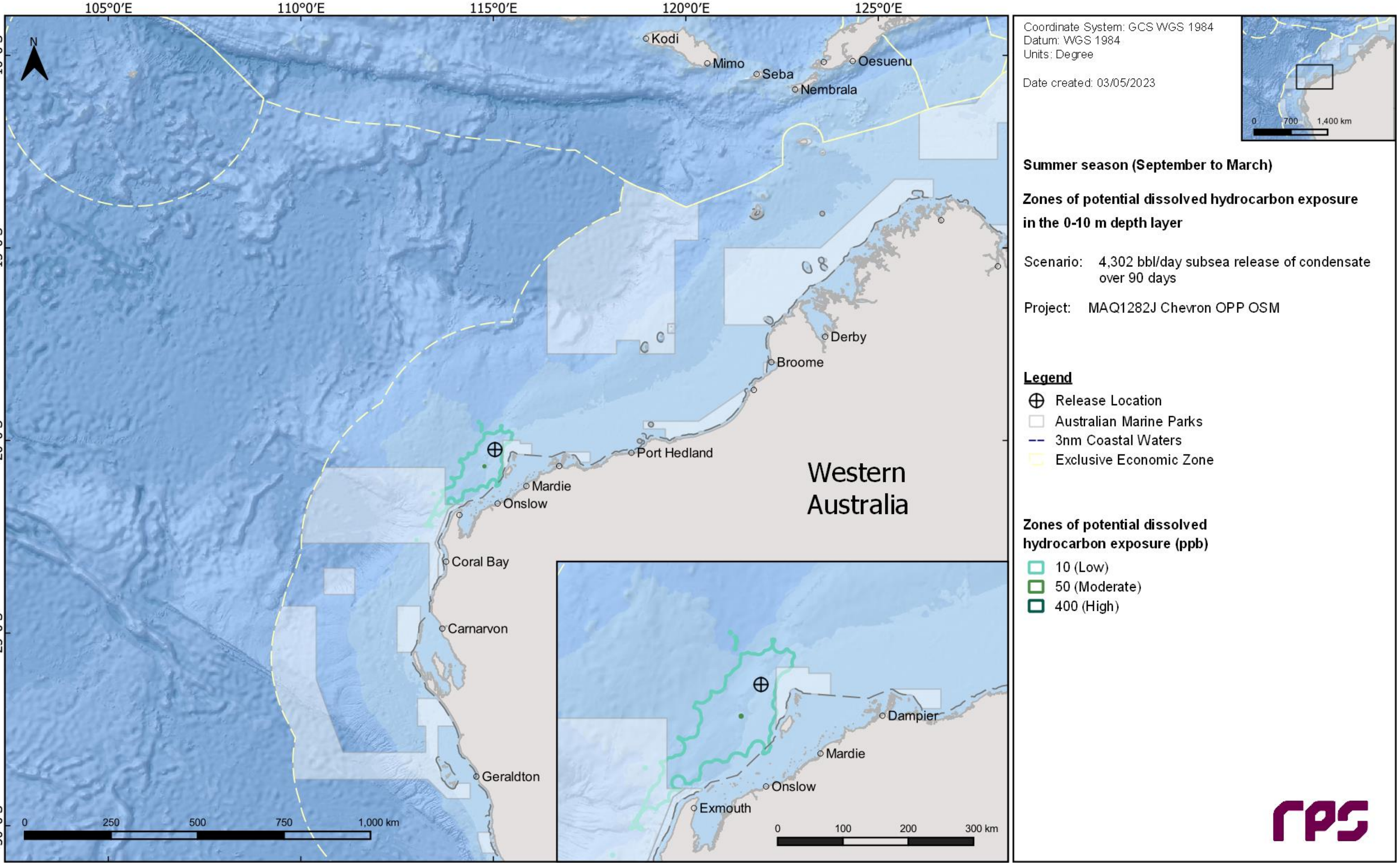


Figure 11.7 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

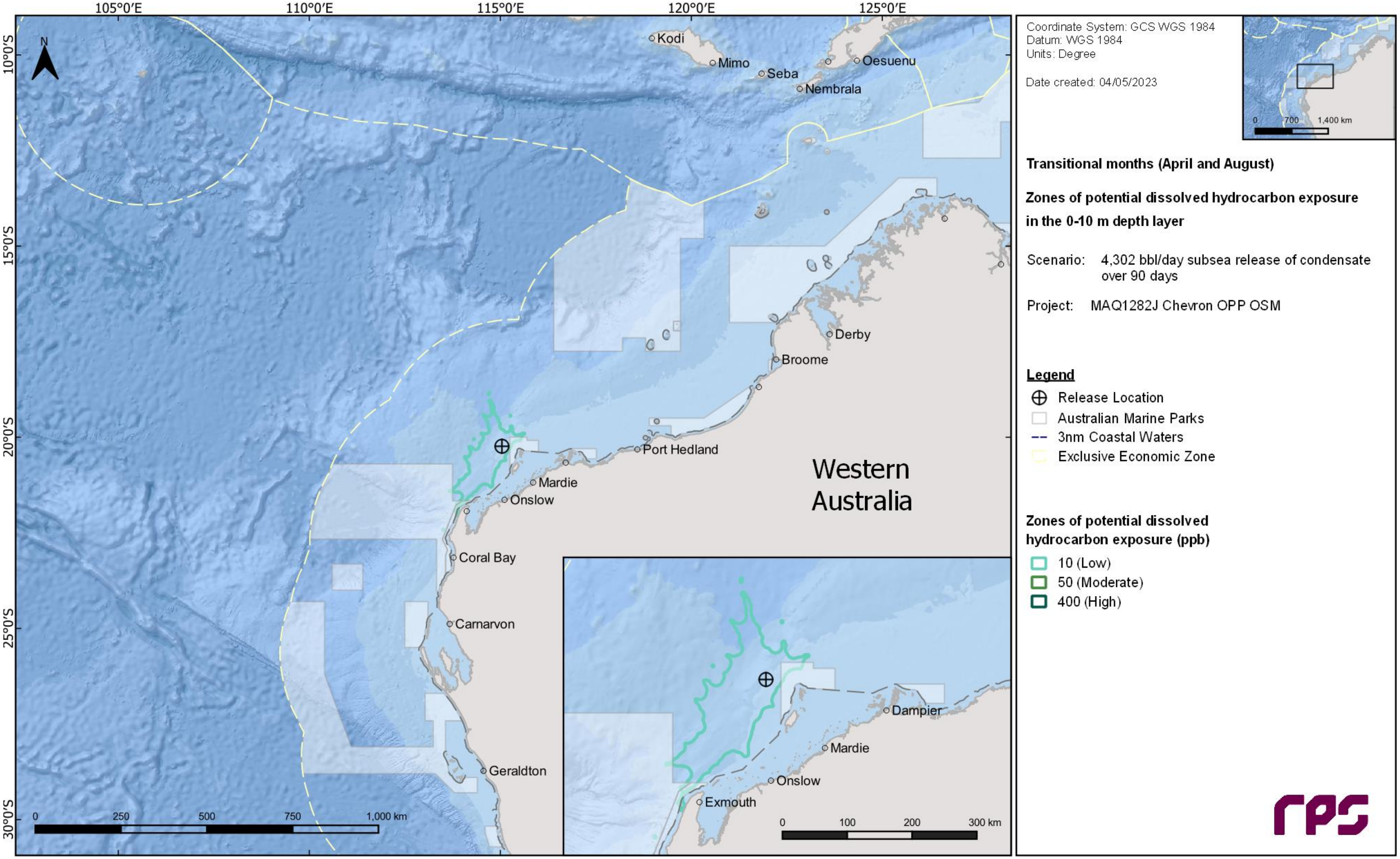


Figure 11.8 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

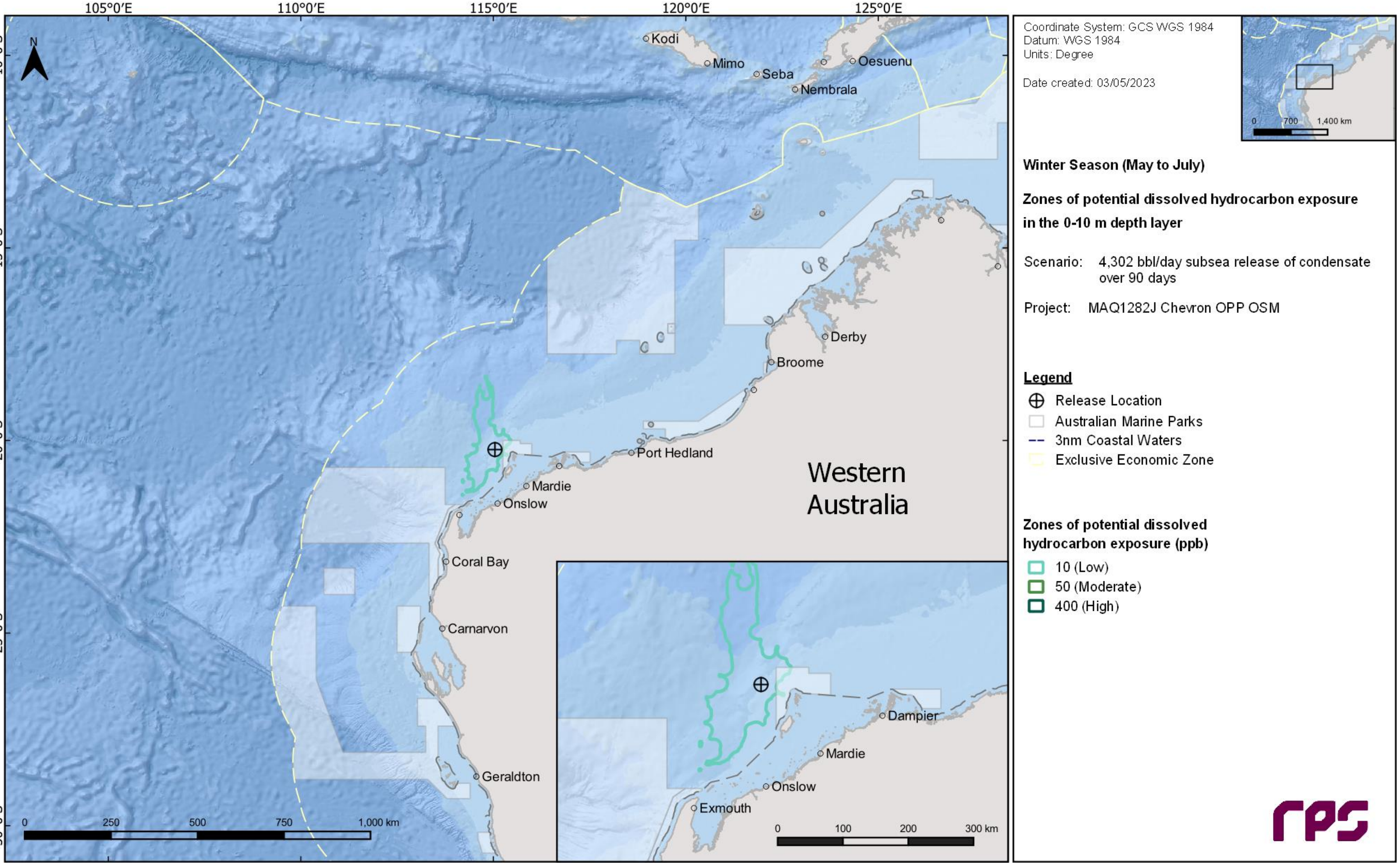


Figure 11.9 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

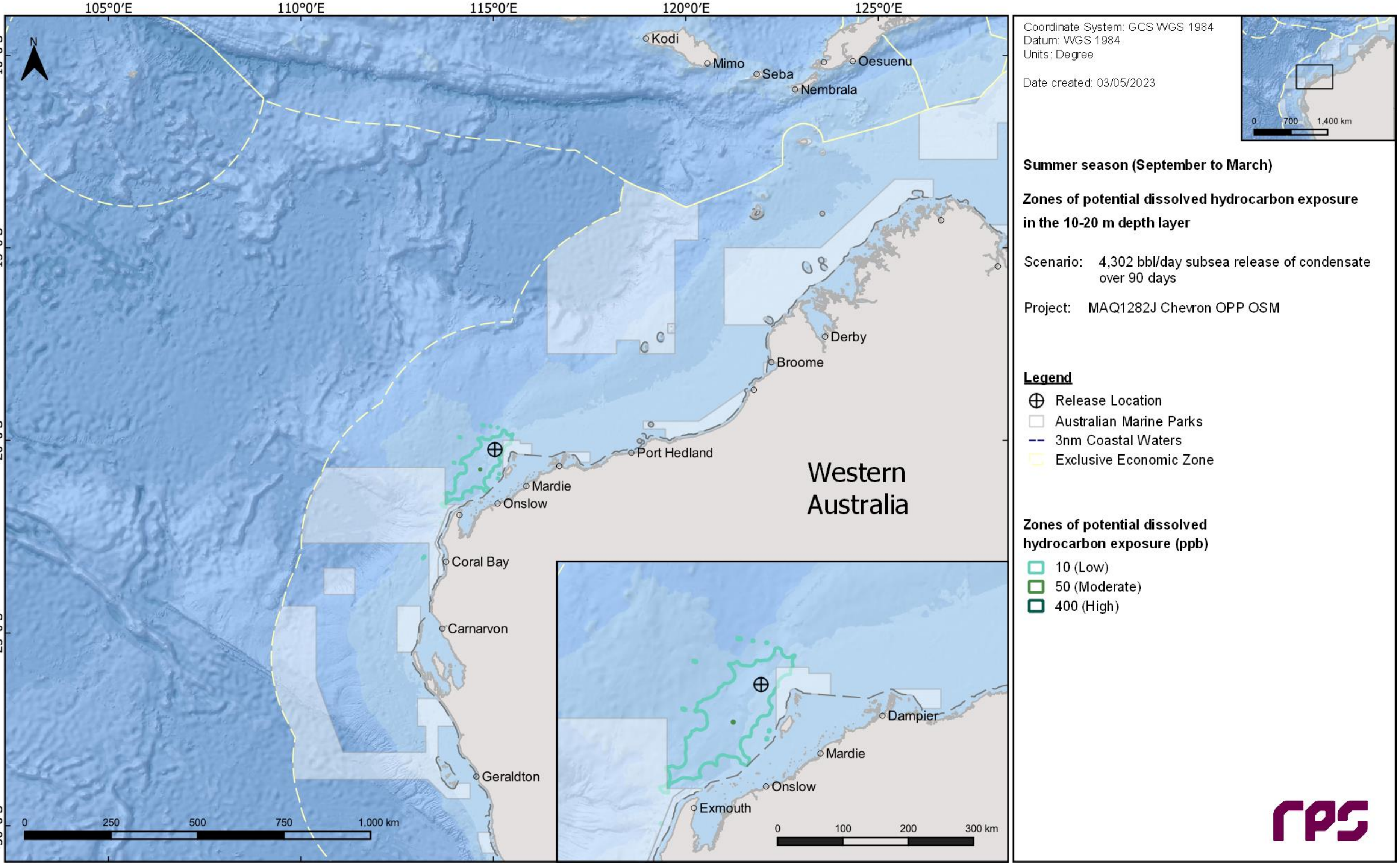


Figure 11.10 Zones of potential dissolved hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

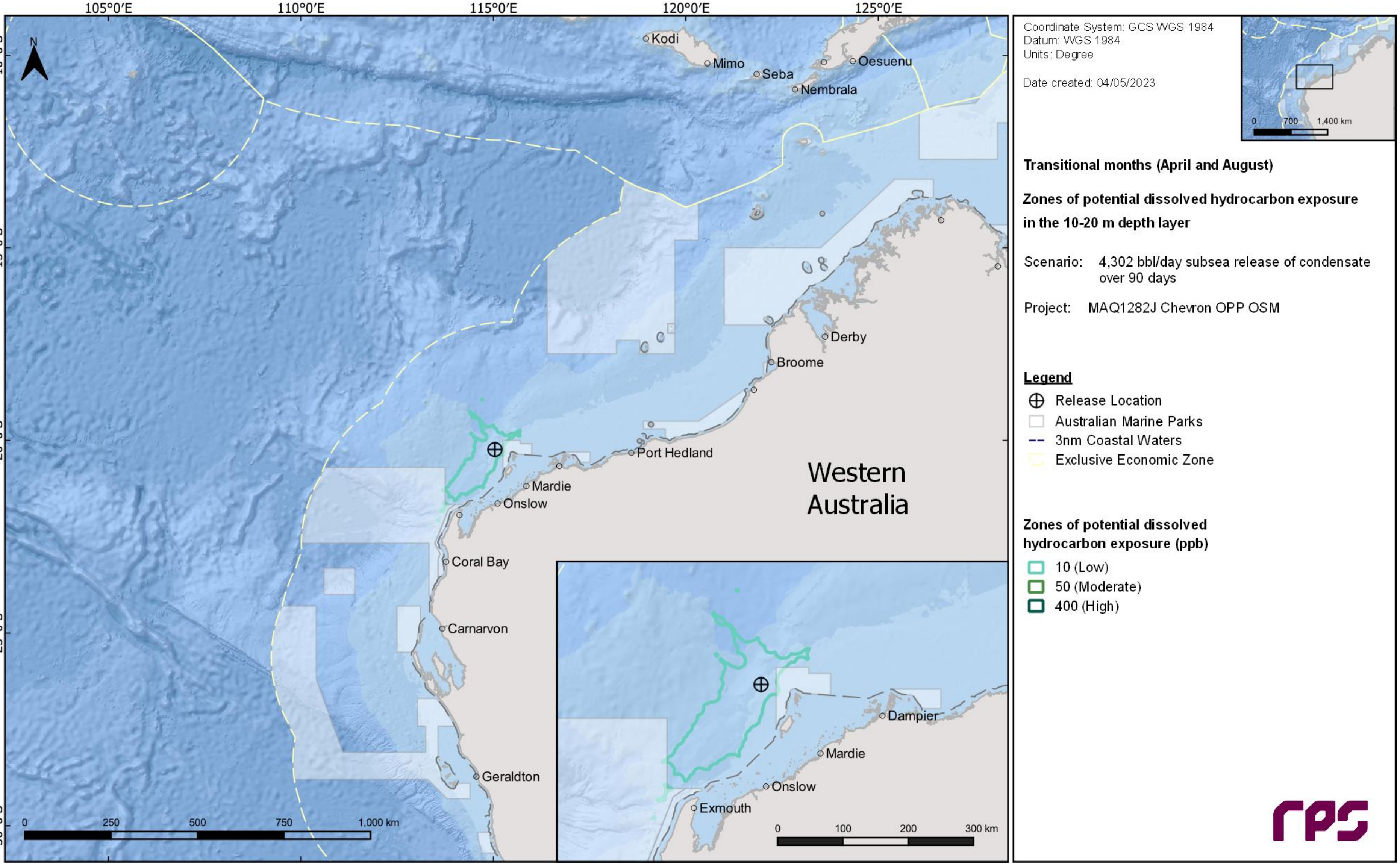


Figure 11.11 Zones of potential dissolved hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

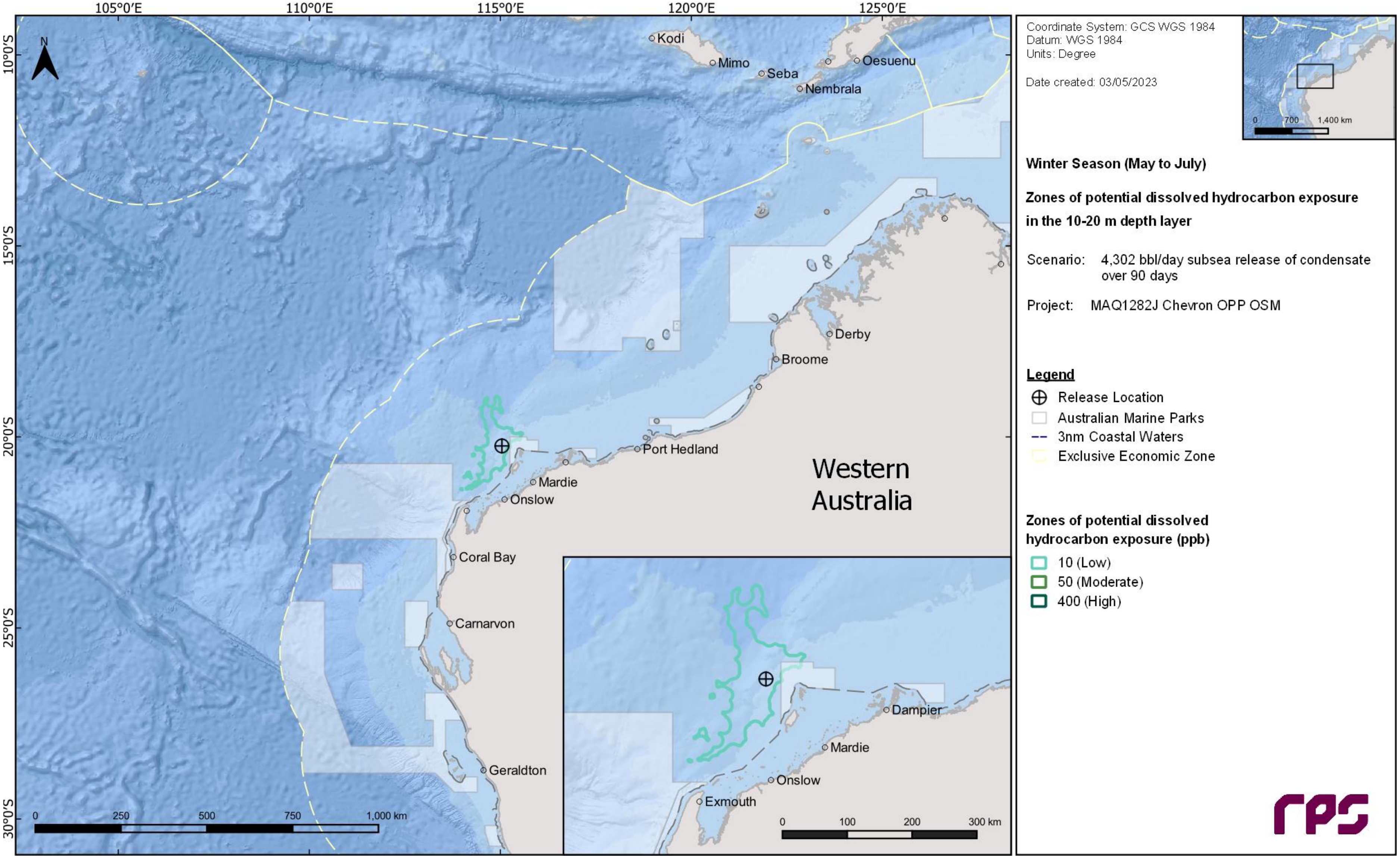


Figure 11.12 Zones of potential dissolved hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3.2 Entrained Hydrocarbons

Table 11.8 summarises the probability and minimum time before exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

In the surface (0-10 m) depth layer, a total of 44, 39 and 40 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter respectively. Excluding the 4 BIAs (Flatback Turtle - Internesting Buffer, Pygmy Blue Whale - Distribution, Wedge-tailed Shearwater - Breeding and Whale Shark – Foraging) that the release location resides within (see Section 10.3), the highest probabilities of exposure to low entrained hydrocarbons were predicted for the Flatback Turtle - Nesting (98% during summer and 100% during transitional and winter) and Humpback Whale - Migration BIAs (100% during all seasons).

During summer, 9 AMPs were predicted to be exposed at the low threshold, compared to 7 AMPs during transitional and winter periods. The highest probabilities predicted were at the Gascoyne AMP (96% summer, 100% transitional and 98% winter). Furthermore, during seasonal conditions the Gascoyne, Montebello and Ningaloo AMP were also predicted to be exposed to entrained hydrocarbons at the high threshold.

During summer, transitional and winter conditions, 9, 10 and 11 KEFs were predicted to be exposed by entrained hydrocarbons at the low threshold, respectively. Probabilities of exposure ranged between 9–100%, 4–100% and 2–100%, for summer, transitional and winter, respectively. Excluding the KEF that the release location resides within (Ancient coastline at 125 m depth contour), the KEF with the greatest probability of low exposure for each season was the Continental Slope Demersal Fish Communities KEF (100% during all seasons).

Additionally, 60, 35 and 32 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold. Excluding the Offshore IAA, the probabilities for each season ranged between 1–96%, 1–100% and 7–99% under summer, transitional and winter conditions, respectively, with the maximum probabilities occurring at the Gascoyne IAA during summer and transitional and at Barrow & Montebello Islands IAA during winter.

Furthermore, 70, 29 and 35 RSB receptors were predicted to be exposed to entrained hydrocarbons at the low threshold during summer, transitional and winter, respectively. The maximum probabilities for low threshold exposure were predicted for Rankin Bank (73% and 58% for summer and transitional respectively) and Rosily Shoals (73% for winter).

Figure 11.13 to Figure 11.15 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

The same maps for the 10-20 m depth layer are presented in Figure 11.16 to Figure 11.18.

Table 11.8 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at WTR Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
AMP	Abrolhos	88.7	11	-	23.25	-	30.1	13	-	30.54	-	27.6	10	-	32.13	-
	Argo-Rowley Terrace	92.2	29	-	24.21	-	96.6	34	-	20.13	-	95.6	42	-	32	-
	Carnarvon Canyon	41.7	20	-	25.83	-	43.4	17	-	17.08	-	43.3	11	-	17.75	-
	Dampier	22.2	1	-	38.96	-	1.1	-	-	-	-	1.5	-	-	-	-
	Gascoyne	481.2	96	34	5.17	7.13	469.9	100	45	5.13	8.17	282.4	98	40	5	8.58
	Mermaid Reef	11.7	1	-	68.96	-	2.1	-	-	-	-	3.8	-	-	-	-
	Montebello	728.6	90	77	1.29	1.92	618.2	90	78	1.71	2.33	531.8	99	75	1	1.17
	Ningaloo	343.3	67	31	5.92	7.46	331.7	73	32	6.42	19.83	485.6	92	39	5.75	10.58
	Shark Bay	136	25	2	33.88	52.08	24.7	37	-	18.08	-	27.7	16	-	20.83	-
BIA	Bridled Tern - Foraging	41.2	15	-	40.67	-	28.1	19	-	28.13	-	26	7	-	23.58	-
	Dugong - Breeding	271.5	50	21	7.71	8.17	312.4	58	21	7.54	23.33	498.5	74	34	6.04	10.83
	Dugong - Calving	271.5	50	21	7.71	8.17	312.4	58	21	7.54	23.33	498.5	74	34	6.04	10.83
	Dugong - Foraging	271.5	50	21	7.71	8.17	312.4	58	21	7.54	23.33	498.5	74	34	6.04	10.83
	Dugong - Nursing	271.5	50	21	7.71	8.17	312.4	58	21	7.54	23.33	498.5	74	34	6.04	10.83
	Fairy Tern - Breeding	969.9	57	31	4.08	5.79	331.7	68	24	6	10	498.5	91	34	6.04	6.96
	Flatback Turtle - Aggregation	116.3	26	5	8.63	32.17	113.9	6	3	37.63	81.17	16	8	-	31.79	-
	Flatback Turtle - Foraging	267	27	16	6.67	8.33	113.9	7	3	21	81.17	57.2	25	-	12.13	-
	Flatback Turtle - Internesting	116.3	26	5	8.63	32.17	113.9	6	3	37.63	81.17	16	8	-	31.79	-
	Flatback Turtle - Internesting Buffer*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	Flatback Turtle - Mating	240	27	16	6.67	8	113.9	7	3	21	81.17	57.2	25	-	12.13	-
	Flatback Turtle - Migration	20.6	9	-	31.25	-	0.8	-	-	-	-	1.7	-	-	-	-
	Flatback Turtle - Nesting	1,143.40	98	85	0.58	1.17	1,225.20	100	98	1.13	1.46	1,155	100	100	1.17	1.29
	Green Turtle - Aggregation	116	26	5	8.63	32	113.9	6	3	38	81.17	16	8	-	31.79	-
	Green Turtle - Basking	243.6	29	16	6.67	8.33	73.5	7	-	21	-	65	30	-	11.75	-
	Green Turtle - Foraging	267	33	16	6.67	8.33	139.7	18	5	21	80.96	57.2	25	-	12.13	-
	Green Turtle - Internesting	243.6	33	16	6.67	8.33	139.7	18	5	21	80.96	57.2	25	-	12.13	-
	Green Turtle - Internesting Buffer	911.2	80	51	1.5	4.29	551.1	91	42	3.04	3.92	535.4	96	59	2.83	5.54
	Green Turtle - Mating	243.6	33	16	6.67	8.33	139.7	18	5	21	80.96	65	26	-	11.75	-
	Green Turtle - Migration	20.6	9	-	31.25	-	0.8	-	-	-	-	1.7	-	-	-	-
	Green Turtle - Nesting	982.8	80	38	1.63	5.08	552.3	86	38	3.83	8	518.1	96	39	3.08	5.83
	Hawksbill Turtle - Foraging	267	27	16	6.67	8.33	98.2	7	-	21	-	57.2	25	-	12.08	-
	Hawksbill Turtle - Internesting	62.9	21	-	12.96	-	11.9	3	-	80.96	-	11.8	2	-	44.71	-
	Hawksbill Turtle - Internesting Buffer	969.9	80	46	1.46	4.83	560.7	91	42	4.42	6.42	540.8	98	61	2.58	5.63
	Hawksbill Turtle - Mating	240	27	16	6.67	8.33	98.2	7	-	21	-	57.2	25	-	12.13	-
	Hawksbill Turtle - Migration	20.6	9	-	31.25	-	0.8	-	-	-	-	1.7	-	-	-	-
	Hawksbill Turtle - Nesting	982.8	80	38	1.63	5.08	552.3	86	38	3.83	7.96	518.1	96	38	3.08	5.83
	Humpback Whale - Migration	1,229.50	100	100	0.25	0.29	921.9	100	100	0.63	0.71	912	100	100	0.63	0.71

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Humpback Whale - Resting	112	37	3	9.33	41.71	134.7	36	3	18.83	30.46	111.8	55	1	14.75	27.63
	Lesser Crested Tern - Breeding	982.8	58	30	3.63	5.08	401.6	78	29	4.46	8.25	335.3	87	28	4.04	5.88
	Lesser Frigatebird - Breeding	10.1	1	-	69	-	5.3	-	-	-	-	6.8	-	-	-	-
	Little Shearwater - Foraging	15.3	3	-	88.13	-	20.9	5	-	54.58	-	20.5	3	-	40.79	-
	Little Tern - Resting	92.6	10	-	24.04	-	5.4	-	-	-	-	61.2	8	-	59.08	-
	Loggerhead Turtle - Internesting Buffer	423.6	72	35	4.75	5.29	331.7	86	42	3.75	3.92	512	94	52	5.17	9.63
	Loggerhead Turtle - Nesting	380.4	68	32	5.75	7.29	331.7	77	32	4.92	19.83	498.5	92	39	5.71	10.5
	Pygmy Blue Whale – Distribution*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	Pygmy Blue Whale - Foraging	406	85	31	6.13	7	297	83	27	5	8.25	345.4	93	36	5.58	11
	Roseate Tern - Breeding	982.8	72	33	3.25	6.79	306.8	85	38	7	18.63	301.9	92	38	3.92	4.67
	Sooty Tern - Foraging	38.8	17	-	28.71	-	29	19	-	25.75	-	27.6	12	-	23.83	-
	Wedge-tailed Shearwater – Breeding*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	Wedge-tailed Shearwater - Foraging	41	21	-	31.42	-	28.1	19	-	26	-	26.6	8	-	23.58	-
	Whale Shark – Foraging*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	White-faced Storm-petrel - Foraging	16	3	-	87.29	-	21.5	5	-	55	-	20.5	3	-	40.67	-
	White-tailed Tropicbird - Breeding	103.5	27	1	20.17	71.96	50.5	12	-	32.38	-	83.5	17	-	55.42	-
CP	Montebello Islands	74.3	19	-	14.63	-	73.9	5	-	80.54	-	11.2	3	-	46.71	-
	Australian Exclusive Economic Zone *	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
EEZ	Christmas Island Exclusive Economic Zone	12	2	-	38.83	-	16.1	1	-	58	-	18.3	4	-	82	-
	Indonesian Exclusive Economic Zone	13.1	3	-	36.08	-	20.4	7	-	50.58	-	23.4	6	-	63.58	-
	Abrolhos Islands IAA	88.7	11	-	23.25	-	30.1	13	-	30.54	-	27.6	10	-	32.13	-
	Abutilon Island	22	16	-	14.58	-	3	-	-	-	-	9.7	-	-	-	-
	Airlie Island	779.3	24	4	11.42	79.96	39.1	17	-	52.79	-	38	32	-	8.25	-
	Argo-Rowley Terrace IAA	92.2	29	-	24.21	-	96.6	34	-	20.13	-	95.6	42	-	32	-
	Ashburton Island	29.2	14	-	36.04	-	5.5	-	-	-	-	16.6	11	-	32.83	-
	Barrow & Montebello Islands IAA	728.6	90	77	1.29	1.92	618.2	90	78	1.71	2.33	531.8	99	75	1	1.17
	Barrow Island (East Coast)	118.3	21	5	9.42	33.17	11	1	-	25.33	-	20.6	8	-	13.63	-
	Barrow Island (West Coast)	217.2	25	11	7.21	11.96	44.6	7	-	22	-	43.8	18	-	12.13	-
	Barrow Island Group	234.1	25	12	7.21	8.38	44.6	7	-	22	-	64.9	18	-	12.13	-
IAA	Bedwell Island (Clerke Reef)	14.4	5	-	31.21	-	1.2	-	-	-	-	6.5	-	-	-	-
	Bessieres Island	249.1	42	9	9.33	37.29	364.7	56	5	9.04	10.04	63.1	68	-	12.04	-
	Boodie Island	223.2	25	12	7.29	8.38	20.5	6	-	22.71	-	64.9	17	-	12.75	-
	Cape Range National Park	246.3	38	7	8.75	9.75	107.7	43	1	15.5	103.96	346.1	53	12	12.29	19.25
	Cunningham Island (Imperieuse Reef)	66.5	8	-	28.21	-	1.6	-	-	-	-	61.2	8	-	60.25	-
	Dampier Archipelago IAA	237.6	15	3	15.5	90.08	5.8	-	-	-	-	5.6	-	-	-	-
	Dampier Archipelago Island Group	30.9	11	-	30.67	-	0.9	-	-	-	-	1.9	-	-	-	-
	Dampier mainland coastline	123.5	8	3	58	93.08	0.7	-	-	-	-	2.3	-	-	-	-
	Dirk Hartog Island	15.9	5	-	81.42	-	15.3	5	-	56.83	-	5.7	-	-	-	-
	Double Island	20.2	11	-	21.42	-	2.8	-	-	-	-	8.8	-	-	-	-

Receptor	Summer					Transitional					Winter				
	Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
		Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
Eaglehawk Island	22.1	10	-	30.67	-	0.5	-	-	-	-	1.4	-	-	-	-
Enderby Island	20.9	10	-	30.67	-	0.8	-	-	-	-	1.6	-	-	-	-
Exmouth Gulf Mainland Coastline	20.3	21	-	31.42	-	18.6	19	-	34.88	-	27.5	20	-	25.42	-
Exmouth IAA	120.2	38	8	8.83	41.29	155.9	43	10	9.08	28.88	125.3	59	4	7.38	20.83
Gascoyne IAA	481.2	96	34	5.17	7.13	469.9	100	45	5.13	8.17	282.4	98	40	5	8.58
Glomar Shoal	135.2	11	2	13.04	13.75	10.3	1	-	85.63	-	2.7	-	-	-	-
Goodwyn Island	23.5	10	-	33.83	-	0.7	-	-	-	-	1.7	-	-	-	-
Great Sandy Island	186.3	13	3	21.38	86.25	2.4	-	-	-	-	9.7	-	-	-	-
Hermite Island	87.2	19	-	12.83	-	74.7	5	-	80.42	-	12.4	7	-	45.96	-
Legendre Island	11.2	1	-	40.21	-	0.9	-	-	-	-	1.4	-	-	-	-
Locker Island	22.7	16	-	33.08	-	11.2	3	-	35.25	-	7.1	-	-	-	-
Lowendal Islands Group	22	16	-	14.58	-	3	-	-	-	-	9.7	-	-	-	-
Malus Islands	23.4	10	-	36.75	-	0.6	-	-	-	-	1.6	-	-	-	-
Mermaid Reef	10.2	1	-	69.42	-	1.3	-	-	-	-	2.7	-	-	-	-
Middle Island	234.1	25	12	7.29	8.88	24	6	-	23.38	-	55.6	15	-	13.13	-
Middle Ningaloo Coast - World Heritage Area	158.8	34	9	9.17	11.83	73.4	36	-	26.92	-	54.6	30	-	20.38	-
Montebello Islands Group	87.2	19	-	12.83	-	74.7	5	-	80.42	-	12.4	7	-	45.96	-
Muiron Islands	221.6	46	18	7.75	39.58	170.3	59	12	6.92	22.21	398.6	73	22	6.08	17.5
Ningaloo Coast World Heritage Area	343.3	67	31	5.92	7.46	331.7	73	32	6.21	19.83	512	92	39	5.75	10.58
North Muiron Island	221.6	46	18	7.75	39.58	170.3	59	11	6.92	22.21	398.6	73	22	6.08	17.5
North Ningaloo Coast - World Heritage Area	251.4	42	9	8.75	11.38	261.6	44	9	15.83	42.92	256.6	57	18	12.04	17.63
North Sandy Island	156.7	13	3	18.83	87.83	1.6	-	-	-	-	6.4	-	-	-	-
Offshore Area*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
Onslow Area Mainland Coastline	123	6	3	36.42	88	2.9	-	-	-	-	6.2	-	-	-	-
Passage Island	97.4	4	-	62.42	-	0.9	-	-	-	-	3.2	-	-	-	-
Pilbara Coast IAA	969.9	50	24	4.21	10.42	512.1	78	23	4.46	8.25	510.4	84	28	5.46	8.67
Pilbara Coast Islands Group	779.3	43	12	9.29	37.29	364.7	56	5	9.04	10.04	63.1	68	-	8.25	-
Pilbara Mainland Coast	122.6	6	3	36.42	88.33	2.9	-	-	-	-	6.2	-	-	-	-
Potter Island	80.8	3	-	91.38	-	0.7	-	-	-	-	2.1	-	-	-	-
Rankin Bank	360.9	73	59	3.58	4.96	412.2	58	42	8.29	10.96	428.8	72	53	3.46	14.17
Rosemary Island	30.9	11	-	35.21	-	0.9	-	-	-	-	1.9	-	-	-	-
Serrurier Island	176	43	12	9.29	37.63	216.1	54	4	10.38	18.17	59.7	68	-	12.54	-
Shark Bay mainland coastline	136	25	2	14.63	51.63	32	39	-	17.42	-	27.3	16	-	20.54	-
Shark Bay World Heritage Site	15.9	5	-	81.42	-	15.3	5	-	56.83	-	5.7	-	-	-	-
Sholl Island	196.6	13	3	18.79	89.33	0.8	-	-	-	-	3	-	-	-	-
South Muiron Island	173.2	42	14	7.92	40.42	160.7	55	12	7.88	29.08	252	72	18	6.63	17.75
South Ningaloo Coast - World Heritage Area	45	14	-	14.54	-	24.2	5	-	50.5	-	28.9	14	-	30.17	-
Thevenard Island	461.6	37	4	11.38	79.67	106.8	37	2	10.83	19	54.7	43	-	10	-
Trimouille Island	39.5	17	-	15.67	-	16.8	5	-	81.42	-	9.1	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	West Lewis Island	16.9	8	-	36.75	-	0.5	-	-	-	-	1.2	-	-	-	-
	Yammadery Island	30.8	3	-	64.96	-	1.6	-	-	-	-	3.3	-	-	-	-
IBRA	Cape Range	251.4	46	18	7.21	9.79	358.3	59	12	5.5	10.38	398.6	73	22	6.08	17.38
	Edel	15.9	5	-	81.29	-	15.6	5	-	56.83	-	6.8	-	-	-	-
	Roebourne	779.3	25	12	7.29	8.38	33.6	17	-	22.71	-	57.2	31	-	8.29	-
	Wooramel	13.6	4	-	34.38	-	5.8	-	-	-	-	4.8	-	-	-	-
IMCRA	Ningaloo	423.9	72	33	5.54	6.38	331.7	86	32	4.42	9.04	498.5	96	41	5.04	6.83
	Northwest Shelf	1,009.20	95	89	0.54	0.63	1,094.80	93	89	0.63	1.63	1,034.50	100	96	1.08	1.17
	Pilbara (nearshore)	378	41	8	8.88	40	165.6	43	4	7	27.92	117.9	57	1	9.25	27.67
	Pilbara (offshore)*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	Zuytdorp	136	26	2	14.63	52	32	40	-	17	-	27.3	16	-	20.54	-
KEF	Ancient coastline at 125 m depth contour*	3,935	100	100	0.04	0.04	3,878.40	100	100	0.04	0.04	3,989.40	100	100	0.04	0.04
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	5	-	-	-	-	18.4	7	-	49	-	17.5	5	-	90.42	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	433.1	96	43	2.79	6.38	382.6	91	53	3.75	3.92	519.9	100	51	4.38	6.92
	Commonwealth waters adjacent to Ningaloo Reef	343.3	67	31	5.92	7.46	331.7	73	32	6.42	19.83	485.6	92	39	5.75	10.58
	Continental Slope Demersal Fish Communities	1,511	100	100	0.38	0.42	1,350.90	100	100	0.33	0.42	1,256.80	100	100	0.42	0.5
	Exmouth Plateau	387	90	22	7	10	383.7	100	27	7	10.13	383.8	94	19	5.75	7.29
	Glomar Shoals	328.1	21	7	11.71	12.13	21.5	11	-	53	-	17.8	2	-	73.92	-
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	90.4	11	-	24.08	-	2.9	-	-	-	-	61.2	8	-	58.92	-
	Perth Canyon and adjacent shelf break, and other west coast canyons	9.5	-	-	-	-	15.3	4	-	55.54	-	15.1	3	-	41.79	-
	Wallaby Saddle	84.9	9	-	23.92	-	15.6	5	-	46.29	-	15.2	5	-	36.79	-
	Western demersal slope and associated fish communities	41.2	21	-	28.71	-	28.1	19	-	25.63	-	26.6	12	-	23.58	-
MMA	Barrow Island	639.4	43	17	5.79	6.67	142.5	24	5	10.96	79.04	69.2	39	-	10.96	-
	Muiron Islands	222.9	48	18	7.33	39.38	190.9	61	19	6.21	22.21	512	73	31	5.83	16.21
MP	Barrow Island	124.3	33	10	6.21	9.38	91.9	18	-	22.96	-	39.5	39	-	11.04	-
	Montebello Islands	157.8	38	13	7.96	10	151.5	25	5	9.63	80.42	19.3	28	-	14.5	-
	Ningaloo	271.5	49	21	7.88	8.33	276.9	55	21	8.21	23.42	498.5	67	34	6.25	15.17
	Rowley Shoals	84.2	9	-	26.75	-	1.6	-	-	-	-	61.2	8	-	59.42	-
NR	Great Sandy Island	542.2	18	3	12.42	83.13	2	-	-	-	-	9.2	-	-	-	-
	Thevenard Island	149.4	25	2	11.42	80	55	27	-	17.92	-	43.1	33	-	10.79	-
RSB	Ashworth Shoal	93.6	3	-	91.88	-	0.8	-	-	-	-	2	-	-	-	-
	Australind Shoal	32.4	19	-	24.29	-	8.8	-	-	-	-	20.7	11	-	32.83	-
	Barrow Island Reefs and Shoals	561.8	19	3	11.88	83.08	2.3	-	-	-	-	11.7	2	-	36.33	-
	Baylis Patches	25.8	18	-	20.79	-	24.2	3	-	27.88	-	7	-	-	-	-
	Beryl Reef	33	10	-	29.79	-	44.2	6	-	23	-	31.4	13	-	22.96	-
	Brewis Reef	96.4	27	-	11	-	102.2	26	1	10.54	24.33	49.1	35	-	11.88	-
	Clerke Reef	15.3	5	-	31.21	-	1.2	-	-	-	-	7.6	-	-	-	-

Receptor	Summer: Maximum exposure to entrained hydrocarbons (ppb)	Summer: Probability of exposure to entrained hydrocarbons (%)		Summer: Minimum time before exposure to entrained hydrocarbons (Days)		Transitional: Maximum exposure to entrained hydrocarbons (ppb)	Transitional: Probability of exposure to entrained hydrocarbons (%)		Transitional: Minimum time before exposure to entrained hydrocarbons (Days)		Winter: Maximum exposure to entrained hydrocarbons (ppb)	Winter: Probability of exposure to entrained hydrocarbons (%)		Winter: Minimum time before exposure to entrained hydrocarbons (Days)	
		Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
Cod Bank	60.3	13	-	27.67	-	0.7	-	-	-	-	1.7	-	-	-	-
Combe Reef	78.5	36	-	10.33	-	125.5	24	3	21.38	29.96	39.4	37	-	18.17	-
Courtenay Shoal	17.1	8	-	37.71	-	0.6	-	-	-	-	1.2	-	-	-	-
Curlew Bank	11.6	1	-	99.75	-	1.2	-	-	-	-	4.9	-	-	-	-
Dailey Shoal	164.1	42	11	9.33	39.25	191.9	46	4	6.13	28.04	48	62	-	12.96	-
Eliassen Rocks	88.5	3	-	90.92	-	0.7	-	-	-	-	2.7	-	-	-	-
Exmouth Reef	46.7	31	-	10	-	93	17	-	22.42	-	47.7	24	-	19.29	-
Fairway Reef	96.3	37	-	10.5	-	144.1	37	3	7.04	27.88	25	40	-	14.33	-
Flinders Shoal	264.2	19	3	21.33	83.17	2.2	-	-	-	-	11.9	2	-	49.21	-
Fortescue Reef	133.9	7	2	49.79	94.13	0.7	-	-	-	-	2.6	-	-	-	-
Glennie Patches	23.5	16	-	35.38	-	6.6	-	-	-	-	14.1	7	-	33.38	-
Glomar Shoal	136	11	2	13.04	13.75	10.5	1	-	85.63	-	2.7	-	-	-	-
Gorgon Patch	45.7	6	-	41.75	-	1.7	-	-	-	-	8.2	-	-	-	-
Hammersley Shoal	13.7	4	-	52.92	-	0.8	-	-	-	-	1.2	-	-	-	-
Hastings Shoal	38.7	3	-	66.08	-	1.7	-	-	-	-	7.4	-	-	-	-
Hayman Rock	31	28	-	20.75	-	36.8	5	-	21.92	-	9.9	-	-	-	-
Herald Reef	41.7	10	-	42.29	-	1.5	-	-	-	-	5.4	-	-	-	-
Hood Reef	140.1	40	8	10.33	38.63	182.1	47	4	6.54	27.42	29.4	58	-	12.92	-
Imperieuse Reef	66.5	8	-	28.21	-	1.6	-	-	-	-	61.2	8	-	60.25	-
Inner Northwest Patch	21.8	17	-	35.42	-	5.7	-	-	-	-	7.5	-	-	-	-
Koolinda Patch	40.8	3	-	66.21	-	1.3	-	-	-	-	5	-	-	-	-
Lightfoot Reef	243.1	15	3	21.46	84.13	2.6	-	-	-	-	10.2	1	-	100.54	-
Little Shoals	45.4	18	-	29	-	2.4	-	-	-	-	8.6	-	-	-	-
Locker Reef	36.5	28	-	20.33	-	34.7	5	-	21.46	-	8.3	-	-	-	-
Madeleine Shoals	22	1	-	39	-	0.9	-	-	-	-	1.3	-	-	-	-
Manicom Bank	18.8	14	-	36.04	-	5.2	-	-	-	-	6.6	-	-	-	-
Mardie Rock	102.6	3	1	90.92	97.21	1	-	-	-	-	2.7	-	-	-	-
McLennan Bank	179.4	13	3	24.83	91.25	0.9	-	-	-	-	2	-	-	-	-
Meda Reef	132.8	13	3	20.38	88.92	0.8	-	-	-	-	2.5	-	-	-	-
Mermaid Reef	10.3	1	-	69.42	-	1.3	-	-	-	-	3	-	-	-	-
Miles Shoal	33.8	13	-	36.5	-	5.3	-	-	-	-	16.1	11	-	33.71	-
Montebello Shoals	125.7	29	2	8.42	52	114.9	11	5	79.88	81.5	16	7	-	35.25	-
Moresby Shoals	45	14	-	38.33	-	2.2	-	-	-	-	6	-	-	-	-
Nares Rock	46.4	14	-	33.04	-	2.2	-	-	-	-	6.1	-	-	-	-
Ningaloo Reef	261	42	13	8.46	9	276.9	45	12	15	42.88	376.8	59	18	6.63	17.54
North West Reef	26.3	11	-	29.33	-	0.6	-	-	-	-	1.6	-	-	-	-
North West Reef	152.8	39	9	8.92	41.13	154.8	36	9	16.17	44.96	161.2	58	18	14.54	18.33
O'Grady Shoal	193.4	11	3	48.88	91.33	0.7	-	-	-	-	2.3	-	-	-	-
Otway Reef	130.2	40	8	10.33	40.75	160.6	40	4	8.67	28.83	26.7	55	-	13.79	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Outtrim Patches	204	45	15	7.83	39.42	161.3	57	5	6.21	24.58	273.1	70	14	6.33	17.5
	Paroo Shoal	38.2	11	-	37.08	-	3.5	-	-	-	-	13.4	8	-	35.71	-
	Pearl Reef	23.6	7	-	30.33	-	34.3	3	-	29.96	-	18.8	13	-	23.46	-
	Penguin Bank	905.2	42	11	7.67	36.42	159.5	40	10	14.33	32.08	155.8	70	6	7.13	27.42
	Poivre Reef	220.6	34	12	7.21	7.33	27.7	10	-	14.92	-	62.5	35	-	12.38	-
	Rankin Bank	360.9	73	59	3.58	4.04	421.7	58	42	7.83	10.96	428.8	72	53	3.42	14.17
	Ripple Shoals	535.4	21	3	8.96	81.17	8.8	-	-	-	-	53	17	-	10.67	-
	Roller Shoal	16.5	1	-	99.13	-	2.1	-	-	-	-	5.2	-	-	-	-
	Rosily Shoals	880.9	42	6	7.17	79.13	160.7	51	9	10.54	18.88	112.5	73	3	8.5	27.88
	Saladin Shoal	41.5	7	-	66.63	-	2.9	-	-	-	-	11.3	4	-	41.83	-
	Santo Rock	45	21	-	24.33	-	33.3	12	-	18.54	-	17.2	14	-	14.75	-
	South East Reef	14.6	8	-	32.75	-	0.4	-	-	-	-	1.2	-	-	-	-
	South West Reef	25.9	10	-	30.79	-	0.5	-	-	-	-	1.2	-	-	-	-
	Southwest Patch	14.3	2	-	37.5	-	3.1	-	-	-	-	7.2	-	-	-	-
	Spider Reef	62.8	31	-	12.54	-	96.8	15	-	20.29	-	19.4	17	-	14.67	-
	Sultan Reef	225.9	20	3	15.67	80.08	28.1	8	-	53.33	-	27.8	14	-	8.83	-
	Taunton Reef	586.9	23	3	12.38	80.13	26.8	9	-	53.29	-	26	11	-	8.83	-
	Tongue Shoals	26.8	17	-	17.58	-	10.7	2	-	27.92	-	9.7	-	-	-	-
	Trap Reef	624.3	35	3	11.38	79.58	62.7	29	-	18	-	52.1	36	-	9.58	-
	Tryal Rocks	376.2	55	19	4.29	10.54	155.7	46	13	5.83	41.67	147	52	11	5.58	20.38
	Ward Reef	24.6	2	-	95.96	-	1.2	-	-	-	-	5.1	-	-	-	-
	Web Reef	48.6	26	-	12.42	-	90.3	11	-	20.38	-	18.9	13	-	21.75	-
	Weeks Shoal	45.3	10	-	39.33	-	1.9	-	-	-	-	10.6	1	-	90.58	-
	West Reef	89.9	15	-	30.42	-	2.2	-	-	-	-	9.8	-	-	-	-
Nearshore Waters	Airlie Island	779.3	24	4	11.42	79.96	39.1	17	-	52.79	-	38	32	-	8.25	-
	Ashburton	39.2	7	-	52.96	-	14.4	3	-	29.96	-	8.1	-	-	-	-
	Ashburton Island	29.2	12	-	36.04	-	4.6	-	-	-	-	14.3	11	-	32.83	-
	Barrow Island	217.2	25	11	7.21	11.96	44.5	7	-	22	-	43.8	18	-	12.13	-
	Bessieres Island	249.1	42	9	9.33	37.29	364.7	56	5	9.04	10.04	63.1	68	-	12.04	-
	Boodie Island	223.2	25	12	7.29	8.38	20.5	6	-	22.71	-	57.2	17	-	12.75	-
	Carnarvon	45	16	-	14.38	-	25.3	5	-	50.63	-	28.9	14	-	30	-
	Clerke Reef	11.6	1	-	72.63	-	1.1	-	-	-	-	5.4	-	-	-	-
	Cohen Island	13.7	3	-	93.13	-	0.8	-	-	-	-	1.2	-	-	-	-
	Cunningham Island	63.4	6	-	28.25	-	1.3	-	-	-	-	52.4	8	-	61.25	-
	Direction Island	42.1	10	-	42.25	-	1.4	-	-	-	-	5.3	-	-	-	-
	Dirk Hartog Island	15.9	5	-	81.33	-	15.6	5	-	56.83	-	5.7	-	-	-	-
	Eaglehawk Island	24.4	10	-	30.17	-	0.5	-	-	-	-	1.6	-	-	-	-
	Enderby Island	21.8	10	-	29.67	-	0.8	-	-	-	-	1.7	-	-	-	-
	Exmouth	251.4	43	9	8.67	9.79	261.6	44	9	15.46	42.92	357.5	57	18	12.04	17.63

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Flat Island	200.9	43	10	9.17	37.71	235.8	53	4	6.5	18.63	63.4	62	-	9.33	-
	Fly Island	37.7	27	-	12.46	-	81.4	11	-	20.83	-	18.5	12	-	21.21	-
	Goodwyn Island	24.4	10	-	33.83	-	0.7	-	-	-	-	1.7	-	-	-	-
	Imperieuse Reef	66.5	6	-	28.21	-	1.6	-	-	-	-	55.9	8	-	60.63	-
	Karratha	166.2	11	3	47.75	88.38	1.9	-	-	-	-	5.6	-	-	-	-
	Kendrew Island	27.1	11	-	35	-	1.1	-	-	-	-	2	-	-	-	-
	Legendre Island	11.6	1	-	40.08	-	0.9	-	-	-	-	1.7	-	-	-	-
	Locker Island	22.7	16	-	33.08	-	11.2	3	-	35.25	-	7.1	-	-	-	-
	Lowendal Island	46.2	20	-	12.96	-	9.2	-	-	-	-	11.4	1	-	61.04	-
	Malus Island	23.4	10	-	36.75	-	0.7	-	-	-	-	1.6	-	-	-	-
	Mangrove Islands	39.5	3	-	61.79	-	2.2	-	-	-	-	5.6	-	-	-	-
	Mary Anne Group	247.4	18	3	21.46	83.17	2.6	-	-	-	-	10.6	1	-	46.71	-
	Middle Island	234.1	25	12	7.29	8.88	24	6	-	23.38	-	55.6	16	-	13.13	-
	Montebello Islands	105	26	2	8.5	52.13	112.7	5	1	80.38	97.63	13.8	7	-	38.79	-
	Muiron Islands	221.6	46	18	7.75	39.67	170.3	59	12	6.92	22.21	398.6	73	22	6.08	17.54
	Observation Island	109.1	40	6	11.33	42.79	142.8	37	4	20	28.38	25	42	-	13.71	-
	Passage Islands	220.8	13	3	18.75	86.25	2.4	-	-	-	-	9.7	-	-	-	-
	Peak Island	191	45	14	8.21	38.46	220.9	54	4	5.5	27.54	166.6	68	12	7.75	17.33
	Ragnard Islands	130.5	10	3	47.29	93.58	0.7	-	-	-	-	1.4	-	-	-	-
	Rivoli Islands	22.1	7	-	30.38	-	39.4	8	-	29.46	-	15.9	12	-	23.5	-
	Rosemary Island	31.6	11	-	35.21	-	0.9	-	-	-	-	2.3	-	-	-	-
	Round Island	109.5	41	8	10.38	38.71	152.4	46	4	7.54	27.29	34.8	57	-	13.17	-
	Serrurier Island	170.7	43	12	9.33	37.63	205.2	54	4	10.46	18.17	59.7	67	-	12.58	-
	Sunday Island	147.3	43	11	8.42	40.29	182.8	46	4	7.17	28.75	71.7	66	-	9.83	-
	Table Island	143.5	36	1	9.92	99.29	137.5	45	3	10.67	18.58	47.9	51	-	13.96	-
	Thevenard Island	149.4	25	2	11.42	80	48.6	26	-	17.96	-	40.2	33	-	10.79	-
	Tortoise Island	54.7	22	-	10.92	-	52.4	13	-	18	-	33.4	26	-	14.25	-
	Twin Island	43.9	9	-	44.83	-	1.6	-	-	-	-	5.6	-	-	-	-
	West Lewis Island	17.2	8	-	36.75	-	0.7	-	-	-	-	1.2	-	-	-	-
State Waters	Western Australia State Waters	982.8	49	24	4.13	6.83	398.7	61	21	4.92	9	512	80	34	4.83	8.04

*The release location resides within the receptor boundaries.

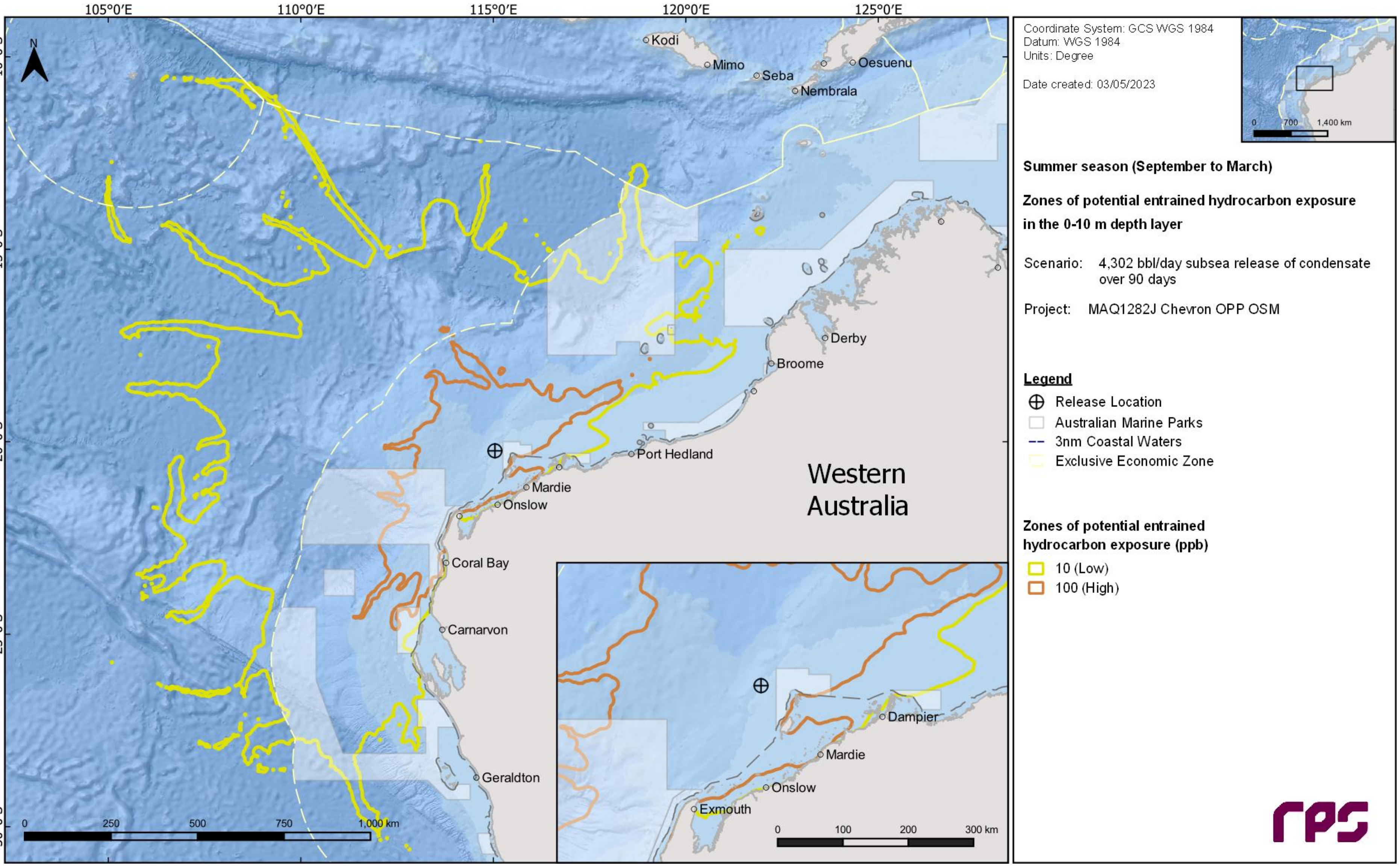


Figure 11.13 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

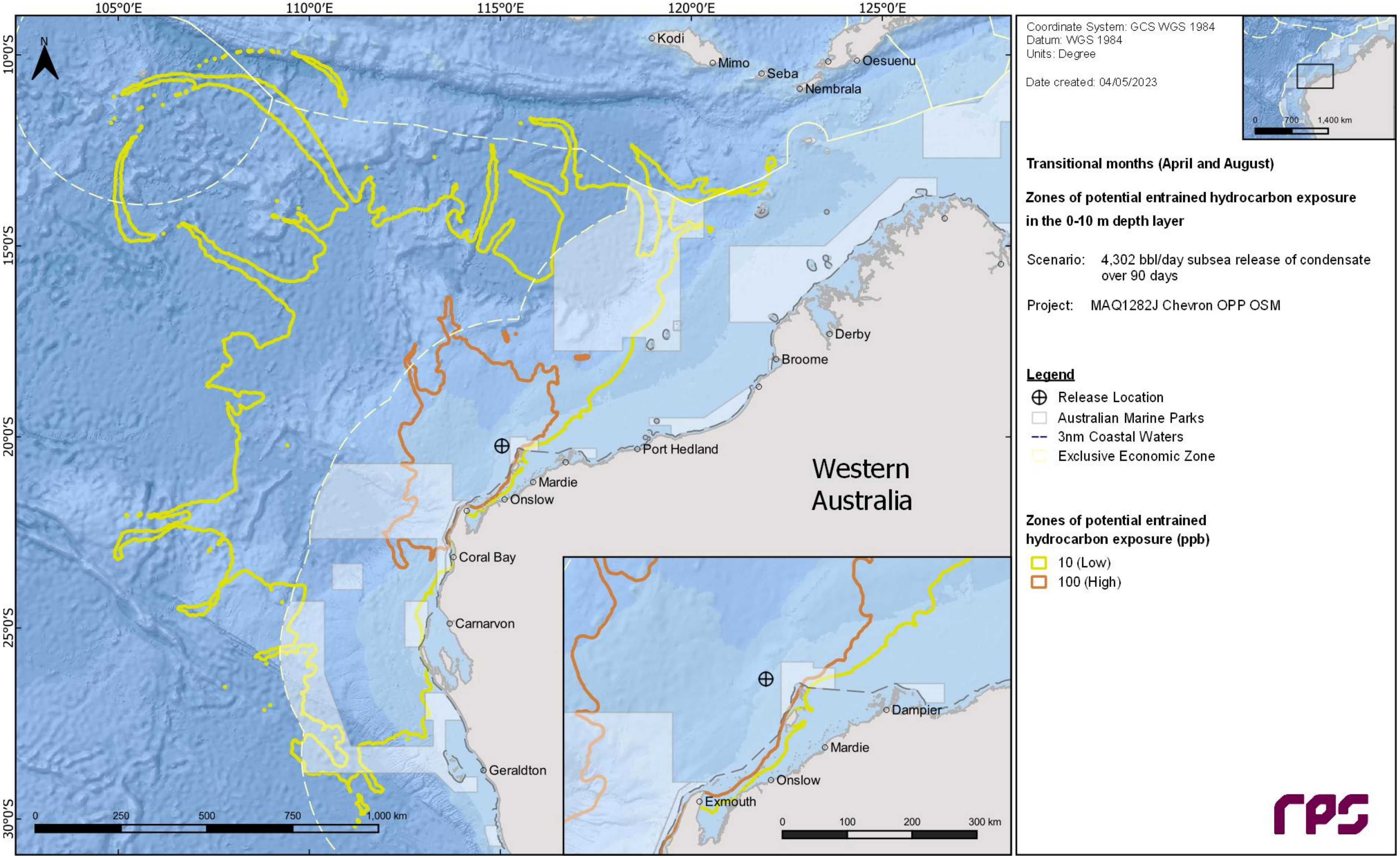


Figure 11.14 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

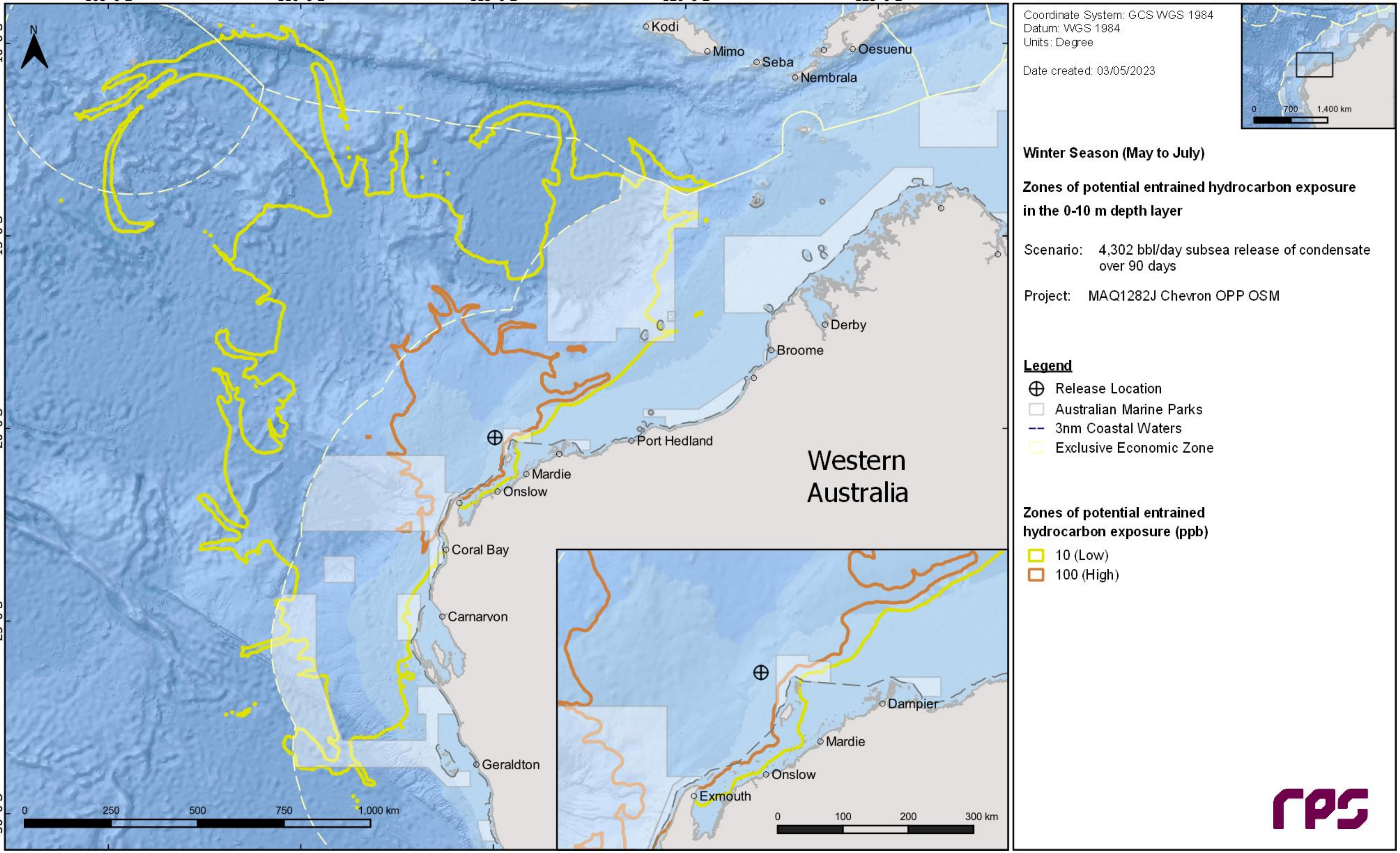


Figure 11.15 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

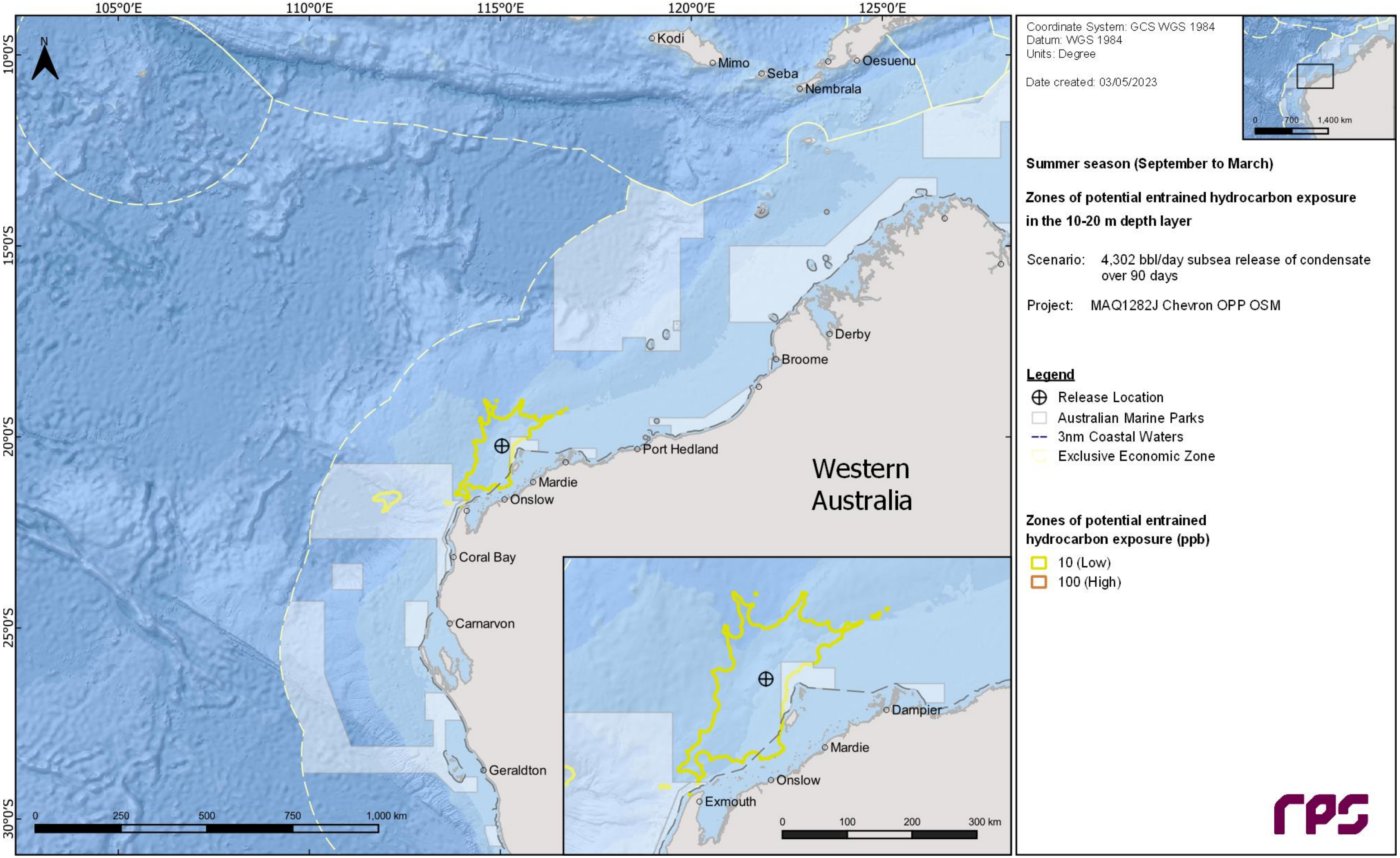


Figure 11.16 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

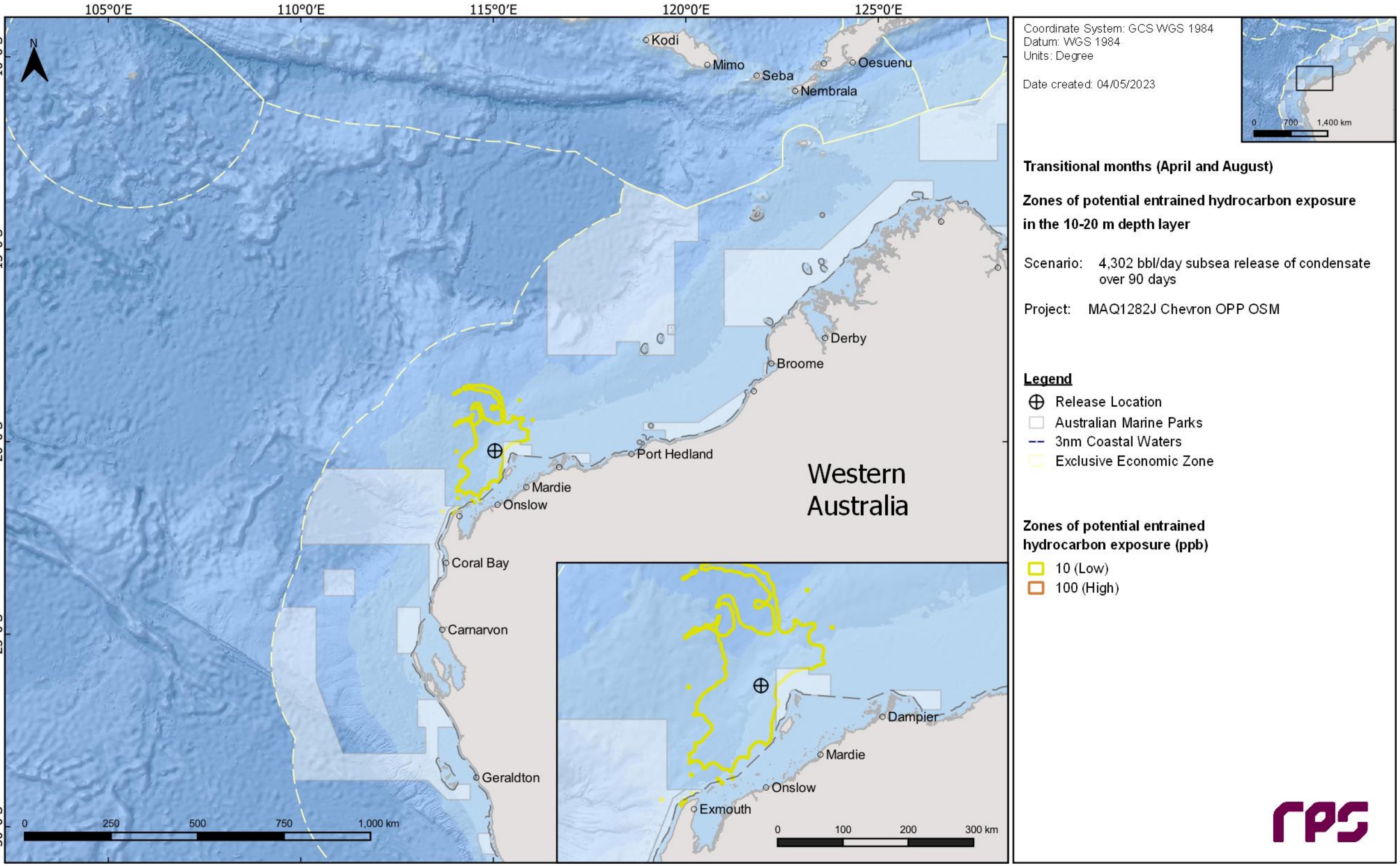


Figure 11.17 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

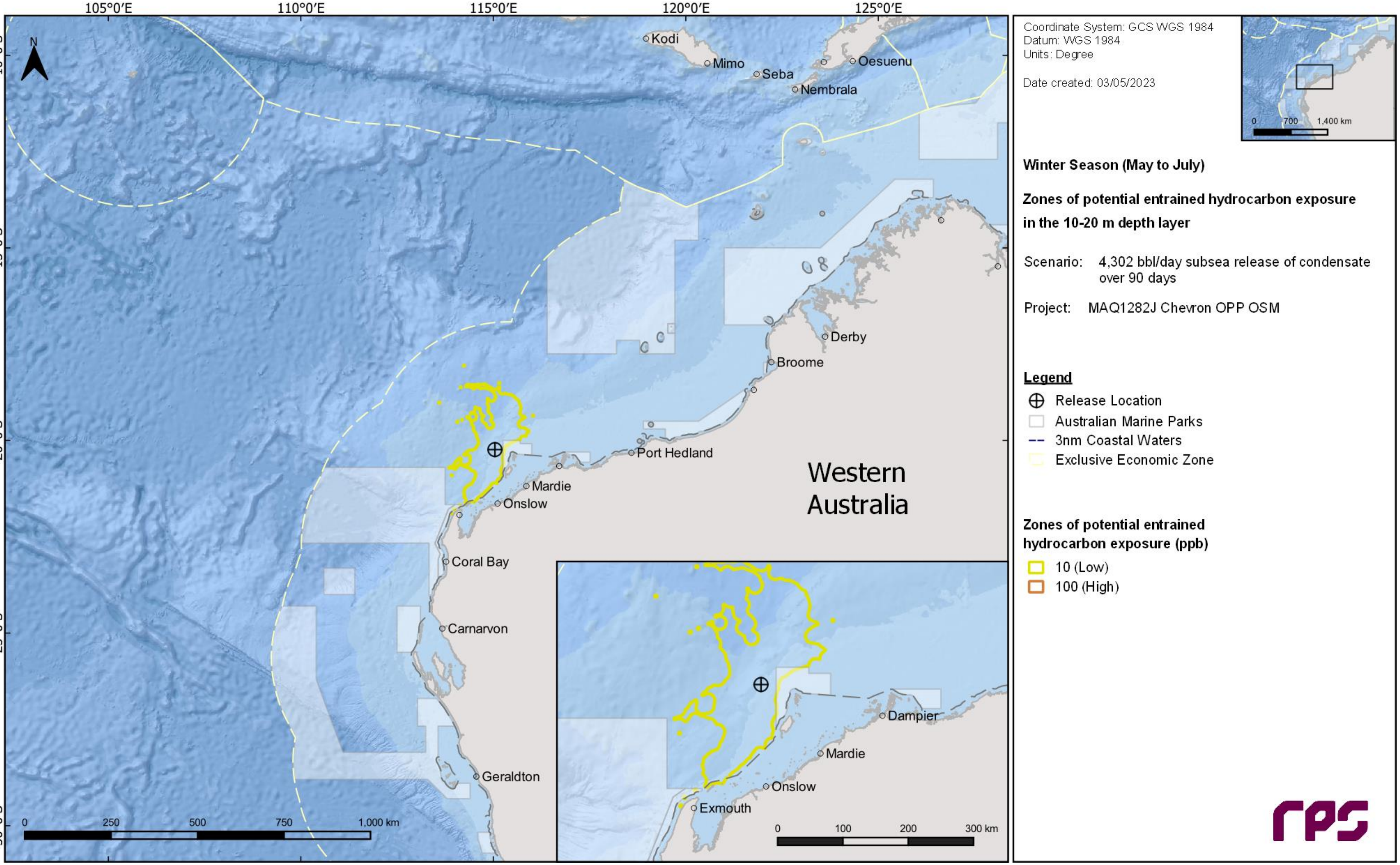


Figure 11.18 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at WTR Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating condensate above 10 g/m^2 (see Section 11.2.1), the largest swept area of floating condensate above 50 g/m^2 (see Section 11.2.2), largest volume of oil ashore (see Section 11.2.3), longest length of shoreline accumulation above 100 g/m^2 (see Section 11.2.4), the largest area of entrained hydrocarbons above 100 ppb (see Section 11.2.5), and the largest area of dissolved hydrocarbons above 50 ppb (see Section 11.2.6).

Table 11.9 presents a summary of all deterministic analysis criteria and the corresponding floating condensate, shoreline accumulation, entrained and dissolved hydrocarbon values at the assessed thresholds.

Interpretation of the deterministic analysis result table and timeseries plots:

The summary deterministic analysis results presented in the table below should be interpreted as **maximum values**, representing the total volume or swept area exposed by floating or in-water hydrocarbons throughout the entire simulation duration. In this particular case, the simulation showed that a maximum of 3,033 km^2 was exposed to floating oil above the low threshold over a period of 104 days.

However, it's important to note that the timeseries plots present **peak values** at specific points in time. For example, when considering shoreline volume, the peak value in the timeseries plot does not account for oil that may have reached the shore earlier in the simulation but was subsequently lost through evaporation or other weathering processes.

Continuing with the previous example, the timeseries plot indicates that the peak floating oil swept area above the low threshold reached 220 km^2. This value represents the highest swept area recorded at a single point in time during the simulation.

Table 11.9 Summary of the deterministic analysis following a subsea LOWC at WTR Well 5.

Variable	Threshold	Deterministic Analysis Criteria					
		Largest swept area of floating condensate above 10 g/m²	Largest swept area of floating condensate above 50 g/m²	Largest volume of oil ashore	Longest length of shoreline accumulation above 100 g/m²	Largest area of entrained hydrocarbons above 100 ppb	Largest area of dissolved hydrocarbons above 50 ppb
Season		Summer	Summer	Summer	Summer	Summer	Summer
Run Number		38	31	4	70	60	82
Floating Oil (km²)	1 g/m²	3,033	3,481	2,760	3,129	2,356	1,046
	10 g/m²	**485**	469	330	358	231	111
	50 g/m²	4	**14**	3	5	1	2
Shoreline Length (km)	10 g/m²	112	-	145	146	21	-
	100 g/m²	9	-	35	**38**	1	-
	1,000 g/m²	-	-	-	-	-	-
Minimum Time (days)		7.04	-	65.91	35.41	41.04	-
Maximum Volume (m³)		26.1	-	**128**	75.1	5.1	-
Entrained Area (km²)	10 ppb	230,518	199,868	183,515	204,955	281,749	222,881
	100 ppb	38,746	27,375	29,171	37,256	**45,223**	23,545
Dissolved Area (km²)	10 ppb	156	136	156	189	176	176
	50 ppb	-	-	-	-	-	**1**
	400 ppb	-	-	-	-	-	-
Start Date		9 January 2012	28 January 2014	7 November 2011	8 December 2011	31 January 2015	14 September 2019

11.2.1 Deterministic Case: Largest swept area of floating condensate above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 was identified as run number 38 during the summer period.

Figure 11.19 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.20 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.21 presents the fates and weathering for the corresponding simulation and Table 11.10 summarises peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.10 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	1,165	9	1
Entrained (m^3)	9,458	90	6,965
Dissolved (m^3)	3	84	0
Evaporation (m^3)	40,477	101	40,477
Decay (m^3)	14,039	104	14,039
Ashore (m^3)	62	30	30

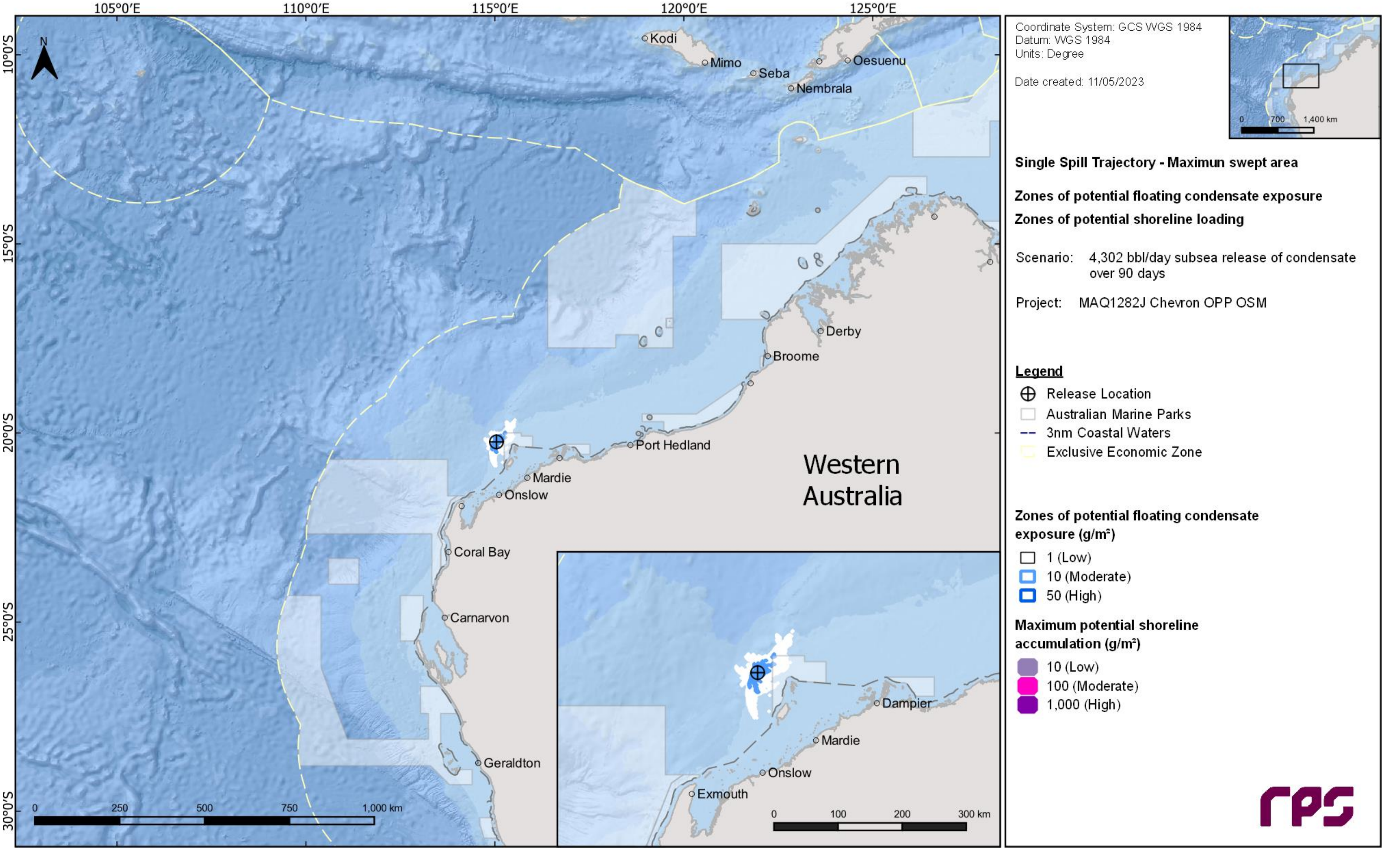


Figure 11.19 Zones of potential floating oil exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at WTR Well 5.

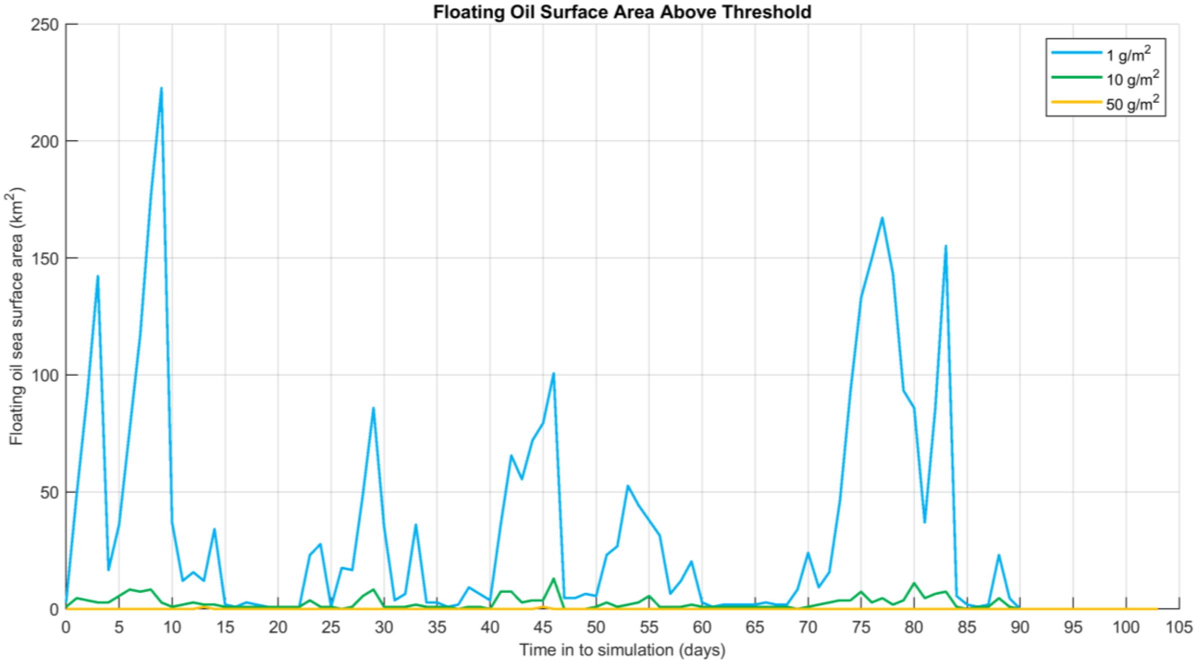


Figure 11.20 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at WTR Well 5.

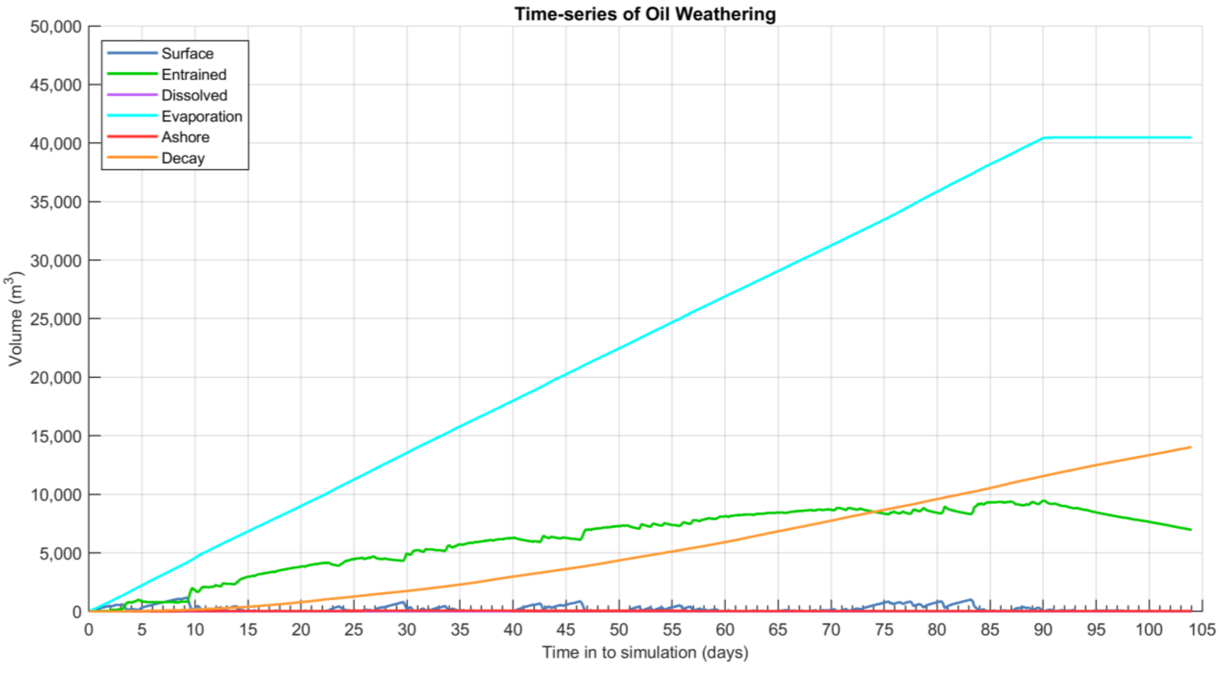


Figure 11.21 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at WTR Well 5.

11.2.2 Deterministic Case: Largest swept area of floating condensate above 50 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 50 g/m^2 was identified as run number 31 during the summer period.

Figure 11.19 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.20 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.21 presents the fates and weathering for the corresponding simulation and Table 11.10 summarises peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.11 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 50 g/m^2 following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	889	60	4
Entrained (m^3)	9,630	90	7,103
Dissolved (m^3)	3	53	0
Evaporation (m^3)	40,650	103	40,650
Decay (m^3)	13,751	104	13,751
Ashore (m^3)	4	101	4

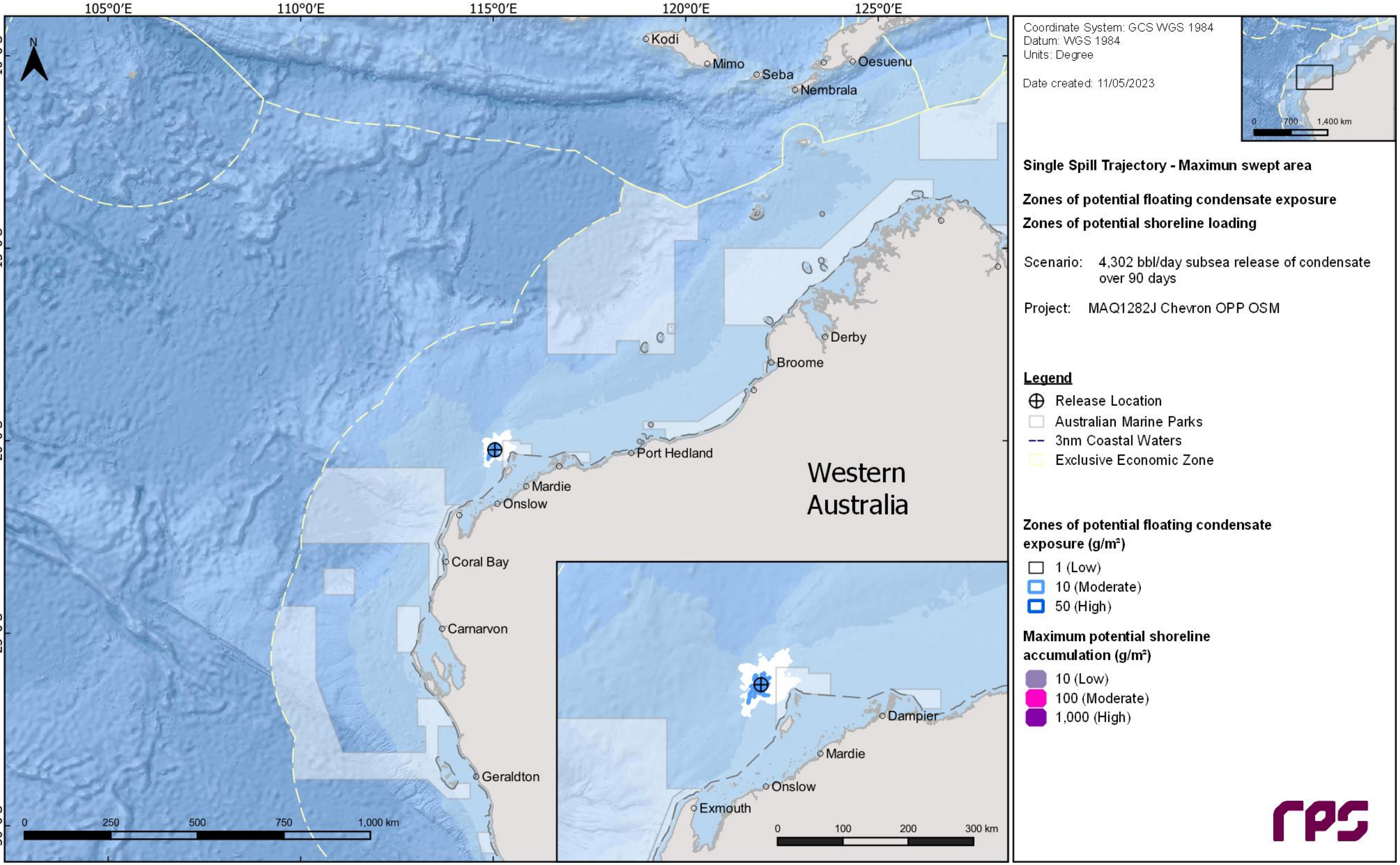


Figure 11.22 Zones of potential floating oil exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 50 g/m^2 following a subsea LOWC at WTR Well 5.

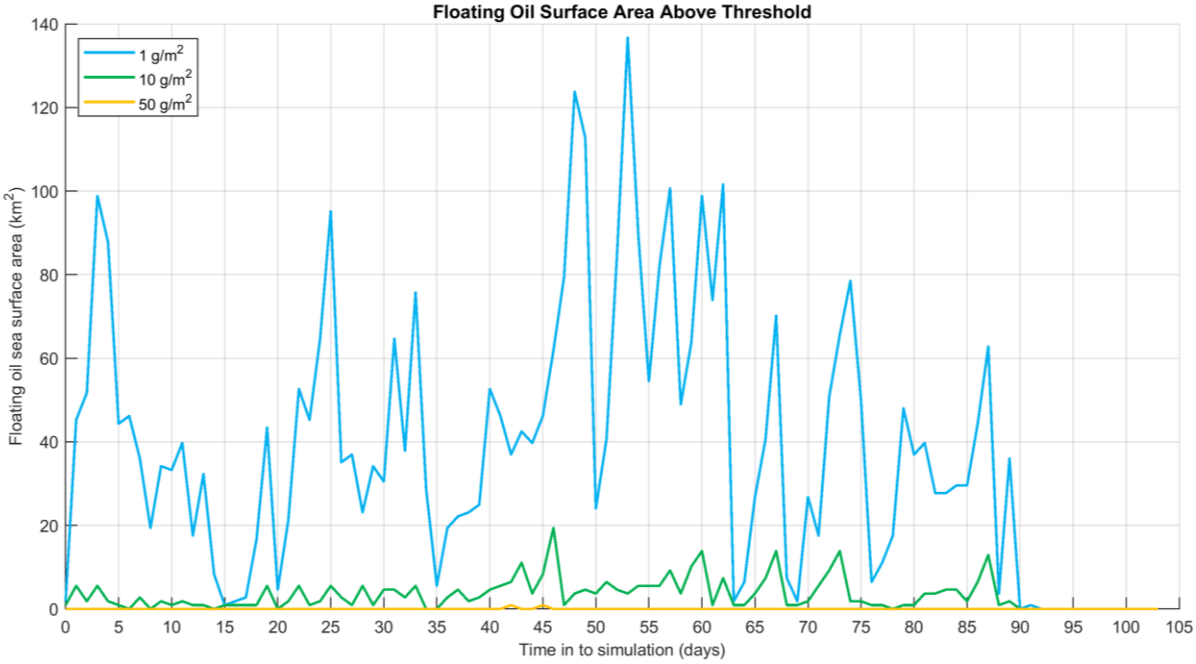


Figure 11.23 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating condensate above 50 g/m² following a subsea LOWC at WTR Well 5.

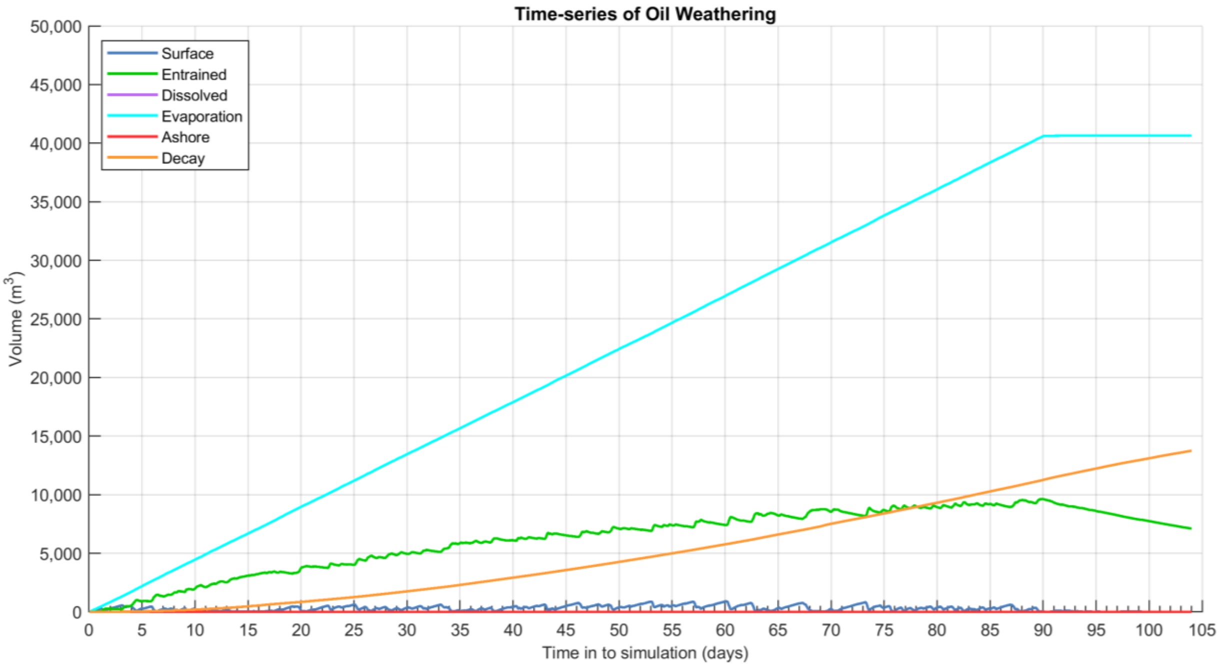


Figure 11.24 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 50 g/m² following a subsea LOWC at WTR Well 5.

11.2.3 Deterministic Case: Largest volume of oil ashore

The deterministic simulation that resulted in the largest volume of oil ashore was identified as run number 4 during the summer period.

Figure 11.25 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.26 displays the time series of the volume of oil accumulating on shorelines at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.27 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.12 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.12 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest volume of oil ashore following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	1,211	72	20
Entrained (m^3)	8,831	88	6,539
Dissolved (m^3)	3	73	0
Evaporation (m^3)	40,583	104	40,583
Decay (m^3)	14,257	104	14,257
Ashore (m^3)	128	91	113

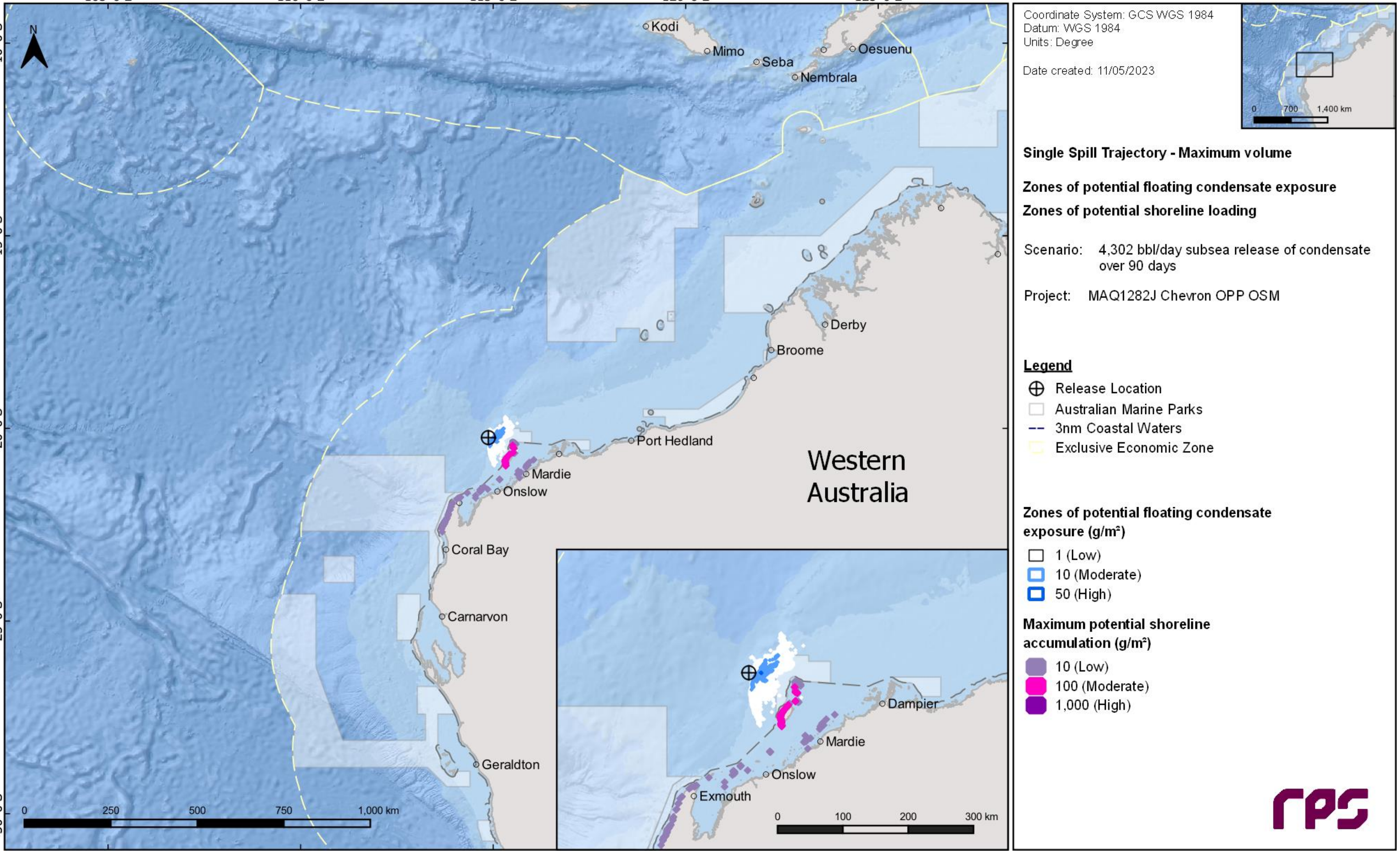


Figure 11.25 Zones of potential floating oil and shoreline exposure over the entire 104 days, for the simulation with the largest volume of oil ashore following a subsea LOWC at WTR Well 5.

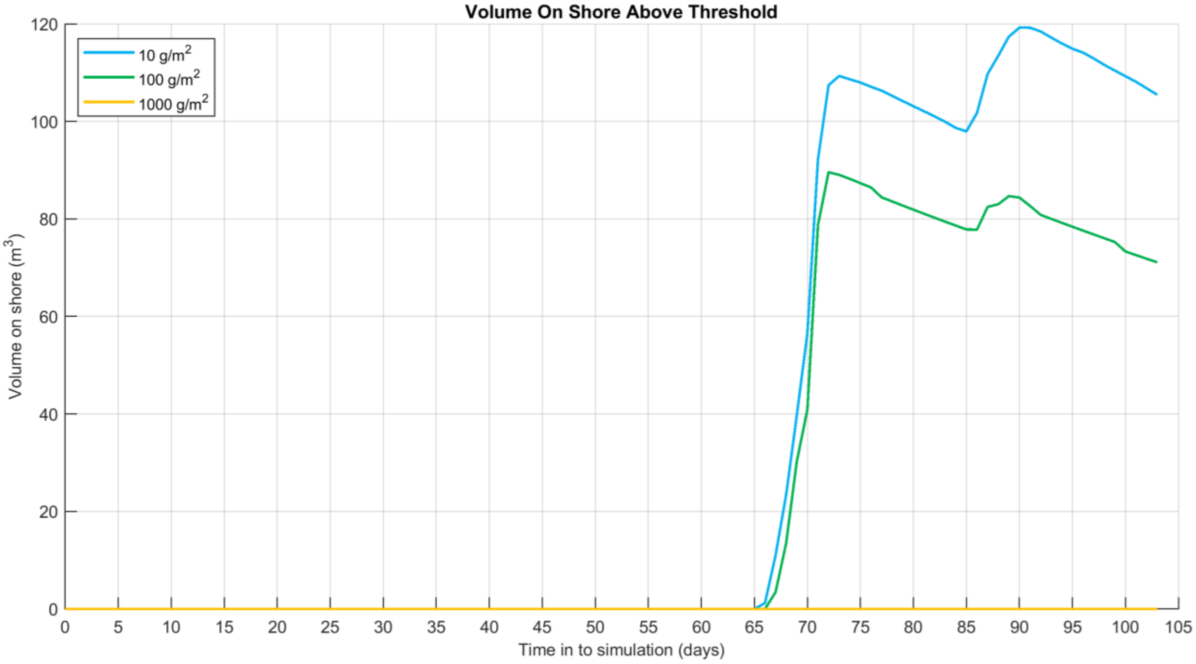


Figure 11.26 Time series of the volume of oil ashore at each threshold for the simulations with the largest volume ashore following a subsea LOWC at WTR Well 5.

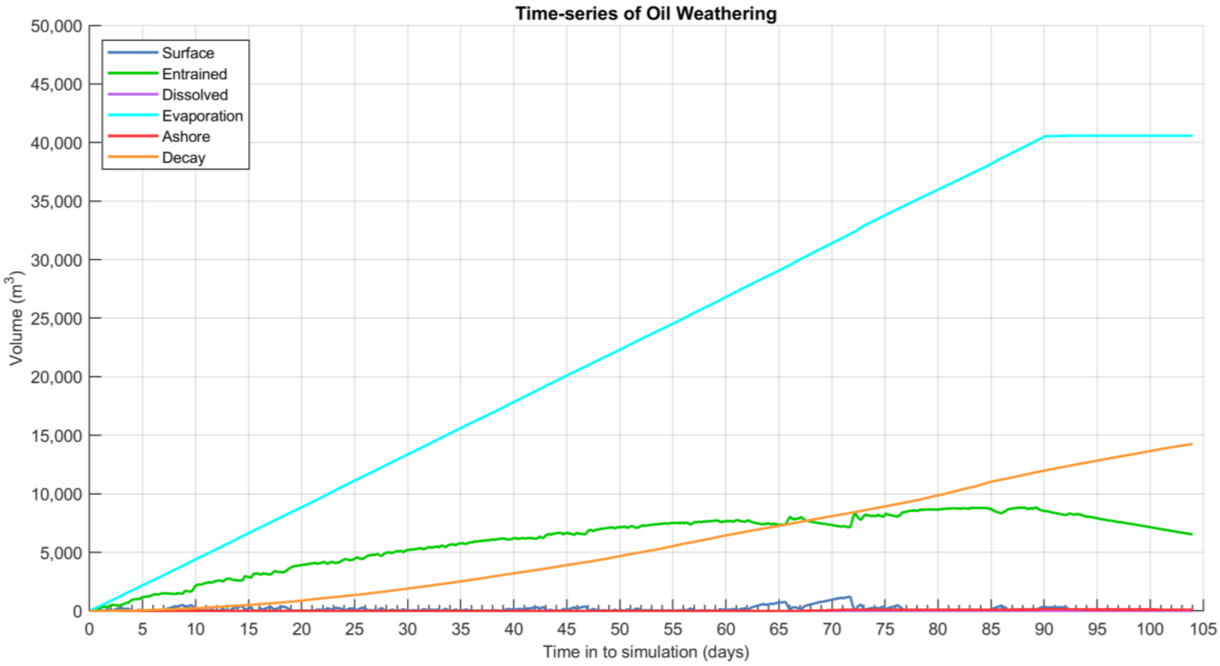


Figure 11.27 Predicted weathering and fates for the simulation with largest volume of oil ashore following a subsea LOWC at WTR Well 5.

11.2.4 Deterministic Case: Longest length of shoreline with accumulation above 100 g/m^2

The deterministic simulation that resulted in the longest length of shoreline with accumulation above 100 g/m^2 (moderate threshold) was identified as run number 70 during the summer period.

Figure 11.28 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.29 displays the time series of the length of shoreline with accumulation above the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.30 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.13 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.13 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the longest length of shoreline accumulation above 100 g/m^2 following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	1,212	41	1
Entrained (m^3)	9,282	90	6,916
Dissolved (m^3)	3	38	0
Evaporation (m^3)	40,452	104	40,452
Decay (m^3)	14,065	104	14,065
Ashore (m^3)	121	60	80

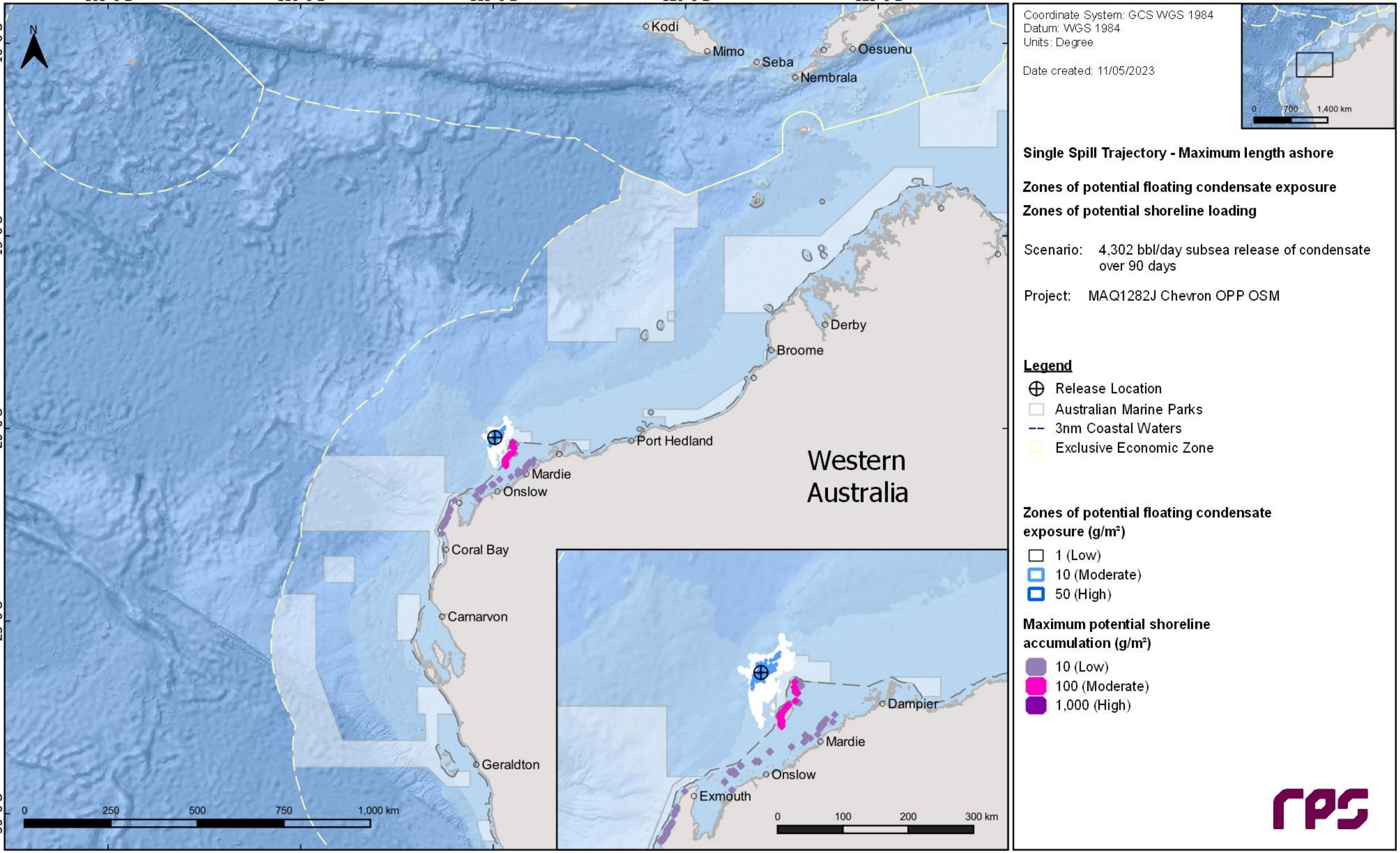


Figure 11.28 Zones of potential floating oil and shoreline exposure over the entire 104 days, for the simulation with the longest length of shoreline accumulation above 100 g/m^2 following a subsea LOWC at WTR Well 5.

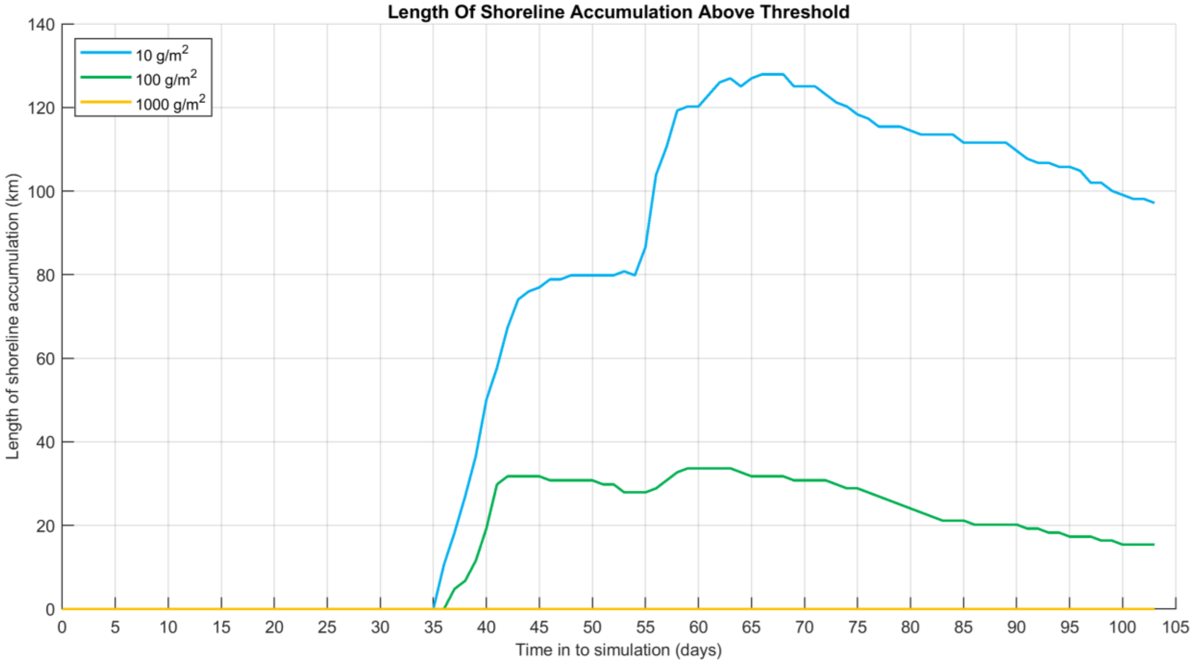


Figure 11.29 Time series of the length of shoreline at each threshold for the simulation with the longest length of shoreline with accumulation above 100 g/m² following a subsea LOWC at WTR Well 5.

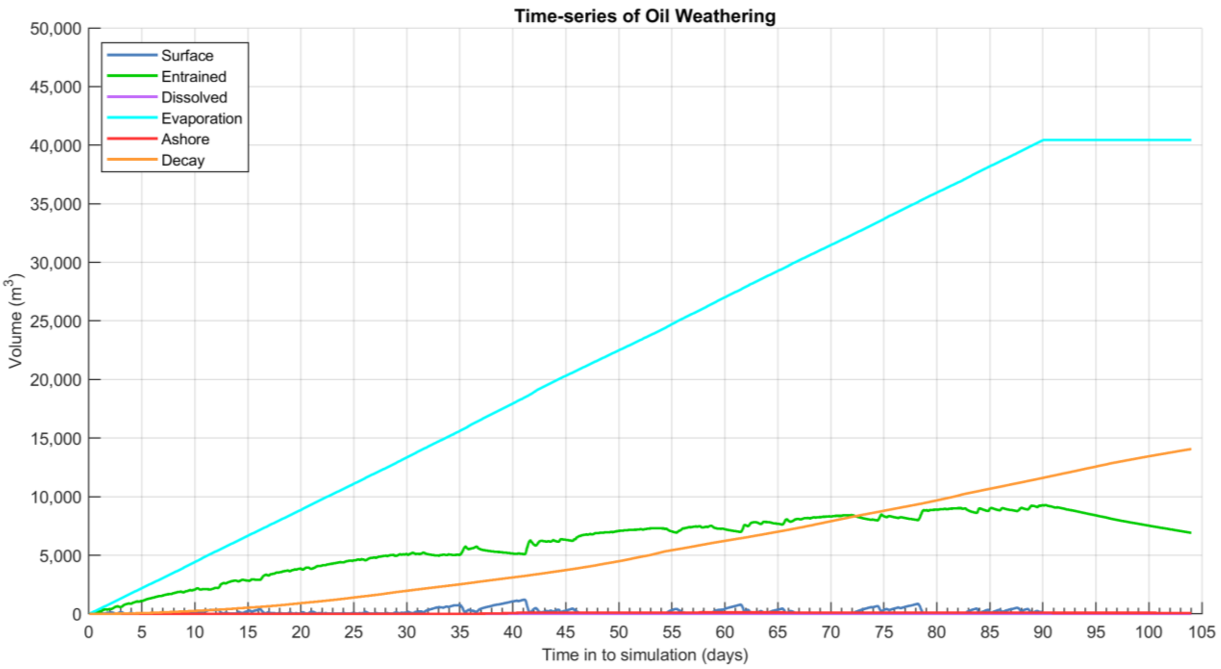


Figure 11.30 Predicted weathering and fates for the simulation with the longest length of shoreline with accumulation above 100 g/m² following a subsea LOWC at WTR Well 5.

11.2.5 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (high threshold) was identified as run number 60 during the summer period.

Figure 11.31 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.32 displays the time series of the area of entrained hydrocarbons at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds over the 104-day simulation.

Figure 11.33 presents the fates and weathering for the corresponding single spill trajectory and Table 11.14 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.14 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the trajectory with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	780	69	0
Entrained (m^3)	9,262	89	6,603
Dissolved (m^3)	3	76	0
Evaporation (m^3)	40,243	104	40,243
Decay (m^3)	14,659	104	14,659
Ashore (m^3)	10	45	6

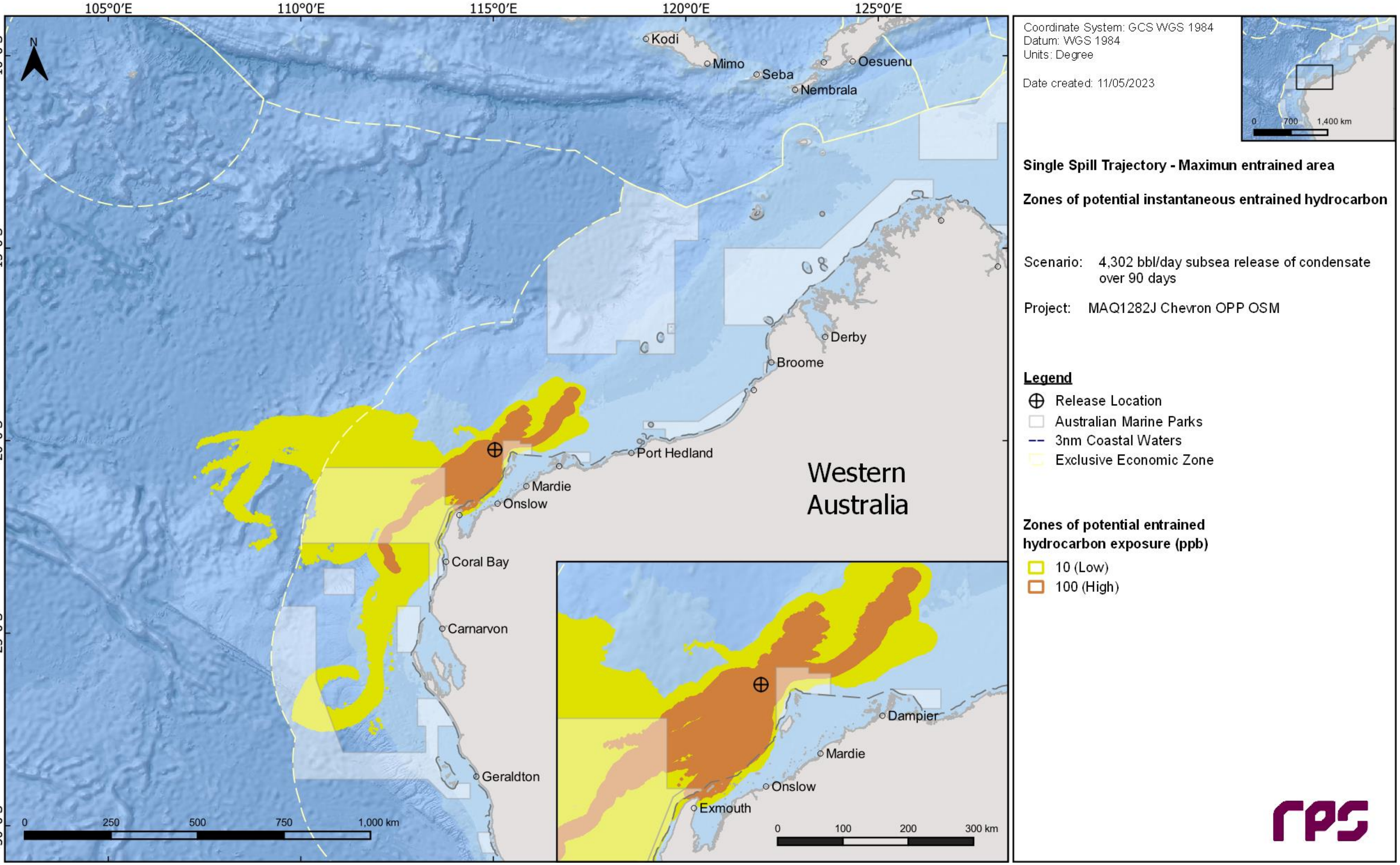


Figure 11.31 Zones of potential entrained hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

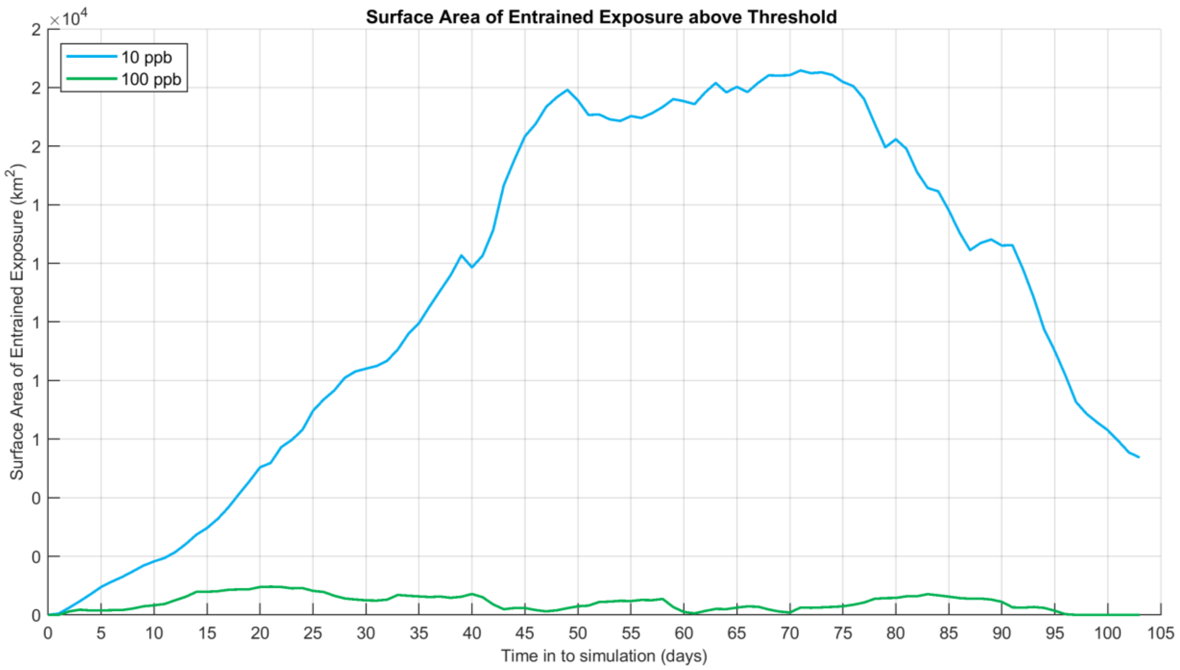


Figure 11.32 Time series of the area of entrained hydrocarbons for each threshold, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

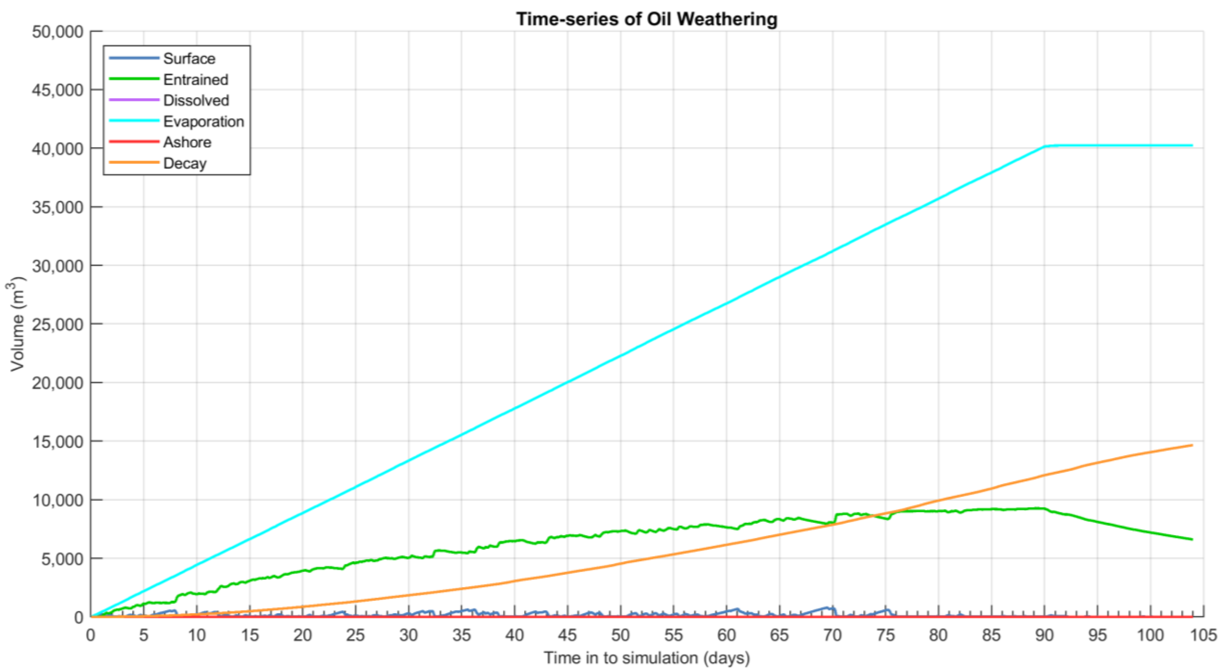


Figure 11.33 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at WTR Well 5.

11.2.6 Deterministic Case: Largest area of dissolved hydrocarbons above 50 ppb

The deterministic simulation that resulted in the largest area of dissolved hydrocarbons above 50 ppb (moderate threshold) was identified as run number 82 during the summer period.

Figure 11.34 presents the extent of the predicted dissolved hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.35 displays the time series of the area of dissolved hydrocarbons at the low (≥ 10 ppb), moderate (≥ 50 ppb) and high (≥400 ppb) thresholds over the 104-day simulation.

Figure 11.36 presents the fates and weathering for the corresponding single spill trajectory and Table 11.15 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the simulation.

Table 11.15 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the trajectory with the largest area of dissolved hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	475	2	7
Entrained (m^3)	9,207	90	6,714
Dissolved (m^3)	3	33	0
Evaporation (m^3)	40,117	104	40,117
Decay (m^3)	14,685	104	14,685
Ashore (m^3)	0	46	0

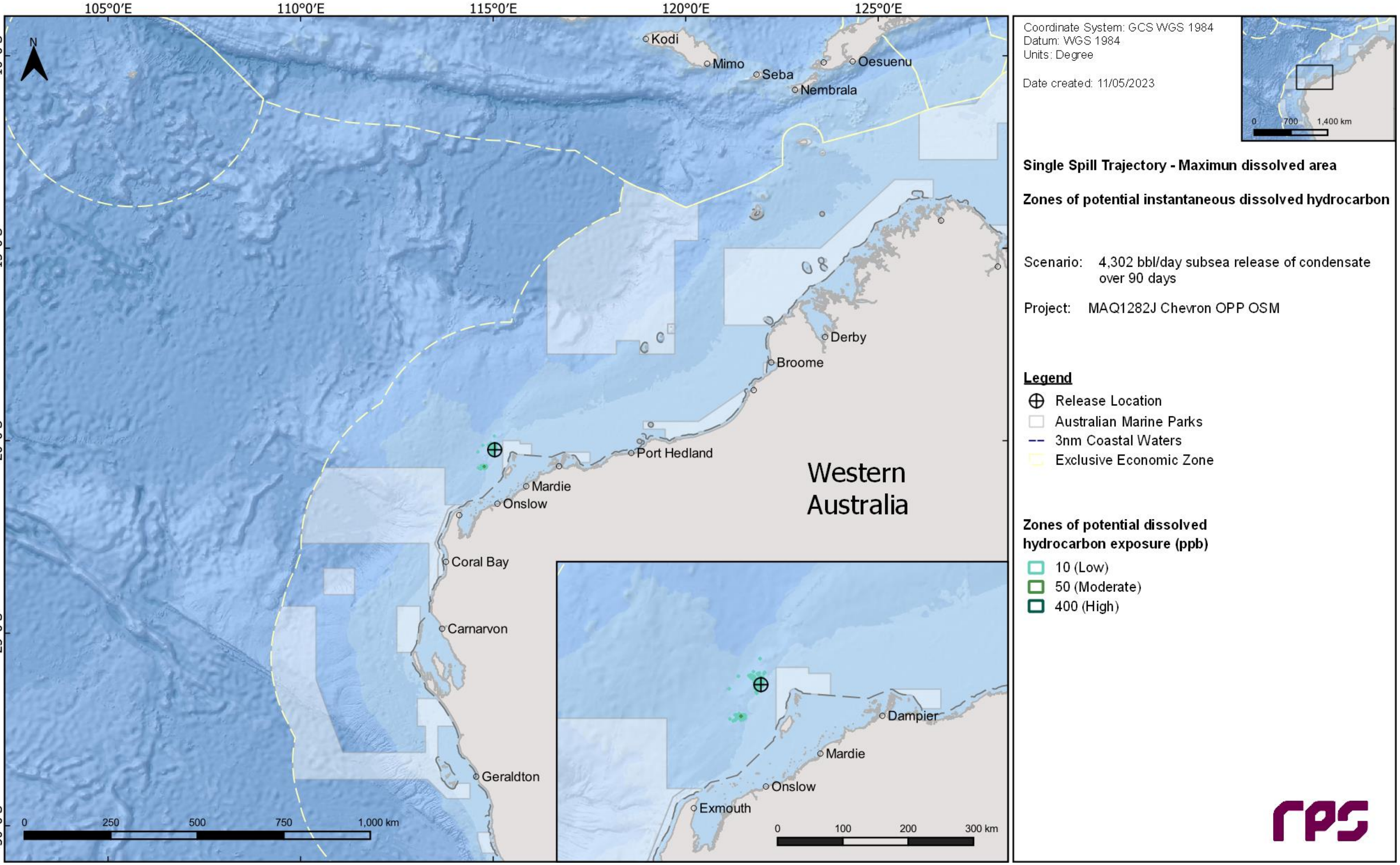


Figure 11.34 Zones of potential dissolved hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

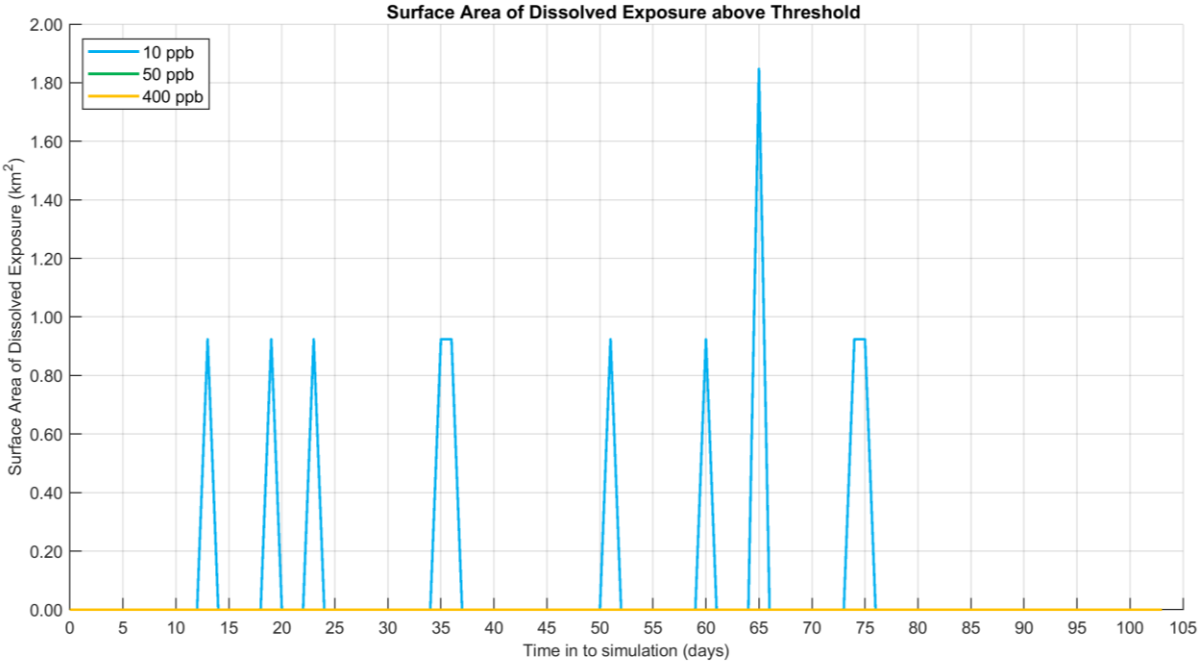


Figure 11.35 Time series of the area of dissolved hydrocarbons for each threshold, for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

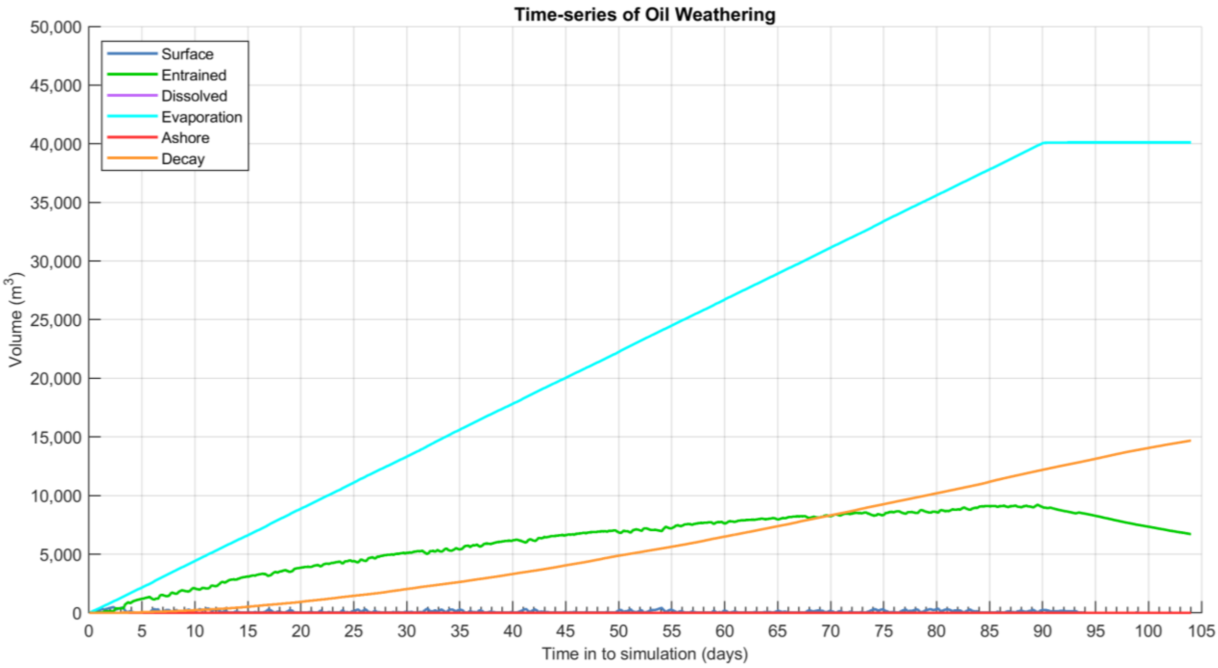


Figure 11.36 Predicted weathering and fates graph for the simulation with the largest area of dissolved hydrocarbons above 50 ppb following a subsea LOWC at WTR Well 5.

12 REFERENCES

American Society for Testing and Materials (ASTM) 2013, 'F2067-13 Standard Practice for Development and Use of Oil-Spill Trajectory Models', ASTM International, West Conshohocken (PA).

Andersen, OB 1995, 'Global ocean tides from ERS 1 and TOPEX/POSEIDON altimetry', *Journal of Geophysical Research: Oceans*, vol. 100, no. C12, pp. 25249–25259.

Anderson JW, Neff JM, Cox BA, Tatem HE & Hightower GM 1974, 'Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish', *Marine Biology*, vol. 27, no. 1, pp. 75–88.

Anderson JW, Riley R, Kiesser S & Gurtisen J 1987, 'Toxicity of dispersed and undispersed Prudhoe Bay crude oil fractions to shrimp and fish', Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 235–240.

Applied Science Associates (ASA) 2011, OILMAP-DEEP: Blowout Plume Model Technical Manual, Applied Science Associates Inc, South Kingstown, USA.

Asia-Pacific ASA 2010, 'Montara well release monitoring study S7.2. Oil fate and effects assessment: modelling of chemical dispersant operation', Prepared for PTTEP Australasia.

Australian Maritime Safety Authority (AMSA) 2014, 'Identification of oil on water: Aerial observations and identification guide', viewed 4 June 2020, https://www.amsa.gov.au/sites/default/files/2014-01-mp-amsa22-identification-oil-on-water.pdf

Australian Maritime Safety Authority (AMSA) 2015, 'Australian Maritime Safety Authority Technical Guideline for the Preparation of Marine Pollution Contingency Plans for Marine and Coastal Facilities Australian Maritime Safety Authority', viewed 20 June 2017, https://www.amsa.gov.au/forms-and-publications/Publications/AMSA413_Contingency_Planning_Guidelines.pdf

Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, 'Australian and New Zealand Guidelines for Fresh and Marine Water', Australian & New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Becker, JJ, Sandwell, DT, Smith, WHF, Braud, J, Binder, B, Depner, J, Fabre, D, Factor, J, Ingalls, S, Kim, S-H, Ladner, R, Marks, K, Nelson, S, Pharaoh, A, Trimmer, R, Von Rosenberg, J, Wallace, G & Weatherall, P 2009, 'Global bathymetry and evaluation data at 30 arc seconds resolution: SRTM30_PLUS', *Marine Geodesy*, vol. 32, no. 4, pp. 355–371.

Belore, UC 2014, Subsea chemical dispersant research. Proceedings of the 37th AMOP Technical Seminar on Environmental Contamination and Response, Environmental Canada, Canmore, Alberta, Canada pp 618–650.

Bonn Agreement 2009, 'Bonn Agreement aerial operations handbook, 2009 - Publication of the Bonn Agreement', London, viewed 13 January 2015, http://www.bonnagreement.org/site/assets/files/3947/ba-aoh_revision_2_april_2012.pdf.

Brandvik, PJ, Johansen, O, Leirvik, F, Farooq, U & Daling PS 2013, 'Droplet Breakup in subsurface oil releases – Part 1: Experimental study of droplet breakup and effectiveness of dispersant injection', *Marine Pollution Bulletin*, vol. 73, no. 1, pp 319–326.

Brandvik, PJ, Johansen, O, Farooq, U, Angell, G & Leirvik F 2014, 'Sub-surface oil releases – Experimental study of droplet distributions and different dispersant injection techniques- version 2', A scaled experimental approach using the SINTEF Tower basin. SINTEF report no: A25122. Trondheim Norway 2014. ISBN: 9788214057393

Carls, MG, Holland, L, Larsen, M, Collier, TK, Scholz, NL & Incardona, JP 2008, 'Fish embryos are damaged by dissolved PAHs, not oil particles', *Aquatic toxicology*, 88(2), pp.121–127.

Chassignet, EP, Hurlburt, HE, Smedstad, OM, Halliwell, GR, Hogan, PJ, Wallcraft, AJ, Baraille, R & Bleck, R 2007, 'The HYCOM (hybrid coordinate ocean model) data assimilative system', *Journal of Marine Systems*, vol. 65, no. 1, pp. 60–83.

Chassignet, E, Hurlburt, H, Metzger, E, Smedstad, O, Cummings, J & Halliwell, G 2009, 'U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)', *Oceanography*, vol. 22, no. 2, pp. 64–75.

Condie, SA., & Andrewartha, JR 2008, 'Circulation and connectivity on the Australian Northwest Shelf', *Continental Shelf Research*, 28, 1724–1739.

Davies, AM 1977a, 'The numerical solutions of the three-dimensional hydrodynamic equations using a B-spline representation of the vertical current profile', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 1–25.

Davies, AM 1977b, 'Three-dimensional model with depth-varying eddy viscosity', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 27–48.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2007, 'Characterisation of the marine environment in the north marine region', Marine Division, Department of the environment, water heritage and the arts.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2008, 'The North-West Marine Bioregional Plan - Bioregional Profile', Retrieved February 12, 2013, from Australian Government Department of Environment, Water, Heritage and the Arts: http://www.environment.gov.au/coasts/mbp/publications/north-west/pubs/bioregional-profile.pdf

French, D, Reed, M, Jayko, K., Feng, S, Rines, H & Pavignano, S 1996, 'The CERCLA Type A Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME), Technical Documentation, Vol. I - Model Description', Office of Environmental Policy and Compliance, U.S. Department of the Interior. Washington, D.C.: Contract No. 14-0001-91-C-11.

French, D, Schuttenberg, H & Isaji, T 1999, 'Probabilities of oil exceeding thresholds of concern: examples from an evaluation for Florida Power and Light', Proceedings of the 22nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Alberta, pp. 243–270.

French-McCay, DP 2002, 'Development and application of an oil toxicity and exposure model, OilToxEx', *Environmental Toxicology and Chemistry*, vol. 21, no. 10, pp. 2080–2094.

French-McCay, DP 2003, 'Development and application of damage assessment modelling: example assessment for the North Cape oil spill', *Marine Pollution Bulletin*, vol. 47, no. 9, pp. 9–12.

French-McCay, DP 2004, 'Spill impact modelling: development and validation', *Environmental Toxicology and Chemistry*, vol. 23, no.10, pp. 2441–2456.

French-McCay, DP 2009, 'State-of-the-art and research needs for oil spill impact assessment modelling', Proceedings of the 32nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 601–653.

French-McCay, D, Rowe, JJ, Whittier, N, Sankaranarayanan, S, & Etkin, DS 2004, 'Estimate of potential impacts and natural resource damages of oil', *Journal of Hazardous Materials*, vol. 107, no. 1, pp. 11–25.

French-McCay, D, Whittier, N, Dalton, C, Rowe, J, Sankaranarayanan, S & Aurand, D 2005a, 'Modeling the fates of hypothetical oil spills in Delaware, Florida, Texas, California, and Alaska waters, varying

response options including use of dispersants', Proceedings of the International Oil Spill Conference 2005, American Petroleum Institute, Washington DC, paper 399.

French-McCay, D, Whittier, N, Rowe, J, Sankaranarayanan, S, Kim, H-S & Aurand, D 2005b, 'Use of probabilistic trajectory and impact modeling to assess consequences of oil spills with various response strategies,' Proceedings of the 28th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 253–271.

French-McCay, D, Reich, D, Rowe, J, Schroeder, M & Graham, E 2011, 'Oil spill modeling input to the offshore environmental cost model (OECM) for US-BOEMRE's spill risk and costs evaluations', Proceedings of the 34th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Reich, D, Michel, J, Etkin, DS, Symons, L, Helton, D, & Wagner J 2012, 'Oil spill consequence analysis of potentially-polluting shipwrecks', Proceedings of the 35th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Jayko, K, Li, Z, Horn, M, Kim, Y, Isaji, T, Crowley, D, Spaulding, M, Decker, L, Turner, C, Zamorski, S, Fontenault, J, Schmmkler, R & Rowe, J 2015, 'Technical Reports for Deepwater Horizon Water Column Injury Assessment: WC_TR.14: Modeling Oil Fate and Exposure Concentrations in the Deepwater Plume and Rising Oil Resulting from the Deepwater Horizon Oil Spill', RPS ASA, South Kingston, Rhode Island.

Gordon, R 1982, 'Wind driven circulation in Narragansett Bay' PhD thesis, Department of Ocean Engineering, University of Rhode Island.

Grant, DL, Clarke, PJ & Allaway, WG 1993, 'The response of grey mangrove (*Avicennia marina* (Forsk.) Vierh) seedlings to spills of crude oil,' *The Journal of Experimental Marine Biological Ecology*, vol. 171, no. 2, pp. 273–295.

Isaji, T & Spaulding, M 1984, 'A model of the tidally induced residual circulation in the Gulf of Maine and Georges Bank', *Journal of Physical Oceanography*, vol. 14, no. 6, pp. 1119–1126.

Isaji, T, Howlett, E, Dalton C, & Anderson, E 2001, 'Stepwise-continuous-variable-rectangular grid hydrodynamics model', Proceedings of the 24th Arctic and Marine Oil spill Program (AMOP) Technical Seminar (including 18th TSOCS and 3rd PHYTO), Environment Canada, Edmonton, pp. 597–610.

Koops, W, Jak, RG & van der Veen, DPC 2004, 'Use of dispersants in oil spill response to minimise environmental damage to birds and aquatic organisms', Proceedings of the Interspill 2004: Conference and Exhibition on Oil Spill Technology, Trondheim, presentation 429.

Kostianoy, AG, Ginzburg, AI, Lebedev, SA, Frankignoulle, M & Delille, B 2003, 'Fronts and mesoscale variability in the southern Indian Ocean as inferred from the TOPEX/POSEIDON and ERS-2 Altimetry data', *Oceanology*, vol. 43, no. 5, pp. 632–642.

Li, Z, Spaulding, M, French-McCay, D, Crowley, D & Payne JR 2017, 'Development of a unified oil droplet size distribution model with application to surface breaking waves and subsea blowout releases considering dispersant effects', *Marine Pollution Bulletin*, vol. 114, no. 1, pp 247–257.

Lin, Q & Mendelssohn, IA 1996, 'A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish and Salt Marshes', *Marine Pollution Bulletin*, vol. 32, no. 2, pp. 202–209.

Ludicone, D, Santoleri, R, Marullo, S & Gerosa, P 1998, 'Sea level variability and surface eddy statistics in the Mediterranean Sea from TOPEX/POSEIDON data', *Journal of Geophysical Research I*, vol. 103, no. C2, pp. 2995–3011.

Mackay D, Puig H & McCarty LS 1992, 'An equation describing the time course and variability in uptake and toxicity of narcotic chemicals to fish', *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, p.941–951.

Malins DC & Hodgins HO 1981, 'Petroleum and marine fishes: a review of uptake, disposition, and effects', *Environmental Science & Technology*, vol. 15, no. 11, pp.1272–1280.

Matsumoto, K, Takanezawa, T & Ooe, M 2000, 'Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan', *Journal of Oceanography*, vol. 56, no.5, pp. 567–581.

McAuliffe CD 1987, 'Organism exposure to volatile/soluble hydrocarbons from crude oil spills – a field and laboratory comparison', Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 275–288.

McCarty LS 1986, 'The relationship between aquatic toxicity QSARs and bioconcentration for some organic chemicals', *Environmental Toxicology and Chemistry*, vol. 5, no. 12, pp. 1071–1080.

McCarty LS & Mackay D 1993, 'Enhancing ecotoxicological modelling and assessment. Body residues and modes of toxic action', *Environmental Science & Technology*, vol. 27, no. 9, pp. 1718–1728.

McCarty LS, Dixon DG, MacKay D, Smith AD & Ozburn GW 1992a, 'Residue-based interpretation of toxicity and bioconcentration QSARs from aquatic bioassays: Neutral narcotic organics', *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, pp.917–930.

McCarty LP, Flannagan DC, Randall SA & Johnson KA 1992b, 'Acute toxicity in rats of chlorinated hydrocarbons given via the intratracheal route', *Human & Experimental Toxicology*, vol. 11, no. 3, pp.173–117.

McGrath JA, & Di Toro DM 2009, 'Validation of the target lipid model for toxicity assessment of residual petroleum constituents: monocyclic and polycyclic aromatic hydrocarbons', *Environmental Toxicology and Chemistry*, vol. 28, no. 6, pp. 1130–1148.

National Oceanic and Atmospheric Administration (NOAA) 2013, 'Screening level risk assessment package Gulf state', Office of National Marine Sanctuaries & Office of Response and Restoration, Washington DC.x

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2018, 'At a glance: Oil spill modelling', viewed 15 November 2018, https://www.nopsema.gov.au/assets/Publications/A626200.pdf

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2019, 'NOPSEMA Bulletin #1: Oil spill modelling', viewed April 2019, https://www.nopsema.gov.au/assets/Bulletins/A652993.pdf

National Research Council (NRC) 2003, 'Oil in the sea III: Inputs, fates and effects', The National Academic Press, Washington D.C.

Neff JM, Anderson JW 1981, 'Response of marine animals to petroleum and specific petroleum hydrocarbons' United States Department of Energy, United States.

Nirmalakhandan N & Speece RE 1998, 'Quantitative techniques for predicting the behaviour of chemicals in the ecosystem', *Environmental Science & Technology*, vol. 22, no. 6, pp. 606–615.

Nordtug, T, Olsen, AJ, Altin, D, Overrein, I, Storøy, W, Hansen, BH & De Laender, F 2011, 'Oil droplets do not affect assimilation and survival probability of first feeding larvae of North-East Arctic cod', *Science of the Total Environment*, 412, pp.148–153.

Oil Spill Solutions 2015, 'Evaluation - The Theory of Oil Slick Appearances', viewed 6 January 2015, http://www.oilspillsolutions.org/evaluation.htm

Owen, A 1980, 'A three-dimensional model of the Bristol Channel', *Journal of Physical Oceanography*, vol. 10, no. 8, pp. 1290–1302.

Qiu, B & Chen, S 2010, 'Eddy-mean flow interaction in the decadally modulating Kuroshio Extension system', *Deep-Sea Research II*, vol. 57, no. 13, pp. 1098–1110.

Redman AD 2015, 'Role of entrained droplet oil on the bioavailability of petroleum substances in aqueous exposures', *Marine Pollution Bulletin*, vol. 97, no. (1–2), pp. 342–348.

Saha, S, Moorthi, S, Pan, H-L, Wu, X, Wang, J & Nadiga, S 2010, 'The NCEP Climate Forecast System Reanalysis', *Bulletin of the American Meteorological Society*, vol. 91, no. 8, pp. 1015–1057.

Scholten, MCTh, Kaag, NHBM, Dokkum, HP van, Jak, R.G., Schobben, HPM & Slob, W 1996, Toxische effecten van olie in het aquatische milieu, TNO report TNO-MEP – R96/230, Den Helder.

Spaulding, ML., Kolluru, VS, Anderson, E & Howlett, E 1994, 'Application of three-dimensional oil spill model (WOSM/OILMAP) to hindcast the Braer Spill', *Spill Science and Technology Bulletin*, vol. 1, no. 1, pp. 23–35.

Spaulding, MS, Mendelsohn, D, Crowley, D, Li, Z, and Bird A, 2015. Technical Reports for Deepwater Horizon Water Column Injury Assessment- WC_TR.13: Application of OILMAP DEEP to the Deepwater Horizon Blowout. RPS APASA, 55 Village Square Drive, South Kingstown, RE 02879.

Suprayogi, B & Murray, F 1999, 'A field experiment of the physical and chemical effects of two oils on mangroves', *Environmental and Experimental Botany*, vol. 42, no. 3, pp. 221–229.

Swartz RC, Schults DW, Ozretich RJ, Lamberson JO, Cole FA, Ferraro SP, Dewitt TH & Redmond MS 1995, 'ΣPAH: A Model to predict the toxicity of polynuclear aromatic hydrocarbon mixtures in field-collected sediments', *Environmental Toxicology and Chemistry*, vol. 14, no. 11, pp. 1977–1187.

Verhaar HJM, Van Leeuwen CJ & Hermens JLM 1992, 'Classifying environmental pollutants', *Chemosphere*, vol. 24, no. 4, pp. 471–491.

Verhaar HJM, de Jongh J & Hermens JLM 1999, 'Modelling the bioconcentration of organic compounds by fish: A novel approach', *Environmental Science & Technology*, vol. 33, no. 22, pp. 4069–4072.

Yaremchuk, M & Tangdong, Q 2004, 'Seasonal variability of the large-scale currents near the coast of the Philippines', *Journal of Physical Oceanography*, vol. 34, no., 4, pp. 844–855.

Zigic, S, Zapata, M, Isaji, T, King, B, & Lemckert, C 2003, 'Modelling of Moreton Bay using an ocean/coastal circulation model', Proceedings of the 16th Australasian Coastal and Ocean Engineering Conference, the 9th Australasian Port and Harbour Conference and the Annual New Zealand Coastal Society Conference, Institution of Engineers Australia, Auckland, paper 170.

GREATER GORGON – GERYON–EURYTION

Oil Spill Modelling

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Prepared by:

RPS

Jeremie Bernard
Senior Coastal Engineer

Lakeside Corporate Space, Suite 425
Level 2, 34-38 Glenferrie Drive
Robina, QLD, 4226, Australia

T +61 7 5553 6900
E Jeremie.Bernard@rpsgroup.com

Prepared for:

CHEVRON AUSTRALIA PTY LTD

Mike Daly
HSE Specialist - Environment

Level 13, 250 St Georges Tce
Perth WA 6000 Australia

T +61 418 488 728
E mike.daly@chevron.com

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TERMS AND ABBREVIATIONS

°	Degrees
‘	Minutes
“	Seconds
µm	Micrometre (unit of length; 1 µm = 0.001 mm)
Actionable oil	Oil which is thick enough for the effective use of mitigation strategies
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute gravity. A measure of how heavy or light a petroleum liquid is compared to water.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m^3)
bbl/d	Barrels per day
Bonn Agreement	An agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983, includes: Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
cP	Centipoise (unit of dynamic viscosity)
Decay	The process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions.
Dynamic viscosity	The dynamic viscosity of a fluid expresses its resistance to shearing flows, where adjacent layers move parallel to each other with different speeds.
Floating oil exposure	Contact by floating oil on the sea surface at concentrations equal to or exceeding defined threshold concentrations. The consequence will vary depending on the threshold and the receptors
g/m^2	Grams per square meter (unit of surface area density)
GODAE	Global Ocean Data Assimilation Experiment
HYCOM	Hybrid Coordinate Ocean Model. A data-assimilative, three-dimensional ocean model
HYDROMAP	Advanced ocean/coastal tidal model used to predict tidal water levels, current speed and current direction.
IAA	Impact Assessment Area
IBRA	Interim Biogeographic Regionalisation for Australia

IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
Shoreline contact	Arrival of oil at or near shorelines at on-water concentrations equal to or exceeding defined threshold concentrations. Shoreline contact is judged for floating oil arriving within a 2 km buffer zone from any shoreline as a conservative measure
SIMAP	Spill Impact Model Application Package. SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for surface or subsea releases
Single Oil spill modelling	Oil spill modelling involving a computer simulation of a single hypothetical oil spill event subject to a single sequence of wind, current and other sea conditions over time. Single oil spill modelling, also referred to as “deterministic modelling” provides a simulation of one possible outcome of a given spill scenario, subject to the metocean conditions that are imposed. Single oil spill modelling is commonly used to consider the fate and effects of ‘worst-case’ oil spill scenarios that are carefully selected in consideration of the nature and scale of the offshore petroleum activity and the local environment (NOPSEMA, 2017). Because the outcomes of a single oil spill simulation can only represent the outcome of that scenario under one sequence of metocean conditions, worst-case conditions are often identified from stochastic modelling. It is impossible to calculate the likelihood of any outcome from a single oil spill simulation. Single oil spill modelling is generally used for response planning, preparedness planning and for supporting oil spill response operations in the event of an actual spill

SRTM	Shuttle Radar Topography Mission
Stochastic oil spill modelling	Stochastic oil spill modelling is created by overlaying and statistically analysing the outcomes of many single oil-spill simulations of a defined spill scenario, where each simulation was subject to a different sequence of metocean conditions, selected objectively (typically by random selection) from a long sequence of historic conditions for the study area. Analysis of this larger set of simulations provides a more accurate indication of the environment that maybe affected (EMBA) and indicates which locations are more likely to be affected (as well as other statistics). Stochastic oil spill modelling avoids biases that affect single oil spill modelling (due to the reliance on only one possible sequence of conditions). However, when interpreting stochastic modelling, which is based on a wide range of potential conditions that might happen to occur, it is essential to understand that calculations will encompass a much larger area than could be affected in any single spill event, where a more limited set of conditions will occur. Consequently, it is misleading to imply that the region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) Stochastic modelling is generally used for risk assessment and preparedness planning by indicating locations that could be exposed and may require response or subsequent impact assessment
TOPEX/ Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed, quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Geryon and Eurytion (G&E) fields situated within the Northern Carnarvon Basin in Permit area WA-22-R and WA-39-L, respectively, northwest of Barrow Island off the north-west coast of Western Australia. Chevron commissioned RPS to undertake an oil spill modelling to support environmental approvals.

The oil spill modelling study was conducted to assess the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 3,506 stb/day (557.47 m^3/day) subsea release of condensate over 90 days (totalling 315,540 stb or 50,165 m^3) from a loss of well control (LOWC).

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

Methodology

The modelling study was carried out in stages. Firstly, a 10-year current dataset (2010–2019) that includes the combined influence of large-scale ocean and nearshore tidal currents was developed. Secondly, the currents, local winds and detailed hydrocarbon characteristics were used as inputs in the three-dimensional oil spill model (SIMAP) to simulate the drift, spread, weathering and fate of the spilled oil.

As spills can occur during any set of wind and current conditions, modelling was conducted using a stochastic (or probabilistic) approach, which involved running 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Condensate Properties

Geryon condensate has an API of 42.67, a density of 810 kg/m^3 (at 15ºC) and a low viscosity value of 5.2 cP. When exposed to the atmosphere at local temperatures, about 31.5% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 27.1% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~31.7%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 9.7% of the condensate is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.5%), indicating a very low propensity for the mixture to take up water to form water-in-oil emulsion over the weathering cycle. The soluble aromatic hydrocarbons contribute approximately 2.9% by mass of the whole oil, which is contained in the volatile fractions, which are highly soluble.

Key Findings

- The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 132.6 km south (summer) and 60.4 km southeast (winter), respectively. No exposure was predicted at the high (≥ 50 g/m^2) threshold.

- The Offshore Area IAA, Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater - Breeding BIAs, which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low threshold was 100% for all seasons for these receptors. Probabilities of moderate exposure for these rectors ranged between 51% (all receptors; summer) and 82% (Pygmy Blue Whale - Distribution (BIA) and Offshore Area IAA); winter). Additionally, the Flatback Turtle - Internesting Buffer and Whale Shark - Foraging BIAs were also predicted to be exposed at the low threshold during summer (7% and 1%), transitional (13% and 6%) and winter (15% and 13%), respectively. The minimum time before low exposure for the Flatback Turtle - Internesting Buffer and Whale Shark - Foraging BIAs was 5.79 days during summer conditions. Furthermore, the probability of exposure at the low threshold for the Continental Slope Demersal Fish Communities (KEF) was 96%, 80% and 84% during summer, transitional and winter, respectively. The corresponding minimum time before low exposure at the Continental Slope Demersal Fish Communities (KEF) was 1.88 days (summer).

- The probability of shoreline accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 23%, while the minimum time before shoreline accumulation was 7.46 days and the maximum volume of oil ashore 23.2 m^3. Additionally, no shoreline accumulation was predicted during transitional conditions, nor was there any high (≥ 1,000 g/m^2) shoreline threshold accumulation predicted during any seasonal conditions modelled.

- During summer conditions, condensate had accumulated on 38 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA and Barrow Island Group (15%). In comparison, during winter conditions, condensate was predicted to accumulate on 4 shoreline receptors and each with an 8% probability.

- No dissolved hydrocarbon exposure was predicted for this scenario at, or above, the low reporting threshold (≥10 ppb) during any of the seasons modelled.

- In the 0-10 m depth layer, a total of 40, 22 and 22 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter conditions respectively. Excluding the Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater – Breeding BIAs which the release location resides within, the highest probabilities of exposure were predicted for Humpback Whale - Migration BIA (95% summer, 91% transitional and 87% winter). Additionally, within the same depth layer, during summer, transitional and winter conditions, 8, 7 and 7 KEFs were predicted to be exposed at the low threshold, respectively. Probabilities ranged between 2–100%, 2–100% and 3–100% for summer, transitional and winter, respectively.

- In the 0-10 m depth layer, a total of 50, 17 and 15 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold during summer, transitional and winter conditions, respectively. Excluding the Offshore IAA, the probabilities for each season ranged between 1–92%, 1–97% and 1–86% under summer, transitional and winter conditions, respectively with the maximum probabilities occurring at the Gascoyne IAA during all seasons. Furthermore, 59, 5 and 4 RSB receptors were predicted to be exposed to entrained hydrocarbons at the low threshold during summer, transitional and winter conditions, respectively. Maximum summer, transitional and winter probabilities of 23% for Rankin Bank, 6% for Rankin Bank and Outtrim Patches and 14% for Outtrim Patches, respectively, were predicted.

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Geryon and Eurytion (G&E) fields situated within the Northern Carnarvon Basin in Permit area WA-22-R and WA-39-L, respectively, northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the G&E fields, Chevron commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 3,506 stb/day (557.47 m^3/day) subsea release of condensate over 90 days (totalling 315,540 stb or 50,165 m^3) from a loss of well control (LOWC).

The release location used for the oil spill assessment is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the ‘outer boundaries’ of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis Program (SIMAP). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, RPS warrants that this work meets and exceeds the American Society for Testing and Materials (ASTM) Standard F2067-13 “*Standard Practice for Development and Use of Oil Spill Models*”.

Table 1.1 Coordinates of the Geryon–Eurytion release location.

Location	Latitude	Longitude	Depth (mLAT)
GER FL 2	19.94487º S	114.89167º E	410

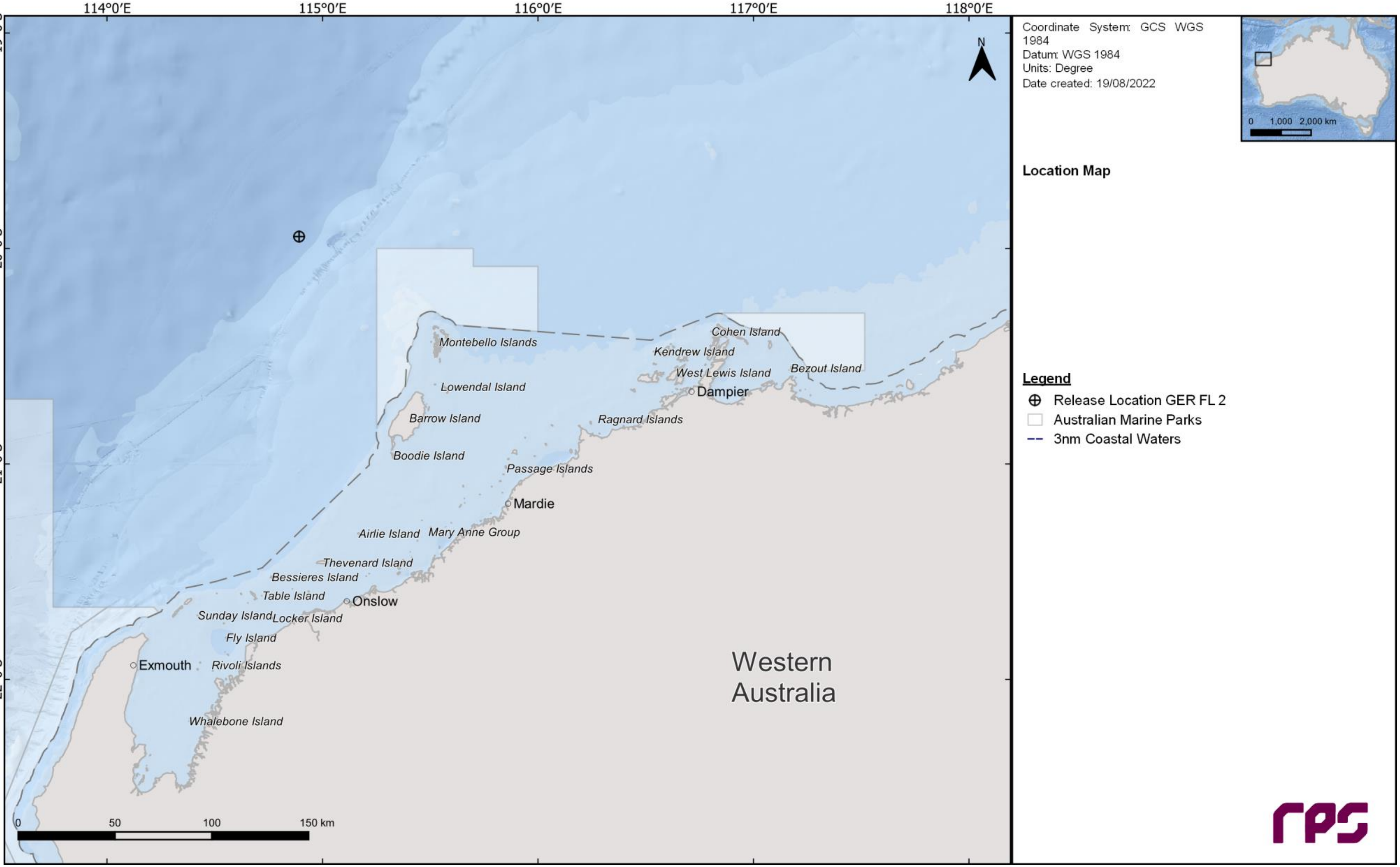


Figure 1.1 Geryon and Eurytion hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate 10-years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. Run 100 simulations for each season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds; and

5. From the 300 simulations modelled, identify and present the "worst case" deterministic runs, which can be used to inform response planning based on the following criteria:
   a. Largest swept area of floating hydrocarbon above 10 g/m^2
   b. Largest swept area of floating hydrocarbon above 50 g/m^2
   c. Largest volume of oil ashore
   d. Longest length of shoreline accumulation above 100 g/m^2
   e. Largest area of entrained hydrocarbons above 100 ppb
   f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no floating hydrocarbons at or above 50 g/m^2 and no dissolved hydrocarbon exposure at or above 50 ppb, for any of the 300 simulations, the deterministic results are presented based on criteria a, c, d and e only.

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

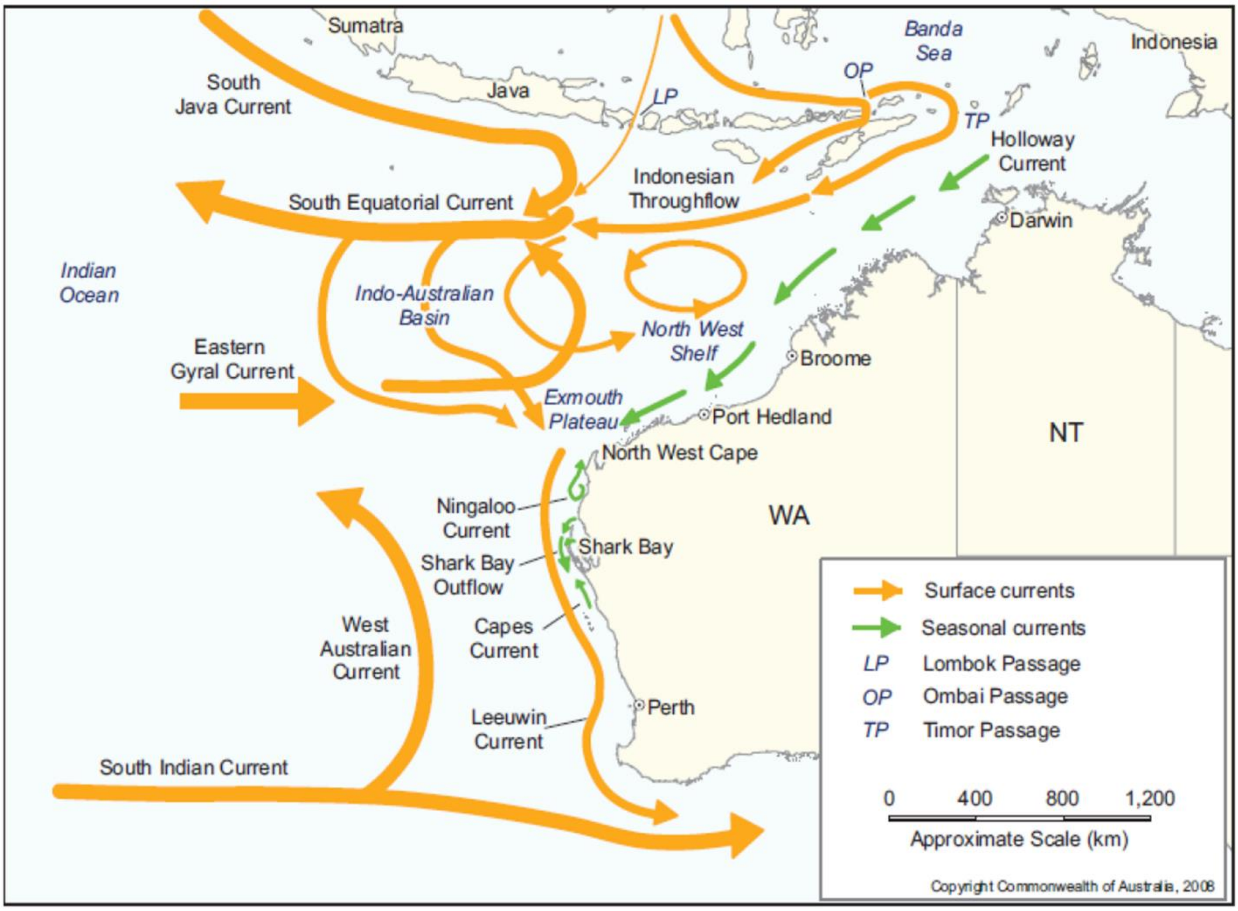


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

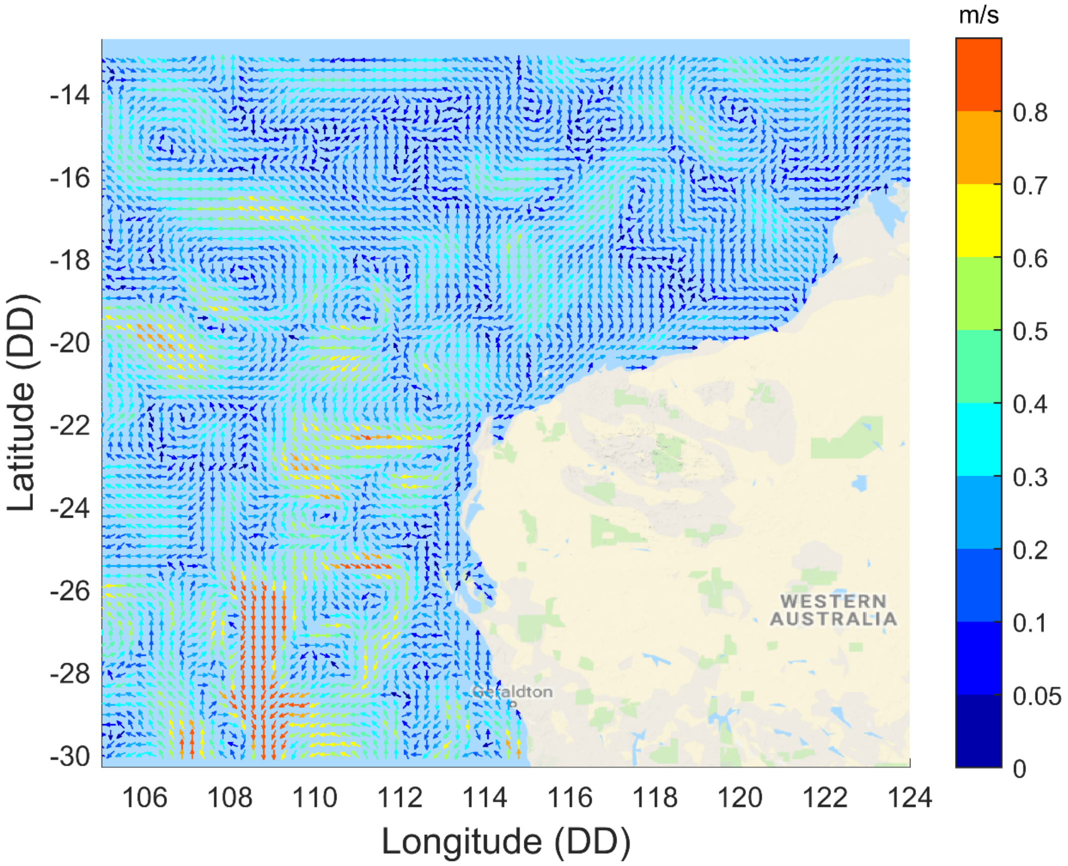


Figure 3.2 Typical ocean current circulation pattern during the summer months.

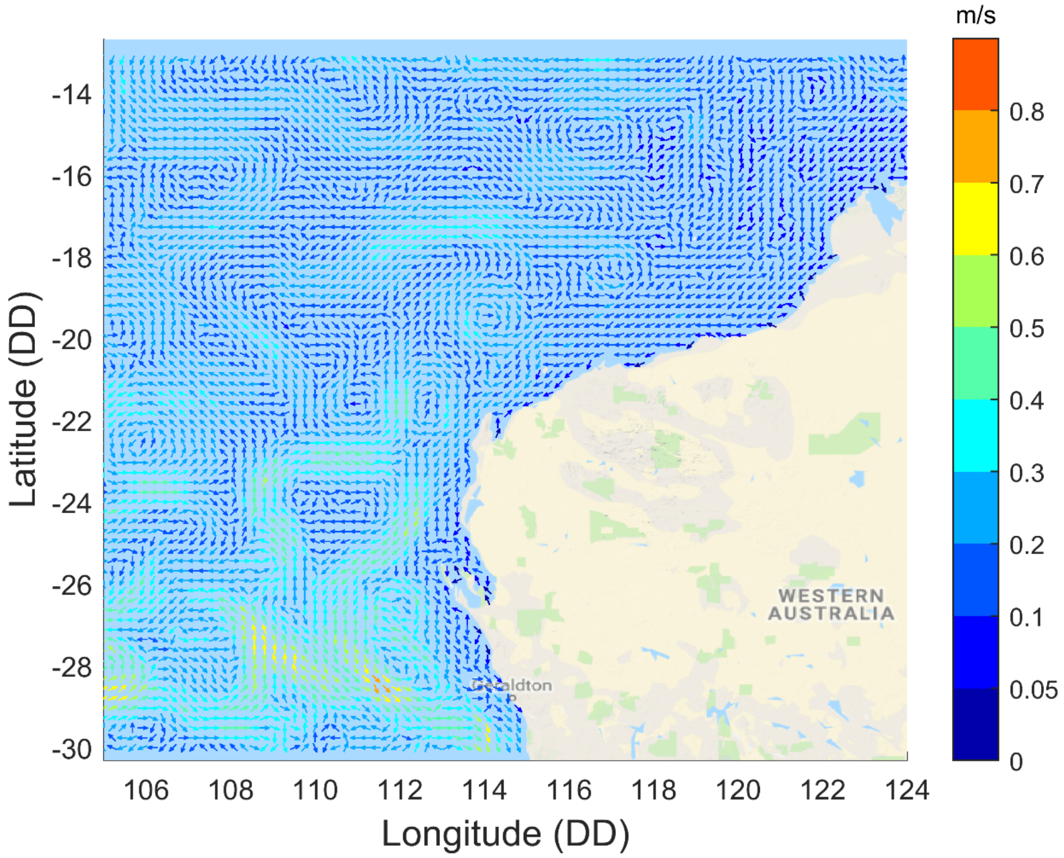


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grids were allocated in a step-wise fashion to resolve flows more accurately along the coastline, around islands and over regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

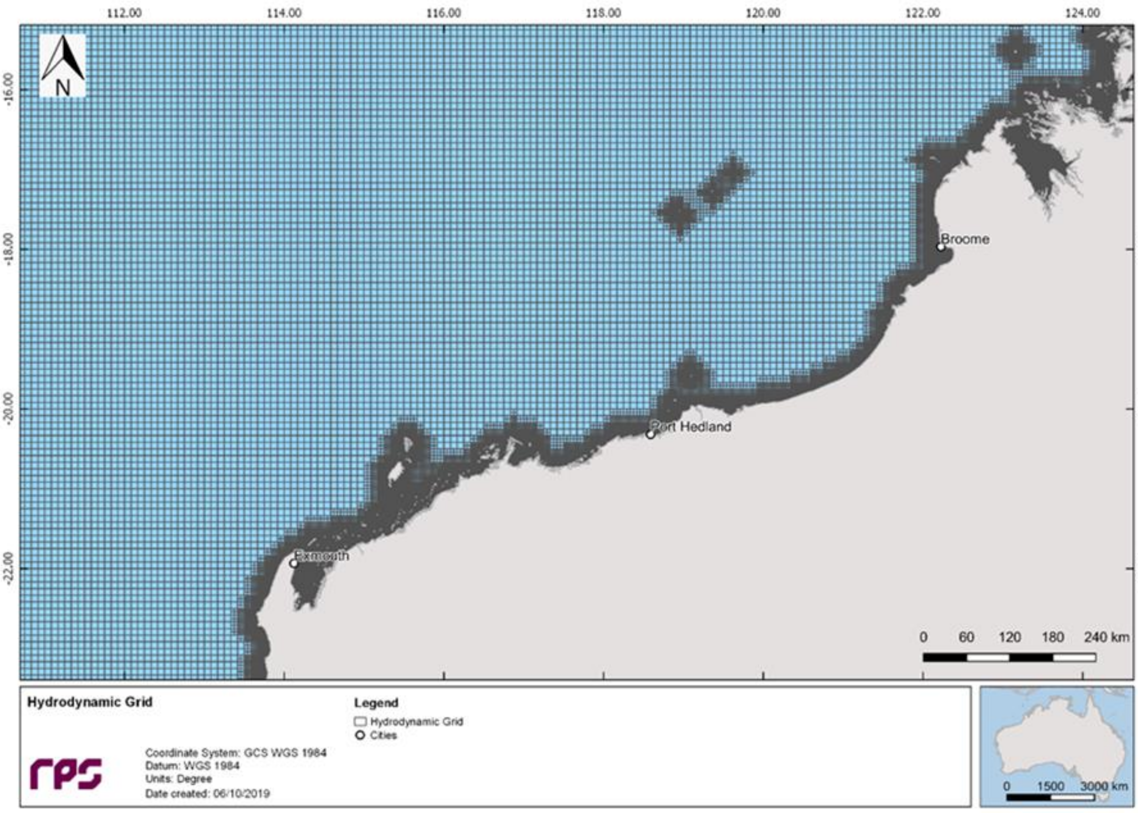


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

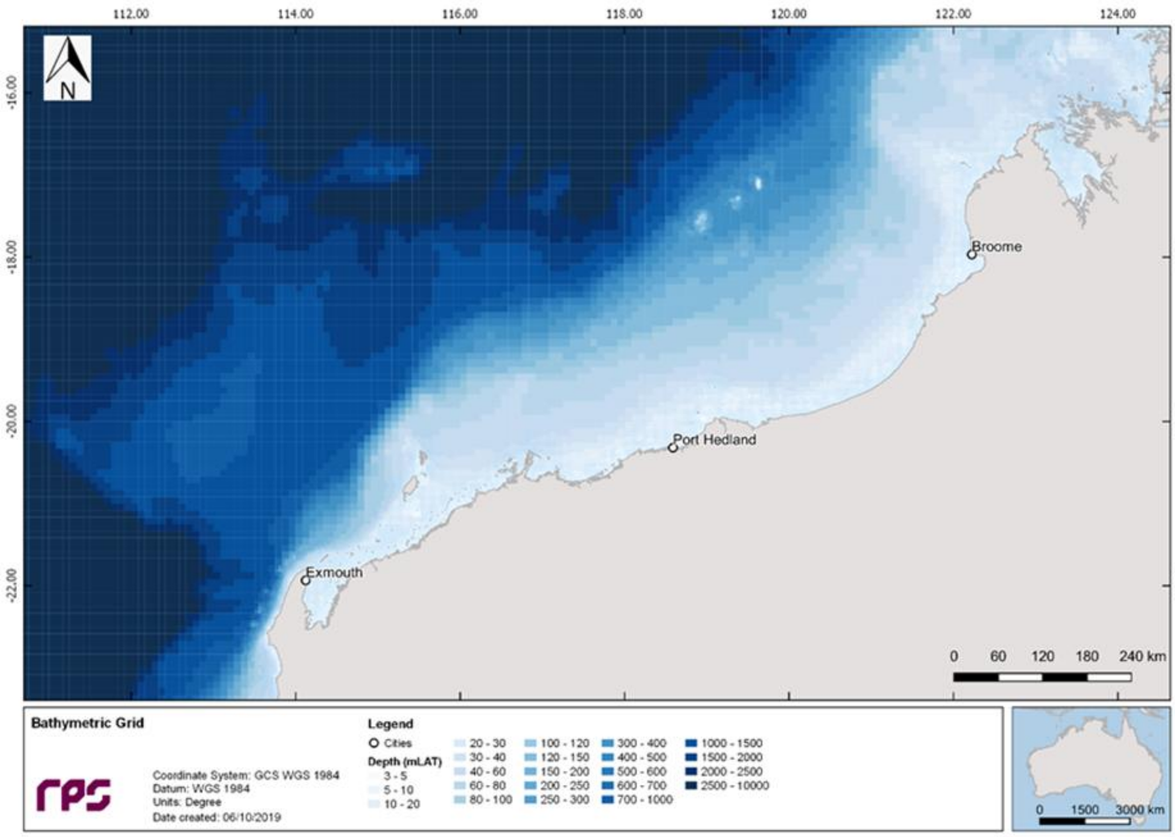


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.19 m/s (February, November and December) and 0.25 m/s (June). Additionally, the monthly maximums ranged between 0.62 m/s (November) and 1.53 m/s (January). The general surface current directions were towards the southwest. Figure 3.6 and Figure 3.7 present the monthly and total surface current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.20	1.53	Variable
	February	0.19	1.11	Variable
	March	0.21	1.35	Southwest
Transitional	April	0.23	1.02	Southwest
Winter	May	0.23	0.78	Southwest
	June	0.25	0.84	Southwest
	July	0.23	0.90	Southwest
Transitional	August	0.21	0.79	Variable
Summer	September	0.22	0.83	Northeast and Southwest
	October	0.19	0.63	Northeast and Southwest
	November	0.19	0.62	Southwest
	December	0.19	0.71	Southwest
Minimum		**0.19**	**0.62**	
Maximum		**0.25**	**1.53**	

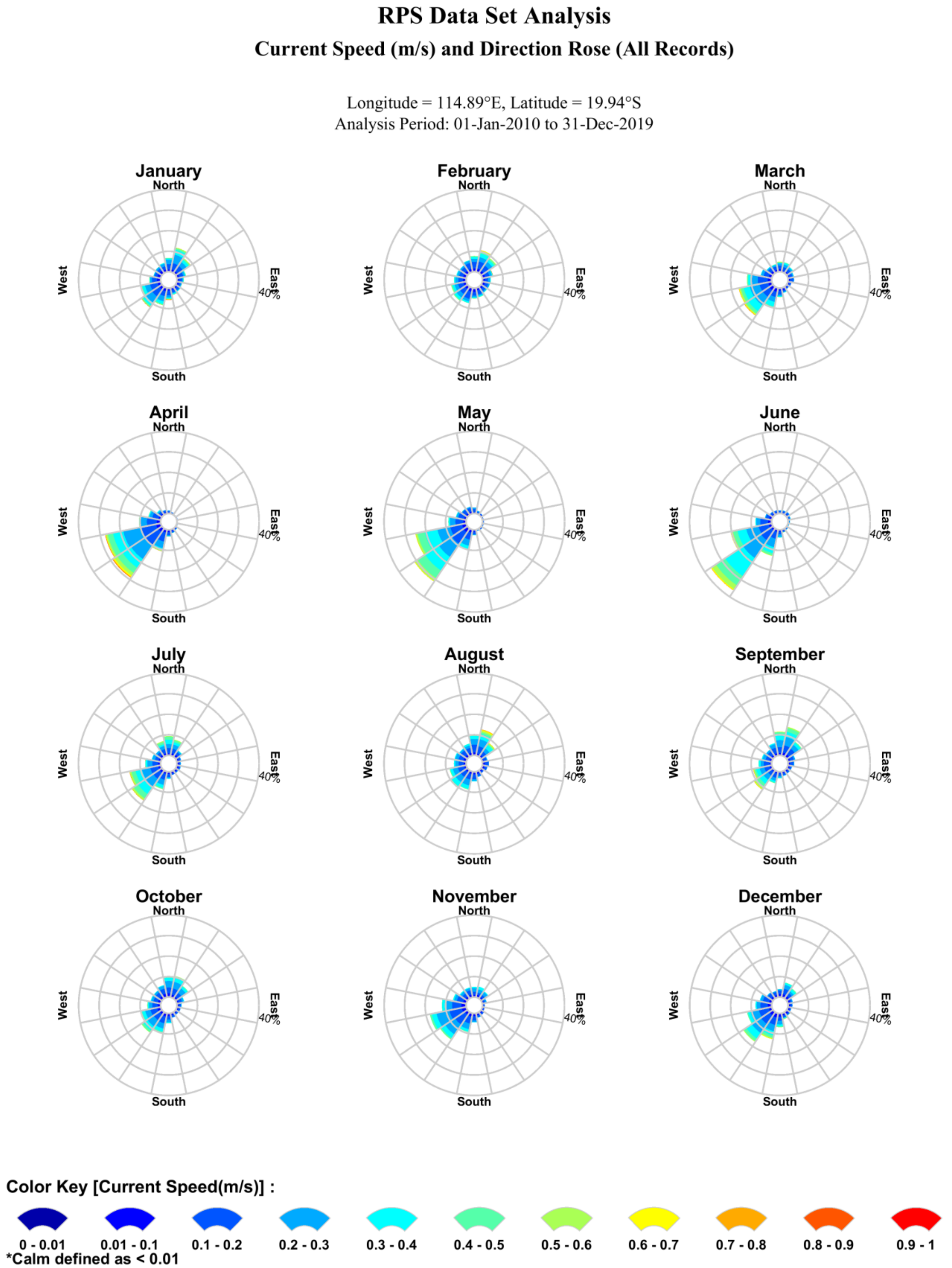


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

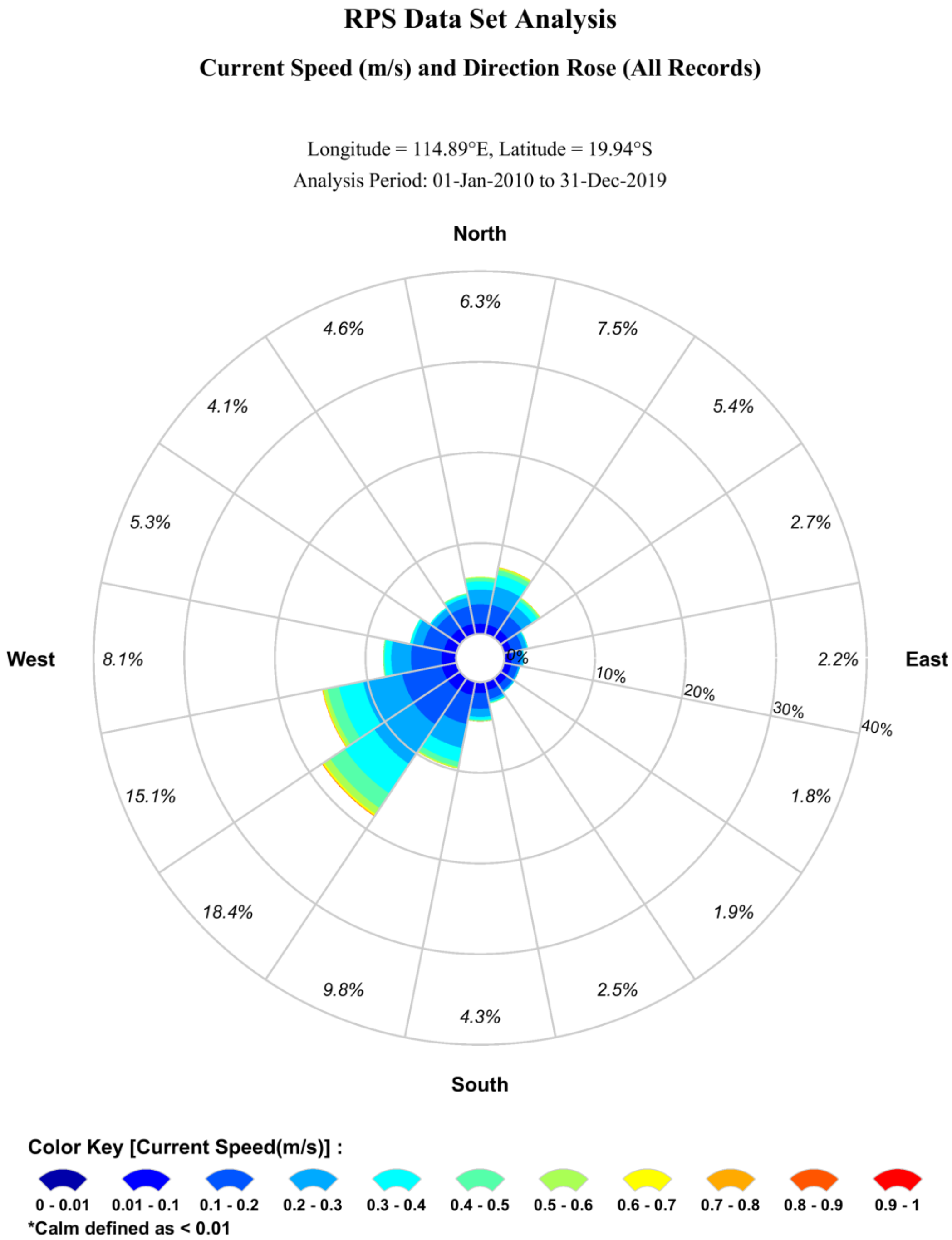


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 45 knots (July). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

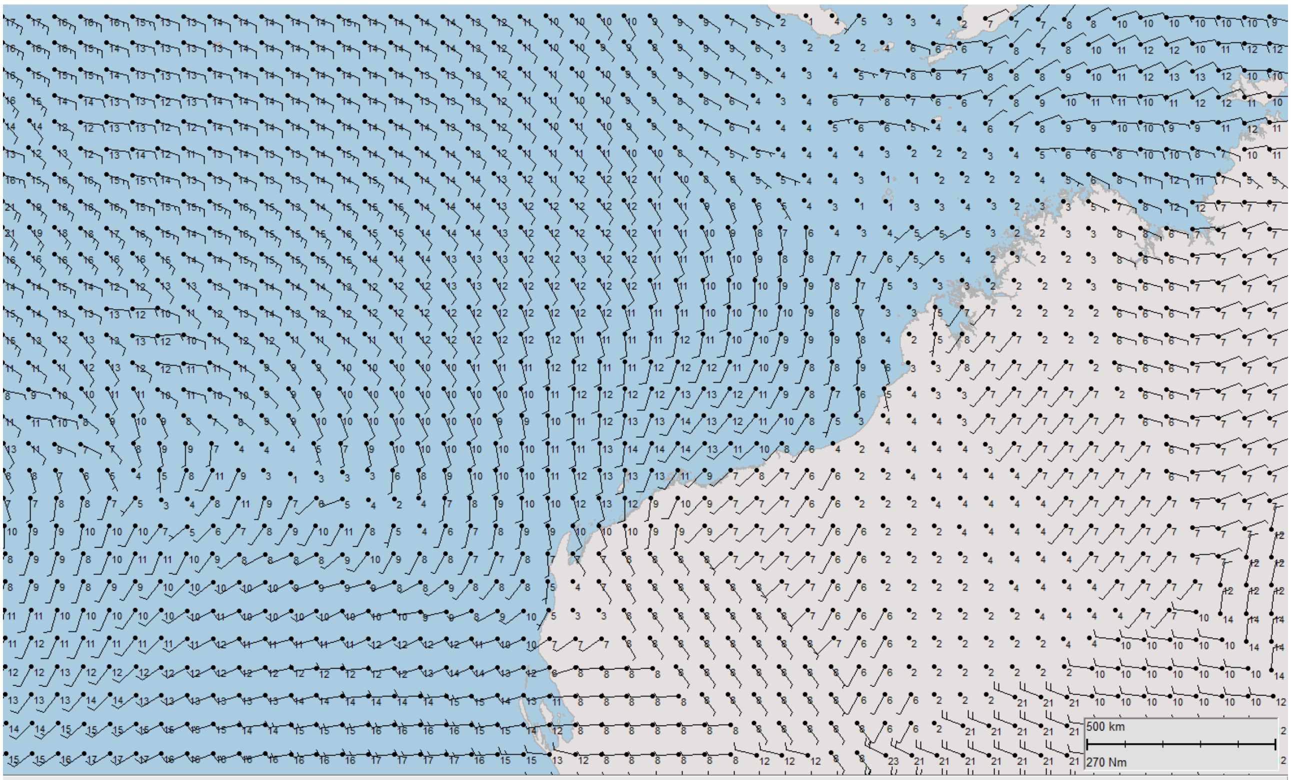


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	42	Southwest
	February	11	43	Southwest
	March	10	35	Southwest
Transitional	April	10	37	Variable
Winter	May	12	39	East
	June	14	30	East
	July	13	45	East to South
Transitional	August	11	30	Variable
Summer	September	12	27	South-Southwest
	October	13	26	South-Southwest
	November	13	25	South-Southwest
	December	12	30	Southwest
Minimum		**10**	**25**	
Maximum		**14**	**45**	

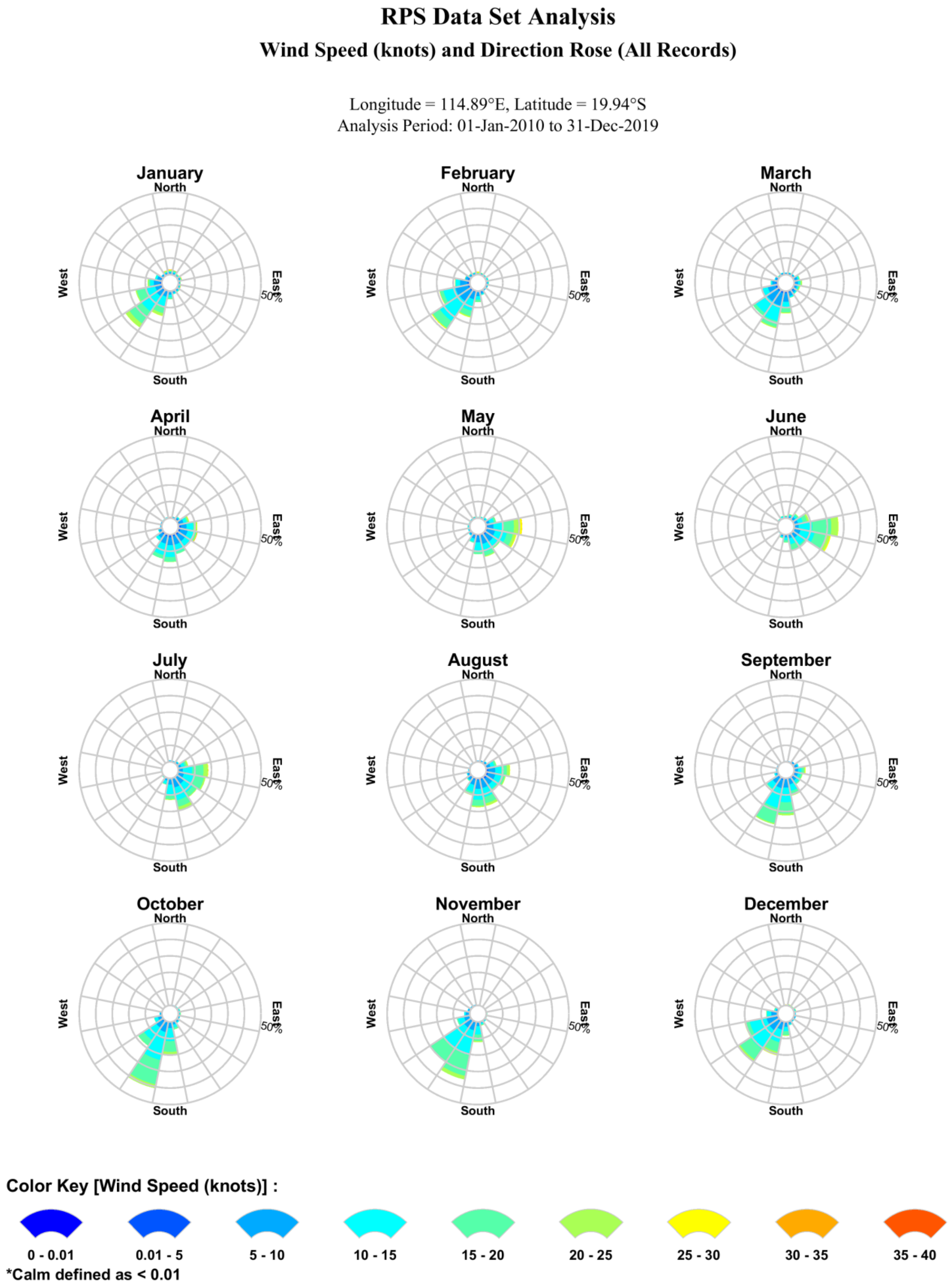


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

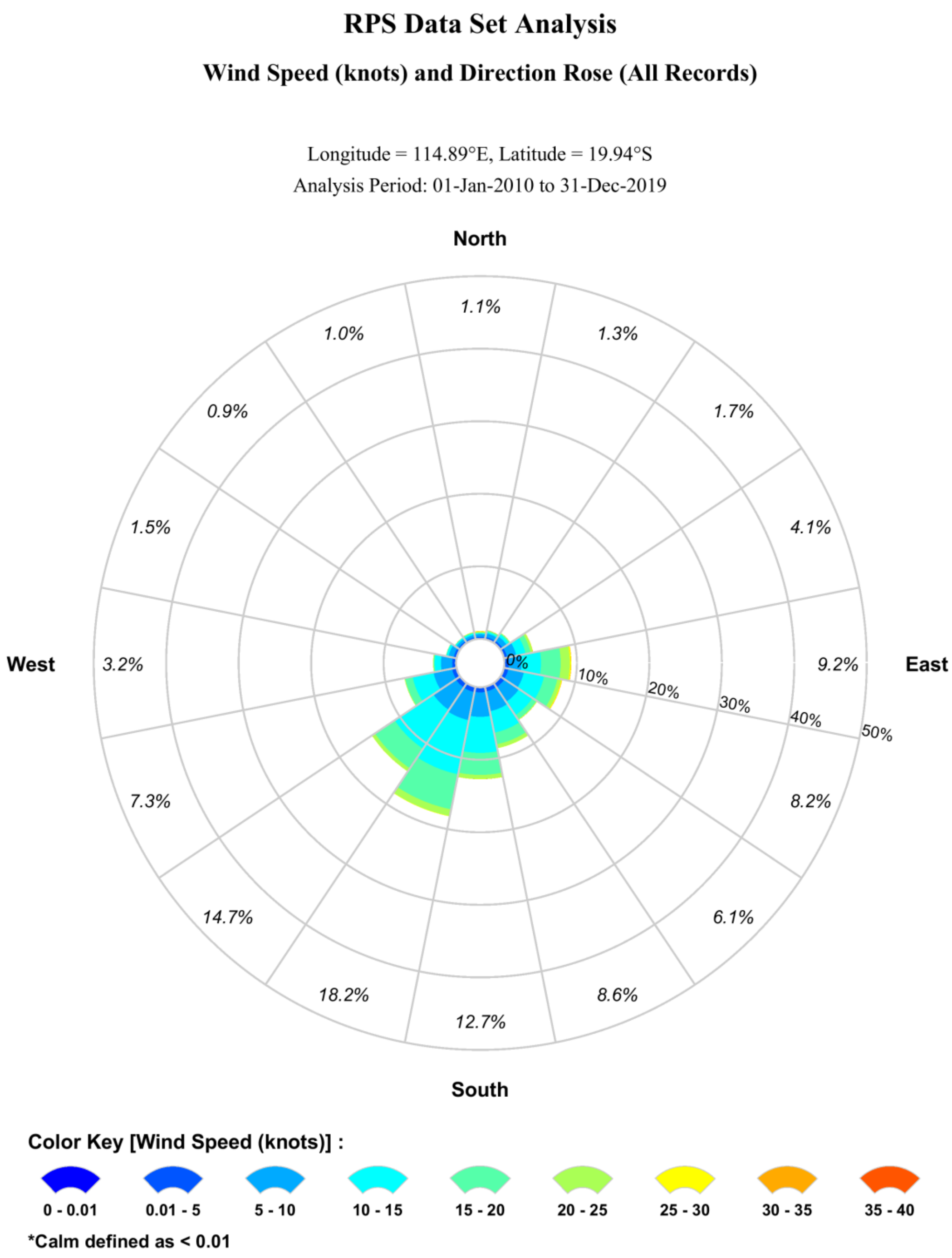


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from HYCOM (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.1°C (September) to 29.6°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.5–34.9 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	27.8	28.6	29.6	28.9	27.8	26.9	25.4	24.4	24.1	24.9	27.2	27.0
Salinity (psu)	34.9	34.6	34.6	34.5	34.7	34.8	34.6	34.7	34.7	34.7	34.7	34.7

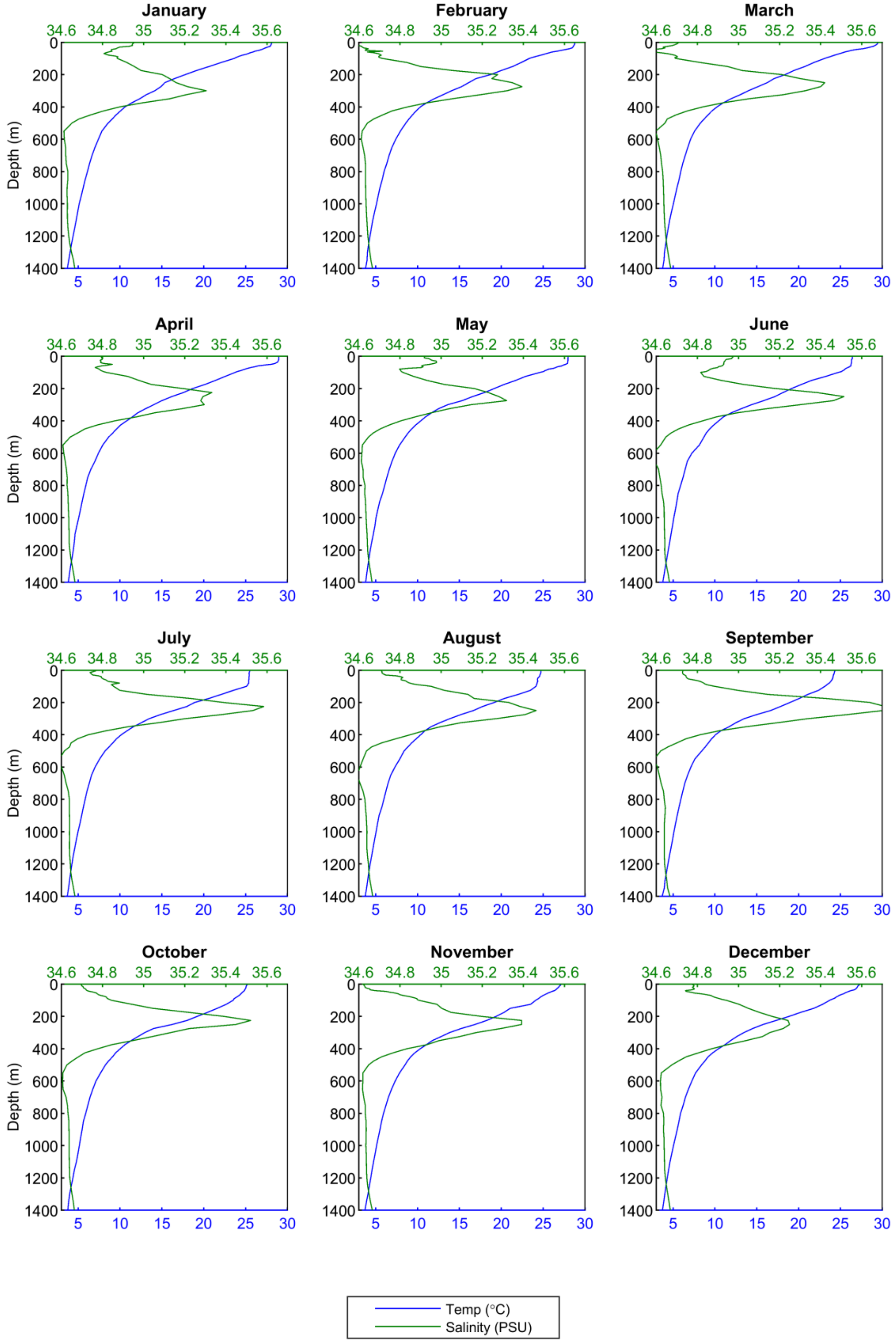


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 SUBSEA PLUME MODEL – OILMAP DEEP

The LOWC scenario is a high-pressure release of mostly gas and condensate and where gas is released with condensate, the buoyancy of the expanding gas cloud will entrain ambient seawater and propel the droplets towards the surface at a faster rate than would occur from the relative buoyancy of the condensate alone. Furthermore, the turbulence generated by such an intense discharge will tend to break the condensate up into droplets of various sizes.

To define the near-field plume dynamics, the subsea blowout model, OILMAP-DEEP, was applied. The model simulates the plume rise dynamics in two phases, the initial jet phase and the buoyant plume phase. The initial jet phase governs the plume dynamics directly above the subsurface release location and is predominately driven by the exit velocity. During this phase, the condensate droplet size and distribution is calculated. Next, the rise dynamics are dominated by the buoyant nature of the plume until the termination of the plume phase (known as the trapping depth). At this point, the results from OILMAP-DEEP (including plume trapping depth, plume diameter and droplet size distribution) are integrated into the far-field model SIMAP to simulate the rise and dispersion of the condensate droplets.

More details on the OILMAP-DEEP model, can be found in Spaulding et al. (2015). The model has been validated against observations from Deepwater Horizon as well as small and large-scale laboratory studies on subsurface oil releases (Brandvik et al., 2013, 2014; Belore, 2014; Spaulding et al., 2015; Li et al., 2017).

Table 6.1 presents the input parameters for the OILMAP-DEEP model and key results related to the near-field plume dynamics. The results indicated that the mixture of gas and condensate rose through the water column (whilst gradually losing momentum) to a trapping depth of approximately 103 m below mean sea level. After this point the condensate droplets would rise due to their own buoyancy. The modelling predicted droplets ranging in size from 53 to 307 µm.

Figure 6.1 illustrates the various stages of an example blowout plume.

Table 6.1 Input data and key results for the subsea plume modelling.

Input Variable	Value
Scenario	Loss of Well Control
Well name	GER FL2
Water depth (m)	410
Tubing diameter (inch) [m]	7 5/8 [0.194]
Condensate rate (stb/day)	3,506
Gas rate (MMscf/day)	551
Gas to condensate ratio (scf/bbl)	157,159
Formation water flow rate (stb/day)	0
Operating pressure (psia)	4,670
Key results	
Plume execution depth (m BMSL)	103
Droplet sizes (µm)	53 to 307

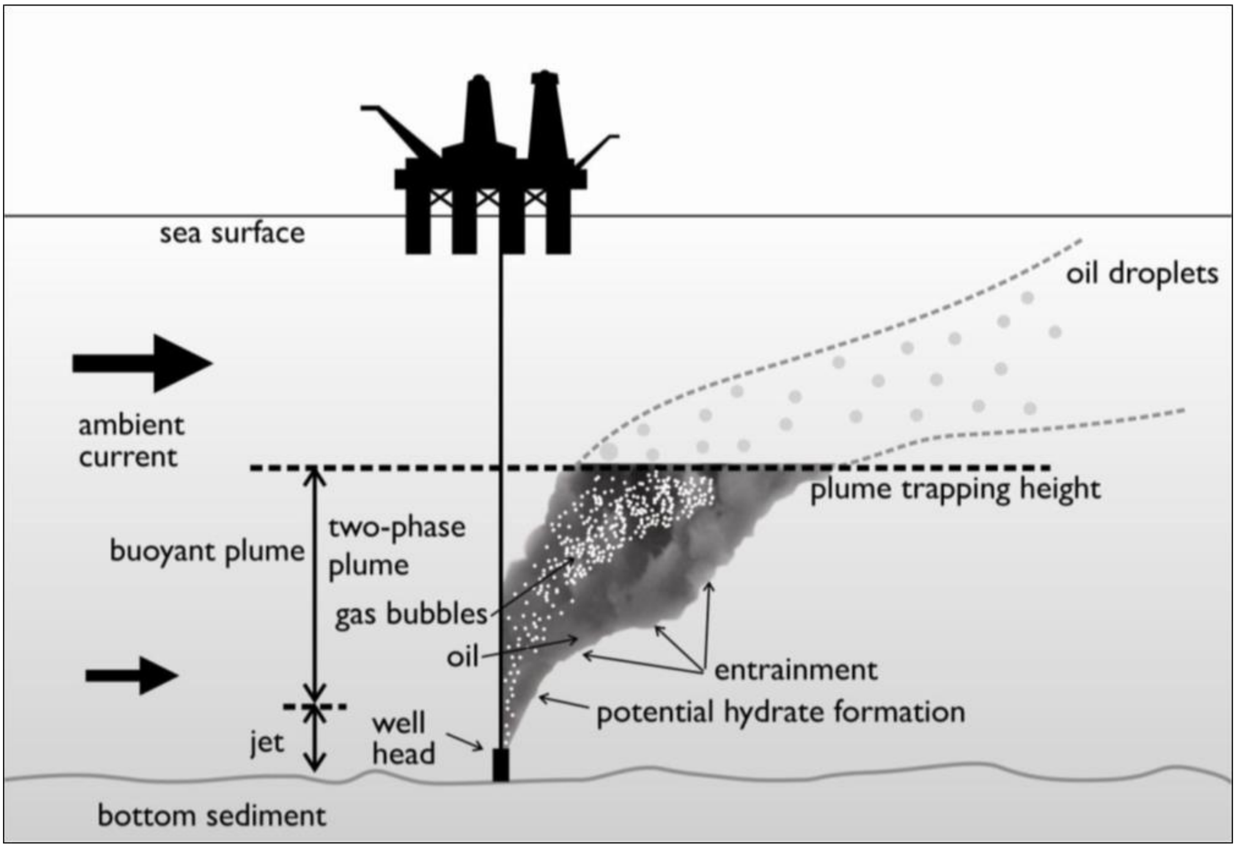


Figure 6.1 Example of a subsea plume and the various stages of the plume in the water column (Source: ASA, 2011).

7 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application. The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

7.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 7.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and
- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

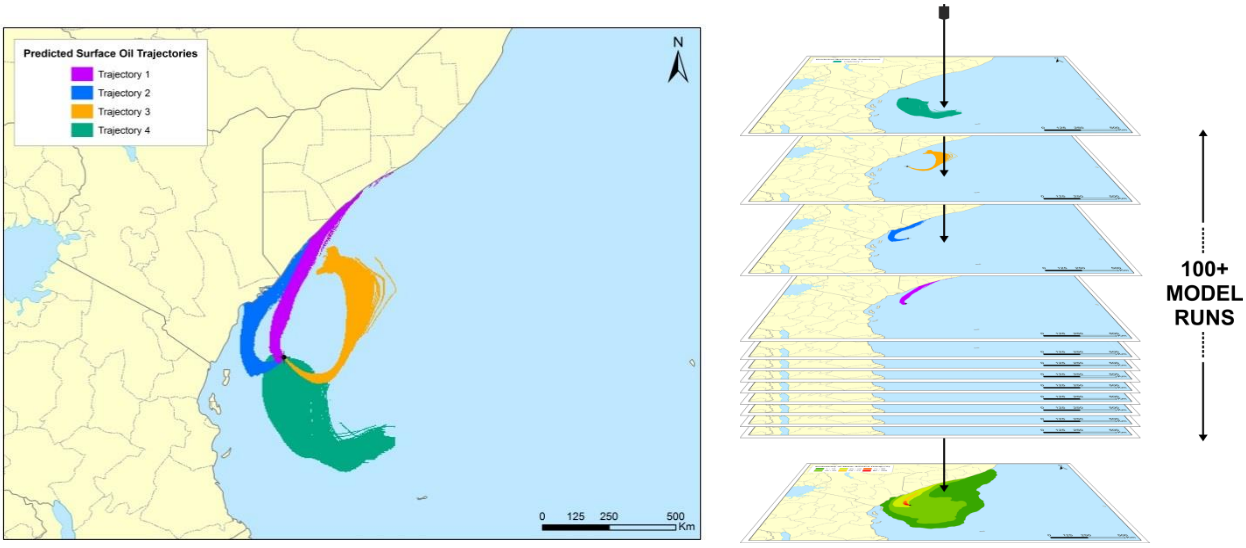


Figure 7.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

7.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 7.2.1 to 7.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

7.2.1 Floating Oil Exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating oil exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil exposure, was 1 g/m^2, which equates approximately to an average thickness of 1 μm, referred to as visible oil. Oil of this thickness is described as rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement, 2009; AMSA, 2014) (see Table 7.1). Figure 7.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. This threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to its visibility on the sea surface and potential to trigger temporary closures of areas (i.e. fishing grounds) as a precautionary measure. Table 7.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil exposure.

Ecological impact has been estimated to occur at 10 g/m^2 (a film thickness of approximately 10 μm or 0.01 mm) according to French et al. (1996) and French-McCay (2009) as this level of fresh oiling has been observed to mortally impact some birds through adhesion of oil to their feathers, exposing them to secondary effects such as hypothermia. The appearance of oil at this average thickness has been described as a metallic sheen (Bonn Agreement, 2009). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at oil concentrations on the sea surface of 25 g/m^2 (or greater), would be harmful for all birds that have landed in an oil film due to potential contamination of their feathers, with secondary effects such as loss of temperature regulation and ingestion of oil through preening. The appearance of oil at this thickness is also described as metallic sheen (Bonn Agreement, 2009). For this study the high exposure threshold was set to 50 g/m^2 and above based on NOPSEMA (2019). This threshold can also be used to inform response planning.

Table 7.2 defines the thresholds used to classify the zones of floating oil exposure reported herein.

Table 7.1 The Bonn Agreement Oil Appearance Code.

Code	Description Appearance	Layer Thickness Interval (g/m^2 or µm)	Litres per km^2
1	Sheen (silvery/grey)	0.04 – 0.30	40 – 300
2	Rainbow	0.30 – 5.0	300 – 5,000
3	Metallic	5.0 – 50	5,000 – 50,000
4	Discontinuous True Oil Colour	50 – 200	50,000 – 200,000
5	Continuous True Oil Colour	≥ 200	≥ 200,000

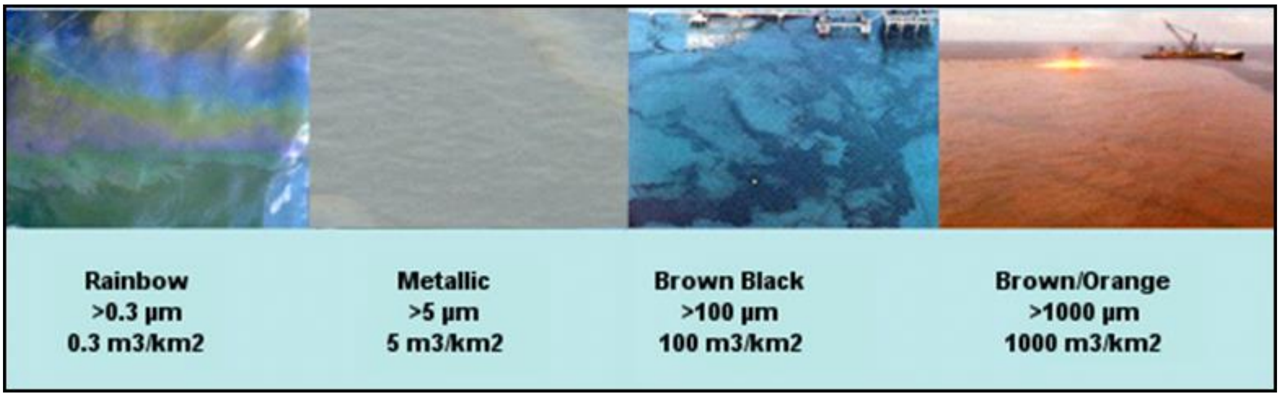


Figure 7.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 7.2 Floating oil exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (g/m^2)	Description
Low	1	Approximates range of socioeconomic effects and establishes planning area for scientific monitoring
Moderate	10	Approximates lower limit for harmful exposures to birds and marine mammals
High	50*	Approximates surface oil slick and informs response planning

* 50 g/m^2 also used to define the threshold for actionable floating oil.

7.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential “low shoreline accumulation”.

French et al. (1996) and French-McCay (2009) define a shoreline oil accumulation threshold of 100 g/m^2, or above, would potentially harm shorebirds and wildlife (furbearing aquatic mammals and marine reptiles on or along the shore) based on studies for sub-lethal and lethal impacts. This threshold has been used in previous environmental risk assessment studies (see French-McCay, 2003; French-McCay et al., 2004, French-McCay et al., 2011; 2012; NOAA, 2013). Additionally, a shoreline concentration of 100 g/m^2, or above, is the minimum limit that the oil can be effectively cleaned according to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential “moderate shoreline accumulation”.

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential “high shoreline accumulation”. It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 7.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 7.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	10	Predicts potential for some socio-economic impact
Moderate	100*	Loading predicts area likely to require clean-up effort
High	> 1,000	Loading predicts area likely to require intensive clean-up effort

* 100 g/m^2 also used to define the threshold for actionable shoreline oil.

7.2.3 In-water Exposure Thresholds

Oil is a mixture of thousands of hydrocarbons of varying physical, chemical, and toxicological characteristics, and therefore, demonstrate varying fates and impacts on organisms. As such, for in-water exposure, the SIMAP model provides separate outputs for dissolved and entrained hydrocarbons from oil droplets. The consequences of exposure to dissolved and entrained components will differ because they have different modes and magnitudes of effect.

Entrained hydrocarbon concentrations were calculated based on oil droplets that are suspended in the water column, though not dissolved. The composition of this oil would vary with the state of weathering (oil age) and may contain soluble hydrocarbons when the oil is fresh. Calculations for dissolved hydrocarbons specifically calculates oil components which are dissolved in water, which are known to be the primary source of toxicity exerted by oil.

7.2.3.1 Dissolved Hydrocarbons

Laboratory studies have shown that dissolved hydrocarbons exert most of the toxic effects of oil on aquatic biota (Carls et al., 2008; Nordtug et al., 2011; Redman, 2015). The mode of action is a narcotic effect, which is positively related to the concentration of soluble hydrocarbons in the body tissues of organisms (French-McCay, 2002). Dissolved hydrocarbons are taken up by organisms directly from the water column by absorption through external surfaces and gills, as well as through the digestive tract. Thus, soluble hydrocarbons are termed “bioavailable”.

Hydrocarbon compounds vary in water-solubility and the toxicity exerted by individual compounds is inversely related to solubility, however bioavailability will be modified by the volatility of individual compounds (Nirmalakhandan & Speece, 1988; McCarty, 1986; McCarty et al., 1992a, 1992b; Mackay et al., 1992; McCarty & Mackay, 1993; Verhaar et al., 1992, 1999; Swartz et al., 1995; French-McCay, 2002; McGrath & Di Toro, 2009). Of the soluble compounds, the greatest contributor to toxicity for water-column and benthic organisms are the lower-molecular-weight aromatic compounds, which are both volatile and soluble in water. Although they are not the most water-soluble hydrocarbons within most oil types, the polynuclear aromatic hydrocarbons (PAHs) containing 2-3 aromatic ring structures typically exert the largest narcotic effects because they are semi-soluble and not highly volatile, so they persist in the environment long enough for significant accumulation to occur (Anderson et al., 1974, 1987; Neff & Anderson, 1981; Malins & Hodgins, 1981; McAuliffe, 1987; NRC, 2003). The monoaromatic hydrocarbons (MAHs), including the BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), and the soluble alkanes (straight chain hydrocarbons) also contribute to toxicity, but these compounds are highly volatile, so that their contribution will be low when oil is exposed to evaporation and higher when oil is discharged at depth where volatilisation does not occur (French-McCay, 2002).

French-McCay (2002) reviewed available toxicity data, where marine biota was exposed to dissolved hydrocarbons prepared from oil mixtures, finding that 95% of species and life stages exhibited 50% population mortality (LC_{50}) between 6 and 400 ppb total PAH concentration after 96 hrs exposure, with an average of 50 ppb. Hence, concentrations lower than 6 ppb total PAH value should be protective of 97.5% of species and life stages even with exposure periods of days (at least 96 hours). Early life-history stages of fish appear to be more sensitive than older fish stages and invertebrates.

Exceedances of 10, 50 or 400 ppb over a 1 hour timestep (see Table 7.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on NOPSEMA (2019).

7.2.3.2 Entrained Hydrocarbons

Entrained hydrocarbons consist of oil droplets that are suspended in the water column and insoluble. As such, insoluble compounds in oil cannot be absorbed from the water column by aquatic organisms, hence are not bioavailable through absorption of compounds from the water. Exposure to these compounds would require routes of uptake other than absorption of soluble compounds. The route of exposure of organisms to whole oil alone include direct contact with tissues of organisms and uptake of oil by direct consumption, with potential for biomagnification through the food chain (NRC, 2003).

The 10 ppb threshold represents the very lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the ANZECC & ARMCANZ (2000) water quality guidelines. Due to the requirement for relatively long exposure times (> 24 hours) for these concentrations to be significant, they are likely to be more meaningful for juvenile fish, larvae and planktonic organisms that might be entrained (or otherwise moving) within the entrained plumes, or when entrained hydrocarbons adhere to organisms or trapped against a shoreline for periods of several days or more.

This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the entrained hydrocarbon at this level.

Thresholds of 10 ppb and 100 ppb were applied over a 1 hour time exposure (Table 7.4), to cover the range of thresholds outlined in the ANZECC & ARMCANZ (2000) water quality guidelines, the incremental change for greater potential effect and is per NOPSEMA (2019).

A complicating factor that should be considered when assessing the consequence of dissolved and entrained oil distributions is that there will be some areas where both physically entrained oil droplets and dissolved hydrocarbons co-exist. Higher concentrations of each will tend to occur close to the source where sea conditions can force mixing of relatively unweathered oil into the water column, resulting in more rapid dissolution of soluble compounds.

Table 7.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

8 CONDENSATE PROPERTIES

8.1 Properties

As a conservative approach, Chevron had chosen Geryon condensate for the purposes of the modelling and hence provided physical properties and boiling point distributions, which are presented in Table 8.1 and Table 8.2, respectively.

Geryon condensate has an API of 42.67, a density of 810 kg/m^3 (at 15ºC) and a low viscosity value of 5.2 cP. When exposed to the atmosphere at local temperatures, about 31.5% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 27.1% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~31.7%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 9.7% of the condensate is shown to be persist in the marine environment for much longer periods and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.5%), indicating a very low propensity for the mixture to take up water to form water-in-oil emulsion over the weathering cycle.

Soluble, aromatic hydrocarbons contribute approximately 2.9% by mass of the whole oil. For this condensate they are all contained in the volatile fractions, which are highly soluble. Discharges onto the water surface will favour the process of evaporation over dissolution under calm sea conditions, but increased entrainment of oil and dissolution of soluble compounds can be expected under stronger wind periods with the presence of small breaking waves (whitecaps).

Table 8.1 Physical properties of Geryon condensate.

Characteristic	Geryon Condensate
Density (kg/m^3)	810.0 (at 15°C)
API	42.67
Dynamic viscosity (cP)	5.2 (at 15°C)
Pour point (°C)	-20
Surface tension (dyne/cm)	19
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light-persistent

Table 8.2 Boiling point ranges of Geryon condensate.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 $>C_{20}$
Geryon Condensate	% of total	31.5	27.1	31.7	9.7
	% of aromatics	2.9	0	0	0

8.2 Weathering Characteristics

8.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this condensate when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.

- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the condensate reaches the surface.

8.2.2 Results

The mass balance forecast for the calm-wind case (Figure 8.1) shows that 58.8% of the condensate is predicted to evaporate within 24 hours. Majority of the remaining condensate on the water surface will weather at a slower rate due to the low volatile components. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.2), where the winds are of greater strength on average, entrainment of Geryon condensate into the water column is predicted to increase. Approximately 24 hours after the spill, 20.9% of the condensate mass is forecast to have entrained and a further 18.3% is forecast to have evaporated, leaving only a small proportion of the condensate floating on the water surface (<0.3%). The residual compounds will tend to remain entrained beneath the surface under conditions that generate wind waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case will result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and condensate droplets in the water column occurs at an approximate rate of ~0.64% per day with an accumulated total of ~4.5% after 7 days, in comparison to a rate of <0.15% per day and an accumulated total of 1.04% after 7 days in the constant-wind case. Given the proportion of entrained condensate and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

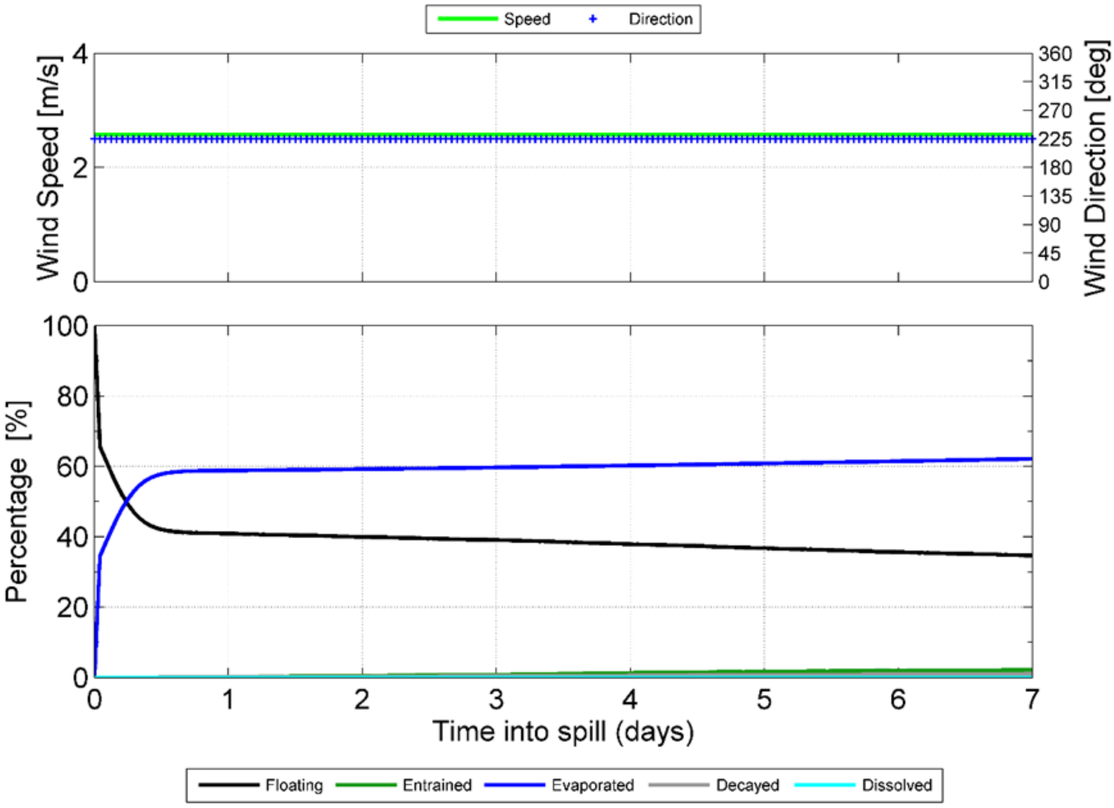


Figure 8.1 Proportional mass balance plot representing the weathering of Geryon condensate spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature.

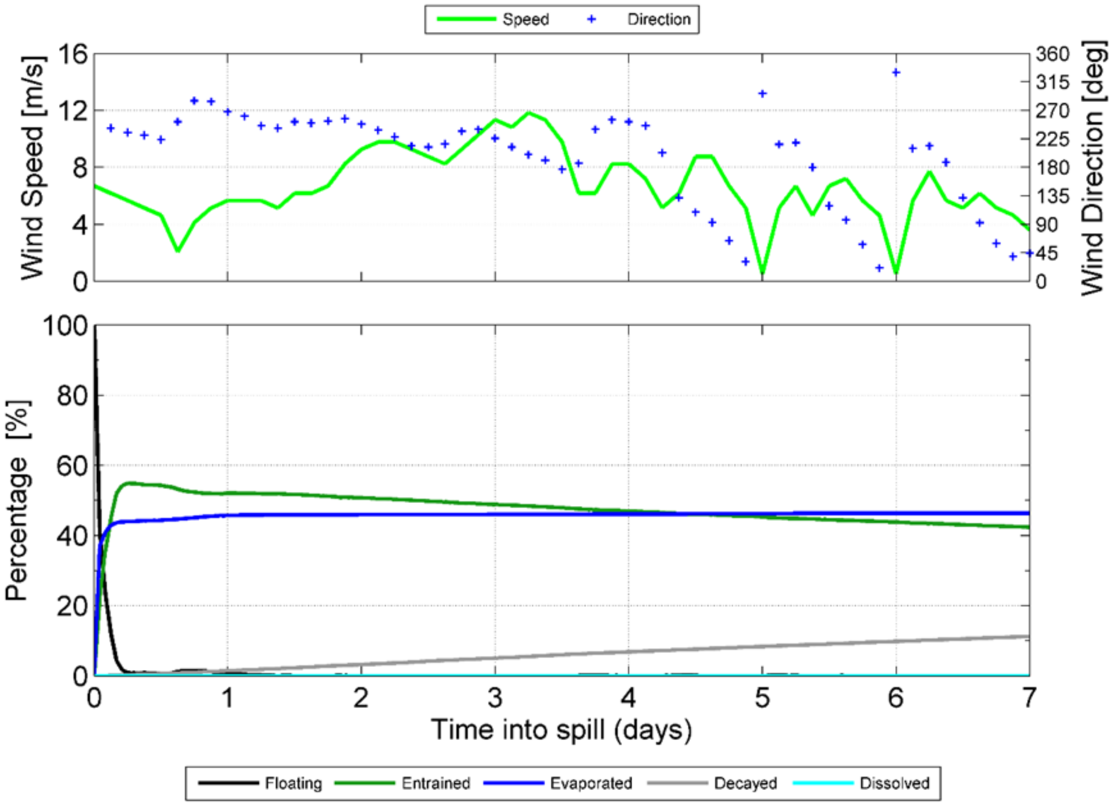


Figure 8.2 Proportional mass balance plot representing the weathering of Geryon condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature.

9 MODEL SETTINGS

Table 9.1 provides a summary of the oil spill model settings.

Table 9.1 Summary of the oil spill model settings used in this assessment.

	Scenario
Location	GER FL 2
Number of spill simulations with randomly selected start times	100 per season (300 total)
Spill volume (m^3) [bbl]	50,165 [315,540]
Condensate type	Geryon condensate
Release type (depth)	Subsea (400 m)
Release duration (days)	90
Simulation length (days)	104
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour, high exposure

10 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

10.1 Stochastic Analysis

10.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***Probability of condensate exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***Minimum time before condensate exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

10.2 Deterministic Trajectories

The deterministic results in Section 11.2 are based on the following criteria:

a. Largest swept area of floating hydrocarbon above 10 g/m^2
b. Largest swept area of floating hydrocarbon above 50 g/m^2
c. Largest volume of oil ashore
d. Longest length of shoreline accumulation above 100 g/m^2
e. Largest area of entrained hydrocarbons above 100 ppb
f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no dissolved hydrocarbon exposure at or above 50 ppb, for any of the 300 simulations, there is no deterministic results presented.

10.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 10.1 to Figure 10.10). Receptor categories (see Table 10.1) include sections of shorelines and offshore islands. All other sensitive receptors other than submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

Table 10.2 summarises the receptors that the location resides within.

Table 10.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	✗
Biologically Important Area	BIA	✓	✓	✗
Marine Park	MP	✓	✓	✗
Marine Management Area	MMA	✓	✓	✗
Nature Reserve	NR	✓	✓	✗
Integrated Marine and Coastal Regionalisation of Australia	IMCRA	✓	✓	✗
Interim Biogeographic Regionalisation of Australia	IBRA	✓	✓	✗
Reefs, Shoals and Banks	RSB	✓	✓	✗
Key Ecological Feature	KEF	✓	✓	✗
Ramsar Sites	Ramsar	✓	✓	✗
State Waters	State Waters	✓	✓	✗
Impact Assessment Area	IAA	✓	✓	✓
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 10.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Pygmy Blue Whale - Distribution	BIA	✓
Wedge-tailed Shearwater - Breeding	BIA	✓
Offshore Area	IAA	✓

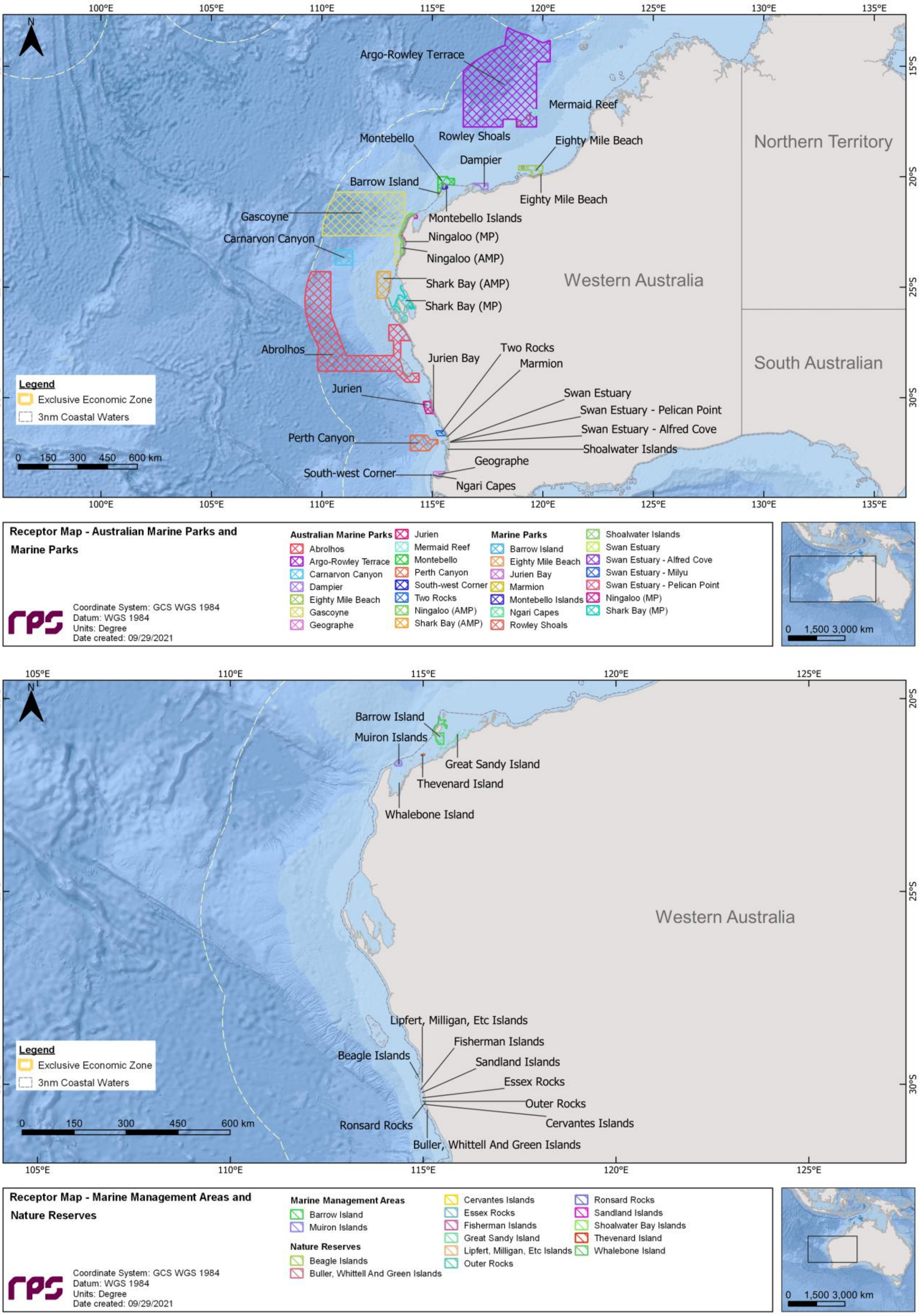


Figure 10.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).

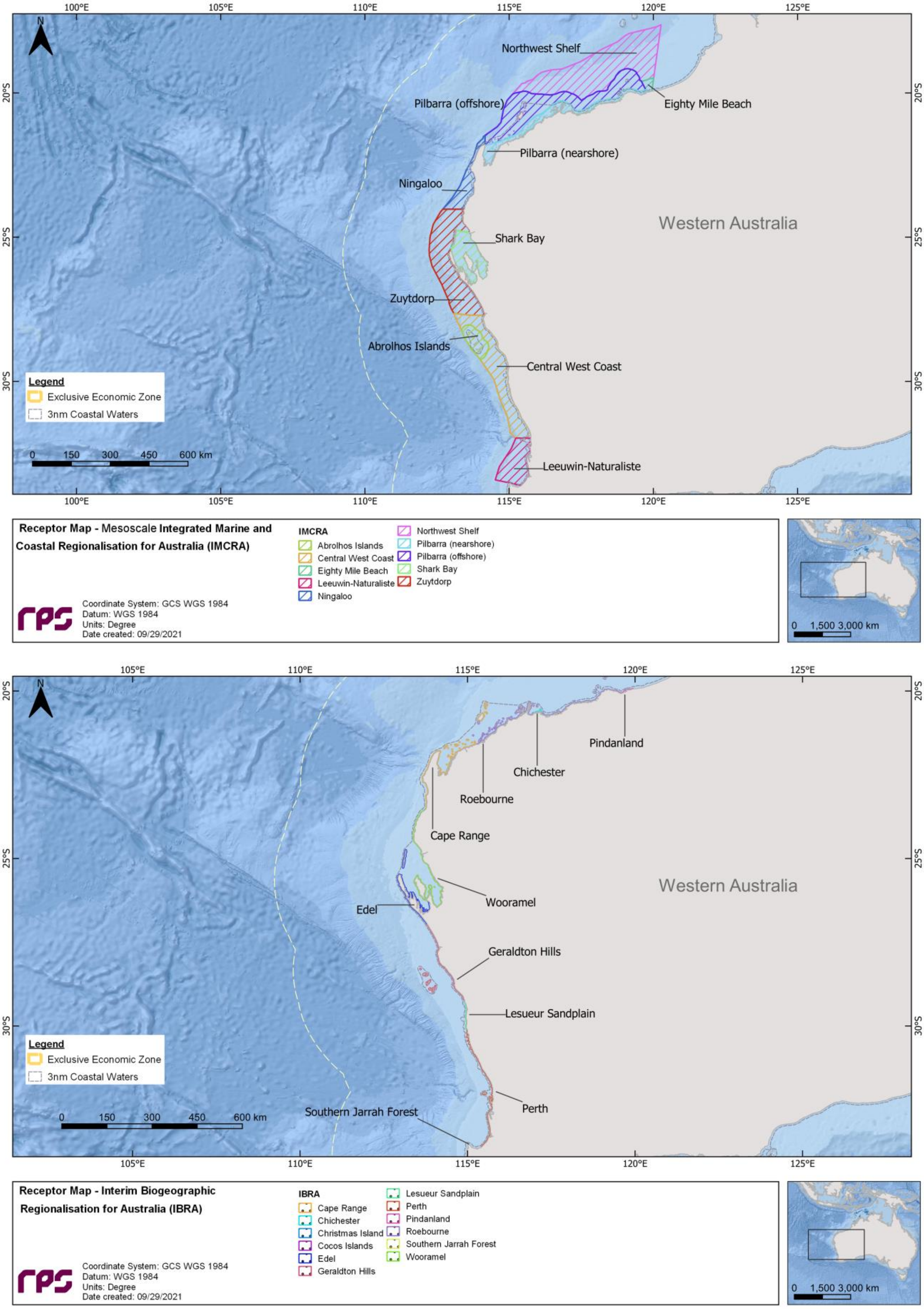
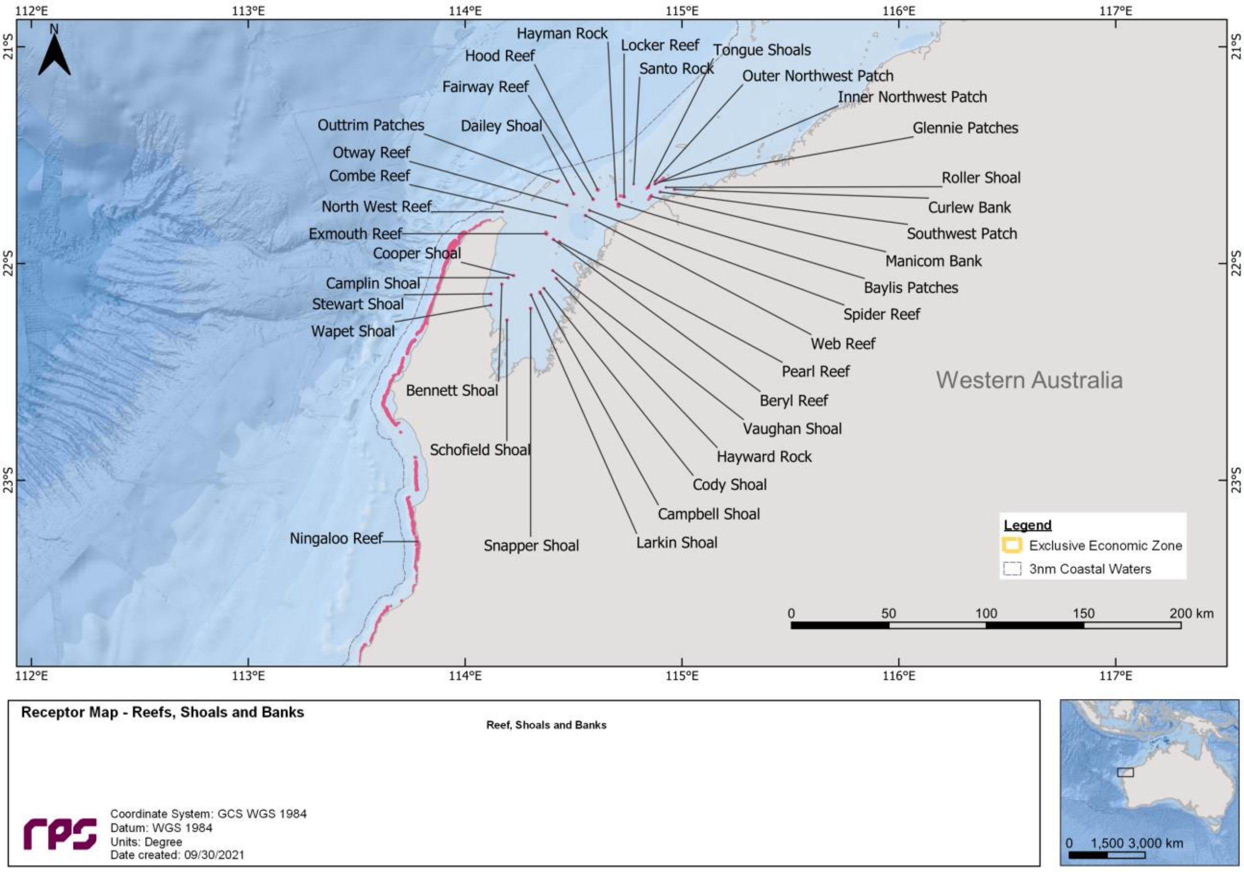


Figure 10.2 Receptor maps for Mesoscale Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).



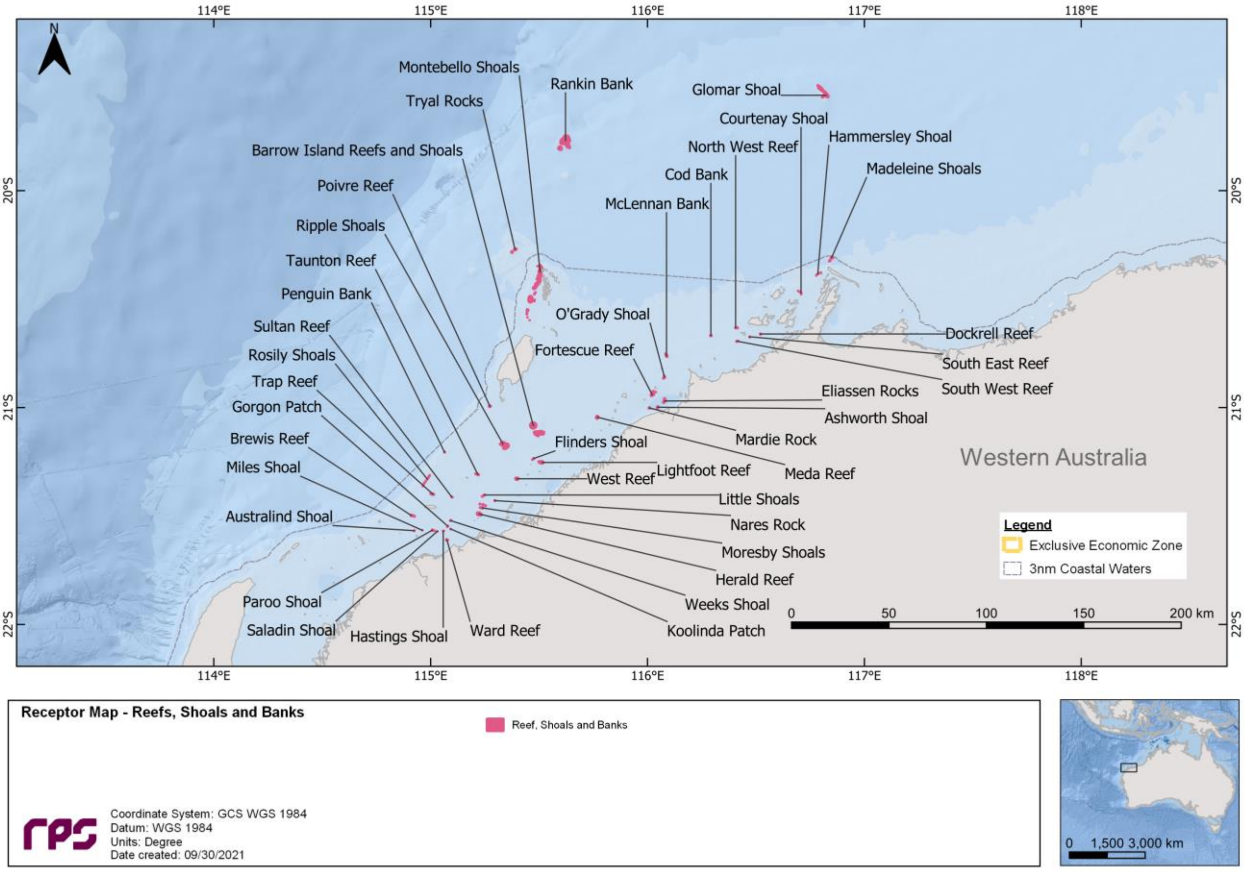


Figure 10.3 Receptor maps for Reefs, Shoals and Banks (RSB).

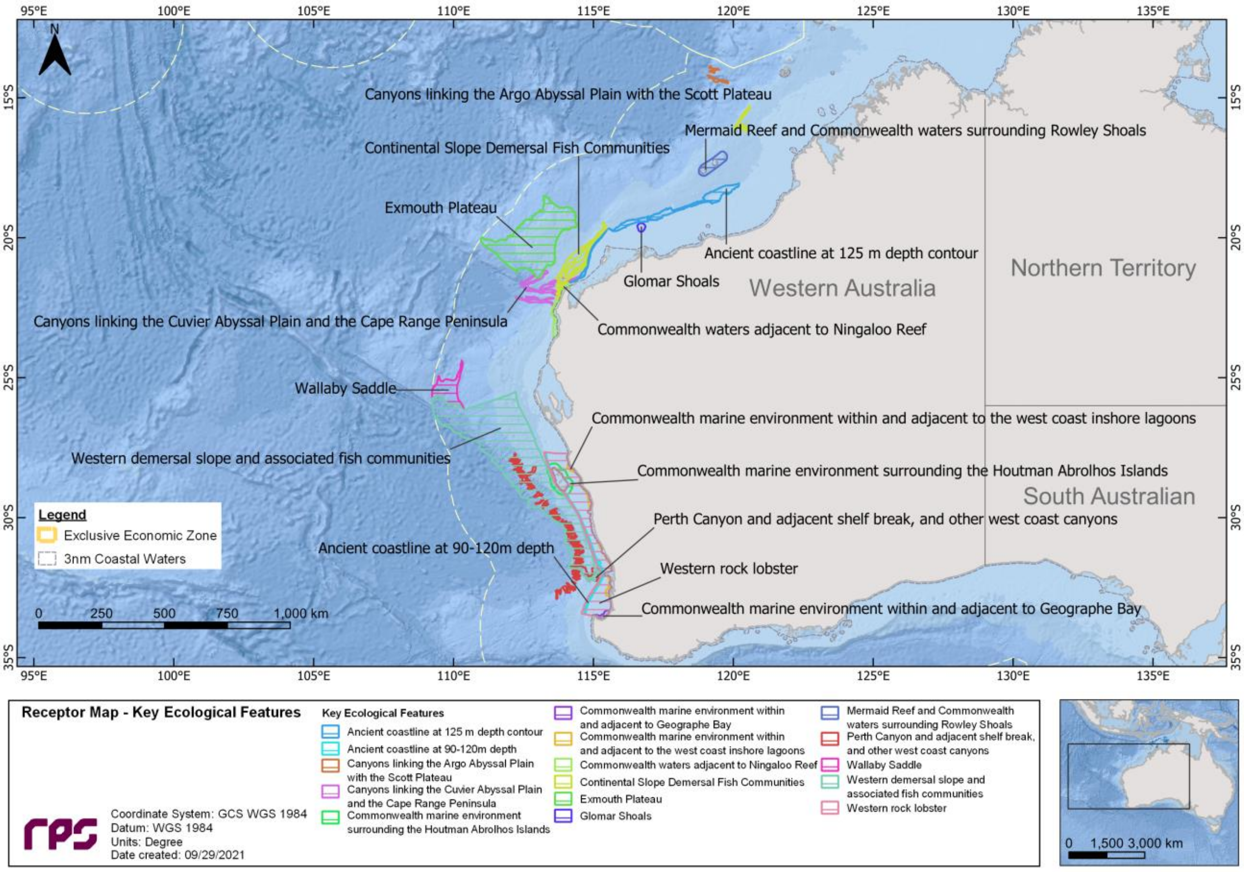


Figure 10.4 Receptor maps for Key Ecological Features (KEFs).

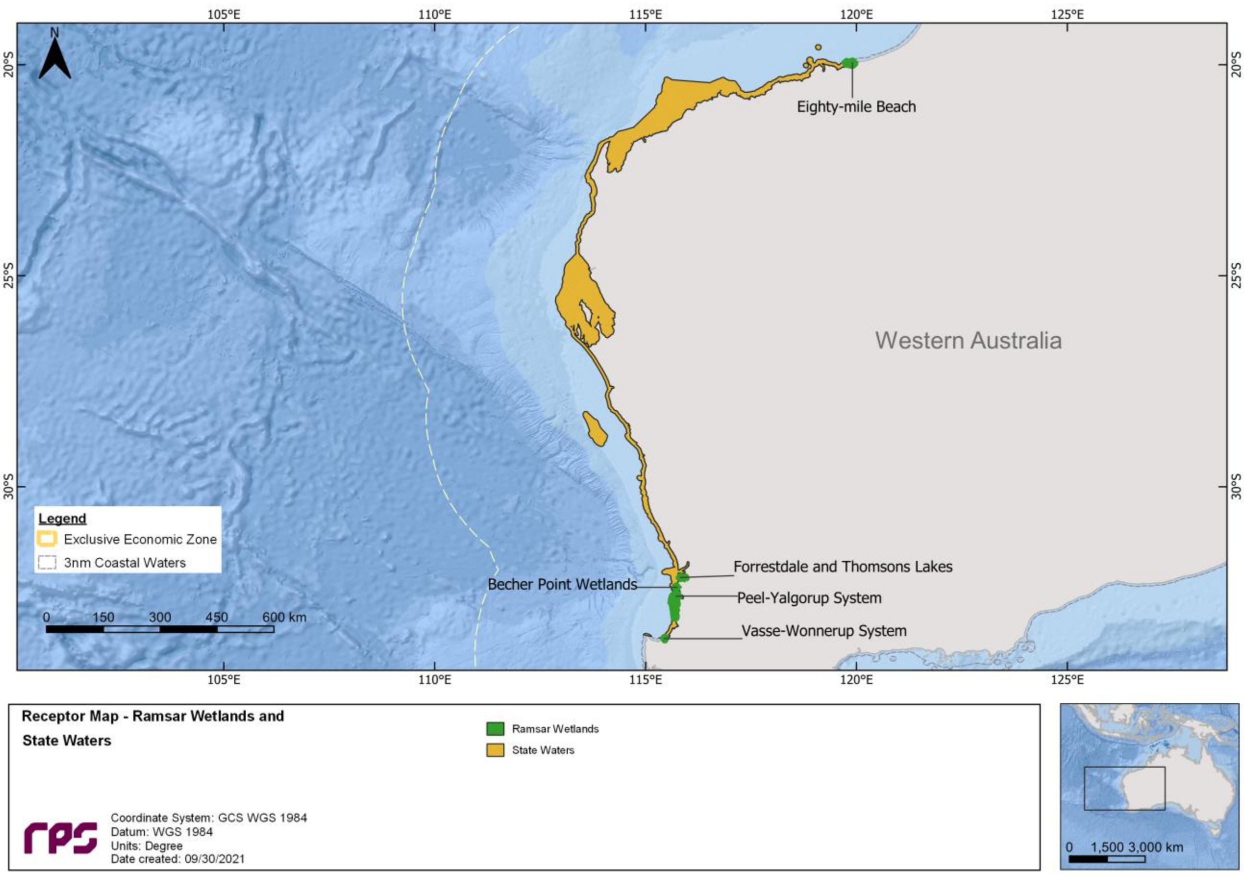


Figure 10.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.

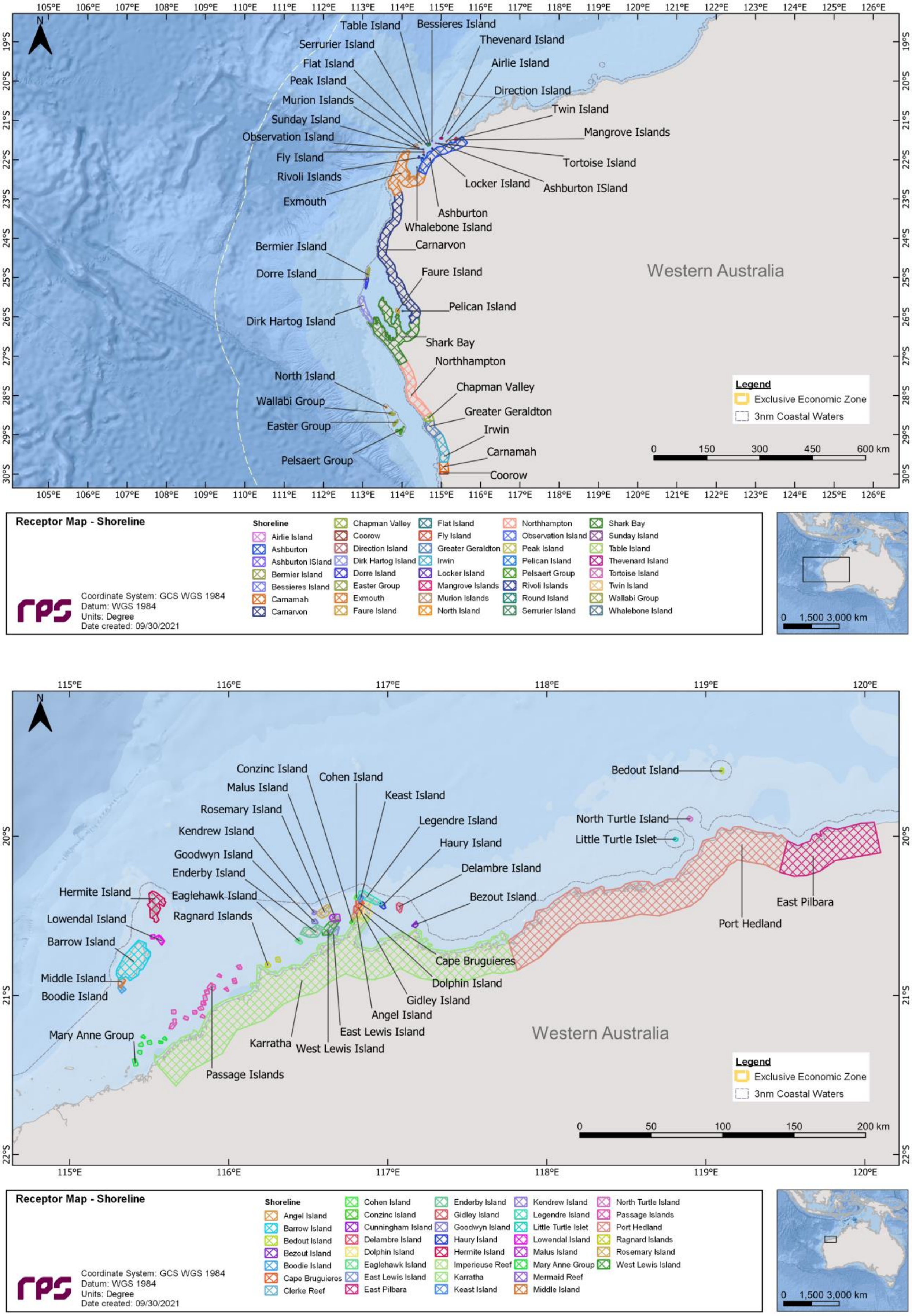


Figure 10.6 Receptor maps for Shorelines (1 of 2).

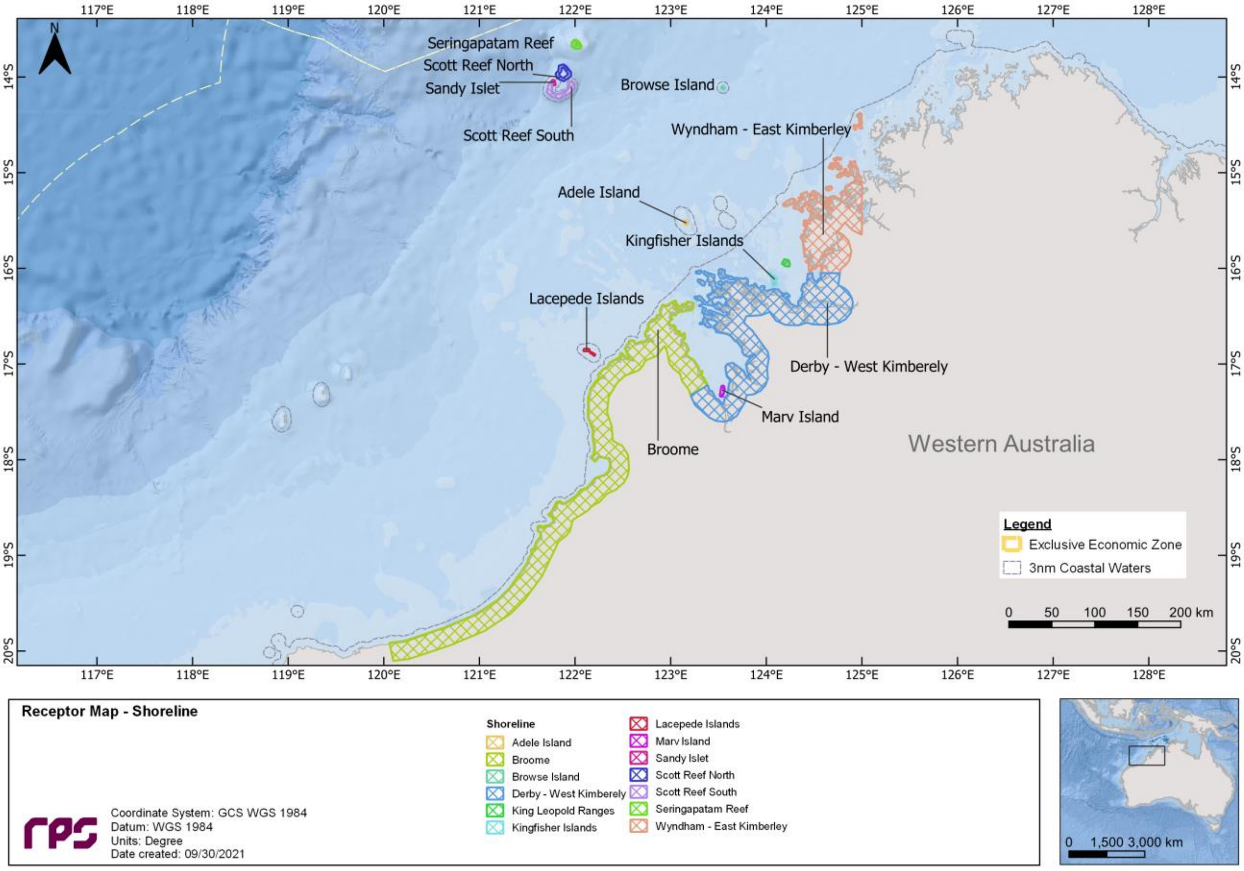


Figure 10.7 Receptor maps for Shorelines (2 of 2).

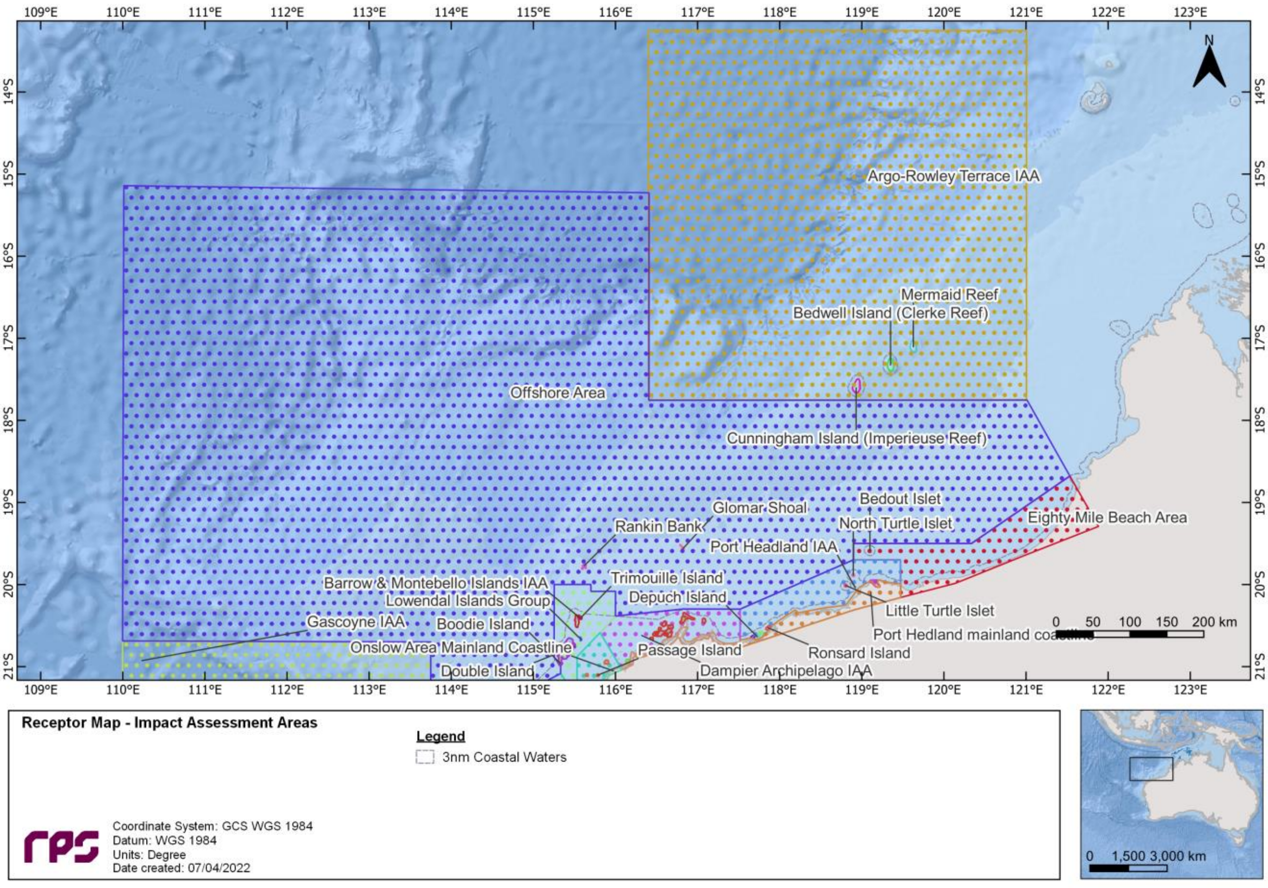


Figure 10.8 Receptor maps for Impact Assessment Areas (1 of 3).

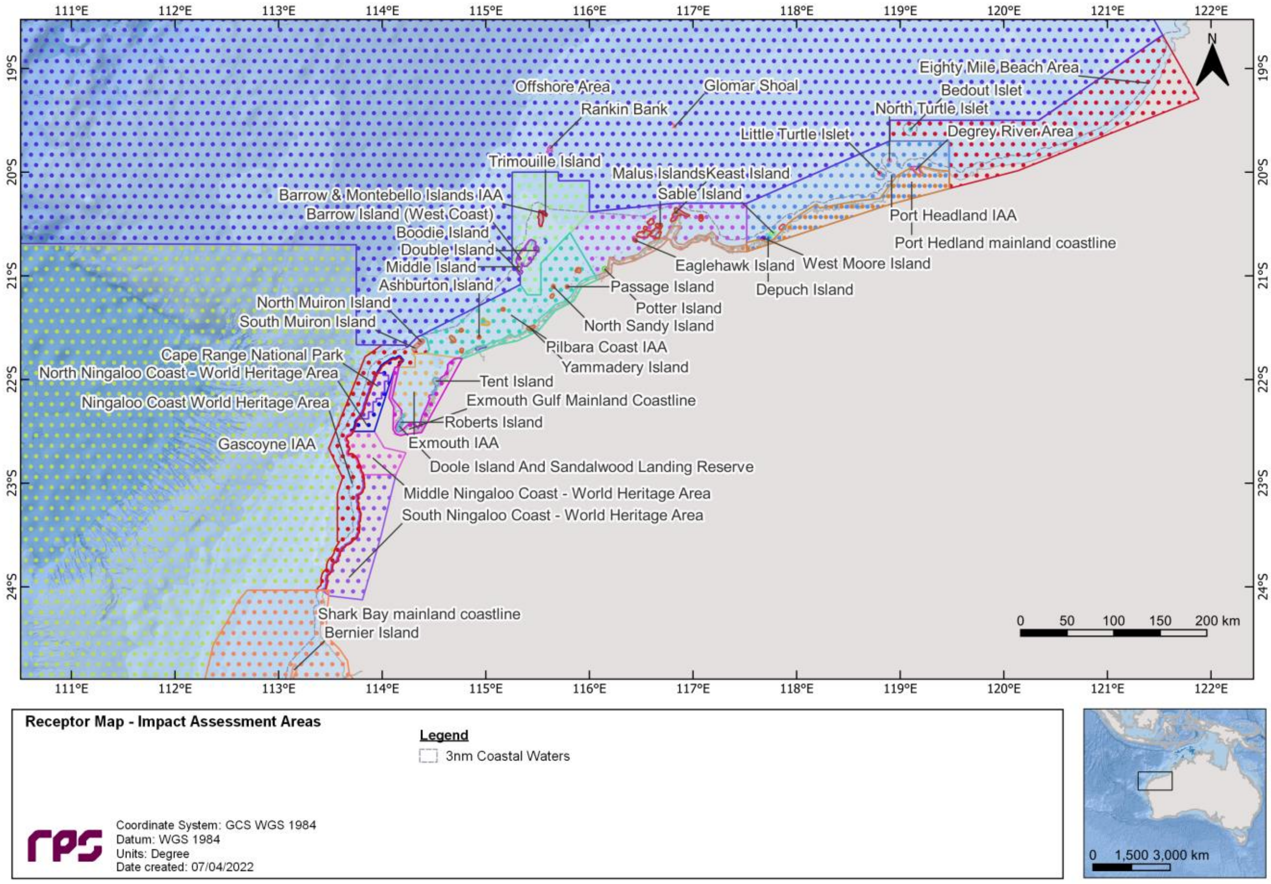


Figure 10.9 Receptor maps for Impact Assessment Areas (2 of 3).

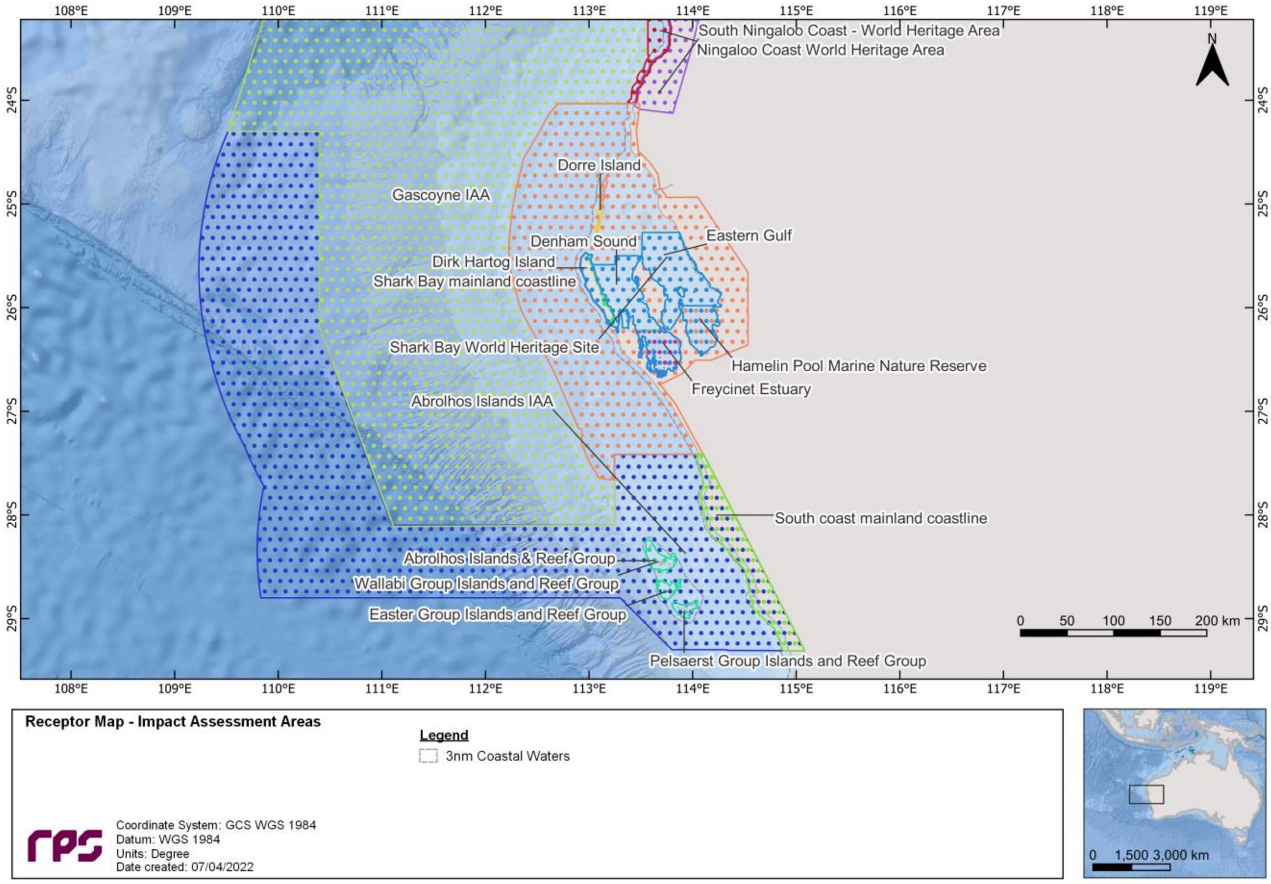


Figure 10.10 Receptor maps for Impact Assessment Areas (3 of 3).

11 RESULTS: GERYON-EURYTION LOSS OF WELL CONTROL

This scenario examined a 315,540 stb (or 50,165 m^3) subsea release of condensate over 90 days, following a LOWC. A total of 300 spill simulations were run for each of the three seasons (i.e. 100 spills per season) and tracked for 104 days.

Section 11.1 presents the seasonal (or stochastic) analysis results, while Section 11.2 presents the deterministic results.

11.1 Stochastic Analysis

11.1.1 Floating Condensate Exposure

Table 11.1 summarises the maximum distances from the release location to floating condensate exposure zones for each season. The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 132.6 km south (summer) and 60.4 km southeast (winter), respectively.

No exposure was predicted at the high (≥ 50 g/m^2) threshold.

Table 11.2 summarises the potential floating condensate exposure to individual receptors during each season.

The Offshore Area IAA, Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater - Breeding BIAs, which the release location resides within (see Section 10.3), were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low threshold was 100% for all seasons for these receptors. Probabilities of moderate exposure for these rectors ranged between 51% (all receptors; summer) and 82% (Pygmy Blue Whale - Distribution (BIA) and Offshore Area IAA); winter). Additionally, the Flatback Turtle - Internesting Buffer and Whale Shark - Foraging BIAs were also predicted to be exposed at the low threshold during summer (7% and 1%), transitional (13% and 6%) and winter (15% and 13%), respectively. The minimum time before low exposure for the Flatback Turtle - Internesting Buffer and Whale Shark - Foraging BIAs was 5.79 days during summer conditions. Furthermore, the probability of exposure at the low threshold for the Continental Slope Demersal Fish Communities (KEF) was 96%, 80% and 84% during summer, transitional and winter, respectively. The corresponding minimum time before low exposure at the Continental Slope Demersal Fish Communities (KEF) was 1.88 days (summer).

Figure 11.1 to Figure 11.3 present the zones of floating condensate exposure for each season.

Table 11.1 Maximum distances and directions travelled from the release location to floating condensate exposure for each season and threshold, following a subsea LOWC at GER FL2. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating condensate exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	132.6	59.1	-
	Max. distance from release site (km) (99th percentile)	114.1	59.1	-
	Direction	South	Southeast	-
Transitional	Max. distance from release site (km)	129.2	59.9	-
	Max. distance from release site (km) (99th percentile)	105.5	59.9	-
	Direction	South	Southeast	-
Winter	Max. distance from release site (km)	123	60.4	-
	Max. distance from release site (km) (99th percentile)	96	60.3	-
	Direction	South	Southeast	-

Table 11.2 Summary of the potential floating condensate exposure to individual receptors, following a LOWC at GER FL2. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
BIA	Flatback Turtle - Internesting Buffer	7	-	-	5.79	-	-	13	-	-	11.04	-	-	15	-	-	22.75	-	-
	Pygmy Blue Whale - Distribution *	100	51	-	0.46	1.46	-	100	77	-	0.46	1.25	-	100	82	-	0.46	1.17	-
	Wedge-tailed Shearwater - Breeding *	100	51	-	0.46	1.46	-	100	76	-	0.46	1.25	-	100	79	-	0.46	1.17	-
	Whale Shark - Foraging	1	-	-	5.79	-	-	6	-	-	11.04	-	-	13	-	-	22.92	-	-
EEZ	Australian Exclusive Economic Zone *	100	51	-	0.46	1.46	-	100	77	-	0.46	1.25	-	100	82	-	0.46	1.17	-
IAA	Offshore Area *	100	51	-	0.46	1.46	-	100	77	-	0.46	1.25	-	100	82	-	0.46	1.17	-
IMCRA	Northwest Shelf	1	-	-	5.79	-	-	5	-	-	11.17	-	-	5	-	-	42.88	-	-
	Pilbara (offshore)	1	-	-	11.71	-	-	2	-	-	11.04	-	-	8	-	-	22.92	-	-
KEF	Ancient coastline at 125 m depth contour	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	58.63	-	-
	Continental Slope Demersal Fish Communities	96	-	-	1.88	-	-	80	-	-	2.29	-	-	84	-	-	2.08	-	-

*The release location resides within the receptor boundaries.

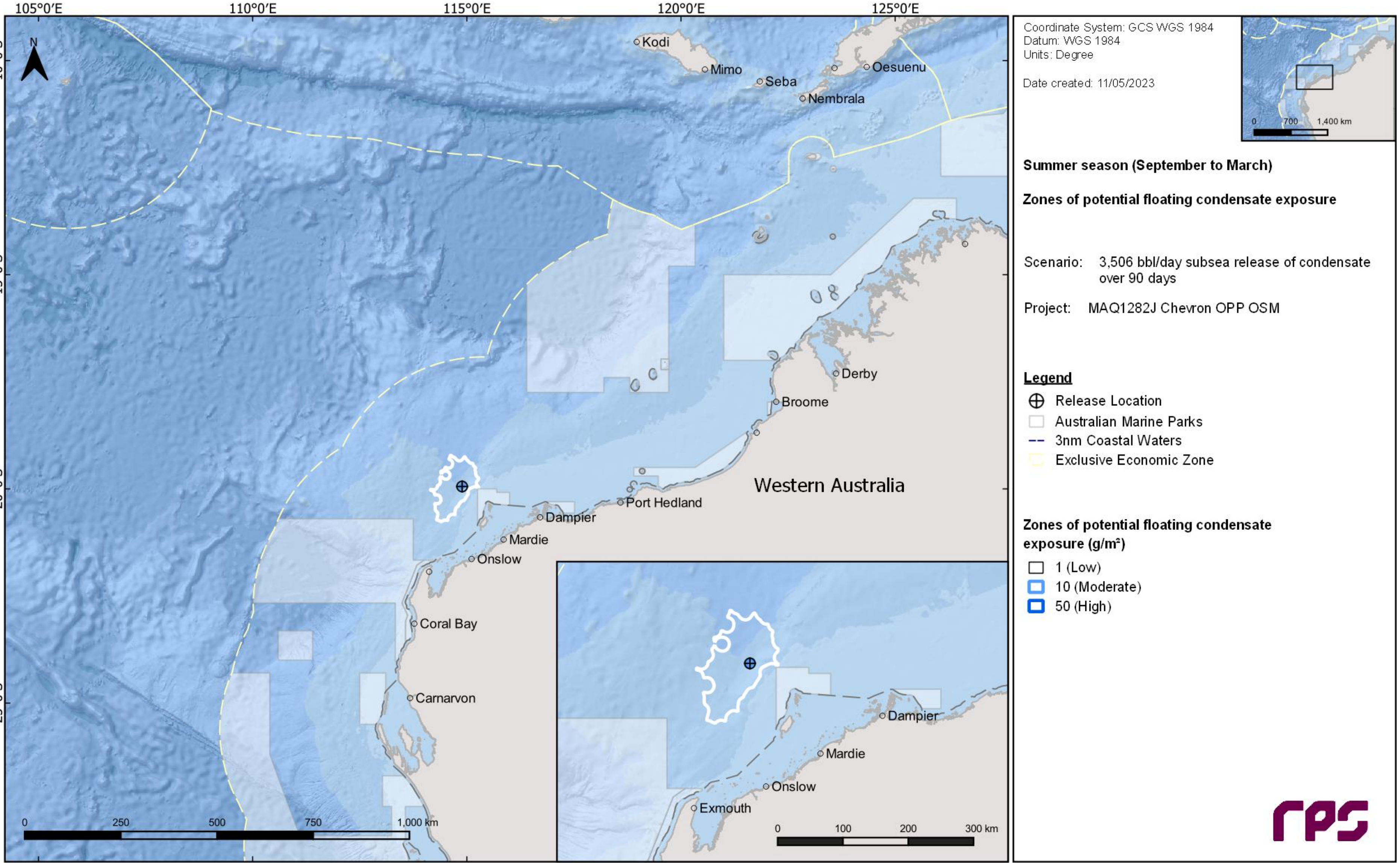


Figure 11.1 Zones of potential floating condensate exposure following a subsea LOWC at GER FL2 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

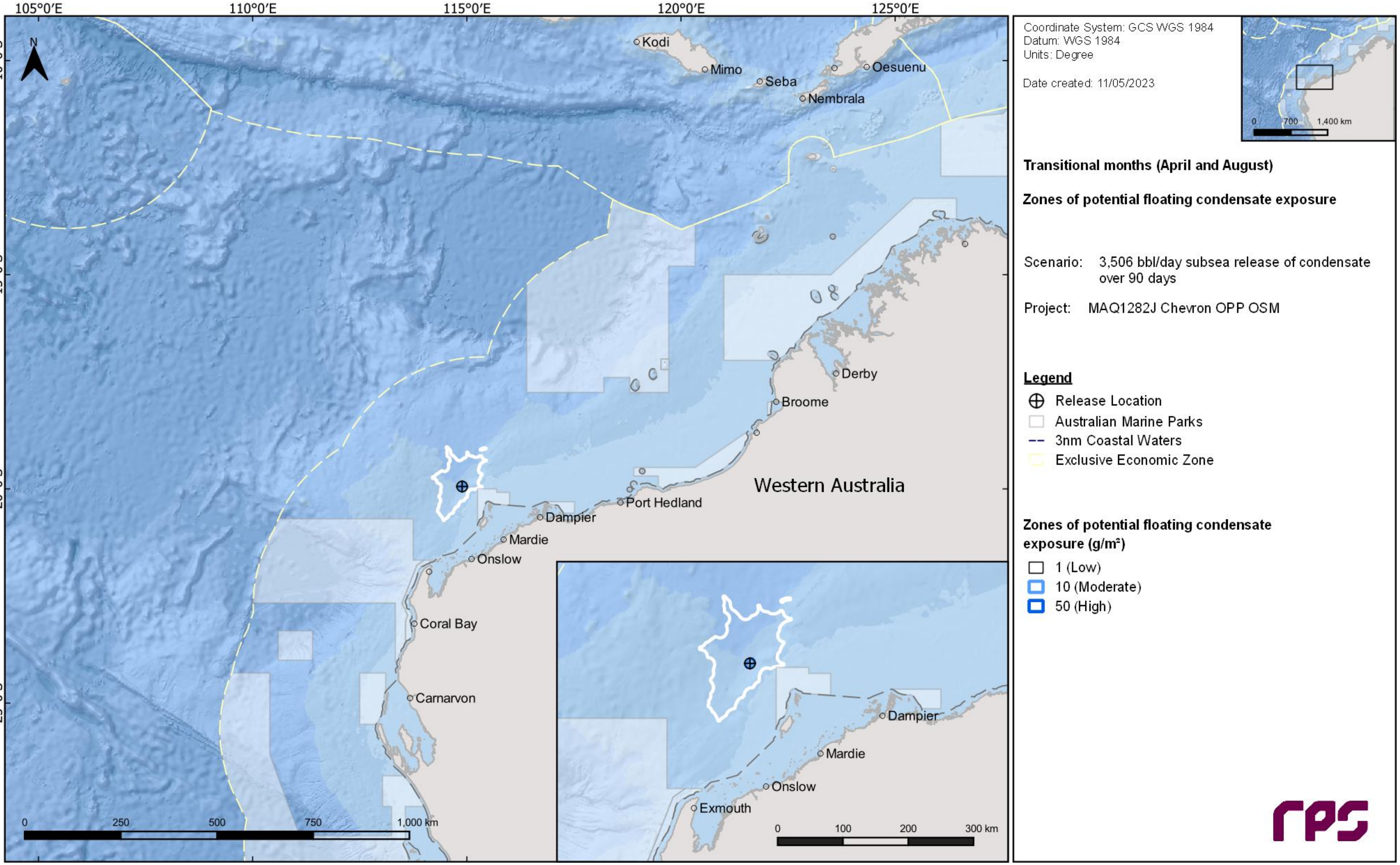


Figure 11.2 Zones of potential floating condensate exposure following a subsea LOWC at GER FL2 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

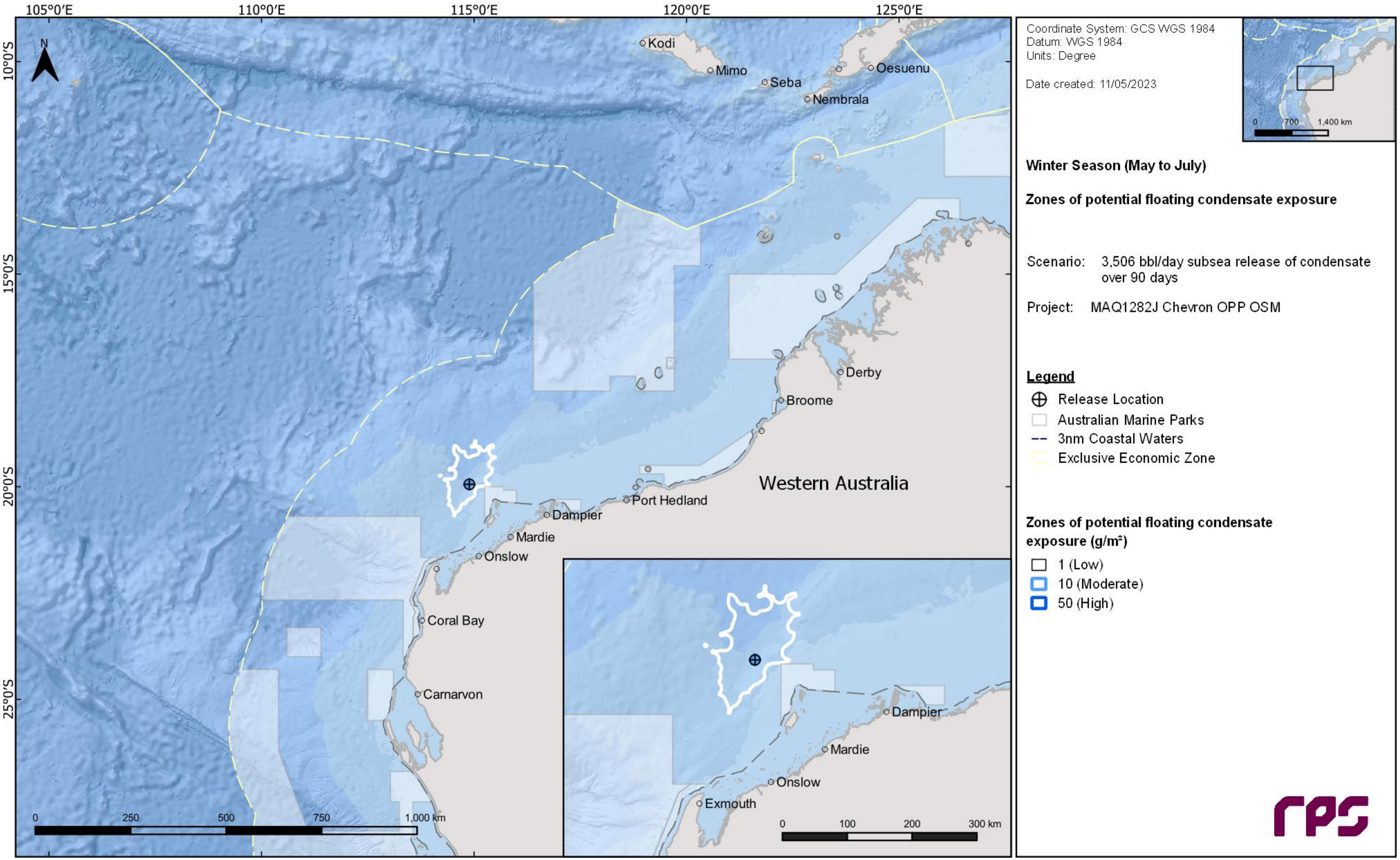


Figure 11.3 Zones of potential floating condensate exposure following a subsea LOWC at GER FL2 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.2 Shoreline Accumulation

Table 11.3 presents a summary of the predicted shoreline accumulation during summer, transitional and winter seasons. The probability of shoreline accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 23%, while the minimum time before shoreline accumulation was 7.46 days and the maximum volume of oil ashore was 23.2 m^3. No shoreline accumulation was predicted during transitional conditions.

Additionally, no high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

Table 11.4 and Table 11.5 summarises the shoreline accumulation on individual receptors for the summer and winter season.

During summer conditions, condensate had accumulated on 38 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA and Barrow Island Group (15%). In comparison, during winter conditions, condensate was predicted to accumulate on 4 shoreline receptors and each with an 8% probability.

The maximum potential shoreline accumulation is presented for the summer and winter season in Figure 11.4 and Figure 11.5.

Table 11.3 Summary of condensate accumulation across all shorelines for each season and threshold, following a subsea LOWC at GER FL2. The results were calculated from 100 spill trajectories per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of accumulation on any shoreline (%)	23	-	8
Absolute minimum time for visible oil to shore (days)	7.46	-	43.75
Maximum volume of hydrocarbons ashore (m^3)	23.2	-	1.9
Average volume of hydrocarbons ashore (m^3)	9.4	-	0.8
Maximum length of the shoreline at **10 g/m^2** (km)	79	-	7
Average shoreline length (km) at **10 g/m^2** (km)	31.4	-	4.9
Maximum length of the shoreline at **100 g/m^2** (km)	2	-	-
Average shoreline length (km) at **100 g/m^2** (km)	1.1	-	-
Maximum length of the shoreline at **1,000 g/m^2** (km)	-	-	-
Average shoreline length (km) at **1,000 g/m^2** (km)	-	-	-

Table 11.4 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at GER FL2. The results were calculated from 100 spill trajectories days during summer (September to the following March) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	3	-	-	14.38	-	-	6	17	0.2	0.3	1.3	-	-	1.9	-	-
	Argo-Rowley Terrace IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	15	7	-	12.5	30.92	-	12	155	10	23.2	31.7	1	-	55.8	1	-
	Barrow Island (West Coast)	14	-	-	12.88	-	-	15	98	5	8.6	16.3	-	-	22.1	-	-
	Barrow Island Group	15	7	-	12.5	30.92	-	18	155	9.2	16.5	23.2	1	-	33.7	1	-
	Bessieres Island	3	-	-	27.83	-	-	7	20	0.2	0.5	1.3	-	-	1.9	-	-
	Boodie Island	14	7	-	12.5	30.92	-	45	155	2.5	4.1	3.4	1	-	3.8	1	-
	Cape Range National Park	11	-	-	7.5	-	-	5	34	2.1	4.7	6.9	-	-	13.5	-	-
	Cunningham Island (Imperieuse Reef)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago IAA	1	-	-	81.75	-	-	4	15	1.5	2.1	2.9	-	-	2.9	-	-
	Dampier Archipelago Island Group	1	-	-	84.38	-	-	4	14	0.7	1.3	1.9	-	-	1.9	-	-
	Enderby Island	1	-	-	88.5	-	-	4	14	0.2	0.5	1	-	-	1	-	-
	Hermite Island	12	-	-	12.92	-	-	8	54	1.3	3.7	6.7	-	-	14.4	-	-
	Middle Island	13	-	-	12.67	-	-	28	90	2.7	4.5	5.5	-	-	7.7	-	-
	Middle Ningaloo Coast - World Heritage Area	8	-	-	8.21	-	-	4	23	0.6	1.2	1.6	-	-	2.9	-	-
	Montebello Islands Group	12	-	-	12.92	-	-	7	54	1.4	4	6.7	-	-	14.4	-	-
	Muiron Islands	11	2	-	7.46	37	-	9	129	1.7	7.6	7	1	-	15.4	1	-
	Ningaloo Coast World Heritage Area	11	2	-	7.46	37	-	6	129	3.3	10.3	16.6	1	-	21.2	1	-
	North Muiron Island	11	2	-	8	37	-	13	129	1	4.3	3.3	1	-	6.7	1	-
	North Ningaloo Coast - World Heritage Area	10	-	-	7.54	-	-	5	26	1.1	2.2	3.6	-	-	5.8	-	-
	Pilbara Coast IAA	5	-	-	14.38	-	-	4	49	0.5	2.9	2.3	-	-	3.8	-	-
	Pilbara Coast Islands Group	5	-	-	14.38	-	-	4	20	0.3	1.1	1.5	-	-	1.9	-	-
	Rosemary Island	1	-	-	84.38	-	-	4	10	0.2	0.4	1	-	-	1	-	-
	South Muiron Island	11	-	-	7.46	-	-	10	66	1.1	3.6	3.7	-	-	8.7	-	-
	Thevenard Island	1	-	-	81.67	-	-	4	12	0.2	0.6	1	-	-	1	-	-
Shoreline	Airlie Island	3	-	-	14.38	-	-	6	17	0.2	0.3	1.3	-	-	1.9	-	-
	Barrow Island	15	-	-	12.88	-	-	15	98	5.7	9.8	16.3	-	-	24	-	-
	Bessieres Island	3	-	-	27.83	-	-	7	20	0.2	0.5	1.3	-	-	1.9	-	-
	Boodie Island	14	7	-	12.5	30.92	-	45	155	3	4.8	4.3	1	-	4.8	1	-
	Cunningham Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	1	-	-	88.5	-	-	4	14	0.2	0.5	1	-	-	1	-	-
	Exmouth	11	-	-	7.5	-	-	5	34	3.3	8	11.3	-	-	20.2	-	-
	Imperieuse Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Island	9	-	-	13.83	-	-	7	36	0.4	1.3	1.9	-	-	4.8	-	-
	Middle Island	13	-	-	12.5	-	-	29	90	3.6	5.3	7.3	-	-	9.6	-	-
	Montebello Islands	12	-	-	12.83	-	-	7	54	2	5.5	9.3	-	-	20.2	-	-
	Murion Islands	11	2	-	7.46	37	-	9	129	1.7	7.6	7	1	-	15.4	1	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Passage Islands	1	-	-	81.75	-	-	4	15	0.4	0.6	1	-	-	1	-	-
Peak Island	3	-	-	27.58	-	-	10	49	0.1	0.6	1	-	-	1	-	-
Rosemary Island	1	-	-	84.38	-	-	4	10	0.2	0.4	1	-	-	1	-	-
Sunday Island	3	-	-	27.38	-	-	6	13	0.1	0.2	1	-	-	1	-	-
Thevenard Island	1	-	-	81.67	-	-	4	12	0.2	0.6	1	-	-	1	-	-

Table 11.5 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at GER FL2. The results were calculated from 100 spill trajectories days during winter (May to July) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Argo-Rowley Terrace IAA	8	-	-	43.75	-	-	7	29	1.3	1.9	4.7	-	-	6.7	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island (Imperieuse Reef)	8	-	-	43.75	-	-	7	29	1.2	1.8	4.7	-	-	6.7	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoreline	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island	8	-	-	48.75	-	-	6	19	0.5	0.8	1.8	-	-	2.9	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Imperieuse Reef	8	-	-	43.75	-	-	8	29	1.1	1.4	3.8	-	-	4.8	-	-
	Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Murion Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sunday Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

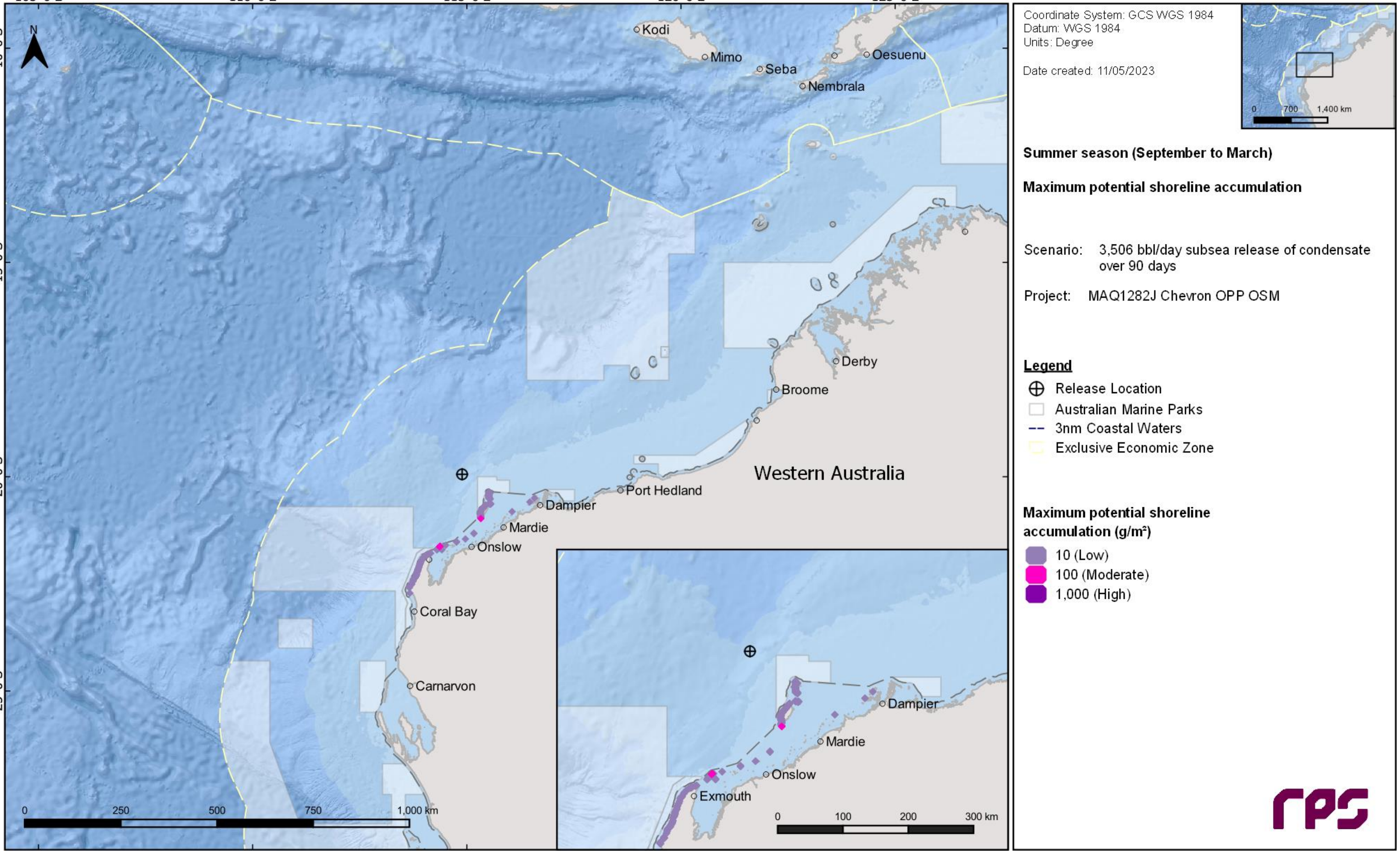


Figure 11.4 Maximum potential shoreline accumulation following a subsea LOWC at GER FL2 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

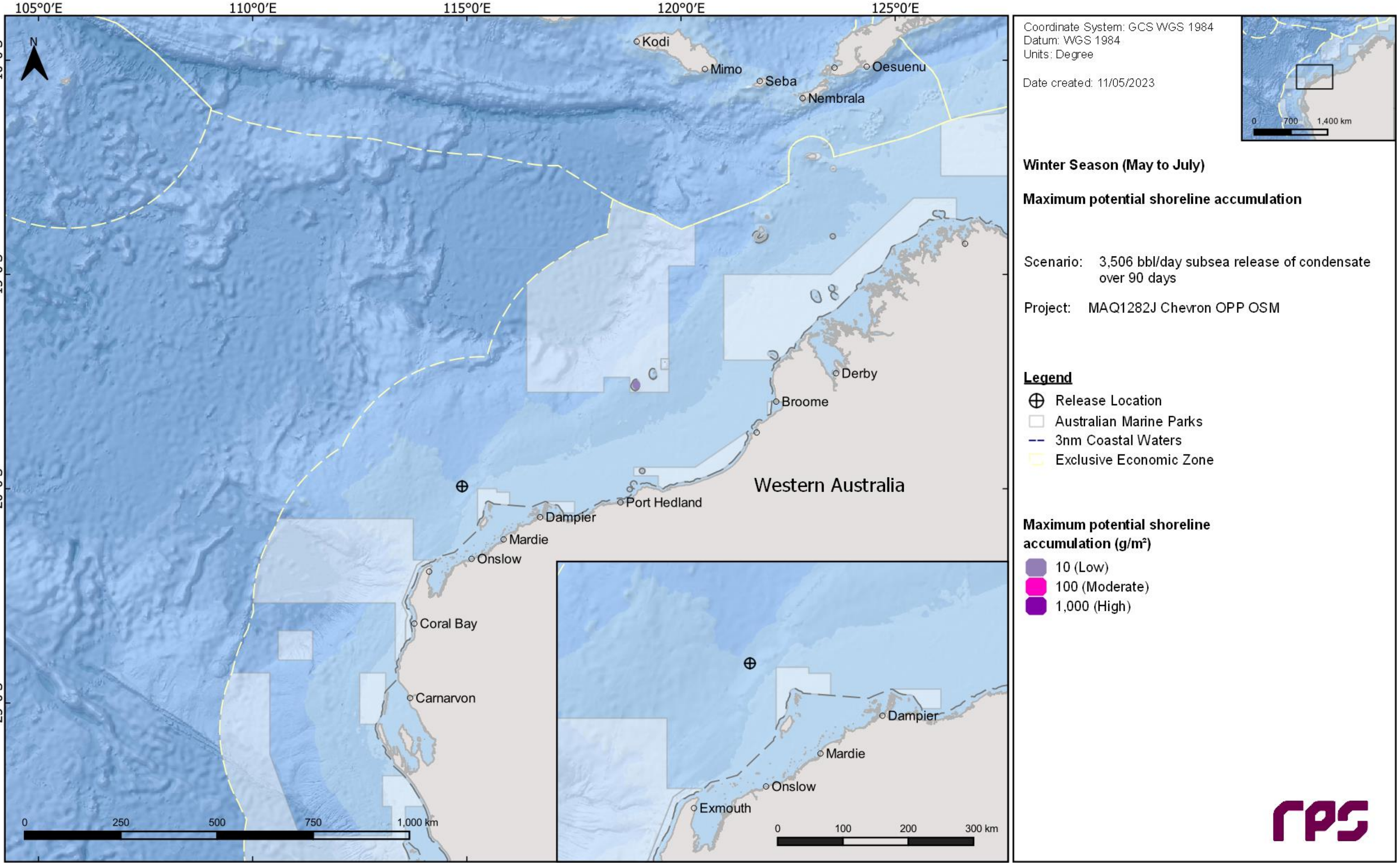


Figure 11.5 Maximum potential shoreline accumulation following a subsea LOWC at GER FL2 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3 Water Column Exposure

11.1.3.1 Dissolved Hydrocarbons

No dissolved hydrocarbon exposure was predicted for this scenario above the low reporting threshold (≥10 ppb) during any of the seasons modelled. Consequently, no results are reported.

11.1.3.2 Entrained Hydrocarbons

Table 11.6 summarises the probability and minimum time before exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

A total of 40, 22 and 22 BIAs were predicted to be exposed at, or above, the low threshold during summer, transitional and winter conditions respectively. Excluding the Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater – Breeding BIAs which the release location resides within, the highest probabilities of exposure were predicted for Humpback Whale - Migration BIA (95% summer, 91% transitional and 87% winter).

During summer and transitional conditions, 7 AMPs were predicted to be exposed at, or above the low threshold, and 6 AMPs under winter conditions. The highest probabilities predicted were at the Gascoyne AMP (92% summer, 97% transitional and 86% winter). Furthermore, the Gascoyne AMP during all seasons (3% summer, 6% transitional and 5% winter) and the Montebello AMP during summer (4%) were predicted to be exposed to entrained hydrocarbons at the high threshold.

During summer, transitional and winter conditions, 8, 7 and 7 KEFs were predicted to be exposed at the low threshold, respectively. Probabilities ranged between 2–100%, 2–100% and 3–100% for summer, transitional and winter, respectively.

Additionally, 50, 17 and 15 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold during summer, transitional and winter conditions, respectively. Excluding the Offshore IAA, the probabilities for each season ranged between 1–92%, 1–97% and 1–86% under summer, transitional and winter conditions, respectively with the maximum probabilities occurring at the Gascoyne IAA during all seasons.

Furthermore, 59, 5 and 4 RSB receptors were predicted to be exposed to entrained hydrocarbons at the low threshold during summer, transitional and winter conditions, respectively. Maximum summer, transitional and winter probabilities of 23% for Rankin Bank, 6% for Rankin Bank and Outtrim Patches and 14% for Outtrim Patches, respectively, were predicted.

Figure 11.6 to Figure 11.8 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

The same maps for the 10-20 m depth layer are presented in Figure 11.9 to Figure 11.11.

Table 11.6 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at GER FL2. The results were calculated from 100 spill simulations per season.

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
AMP	Abrolhos	15.6	2	-	37.13	-	14	3	-	37.13	-	13.7	3	-	46.71	-
	Argo-Rowley Terrace	46.3	17	-	19.83	-	50.6	17	-	16.67	-	90.9	25	-	28.21	-
	Carnarvon Canyon	19.2	7	-	35.96	-	23.3	16	-	27.58	-	21.6	17	-	26.92	-
	Gascoyne	118.9	92	3	5.08	16.42	133.4	97	6	5.5	10.54	130.8	86	5	8.04	13.5
	Montebello	130.1	26	4	3.96	27.33	43.4	21	-	7.75	-	43.2	30	-	4.83	-
	Ningaloo	50.6	26	-	5.96	-	18.6	6	-	16.96	-	22.2	12	-	17.08	-
	Shark Bay	12.1	1	-	79.54	-	9.3	-	-	-	-	7	-	-	-	-
BIA	Bridled Tern - Foraging	14.1	7	-	34.92	-	9.2	-	-	-	-	4.4	-	-	-	-
	Dugong - Breeding	43.3	18	-	6.5	-	15.2	2	-	18.96	-	14.4	10	-	30.96	-
	Dugong - Calving	43.3	18	-	6.5	-	15.2	2	-	18.96	-	14.4	10	-	30.96	-
	Dugong - Foraging	43.3	18	-	6.5	-	15.2	2	-	18.96	-	14.4	10	-	30.96	-
	Dugong - Nursing	43.3	18	-	6.5	-	15.2	2	-	18.96	-	14.4	10	-	30.96	-
	Fairy Tern - Breeding	142.6	21	4	6.13	15.21	26.6	2	-	17.25	-	13	6	-	27.38	-
	Flatback Turtle - Aggregation	46.9	7	-	12.25	-	1.1	-	-	-	-	3.2	-	-	-	-
	Flatback Turtle - Foraging	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Flatback Turtle - Internesting	46.9	7	-	12.25	-	1.1	-	-	-	-	3.2	-	-	-	-
	Flatback Turtle - Internesting Buffer	235.5	85	24	2.42	7	222.9	85	14	2.21	7.38	397	73	15	3	5.96
	Flatback Turtle - Mating	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Flatback Turtle - Migration	15.7	4	-	37.63	-	0.1	-	-	-	-	0.2	-	-	-	-
	Flatback Turtle - Nesting	180	69	5	4.63	10.17	79.5	50	-	3.96	-	73.3	45	-	6.38	-
	Green Turtle - Aggregation	46.9	7	-	12.25	-	1.1	-	-	-	-	3.2	-	-	-	-
	Green Turtle - Basking	142.6	7	3	11.71	61.38	1.9	-	-	-	-	4.9	-	-	-	-
	Green Turtle - Foraging	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Green Turtle - Internesting	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Green Turtle - Internesting Buffer	142.6	27	4	5.88	13.54	21.6	8	-	9.42	-	38.2	23	-	12.25	-
	Green Turtle - Mating	142.6	7	3	11.71	61.38	1.9	-	-	-	-	4.9	-	-	-	-
	Green Turtle - Migration	15.7	4	-	37.63	-	0.1	-	-	-	-	0.2	-	-	-	-
	Green Turtle - Nesting	158.1	27	4	5.96	10.83	32.9	8	-	16.25	-	30.4	24	-	12.33	-
	Hawksbill Turtle - Foraging	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Hawksbill Turtle - Internesting	45.9	6	-	12.67	-	1.1	-	-	-	-	2.5	-	-	-	-
	Hawksbill Turtle - Internesting Buffer	142.6	30	4	5.88	12.17	26.6	8	-	9.83	-	38.2	18	-	12.42	-
	Hawksbill Turtle - Mating	142.6	7	3	11.75	61.42	1.9	-	-	-	-	4.9	-	-	-	-
	Hawksbill Turtle - Migration	15.7	4	-	37.63	-	0.1	-	-	-	-	0.2	-	-	-	-
	Hawksbill Turtle - Nesting	158.1	27	4	6.04	10.83	32.9	7	-	16.25	-	28.8	24	-	12.33	-
	Humpback Whale - Migration	235.5	95	18	3.63	8.46	192.2	91	16	2.21	13.71	195.8	87	14	4.04	10.67
	Humpback Whale - Resting	28.3	3	-	27.33	-	8.8	-	-	-	-	9.2	-	-	-	-
	Lesser Crested Tern - Breeding	148.5	23	4	7.5	11.33	27.8	7	-	16.25	-	17.5	16	-	12.42	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Little Tern - Resting	5.3	-	-	-	-	5.2	-	-	-	-	22.8	8	-	45.46	-
	Loggerhead Turtle - Internesting Buffer	95.6	30	-	5.88	-	21.6	8	-	14.83	-	32.4	20	-	12.42	-
	Loggerhead Turtle - Nesting	72.7	26	-	5.96	-	18.6	8	-	16.54	-	30.4	16	-	14.38	-
	Pygmy Blue Whale - Distribution	844.3	100	100	0.04	0.08	872.2	100	100	0.04	0.08	865.7	100	100	0.04	0.08
	Pygmy Blue Whale - Foraging	76.8	62	-	5.25	-	49.4	40	-	12.04	-	60.2	29	-	12.33	-
	Roseate Tern - Breeding	158.1	38	4	5.79	10.79	20.4	18	-	18.38	-	60.2	17	-	15.71	-
	Sooty Tern - Foraging	13.9	7	-	35.79	-	11.9	2	-	38.71	-	7.8	-	-	-	-
	Wedge-tailed Shearwater - Breeding	844.3	100	100	0.04	0.08	872.2	100	100	0.04	0.08	865.7	100	100	0.04	0.08
	Wedge-tailed Shearwater - Foraging	14.5	7	-	34.92	-	9.2	-	-	-	-	4.9	-	-	-	-
	Whale Shark - Foraging	235.5	83	18	2.46	7.13	201.4	82	9	2.25	7.46	350.6	61	12	3.04	5.96
	White-tailed Tropicbird - Breeding	25.5	9	-	34	-	15.2	4	-	28.29	-	28.6	10	-	40.96	-
CP	Montebello Islands	32.1	4	-	12.83	-	0.9	-	-	-	-	2.4	-	-	-	-
EEZ	Australian Exclusive Economic Zone	844.3	100	100	0.04	0.08	872.2	100	100	0.04	0.08	865.7	100	100	0.04	0.08
	Indonesian Exclusive Economic Zone	8.8	-	-	-	-	11.5	1	-	60	-	12.2	3	-	64.33	-
IAA	Abrolhos Islands IAA	15.6	2	-	37.13	-	14	3	-	37.13	-	13.7	3	-	46.71	-
	Abutilon Island	18	3	-	64.71	-	0.6	-	-	-	-	1.8	-	-	-	-
	Airlie Island	50.9	7	-	13.83	-	2.4	-	-	-	-	2.7	-	-	-	-
	Argo-Rowley Terrace IAA	46.3	17	-	19.83	-	50.6	17	-	16.67	-	90.9	25	-	28.21	-
	Ashburton Island	17.7	3	-	76.88	-	0.5	-	-	-	-	1	-	-	-	-
	Barrow & Montebello Islands IAA	142.6	26	4	3.96	27.33	43.4	21	-	7.75	-	43.2	30	-	4.83	-
	Barrow Island (East Coast)	79.3	7	-	13	-	1.3	-	-	-	-	3.4	-	-	-	-
	Barrow Island (West Coast)	133	7	3	11.83	61.92	1.7	-	-	-	-	4.9	-	-	-	-
	Barrow Island Group	133	7	3	11.83	61.58	1.7	-	-	-	-	4.9	-	-	-	-
	Bessieres Island	48.5	12	-	27.33	-	10.8	1	-	19.13	-	9.5	-	-	-	-
	Boodie Island	126.3	7	3	11.83	61.58	1.3	-	-	-	-	4.2	-	-	-	-
	Cape Range National Park	40.4	11	-	7.58	-	7	-	-	-	-	6.4	-	-	-	-
	Cunningham Island (Imperieuse Reef)	3.5	-	-	-	-	4	-	-	-	-	17.9	8	-	49.88	-
	Dampier Archipelago IAA	38.1	4	-	17.92	-	0.9	-	-	-	-	1.8	-	-	-	-
	Dampier Archipelago Island Group	17.4	4	-	32.67	-	0.1	-	-	-	-	0.3	-	-	-	-
	Dampier mainland coastline	18.3	4	-	30.58	-	0	-	-	-	-	0.2	-	-	-	-
	Double Island	12.4	3	-	65.92	-	0.5	-	-	-	-	2	-	-	-	-
	Eaglehawk Island	15	4	-	32.67	-	0	-	-	-	-	0.1	-	-	-	-
	Enderby Island	15.8	4	-	36.67	-	0	-	-	-	-	0.1	-	-	-	-
	Exmouth IAA	24.9	4	-	26.92	-	9.8	-	-	-	-	13.3	4	-	30.5	-
	Gascoyne IAA	118.9	92	3	5.08	16.42	133.4	97	6	5.5	10.54	130.8	86	5	8.04	13.5
	Glomar Shoal	23.5	3	-	49.29	-	0.4	-	-	-	-	1.2	-	-	-	-
	Goodwyn Island	16.3	4	-	37.21	-	0.1	-	-	-	-	0.1	-	-	-	-
	Great Sandy Island	11	1	-	69	-	0.2	-	-	-	-	0.5	-	-	-	-
	Hermite Island	33	5	-	12.83	-	1.4	-	-	-	-	2.5	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Locker Island	17.8	3	-	75.88	-	1.3	-	-	-	-	1	-	-	-	-
	Lowendal Islands Group	18	3	-	64.71	-	0.6	-	-	-	-	1.8	-	-	-	-
	Malus Islands	11.8	3	-	84.63	-	0	-	-	-	-	0.1	-	-	-	-
	Middle Island	127.6	7	3	11.92	61.67	1.7	-	-	-	-	4.2	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	27.4	17	-	7.96	-	4.3	-	-	-	-	4.2	-	-	-	-
	Montebello Islands Group	33	5	-	12.83	-	1.4	-	-	-	-	2.5	-	-	-	-
	Muiron Islands	72.7	17	-	8	-	15.2	7	-	29.54	-	18.3	15	-	14.46	-
	Ningaloo Coast World Heritage Area	72.7	26	-	5.96	-	18.6	7	-	16.96	-	22.2	16	-	14.13	-
	North Muiron Island	72.7	17	-	8.08	-	14.7	7	-	29.54	-	18.3	15	-	14.46	-
	North Ningaloo Coast - World Heritage Area	40.2	11	-	7.83	-	8	-	-	-	-	7.1	-	-	-	-
	North Sandy Island	12.1	2	-	66.04	-	0.2	-	-	-	-	0.4	-	-	-	-
	Offshore Area	844.3	100	100	0.04	0.08	872.2	100	100	0.04	0.08	865.7	100	100	0.04	0.08
	Onslow Area Mainland Coastline	17.5	3	-	74.29	-	0.8	-	-	-	-	0.4	-	-	-	-
	Pilbara Coast IAA	136.5	19	3	6.54	58	27.9	7	-	16.46	-	19	17	-	13.04	-
	Pilbara Coast Islands Group	50.9	12	-	13.83	-	12	2	-	19.13	-	10.1	1	-	78.71	-
	Pilbara Mainland Coast	17.5	3	-	74.29	-	0.8	-	-	-	-	0.4	-	-	-	-
	Potter Island	14.7	4	-	30.08	-	0	-	-	-	-	0.2	-	-	-	-
	Rankin Bank	133.2	20	4	8.75	26.04	29	4	-	35.17	-	28.8	6	-	77.83	-
	Rosemary Island	17.4	4	-	36.67	-	0.1	-	-	-	-	0.2	-	-	-	-
	Serrurier Island	41.7	11	-	26.96	-	12	2	-	27.54	-	10.1	1	-	78.71	-
	Shark Bay mainland coastline	16.3	7	-	27.17	-	13.2	1	-	33.5	-	8.9	-	-	-	-
	Sholl Island	25.8	4	-	27.04	-	0	-	-	-	-	0.5	-	-	-	-
	South Muiron Island	71.5	16	-	8	-	15.2	7	-	30.13	-	15.5	14	-	14.63	-
	South Ningaloo Coast - World Heritage Area	11.2	2	-	33.13	-	1.7	-	-	-	-	1.6	-	-	-	-
	Thevenard Island	56	7	-	12.42	-	10.2	1	-	19.29	-	4.1	-	-	-	-
	Trimouille Island	23.4	4	-	32.04	-	0.7	-	-	-	-	1.9	-	-	-	-
IBRA	Cape Range	133	17	3	7.58	61.92	15.7	7	-	19.13	-	17.9	15	-	14	-
	Roebourne	127.6	7	3	11.88	61.67	1.9	-	-	-	-	4.2	-	-	-	-
IMCRA	Ningaloo	57.4	29	-	5.79	-	23.1	10	-	13.92	-	23	26	-	12.46	-
	Northwest Shelf	210.1	44	7	2.42	6.71	210.5	44	14	6.38	23.71	206.2	61	13	3.83	10
	Pilbara (nearshore)	34.7	6	-	19.63	-	9.5	-	-	-	-	10.9	1	-	78.83	-
	Pilbara (offshore)	235.5	83	19	3.13	9.29	179.3	83	8	2.25	7.42	378.8	68	12	3.04	5.96
	Zuytdorp	16.3	7	-	27.17	-	13.2	1	-	33.5	-	8.9	-	-	-	-
KEF	Ancient coastline at 125 m depth contour	220.2	67	13	2.92	7.79	153.4	76	6	2.42	24	153.4	58	10	3.42	15.5
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	98.7	76	-	4.96	-	135.8	58	4	10.46	51.5	144.2	63	3	8.58	18.96
	Commonwealth waters adjacent to Ningaloo Reef	50.6	26	-	5.96	-	18.6	6	-	16.96	-	22.2	12	-	17.08	-
	Continental Slope Demersal Fish Communities	336.6	100	57	1.46	3.25	352.3	100	60	1.29	2.04	500.1	100	63	1.58	4.04
	Exmouth Plateau	149.6	96	5	3.88	16.96	166.6	100	13	3.04	10.46	224.3	96	17	2.42	8.04

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Glomar Shoals	27	4	-	24.54	-	0.8	-	-	-	-	2	-	-	-	-
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	4.6	-	-	-	-	4.9	-	-	-	-	22.8	8	-	45.46	-
	Wallaby Saddle	15.6	2	-	37.92	-	13.3	3	-	79.08	-	13	3	-	46.71	-
	Western demersal slope and associated fish communities	14.5	7	-	34.92	-	11.9	2	-	38.71	-	8.8	-	-	-	-
MMA	Barrow Island	142.6	7	3	11.42	61.29	2.1	-	-	-	-	4.9	-	-	-	-
	Muiron Islands	72.7	17	-	6.88	-	16.7	7	-	29	-	18.3	16	-	14.13	-
MP	Barrow Island	60	7	-	11.63	-	1.5	-	-	-	-	4.6	-	-	-	-
	Montebello Islands	48.3	7	-	12.29	-	1.6	-	-	-	-	3.6	-	-	-	-
	Ningaloo	43.3	17	-	7	-	13.1	2	-	31.21	-	14.2	10	-	29.63	-
	Rowley Shoals	4.1	-	-	-	-	4.8	-	-	-	-	22.8	8	-	45.46	-
NR	Great Sandy Island	35.6	5	-	14.54	-	0.3	-	-	-	-	1.3	-	-	-	-
	Thevenard Island	31.2	6	-	31.08	-	4.5	-	-	-	-	2.6	-	-	-	-
RSB	Ashworth Shoal	14.7	3	-	76.25	-	0	-	-	-	-	0.1	-	-	-	-
	Australind Shoal	18	3	-	76.29	-	0.6	-	-	-	-	1.4	-	-	-	-
	Barrow Island Reefs and Shoals	37.7	5	-	13.79	-	0.7	-	-	-	-	1.7	-	-	-	-
	Baylis Patches	17.2	3	-	75.25	-	2.2	-	-	-	-	2.4	-	-	-	-
	Brewis Reef	25.7	5	-	30.67	-	6.1	-	-	-	-	3.1	-	-	-	-
	Cod Bank	22.7	4	-	23.63	-	0.1	-	-	-	-	0.2	-	-	-	-
	Combe Reef	11.5	2	-	41.29	-	7.7	-	-	-	-	5.7	-	-	-	-
	Dailey Shoal	30.8	7	-	26.92	-	11.8	2	-	29.21	-	10.1	1	-	76.63	-
	Eliassen Rocks	14.1	3	-	76.21	-	0	-	-	-	-	0.2	-	-	-	-
	Fairway Reef	16.8	5	-	42.04	-	8.1	-	-	-	-	6	-	-	-	-
	Flinders Shoal	14.7	3	-	63.29	-	0.4	-	-	-	-	0.8	-	-	-	-
	Fortescue Reef	24.7	4	-	27.5	-	0	-	-	-	-	0.3	-	-	-	-
	Glennie Patches	17.7	3	-	77.25	-	0.6	-	-	-	-	0.7	-	-	-	-
	Glomar Shoal	23.5	3	-	49.25	-	0.4	-	-	-	-	1.6	-	-	-	-
	Gorgon Patch	15.4	3	-	79.38	-	0.2	-	-	-	-	0.4	-	-	-	-
	Hastings Shoal	11.2	3	-	80.46	-	0.1	-	-	-	-	0.3	-	-	-	-
	Hayman Rock	19.6	4	-	30.5	-	2.6	-	-	-	-	2.7	-	-	-	-
	Herald Reef	17.6	3	-	82.38	-	0.1	-	-	-	-	0.4	-	-	-	-
	Hood Reef	26.5	8	-	28.63	-	10.8	1	-	45.92	-	6.7	-	-	-	-
	Imperieuse Reef	3.5	-	-	-	-	4	-	-	-	-	17.9	8	-	49.88	-
	Inner Northwest Patch	19.1	4	-	31.58	-	0.6	-	-	-	-	0.8	-	-	-	-
	Koolinda Patch	13.3	3	-	88.17	-	0.2	-	-	-	-	0.3	-	-	-	-
	Lightfoot Reef	11.2	3	-	65.33	-	0.2	-	-	-	-	0.7	-	-	-	-
	Little Shoals	17.8	4	-	36.83	-	0.2	-	-	-	-	0.7	-	-	-	-
	Locker Reef	25.5	4	-	28.96	-	3	-	-	-	-	2.5	-	-	-	-
	Manicom Bank	13.4	3	-	77.29	-	0.4	-	-	-	-	0.4	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Mardie Rock	17.2	3	-	75.17	-	0	-	-	-	-	0.1	-	-	-	-
	McLennan Bank	30.1	4	-	21.71	-	0.1	-	-	-	-	0.4	-	-	-	-
	Meda Reef	12.7	3	-	67.54	-	0.1	-	-	-	-	0.2	-	-	-	-
	Miles Shoal	18.1	3	-	77.25	-	0.4	-	-	-	-	0.6	-	-	-	-
	Montebello Shoals	48.2	7	-	12.25	-	1.3	-	-	-	-	3.4	-	-	-	-
	Moresby Shoals	19.6	4	-	37.25	-	0.2	-	-	-	-	0.5	-	-	-	-
	Nares Rock	18.7	4	-	37.92	-	0.1	-	-	-	-	0.4	-	-	-	-
	Ningaloo Reef	40.4	17	-	7.38	-	9.6	-	-	-	-	6.4	-	-	-	-
	North West Reef	17.1	4	-	24.79	-	0	-	-	-	-	0.1	-	-	-	-
	North West Reef	29.8	8	-	26.42	-	7.3	-	-	-	-	8.8	-	-	-	-
	O'Grady Shoal	24.5	4	-	26	-	0	-	-	-	-	0.5	-	-	-	-
	Otway Reef	16.2	3	-	27.42	-	7.9	-	-	-	-	5.6	-	-	-	-
	Outtrim Patches	55.3	8	-	25.92	-	14.4	6	-	29.46	-	15.7	14	-	14.58	-
	Paroo Shoal	16	3	-	77.33	-	0.4	-	-	-	-	0.6	-	-	-	-
	Penguin Bank	122.1	10	4	11.5	12.29	3.6	-	-	-	-	9.7	-	-	-	-
	Poivre Reef	125.5	7	3	11.71	60.96	1.1	-	-	-	-	3.5	-	-	-	-
	Rankin Bank	134.5	23	4	8.75	23.83	29	6	-	35.13	-	28.8	8	-	58.5	-
	Ripple Shoals	46.8	6	-	12.88	-	0.7	-	-	-	-	2.4	-	-	-	-
	Roller Shoal	10.7	1	-	93.38	-	0.2	-	-	-	-	0.2	-	-	-	-
	Rosily Shoals	81.5	11	-	11.71	-	14.5	2	-	19.25	-	8.7	-	-	-	-
	Saladin Shoal	14.5	3	-	78.25	-	0.2	-	-	-	-	0.5	-	-	-	-
	Santo Rock	26.5	4	-	28.88	-	3.6	-	-	-	-	2.2	-	-	-	-
	South East Reef	12.6	3	-	43.08	-	0	-	-	-	-	0.1	-	-	-	-
	South West Reef	18.2	4	-	32.63	-	0	-	-	-	-	0.1	-	-	-	-
	Southwest Patch	11.1	2	-	78.33	-	0.2	-	-	-	-	0.4	-	-	-	-
	Sultan Reef	23.3	6	-	32.13	-	1.3	-	-	-	-	1.9	-	-	-	-
	Taunton Reef	36.9	6	-	13.96	-	0.8	-	-	-	-	1.9	-	-	-	-
	Tongue Shoals	20.1	4	-	31.04	-	1.3	-	-	-	-	0.9	-	-	-	-
	Trap Reef	56.1	7	-	12.71	-	5.5	-	-	-	-	4.6	-	-	-	-
	Tryal Rocks	46.1	10	-	12.38	-	3.7	-	-	-	-	4	-	-	-	-
	Ward Reef	10	1	-	103.79	-	0.1	-	-	-	-	0.2	-	-	-	-
	Web Reef	11.6	1	-	82.33	-	5.7	-	-	-	-	3.1	-	-	-	-
	Weeks Shoal	15.2	3	-	78.83	-	0.2	-	-	-	-	0.4	-	-	-	-
	West Reef	11.1	2	-	84.21	-	0.2	-	-	-	-	0.9	-	-	-	-
Nearshore Waters	Airlie Island	50.9	7	-	13.83	-	2.4	-	-	-	-	2.7	-	-	-	-
	Ashburton	11.5	3	-	89.25	-	1.2	-	-	-	-	0.6	-	-	-	-
	Ashburton Island	17.7	3	-	77.25	-	0.5	-	-	-	-	1	-	-	-	-
	Barrow Island	133	7	3	11.92	61.92	1.7	-	-	-	-	4.9	-	-	-	-
	Bessieres Island	48.5	12	-	27.33	-	10.8	1	-	19.13	-	9.5	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Boodie Island	122.6	7	3	11.88	61.67	1.1	-	-	-	-	4.2	-	-	-	-
	Carnarvon	12.3	2	-	32.54	-	1.7	-	-	-	-	1.7	-	-	-	-
	Cunningham Island	2.9	-	-	-	-	3.4	-	-	-	-	12.6	8	-	50.58	-
	Direction Island	17	3	-	80.42	-	0.1	-	-	-	-	0.4	-	-	-	-
	Eaglehawk Island	17.8	4	-	32.46	-	0	-	-	-	-	0.1	-	-	-	-
	Enderby Island	15.8	4	-	36.17	-	0	-	-	-	-	0.2	-	-	-	-
	Exmouth	40.4	17	-	7.58	-	8	-	-	-	-	7.1	-	-	-	-
	Flat Island	35.6	11	-	26.92	-	13.5	2	-	27.63	-	11.5	1	-	28.96	-
	Fly Island	11.5	1	-	79.67	-	4.5	-	-	-	-	2.8	-	-	-	-
	Goodwyn Island	16.3	4	-	37	-	0.1	-	-	-	-	0.1	-	-	-	-
	Imperieuse Reef	3.2	-	-	-	-	3.5	-	-	-	-	16.1	8	-	50.17	-
	Karratha	18.9	4	-	29.96	-	0.2	-	-	-	-	0.3	-	-	-	-
	Kendrew Island	17	4	-	25.42	-	0.1	-	-	-	-	0.2	-	-	-	-
	Locker Island	17.8	3	-	75.88	-	1.3	-	-	-	-	1	-	-	-	-
	Lowendal Island	41.2	5	-	12.71	-	1.1	-	-	-	-	2.4	-	-	-	-
	Malus Island	11.8	3	-	84.63	-	0	-	-	-	-	0.1	-	-	-	-
	Mangrove Islands	16.8	3	-	83.46	-	0.1	-	-	-	-	0.2	-	-	-	-
	Mary Anne Group	14.3	3	-	65.29	-	0.3	-	-	-	-	0.9	-	-	-	-
	Middle Island	127.6	7	3	11.92	61.67	1.7	-	-	-	-	4.2	-	-	-	-
	Montebello Islands	39.5	6	-	12.75	-	1.4	-	-	-	-	2.9	-	-	-	-
	Murion Islands	72.7	17	-	8	-	15.2	7	-	29.54	-	17.9	15	-	14.46	-
	Observation Island	15.3	3	-	32.25	-	7.3	-	-	-	-	5.8	-	-	-	-
	Passage Islands	28.2	4	-	22.25	-	0.3	-	-	-	-	0.5	-	-	-	-
	Peak Island	58.8	8	-	25.96	-	15.7	4	-	28.46	-	15	12	-	14	-
	Ragnard Islands	17.6	4	-	30.92	-	0	-	-	-	-	0.2	-	-	-	-
	Rosemary Island	17.4	4	-	36.67	-	0.2	-	-	-	-	0.2	-	-	-	-
	Round Island	36.6	9	-	28.04	-	9.1	-	-	-	-	7.5	-	-	-	-
	Serrurier Island	40.6	11	-	26.96	-	12	2	-	27.54	-	10.1	1	-	78.71	-
	Sunday Island	42.3	7	-	26.33	-	11.5	2	-	30.21	-	12.4	10	-	29.42	-
	Table Island	36.9	7	-	27.75	-	9.5	-	-	-	-	5.6	-	-	-	-
	Thevenard Island	35.8	7	-	31.08	-	4.3	-	-	-	-	2.7	-	-	-	-
	Tortoise Island	23.1	5	-	31.08	-	1.8	-	-	-	-	3.6	-	-	-	-
	Twin Island	15.3	3	-	82.46	-	0.2	-	-	-	-	0.3	-	-	-	-
State Waters	Western Australia State Waters	148.5	19	4	6.88	11.67	26.6	7	-	16.88	-	22.8	17	-	13.21	-

*The release location resides within the receptor boundaries.

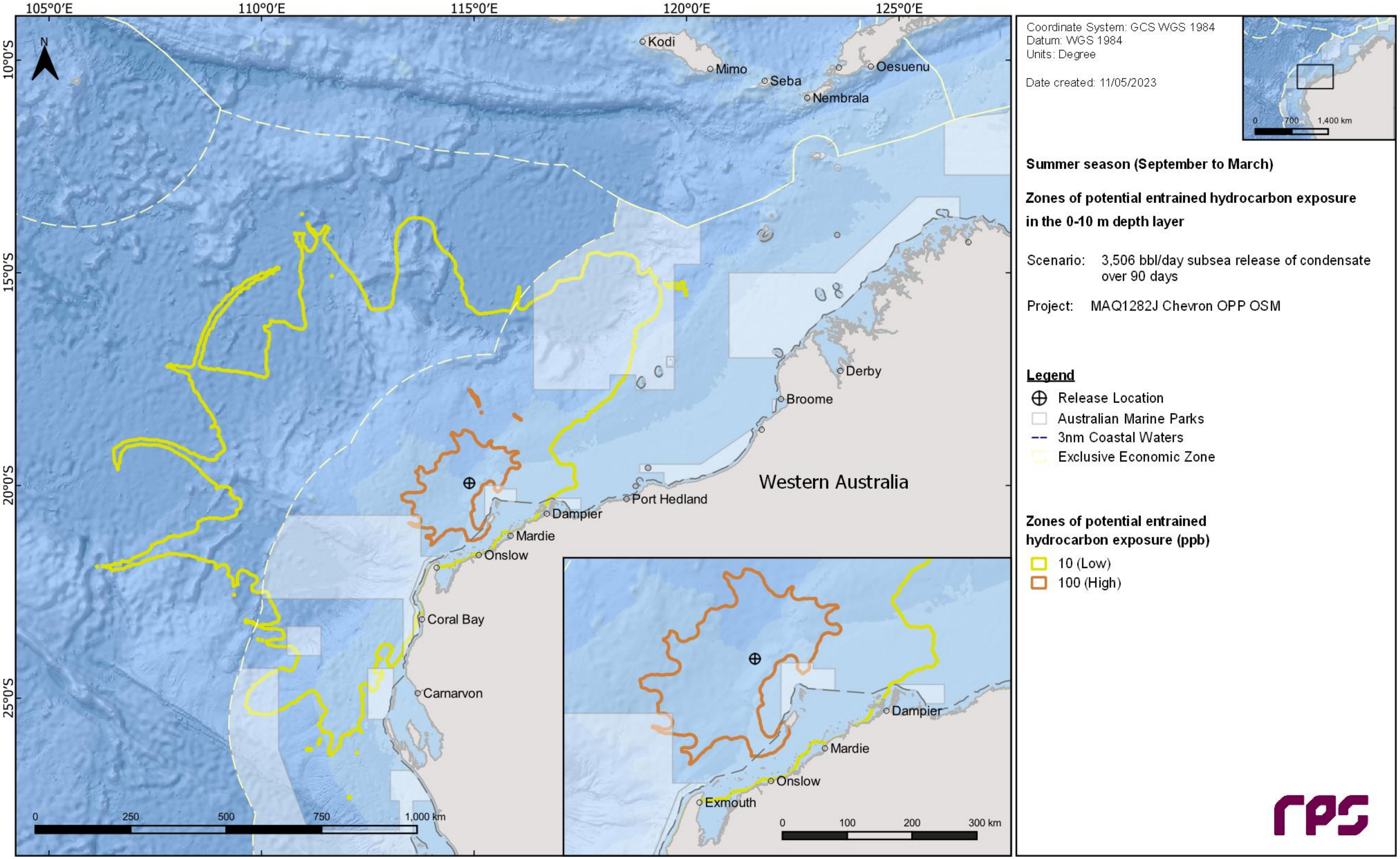


Figure 11.6 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at GER FL2 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

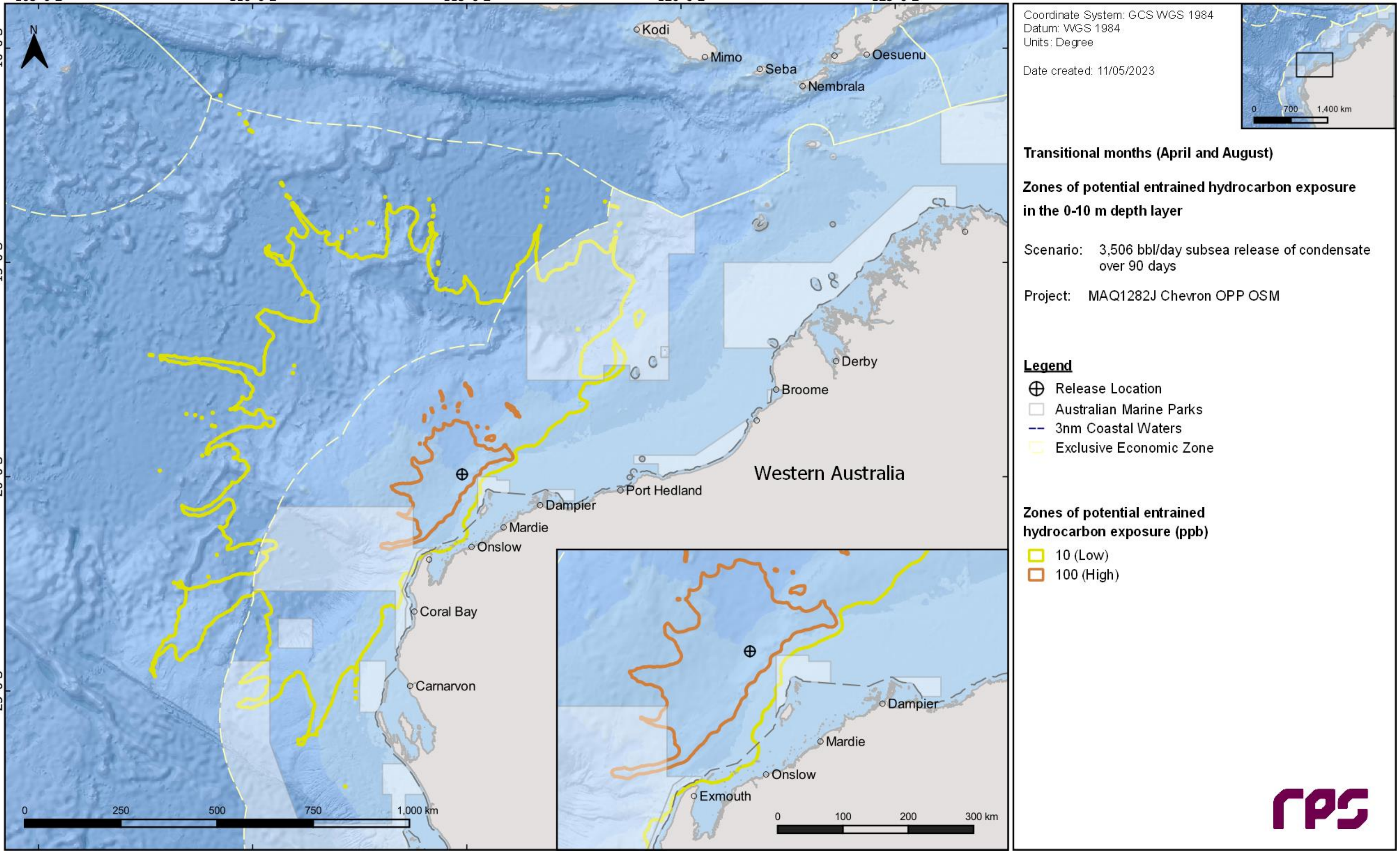


Figure 11.7 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at GER FL2 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

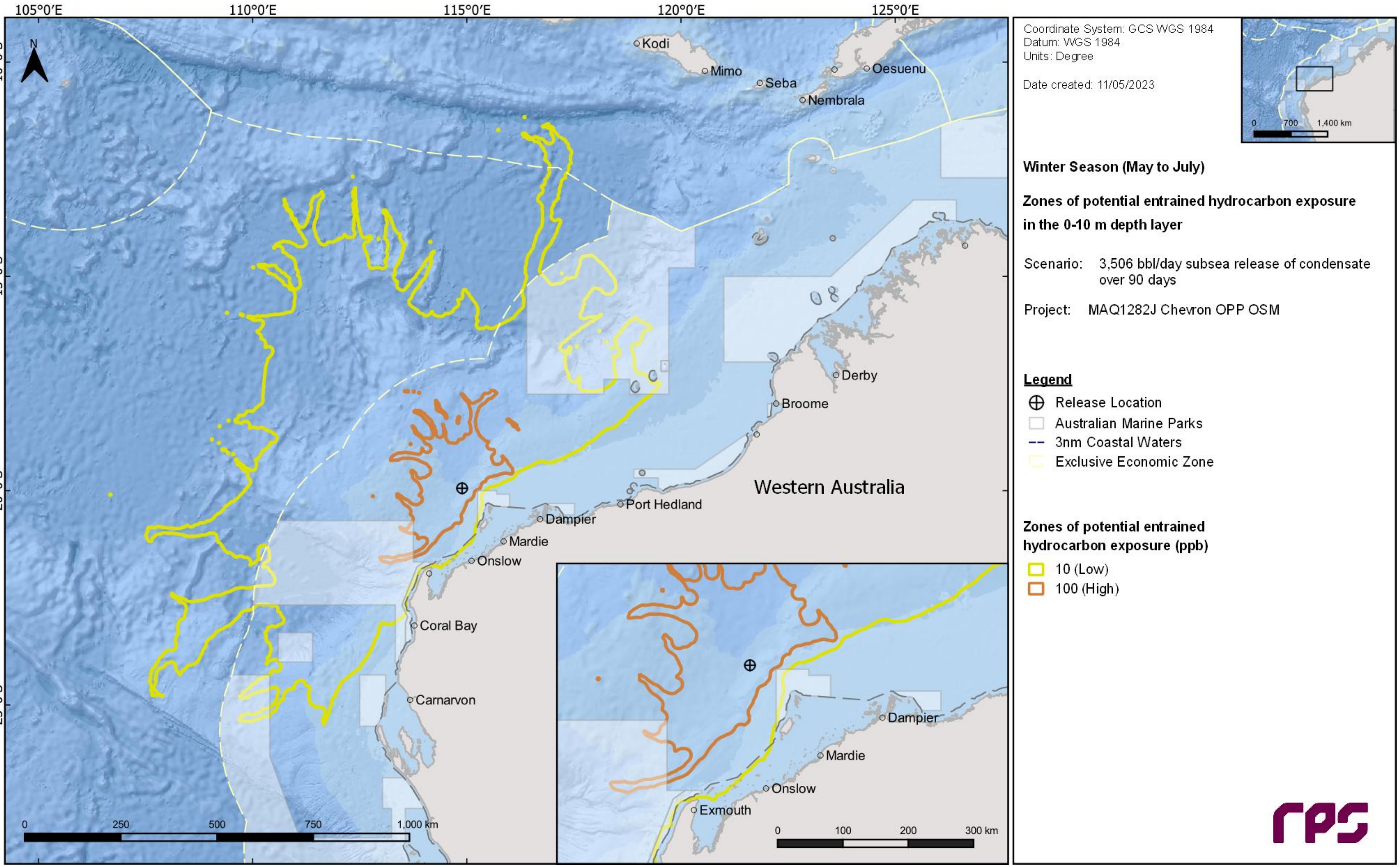


Figure 11.8 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at GER FL2 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

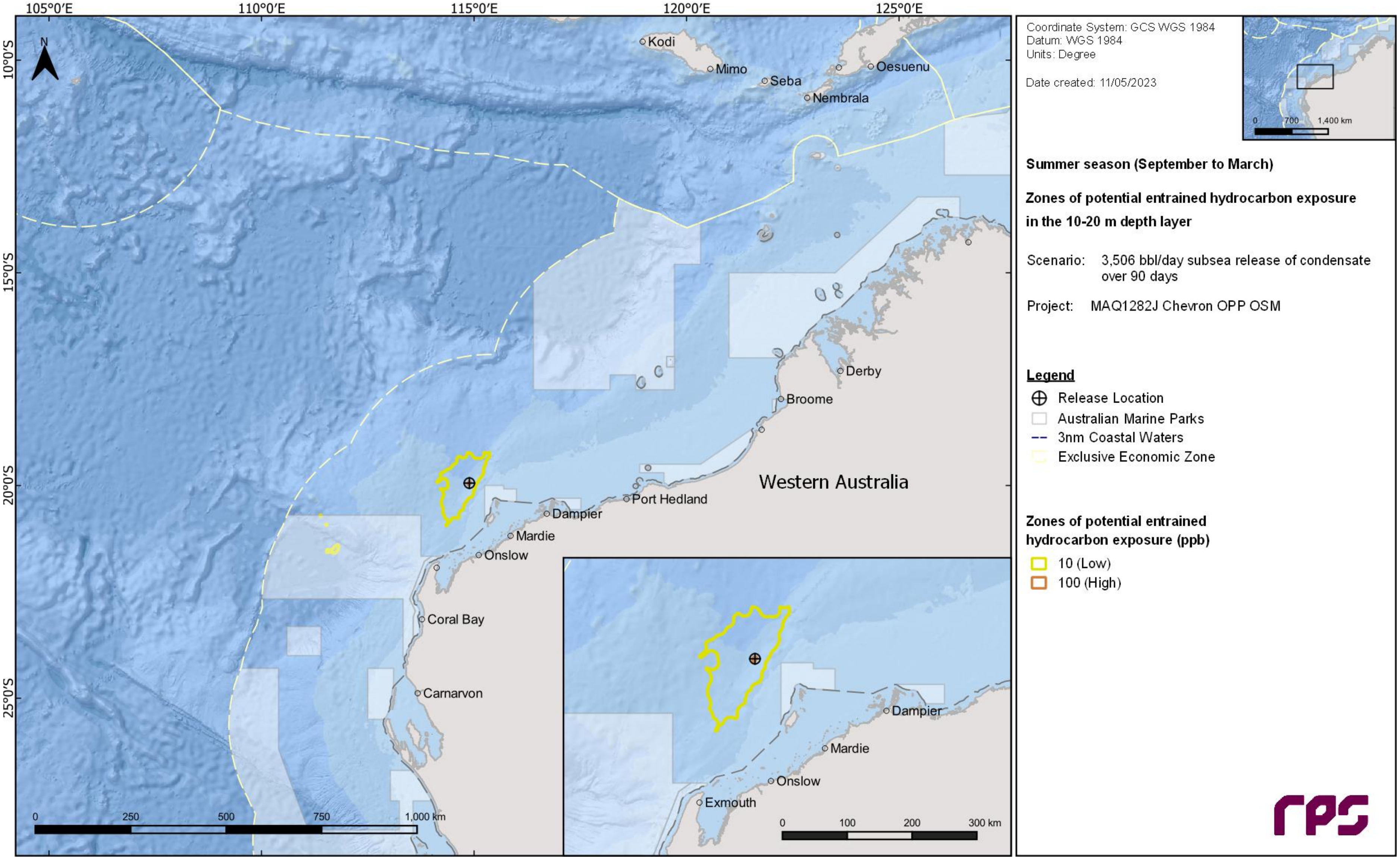


Figure 11.9 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at GER FL2 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

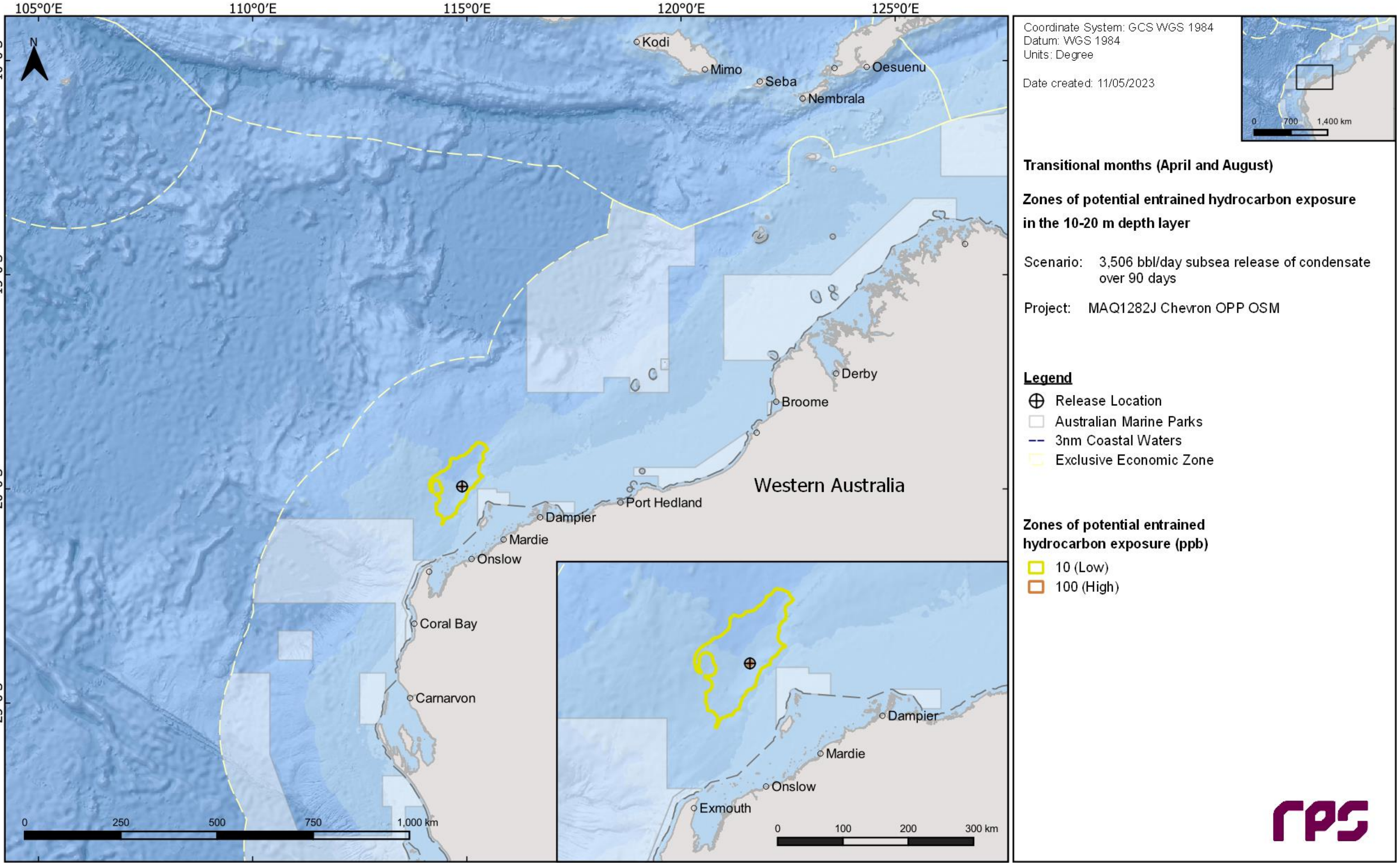


Figure 11.10 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at GER FL2 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

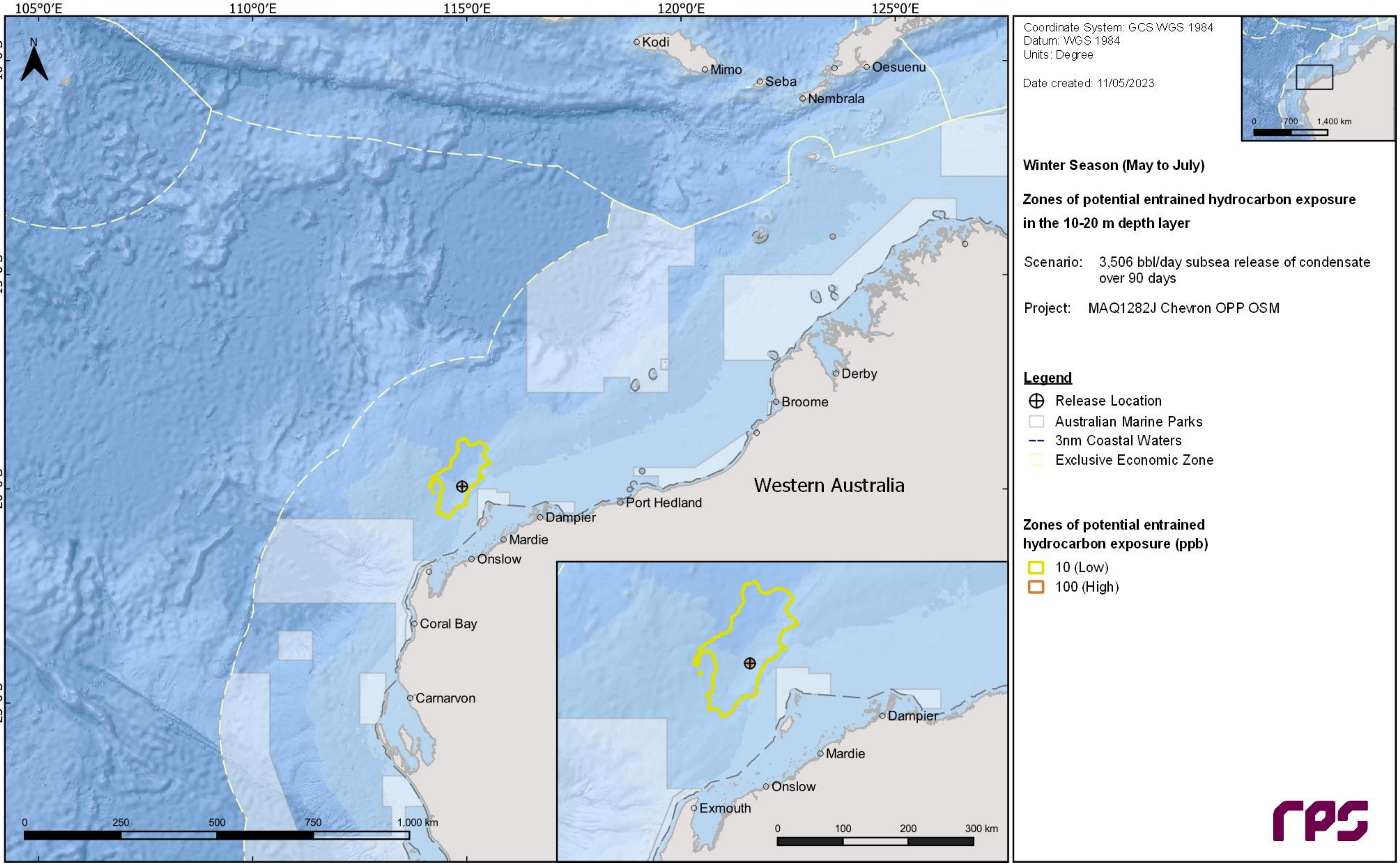


Figure 11.11 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at GER FL2 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating condensate above 10 g/m² (see Section 11.2.1), largest volume of oil ashore (see Section 11.2.2), longest length of shoreline accumulation above 100 g/m² (see Section 11.2.2) and the largest area of entrained hydrocarbons above 100 ppb (see Section 11.2.4).

Table 11.7 presents a summary of all deterministic analysis criteria and the corresponding floating condensate, shoreline accumulation, entrained and dissolved hydrocarbon values at the assessed thresholds.

Note that there was no floating hydrocarbons at or above 50 g/m² and no dissolved hydrocarbon exposure at or above 50 ppb for any of the 300 simulations.

Interpretation of the deterministic analysis result table and timeseries plots:

The summary deterministic analysis results presented in the table below should be interpreted as **maximum values**, representing the total volume or swept area exposed by floating or in-water hydrocarbons throughout the entire simulation duration. In this particular case, the simulation showed that a maximum of 932 km² was exposed to floating oil above the low threshold over a period of 104 days.

However, it's important to note that the timeseries plots present **peak values** at specific points in time. For example, when considering shoreline volume, the peak value in the timeseries plot does not account for oil that may have reached the shore earlier in the simulation but was subsequently lost through evaporation or other weathering processes.

Continuing with the previous example, the timeseries plot indicates that the peak floating oil swept area above the low threshold reached 68 km². This value represents the highest swept area recorded at a single point in time during the simulation.

Table 11.7 Summary of the deterministic analysis following a subsea LOWC at GER FL2.

Variable	Threshold	Deterministic Analysis Criteria			
		Largest swept area of floating condensate above 10 g/m²	Largest volume of oil ashore	Longest length of shoreline accumulation above 100 g/m²	Largest area of entrained hydrocarbons above 100 ppb
Season		Winter	Summer	Summer	Summer
Run Number		64	40	51	15
Floating Oil (km²)	1 g/m²	932.0	804.6	856.3	914.5
	10 g/m²	**22.2**	6.5	4.6	3.7
	50 g/m²	-	-	-	-
Shoreline Length (km)	10 g/m²	-	50	76	55
	100 g/m²	-	1	**2**	-
	1,000 g/m²	-	-	-	-
Minimum Time (days)		-	73.9	12.5	59.0
Maximum Volume (m³)		-	**23.2**	22	13
Entrained Area (km²)	10 ppb	140,946	152,629	129,032	144,042
	100 ppb	2,598	8,677	5,635	**8,847**
Dissolved Area (km²)	10 ppb	-	-	-	-
	50 ppb	-	-	-	-
	400 ppb	-	-	-	-
Start Date		20 June 2011	6 October 2010	6 December 2010	21 October 2010

11.2.1 Deterministic Case: Largest swept area of floating condensate above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 (moderate threshold) was identified as run number 64 during the winter period.

Figure 11.12 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.13 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.14 presents the fates and weathering for the corresponding simulation and Table 11.8 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.8 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at GER FL2.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	442	52.42	1
Entrained (m^3)	4,828	90.00	2,999
Dissolved (m^3)	7	81.46	0
Evaporation (m^3)	33,388	103.54	33,388
Decay (m^3)	14,140	104.00	14,140
Ashore (m^3)	0	0.04	0

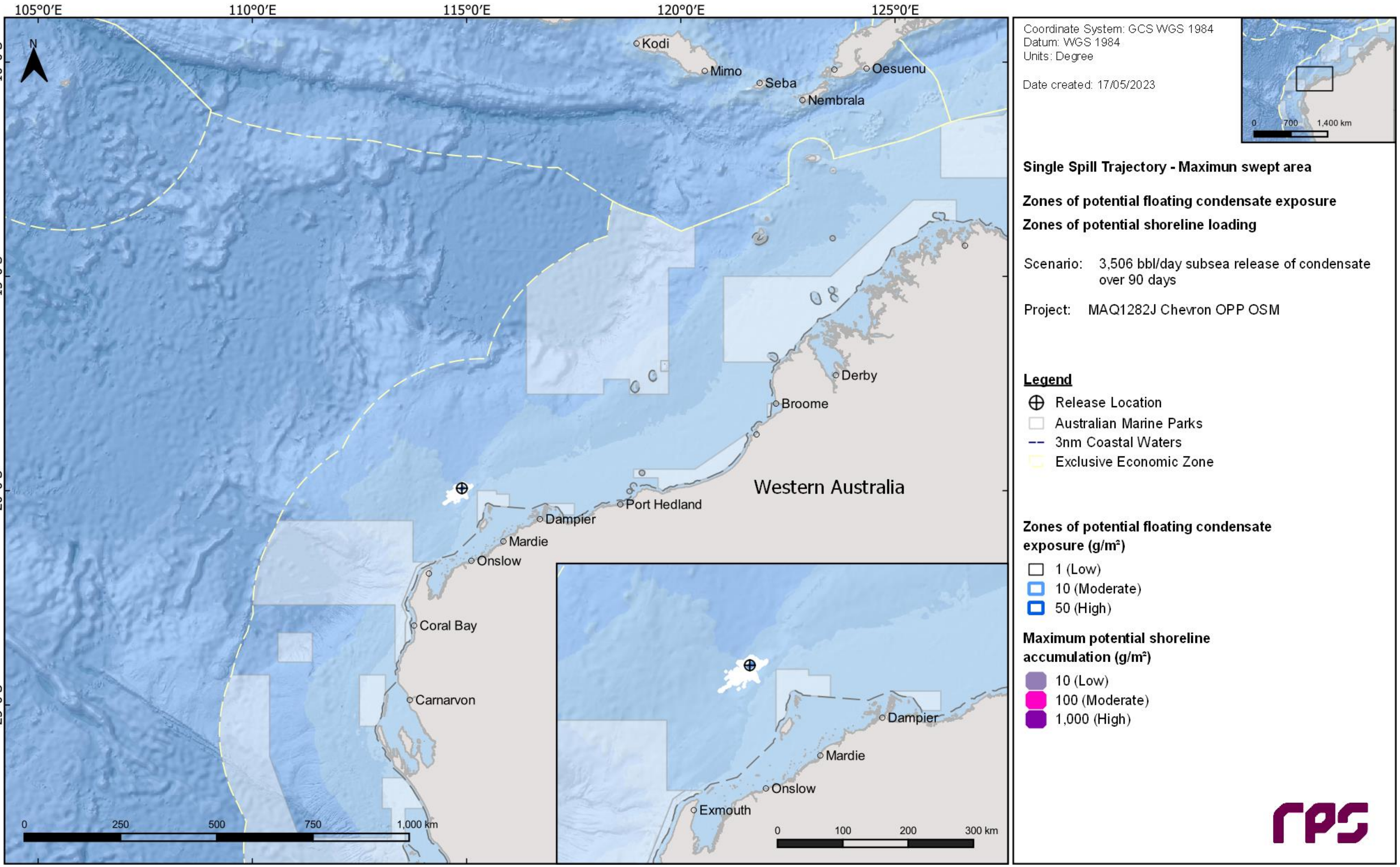


Figure 11.12 Zones of potential floating condensate exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at GER FL2.

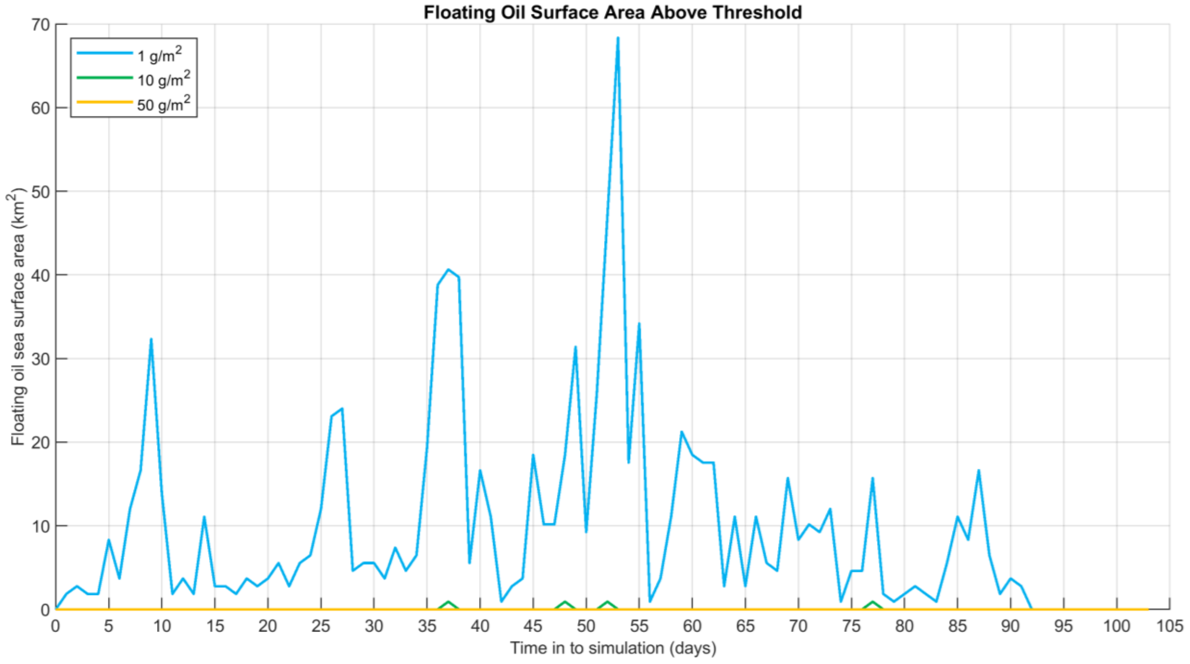


Figure 11.13 Predicted area of floating condensate exposure for each threshold, for the simulation with the largest swept area of floating condensate above 10 g/m² following a LOWC at GER FL2.

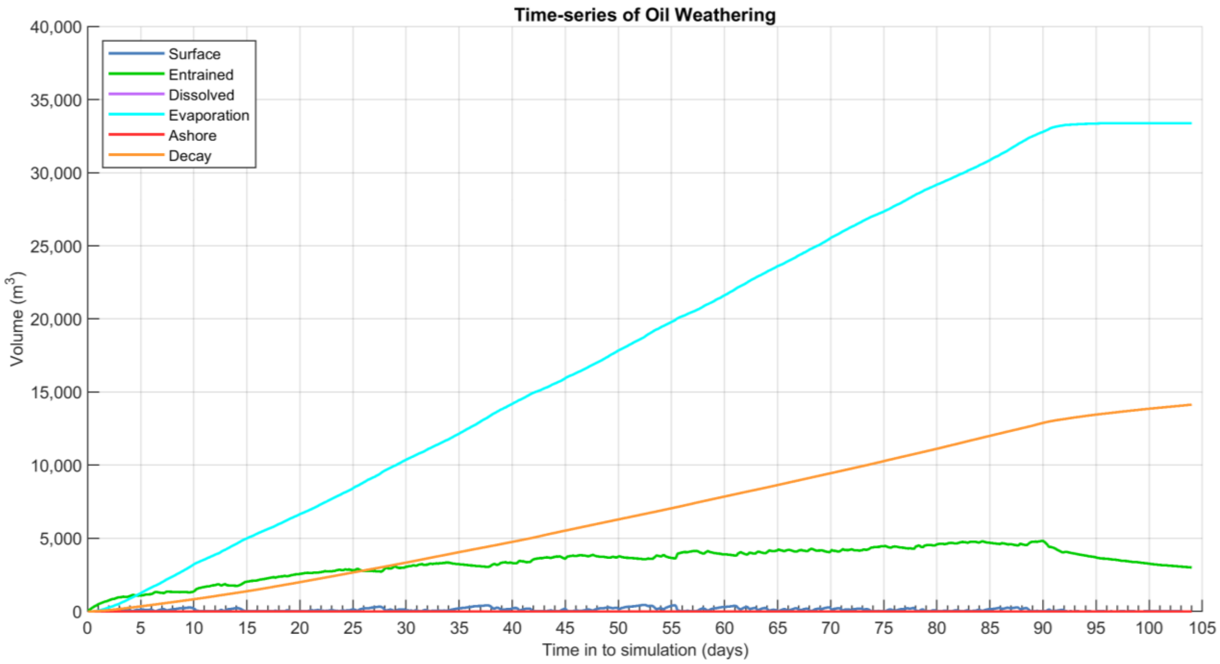


Figure 11.14 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 10 g/m² following a LOWC at GER FL2.

11.2.2 Deterministic Case: Largest volume of oil ashore

The deterministic simulation that resulted in the largest volume of oil ashore was identified as run number 40, during the summer season.

Figure 11.15 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.16 displays the time series of the volume of oil accumulating on shorelines at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.17 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.9 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.9 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest volume of oil ashore following a subsea LOWC at GER FL2.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	277	14	3
Entrained (m^3)	4,975	89	3,112
Dissolved (m^3)	7	69	0
Evaporation (m^3)	32,924	104	32,924
Decay (m^3)	14,469	104	14,469
Ashore (m^3)	23.2	94	19

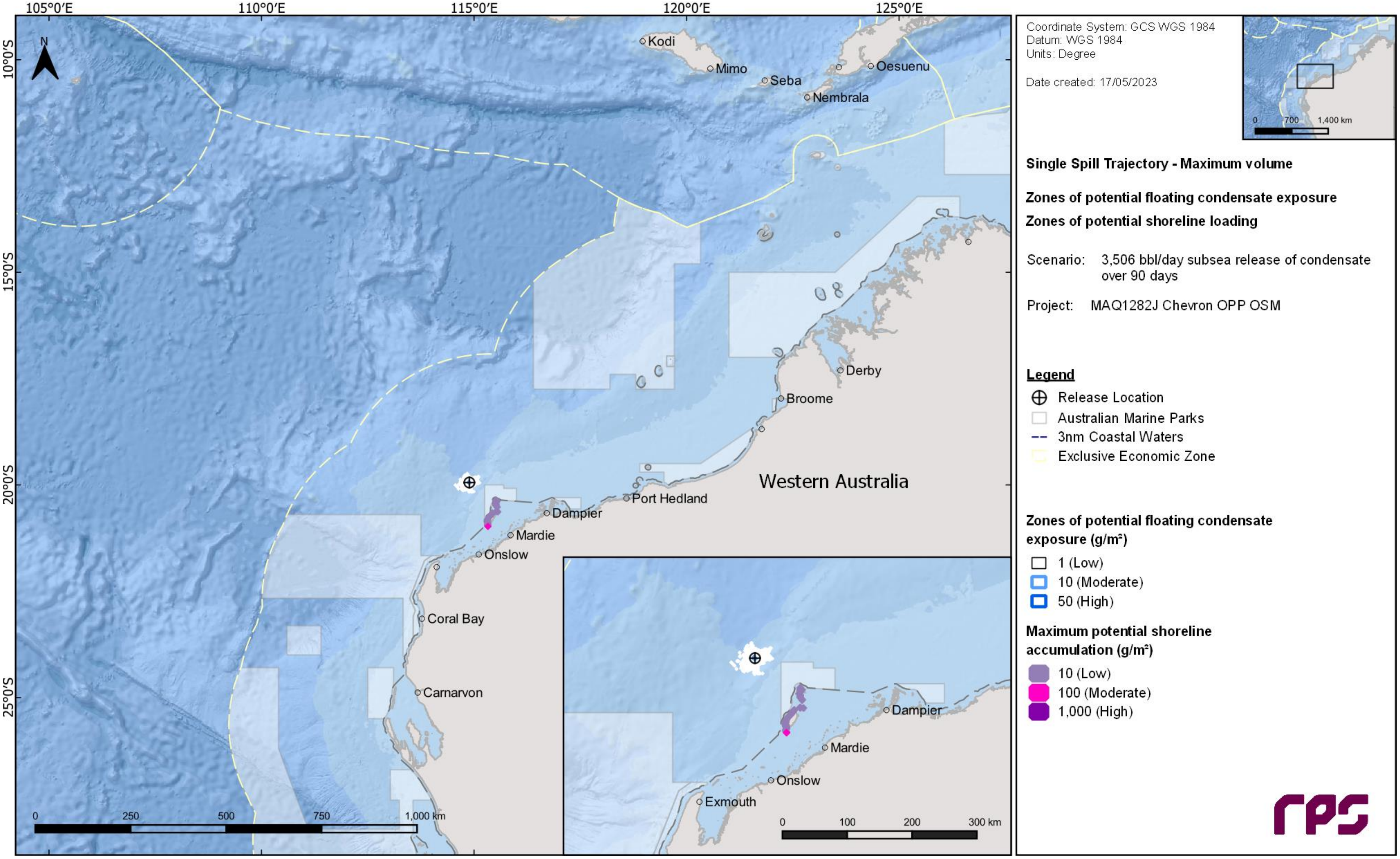


Figure 11.15 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the largest volume of oil ashore following a LOWC at GER FL2.

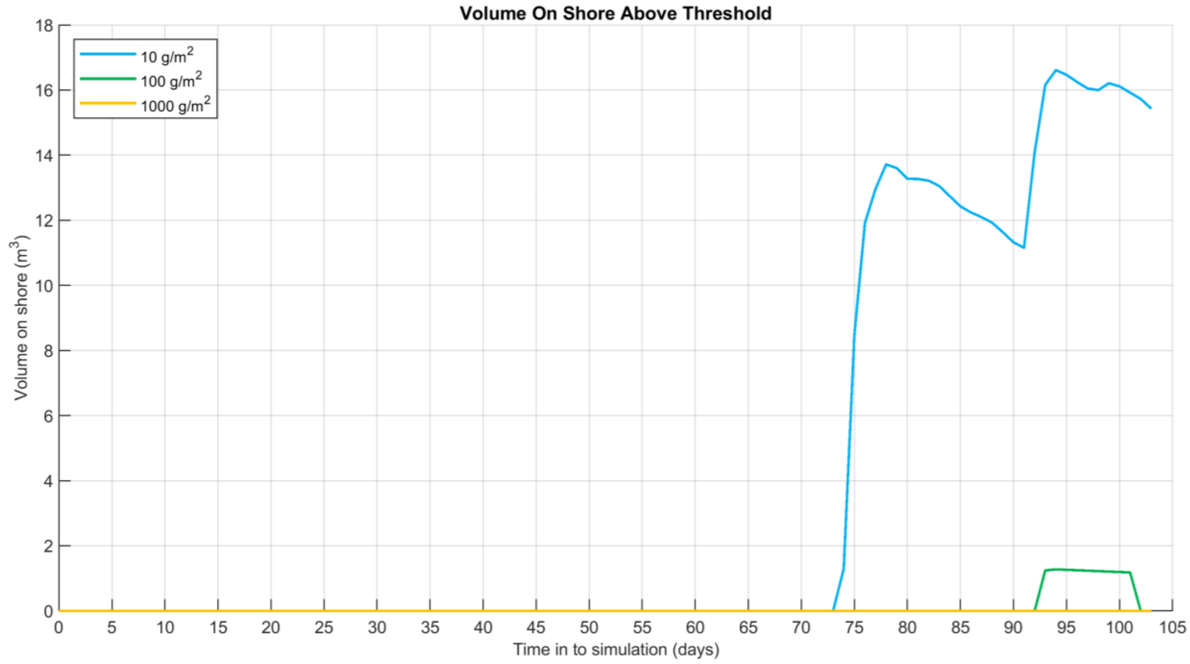


Figure 11.16 Time series of the volume of oil ashore at each threshold for the simulation with the largest volume ashore following a LOWC at GER FL2.

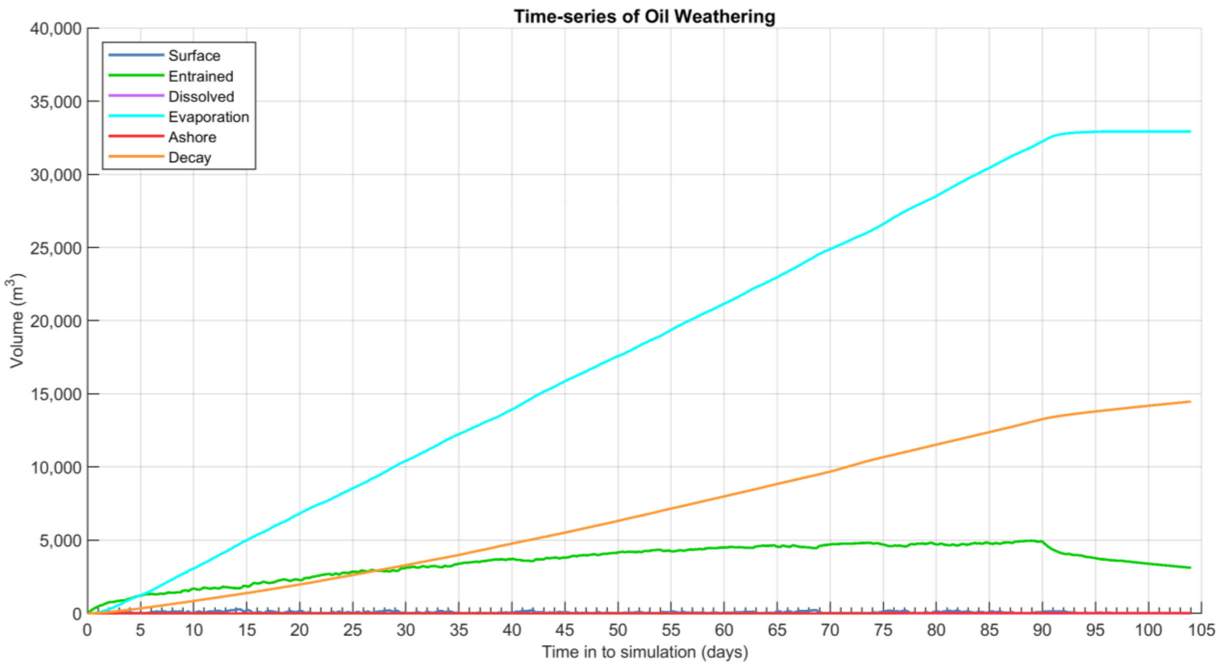


Figure 11.17 Predicted weathering and fates for the simulation with the largest volume of oil ashore following a LOWC at GER FL2.

11.2.3 Deterministic Case: Longest length of shoreline with accumulation above 100 g/m^2

The deterministic simulation that resulted in the longest length of shoreline with accumulation above 100 g/m^2 (moderate threshold) was identified as run number 51 during the summer period.

Figure 11.15 presents the extent of the predicted floating oil exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.16 displays the time series of the length of shoreline with accumulation above the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.17 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.9 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.10 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a subsea LOWC at GER FL2.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	227	55	1
Entrained (m^3)	4,738	89	3,015
Dissolved (m^3)	7	74	0
Evaporation (m^3)	33,548	104	33,548
Decay (m^3)	13,938	104	13,938
Ashore (m^3)	22	82	21

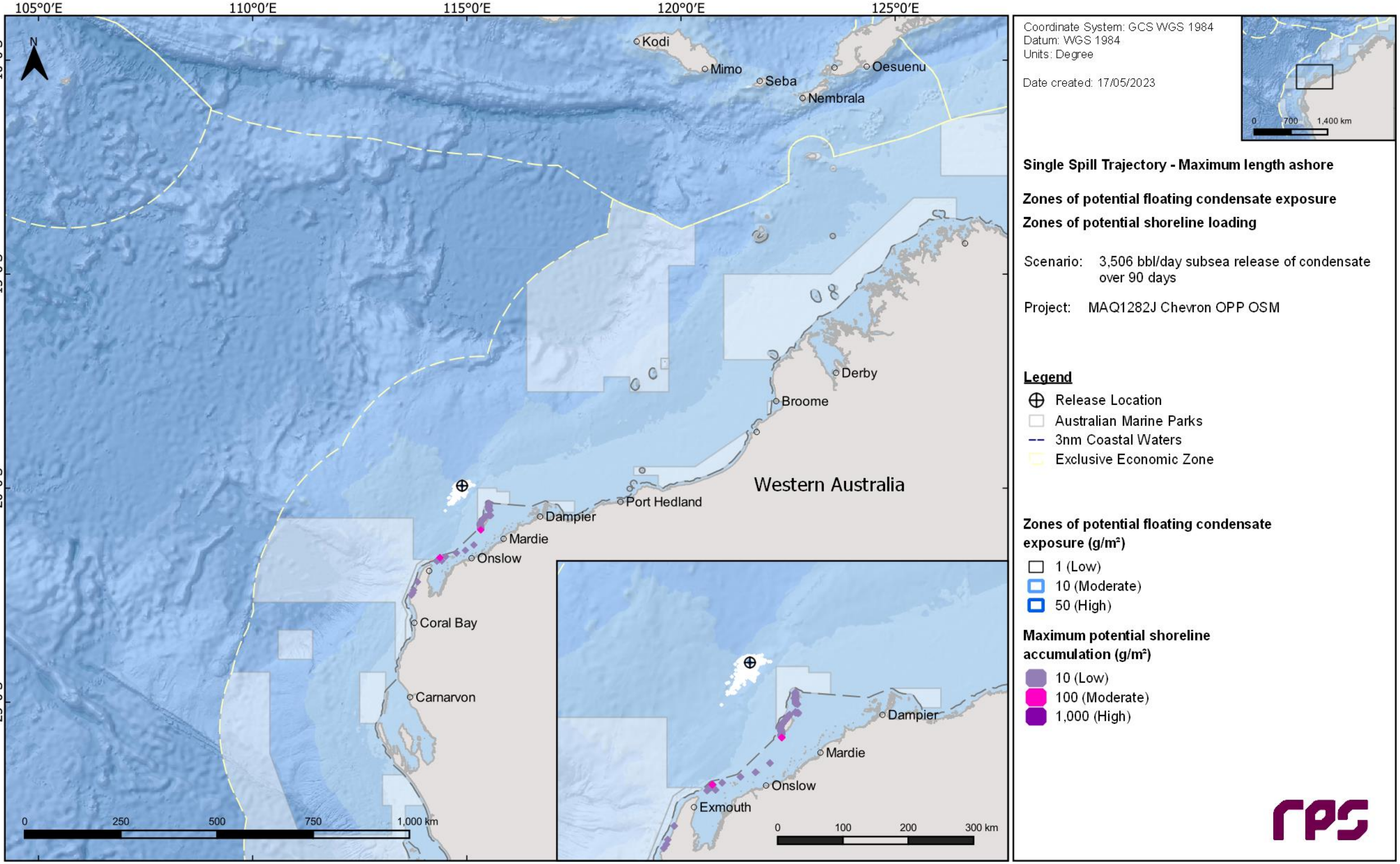


Figure 11.18 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a LOWC at GER FL2.

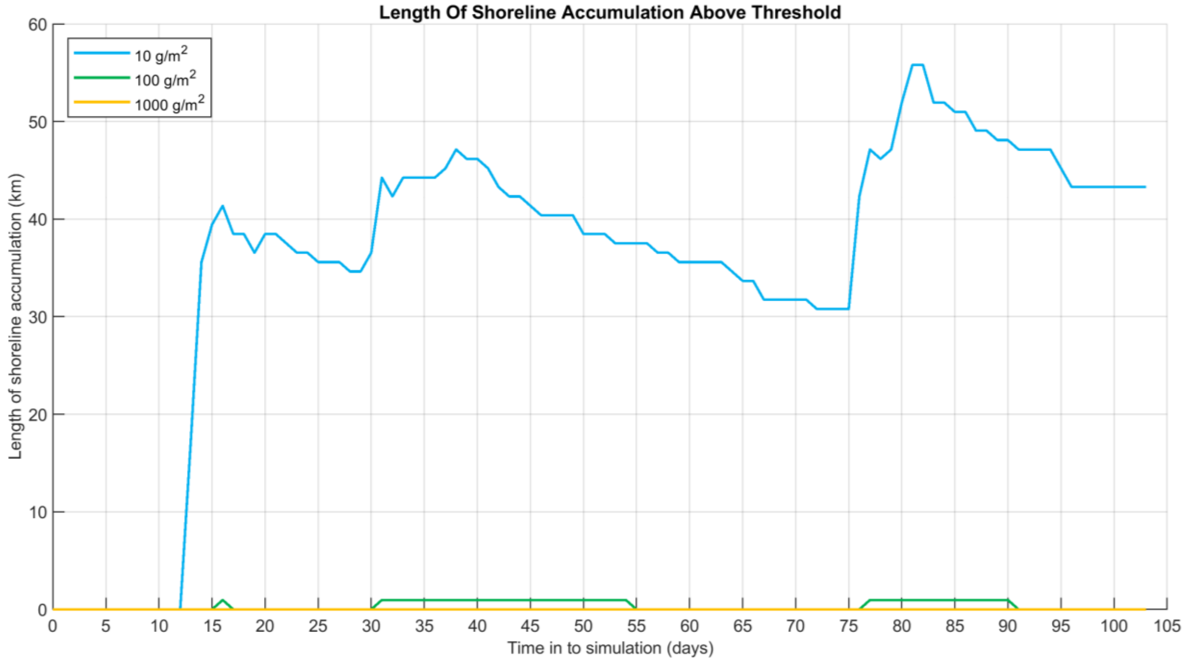


Figure 11.19 Time series of the length of shoreline at each threshold for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a LOWC at GER FL2.

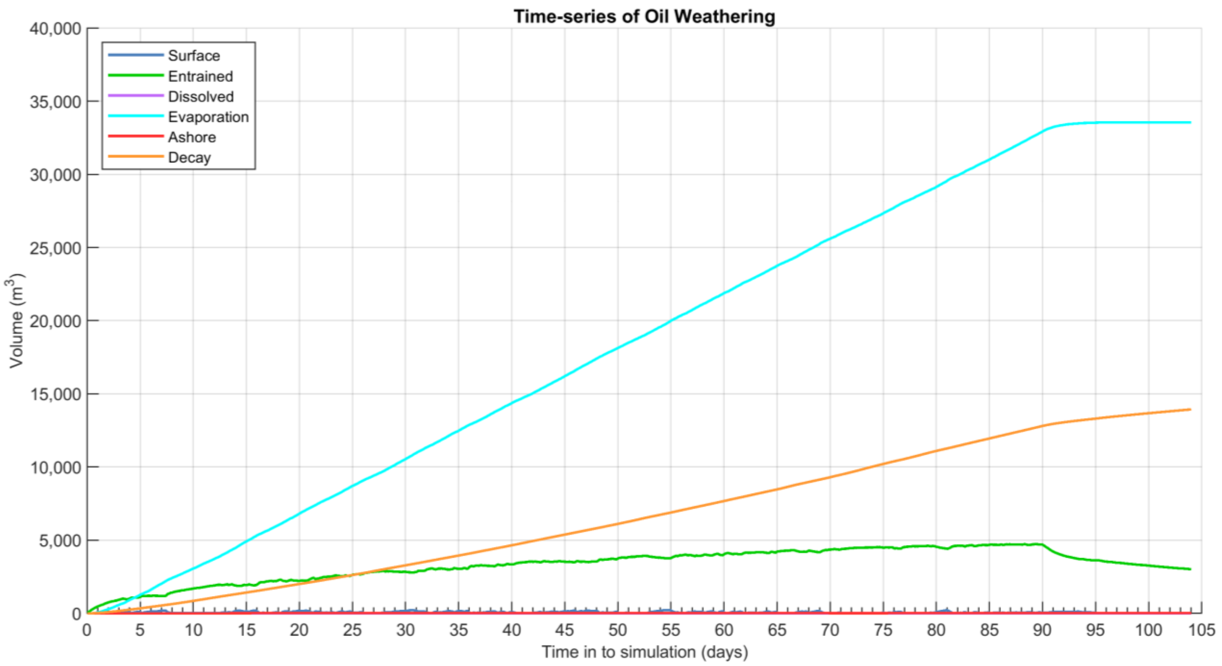


Figure 11.20 Predicted weathering and fates for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a LOWC at GER FL2.

11.2.4 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (low threshold) was identified as run number 15 during the summer period.

Figure 11.21 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.22 displays the time series of the area of entrained hydrocarbons at the low (≥10 ppb) and high (≥100 ppb) thresholds over the 104-day simulation.

Figure 11.23 presents the fates and weathering for the corresponding single spill trajectory and Table 11.11 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.11 Summary of the peak volumes and times of occurrence for each oil phase and the volumes at day 104, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at GER FL2.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	216	54	3
Entrained (m^3)	4,869	89	3,072
Dissolved (m^3)	7	54	0
Evaporation (m^3)	33,018	103	33,018
Decay (m^3)	14,419	104	14,419
Ashore (m^3)	18	80	16

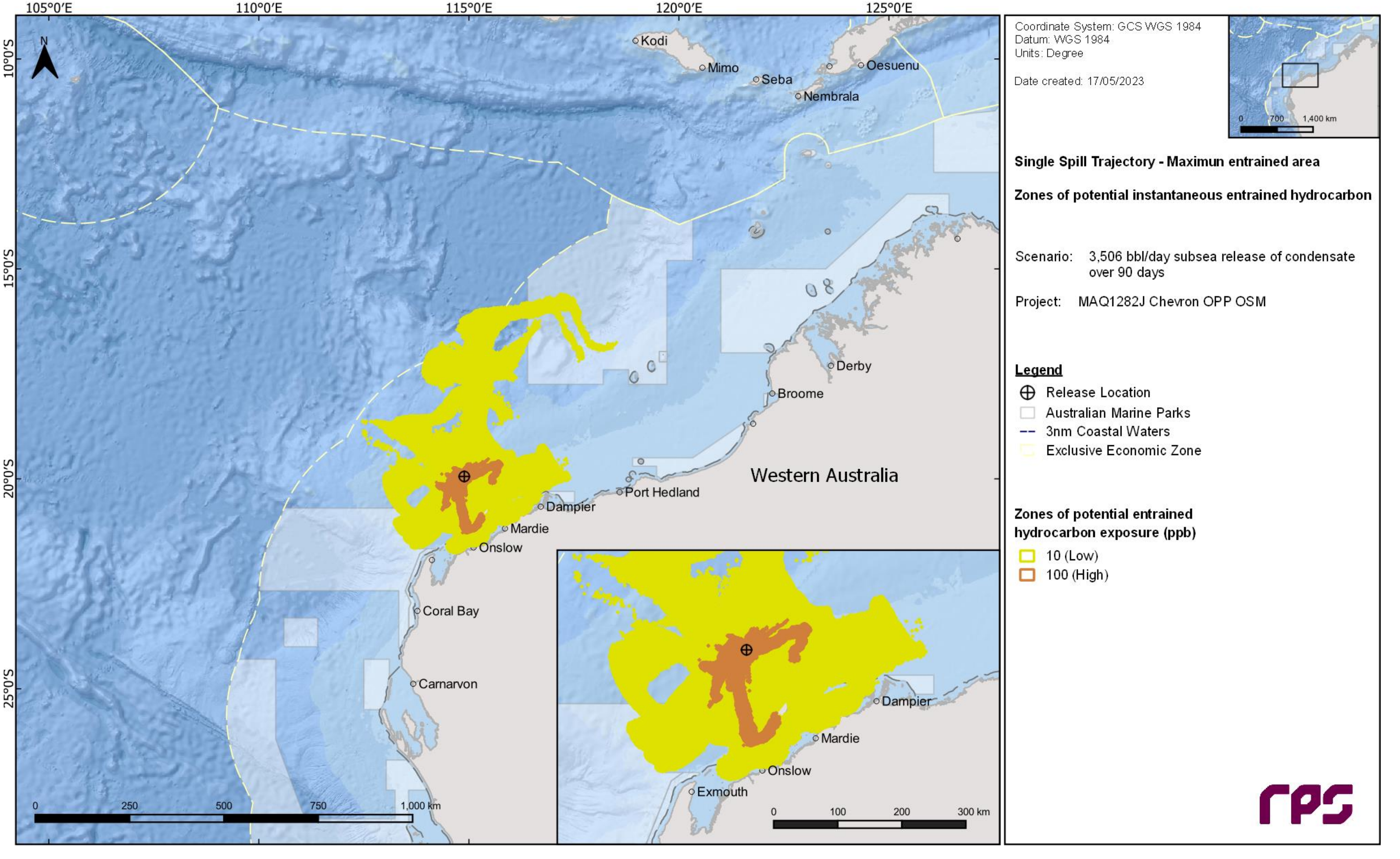


Figure 11.21 Zones of potential entrained hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at GER FL2.

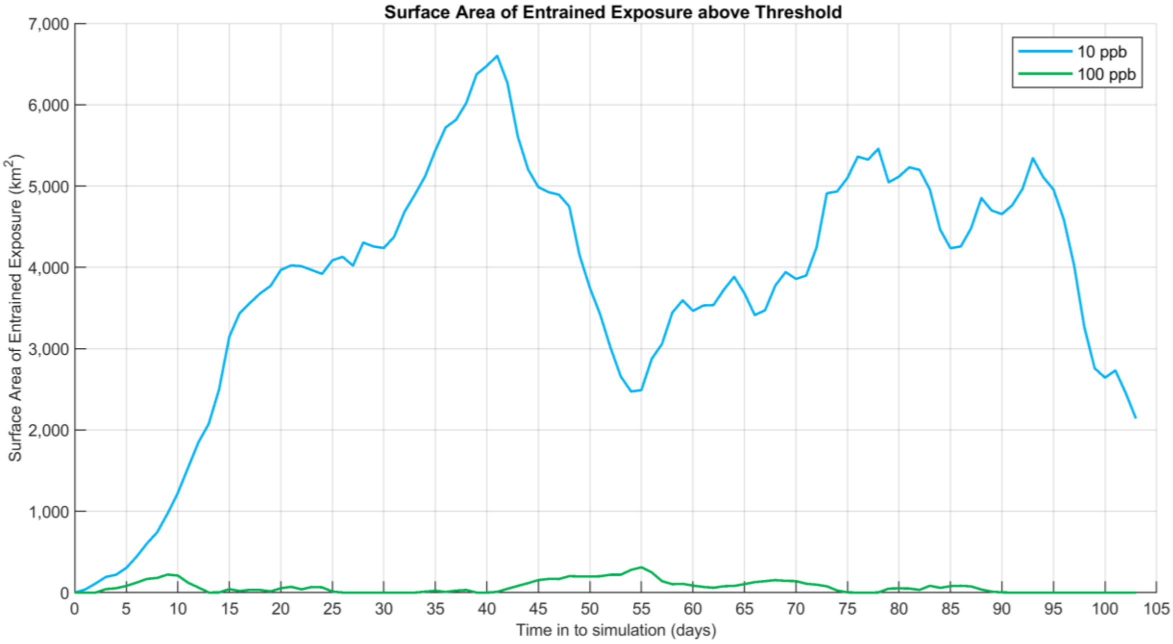


Figure 11.22 Time series of the area of entrained hydrocarbons for each threshold, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at GER FL2.

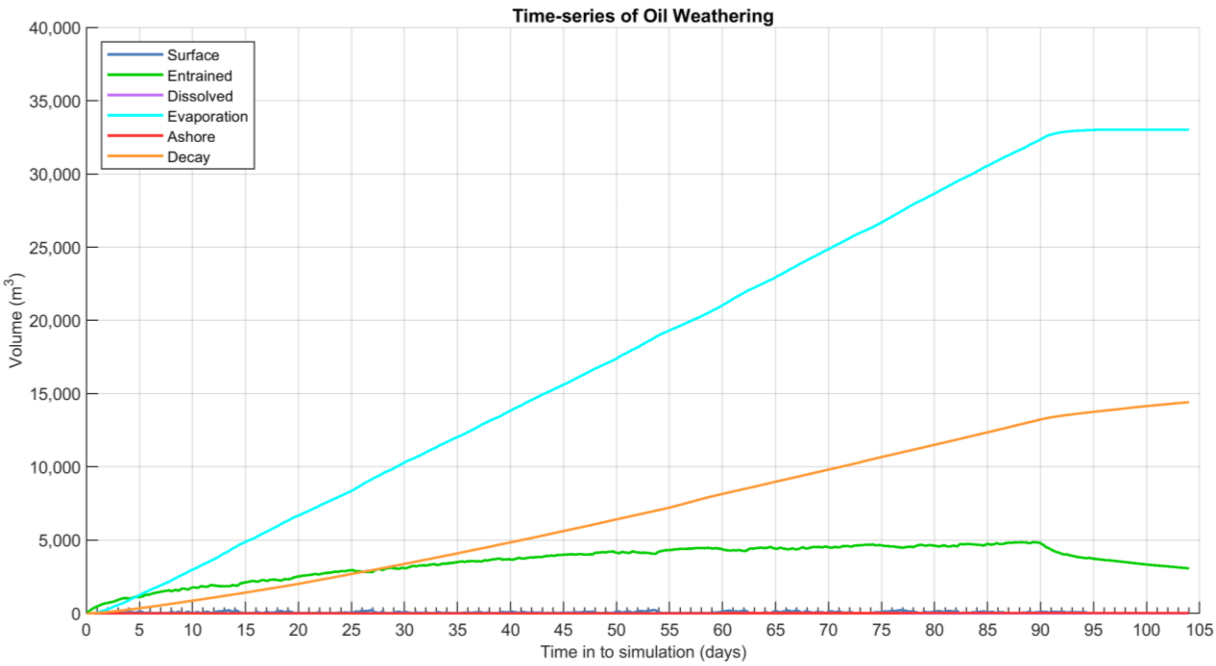


Figure 11.23 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at GER FL2.

12 REFERENCES

American Society for Testing and Materials (ASTM) 2013, 'F2067-13 Standard Practice for Development and Use of Oil-Spill Trajectory Models', ASTM International, West Conshohocken (PA).

Andersen, OB 1995, 'Global ocean tides from ERS 1 and TOPEX/POSEIDON altimetry', *Journal of Geophysical Research: Oceans*, vol. 100, no. C12, pp. 25249–25259.

Anderson, JW, Neff, JM, Cox BA, Tatem HE & Hightower GM 1974, 'Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish', *Marine Biology*, vol. 27, no. 1, pp. 75–88.

Anderson, JW, Riley, R, Kiesser, S & Gurtisen, J 1987, 'Toxicity of dispersed and undispersed Prudhoe Bay crude oil fractions to shrimp and fish', Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 235–240.

Applied Science Associates (ASA) 2011, OILMAP-DEEP: Blowout Plume Model Technical Manual, Applied Science Associates Inc, South Kingstown, USA.

Asia-Pacific ASA 2010, 'Montara well release monitoring study S7.2. Oil fate and effects assessment: modelling of chemical dispersant operation', Prepared for PTTEP Australasia.

Australian Maritime Safety Authority (AMSA) 2014, 'Identification of oil on water: Aerial observations and identification guide', viewed 4 June 2020, https://www.amsa.gov.au/sites/default/files/2014-01-mp-amsa22-identification-oil-on-water.pdf

Australian Maritime Safety Authority (AMSA) 2015, 'Australian Maritime Safety Authority Technical Guideline for the Preparation of Marine Pollution Contingency Plans for Marine and Coastal Facilities Australian Maritime Safety Authority', viewed 20 June 2017, https://www.amsa.gov.au/forms-and-publications/Publications/AMSA413_Contingency_Planning_Guidelines.pdf

Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, 'Australian and New Zealand Guidelines for Fresh and Marine Water', Australian & New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Becker, JJ, Sandwell, DT, Smith, WHF, Braud, J, Binder, B, Depner, J, Fabre, D, Factor, J, Ingalls, S, Kim, S-H, Ladner, R, Marks, K, Nelson, S, Pharaoh, A, Trimmer, R, Von Rosenberg, J, Wallace, G & Weatherall, P 2009, 'Global bathymetry and evaluation data at 30 arc seconds resolution: SRTM30_PLUS', *Marine Geodesy*, vol. 32, no. 4, pp. 355–371.

Belore, UC 2014, Subsea chemical dispersant research. Proceedings of the 37th AMOP Technical Seminar on Environmental Contamination and Response, Environmental Canada, Canmore, Alberta, Canada pp 618–650.

Bonn Agreement 2009, 'Bonn Agreement aerial operations handbook, 2009 - Publication of the Bonn Agreement', London, viewed 13 January 2015, http://www.bonnagreement.org/site/assets/files/3947/ba-aoh_revision_2_april_2012.pdf.

Brandvik, PJ, Johansen, O, Leirvik, F, Farooq, U & Daling PS 2013, 'Droplet Breakup in subsurface oil releases – Part 1: Experimental study of droplet breakup and effectiveness of dispersant injection', *Marine Pollution Bulletin*, vol. 73, no. 1, pp 319–326.

Brandvik, PJ, Johansen, O, Farooq, U, Angell, G & Leirvik F 2014, 'Sub-surface oil releases – Experimental study of droplet distributions and different dispersant injection techniques- version 2', A scaled experimental approach using the SINTEF Tower basin. SINTEF report no: A25122. Trondheim Norway 2014. ISBN: 9788214057393

Carls, MG, Holland, L, Larsen, M, Collier, TK, Scholz, NL & Incardona, JP 2008, 'Fish embryos are damaged by dissolved PAHs, not oil particles', *Aquatic toxicology*, 88(2), pp.121–127.

Chassignet, EP, Hurlburt, HE, Smedstad, OM, Halliwell, GR, Hogan, PJ, Wallcraft, AJ, Baraille, R & Bleck, R 2007, 'The HYCOM (hybrid coordinate ocean model) data assimilative system', *Journal of Marine Systems*, vol. 65, no. 1, pp. 60–83.

Chassignet, E, Hurlburt, H, Metzger, E, Smedstad, O, Cummings, J & Halliwell, G 2009, 'U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)', *Oceanography*, vol. 22, no. 2, pp. 64–75.

Condie, SA., & Andrewartha, JR 2008, 'Circulation and connectivity on the Australian Northwest Shelf', *Continental Shelf Research*, 28, 1724–1739.

Davies, AM 1977a, 'The numerical solutions of the three-dimensional hydrodynamic equations using a B-spline representation of the vertical current profile', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 1–25.

Davies, AM 1977b, 'Three-dimensional model with depth-varying eddy viscosity', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 27–48.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2007, 'Characterisation of the marine environment in the north marine region', Marine Division, Department of the environment, water heritage and the arts.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2008, 'The North-West Marine Bioregional Plan - Bioregional Profile', Retrieved February 12, 2013, from Australian Government Department of Environment, Water, Heritage and the Arts: http://www.environment.gov.au/coasts/mbp/publications/north-west/pubs/bioregional-profile.pdf

French, D, Reed, M, Jayko, K., Feng, S, Rines, H & Pavignano, S 1996, 'The CERCLA Type A Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME), Technical Documentation, Vol. I - Model Description', Office of Environmental Policy and Compliance, U.S. Department of the Interior. Washington, D.C.: Contract No. 14-0001-91-C-11.

French, D, Schuttenberg, H & Isaji, T 1999, 'Probabilities of oil exceeding thresholds of concern: examples from an evaluation for Florida Power and Light', Proceedings of the 22nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Alberta, pp. 243–270.

French-McCay, DP 2002, 'Development and application of an oil toxicity and exposure model, OilToxEx', *Environmental Toxicology and Chemistry*, vol. 21, no. 10, pp. 2080–2094.

French-McCay, DP 2003, 'Development and application of damage assessment modelling: example assessment for the North Cape oil spill', *Marine Pollution Bulletin*, vol. 47, no. 9, pp. 9–12.

French-McCay, DP 2004, 'Spill impact modelling: development and validation', *Environmental Toxicology and Chemistry*, vol. 23, no.10, pp. 2441–2456.

French-McCay, DP 2009, 'State-of-the-art and research needs for oil spill impact assessment modelling', Proceedings of the 32nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 601–653.

French-McCay, D, Rowe, JJ, Whittier, N, Sankaranarayanan, S, & Etkin, DS 2004, 'Estimate of potential impacts and natural resource damages of oil', *Journal of Hazardous Materials*, vol. 107, no. 1, pp. 11–25.

French-McCay, D, Whittier, N, Dalton, C, Rowe, J, Sankaranarayanan, S & Aurand, D 2005a, 'Modeling the fates of hypothetical oil spills in Delaware, Florida, Texas, California, and Alaska waters, varying

response options including use of dispersants', Proceedings of the International Oil Spill Conference 2005, American Petroleum Institute, Washington DC, paper 399.

French-McCay, D, Whittier, N, Rowe, J, Sankaranarayanan, S, Kim, H-S & Aurand, D 2005b, 'Use of probabilistic trajectory and impact modeling to assess consequences of oil spills with various response strategies,' Proceedings of the 28th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 253–271.

French-McCay, D, Reich, D, Rowe, J, Schroeder, M & Graham, E 2011, 'Oil spill modeling input to the offshore environmental cost model (OECM) for US-BOEMRE's spill risk and costs evaluations', Proceedings of the 34th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Reich, D, Michel, J, Etkin, DS, Symons, L, Helton, D, & Wagner J 2012, 'Oil spill consequence analysis of potentially-polluting shipwrecks', Proceedings of the 35th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Jayko, K, Li, Z, Horn, M, Kim, Y, Isaji, T, Crowley, D, Spaulding, M, Decker, L, Turner, C, Zamorski, S, Fontenault, J, Schmmkler, R & Rowe, J 2015, 'Technical Reports for Deepwater Horizon Water Column Injury Assessment: WC_TR.14: Modeling Oil Fate and Exposure Concentrations in the Deepwater Plume and Rising Oil Resulting from the Deepwater Horizon Oil Spill', RPS ASA, South Kingston, Rhode Island.

Gordon, R 1982, 'Wind driven circulation in Narragansett Bay' PhD thesis, Department of Ocean Engineering, University of Rhode Island.

Grant, DL, Clarke, PJ & Allaway, WG 1993, 'The response of grey mangrove (*Avicennia marina* (Forsk.) Vierh) seedlings to spills of crude oil,' *The Journal of Experimental Marine Biological Ecology*, vol. 171, no. 2, pp. 273–295.

Isaji, T & Spaulding, M 1984, 'A model of the tidally induced residual circulation in the Gulf of Maine and Georges Bank', *Journal of Physical Oceanography*, vol. 14, no. 6, pp. 1119–1126.

Isaji, T, Howlett, E, Dalton C, & Anderson, E 2001, 'Stepwise-continuous-variable-rectangular grid hydrodynamics model', Proceedings of the 24th Arctic and Marine Oil spill Program (AMOP) Technical Seminar (including 18th TSOCS and 3rd PHYTO), Environment Canada, Edmonton, pp. 597–610.

Koops, W, Jak, RG & van der Veen, DPC 2004, 'Use of dispersants in oil spill response to minimise environmental damage to birds and aquatic organisms', Proceedings of the Interspill 2004: Conference and Exhibition on Oil Spill Technology, Trondheim, presentation 429.

Kostianoy, AG, Ginzburg, AI, Lebedev, SA, Frankignoulle, M & Delille, B 2003, 'Fronts and mesoscale variability in the southern Indian Ocean as inferred from the TOPEX/POSEIDON and ERS-2 Altimetry data', *Oceanology*, vol. 43, no. 5, pp. 632–642.

Li, Z, Spaulding, M, French-McCay, D, Crowley, D & Payne JR 2017, 'Development of a unified oil droplet size distribution model with application to surface breaking waves and subsea blowout releases considering dispersant effects', *Marine Pollution Bulletin*, vol. 114, no. 1, pp 247–257.

Lin, Q & Mendelssohn, IA 1996, 'A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish and Salt Marshes', *Marine Pollution Bulletin*, vol. 32, no. 2, pp. 202–209.

Ludicone, D, Santoleri, R, Marullo, S & Gerosa, P 1998, 'Sea level variability and surface eddy statistics in the Mediterranean Sea from TOPEX/POSEIDON data', *Journal of Geophysical Research I*, vol. 103, no. C2, pp. 2995–3011.

Mackay, D, Puig, H & McCarty, LS 1992, 'An equation describing the time course and variability in uptake and toxicity of narcotic chemicals to fish', *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, p.941–951.

Malins DC & Hodgins HO 1981, ‘Petroleum and marine fishes: a review of uptake, disposition, and effects’, *Environmental Science & Technology*, vol. 15, no. 11, pp.1272–1280.

Matsumoto, K, Takanezawa, T & Ooe, M 2000, ‘Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan’, *Journal of Oceanography*, vol. 56, no.5, pp. 567–581.

McAuliffe, CD 1987, ‘Organism exposure to volatile/soluble hydrocarbons from crude oil spills – a field and laboratory comparison’, Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 275–288.

McCarty, LS 1986, ‘The relationship between aquatic toxicity QSARs and bioconcentration for some organic chemicals’, *Environmental Toxicology and Chemistry*, vol. 5, no. 12, pp. 1071–1080.

McCarty, LS & Mackay, D 1993, ‘Enhancing ecotoxicological modelling and assessment. Body residues and modes of toxic action’, *Environmental Science & Technology*, vol. 27, no. 9, pp. 1718–1728.

McCarty, LS, Dixon, DG, MacKay, D, Smith, AD & Ozburn, GW 1992a, ‘Residue-based interpretation of toxicity and bioconcentration QSARs from aquatic bioassays: Neutral narcotic organics’, *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, pp.917–930.

McCarty, LP, Flannagan, DC, Randall, SA & Johnson, KA 1992b, ‘Acute toxicity in rats of chlorinated hydrocarbons given via the intratracheal route’, *Human & Experimental Toxicology*, vol. 11, no. 3, pp.173–117.

McGrath, JA, & Di Toro, DM 2009, ‘Validation of the target lipid model for toxicity assessment of residual petroleum constituents: monocyclic and polycyclic aromatic hydrocarbons’, *Environmental Toxicology and Chemistry*, vol. 28, no. 6, pp. 1130–1148.

National Oceanic and Atmospheric Administration (NOAA) 2013, ‘Screening level risk assessment package Gulf state’, Office of National Marine Sanctuaries & Office of Response and Restoration, Washington DC.x

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2018, ‘At a glance: Oil spill modelling’, viewed 15 November 2018, https://www.nopsema.gov.au/assets/Publications/A626200.pdf

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2019, ‘NOPSEMA Bulletin #1: Oil spill modelling’, viewed April 2019, https://www.nopsema.gov.au/assets/Bulletins/A652993.pdf

National Research Council (NRC) 2003, ‘Oil in the sea III: Inputs, fates and effects’, The National Academic Press, Washington D.C.

Neff JM, Anderson JW 1981, ‘Response of marine animals to petroleum and specific petroleum hydrocarbons’ United States Department of Energy, United States.

Nirmalakhandan N & Speece RE 1998, ‘Quantitative techniques for predicting the behaviour of chemicals in the ecosystem’, *Environmental Science & Technology*, vol. 22, no. 6, pp. 606–615.

Nordtug, T, Olsen, AJ, Altin, D, Overrein, I, Storøy, W, Hansen, BH & De Laender, F 2011, ‘Oil droplets do not affect assimilation and survival probability of first feeding larvae of North-East Arctic cod’, *Science of the Total Environment*, 412, pp.148–153.

Oil Spill Solutions 2015, ‘Evaluation - The Theory of Oil Slick Appearances’, viewed 6 January 2015, http://www.oilspillsolutions.org/evaluation.htm

Owen, A 1980, ‘A three-dimensional model of the Bristol Channel’, *Journal of Physical Oceanography*, vol. 10, no. 8, pp. 1290–1302.

Qiu, B & Chen, S 2010, 'Eddy-mean flow interaction in the decadally modulating Kuroshio Extension system', *Deep-Sea Research II*, vol. 57, no. 13, pp. 1098–1110.

Redman AD 2015, 'Role of entrained droplet oil on the bioavailability of petroleum substances in aqueous exposures', *Marine Pollution Bulletin*, vol. 97, no. (1–2), pp. 342–348.

Saha, S, Moorthi, S, Pan, H-L, Wu, X, Wang, J & Nadiga, S 2010, 'The NCEP Climate Forecast System Reanalysis', *Bulletin of the American Meteorological Society*, vol. 91, no. 8, pp. 1015–1057.

Scholten, MCTh, Kaag, NHBM, Dokkum, HP van, Jak, R.G., Schobben, HPM & Slob, W 1996, Toxische effecten van olie in het aquatische milieu, TNO report TNO-MEP – R96/230, Den Helder.

Spaulding, ML., Kolluru, VS, Anderson, E & Howlett, E 1994, 'Application of three-dimensional oil spill model (WOSM/OILMAP) to hindcast the Braer Spill', *Spill Science and Technology Bulletin*, vol. 1, no. 1, pp. 23–35.

Spaulding, MS, Mendelsohn, D, Crowley, D, Li, Z & Bird A, 2015. Technical Reports for Deepwater Horizon Water Column Injury Assessment- WC_TR.13: Application of OILMAP DEEP to the Deepwater Horizon Blowout. RPS APASA, 55 Village Square Drive, South Kingstown, RE 02879.

Suprayogi, B & Murray, F 1999, 'A field experiment of the physical and chemical effects of two oils on mangroves', *Environmental and Experimental Botany*, vol. 42, no. 3, pp. 221–229.

Swartz, RC, Schults, DW, Ozretich, RJ, Lamberson, JO, Cole FA, Ferraro SP, Dewitt TH & Redmond MS 1995, 'ΣPAH: A Model to predict the toxicity of polynuclear aromatic hydrocarbon mixtures in field-collected sediments', *Environmental Toxicology and Chemistry*, vol. 14, no. 11, pp. 1977–1187.

Verhaar, HJM, Van Leeuwen, CJ & Hermens, JLM 1992, 'Classifying environmental pollutants', *Chemosphere*, vol. 24, no. 4, pp. 471–491.

Verhaar, HJM, de Jongh, J & Hermens, JLM 1999, 'Modelling the bioconcentration of organic compounds by fish: A novel approach', *Environmental Science & Technology*, vol. 33, no. 22, pp. 4069–4072.

Yaremchuk, M & Tangdong, Q 2004, 'Seasonal variability of the large-scale currents near the coast of the Philippines', *Journal of Physical Oceanography*, vol. 34, no., 4, pp. 844–855.

Zigic, S, Zapata, M, Isaji, T, King, B, & Lemckert, C 2003, 'Modelling of Moreton Bay using an ocean/coastal circulation model', Proceedings of the 16th Australasian Coastal and Ocean Engineering Conference, the 9th Australasian Port and Harbour Conference and the Annual New Zealand Coastal Society Conference, Institution of Engineers Australia, Auckland, paper 170.

GREATER GORGON – THE CHRYSAOR AND DIONYSUS

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Prepared by:

RPS

Jeremie Bernard
Senior Coastal Engineer

Lakeside Corporate Space, Suite 425
Level 2, 34-38 Glenferrie Drive
Robina, QLD, 4226, Australia

T +61 7 5553 6900
E Jeremie.Bernard@rpsgroup.com

Prepared for:

CHEVRON AUSTRALIA PTY LTD

Mike Daly
HSE Specialist - Environment

Level 13, 250 St Georges Tce
Perth WA 6000 Australia

T +61 418 488 728
E mike.daly@chevron.com

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TERMS AND ABBREVIATIONS

°	Degrees
‘	Minutes
“	Seconds
µm	Micrometre (unit of length; 1 µm = 0.001 mm)
Actionable oil	Oil which is thick enough for the effective use of mitigation strategies
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute gravity. A measure of how heavy or light a petroleum liquid is compared to water.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m3)
bbl/d	Barrels per day
Bonn Agreement	An agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983, includes: Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
cP	Centipoise (unit of dynamic viscosity)
Decay	The process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions.
Dynamic viscosity	The dynamic viscosity of a fluid expresses its resistance to shearing flows, where adjacent layers move parallel to each other with different speeds.
Floating oil exposure	Contact by floating oil on the sea surface at concentrations equal to or exceeding defined threshold concentrations. The consequence will vary depending on the threshold and the receptors
g/m^2	Grams per square meter (unit of surface area density)
GODAE	Global Ocean Data Assimilation Experiment
HYCOM	Hybrid Coordinate Ocean Model. A data-assimilative, three-dimensional ocean model
HYDROMAP	Advanced ocean/coastal tidal model used to predict tidal water levels, current speed and current direction.
IAA	Impact Assessment Area
IBRA	Interim Biogeographic Regionalisation for Australia

IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
Shoreline contact	Arrival of oil at or near shorelines at on-water concentrations equal to or exceeding defined threshold concentrations. Shoreline contact is judged for floating oil arriving within a 2 km buffer zone from any shoreline as a conservative measure
SIMAP	Spill Impact Model Application Package. SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for surface or subsea releases
Single Oil spill modelling	Oil spill modelling involving a computer simulation of a single hypothetical oil spill event subject to a single sequence of wind, current and other sea conditions over time. Single oil spill modelling, also referred to as “deterministic modelling” provides a simulation of one possible outcome of a given spill scenario, subject to the metocean conditions that are imposed. Single oil spill modelling is commonly used to consider the fate and effects of ‘worst-case’ oil spill scenarios that are carefully selected in consideration of the nature and scale of the offshore petroleum activity and the local environment (NOPSEMA, 2017). Because the outcomes of a single oil spill simulation can only represent the outcome of that scenario under one sequence of metocean conditions, worst-case conditions are often identified from stochastic modelling. It is impossible to calculate the likelihood of any outcome from a single oil spill simulation. Single oil spill modelling is generally used for response planning, preparedness planning and for supporting oil spill response operations in the event of an actual spill

SRTM	Shuttle Radar Topography Mission
Stochastic oil spill modelling	Stochastic oil spill modelling is created by overlaying and statistically analysing the outcomes of many single oil-spill simulations of a defined spill scenario, where each simulation was subject to a different sequence of metocean conditions, selected objectively (typically by random selection) from a long sequence of historic conditions for the study area. Analysis of this larger set of simulations provides a more accurate indication of the environment that maybe affected (EMBA) and indicates which locations are more likely to be affected (as well as other statistics). Stochastic oil spill modelling avoids biases that affect single oil spill modelling (due to the reliance on only one possible sequence of conditions). However, when interpreting stochastic modelling, which is based on a wide range of potential conditions that might happen to occur, it is essential to understand that calculations will encompass a much larger area than could be affected in any single spill event, where a more limited set of conditions will occur. Consequently, it is misleading to imply that the region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) Stochastic modelling is generally used for risk assessment and preparedness planning by indicating locations that could be exposed and may require response or subsequent impact assessment
TOPEX/ Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed, quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Chrysaor and Dionysus (C&D) fields situated within the Northern Carnarvon Basin in Permit area WA-15-R northwest of Barrow Island off the north-west coast of Western Australia.

Chevron commissioned RPS to undertake an oil spill modelling to support environmental approvals. The study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 1,308 stb/day (207.9 m^3/day) subsea release of condensate over 90 days (totalling 117,720 stb or 18,715 m^3) from a loss of well control (LOWC).

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

Methodology

The modelling study was carried out in stages. Firstly, a ten-year current dataset (2010–2019) that includes the combined influence of large-scale ocean and nearshore tidal currents was developed. Secondly, the currents, local winds and detailed hydrocarbon characteristics were used as inputs in the three-dimensional oil spill model (SIMAP) to simulate the drift, spread, weathering and fate of the spilled oil.

As spills can occur during any set of wind and current conditions, modelling was conducted using a stochastic (or probabilistic) approach, which involved running 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Condensate Properties

Chrysaor condensate physical properties and boiling point distributions were provided by Chevron. The condensate has an API of 40.2, a density of 824 kg/m^3 (at 15ºC) and a low viscosity value of 5.6 cP. When exposed to the atmosphere at local temperatures, about 23.8% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 33.0% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~32.9%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 10.3% of the condensate is shown to be persist in the marine environment for longer period and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.5%), which is one indicator for a very low propensity to take up water to form water-in-oil emulsion. Soluble aromatic hydrocarbons contribute approximately 3.0% by mass of the whole oil (contained in the volatile fraction).

Key Findings

- The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 82.0 km west (summer) and 4.3 km northeast (transitional and winter), respectively. No exposure was predicted at the high (≥ 50 g/m^2) threshold.

- The Offshore Area IAA, Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater - Breeding BIAs, and the Continental Slope Demersal Fish Communities KEF, which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low threshold were 100% for all seasons for these receptors. Probabilities of moderate exposure for these receptors ranged between 89% (all receptors; summer) and 99% (all receptors; winter). Additionally, the Flatback Turtle - Internesting Buffer BIA was also predicted to be exposed at the low threshold during summer (95%), transitional (100%) and winter (97%), respectively. The minimum time before low exposure for the Flatback Turtle - Internesting Buffer BIA was 0.67 days during summer conditions. Furthermore, the probability of exposure at the low threshold for the Pilbara (offshore) IMCRA and Ancient coastline at 125 m depth contour (KEF) was 88%, 84% and 89% during summer, transitional and winter conditions and 31%, 27% and 41% summer, transitional and winter conditions, respectively. The corresponding minimum time before low exposure at the Pilbara (offshore) IMCRA and Ancient coastline at 125 m depth contour FEF was 0.88 days (summer) and 2.21 days (winter).

- The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 32%, while the minimum time before shoreline accumulation was 4.29 days and the maximum volume of oil ashore was 32.0 m^3.

- During summer conditions, condensate had accumulated on 56 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands and Ningaloo Coast World Heritage Area IAAs (22%). In comparison, during transitional and winter conditions, condensate had accumulated on 6 and 4 shoreline receptors, respectively. The greatest probabilities of shoreline accumulation occurred at Muiron Islands, Ningaloo Coast World Heritage Area and North Muiron Island, all 3% probability during transitional season and at Muiron Islands, Ningaloo Coast World Heritage Area and South Muiron Island, all 1% probability during winter.

- No dissolved hydrocarbon exposure was predicted for this scenario at or above the low reporting threshold (≥10 ppb) during any of the seasons modelled.

- In the 0-10 m depth layer, a total of 38, 12 and 11 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold. Excluding the Offshore, the probabilities for each season ranged between 1–80%, 1–82% and 1–87% under summer, transitional and winter conditions, respectively, with the maximum probabilities occurring at the Gascoyne IAA during all seasons. Furthermore, 46, 5 and 2 RSB receptors were predicted to be exposed to entrained hydrocarbons at the low threshold with maximum seasonal probabilities of 36%, 18% and 26% for Rankin Bank, during summer, transitional and winter, respectively.

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Chrysaor and Dionysus (C&D) fields situated within the Northern Carnarvon Basin in Permit area WA-15-R northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the C&D fields, Chevron commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 1,308 stb/day (207.9 m^3/day) subsea release of condensate over 90 days (totalling 117,720 stb or 18,715 m^3) from a loss of well control (LOWC).

The release location used for the oil spill assessment is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis Program (SIMAP). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, RPS warrants that this work meets and exceeds the American Society for Testing and Materials (ASTM) Standard F2067-13 "*Standard Practice for Development and Use of Oil Spill Models*".

Table 1.1 Coordinates of the Chrysaor–Dionysus release location.

Location	Latitude	Longitude	Depth (mLAT)
Chrysaor Well 5	20.23988º S	114.87716º E	800

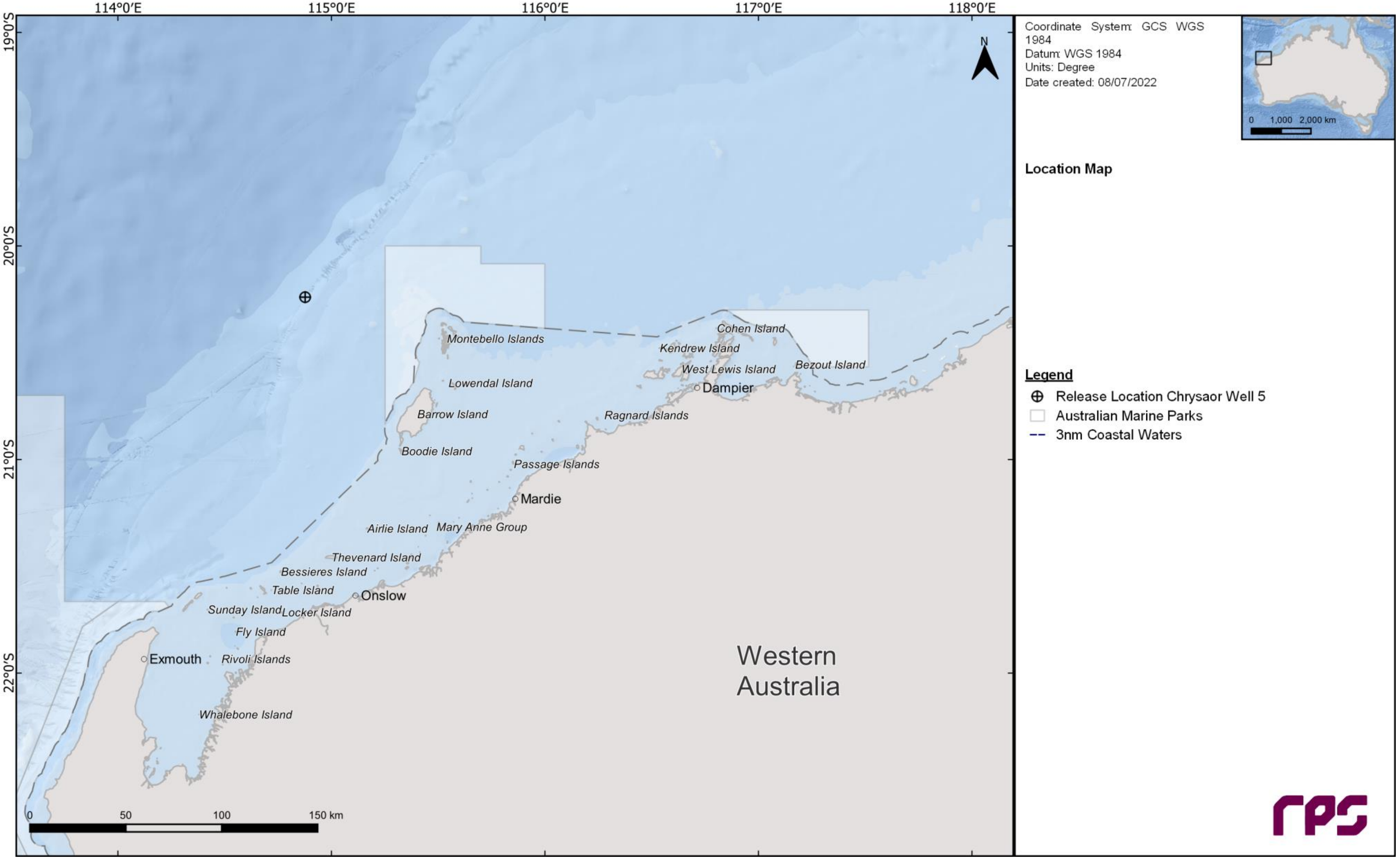


Figure 1.1 Chrysaor and Dionysus hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate ten years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. Run 100 simulations for each season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds; and

5. From the 300 simulations modelled, identify and present the “worst case” deterministic runs, which can be used to inform response planning based on the following criteria:
   a. Largest swept area of floating hydrocarbon above 10 g/m^2
   b. Largest swept area of floating hydrocarbon above 50 g/m^2
   c. Largest volume of oil ashore
   d. Longest length of shoreline accumulation above 100 g/m^2
   e. Largest area of entrained hydrocarbons above 100 ppb
   f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no floating hydrocarbons at or above 50 g/m^2 and no dissolved hydrocarbon exposure at or above 50 ppb, for any of the 300 simulations, the deterministic results are presented based on criteria a, c, d and e only.

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

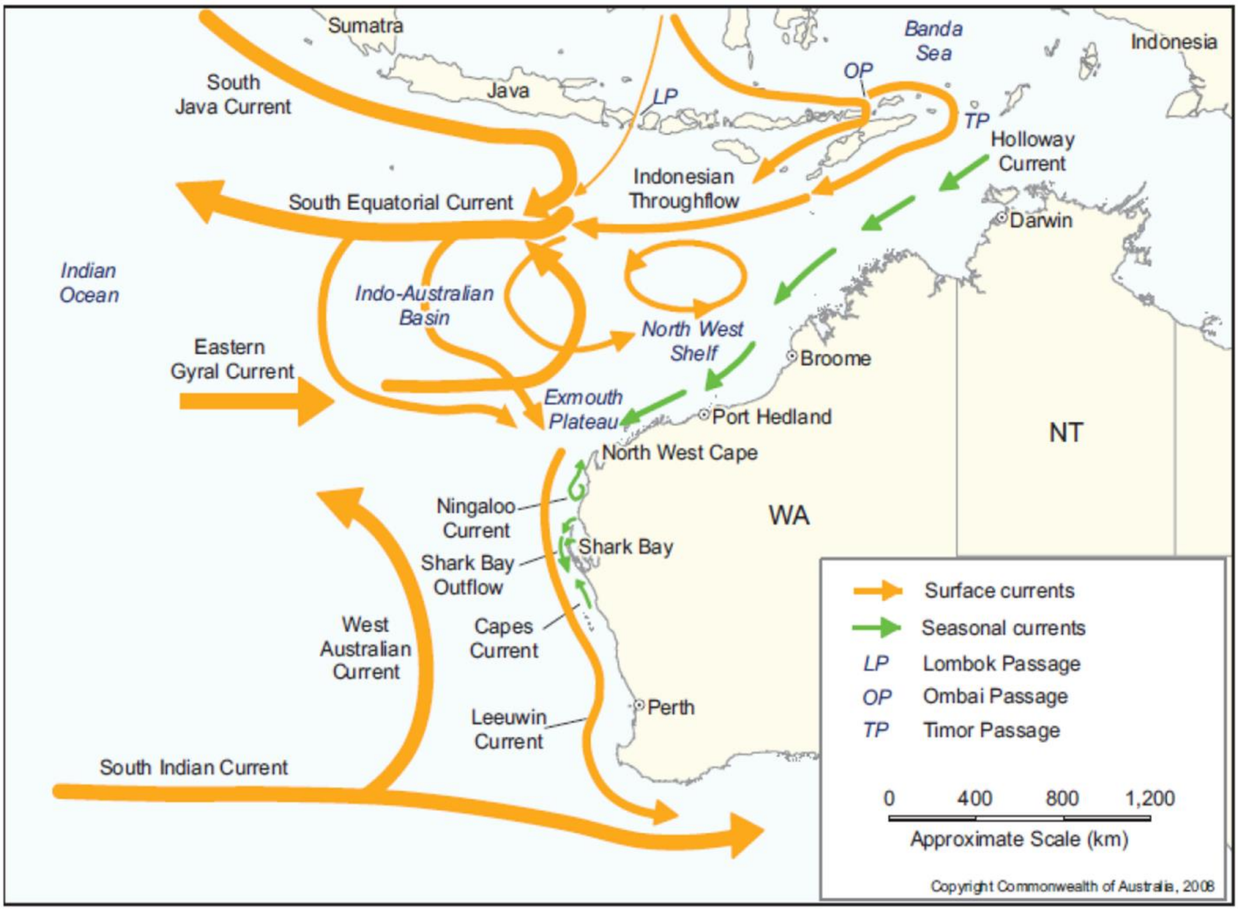


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

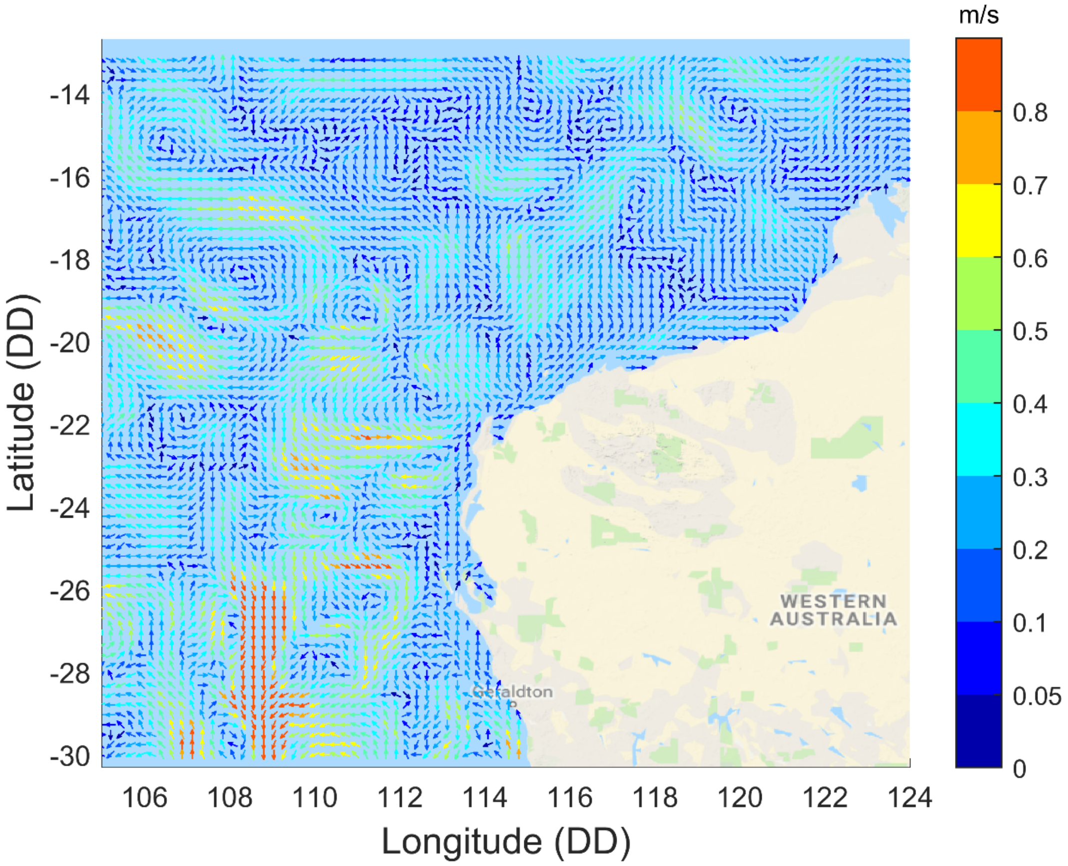


Figure 3.2 Typical ocean current circulation pattern during the summer months.

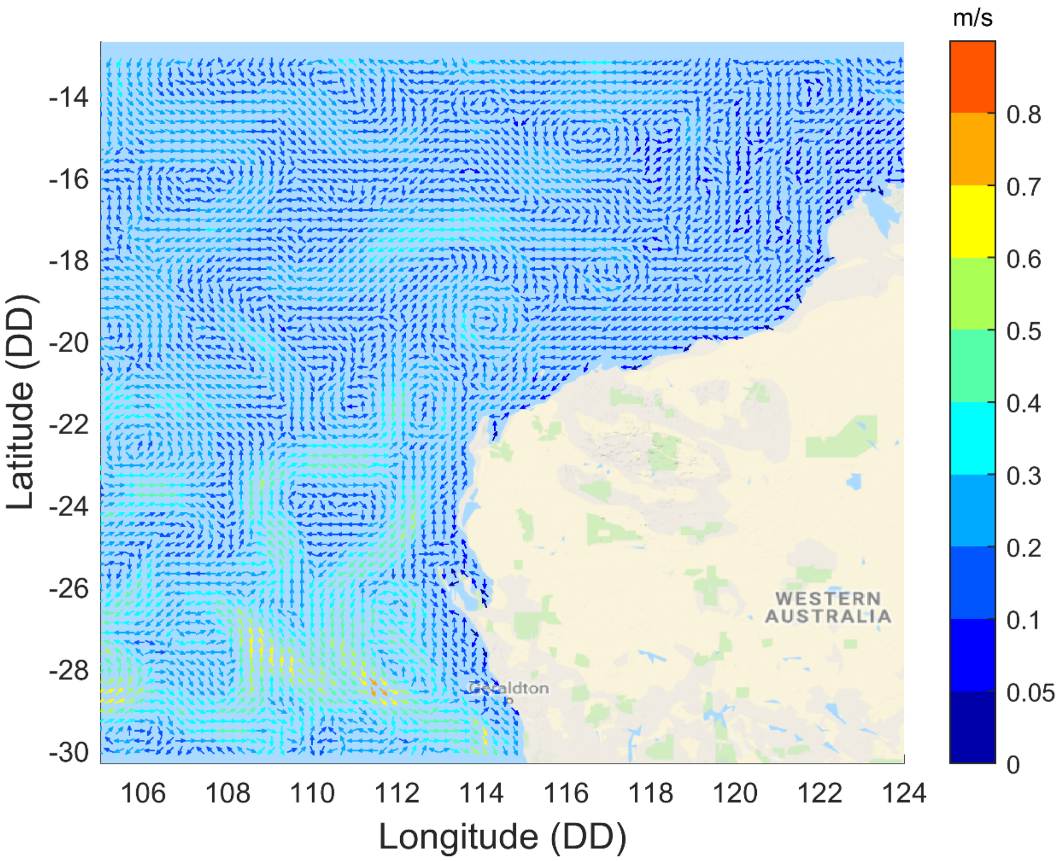


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grids were allocated in a step-wise fashion to resolve flows more accurately along the coastline, around islands and over regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

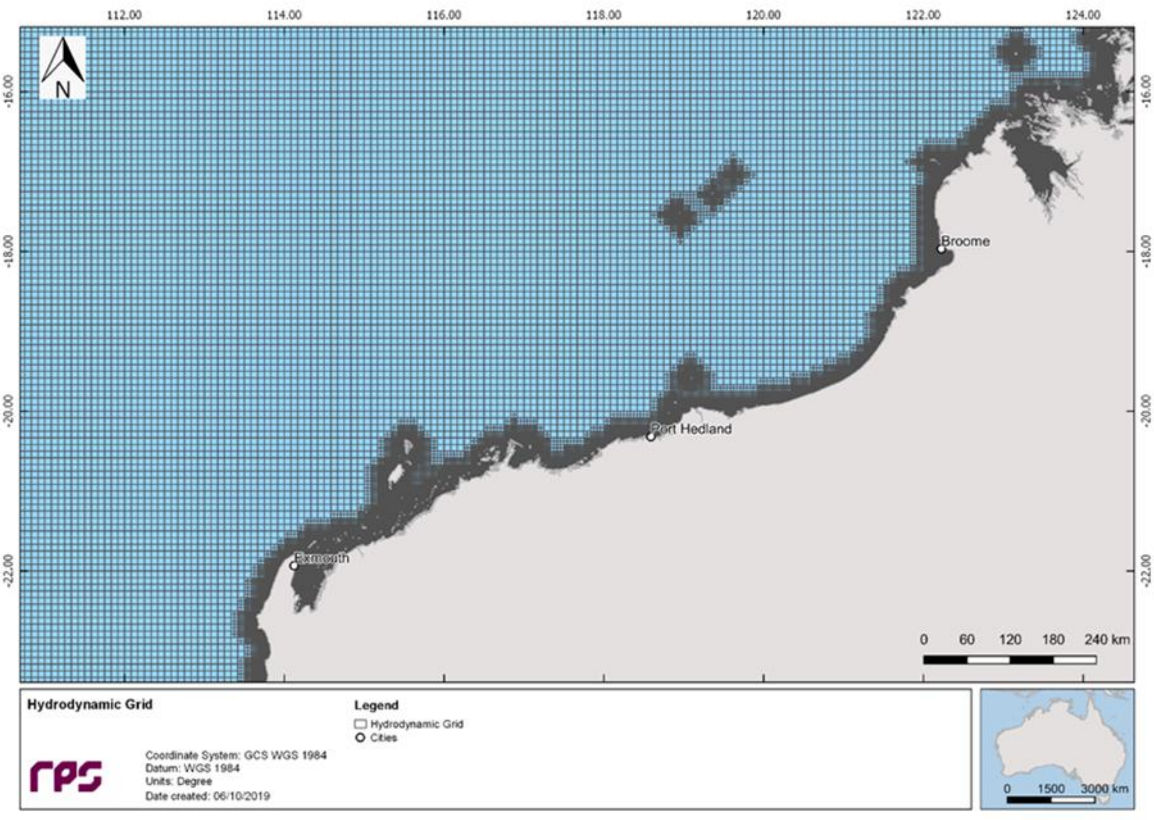


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

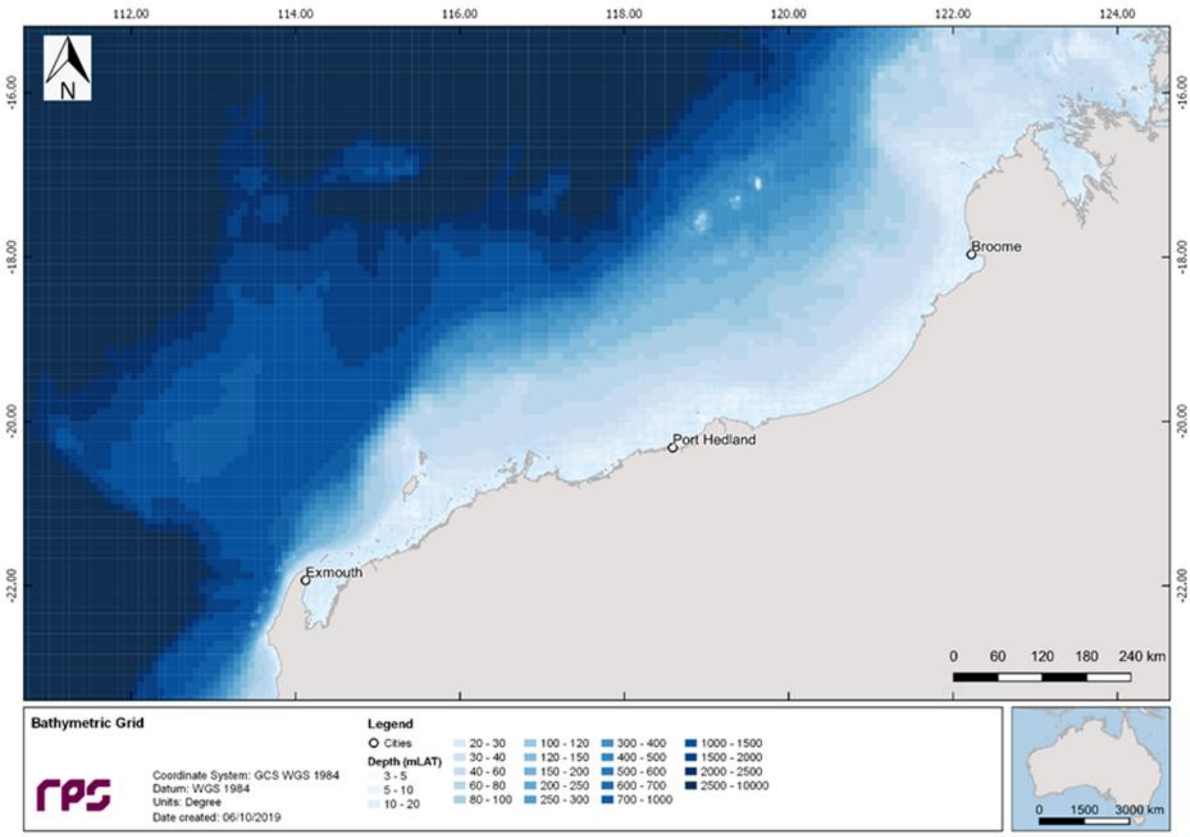


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.16 m/s (November) and 0.27 m/s (June). Additionally, the maximums ranged between 0.55 m/s (November) and 1.76 m/s (January). The general current directions were towards the southwest. Figure 3.6 and Figure 3.7 present the monthly and total current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.21	1.76	North and Southwest
	February	0.19	1.08	Variable
	March	0.21	1.73	Southwest
Transitional	April	0.22	1.02	Southwest
Winter	May	0.24	0.78	Southwest
	June	0.27	0.81	Southwest
	July	0.20	0.90	Southwest
Transitional	August	0.18	0.60	Southwest
Summer	September	0.19	0.93	Northeast and Southwest
	October	0.20	0.75	Northeast and Southwest
	November	0.16	0.55	Southwest
	December	0.21	0.74	Southwest
Minimum		**0.16**	**0.55**	
Maximum		**0.27**	**1.76**	

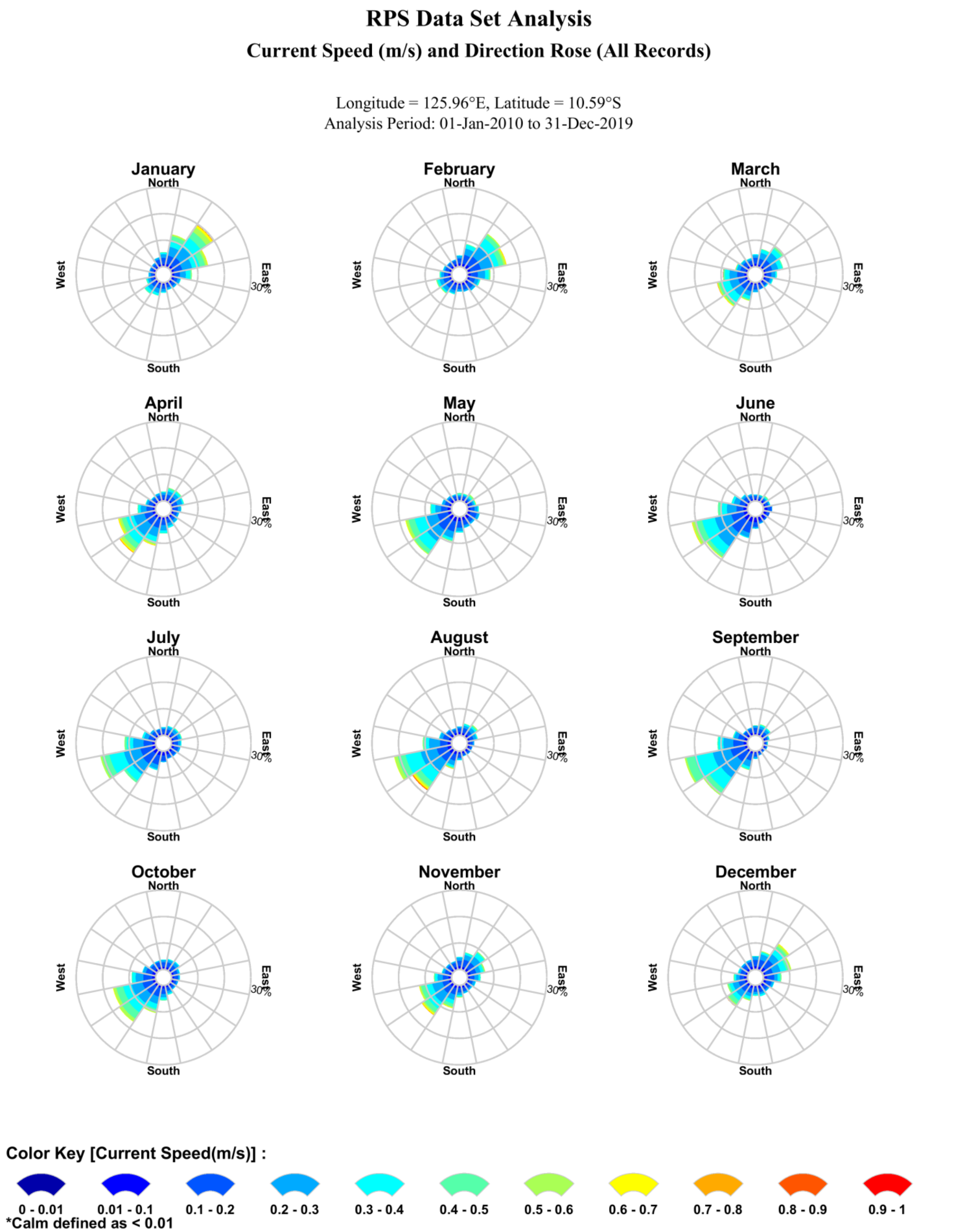


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

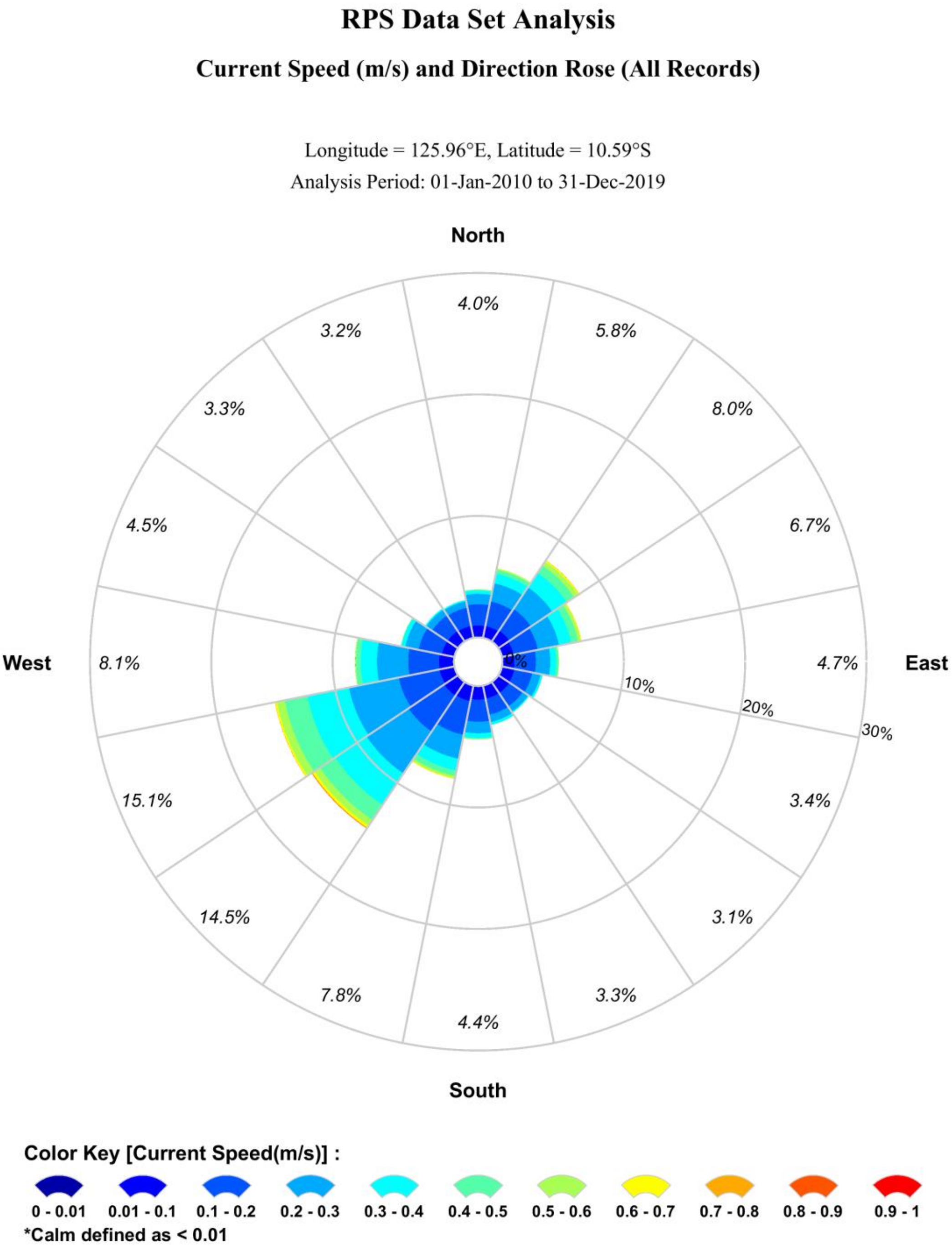


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 48 knots (July). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

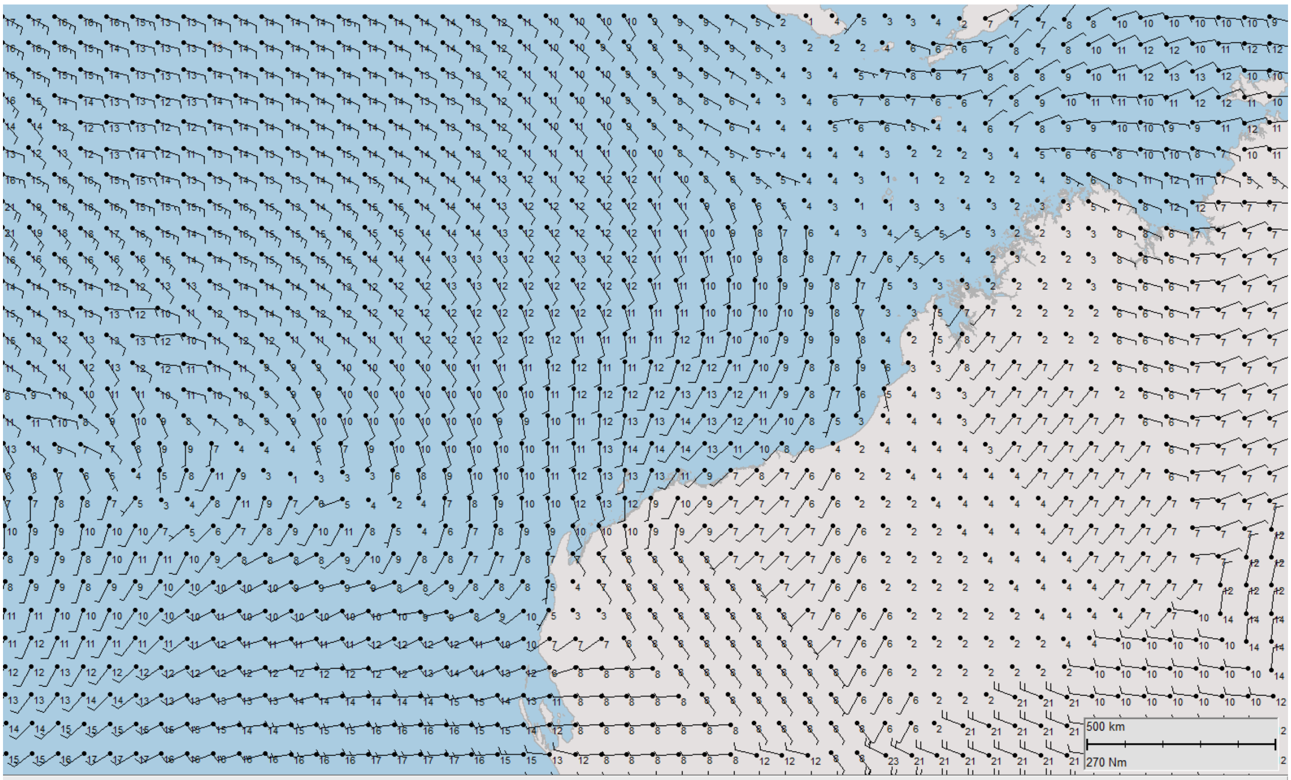


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	45	Southwest
	February	11	46	Southwest
	March	10	34	Southwest
Transitional	April	10	39	Variable
Winter	May	12	43	East
	June	14	29	East
	July	13	48	East to South
Transitional	August	11	30	Variable
Summer	September	12	27	South-Southwest
	October	13	27	South-Southwest
	November	13	25	South-Southwest
	December	13	30	Southwest
Minimum		**10**	**25**	
Maximum		**14**	**48**	

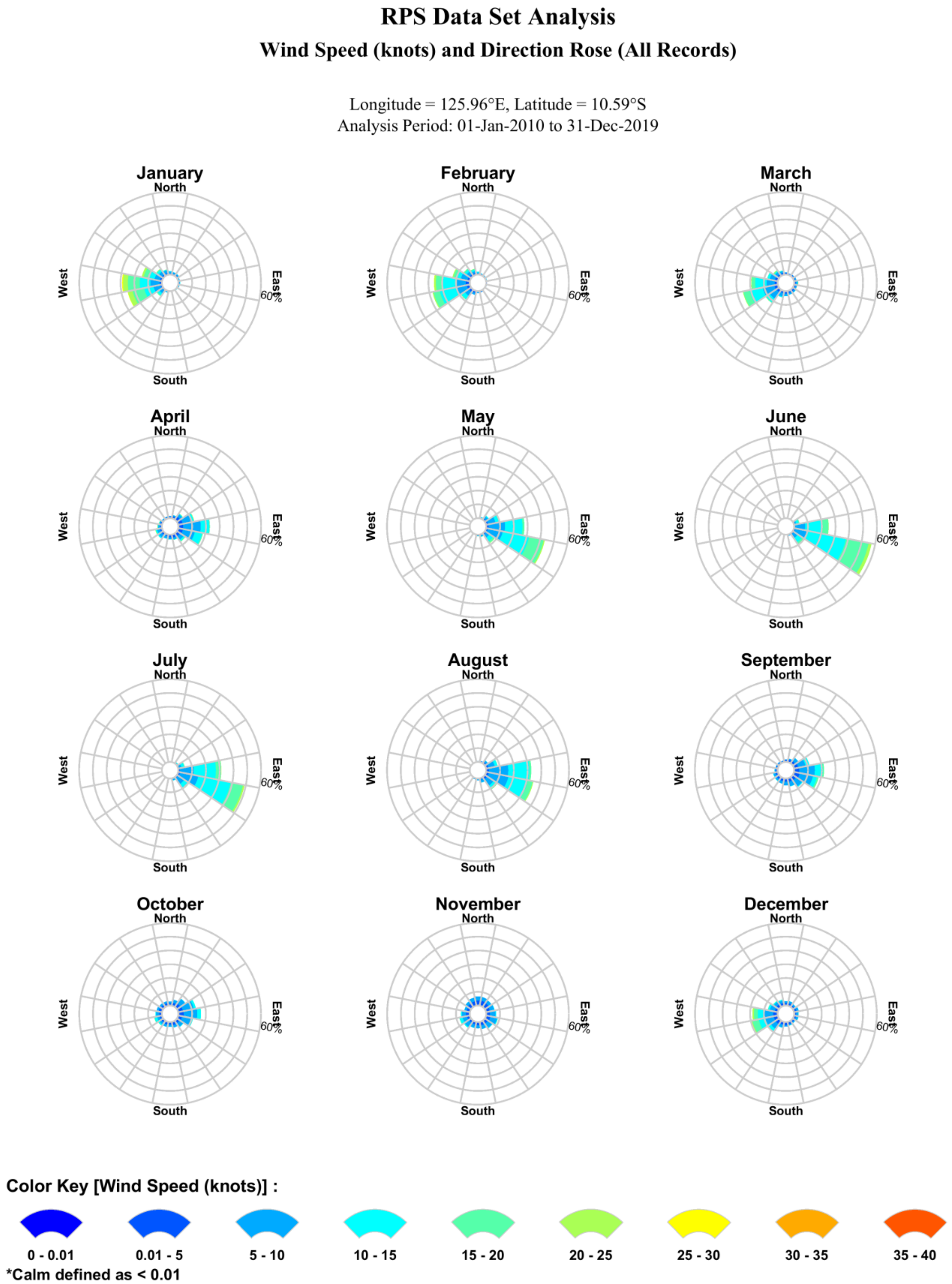


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

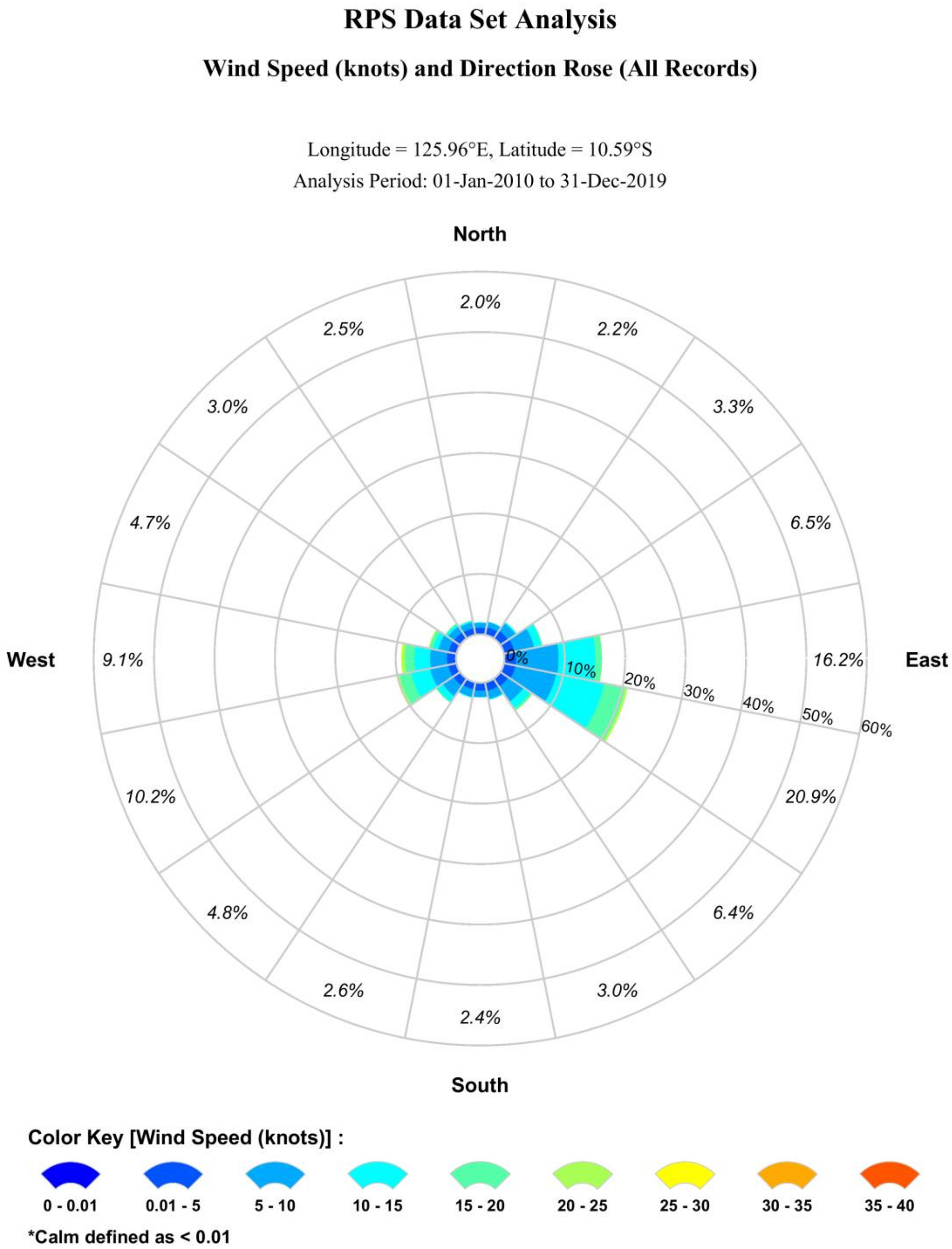


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from the HYbrid Coordinate Ocean Model (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.1°C (September) to 29.6°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.5–34.9 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	27.8	28.6	29.6	28.9	27.8	26.9	25.4	24.4	24.1	24.9	27.2	27.0
Salinity (psu)	34.9	34.6	34.6	34.5	34.7	34.8	34.6	34.7	34.7	34.7	34.7	34.7

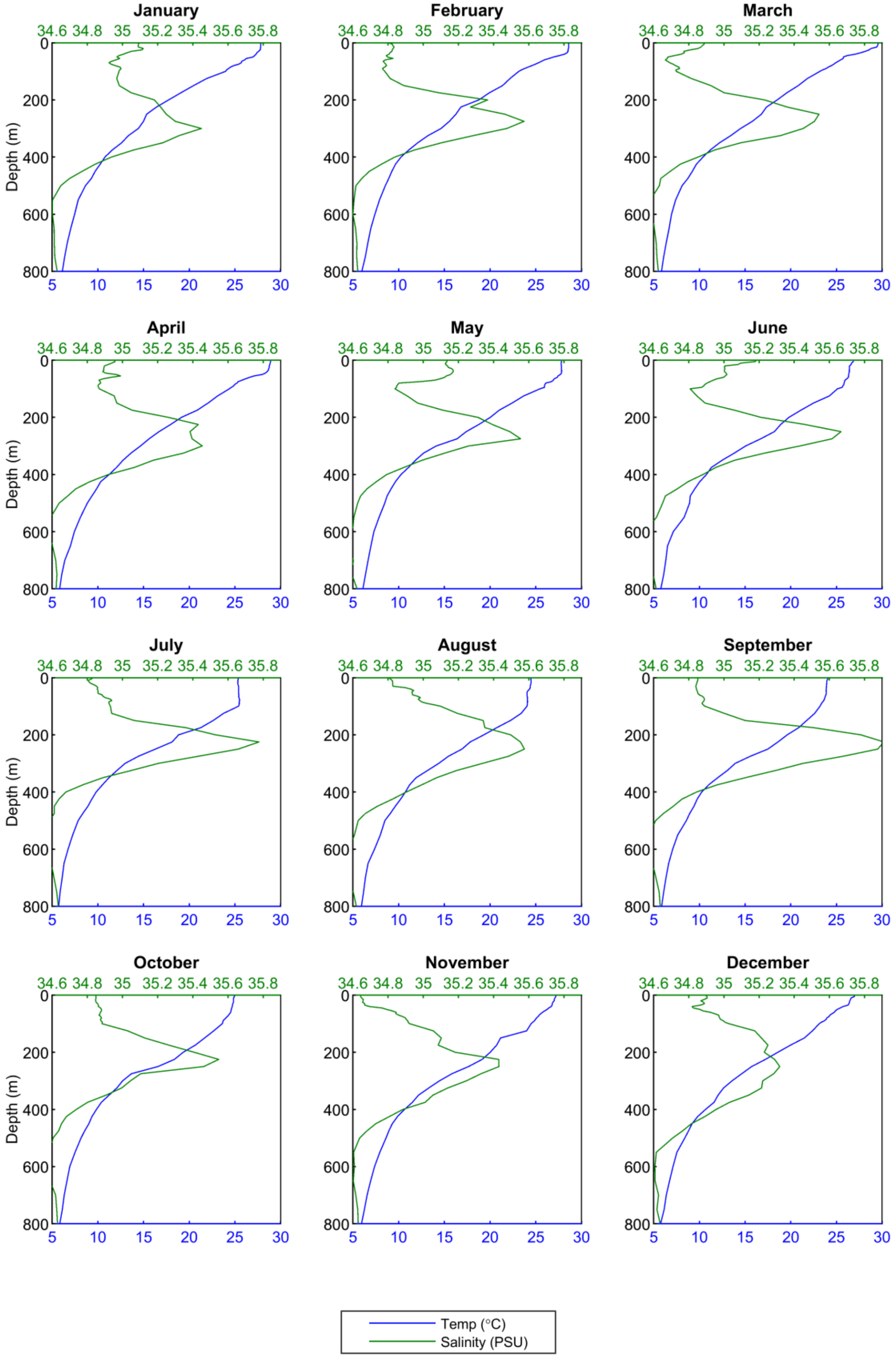


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 SUBSEA PLUME MODEL – OILMAP DEEP

The LOWC scenario is a high-pressure release of mostly gas and condensate and where gas is released with condensate, the buoyancy of the expanding gas cloud will entrain ambient seawater and propel the droplets towards the surface at a faster rate than would occur from the relative buoyancy of the condensate alone. Furthermore, the turbulence generated by such an intense discharge will tend to break the condensate up into droplets of various sizes.

To define the near-field plume dynamics, the subsea blowout model, OILMAP-DEEP, was applied. The model simulates the plume rise dynamics in two phases, the initial jet phase and the buoyant plume phase. The initial jet phase governs the plume dynamics directly above the subsurface release location and is predominately driven by the exit velocity. During this phase, the condensate droplet size and distribution is calculated. Next, the rise dynamics are dominated by the buoyant nature of the plume until the termination of the plume phase (known as the trapping depth). At this point, the results from OILMAP-DEEP (including plume trapping depth, plume diameter and droplet size distribution) are integrated into the far-field model SIMAP to simulate the rise and dispersion of the condensate droplets.

More details on the OILMAP-DEEP model, can be found in Spaulding et al. (2015). The model has been validated against observations from Deepwater Horizon as well as small and large-scale laboratory studies on subsurface oil releases (Brandvik et al., 2013, 2014; Belore, 2014; Spaulding et al., 2015; Li et al., 2017).

Table 6.1 presents the input parameters for the OILMAP-DEEP model and key results related to the near-field plume dynamics. The results indicated that the mixture of gas and condensate rose through the water column (whilst gradually losing momentum) to a trapping depth of approximately 492 m below mean sea level. After this point the condensate droplets would rise due to their own buoyancy, which range in size from 366 to 1,583 µm.

Figure 6.1 illustrates the various stages of an example blowout plume.

Table 6.1 Input data and key results for the subsea plume modelling.

Input Variable	Value
Scenario	Loss of Well Control
Well name	Chrysaor Well 5
Water depth (m)	800
Tubing diameter (inch) [m]	7 5/8 [0.194]
Condensate rate (stb/day)	1,308
Gas rate (MMscf/day)	239
Gas to condensate ratio (scf/bbl)	182,722
Formation water flow rate (stb/day)	0
Operating pressure (psia)	5,097
Key results	
Plume execution depth (m BMSL)	492
Droplet sizes (µm)	366 to 1,583

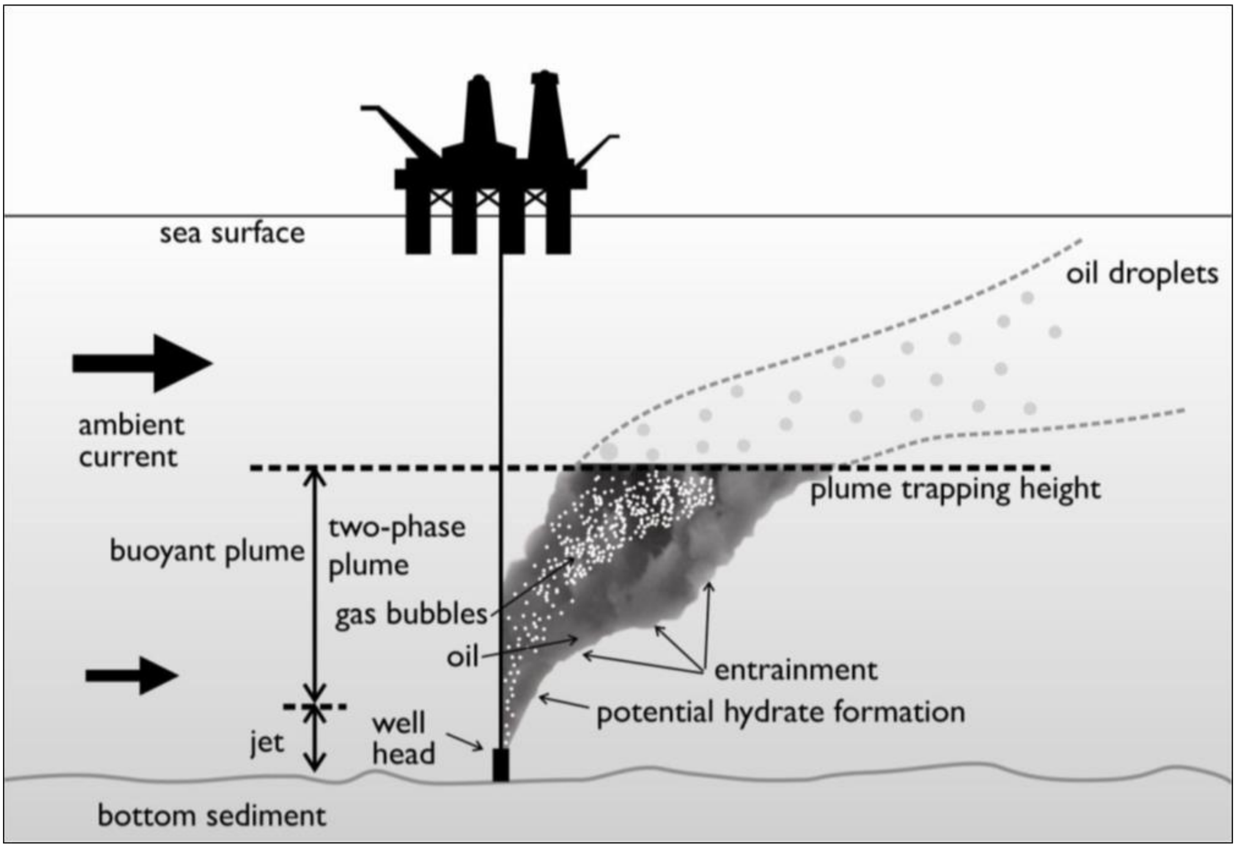


Figure 6.1 Example of a subsea plume and the various stages of the plume in the water column (Source: ASA, 2011).

7 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application.

The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

7.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 7.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and

- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

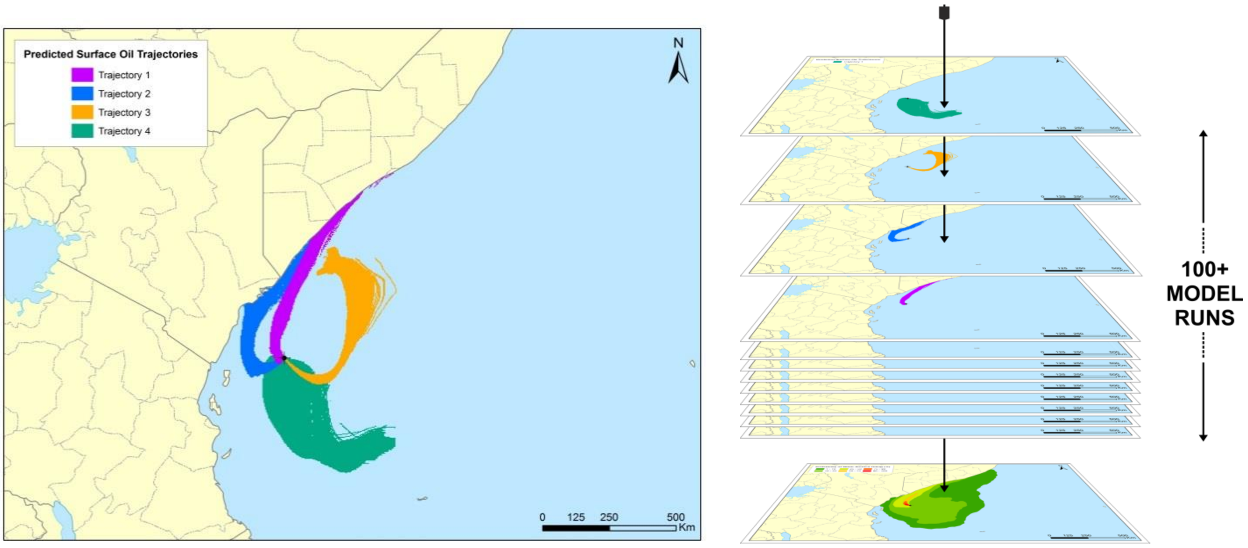


Figure 7.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

7.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 7.2.1 to 7.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

7.2.1 Floating Oil Exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating oil exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil exposure, was 1 g/m^2, which equates approximately to an average thickness of 1 µm, referred to as visible oil. Oil of this thickness is described as rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement, 2009; AMSA, 2014) (see Table 7.1). Figure 7.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. This threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to its visibility on the sea surface and potential to trigger temporary closures of areas (i.e. fishing grounds) as a precautionary measure. Table 7.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil exposure.

Ecological impact has been estimated to occur at 10 g/m^2 (a film thickness of approximately 10 µm or 0.01 mm) according to French et al. (1996) and French-McCay (2009) as this level of fresh oiling has been observed to mortally impact some birds through adhesion of oil to their feathers, exposing them to secondary effects such as hypothermia. The appearance of oil at this average thickness has been described as a metallic sheen (Bonn Agreement, 2009). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at oil concentrations on the sea surface of 25 g/m^2 (or greater), would be harmful for all birds that have landed in an oil film due to potential contamination of their feathers, with secondary effects such as loss of temperature regulation and ingestion of oil through preening. The appearance of oil at this thickness is also described as metallic sheen (Bonn Agreement, 2009). For this study the high exposure threshold was set to 50 g/m^2 and above based on NOPSEMA (2019). This threshold can also be used to inform response planning.

Table 7.2 defines the thresholds used to classify the zones of floating oil exposure reported herein.

Table 7.1 The Bonn Agreement Oil Appearance Code.

Code	Description Appearance	Layer Thickness Interval (g/m^2 or µm)	Litres per km^2
1	Sheen (silvery/grey)	0.04 – 0.30	40 – 300
2	Rainbow	0.30 – 5.0	300 – 5,000
3	Metallic	5.0 – 50	5,000 – 50,000
4	Discontinuous True Oil Colour	50 – 200	50,000 – 200,000
5	Continuous True Oil Colour	≥ 200	≥ 200,000

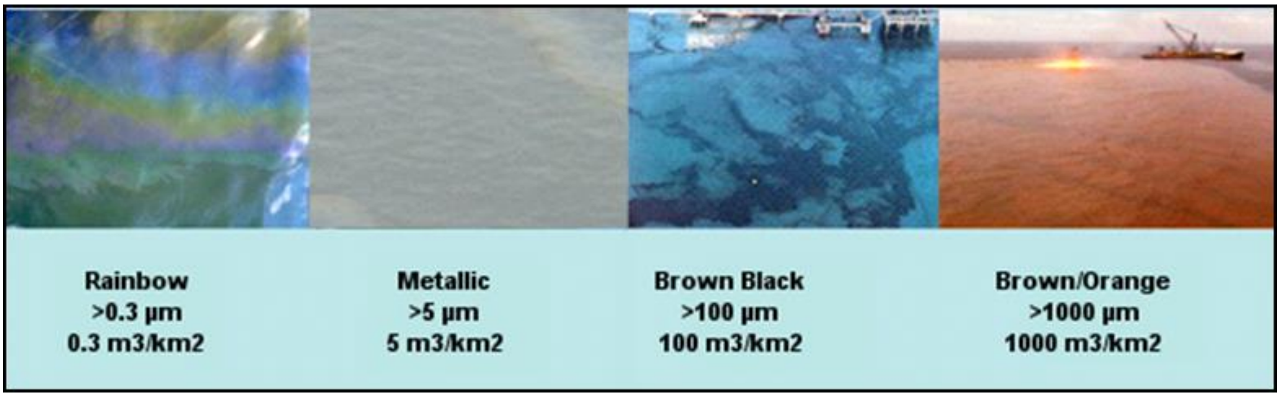


Figure 7.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 7.2 Floating oil exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (g/m^2)	Description
Low	1	Approximates range of socioeconomic effects and establishes planning area for scientific monitoring
Moderate	10	Approximates lower limit for harmful exposures to birds and marine mammals
High	50*	Approximates surface oil slick and informs response planning

* 50 g/m^2 also used to define the threshold for actionable floating oil.

7.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential “low shoreline accumulation”.

French et al. (1996) and French-McCay (2009) define a shoreline oil accumulation threshold of 100 g/m^2, or above, would potentially harm shorebirds and wildlife (furbearing aquatic mammals and marine reptiles on or along the shore) based on studies for sub-lethal and lethal impacts. This threshold has been used in previous environmental risk assessment studies (see French-McCay, 2003; French-McCay et al., 2004, French-McCay et al., 2011; 2012; NOAA, 2013). Additionally, a shoreline concentration of 100 g/m^2, or above, is the minimum limit that the oil can be effectively cleaned according to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential “moderate shoreline accumulation”.

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential “high shoreline accumulation”. It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 7.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 7.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	10	Predicts potential for some socio-economic impact
Moderate	100*	Loading predicts area likely to require clean-up effort
High	> 1,000	Loading predicts area likely to require intensive clean-up effort

* 100 g/m^2 also used to define the threshold for actionable shoreline oil.

7.2.3 In-water Exposure Thresholds

Oil is a mixture of thousands of hydrocarbons of varying physical, chemical, and toxicological characteristics, and therefore, demonstrate varying fates and impacts on organisms. As such, for in-water exposure, the SIMAP model provides separate outputs for dissolved and entrained hydrocarbons from oil droplets. The consequences of exposure to dissolved and entrained components will differ because they have different modes and magnitudes of effect.

Entrained hydrocarbon concentrations were calculated based on oil droplets that are suspended in the water column, though not dissolved. The composition of this oil would vary with the state of weathering (oil age) and may contain soluble hydrocarbons when the oil is fresh. Calculations for dissolved hydrocarbons specifically calculates oil components which are dissolved in water, which are known to be the primary source of toxicity exerted by oil.

7.2.3.1 Dissolved Hydrocarbons

Laboratory studies have shown that dissolved hydrocarbons exert most of the toxic effects of oil on aquatic biota (Carls et al., 2008; Nordtug et al., 2011; Redman, 2015). The mode of action is a narcotic effect, which is positively related to the concentration of soluble hydrocarbons in the body tissues of organisms (French-McCay, 2002). Dissolved hydrocarbons are taken up by organisms directly from the water column by absorption through external surfaces and gills, as well as through the digestive tract. Thus, soluble hydrocarbons are termed “bioavailable”.

Hydrocarbon compounds vary in water-solubility and the toxicity exerted by individual compounds is inversely related to solubility, however bioavailability will be modified by the volatility of individual compounds (Nirmalakhandan & Speece, 1988; Blum & Speece, 1990; McCarty, 1986; McCarty et al., 1992a, 1992b; Mackay et al., 1992; McCarty & Mackay, 1993; Verhaar et al., 1992, 1999; Swartz et al., 1995; French-McCay, 2002; McGrath & Di Toro, 2009). Of the soluble compounds, the greatest contributor to toxicity for water-column and benthic organisms are the lower-molecular-weight aromatic compounds, which are both volatile and soluble in water. Although they are not the most water-soluble hydrocarbons within most oil types, the polynuclear aromatic hydrocarbons (PAHs) containing 2-3 aromatic ring structures typically exert the largest narcotic effects because they are semi-soluble and not highly volatile, so they persist in the environment long enough for significant accumulation to occur (Anderson et al., 1974, 1987; Neff & Anderson, 1981; Malins & Hodgins, 1981; McAuliffe, 1987; NRC, 2003). The monoaromatic hydrocarbons (MAHs), including the BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), and the soluble alkanes (straight chain hydrocarbons) also contribute to toxicity, but these compounds are highly volatile, so that their contribution will be low when oil is exposed to evaporation and higher when oil is discharged at depth where volatilisation does not occur (French-McCay, 2002).

French-McCay (2002) reviewed available toxicity data, where marine biota was exposed to dissolved hydrocarbons prepared from oil mixtures, finding that 95% of species and life stages exhibited 50% population mortality (LC_{50}) between 6 and 400 ppb total PAH concentration after 96 hrs exposure, with an average of 50 ppb. Hence, concentrations lower than 6 ppb total PAH value should be protective of 97.5% of species and life stages even with exposure periods of days (at least 96 hours). Early life-history stages of fish appear to be more sensitive than older fish stages and invertebrates.

Exceedances of 10, 50 or 400 ppb over a 1 hour timestep (see Table 7.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on NOPSEMA (2019).

7.2.3.2 Entrained Hydrocarbons

Entrained hydrocarbons consist of oil droplets that are suspended in the water column and insoluble. As such, insoluble compounds in oil cannot be absorbed from the water column by aquatic organisms, hence are not bioavailable through absorption of compounds from the water. Exposure to these compounds would require routes of uptake other than absorption of soluble compounds. The route of exposure of organisms to whole oil alone include direct contact with tissues of organisms and uptake of oil by direct consumption, with potential for biomagnification through the food chain (NRC, 2003).

The 10 ppb threshold represents the very lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the ANZECC & ARMCANZ (2000) water quality guidelines. Due to the requirement for relatively long exposure times (> 24 hours) for these concentrations to be significant, they are likely to be more meaningful for juvenile fish, larvae and planktonic organisms that might be entrained (or otherwise moving) within the entrained plumes, or when entrained hydrocarbons adhere to organisms or trapped against a shoreline for periods of several days or more.

This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the entrained hydrocarbon at this level.

Thresholds of 10 ppb and 100 ppb were applied over a 1 hour time exposure (Table 7.4), to cover the range of thresholds outlined in the ANZECC & ARMCANZ (2000) water quality guidelines, the incremental change for greater potential effect and is per NOPSEMA (2019).

A complicating factor that should be considered when assessing the consequence of dissolved and entrained oil distributions is that there will be some areas where both physically entrained oil droplets and dissolved hydrocarbons co-exist. Higher concentrations of each will tend to occur close to the source where sea conditions can force mixing of relatively unweathered oil into the water column, resulting in more rapid dissolution of soluble compounds.

Table 7.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

8 CONDENSATE PROPERTIES

8.1 Properties

As a conservative approach, Chevron had chosen Chrysaor condensate for the purposes of the modelling and hence provided physical properties and boiling point distributions, which are presented in Table 8.1 and Table 8.2, respectively.

Chrysaor condensate has an API of 40.20, a density of 824 kg/m^3 (at 15ºC) and a low viscosity value of 5.6 cP. When exposed to the atmosphere at local temperatures, about 23.8% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 33.0% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (~32.9%) should evaporate over a longer period (265°C < BP < 380°C). Additionally, 10.3% of the condensate is shown to be persist in the marine environment for longer period and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity to take up water to form water-in-oil emulsion.

Soluble, aromatic hydrocarbons contribute approximately 3.0% by mass of the whole oil. For this condensate they are all contained in the volatile fractions, which are highly soluble. Discharges onto the water surface will favour the process of evaporation over dissolution under calm sea conditions, but increased entrainment of oil and dissolution of soluble compounds can be expected under stronger wind periods with the presence of small breaking waves (whitecaps).

The actual fate of released oil in the marine environment will depend greatly on the amount of oil that reaches the surface, either through the initial release or by rising after discharge in the water column.

Table 8.1 Physical properties of Chrysaor condensate.

Characteristic	Chrysaor Condensate
Density (kg/m^3)	824 (at 15°C)
API	40.20
Dynamic viscosity (cP)	5.6 (at 15°C)
Pour point (°C)	-9
Surface tension (dyne/cm)	19
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light-persistent

Table 8.2 Boiling point ranges of Chrysaor condensate.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 $>C_{20}$
Chrysaor Condensate	% of total	23.8	33.0	32.9	10.3
	% of aromatics	3.0	0	0	0

8.2 Weathering Characteristics

8.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this condensate when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.

- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the condensate reaches the surface.

8.2.2 Results

The mass balance forecast for the calm-wind case (Figure 8.1) shows that 57.0% of the condensate is predicted to evaporate within 24 hours. Majority of the remaining condensate on the water surface will weather at a slower rate due to the low volatile components. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.2), where the winds are of greater strength on average, entrainment of Chrysaor condensate into the water column is predicted to increase. Approximately 24 hours after the spill, 58.7% of the condensate mass is forecast to have entrained and a further 39.1% is forecast to have evaporated, leaving only a small proportion of the condensate floating on the water surface (0.5%). The residual compounds will tend to remain entrained beneath the surface under conditions that generate wind waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case will result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and condensate droplets in the water column occurs at an approximate rate of ~1.9% per day with an accumulated total of ~13% after 7 days, in comparison to a rate of 0.16% per day and an accumulated total of 1.09% after 7 days in the constant-wind case. Given the proportion of entrained condensate and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

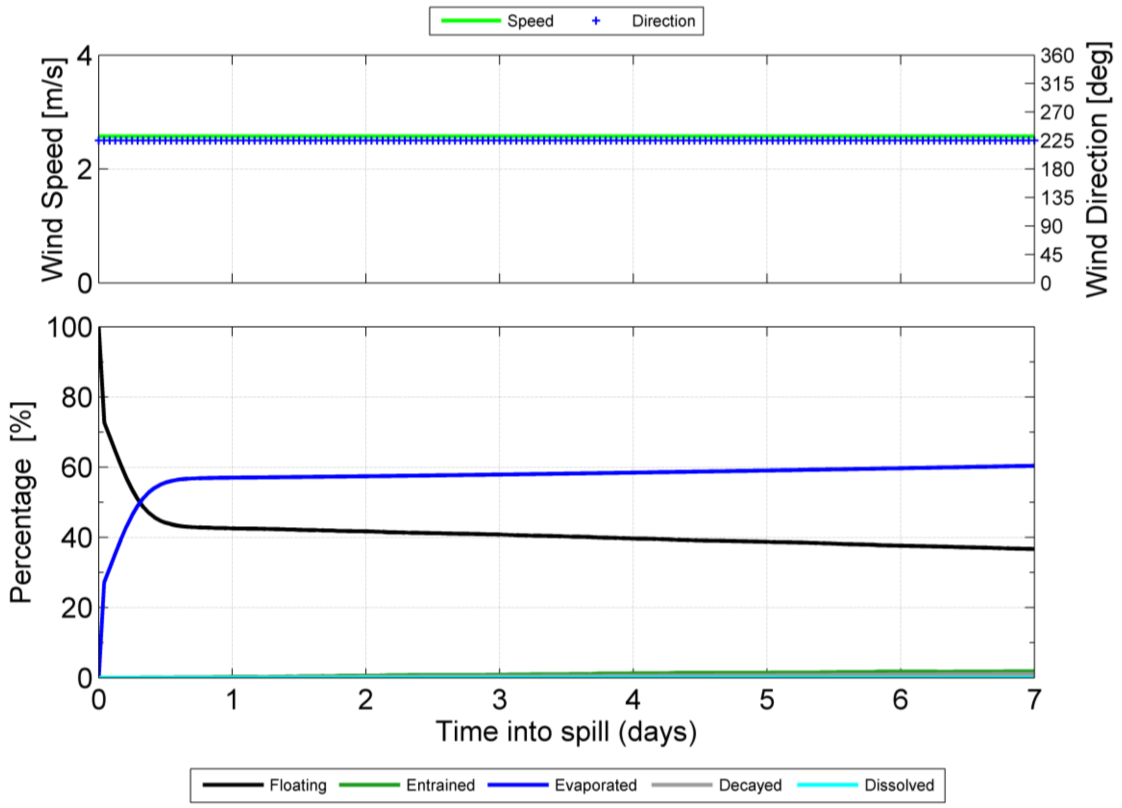


Figure 8.1 Proportional mass balance plot representing the weathering of Chrysaor condensate spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature and 25°C air temperature.

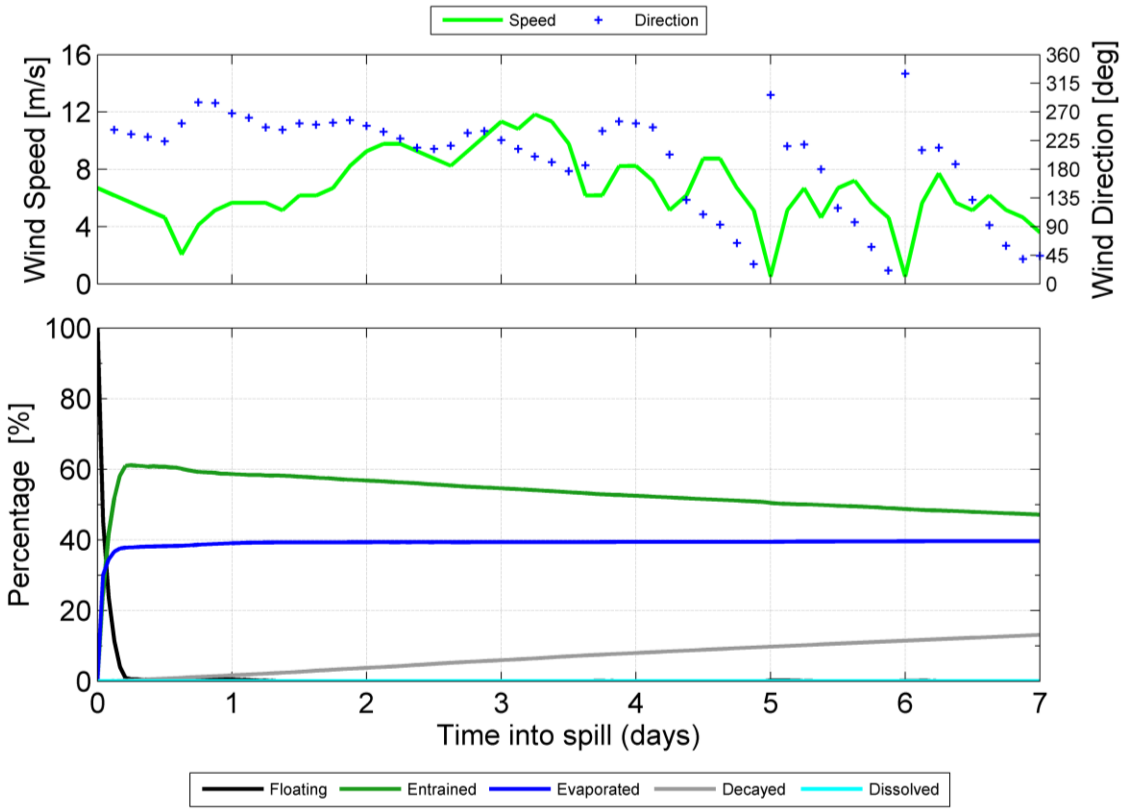


Figure 8.2 Proportional mass balance plot representing the weathering of Chrysaor condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature and 25°C air temperature.

9 MODEL SETTINGS

Table 9.1 provides a summary of the oil spill model settings.

Table 9.1 Summary of the oil spill model settings used in this assessment.

	Scenario
Location	Chrysaor Well 5
Number of spill simulations with randomly selected start times	100 per season (300 total)
Spill volume (m^3) [bbl]	18,715 [117,720]
Condensate type	Chrysaor condensate
Release type (depth)	Subsea (800 m)
Release duration (days)	90
Simulation length (days)	104
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour, high exposure

10 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

10.1 Stochastic Analysis

10.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***Probability of condensate exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***Minimum time before condensate exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

10.2 Deterministic Trajectories

The deterministic results in Section 11.2 are based on the following criteria:

a. Largest swept area of floating hydrocarbon above 10 g/m^2
b. Largest swept area of floating hydrocarbon above 50 g/m^2
c. Largest volume of oil ashore
d. Longest length of shoreline accumulation above 100 g/m^2
e. Largest area of entrained hydrocarbons above 100 ppb
f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no dissolved hydrocarbon exposure at or above 50 ppb, for any of the 300 simulations, the deterministic results are presented based on criteria’s a - e.

10.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 10.1 to Figure 10.10). Receptor categories (see Table 10.1) include sections of shorelines and offshore islands. All other sensitive receptors other than submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

Table 10.2 summarises the receptors that the location resides within.

Table 10.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	×
Biologically Important Area	BIA	✓	✓	×
Marine Park	MP	✓	✓	×
Marine Management Area	MMA	✓	✓	×
Nature Reserve	NR	✓	✓	×
Integrated Marine and Coastal Regionalisation of Australia	IMCRA	✓	✓	×
Interim Biogeographic Regionalisation of Australia	IBRA	✓	✓	×
Reefs, Shoals and Banks	RSB	✓	✓	×
Key Ecological Feature	KEF	✓	✓	×
Ramsar Sites	Ramsar	✓	✓	×
State Waters	State Waters	✓	✓	×
Impact Assessment Area	IAA	✓	✓	✓
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 10.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Pygmy Blue Whale - Distribution	BIA	✓
Wedge-tailed Shearwater - Breeding	BIA	✓
Offshore Area	IAA	✓
Continental Slope Demersal Fish Communities	KEF	✓

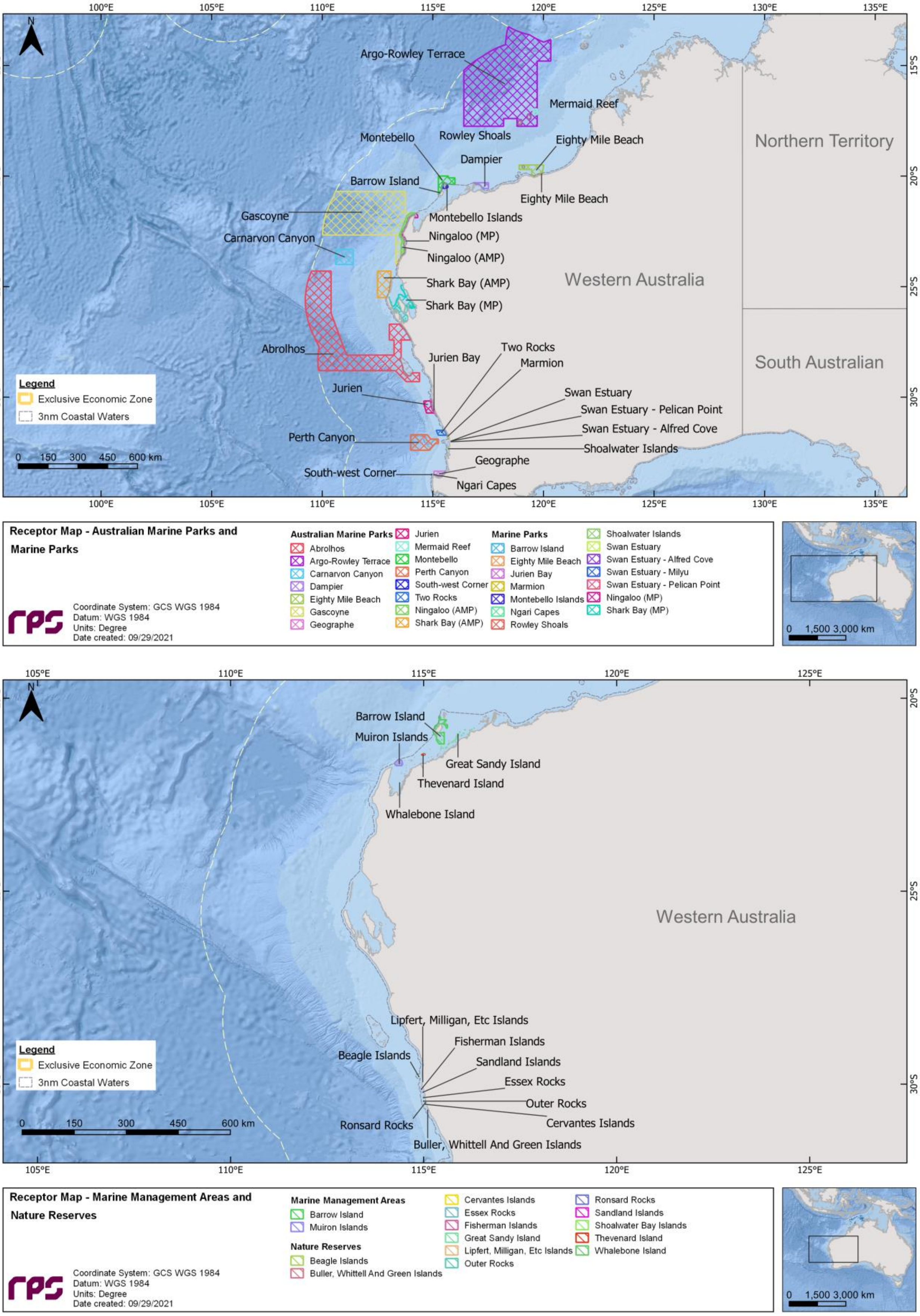


Figure 10.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).

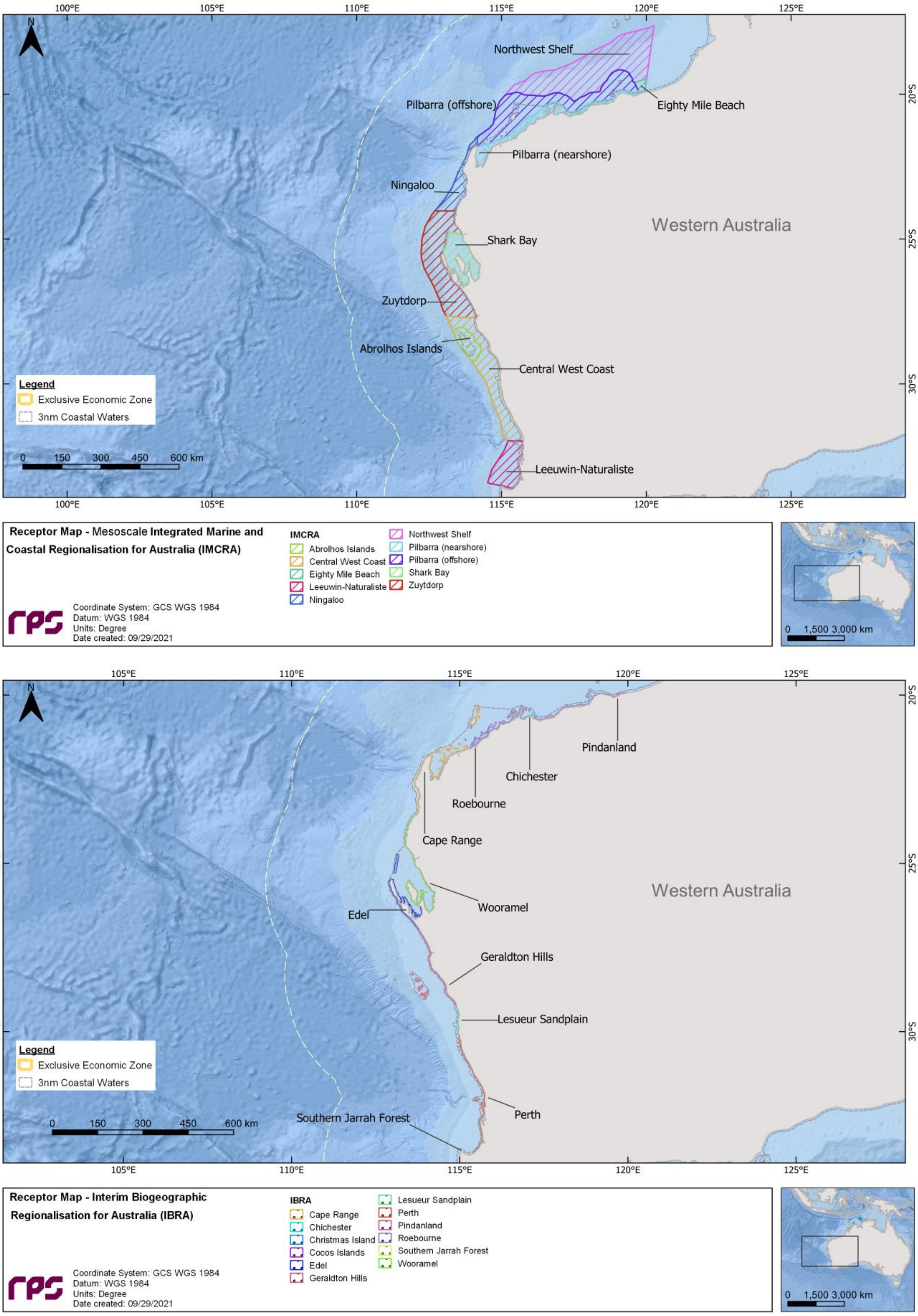


Figure 10.2 Receptor maps for Mesoscale Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).

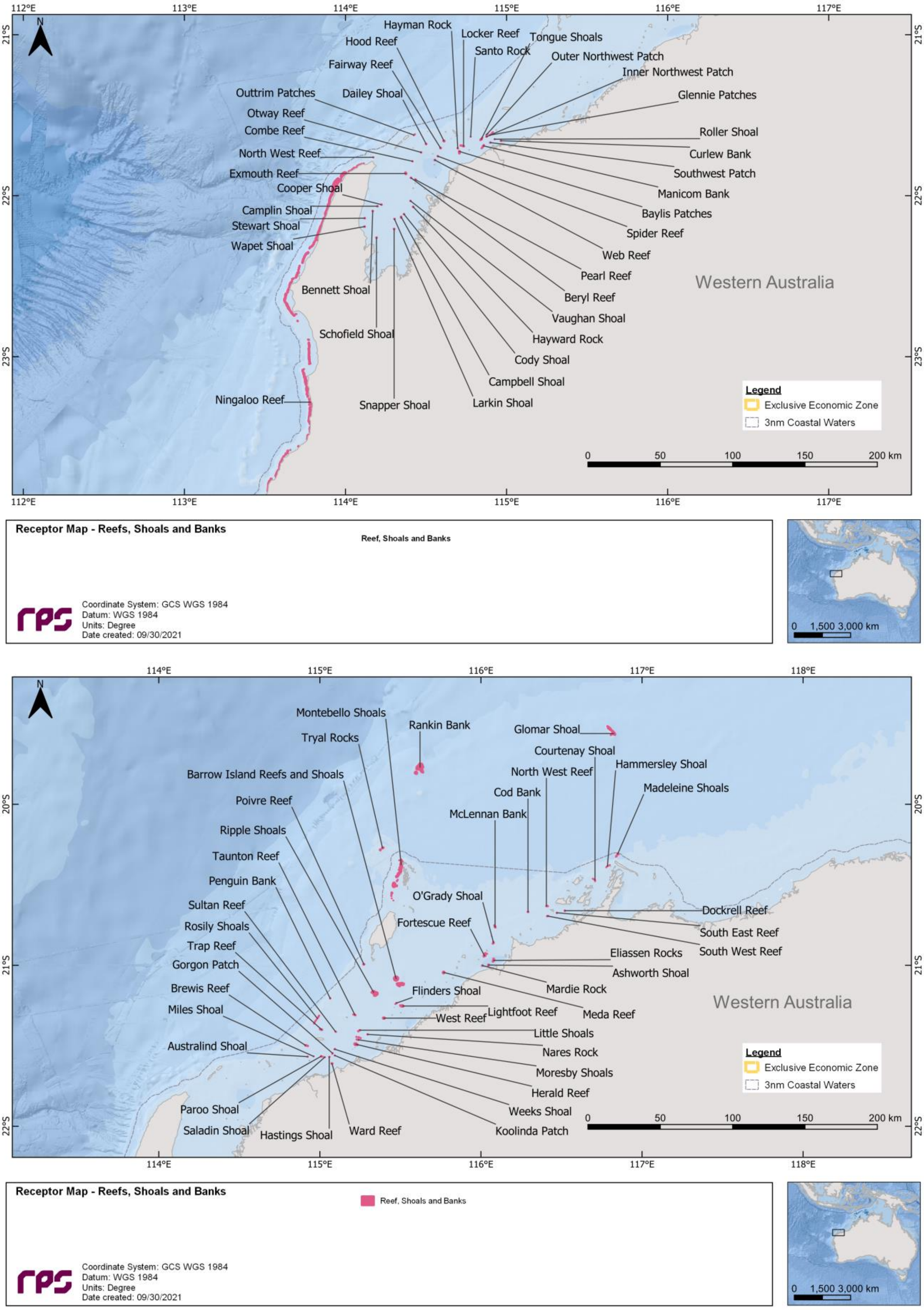


Figure 10.3 Receptor maps for Reefs, Shoals and Banks (RSB).

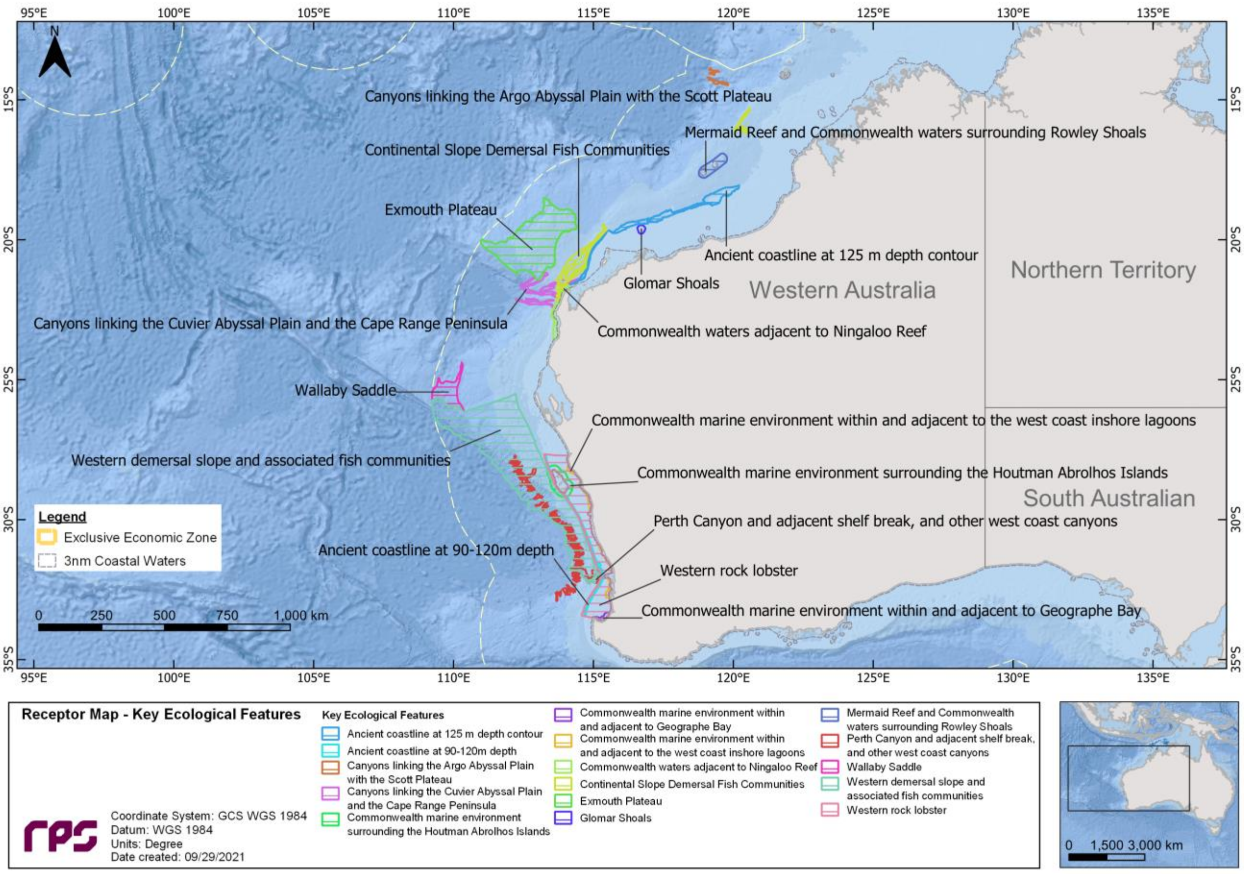


Figure 10.4 Receptor maps for Key Ecological Features (KEFs).

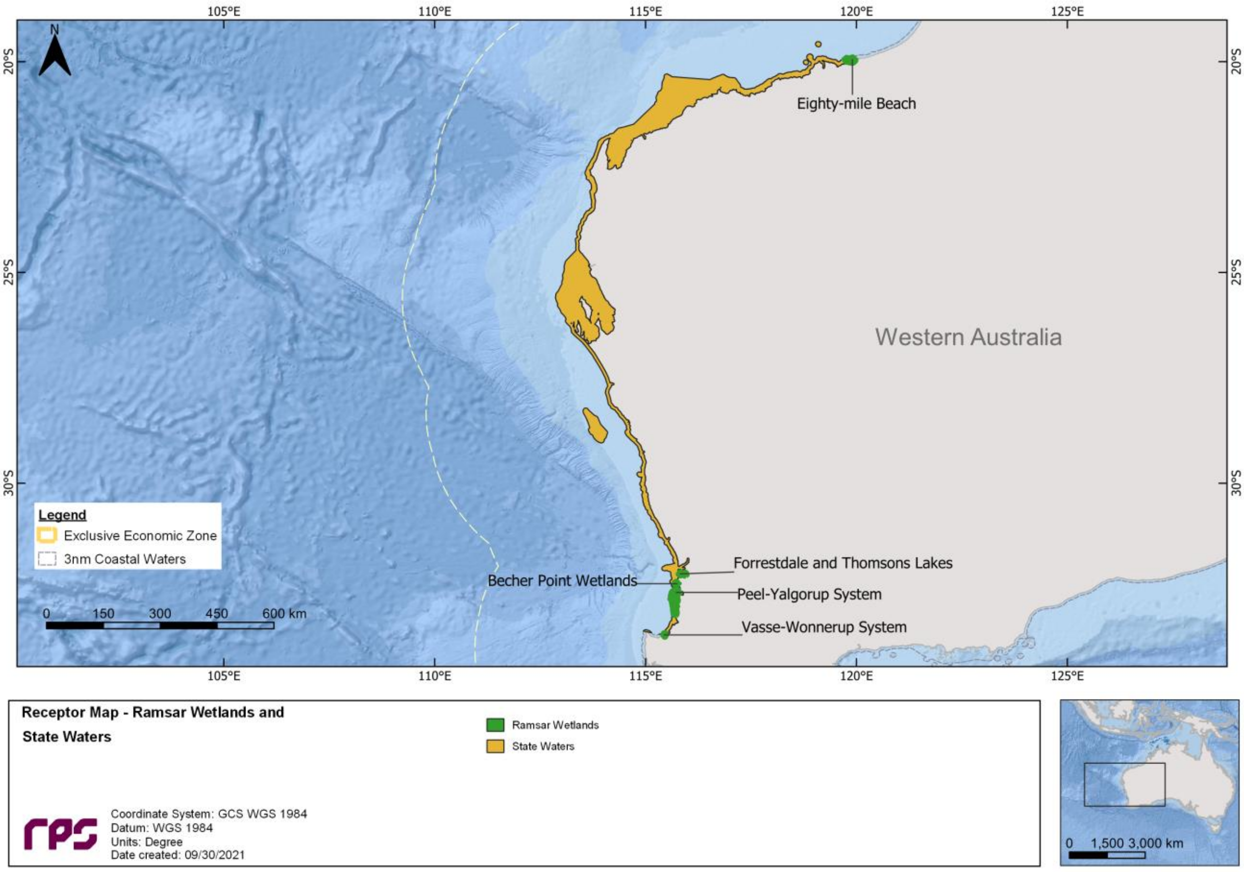
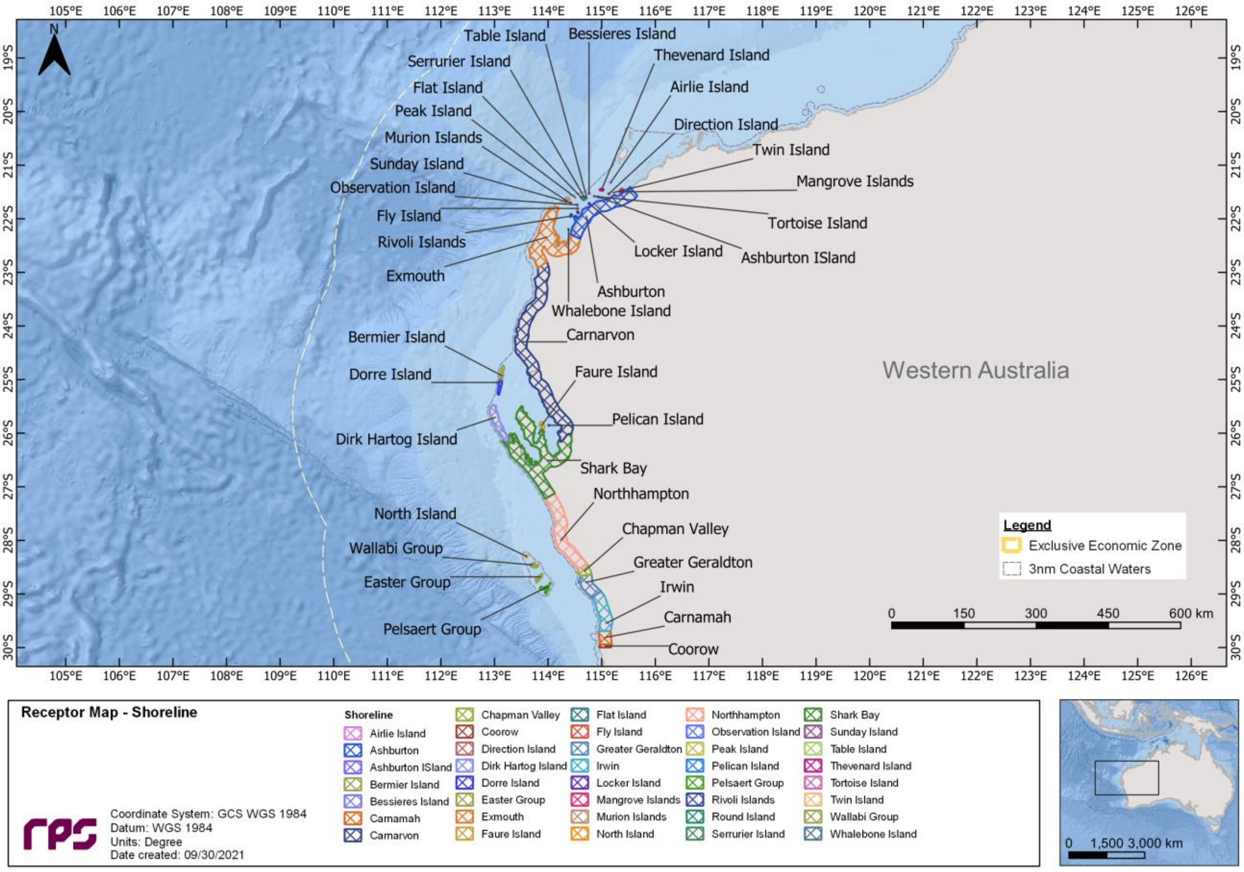


Figure 10.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.



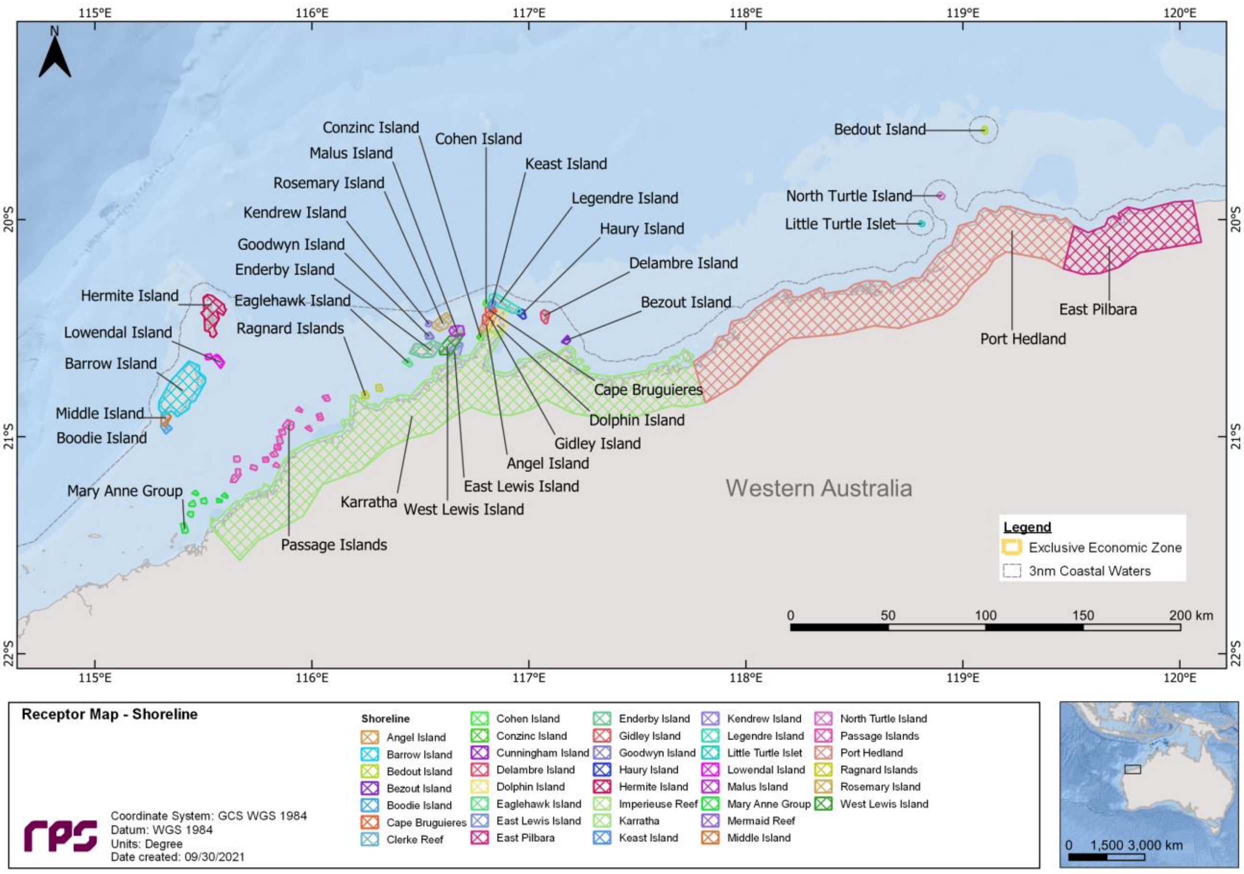


Figure 10.6 Receptor maps for Shorelines (1 of 2).

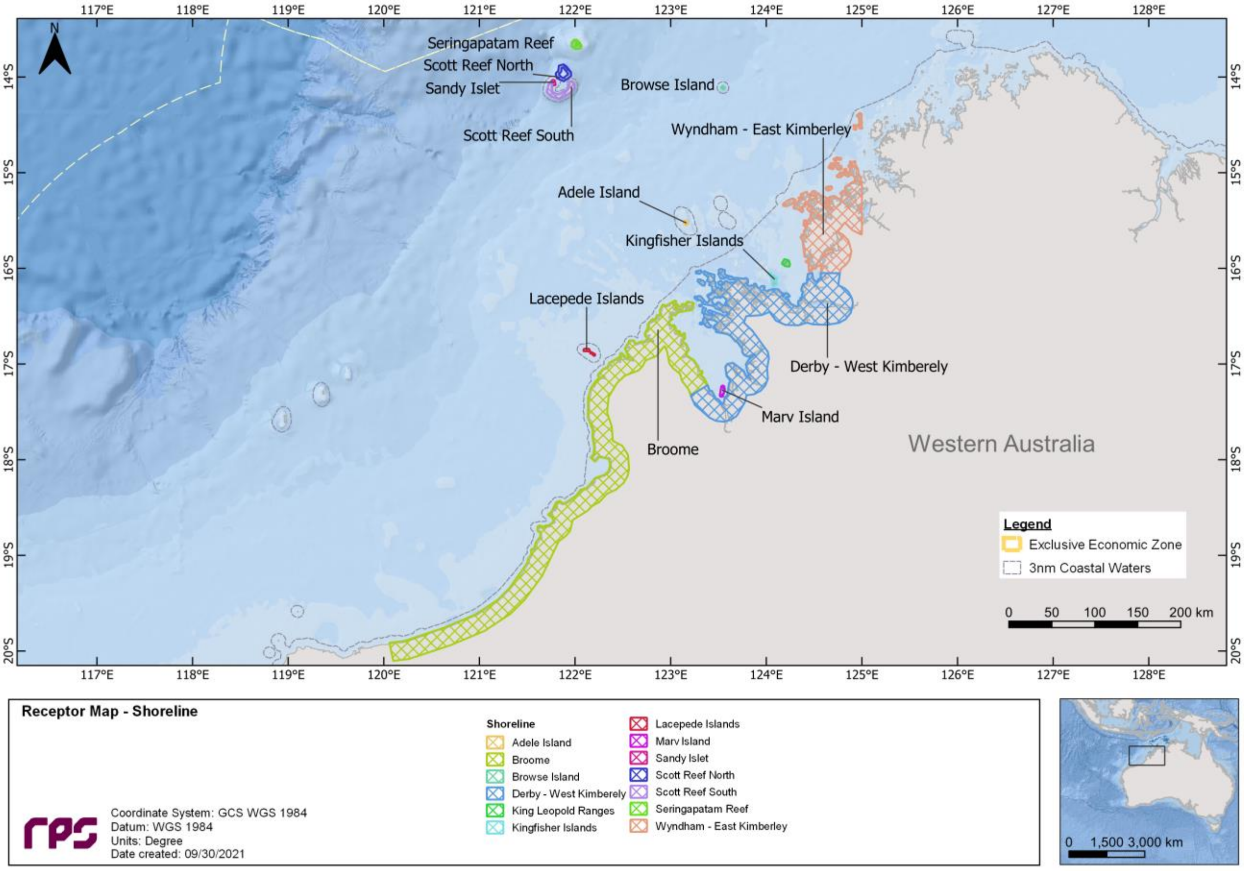


Figure 10.7 Receptor maps for Shorelines (2 of 2).

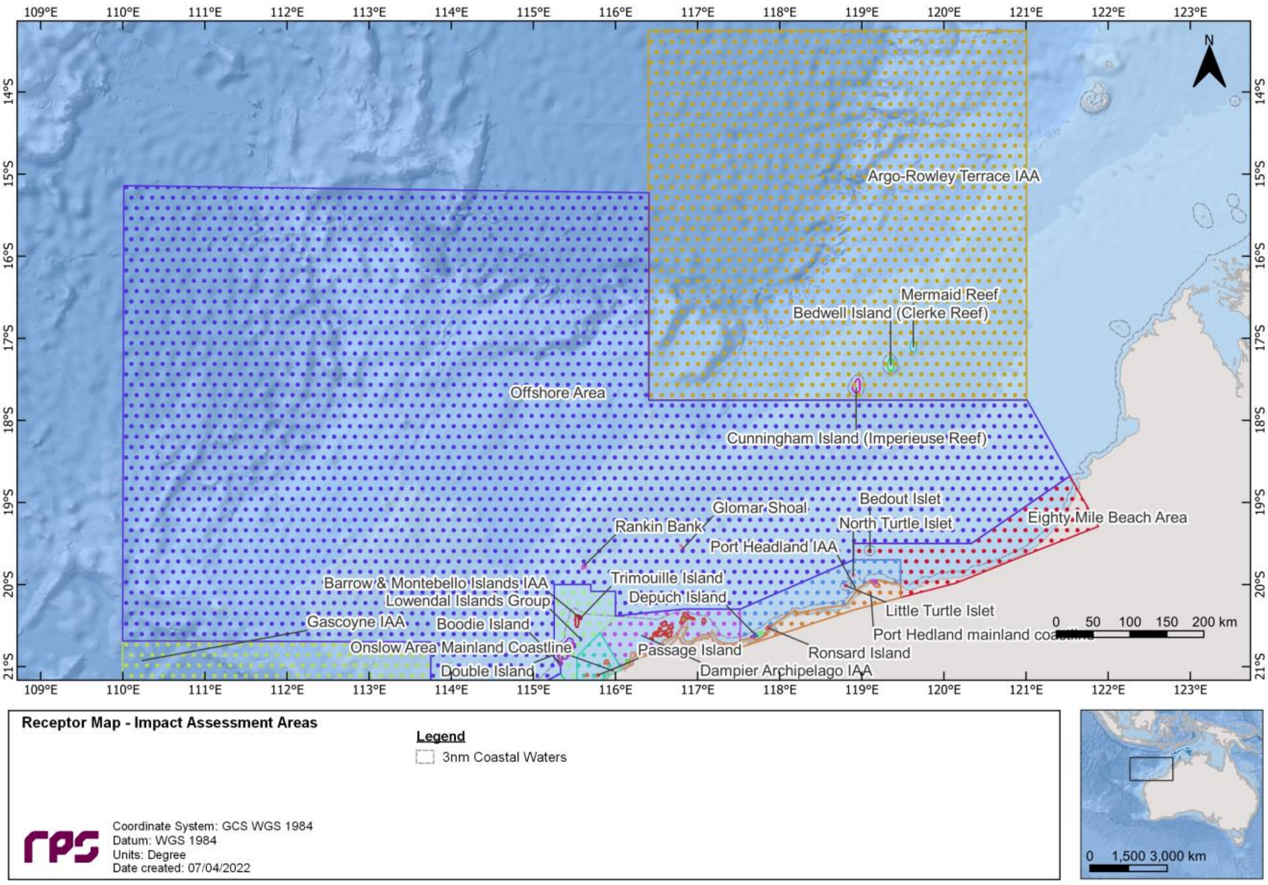


Figure 10.8 Receptor maps for Impact Assessment Areas (1 of 3).

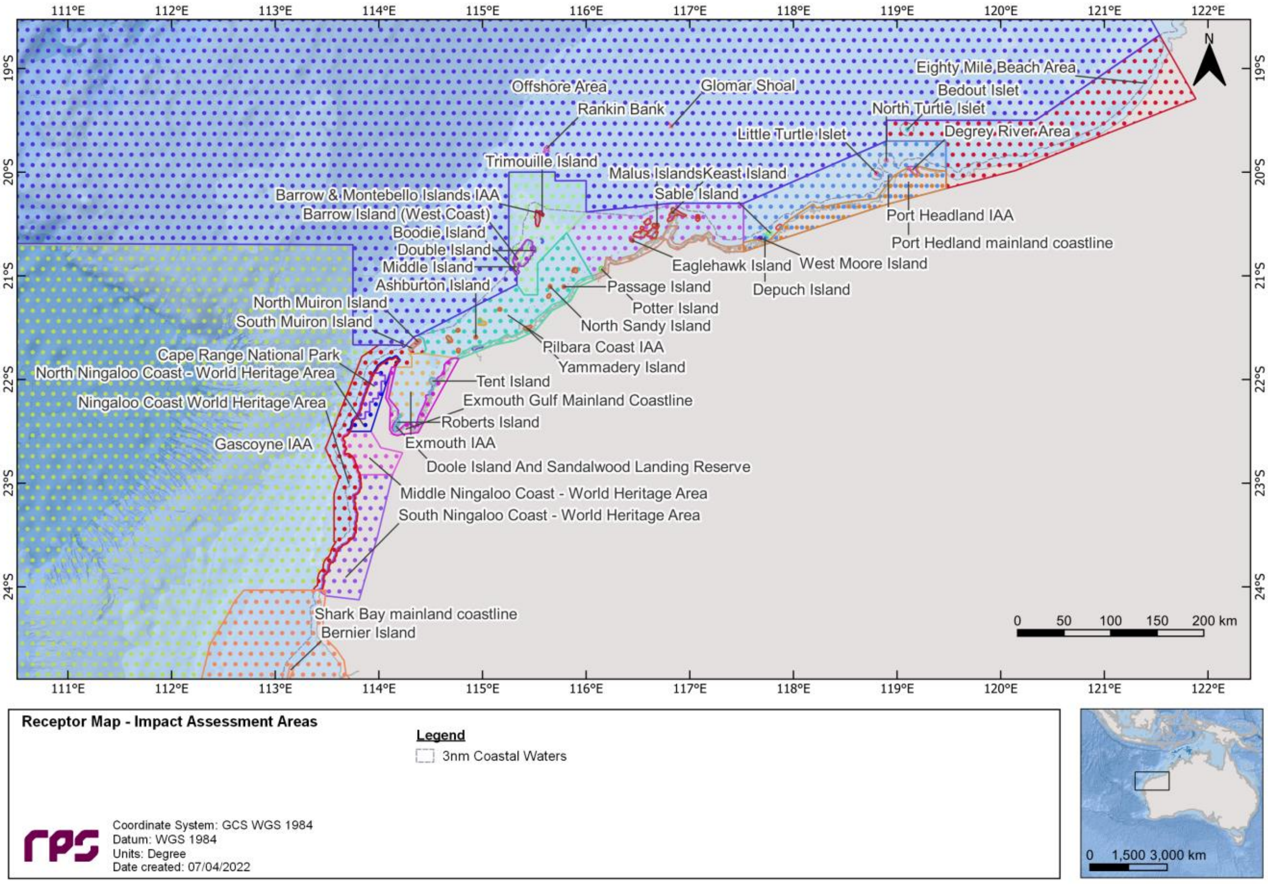


Figure 10.9 Receptor maps for Impact Assessment Areas (2 of 3).

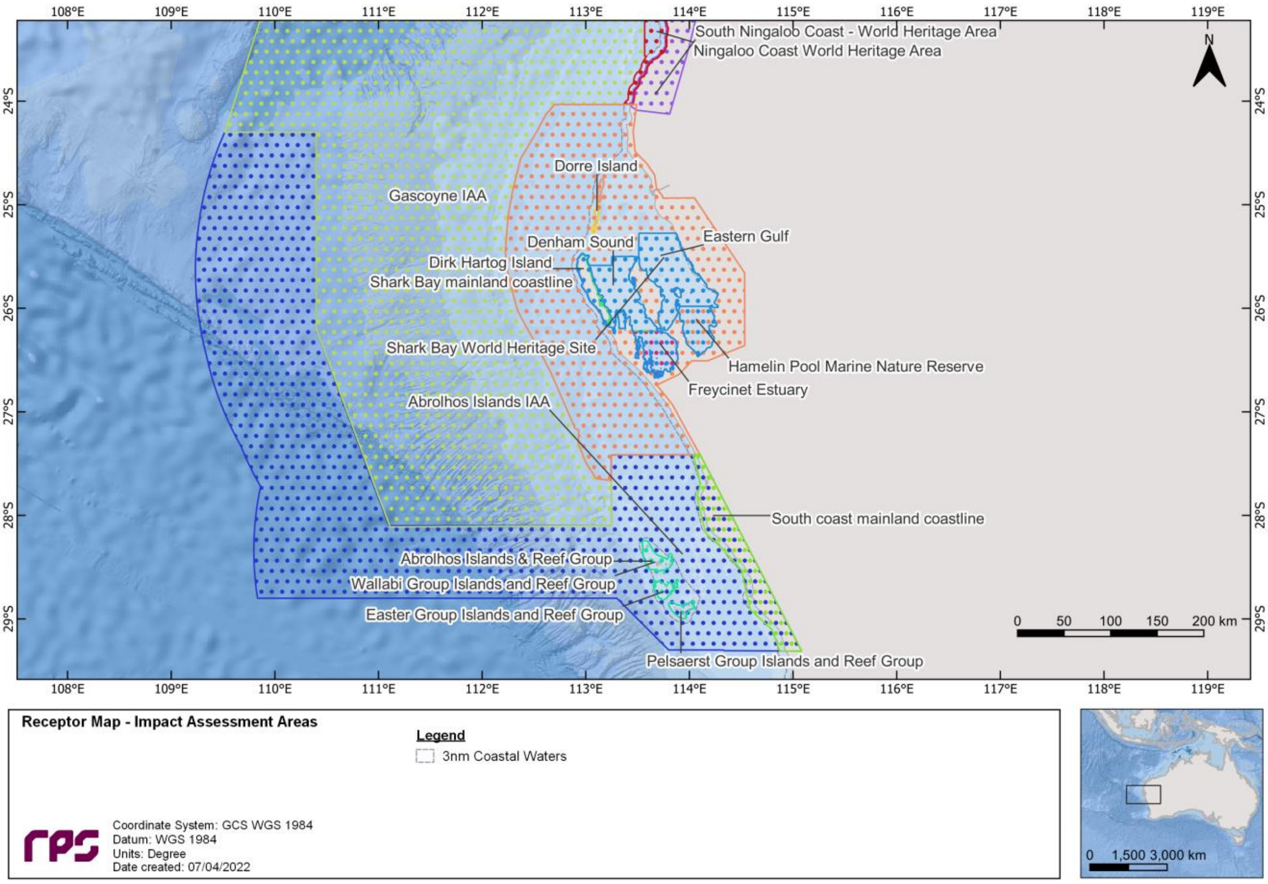


Figure 10.10 Receptor maps for Impact Assessment Areas (3 of 3).

11 RESULTS: CHRYSAOR–DIONYSUS LOSS OF WELL CONTROL

This scenario examined a 117,720 stb (or 18,715 m^3) subsea release of condensate over 90 days, following a LOWC. A total of 300 spill simulations were run for each of the three seasons (i.e. 100 spills per season) and tracked for 104 days.

Section 11.1 presents the seasonal (or stochastic) analysis results, while Section 11.2 presents the deterministic results.

11.1 Stochastic Analysis

11.1.1 Floating Condensate Exposure

Table 11.1 summarises the maximum distances from the release location to floating condensate exposure zones for each season. The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 82.0 km west (summer) and 4.3 km northeast (transitional and winter), respectively.

No exposure was predicted at the high (≥ 50 g/m^2) threshold.

Table 11.2 summarises the potential floating condensate exposure to individual receptors during each season.

The Offshore Area IAA, Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater - Breeding BIAs, and the Continental Slope Demersal Fish Communities KEF, which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low threshold were 100% for all seasons for these receptors. Probabilities of moderate exposure for these receptors ranged between 89% (all receptors; summer) and 99% (all receptors; winter). Additionally, the Flatback Turtle - Internesting Buffer BIA was also predicted to be exposed at the low threshold during summer (95%), transitional (100%) and winter (97%), respectively. The minimum time before low exposure for the Flatback Turtle - Internesting Buffer BIA was 0.67 days during summer conditions. Furthermore, the probability of exposure at the low threshold for the Pilbara (offshore) IMCRA and Ancient coastline at 125 m depth contour (KEF) was 88%, 84% and 89% during summer, transitional and winter conditions and 31%, 27% and 41% summer, transitional and winter conditions, respectively. The corresponding minimum time before low exposure at the Pilbara (offshore) IMCRA and Ancient coastline at 125 m depth contour FEF was 0.88 days (summer) and 2.21 days (winter).

Figure 11.1 to Figure 11.3 present the zones of floating condensate exposure for each season.

Table 11.1 Maximum distances and directions travelled from the release location to floating condensate exposure for each season and threshold, following a subsea LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating condensate exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	82.0	2.6	-
	Max. distance from release site (km) (99th percentile)	45.4	2.6	-
	Direction	West	Southwest	-
Transitional	Max. distance from release site (km)	73.5	4.3	-
	Max. distance from release site (km) (99th percentile)	60.5	4.3	-
	Direction	North-northeast	Northeast	-
Winter	Max. distance from release site (km)	70.3	4.3	-
	Max. distance from release site (km) (99th percentile)	58.5	4.3	-
	Direction	East-northeast	Northeast	-

Table 11.2 Summary of the potential floating condensate exposure to individual receptors, following a LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
AMP	Montebello	-	-	-	-	-	-	6	-	-	6.38	-	-	6	-	-	38.79	-	-
BIA	Flatback Turtle - Internesting Buffer	95	-	-	0.67	-	-	100	-	-	0.88	-	-	97	-	-	0.71	-	-
	Flatback Turtle - Nesting	-	-	-	-	-	-	6	-	-	6.38	-	-	6	-	-	38.67	-	-
	Humpback Whale - Migration	11	-	-	7.75	-	-	15	-	-	3.29	-	-	20	-	-	3.88	-	-
	Pygmy Blue Whale - Distribution*	100	89	-	0.13	0.71	-	100	94	-	0.13	0.46	-	100	99	-	0.13	0.46	-
	Wedge-tailed Shearwater – Breeding*	100	89	-	0.13	0.71	-	100	94	-	0.13	0.46	-	100	99	-	0.13	0.46	-
	Whale Shark - Foraging	89	-	-	0.88	-	-	81	-	-	1.08	-	-	87	-	-	1.29	-	-
EEZ	Australian Exclusive Economic Zone*	100	89	-	0.13	0.71	-	100	94	-	0.13	0.46	-	100	99	-	0.13	0.46	-
IAA	Barrow & Montebello Islands IAA	-	-	-	-	-	-	6	-	-	6.38	-	-	6	-	-	38.79	-	-
	Offshore Area*	100	89	-	0.13	0.71	-	100	94	-	0.13	0.46	-	100	99	-	0.13	0.46	-
IMCRA	Northwest Shelf	3	-	-	32.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara (offshore)	88	-	-	0.88	-	-	84	-	-	1.04	-	-	89	-	-	1.29	-	-
KEF	Ancient coastline at 125 m depth contour	31	-	-	5.79	-	-	27	-	-	3.13	-	-	41	-	-	2.21	-	-
	Continental Slope Demersal Fish Communities*	100	89	-	0.13	0.71	-	100	94	-	0.13	0.46	-	100	99	-	0.13	0.46	-

*The release location resides within the receptor boundaries.

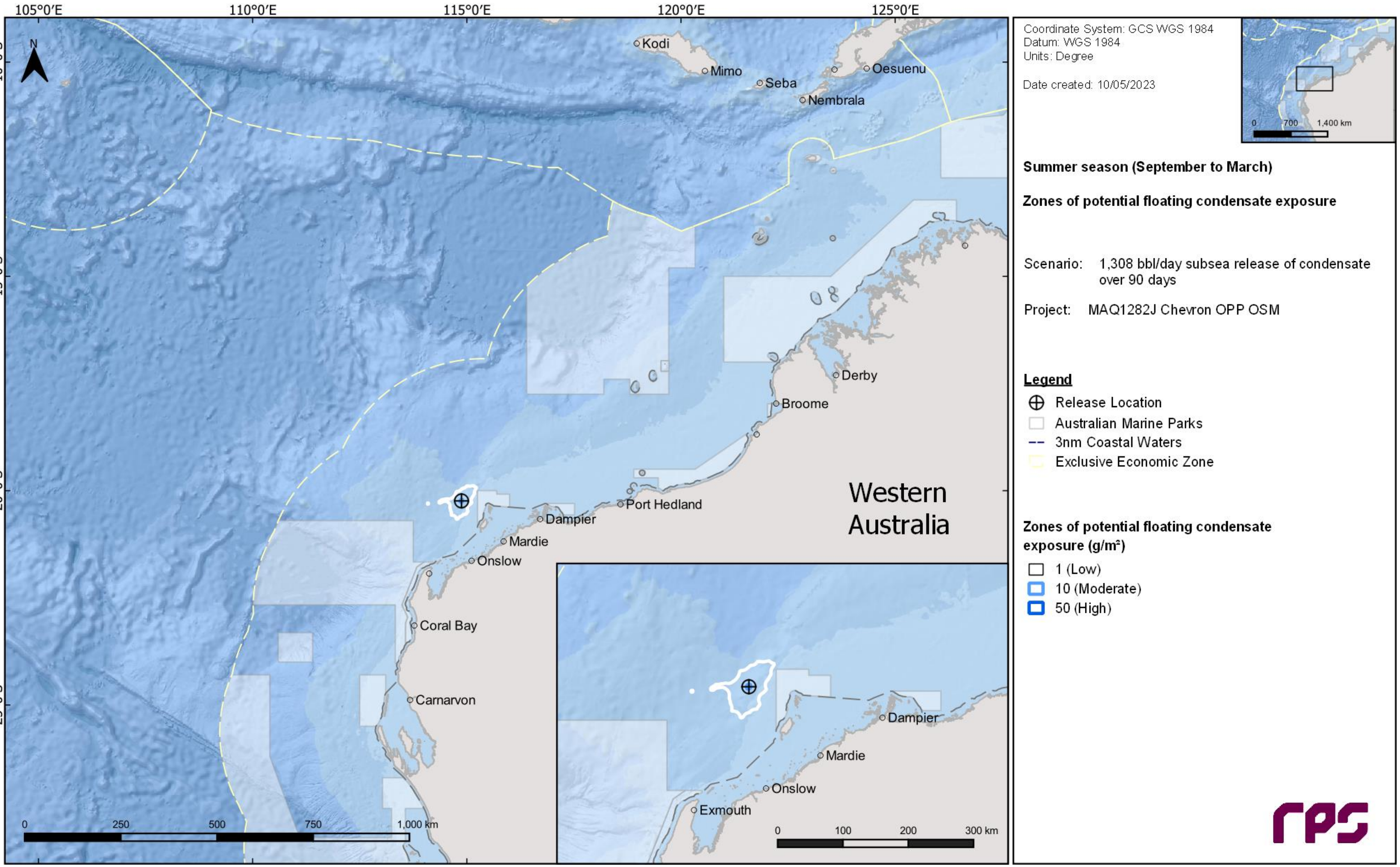


Figure 11.1 Zones of potential floating condensate exposure following a subsea LOWC at Chrysaor Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

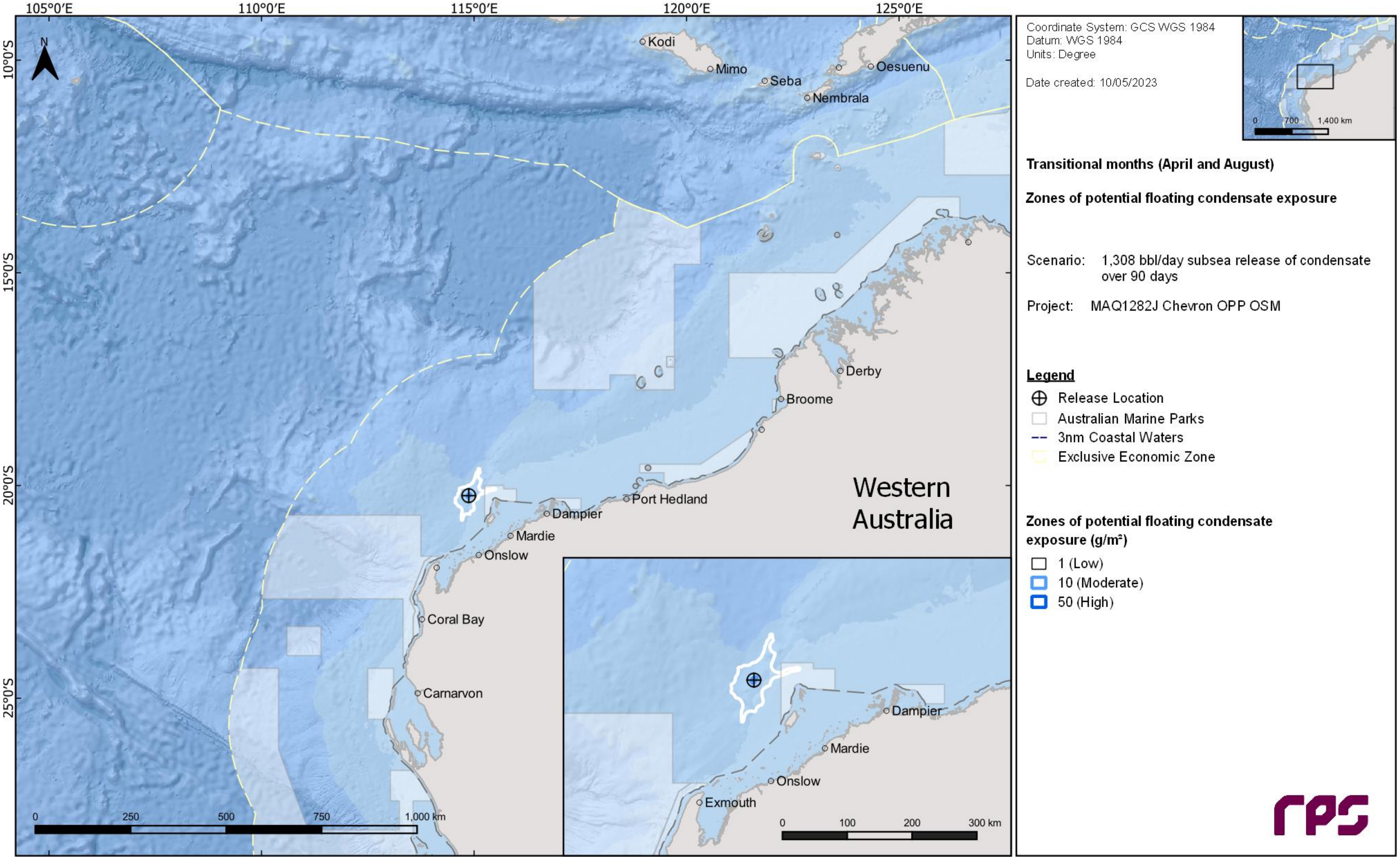


Figure 11.2 Zones of potential floating condensate exposure following a subsea LOWC at Chrysaor Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

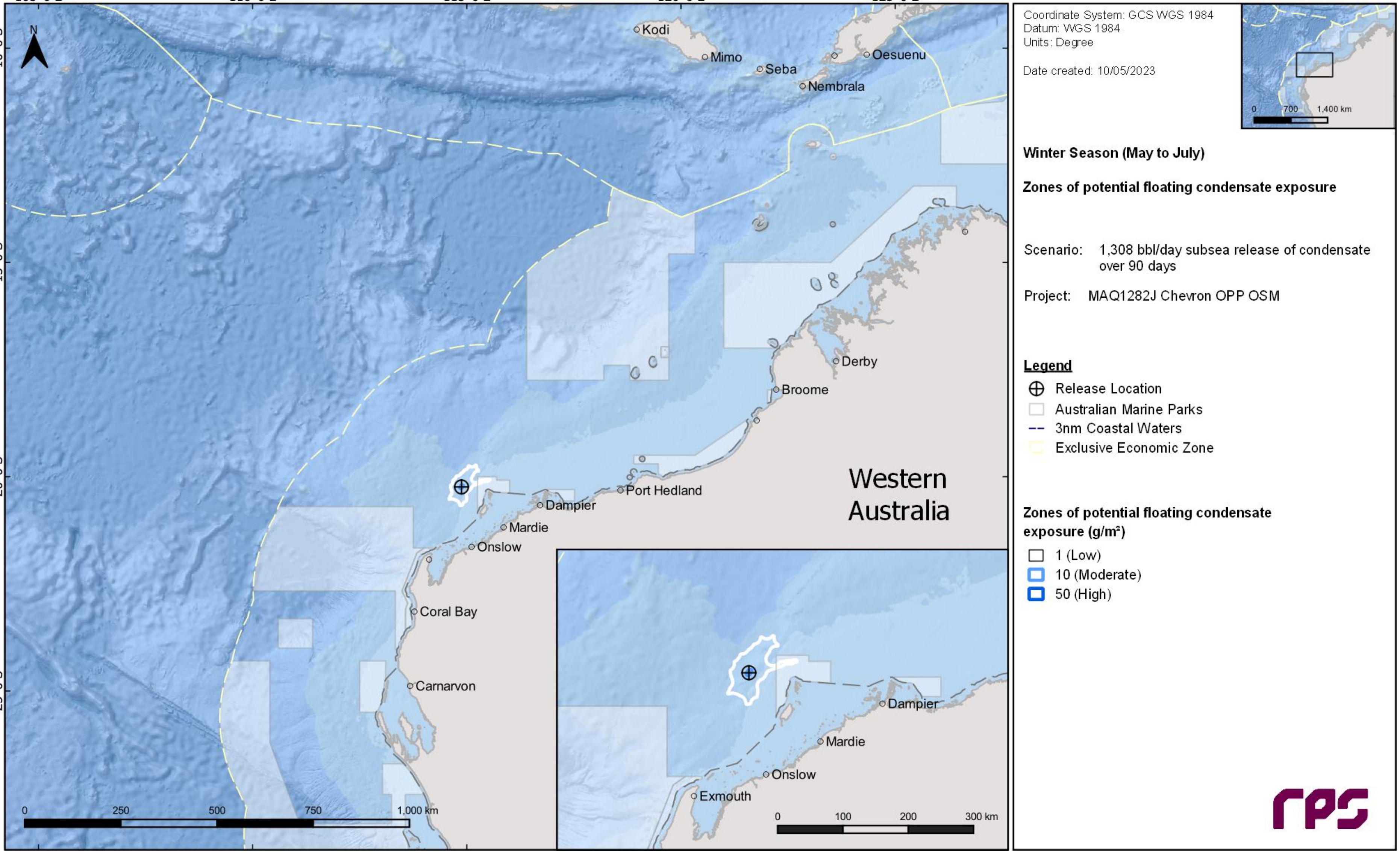


Figure 11.3 Zones of potential floating condensate exposure following a subsea LOWC at Chrysaor Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.2 Shoreline Accumulation

Table 11.3 presents a summary of the predicted shoreline accumulation during summer, transitional and winter seasons. The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 32%, while the minimum time before shoreline accumulation was 4.29 days and the maximum volume of oil ashore was 32.0 m^3.

No high (≥ 1,000 g/m^2) shoreline threshold accumulation was predicted in the modelling results.

Table 11.4 to Table 11.6 summarises the shoreline accumulation on individual receptors for each season.

During summer conditions, condensate had accumulated on 56 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands and Ningaloo Coast World Heritage Area IAAs (22%). In comparison, during transitional and winter conditions, condensate had accumulated on 6 and 4 shoreline receptors, respectively. The greatest probabilities of shoreline accumulation occurred at Muiron Islands, Ningaloo Coast World Heritage Area and North Muiron Island, all 3% probability during transitional season and at Muiron Islands, Ningaloo Coast World Heritage Area and South Muiron Island, all 1% probability during winter.

The maximum potential shoreline accumulation is presented for each season in Figure 11.4 to Figure 11.6.

Table 11.3 Summary of condensate accumulation across all shorelines for each season and threshold, following a subsea LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of accumulation on any shoreline (%)	32	3	1
Absolute minimum time for visible oil to shore (days)	4.29	18.83	36.42
Maximum volume of hydrocarbons ashore (m^3)	32.0	1.2	0.8
Average volume of hydrocarbons ashore (m^3)	9.2	0.2	0.2
Maximum length of the shoreline at **10 g/m^2** (km)	131	2	2
Average shoreline length (km) at **10 g/m^2** (km)	38.8	1.7	2
Maximum length of the shoreline at **100 g/m^2** (km)	5	-	-
Average shoreline length (km) at **100 g/m^2** (km)	2.7	-	-
Maximum length of the shoreline at **1,000 g/m^2** (km)	-	-	-
Average shoreline length (km) at **1,000 g/m^2** (km)	-	-	-

Table 11.4 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories days during summer (September to the following March) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	11	-	-	19.04	-	-	44	85	1.6	2.1	2.4	-	-	2.9	-	-
	Ashburton Island	5	-	-	19.5	-	-	7	17	0.2	0.4	1.3	-	-	1.9	-	-
	Barrow & Montebello Islands IAA	22	4	-	8	23.25	-	7	170	4.6	15.7	22.2	1	-	47.1	1	-
	Barrow Island (West Coast)	15	-	-	19.42	-	-	7	48	1.8	4.9	11	-	-	15.4	-	-
	Barrow Island Group	15	4	-	18.29	23.25	-	9	170	3.6	10.7	19.4	1	-	25	1	-
	Bessieres Island	11	-	-	19.21	-	-	16	52	0.7	1.1	2.1	-	-	2.9	-	-
	Boodie Island	14	4	-	18.29	23.25	-	17	170	1.1	3.7	3.5	1	-	3.8	1	-
	Cape Range National Park	13	-	-	4.5	-	-	5	42	1.4	5.4	6.8	-	-	17.3	-	-
	Dampier Archipelago IAA	2	-	-	44.92	-	-	3	19	0.6	2.1	1.9	-	-	2.9	-	-
	Dampier mainland coastline	1	-	-	45.04	-	-	3	19	0.4	0.8	1.9	-	-	1.9	-	-
	Great Sandy Island	11	-	-	25.13	-	-	12	33	0.5	0.9	2.1	-	-	2.9	-	-
	Hermite Island	17	-	-	24.33	-	-	7	48	1	4.3	6.5	-	-	15.4	-	-
	Lowendal Islands Group	1	-	-	73	-	-	4	10	0.1	0.3	1	-	-	1	-	-
	Middle Island	15	-	-	19.29	-	-	14	84	1.1	2.9	5.2	-	-	6.7	-	-
	Middle Ningaloo Coast - World Heritage Area	5	-	-	83.54	-	-	4	13	0.6	1.4	1.2	-	-	1.9	-	-
	Montebello Islands Group	17	-	-	24.33	-	-	6	48	1.1	4.6	6.6	-	-	15.4	-	-
	Muiron Islands	18	-	-	4.54	-	-	6	34	0.8	2.6	3.3	-	-	9.6	-	-
	Ningaloo Coast World Heritage Area	22	-	-	4.29	-	-	6	69	2.6	8.5	9.2	-	-	22.1	-	-
	North Muiron Island	14	-	-	22.58	-	-	6	26	0.3	0.9	1.6	-	-	3.8	-	-
	North Ningaloo Coast - World Heritage Area	17	-	-	4.29	-	-	7	69	1.7	8	6.1	-	-	22.1	-	-
	North Sandy Island	4	-	-	27.71	-	-	6	15	0.1	0.3	1	-	-	1	-	-
	Onslow Area Mainland Coastline	6	-	-	29.29	-	-	4	22	2.2	3.9	4.2	-	-	4.8	-	-
	Pilbara Coast IAA	14	6	-	17.88	18.71	-	9	278	9.4	28.1	31.4	3.7	-	46.2	4.8	-
	Pilbara Coast Islands Group	11	6	-	17.92	18.71	-	19	278	6.9	16.4	15.7	3.7	-	19.2	4.8	-
	Pilbara Mainland Coast	6	-	-	29.29	-	-	4	22	2.2	3.9	4.2	-	-	4.8	-	-
	Serrurier Island	11	6	-	17.92	18.71	-	41	278	5.1	12.8	7.8	3.7	-	9.6	4.8	-
	Sholl Island	3	-	-	44.33	-	-	5	16	0.2	0.5	1.3	-	-	1.9	-	-
	South Muiron Island	13	-	-	4.54	-	-	7	34	0.5	1.6	2.9	-	-	5.8	-	-
	Thevenard Island	11	-	-	19	-	-	23	95	3	4.8	7.2	-	-	9.6	-	-
	Trimouille Island	2	-	-	48.46	-	-	4	14	0.2	0.4	1	-	-	1	-	-
	Varanus Island	1	-	-	73	-	-	4	10	0.1	0.2	1	-	-	1	-	-
Shoreline	Airlie Island	11	-	-	19.04	-	-	44	85	1.6	2.1	2.4	-	-	2.9	-	-
	Ashburton Island	5	-	-	19.5	-	-	7	17	0.2	0.4	1.3	-	-	1.9	-	-
	Barrow Island	15	-	-	19.42	-	-	7	84	2.1	6	12.2	-	-	16.4	-	-
	Bessieres Island	11	-	-	19.21	-	-	16	52	0.7	1.1	2.1	-	-	2.9	-	-
	Boodie Island	15	4	-	18.29	23.25	-	18	170	1.3	4	4.2	1	-	4.8	1	-
	Direction Island	1	-	-	33.96	-	-	7	15	< 0.1	0.2	1	-	-	1	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Exmouth	18	-	-	4.29	-	-	6	69	2.9	12.1	11	-	-	35.6	-	-
Flat Island	11	-	-	17.88	-	-	19	75	0.8	2	2.5	-	-	3.8	-	-
Karratha	7	-	-	29.29	-	-	4	25	2.1	4.3	4.7	-	-	6.7	-	-
Lowendal Island	11	-	-	36.04	-	-	7	31	0.4	1.1	1.7	-	-	2.9	-	-
Mangrove Islands	1	-	-	43.33	-	-	4	11	0.3	0.4	1	-	-	1	-	-
Mary Anne Group	11	-	-	23.04	-	-	14	50	2	2.8	7.3	-	-	8.7	-	-
Middle Island	15	-	-	19.29	-	-	14	84	1.4	3.9	6.7	-	-	8.7	-	-
Montebello Islands	18	-	-	8	-	-	6	48	1.6	7.1	9.8	-	-	25	-	-
Muiron Islands	18	-	-	4.54	-	-	6	34	0.8	2.6	3.3	-	-	9.6	-	-
Observation Island	2	-	-	68.88	-	-	6	18	0.1	0.3	1	-	-	1	-	-
Passage Islands	11	-	-	25.13	-	-	6	48	1.6	3.5	4.8	-	-	9.6	-	-
Peak Island	4	-	-	32.63	-	-	7	13	< 0.1	0.2	1	-	-	1	-	-
Round Island	8	-	-	21.29	-	-	12	20	0.1	0.2	1	-	-	1	-	-
Serrurier Island	11	6	-	17.92	18.71	-	41	278	5.1	12.8	7.8	3.7	-	9.6	4.8	-
Sunday Island	5	-	-	23.67	-	-	7	19	0.1	0.4	1.3	-	-	1.9	-	-
Table Island	8	-	-	33.13	-	-	11	20	0.1	0.2	1	-	-	1	-	-
Thevenard Island	11	-	-	19	-	-	23	95	3	4.8	7.2	-	-	9.6	-	-
Tortoise Island	2	-	-	18.38	-	-	9	25	0.1	0.3	1	-	-	1	-	-
Twin Island	3	-	-	44.63	-	-	5	12	0.1	0.3	1	-	-	1	-	-

Table 11.5 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories days during transitional (April and August) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IAA	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	3	-	-	18.83	-	-	4	30	0.2	0.9	1	-	-	1	-	-
	Ningaloo Coast World Heritage Area	3	-	-	18.83	-	-	4	30	0.2	1	1	-	-	1	-	-
	North Muiron Island	3	-	-	18.83	-	-	5	30	0.1	0.7	1	-	-	1	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	2	-	-	19.67	-	-	6	15	0.1	0.2	1	-	-	1	-	-
	Pilbara Coast Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Varanus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoreline	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Direction Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flat Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mangrove Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Muiron Islands	3	-	-	18.83	-	-	4	30	0.2	0.9	1	-	-	1	-	-
Observation Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	2	-	-	19.67	-	-	10	15	0.1	0.2	1	-	-	1	-	-
Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sunday Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Table Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tortoise Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Twin Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 11.6 Summary of shoreline condensate accumulation to individual receptors, following a LOWC at Chrysaor Well 5. The results were calculated from 100 spill trajectories days during winter (May to July) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lowendal Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IAA	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	1	-	-	36.42	-	-	4	18	0.2	0.6	1.9	-	-	1.9	-	-
	Ningaloo Coast World Heritage Area	1	-	-	36.42	-	-	4	18	0.1	0.7	1.9	-	-	1.9	-	-
	North Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	1	-	-	36.42	-	-	5	18	0.1	0.4	1.9	-	-	1.9	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Varanus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ashburton Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoreline	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Direction Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flat Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mangrove Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Muiron Islands	1	-	-	36.42	-	-	4	18	0.2	0.6	1.9	-	-	1.9	-	-
Observation Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sunday Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Table Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tortoise Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Twin Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

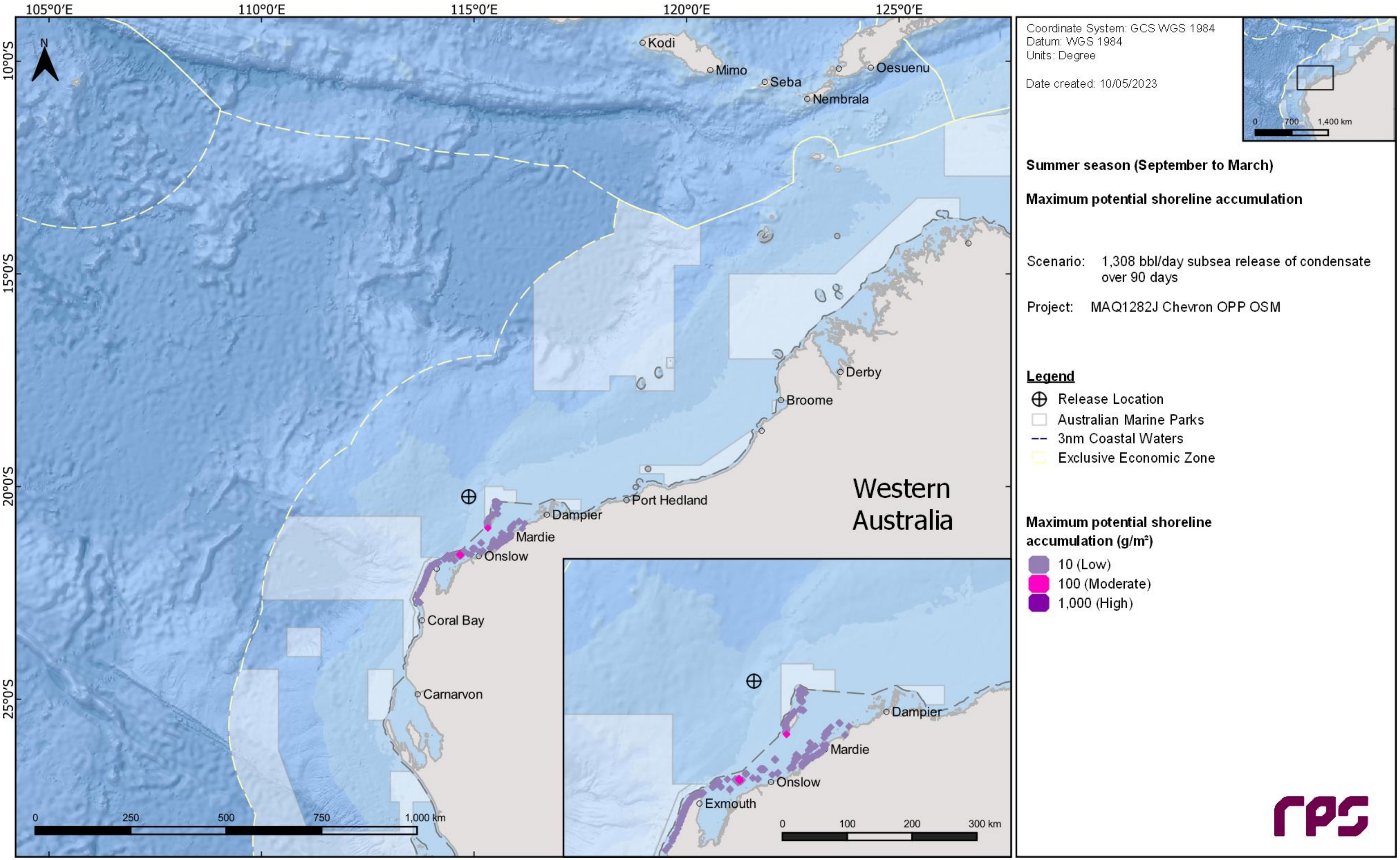


Figure 11.4 Maximum potential shoreline accumulation following a subsea LOWC at Chrysaor Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

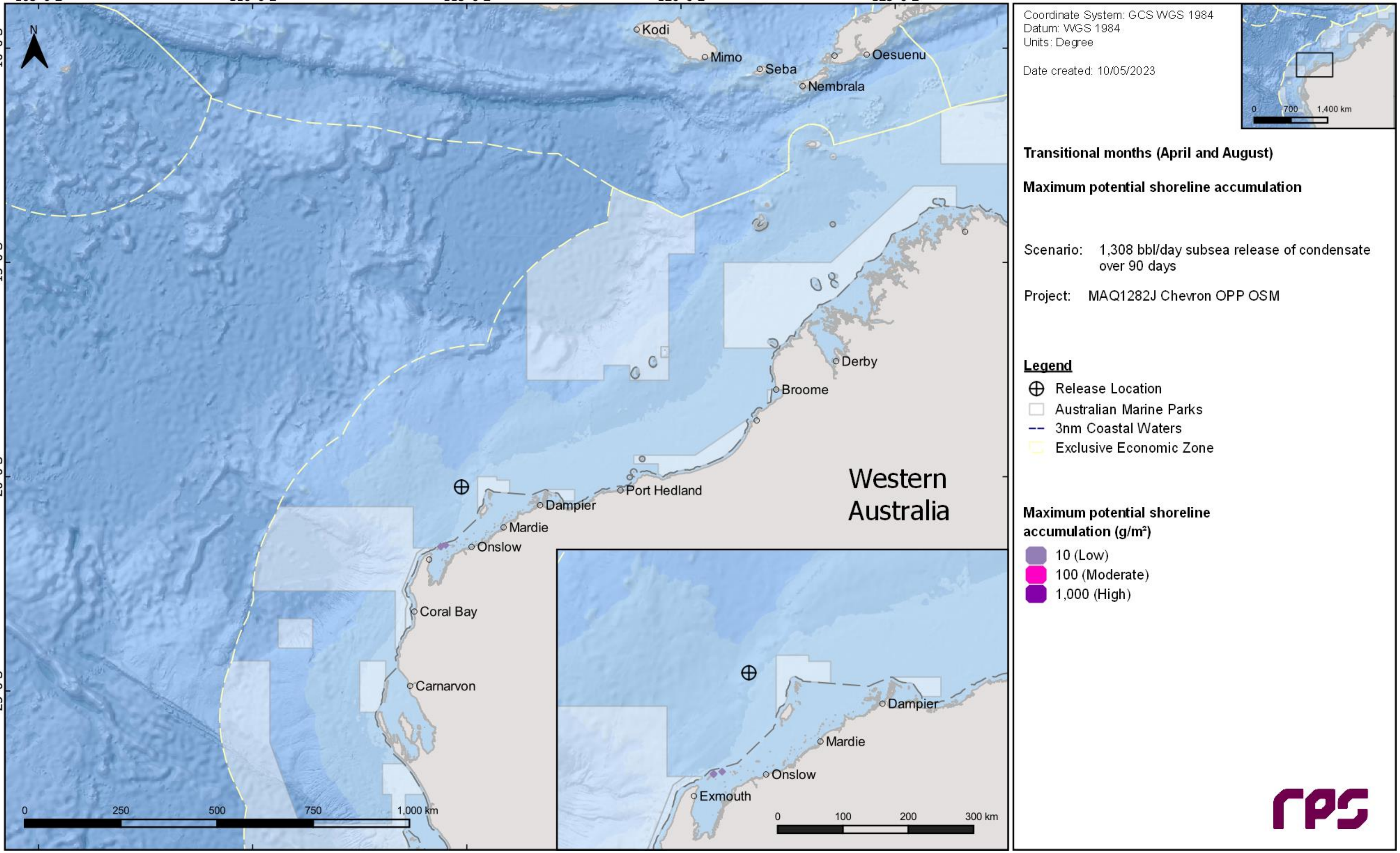


Figure 11.5 Maximum potential shoreline accumulation following a subsea LOWC at Chrysaor Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

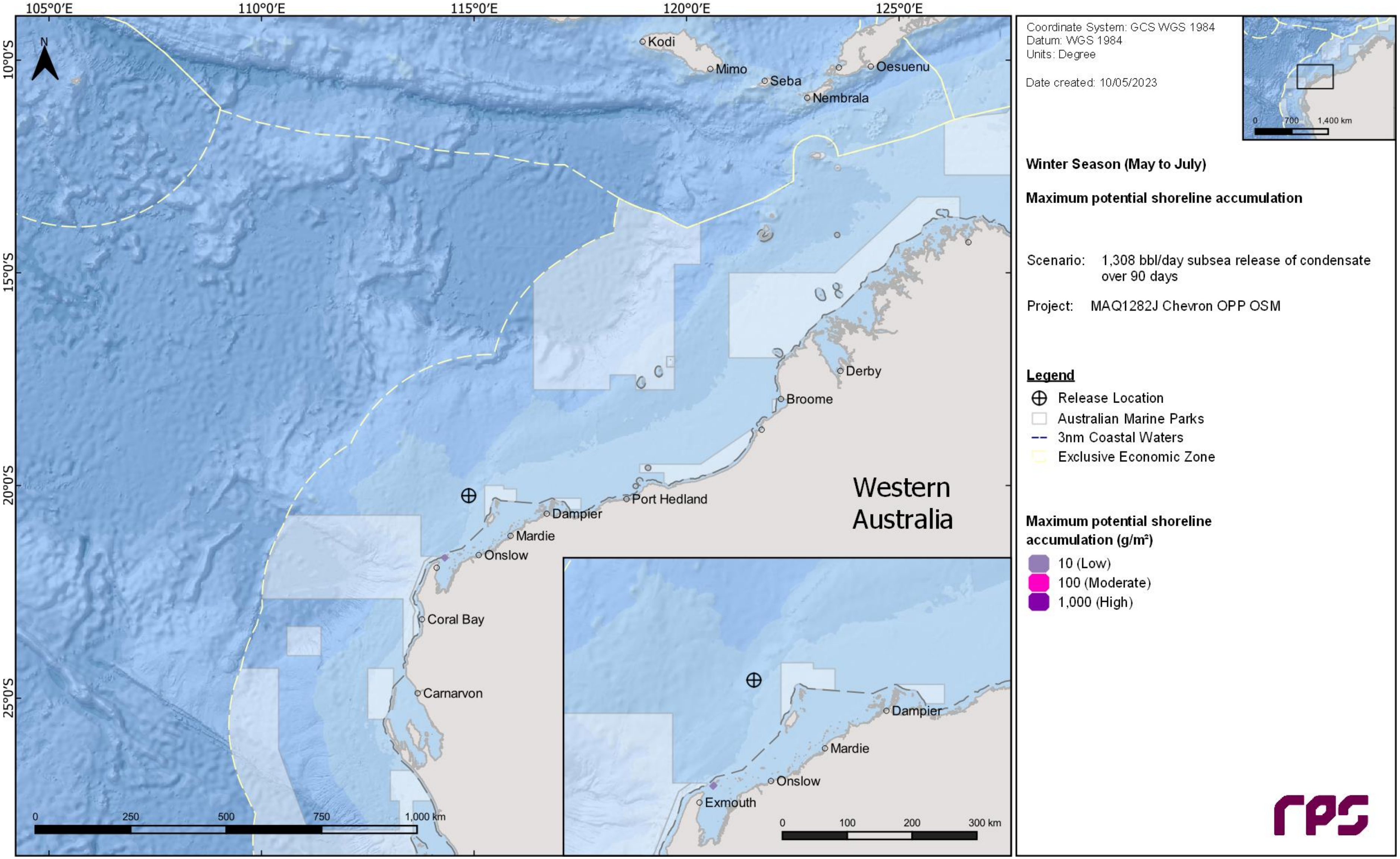


Figure 11.6 Maximum potential shoreline accumulation following a subsea LOWC at Chrysaor Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3 Water Column Exposure

11.1.3.1 Dissolved Hydrocarbons

No dissolved hydrocarbon exposure was predicted for this scenario above the low reporting threshold (≥10 ppb) during any of the seasons modelled. Consequently, no results are reported.

11.1.3.2 Entrained Hydrocarbons

Table 11.7 summarises the probability and minimum time before exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

A total of 35 BIAs were predicted to be exposed at, or above, the low threshold during summer, compared to 20 during transitional and winter. Excluding the Pygmy Blue Whale - Distribution and Wedge-tailed Shearwater – Breeding BIAs which the release location resides within, the highest probabilities of exposure were predicted for the Flatback Turtle - Internesting Buffer and Humpback Whale - Migration BIAs at 100% during all seasons.

During summer conditions, 6 AMPs were predicted to be exposed at, or above the low threshold, and 5 AMPs under transitional and winter conditions. The highest probabilities predicted were at the Gascoyne AMP (80% summer, 82% transitional and 87% winter). Furthermore, the Montebello AMP was predicted to be exposed to entrained hydrocarbons at the high threshold during summer (3%), transitional (6%) and winter (3%), respectively.

During summer, transitional and winter conditions, 7, 5 and 5 KEFs were predicted to be exposed by at the low threshold, respectively. Probabilities ranged between 5–100%, 16–100% and 18–100%, for each season, respectively. Excluding the KEF that the release location resides within (Continental Slope Demersal Fish Communities), the ancient coastline at 125 m depth contour KEF recorded the highest probability of exposure for all three seasons (98%, 100% and 95% during summer, transitional and winter, respectively).

Additionally, 38, 12 and 11 IAA (including the Offshore IAA that the release site is located within), were predicted to be exposed to entrained hydrocarbons at low threshold. Excluding the Offshore, the probabilities for each season ranged between 1–80%, 1–82% and 1–87% under summer, transitional and winter conditions, respectively, with the maximum probabilities occurring at the Gascoyne IAA during all seasons.

Furthermore, a total of 46, 5 and 2 RSB receptors were predicted to be exposed to entrained hydrocarbons at the low threshold with maximum seasonal probabilities of 36%, 18% and 26% for Rankin Bank, during summer, transitional and winter, respectively.

Figure 11.7 to Figure 11.9 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

The same maps for the 10-20 m depth layer are presented in Figure 11.10 to Figure 11.12.

Table 11.7 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at Chrysaor Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
AMP	Argo-Rowley Terrace	28.8	11	-	21.17	-	27.9	8	-	22.46	-	31.5	9	-	41.04	-
	Carnarvon Canyon	12.9	2	-	99.5	-	12.4	2	-	42.75	-	15.2	3	-	22.88	-
	Gascoyne	100.6	80	1	2.42	73.13	93.3	82	-	5.67	-	73.8	87	-	4.58	-
	Montebello	117.3	49	3	3.17	7.08	121.6	30	6	6.17	27.42	123.6	41	3	6.63	54.46
	Ningaloo	67.8	25	-	3.21	-	25.8	16	-	12.25	-	25.2	18	-	8.92	-
	Shark Bay	15.8	4	-	82	-	9.3	-	-	-	-	7.9	-	-	-	-
BIA	Dugong - Breeding	66.6	23	-	3.63	-	24.9	10	-	13.5	-	25.2	8	-	9.5	-
	Dugong - Calving	66.6	23	-	3.63	-	24.9	10	-	13.5	-	25.2	8	-	9.5	-
	Dugong - Foraging	66.6	23	-	3.63	-	24.9	10	-	13.5	-	25.2	8	-	9.5	-
	Dugong - Nursing	66.6	23	-	3.63	-	24.9	10	-	13.5	-	25.2	8	-	9.5	-
	Fairy Tern - Breeding	80.8	20	-	3.75	-	25.8	11	-	12.21	-	24.1	15	-	9.33	-
	Flatback Turtle - Aggregation	25.4	11	-	22.83	-	2.3	-	-	-	-	1.4	-	-	-	-
	Flatback Turtle - Foraging	39.1	11	-	18	-	2.3	-	-	-	-	2.1	-	-	-	-
	Flatback Turtle - Internesting	25.4	11	-	22.83	-	2.3	-	-	-	-	1.4	-	-	-	-
	Flatback Turtle - Internesting Buffer	362.9	100	80	0.46	0.75	348.9	100	55	0.88	3.21	345.8	100	77	0.38	0.63
	Flatback Turtle - Mating	39.1	11	-	18	-	2.3	-	-	-	-	2.1	-	-	-	-
	Flatback Turtle - Nesting	149.4	75	6	1.63	15.54	86.5	62	-	4.25	-	105.4	75	1	2.75	3.96
	Green Turtle - Aggregation	25.4	11	-	22.83	-	2.3	-	-	-	-	1.4	-	-	-	-
	Green Turtle - Basking	39.1	11	-	17.92	-	1.7	-	-	-	-	2.1	-	-	-	-
	Green Turtle - Foraging	39.1	11	-	5.63	-	3.3	-	-	-	-	2.1	-	-	-	-
	Green Turtle - Internesting	39.1	11	-	5.63	-	3.3	-	-	-	-	2.1	-	-	-	-
	Green Turtle - Internesting Buffer	123.3	30	6	2.5	16.75	41.8	25	-	8.33	-	43	31	-	4.92	-
	Green Turtle - Mating	39.1	11	-	5.63	-	3.3	-	-	-	-	2.1	-	-	-	-
	Green Turtle - Nesting	123.3	30	6	2.63	16.71	44.7	21	-	8.38	-	43.9	23	-	5.33	-
	Hawksbill Turtle - Foraging	39.1	11	-	18	-	1.7	-	-	-	-	2.1	-	-	-	-
	Hawksbill Turtle - Internesting	17.7	8	-	37.63	-	0.6	-	-	-	-	1.2	-	-	-	-
	Hawksbill Turtle - Internesting Buffer	90.8	33	-	2.67	-	42.9	24	-	8.25	-	43	21	-	4.96	-
	Hawksbill Turtle - Mating	39.1	11	-	18	-	1.7	-	-	-	-	2.1	-	-	-	-
	Hawksbill Turtle - Nesting	123.3	30	6	2.63	16.71	40.9	21	-	8.38	-	43.7	23	-	5.33	-
	Humpback Whale - Migration	188.3	100	12	0.54	4.54	141.5	100	10	1.79	5.42	143	100	14	1.17	3.25
	Humpback Whale - Resting	44.6	15	-	17.67	-	5.6	-	-	-	-	5.5	-	-	-	-
	Lesser Crested Tern - Breeding	92.1	24	-	3.75	-	41.8	12	-	11.13	-	42.8	13	-	6.08	-
	Little Tern - Resting	12.9	1	-	65.58	-	3.6	-	-	-	-	3.8	-	-	-	-
	Loggerhead Turtle - Internesting Buffer	123.3	33	6	2.5	16.75	32.9	24	-	9.83	-	38.7	31	-	6.67	-
	Loggerhead Turtle - Nesting	67.8	29	-	2.83	-	25.8	17	-	11.96	-	25.2	19	-	8.38	-
	Pygmy Blue Whale – Distribution*	720.1	100	100	0.04	0.17	760.3	100	100	0.04	0.17	757.1	100	100	0.04	0.17
	Pygmy Blue Whale - Foraging	49.8	57	-	2.46	-	45.4	38	-	6.08	-	35.6	35	-	5.75	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Roseate Tern - Breeding	109.8	25	1	2.92	47.5	42.6	17	-	7.25	-	39.6	28	-	6.54	-
	Wedge-tailed Shearwater – Breeding*	720.1	100	100	0.04	0.17	760.3	100	100	0.04	0.17	757.1	100	100	0.04	0.17
	Whale Shark - Foraging	336.2	100	59	0.63	1.21	309	100	42	1.21	3.38	306.5	100	54	0.46	1.58
	White-tailed Tropicbird - Breeding	14.5	2	-	60.54	-	7.1	-	-	-	-	6.7	-	-	-	-
CP	Montebello Islands	22.8	9	-	41.08	-	0.7	-	-	-	-	0.5	-	-	-	-
EEZ	Australian Exclusive Economic Zone *	720.1	100	100	0.04	0.17	760.3	100	100	0.04	0.17	757.1	100	100	0.04	0.17
	Airlie Island	43.6	11	-	18.42	-	2.3	-	-	-	-	2.9	-	-	-	-
	Argo-Rowley Terrace IAA	28.8	11	-	21.17	-	27.9	8	-	22.46	-	31.5	9	-	41.04	-
	Ashburton Island	20	6	-	18.42	-	0.5	-	-	-	-	0.6	-	-	-	-
	Barrow & Montebello Islands IAA	117.3	49	3	3.17	7.08	121.6	30	6	6.17	27.42	123.6	41	3	6.63	54.46
	Barrow Island (East Coast)	19.5	11	-	36.46	-	0.3	-	-	-	-	1.2	-	-	-	-
	Barrow Island (West Coast)	36.8	11	-	18.46	-	1.3	-	-	-	-	1.6	-	-	-	-
	Barrow Island Group	39.1	11	-	18	-	1.3	-	-	-	-	1.7	-	-	-	-
	Bessieres Island	63.5	14	-	16.25	-	15.7	4	-	17.29	-	7.4	-	-	-	-
	Boodie Island	38.6	11	-	18	-	0.5	-	-	-	-	1.5	-	-	-	-
	Cape Range National Park	23.8	9	-	37.42	-	11.7	1	-	17.38	-	8.5	-	-	-	-
	Dampier Archipelago IAA	13	5	-	28.88	-	1.1	-	-	-	-	1.5	-	-	-	-
	Exmouth IAA	31.6	20	-	16.58	-	8.5	-	-	-	-	7.4	-	-	-	-
	Gascoyne IAA	100.6	80	1	2.42	73.13	93.3	82	-	5.67	-	73.8	87	-	4.58	-
	Glomar Shoal	26.4	5	-	30.71	-	0.6	-	-	-	-	0.8	-	-	-	-
	Great Sandy Island	27.4	6	-	23.58	-	0.3	-	-	-	-	0.4	-	-	-	-
	Hermite Island	22.8	10	-	40.29	-	1	-	-	-	-	0.6	-	-	-	-
IAA	Middle Island	39.1	11	-	21.5	-	0.5	-	-	-	-	1.7	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	14.2	8	-	6.46	-	7.5	-	-	-	-	7.5	-	-	-	-
	Montebello Islands Group	22.8	10	-	40.29	-	1	-	-	-	-	0.6	-	-	-	-
	Muiron Islands	45.9	29	-	3.54	-	9.8	-	-	-	-	10.4	1	-	34.33	-
	Ningaloo Coast World Heritage Area	67.8	29	-	3.21	-	25.8	16	-	12.25	-	25.2	18	-	8.42	-
	North Muiron Island	41.7	29	-	3.54	-	9.8	-	-	-	-	10.4	1	-	34.33	-
	North Ningaloo Coast - World Heritage Area	53.9	22	-	17.67	-	6.4	-	-	-	-	5	-	-	-	-
	North Sandy Island	18.3	6	-	27.75	-	0.2	-	-	-	-	0.3	-	-	-	-
	Offshore Area*	720.1	100	100	0.04	0.17	760.3	100	100	0.04	0.17	757.1	100	100	0.04	0.17
	Onslow Area Mainland Coastline	17.3	6	-	25.63	-	0.3	-	-	-	-	0.7	-	-	-	-
	Passage Island	11.7	4	-	29.13	-	0.1	-	-	-	-	0.3	-	-	-	-
	Pilbara Coast IAA	123.3	29	6	3.42	16.71	21.8	11	-	11.38	-	19	7	-	6.83	-
	Pilbara Coast Islands Group	118.5	14	5	16.17	21.25	15.8	4	-	17.29	-	10.2	1	-	48.17	-
	Pilbara Mainland Coast	17.3	6	-	25.63	-	0.3	-	-	-	-	0.7	-	-	-	-
	Rankin Bank	111.7	36	1	4.83	14.67	108.4	17	3	9.33	29.04	110.8	26	3	6.75	56.08
	Serrurier Island	118.5	14	5	16.17	21.25	15.8	4	-	18.13	-	10.2	1	-	48.17	-
	Shark Bay mainland coastline	19.6	4	-	81.08	-	11.1	1	-	48	-	9.8	-	-	-	-

Receptor		Summer: Maximum exposure to entrained hydrocarbons (ppb)	Summer: Probability of exposure to entrained hydrocarbons (%)		Summer: Minimum time before exposure to entrained hydrocarbons (Days)		Transitional: Maximum exposure to entrained hydrocarbons (ppb)	Transitional: Probability of exposure to entrained hydrocarbons (%)		Transitional: Minimum time before exposure to entrained hydrocarbons (Days)		Winter: Maximum exposure to entrained hydrocarbons (ppb)	Winter: Probability of exposure to entrained hydrocarbons (%)		Winter: Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Sholl Island	11.2	1	-	46.04	-	0.1	-	-	-	-	0.3	-	-	-	-
	South Muiron Island	45.9	27	-	13.71	-	7.9	-	-	-	-	7.9	-	-	-	-
	Thevenard Island	51.6	12	-	17.13	-	3.3	-	-	-	-	2.7	-	-	-	-
	Trimouille Island	13.7	4	-	42.21	-	0.4	-	-	-	-	0.5	-	-	-	-
	Yammadery Island	11.6	4	-	37.79	-	0.1	-	-	-	-	0.2	-	-	-	-
IBRA	Cape Range	119.5	29	5	3.54	17.75	16.5	6	-	17.38	-	10.4	1	-	34.33	-
	Roebourne	41.4	11	-	18	-	2.3	-	-	-	-	2.9	-	-	-	-
IMCRA	Ningaloo	67.8	39	-	2.83	-	34.3	27	-	11.08	-	34.6	24	-	8.42	-
	Northwest Shelf	174.7	76	4	1.92	5.54	178.7	71	9	7.08	25.83	184.9	70	5	4.29	30.21
	Pilbara (nearshore)	47.4	22	-	16.58	-	9.9	-	-	-	-	8.7	-	-	-	-
	Pilbara (offshore)	337.1	100	63	0.63	1.21	323	100	47	1.25	3.42	332.3	100	59	0.42	1.54
	Zuytdorp	19.6	4	-	81.04	-	11.1	1	-	48	-	9.8	-	-	-	-
KEF	Ancient coastline at 125 m depth contour	243.4	98	35	0.88	3.75	194.5	100	16	1.92	7.79	179.3	95	17	0.71	2.79
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	66.8	76	-	2.17	-	70.3	60	-	5.46	-	58.4	67	-	5.29	-
	Commonwealth waters adjacent to Ningaloo Reef	67.8	25	-	3.21	-	25.8	16	-	12.25	-	25.2	18	-	8.92	-
	Continental Slope Demersal Fish Communities*	720.1	100	100	0.04	0.17	760.3	100	100	0.04	0.17	757.1	100	100	0.04	0.17
	Exmouth Plateau	74.1	78	-	4.46	-	83.9	82	-	4.29	-	90.3	82	-	3.08	-
	Glomar Shoals	29	5	-	16.08	-	1	-	-	-	-	1.1	-	-	-	-
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	14.5	1	-	65.08	-	3.6	-	-	-	-	5.1	-	-	-	-
MMA	Barrow Island	46.5	12	-	5.04	-	4	-	-	-	-	2.6	-	-	-	-
	Muiron Islands	60	29	-	3.54	-	14.7	4	-	24.25	-	15.7	6	-	8.42	-
MP	Barrow Island	28.5	11	-	18	-	2.7	-	-	-	-	1.9	-	-	-	-
	Montebello Islands	25.4	12	-	5.42	-	4.3	-	-	-	-	1.7	-	-	-	-
	Ningaloo	66.6	25	-	4.13	-	23.9	10	-	13.5	-	23.1	8	-	9.67	-
	Rowley Shoals	11.6	1	-	65.96	-	3.6	-	-	-	-	3.8	-	-	-	-
NR	Great Sandy Island	38.6	11	-	21.46	-	0.2	-	-	-	-	0.5	-	-	-	-
	Thevenard Island	49.3	11	-	17.92	-	1.8	-	-	-	-	1.7	-	-	-	-
RSB	Australind Shoal	26.1	6	-	18.38	-	0.7	-	-	-	-	0.6	-	-	-	-
	Barrow Island Reefs and Shoals	38.6	11	-	21.08	-	0.4	-	-	-	-	0.8	-	-	-	-
	Brewis Reef	49.6	11	-	17.46	-	1.3	-	-	-	-	1.6	-	-	-	-
	Combe Reef	17.6	10	-	32.58	-	6.6	-	-	-	-	4.6	-	-	-	-
	Dailey Shoal	84.2	26	-	14.88	-	11.4	1	-	24.21	-	7.9	-	-	-	-
	Exmouth Reef	10.4	1	-	92.96	-	2.2	-	-	-	-	2.9	-	-	-	-
	Fairway Reef	53.9	14	-	17.04	-	7.4	-	-	-	-	6.9	-	-	-	-
	Flinders Shoal	34.2	6	-	22.08	-	0.3	-	-	-	-	0.4	-	-	-	-
	Glennie Patches	12.4	2	-	22.58	-	0.7	-	-	-	-	0.6	-	-	-	-
	Glomar Shoal	26.4	5	-	30.71	-	0.6	-	-	-	-	1	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Gorgon Patch	16.6	6	-	34.42	-	0.3	-	-	-	-	0.5	-	-	-	-
	Hastings Shoal	12.6	5	-	35.38	-	0.1	-	-	-	-	0.3	-	-	-	-
	Hayman Rock	10.3	2	-	77.83	-	2.1	-	-	-	-	2	-	-	-	-
	Herald Reef	13.7	5	-	33.71	-	0.2	-	-	-	-	0.6	-	-	-	-
	Hood Reef	89	14	-	16.42	-	9.5	-	-	-	-	9.1	-	-	-	-
	Inner Northwest Patch	10.7	1	-	83.88	-	0.3	-	-	-	-	0.8	-	-	-	-
	Koolinda Patch	13	5	-	37.17	-	0.1	-	-	-	-	0.4	-	-	-	-
	Lightfoot Reef	29.5	6	-	22.5	-	0.3	-	-	-	-	0.4	-	-	-	-
	Little Shoals	29.8	6	-	20.46	-	0.3	-	-	-	-	0.5	-	-	-	-
	Locker Reef	16	5	-	18.08	-	2.2	-	-	-	-	2.1	-	-	-	-
	McLennan Bank	11.8	1	-	45.38	-	0.1	-	-	-	-	0.3	-	-	-	-
	Meda Reef	10.8	1	-	94.71	-	0.1	-	-	-	-	0.3	-	-	-	-
	Miles Shoal	18.6	6	-	18.46	-	0.3	-	-	-	-	0.6	-	-	-	-
	Montebello Shoals	23.5	10	-	5.83	-	2.5	-	-	-	-	1.1	-	-	-	-
	Moresby Shoals	17.2	6	-	20.5	-	0.3	-	-	-	-	0.4	-	-	-	-
	Nares Rock	19.6	6	-	21.46	-	0.2	-	-	-	-	0.4	-	-	-	-
	Ningaloo Reef	50.8	22	-	4.38	-	13.3	4	-	15.83	-	12	3	-	9.96	-
	North West Reef	55.6	21	-	17.13	-	4.9	-	-	-	-	5.2	-	-	-	-
	Otway Reef	30.5	20	-	17.17	-	7.4	-	-	-	-	6.1	-	-	-	-
	Outtrim Patches	40.8	27	-	12.46	-	9	-	-	-	-	7	-	-	-	-
	Paroo Shoal	16.9	6	-	19.42	-	0.4	-	-	-	-	0.7	-	-	-	-
	Penguin Bank	37.8	15	-	16.13	-	17.4	4	-	11.29	-	2.4	-	-	-	-
	Poivre Reef	36.9	11	-	17.54	-	0.8	-	-	-	-	1.7	-	-	-	-
	Rankin Bank	111.7	36	1	4.42	14.67	108.4	18	3	9.13	29.04	110.8	26	3	6.75	56.08
	Ripple Shoals	44.6	11	-	19	-	0.6	-	-	-	-	1.6	-	-	-	-
	Rosily Shoals	54.6	14	-	16.29	-	14.6	4	-	15	-	3.2	-	-	-	-
	Saladin Shoal	13.9	5	-	23.71	-	0.3	-	-	-	-	0.5	-	-	-	-
	Santo Rock	18.4	6	-	17.46	-	1.6	-	-	-	-	1.6	-	-	-	-
	Spider Reef	14.1	8	-	78.38	-	5.3	-	-	-	-	5.5	-	-	-	-
	Sultan Reef	35.4	10	-	18.46	-	1.3	-	-	-	-	1.5	-	-	-	-
	Taunton Reef	33.1	11	-	19.38	-	1.4	-	-	-	-	1.6	-	-	-	-
	Tongue Shoals	11.6	3	-	22.67	-	0.6	-	-	-	-	1.1	-	-	-	-
	Trap Reef	41.8	11	-	17.29	-	2.4	-	-	-	-	2.4	-	-	-	-
	Tryal Rocks	24.2	15	-	5.08	-	6.1	-	-	-	-	1.4	-	-	-	-
	Weeks Shoal	16.2	6	-	20.5	-	0.2	-	-	-	-	0.5	-	-	-	-
	West Reef	26.5	6	-	21.58	-	0.4	-	-	-	-	0.5	-	-	-	-
Nearshore Waters	Airlie Island	43.6	11	-	18.42	-	2.3	-	-	-	-	2.9	-	-	-	-
	Ashburton	17.3	6	-	33.13	-	1	-	-	-	-	1.4	-	-	-	-
	Ashburton Island	17.2	6	-	18.42	-	0.4	-	-	-	-	0.6	-	-	-	-

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Barrow Island	36.8	11	-	18.46	-	1.1	-	-	-	-	1.6	-	-	-	-
	Bessieres Island	63.5	14	-	16.25	-	15.7	4	-	17.29	-	7.4	-	-	-	-
	Boodie Island	38.6	11	-	18	-	0.5	-	-	-	-	1.5	-	-	-	-
	Direction Island	14.8	6	-	34.42	-	0.3	-	-	-	-	0.4	-	-	-	-
	Exmouth	53.9	22	-	6.46	-	10.7	1	-	17.38	-	8.4	-	-	-	-
	Flat Island	119.5	16	5	16.13	17.75	16.5	6	-	18.13	-	10.4	1	-	48.33	-
	Karratha	16.9	6	-	25.75	-	0.4	-	-	-	-	0.5	-	-	-	-
	Lowendal Island	14.9	5	-	38.13	-	0.4	-	-	-	-	0.7	-	-	-	-
	Mangrove Islands	12.6	6	-	35.5	-	0.2	-	-	-	-	0.3	-	-	-	-
	Mary Anne Group	29	6	-	22.08	-	0.5	-	-	-	-	0.6	-	-	-	-
	Middle Island	39.1	11	-	21.21	-	0.5	-	-	-	-	1.7	-	-	-	-
	Montebello Islands	23.9	10	-	38.54	-	1.5	-	-	-	-	1.1	-	-	-	-
	Muiron Islands	45.9	29	-	3.54	-	9.8	-	-	-	-	10.4	1	-	34.33	-
	Observation Island	37.2	12	-	17.38	-	7.5	-	-	-	-	7.5	-	-	-	-
	Passage Islands	27.4	6	-	23.58	-	0.3	-	-	-	-	0.5	-	-	-	-
	Peak Island	114.9	26	3	12.54	32.04	11.8	2	-	18.58	-	9.4	-	-	-	-
	Round Island	104.2	14	1	16.38	82.33	10.6	1	-	21.75	-	8	-	-	-	-
	Serrurier Island	118.5	14	5	16.17	21.25	14.1	4	-	18.13	-	10.2	1	-	48.17	-
	Sunday Island	37.9	27	-	13.96	-	9.6	-	-	-	-	7.1	-	-	-	-
	Table Island	77.4	14	-	16.83	-	8.8	-	-	-	-	6.5	-	-	-	-
	Thevenard Island	51.6	11	-	17.92	-	1.8	-	-	-	-	1.9	-	-	-	-
	Tortoise Island	37.7	10	-	17.46	-	1.2	-	-	-	-	1.5	-	-	-	-
	Twin Island	12.1	3	-	35.42	-	0.2	-	-	-	-	0.4	-	-	-	-
State Waters	Western Australia State Waters	123.3	29	6	3.54	16.71	27.2	10	-	10.29	-	23.1	8	-	7.79	-

*The release location resides within the receptor boundaries.

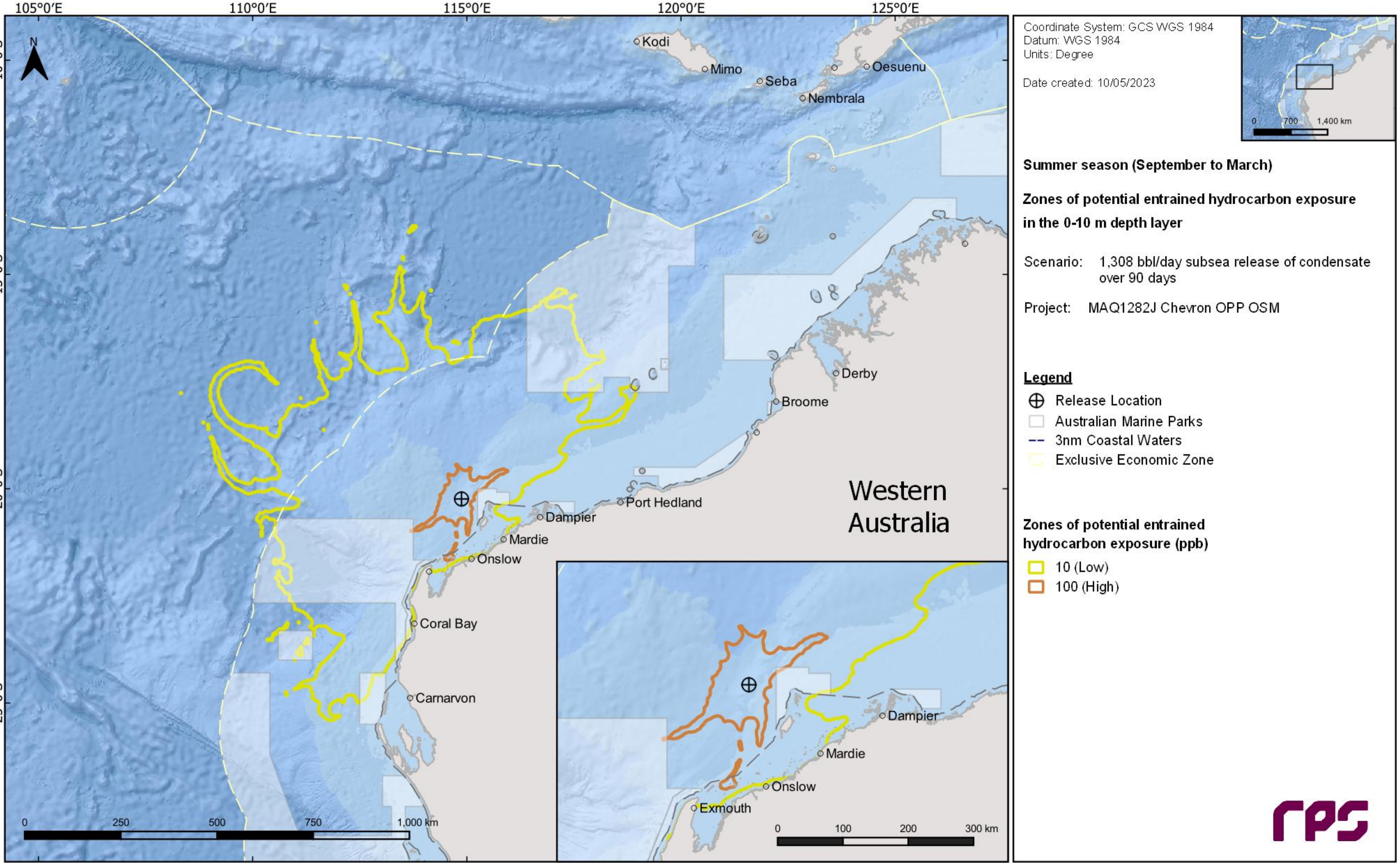


Figure 11.7 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Chrysaor Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

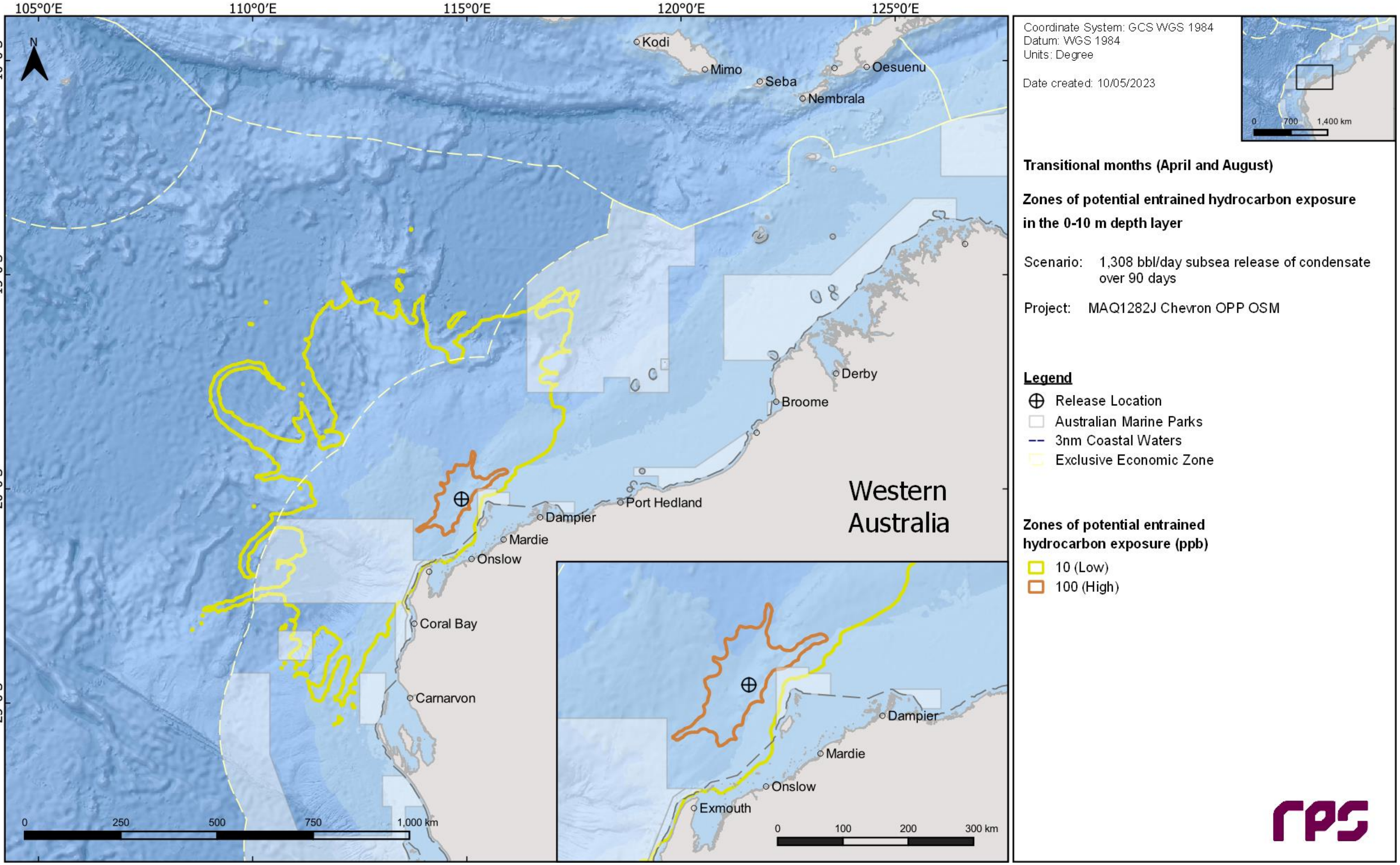


Figure 11.8 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Chrysaor Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

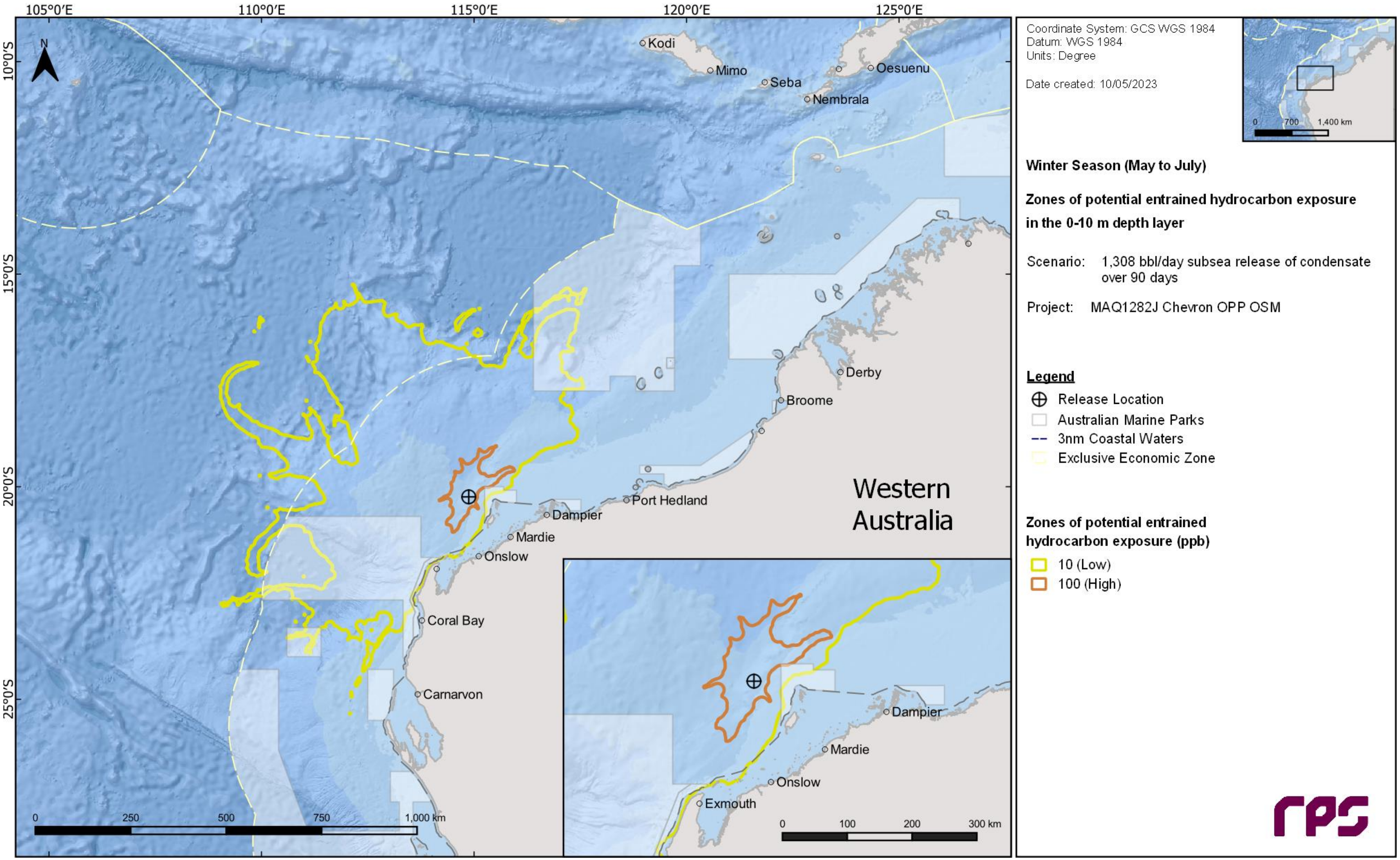


Figure 11.9 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Chrysaor Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

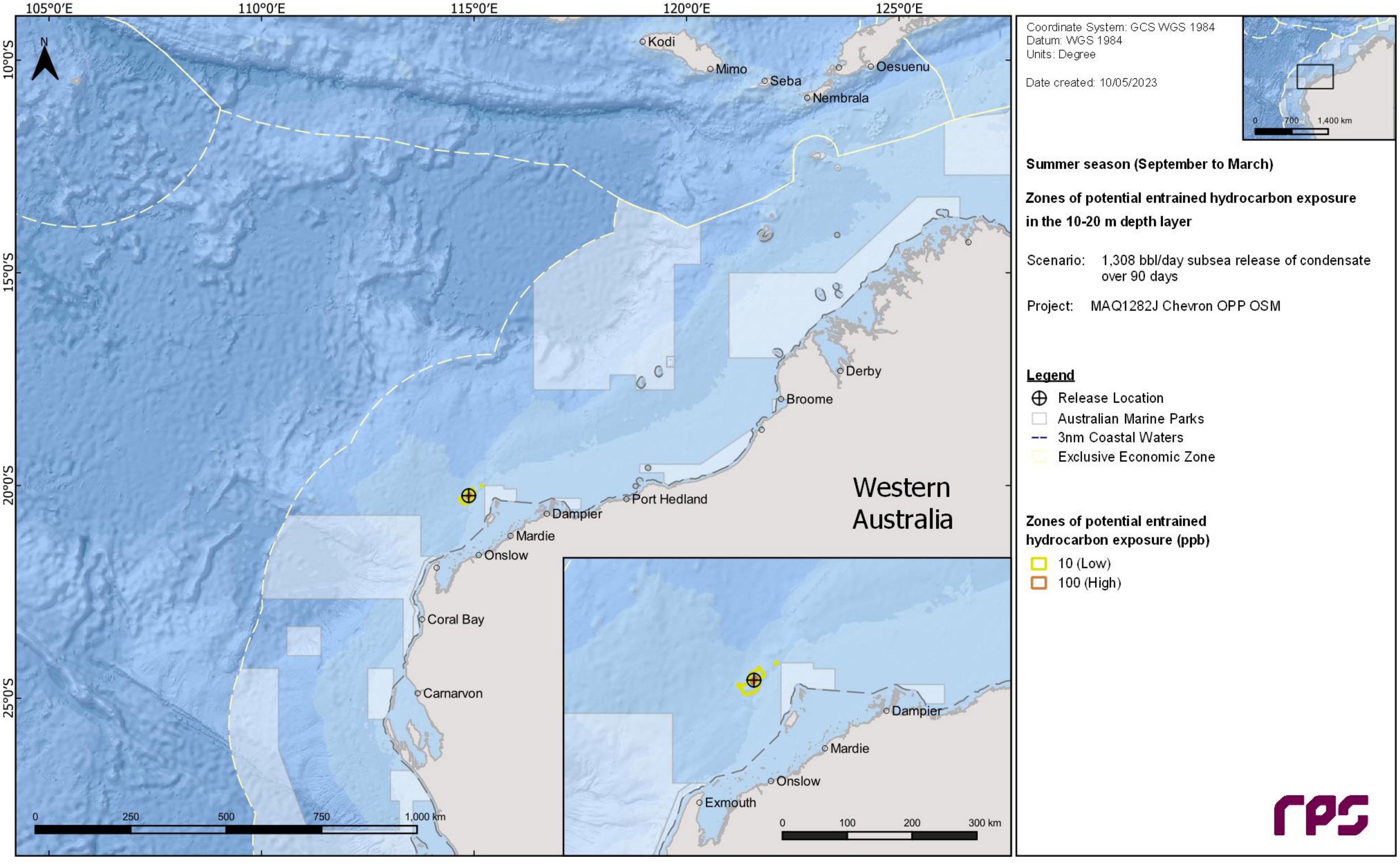


Figure 11.10 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Chrysaor Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

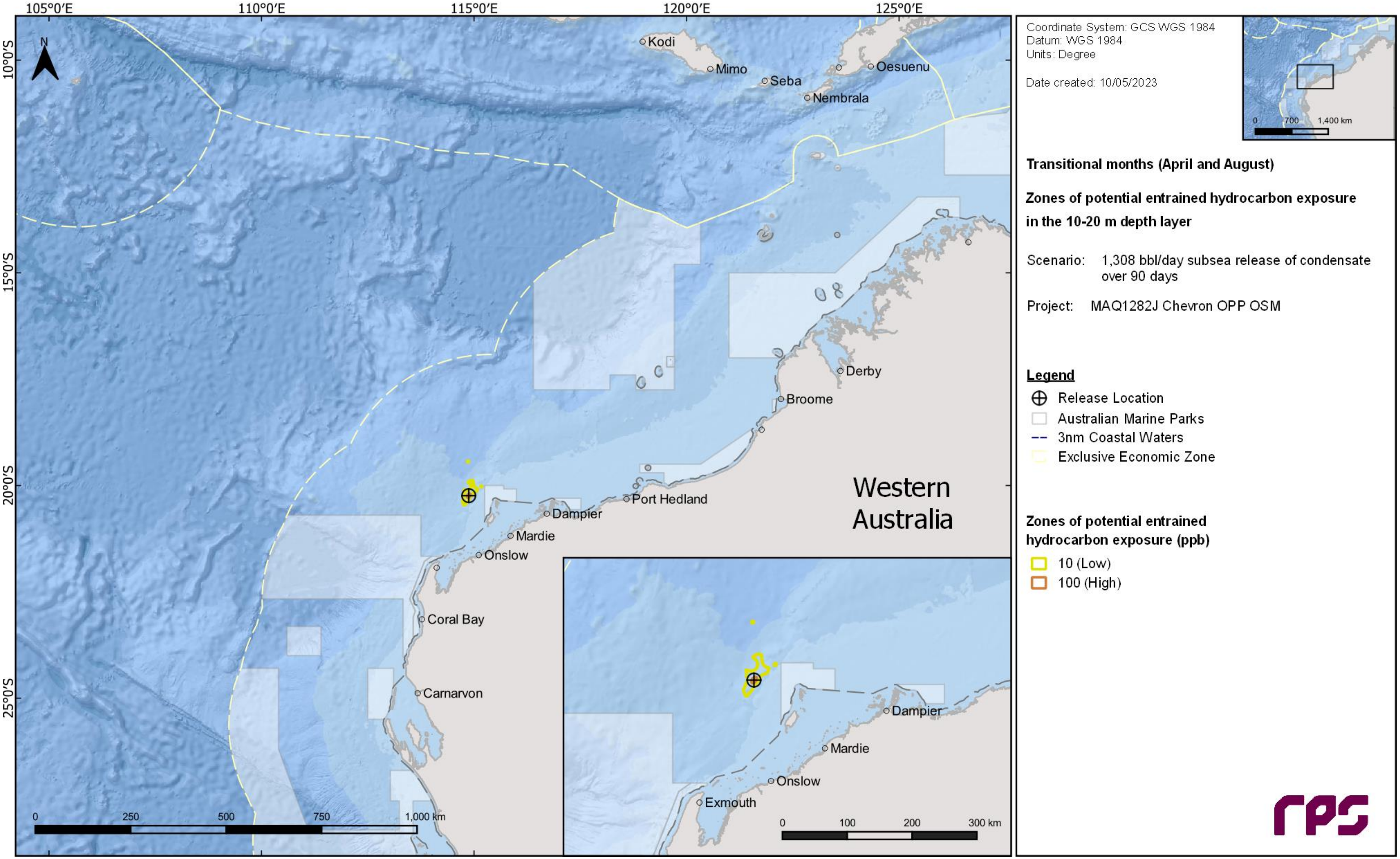


Figure 11.11 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Chrysaor Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

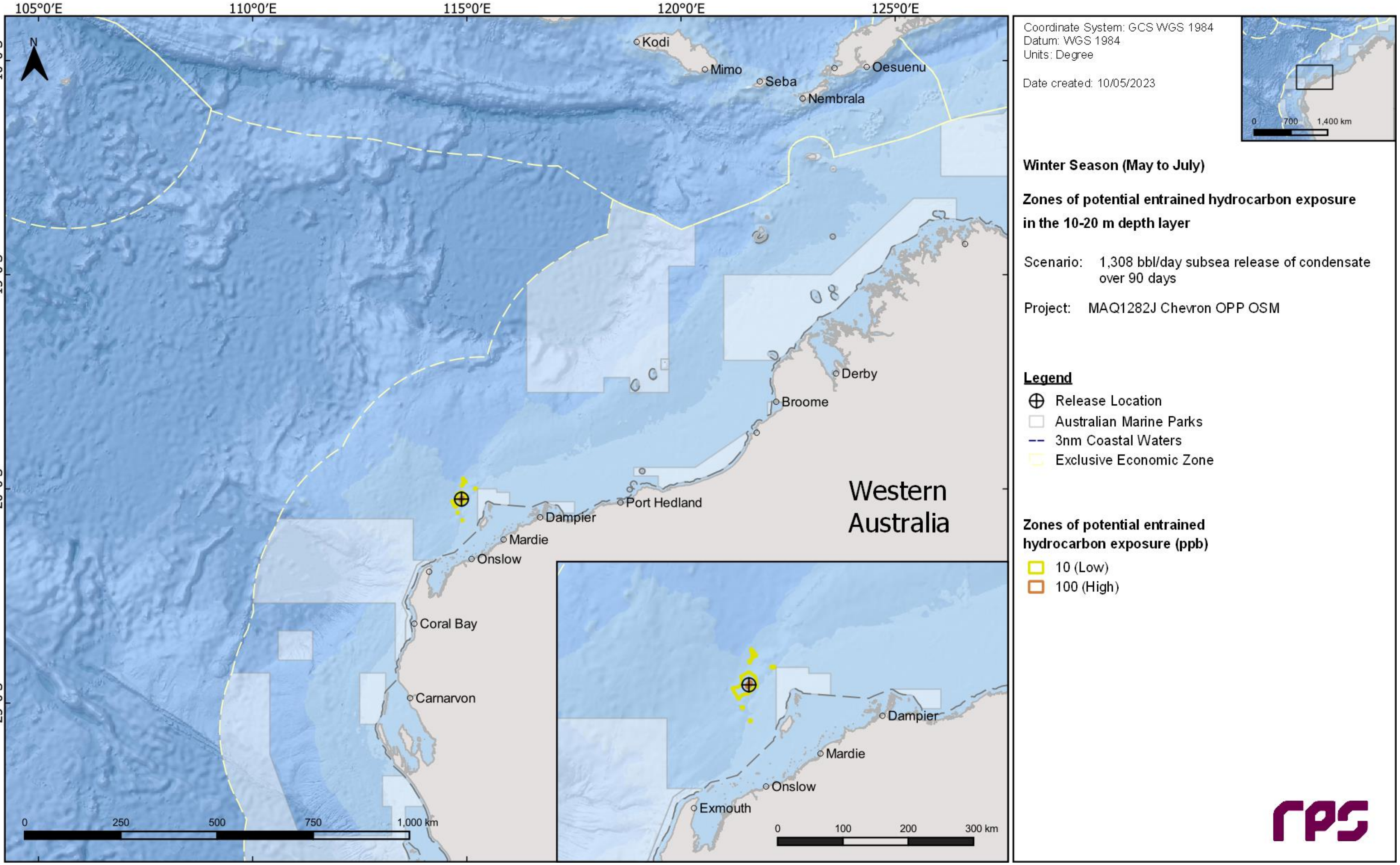


Figure 11.12 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Chrysaor Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating condensate above 10 g/m² (see Section 11.2.1), largest volume of oil ashore (see Section 11.2.2), longest length of shoreline accumulation above 100 g/m² (see Section 11.2.2) and the largest area of entrained hydrocarbons above 100 ppb (see Section 11.2.4).

Table 11.8 presents a summary of all deterministic analysis criteria and the corresponding floating condensate, shoreline accumulation and entrained hydrocarbon values at the assessed thresholds.

Note there was no floating hydrocarbons at or above 50 g/m² and no dissolved hydrocarbon exposure at or above 50 ppb for any of the 300 simulations.

Interpretation of the deterministic analysis result table and timeseries plots:

The summary deterministic analysis results presented in the table below should be interpreted as **maximum values**, representing the total volume or swept area exposed by floating or in-water hydrocarbons throughout the entire simulation duration. In this particular case, the simulation showed that a maximum of 481 km² was exposed to floating oil above the low threshold over a period of 104 days.

However, it's important to note that the timeseries plots present **peak values** at specific points in time. For example, when considering shoreline volume, the peak value in the timeseries plot does not account for oil that may have reached the shore earlier in the simulation but was subsequently lost through evaporation or other weathering processes.

Continuing with the previous example, the timeseries plot indicates that the peak floating oil swept area above the low threshold reached 27 km². This value represents the highest swept area recorded at a single point in time during the simulation.

Table 11.8 Summary of the deterministic analysis following a subsea LOWC at Chrysaor Well 5.

Variable	Threshold	Deterministic Analysis Criteria			
		Largest swept area of floating condensate above 10 g/m²	Largest volume of oil ashore	Longest length of shoreline accumulation above 100 g/m²	Largest area of entrained hydrocarbons above 100 ppb
Season		Transitional	Summer	Summer	Transitional
Run Number		78	80	46	55
Floating Oil (km²)	1 g/m²	481	322	294	251
	10 g/m²	**7**	4	2	2
	50 g/m²	-	-	-	-
Shoreline Length (km)	10 g/m²	-	110	67	-
	100 g/m²	-	3	**5**	-
	1,000 g/m²	-	-	-	-
Minimum Time (days)		-	32.4	81.0	-
Maximum Volume (m³)		-	**32**	29	-
Entrained Area (km²)	10 ppb	49,383	78,046	79,755	105,594
	100 ppb	1,232	1,342	1,471	**2,628**
Dissolved Area (km²)	10 ppb	-	-	-	-
	50 ppb	-	-	-	-
	400 ppb	-	-	-	-
Start Date		1 April 2016	15 November 2010	27 September 2010	25 August 2013

11.2.1 Deterministic Case: Largest swept area of floating condensate above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 (moderate threshold) was identified as run number 78 during the transitional period.

Figure 11.13 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.14 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.15 presents the fates and weathering for the corresponding simulation and Table 11.9 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.9 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at Chrysaor Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	175	55	2
Entrained (m^3)	1,679	90	1,161
Dissolved (m^3)	2	48	0
Evaporation (m^3)	14,634	104	14,634
Decay (m^3)	3,015	104	3,015
Ashore (m^3)	0	0	0

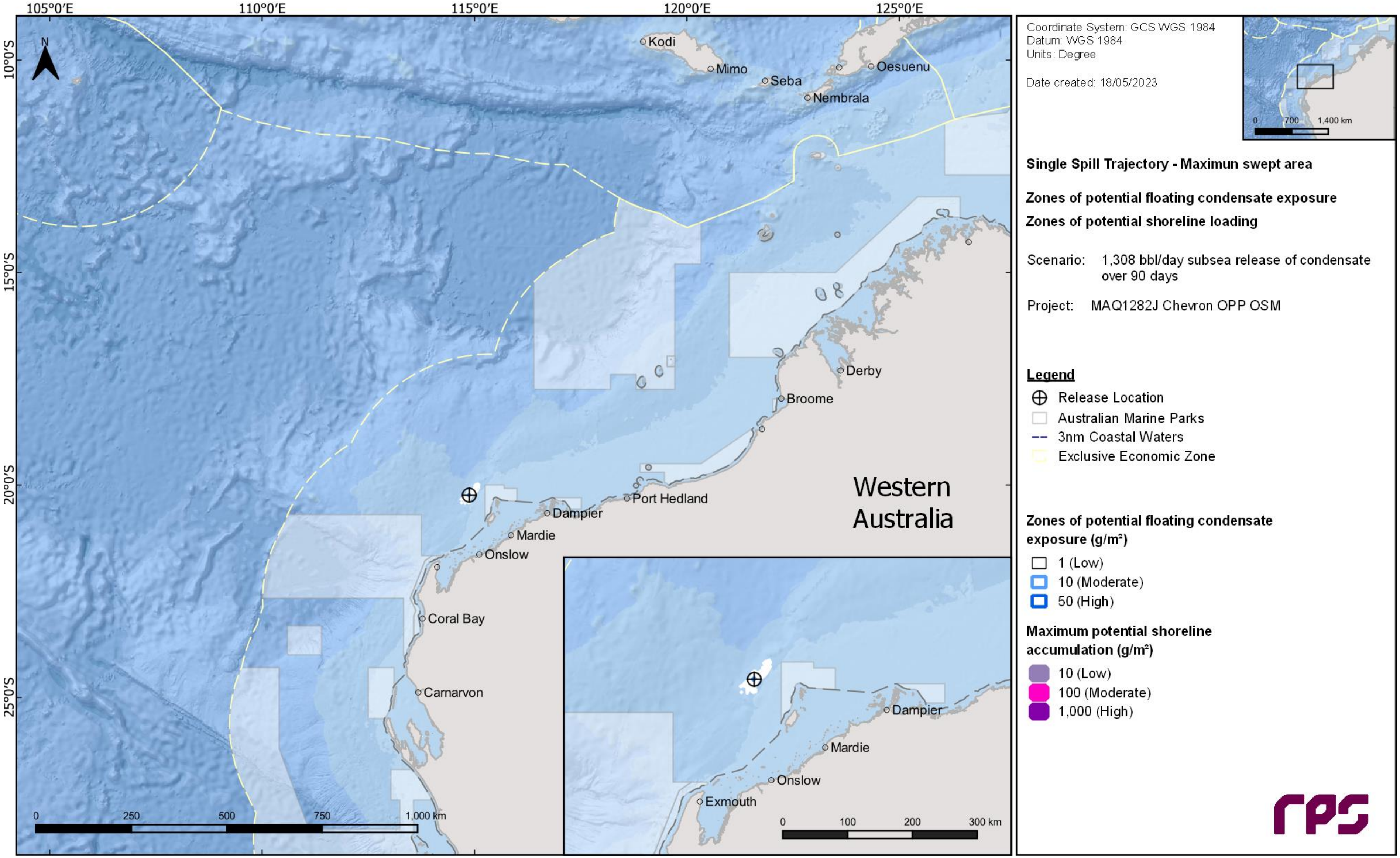


Figure 11.13 Zones of potential floating condensate exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at Chrysaor Well 5.

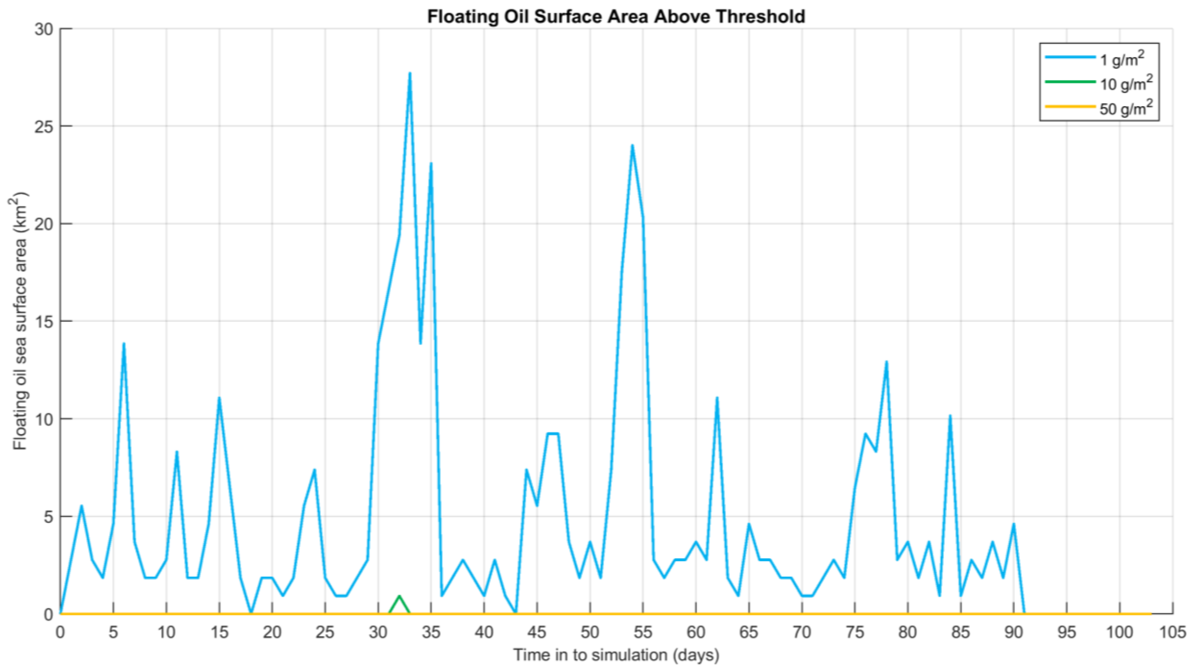


Figure 11.14 Predicted area of floating oil exposure for each threshold, for the simulation with the largest swept area of floating condensate above 10 g/m² following a LOWC at Chrysaor Well 5.

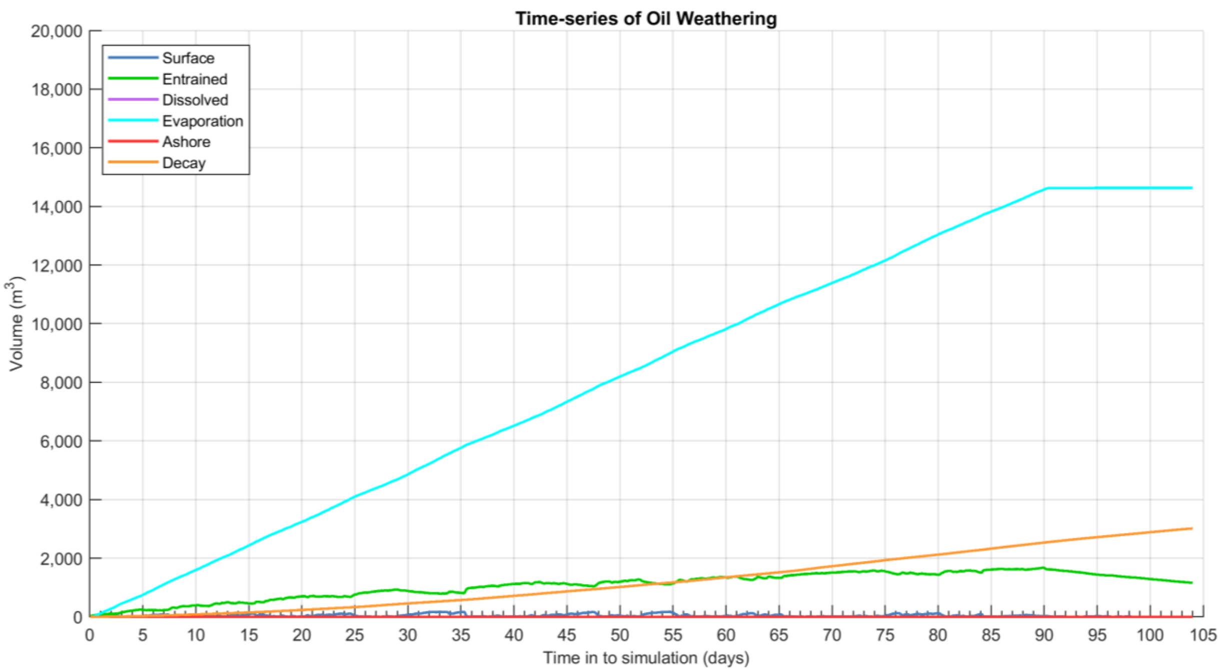


Figure 11.15 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 10 g/m² following a LOWC at Chrysaor Well 5.

11.2.2 Deterministic Case: Largest volume of oil ashore

The deterministic simulation that resulted in the largest volume of oil ashore was identified as run number 80, during the summer season.

Figure 11.16 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.17 displays the time series of the volume of oil accumulating on shorelines at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.18 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.10 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.10 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest volume of oil ashore following a subsea LOWC at Chrysaor Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	130	75	0
Entrained (m^3)	1,668	88	1,153
Dissolved (m^3)	2	59	0
Evaporation (m^3)	14,494	104	14,494
Decay (m^3)	3,138	104	3,138
Ashore (m^3)	32	103	31

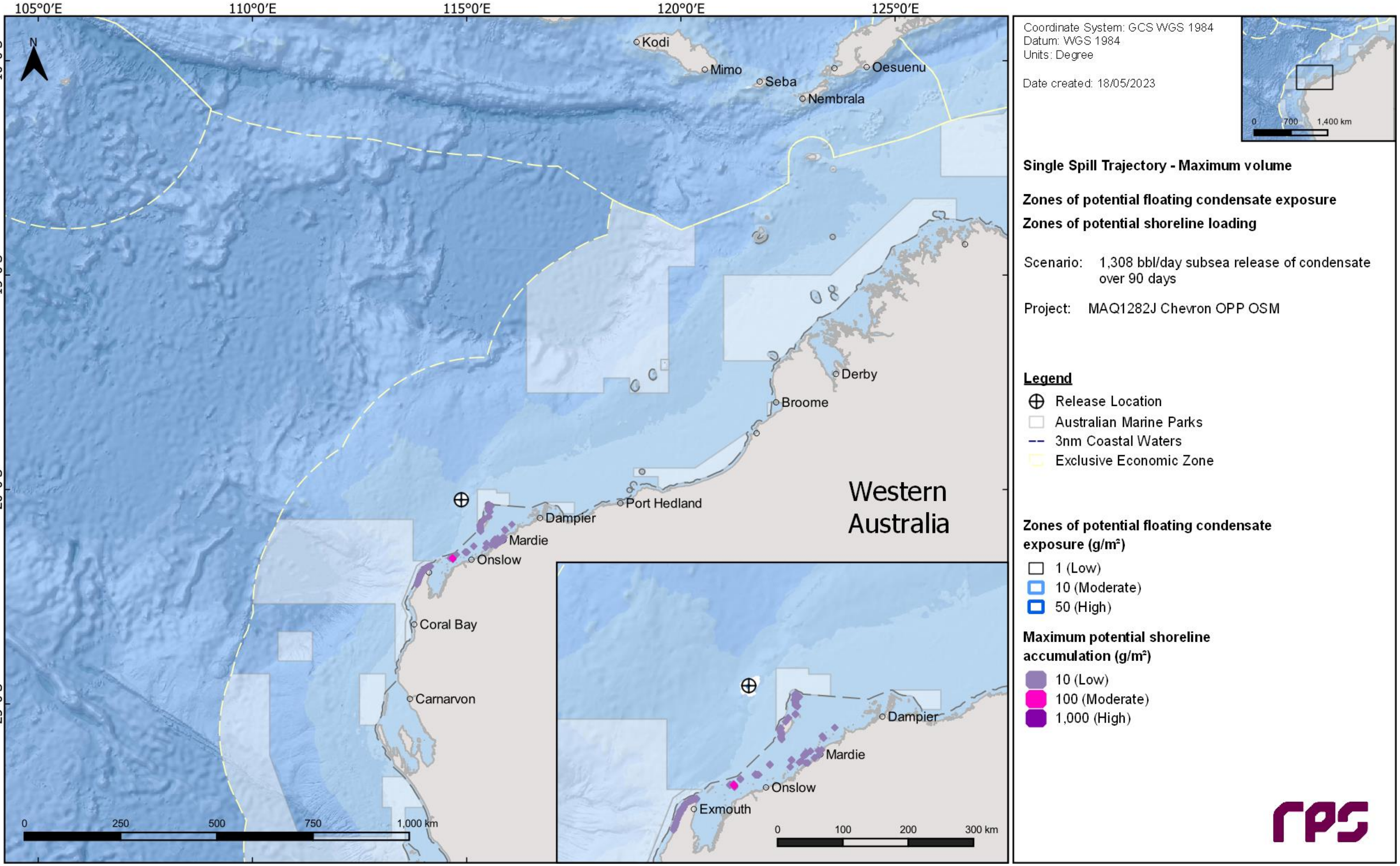


Figure 11.16 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the largest volume of oil ashore following a LOWC at Chrysaor Well 5.

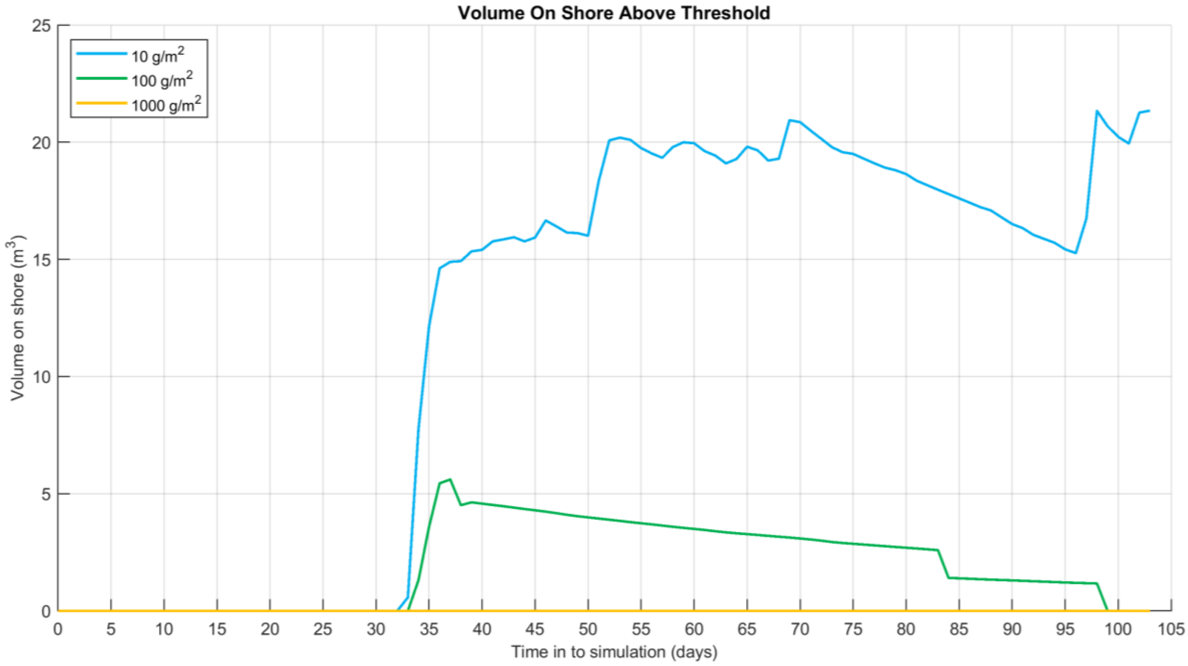


Figure 11.17 Time series of the volume of oil ashore at each threshold for the simulation with the largest volume ashore following a LOWC at Chrysaor Well 5.

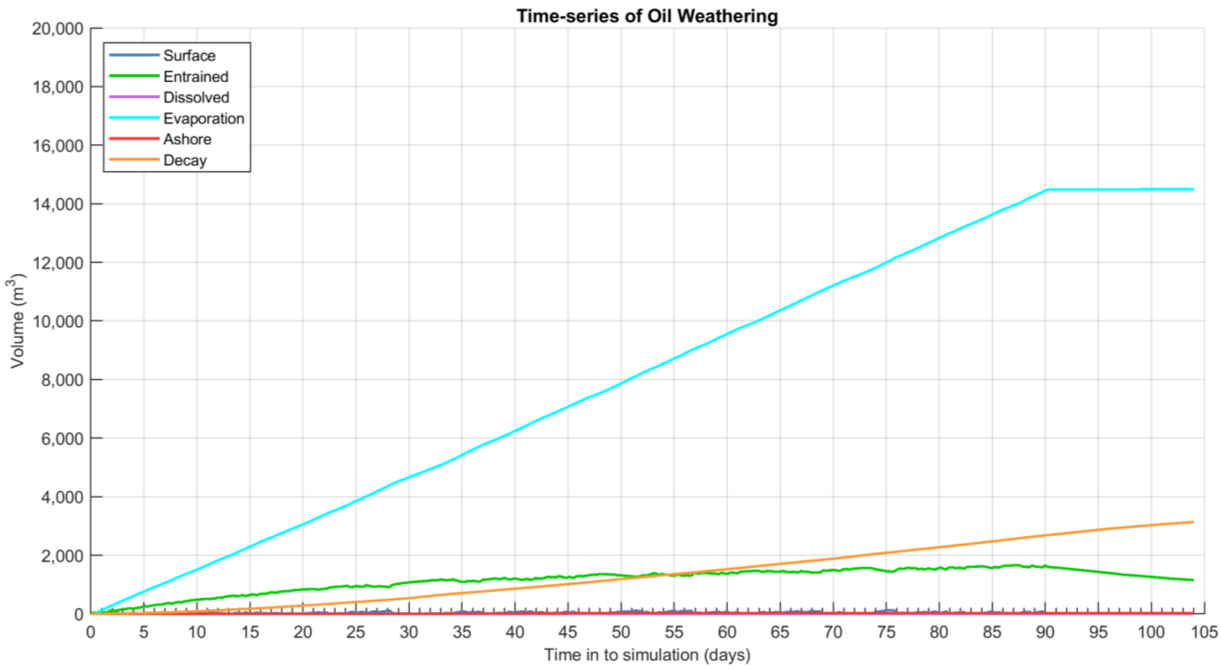


Figure 11.18 Predicted weathering and fates for the simulation with the largest volume of oil ashore following a LOWC at Chrysaor Well 5.

11.2.3 Deterministic Case: Longest length of shoreline with accumulation above 100 g/m^2

The deterministic simulation that resulted in the longest length of shoreline with accumulation above 100 g/m^2 (moderate threshold) was identified as run number 46 during the summer period.

Figure 11.16 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.17 displays the time series of the length of shoreline with accumulation above the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.18 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.10 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.11 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a subsea LOWC at Chrysaor Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	134	23	8
Entrained (m^3)	1,788	82	1,219
Dissolved (m^3)	2	33	0
Evaporation (m^3)	14,203	104	14,203
Decay (m^3)	3,357	104	3,357
Ashore (m^3)	29	101	29

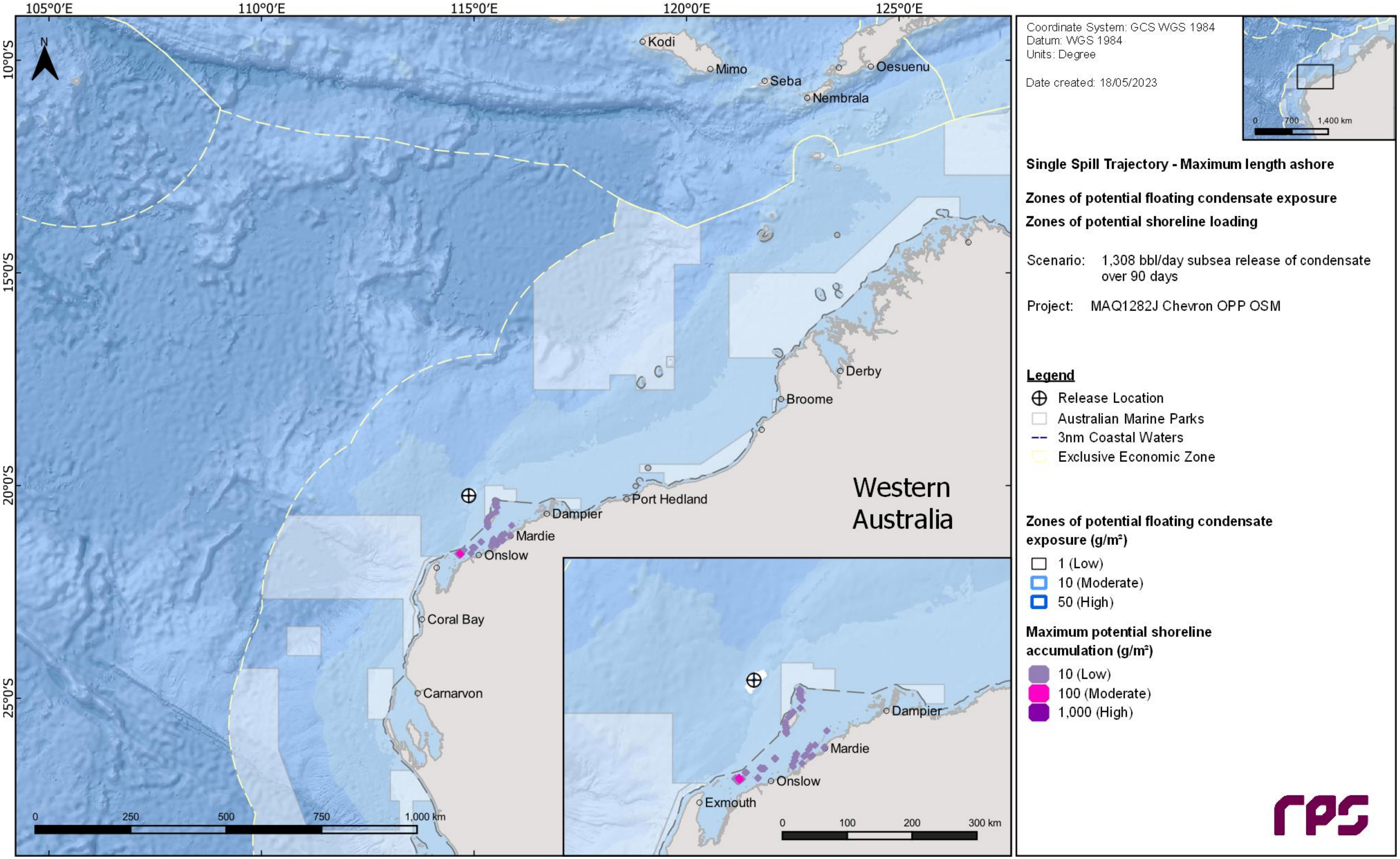


Figure 11.19 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a LOWC at Chrysaor Well 5.

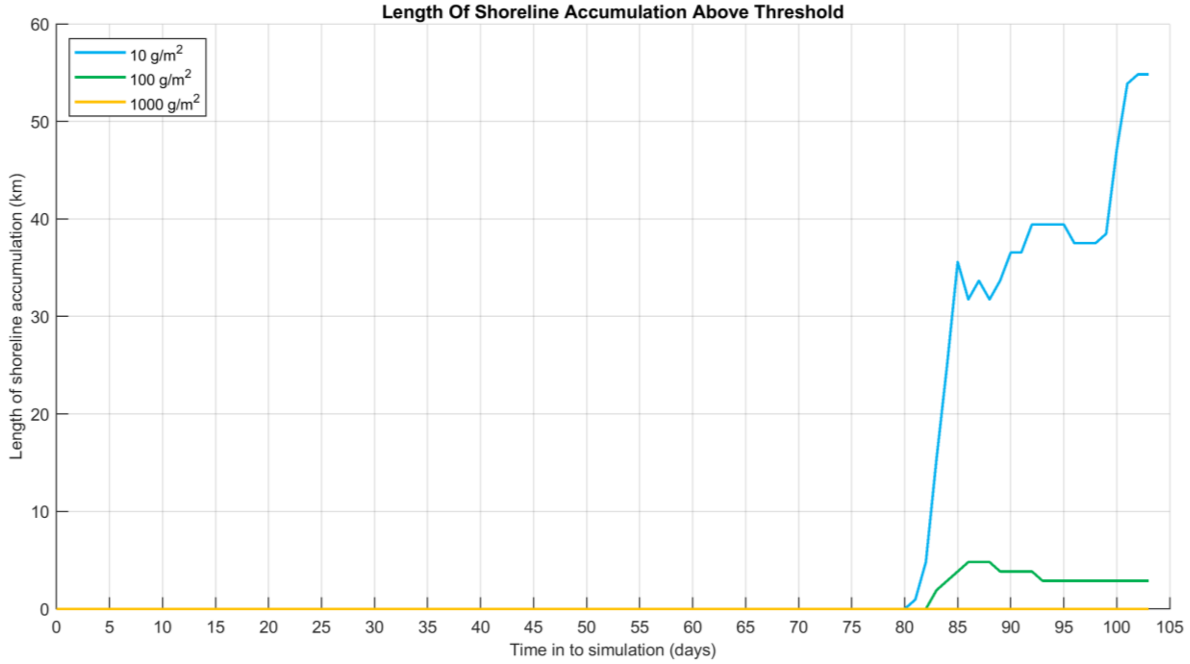


Figure 11.20 Time series of the length of shoreline at each threshold for the simulation with the longest length of shoreline with accumulation above 100 g/m² following a LOWC at Chrysaor Well 5.

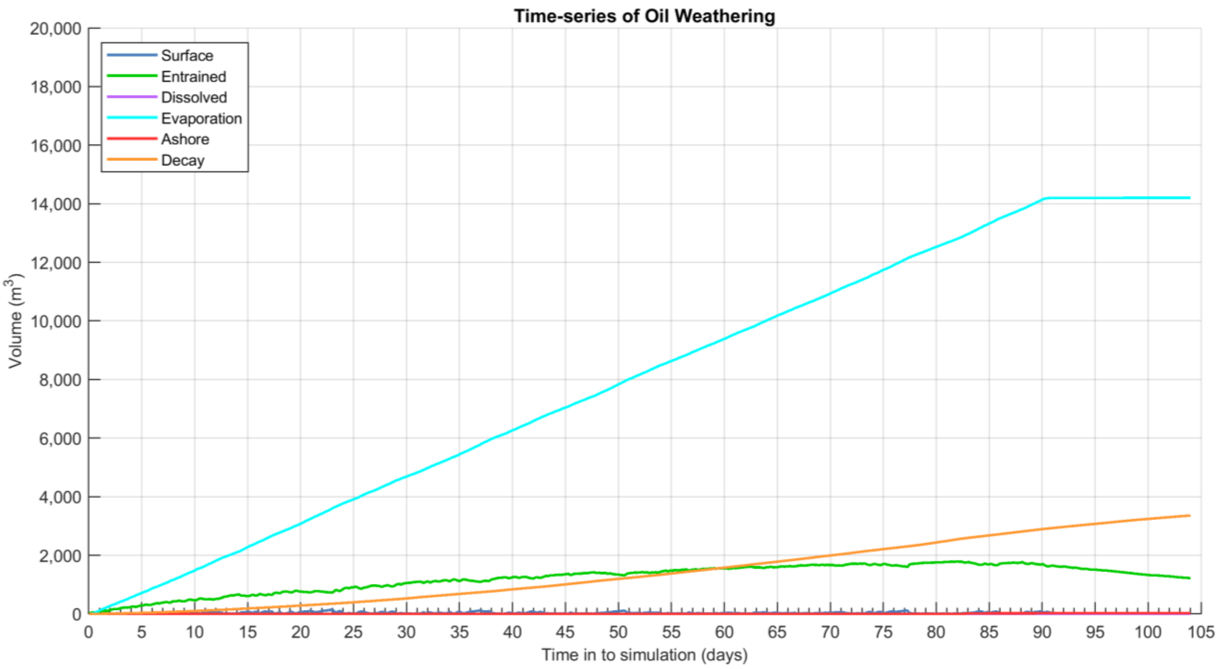


Figure 11.21 Predicted weathering and fates for the simulation with the longest length of shoreline with accumulation above 100 g/m² following a LOWC at Chrysaor Well 5.

11.2.4 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (moderate threshold) was identified as run number 55 during the transitional period.

Figure 11.22 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.23 displays the time series of the area of entrained hydrocarbons at the low (≥10 ppb) and high (≥100 ppb) thresholds over the 104-day simulation.

Figure 11.24 presents the fates and weathering for the corresponding single spill trajectory and Table 11.12 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.12 Summary of the peak volumes and times of occurrence for each oil phase and the volumes at day 104, for the trajectory with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chrysaor Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	113	38	8
Entrained (m^3)	1,902	90	1,336
Dissolved (m^3)	2	81	0
Evaporation (m^3)	13,817	104	13,817
Decay (m^3)	3,656	104	3,656
Ashore (m^3)	0	0	0

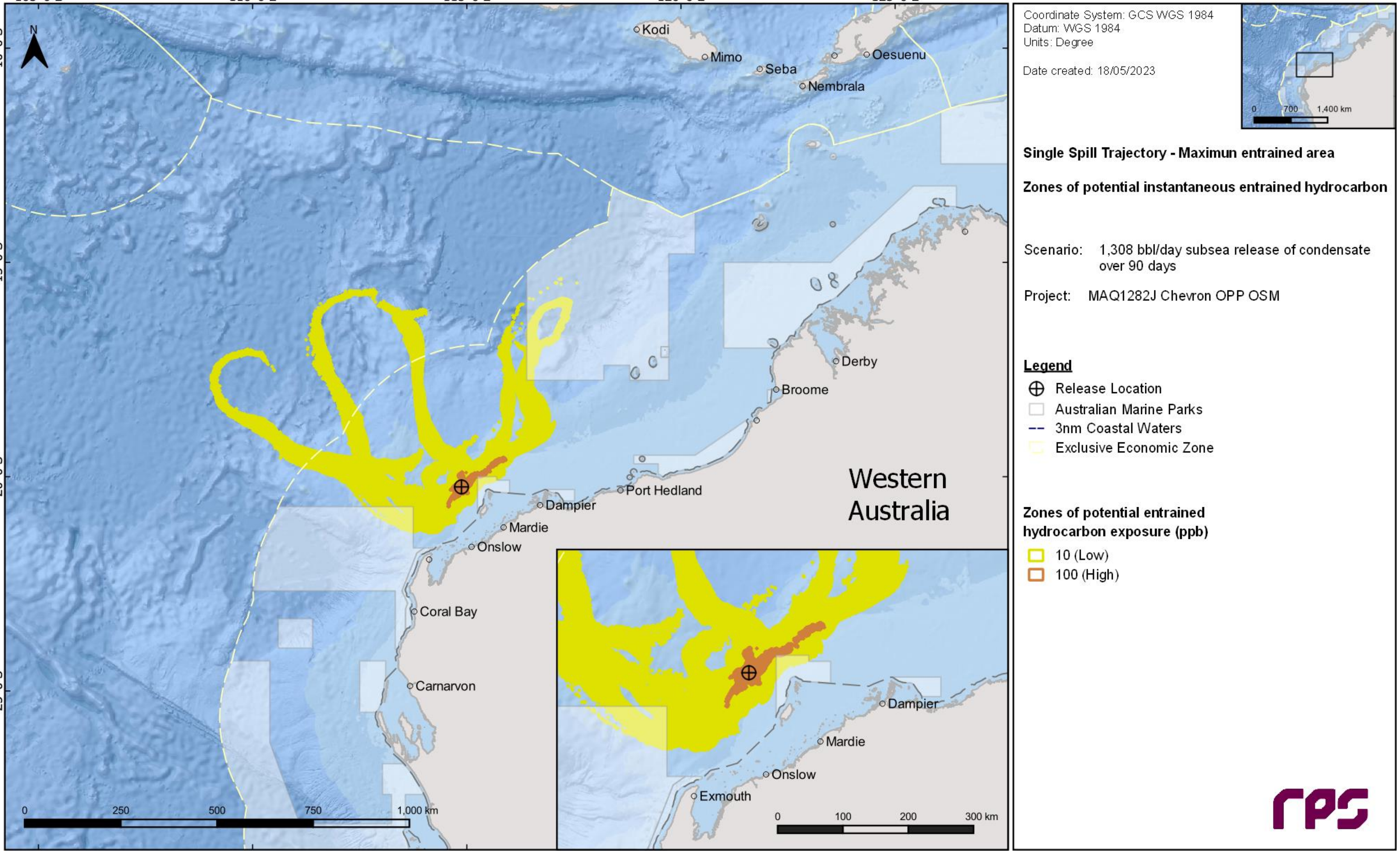


Figure 11.22 Zones of potential entrained hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chrysaor Well 5.

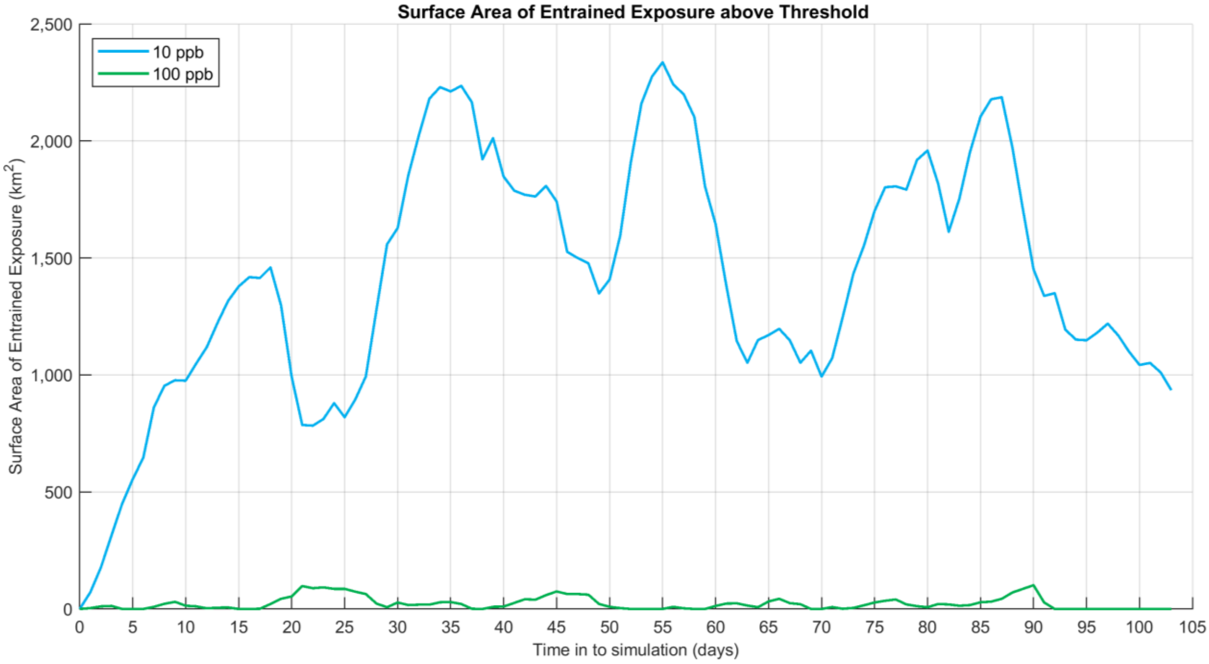


Figure 11.23 Time series of the area of entrained hydrocarbons for each threshold for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chrysaor Well 5.

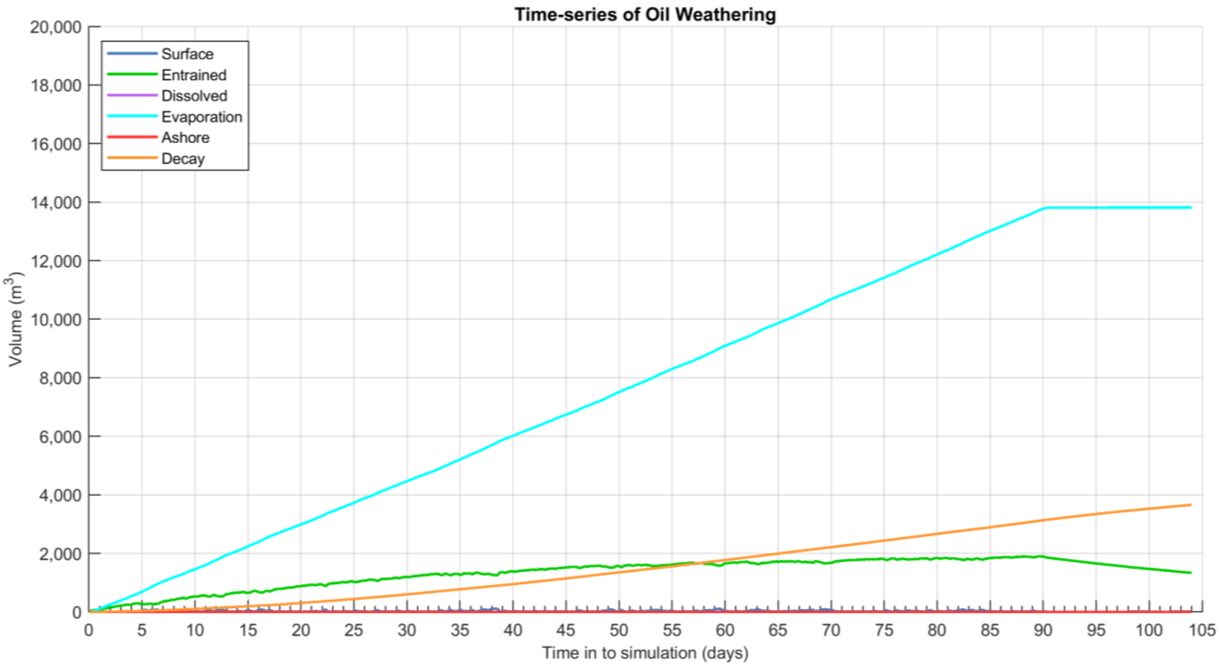


Figure 11.24 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chrysaor Well 5.

12 REFERENCES

American Society for Testing and Materials (ASTM) 2013, 'F2067-13 Standard Practice for Development and Use of Oil-Spill Trajectory Models', ASTM International, West Conshohocken (PA).

Andersen, OB 1995, 'Global ocean tides from ERS 1 and TOPEX/POSEIDON altimetry', *Journal of Geophysical Research: Oceans*, vol. 100, no. C12, pp. 25249–25259.

Anderson JW, Neff JM, Cox BA, Tatem HE & Hightower GM 1974, 'Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish', *Marine Biology*, vol. 27, no. 1, pp. 75–88.

Anderson JW, Riley R, Kiesser S & Gurtisen J 1987, 'Toxicity of dispersed and undispersed Prudhoe Bay crude oil fractions to shrimp and fish', Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 235–240.

Applied Science Associates (ASA) 2011, OILMAP-DEEP: Blowout Plume Model Technical Manual, Applied Science Associates Inc, South Kingstown, USA.

Asia-Pacific ASA 2010, 'Montara well release monitoring study S7.2. Oil fate and effects assessment: modelling of chemical dispersant operation', Prepared for PTTEP Australasia.

Australian Maritime Safety Authority (AMSA) 2014, 'Identification of oil on water: Aerial observations and identification guide', viewed 4 June 2020, https://www.amsa.gov.au/sites/default/files/2014-01-mp-amsa22-identification-oil-on-water.pdf

Australian Maritime Safety Authority (AMSA) 2015, 'Australian Maritime Safety Authority Technical Guideline for the Preparation of Marine Pollution Contingency Plans for Marine and Coastal Facilities Australian Maritime Safety Authority', viewed 20 June 2017, https://www.amsa.gov.au/forms-and-publications/Publications/AMSA413_Contingency_Planning_Guidelines.pdf

Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, 'Australian and New Zealand Guidelines for Fresh and Marine Water', Australian & New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Becker, JJ, Sandwell, DT, Smith, WHF, Braud, J, Binder, B, Depner, J, Fabre, D, Factor, J, Ingalls, S, Kim, S-H, Ladner, R, Marks, K, Nelson, S, Pharaoh, A, Trimmer, R, Von Rosenberg, J, Wallace, G & Weatherall, P 2009, 'Global bathymetry and evaluation data at 30 arc seconds resolution: SRTM30_PLUS', *Marine Geodesy*, vol. 32, no. 4, pp. 355–371.

Belore, UC 2014, Subsea chemical dispersant research. Proceedings of the 37th AMOP Technical Seminar on Environmental Contamination and Response, Environmental Canada, Canmore, Alberta, Canada pp 618–650.

Bonn Agreement 2009, 'Bonn Agreement aerial operations handbook, 2009 - Publication of the Bonn Agreement', London, viewed 13 January 2015, http://www.bonnagreement.org/site/assets/files/3947/ba-aoh_revision_2_april_2012.pdf.

Brandvik, PJ, Johansen, O, Leirvik, F, Farooq, U & Daling PS 2013, 'Droplet Breakup in subsurface oil releases – Part 1: Experimental study of droplet breakup and effectiveness of dispersant injection', *Marine Pollution Bulletin*, vol. 73, no. 1, pp 319–326.

Brandvik, PJ, Johansen, O, Farooq, U, Angell, G & Leirvik F 2014, 'Sub-surface oil releases – Experimental study of droplet distributions and different dispersant injection techniques- version 2', A scaled experimental approach using the SINTEF Tower basin. SINTEF report no: A25122. Trondheim Norway 2014. ISBN: 9788214057393

Carls, MG, Holland, L, Larsen, M, Collier, TK, Scholz, NL & Incardona, JP 2008, 'Fish embryos are damaged by dissolved PAHs, not oil particles', *Aquatic toxicology*, 88(2), pp.121–127.

Chassignet, EP, Hurlburt, HE, Smedstad, OM, Halliwell, GR, Hogan, PJ, Wallcraft, AJ, Baraille, R & Bleck, R 2007, 'The HYCOM (hybrid coordinate ocean model) data assimilative system', *Journal of Marine Systems*, vol. 65, no. 1, pp. 60–83.

Chassignet, E, Hurlburt, H, Metzger, E, Smedstad, O, Cummings, J & Halliwell, G 2009, 'U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)', *Oceanography*, vol. 22, no. 2, pp. 64–75.

Condie, SA., & Andrewartha, JR 2008, 'Circulation and connectivity on the Australian Northwest Shelf', *Continental Shelf Research*, 28, 1724–1739.

Davies, AM 1977a, 'The numerical solutions of the three-dimensional hydrodynamic equations using a B-spline representation of the vertical current profile', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 1–25.

Davies, AM 1977b, 'Three-dimensional model with depth-varying eddy viscosity', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 27–48.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2007, 'Characterisation of the marine environment in the north marine region', Marine Division, Department of the environment, water heritage and the arts.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2008, 'The North-West Marine Bioregional Plan - Bioregional Profile', Retrieved February 12, 2013, from Australian Government Department of Environment, Water, Heritage and the Arts: http://www.environment.gov.au/coasts/mbp/publications/north-west/pubs/bioregional-profile.pdf

French, D, Reed, M, Jayko, K., Feng, S, Rines, H & Pavignano, S 1996, 'The CERCLA Type A Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME), Technical Documentation, Vol. I - Model Description', Office of Environmental Policy and Compliance, U.S. Department of the Interior. Washington, D.C.: Contract No. 14-0001-91-C-11.

French, D, Schuttenberg, H & Isaji, T 1999, 'Probabilities of oil exceeding thresholds of concern: examples from an evaluation for Florida Power and Light', Proceedings of the 22nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Alberta, pp. 243–270.

French-McCay, DP 2002, 'Development and application of an oil toxicity and exposure model, OilToxEx', *Environmental Toxicology and Chemistry*, vol. 21, no. 10, pp. 2080–2094.

French-McCay, DP 2003, 'Development and application of damage assessment modelling: example assessment for the North Cape oil spill', *Marine Pollution Bulletin*, vol. 47, no. 9, pp. 9–12.

French-McCay, DP 2004, 'Spill impact modelling: development and validation', *Environmental Toxicology and Chemistry*, vol. 23, no.10, pp. 2441–2456.

French-McCay, DP 2009, 'State-of-the-art and research needs for oil spill impact assessment modelling', Proceedings of the 32nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 601–653.

French-McCay, D, Rowe, JJ, Whittier, N, Sankaranarayanan, S, & Etkin, DS 2004, 'Estimate of potential impacts and natural resource damages of oil', *Journal of Hazardous Materials*, vol. 107, no. 1, pp. 11–25.

French-McCay, D, Whittier, N, Dalton, C, Rowe, J, Sankaranarayanan, S & Aurand, D 2005a, 'Modeling the fates of hypothetical oil spills in Delaware, Florida, Texas, California, and Alaska waters, varying

response options including use of dispersants', Proceedings of the International Oil Spill Conference 2005, American Petroleum Institute, Washington DC, paper 399.

French-McCay, D, Whittier, N, Rowe, J, Sankaranarayanan, S, Kim, H-S & Aurand, D 2005b, 'Use of probabilistic trajectory and impact modeling to assess consequences of oil spills with various response strategies,' Proceedings of the 28th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 253–271.

French-McCay, D, Reich, D, Rowe, J, Schroeder, M & Graham, E 2011, 'Oil spill modeling input to the offshore environmental cost model (OECM) for US-BOEMRE's spill risk and costs evaluations', Proceedings of the 34th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Reich, D, Michel, J, Etkin, DS, Symons, L, Helton, D, & Wagner J 2012, 'Oil spill consequence analysis of potentially-polluting shipwrecks', Proceedings of the 35th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Jayko, K, Li, Z, Horn, M, Kim, Y, Isaji, T, Crowley, D, Spaulding, M, Decker, L, Turner, C, Zamorski, S, Fontenault, J, Schmmkler, R & Rowe, J 2015, 'Technical Reports for Deepwater Horizon Water Column Injury Assessment: WC_TR.14: Modeling Oil Fate and Exposure Concentrations in the Deepwater Plume and Rising Oil Resulting from the Deepwater Horizon Oil Spill', RPS ASA, South Kingston, Rhode Island.

Gordon, R 1982, 'Wind driven circulation in Narragansett Bay' PhD thesis, Department of Ocean Engineering, University of Rhode Island.

Grant, DL, Clarke, PJ & Allaway, WG 1993, 'The response of grey mangrove (*Avicennia marina* (Forsk.) Vierh) seedlings to spills of crude oil,' *The Journal of Experimental Marine Biological Ecology*, vol. 171, no. 2, pp. 273–295.

Isaji, T & Spaulding, M 1984, 'A model of the tidally induced residual circulation in the Gulf of Maine and Georges Bank', *Journal of Physical Oceanography*, vol. 14, no. 6, pp. 1119–1126.

Isaji, T, Howlett, E, Dalton C, & Anderson, E 2001, 'Stepwise-continuous-variable-rectangular grid hydrodynamics model', Proceedings of the 24th Arctic and Marine Oil spill Program (AMOP) Technical Seminar (including 18th TSOCS and 3rd PHYTO), Environment Canada, Edmonton, pp. 597–610.

Koops, W, Jak, RG & van der Veen, DPC 2004, 'Use of dispersants in oil spill response to minimise environmental damage to birds and aquatic organisms', Proceedings of the Interspill 2004: Conference and Exhibition on Oil Spill Technology, Trondheim, presentation 429.

Kostianoy, AG, Ginzburg, AI, Lebedev, SA, Frankignoulle, M & Delille, B 2003, 'Fronts and mesoscale variability in the southern Indian Ocean as inferred from the TOPEX/POSEIDON and ERS-2 Altimetry data', *Oceanology*, vol. 43, no. 5, pp. 632–642.

Li, Z, Spaulding, M, French-McCay, D, Crowley, D & Payne JR 2017, 'Development of a unified oil droplet size distribution model with application to surface breaking waves and subsea blowout releases considering dispersant effects', *Marine Pollution Bulletin*, vol. 114, no. 1, pp 247–257.

Lin, Q & Mendelssohn, IA 1996, 'A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish and Salt Marshes', *Marine Pollution Bulletin*, vol. 32, no. 2, pp. 202–209.

Ludicone, D, Santoleri, R, Marullo, S & Gerosa, P 1998, 'Sea level variability and surface eddy statistics in the Mediterranean Sea from TOPEX/POSEIDON data', *Journal of Geophysical Research I*, vol. 103, no. C2, pp. 2995–3011.

Mackay D, Puig H & McCarty LS 1992, 'An equation describing the time course and variability in uptake and toxicity of narcotic chemicals to fish', *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, p.941–951.

Malins DC & Hodgins HO 1981, 'Petroleum and marine fishes: a review of uptake, disposition, and effects', *Environmental Science & Technology*, vol. 15, no. 11, pp.1272–1280.

Matsumoto, K, Takanezawa, T & Ooe, M 2000, 'Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan', *Journal of Oceanography*, vol. 56, no.5, pp. 567–581.

McAuliffe CD 1987, 'Organism exposure to volatile/soluble hydrocarbons from crude oil spills – a field and laboratory comparison', Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 275–288.

McCarty LS 1986, 'The relationship between aquatic toxicity QSARs and bioconcentration for some organic chemicals', *Environmental Toxicology and Chemistry*, vol. 5, no. 12, pp. 1071–1080.

McCarty LS & Mackay D 1993, 'Enhancing ecotoxicological modelling and assessment. Body residues and modes of toxic action', *Environmental Science & Technology*, vol. 27, no. 9, pp. 1718–1728.

McCarty LS, Dixon DG, MacKay D, Smith AD & Ozburn GW 1992a, 'Residue-based interpretation of toxicity and bioconcentration QSARs from aquatic bioassays: Neutral narcotic organics', *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, pp.917–930.

McCarty LP, Flannagan DC, Randall SA & Johnson KA 1992b, 'Acute toxicity in rats of chlorinated hydrocarbons given via the intratracheal route', *Human & Experimental Toxicology*, vol. 11, no. 3, pp.173–117.

McGrath JA, & Di Toro DM 2009, 'Validation of the target lipid model for toxicity assessment of residual petroleum constituents: monocyclic and polycyclic aromatic hydrocarbons', *Environmental Toxicology and Chemistry*, vol. 28, no. 6, pp. 1130–1148.

National Oceanic and Atmospheric Administration (NOAA) 2013, 'Screening level risk assessment package Gulf state', Office of National Marine Sanctuaries & Office of Response and Restoration, Washington DC.x

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2018, 'At a glance: Oil spill modelling', viewed 15 November 2018, https://www.nopsema.gov.au/assets/Publications/A626200.pdf

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2019, 'NOPSEMA Bulletin #1: Oil spill modelling', viewed April 2019, https://www.nopsema.gov.au/assets/Bulletins/A652993.pdf

National Research Council (NRC) 2003, 'Oil in the sea III: Inputs, fates and effects', The National Academic Press, Washington D.C.

Neff JM, Anderson JW 1981, 'Response of marine animals to petroleum and specific petroleum hydrocarbons' United States Department of Energy, United States.

Nirmalakhandan N & Speece RE 1998, 'Quantitative techniques for predicting the behaviour of chemicals in the ecosystem', *Environmental Science & Technology*, vol. 22, no. 6, pp. 606–615.

Nordtug, T, Olsen, AJ, Altin, D, Overrein, I, Storøy, W, Hansen, BH & De Laender, F 2011, 'Oil droplets do not affect assimilation and survival probability of first feeding larvae of North-East Arctic cod', *Science of the Total Environment*, 412, pp.148–153.

Oil Spill Solutions 2015, 'Evaluation - The Theory of Oil Slick Appearances', viewed 6 January 2015, http://www.oilspillsolutions.org/evaluation.htm

Owen, A 1980, 'A three-dimensional model of the Bristol Channel', *Journal of Physical Oceanography*, vol. 10, no. 8, pp. 1290–1302.

Qiu, B & Chen, S 2010, 'Eddy-mean flow interaction in the decadally modulating Kuroshio Extension system', *Deep-Sea Research II*, vol. 57, no. 13, pp. 1098–1110.

Redman AD 2015, 'Role of entrained droplet oil on the bioavailability of petroleum substances in aqueous exposures', *Marine Pollution Bulletin*, vol. 97, no. (1–2), pp. 342–348.

Saha, S, Moorthi, S, Pan, H-L, Wu, X, Wang, J & Nadiga, S 2010, 'The NCEP Climate Forecast System Reanalysis', *Bulletin of the American Meteorological Society*, vol. 91, no. 8, pp. 1015–1057.

Scholten, MCTh, Kaag, NHBM, Dokkum, HP van, Jak, R.G., Schobben, HPM & Slob, W 1996, Toxische effecten van olie in het aquatische milieu, TNO report TNO-MEP – R96/230, Den Helder.

Spaulding, ML., Kolluru, VS, Anderson, E & Howlett, E 1994, 'Application of three-dimensional oil spill model (WOSM/OILMAP) to hindcast the Braer Spill', *Spill Science and Technology Bulletin*, vol. 1, no. 1, pp. 23–35.

Spaulding, MS, Mendelsohn, D, Crowley, D, Li, Z, and Bird A, 2015. Technical Reports for Deepwater Horizon Water Column Injury Assessment- WC_TR.13: Application of OILMAP DEEP to the Deepwater Horizon Blowout. RPS APASA, 55 Village Square Drive, South Kingstown, RE 02879.

Suprayogi, B & Murray, F 1999, 'A field experiment of the physical and chemical effects of two oils on mangroves', *Environmental and Experimental Botany*, vol. 42, no. 3, pp. 221–229.

Swartz RC, Schults DW, Ozretich RJ, Lamberson JO, Cole FA, Ferraro SP, Dewitt TH & Redmond MS 1995, 'ΣPAH: A Model to predict the toxicity of polynuclear aromatic hydrocarbon mixtures in field-collected sediments', *Environmental Toxicology and Chemistry*, vol. 14, no. 11, pp. 1977–1187.

Verhaar HJM, Van Leeuwen CJ & Hermens JLM 1992, 'Classifying environmental pollutants', *Chemosphere*, vol. 24, no. 4, pp. 471–491.

Verhaar HJM, de Jongh J & Hermens JLM 1999, 'Modelling the bioconcentration of organic compounds by fish: A novel approach', *Environmental Science & Technology*, vol. 33, no. 22, pp. 4069–4072.

Yaremchuk, M & Tangdong, Q 2004, 'Seasonal variability of the large-scale currents near the coast of the Philippines', *Journal of Physical Oceanography*, vol. 34, no., 4, pp. 844–855.

Zigic, S, Zapata, M, Isaji, T, King, B, & Lemckert, C 2003, 'Modelling of Moreton Bay using an ocean/coastal circulation model', Proceedings of the 16th Australasian Coastal and Ocean Engineering Conference, the 9th Australasian Port and Harbour Conference and the Annual New Zealand Coastal Society Conference, Institution of Engineers Australia, Auckland, paper 170.

GREATER GORGON – SEMELE

Oil Spill Modelling

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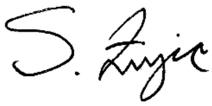
Dr. Sasha Zigic		5 July 2023

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Prepared by:

RPS

Jeremie Bernard
Senior Coastal Engineer

Lakeside Corporate Space, Suite 425
Level 2, 34-38 Glenferrie Drive
Robina, QLD, 4226, Australia

T +61 7 5553 6900
E Jeremie.Bernard@rpsgroup.com

Prepared for:

CHEVRON AUSTRALIA PTY LTD

Mike Daly
HSE Specialist - Environment

Level 13, 250 St Georges Tce
Perth WA 6000 Australia

T +61 418 488 728
E mike.daly@chevron.com

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TERMS AND ABBREVIATIONS

°	Degrees
‘	Minutes
“	Seconds
µm	Micrometre (unit of length; 1 µm = 0.001 mm)
Actionable oil	Oil which is thick enough for the effective use of mitigation strategies
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute gravity. A measure of how heavy or light a petroleum liquid is compared to water.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m3)
bbl/d	Barrels per day
Bonn Agreement	An agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983, includes: Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
cP	Centipoise (unit of dynamic viscosity)
Decay	The process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions.
Dynamic viscosity	The dynamic viscosity of a fluid expresses its resistance to shearing flows, where adjacent layers move parallel to each other with different speeds.
Floating condensate exposure	Contact by floating oil on the sea surface at concentrations equal to or exceeding defined threshold concentrations. The consequence will vary depending on the threshold and the receptors
g/m^2	Grams per square meter (unit of surface area density)
GODAE	Global Ocean Data Assimilation Experiment
HYCOM	Hybrid Coordinate Ocean Model. A data-assimilative, three-dimensional ocean model
HYDROMAP	Advanced ocean/coastal tidal model used to predict tidal water levels, current speed and current direction.
IAA	Impact Assessment Area

IBRA	Interim Biogeographic Regionalisation for Australia
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
Shoreline contact	Arrival of oil at or near shorelines at on-water concentrations equal to or exceeding defined threshold concentrations. Shoreline contact is judged for floating oil arriving within a 2 km buffer zone from any shoreline as a conservative measure
SIMAP	Spill Impact Model Application Package. SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for surface or subsea releases
Single Oil spill modelling	Oil spill modelling involving a computer simulation of a single hypothetical oil spill event subject to a single sequence of wind, current and other sea conditions over time. Single oil spill modelling, also referred to as “deterministic modelling” provides a simulation of one possible outcome of a given spill scenario, subject to the metocean conditions that are imposed. Single oil spill modelling is commonly used to consider the fate and effects of ‘worst-case’ oil spill scenarios that are carefully selected in consideration of the nature and scale of the offshore petroleum activity and the local environment (NOPSEMA, 2017). Because the outcomes of a single oil spill simulation can only represent the outcome of that scenario under one sequence of metocean conditions, worst-case conditions are often identified from stochastic modelling. It is impossible to calculate the likelihood of any outcome

	from a single oil spill simulation. Single oil spill modelling is generally used for response planning, preparedness planning and for supporting oil spill response operations in the event of an actual spill
SRTM	Shuttle Radar Topography Mission
Stochastic oil spill modelling	Stochastic oil spill modelling is created by overlaying and statistically analysing the outcomes of many single oil-spill simulations of a defined spill scenario, where each simulation was subject to a different sequence of metocean conditions, selected objectively (typically by random selection) from a long sequence of historic conditions for the study area. Analysis of this larger set of simulations provides a more accurate indication of the environment that maybe affected (EMBA) and indicates which locations are more likely to be affected (as well as other statistics). Stochastic oil spill modelling avoids biases that affect single oil spill modelling (due to the reliance on only one possible sequence of conditions). However, when interpreting stochastic modelling, which is based on a wide range of potential conditions that might happen to occur, it is essential to understand that calculations will encompass a much larger area than could be affected in any single spill event, where a more limited set of conditions will occur. Consequently, it is misleading to imply that the region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) Stochastic modelling is generally used for risk assessment and preparedness planning by indicating locations that could be exposed and may require response or subsequent impact assessment
TOPEX/Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed, quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Semele field situated within the Northern Carnarvon Basin in Permit area WA-15-R, northwest of Barrow Island off the north-west coast of Western Australia.

Chevron commissioned RPS to undertake an oil spill modelling to support environmental approvals. The oil spill modelling study was conducted to assess the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 2,441 stb/day (388.1 m^3/day) subsea release of condensate over 90 days (totalling 219,690 stb or 34,927 m^3) from a loss of well control (LOWC).

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

Methodology

The modelling study was carried out in stages. Firstly, a ten-year current dataset (2010–2019) that includes the combined influence of large-scale ocean and nearshore tidal currents was developed. Secondly, the currents, local winds and detailed hydrocarbon characteristics were used as inputs in the three-dimensional oil spill model (SIMAP) to simulate the drift, spread, weathering and fate of the spilled oil.

As spills can occur during any set of wind and current conditions, modelling was conducted using a stochastic (or probabilistic) approach, which involved running 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Condensate Properties

Semele condensate has an API of 41.9, a density of 816 kg/m^3 (at 15ºC) and a viscosity value of 6.7 cP at 15 ºC. When exposed to the atmosphere at local temperatures, about 33% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 32.5% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (27.9%) should evaporate over a longer period (265°C < BP < 380°C). The remaining 6.5% of the condensate would persist in the marine environment for much longer periods and be subject to relatively slow degradation. The process of evaporation will be greater than under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity to take up water to form water-in-oil emulsion. For this condensate, the aromatic hydrocarbons contribute 3.9% and are all contained in the volatile fractions, which are highly soluble.

Key Findings

- The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 144.5 km southwest (summer) and 2.2 km west southwest (winter and transitional), respectively. No exposure was predicted at the high (≥ 50 g/m^2) threshold. No exposure was predicted at the high (≥ 50 g/m^2) threshold.

- The Offshore Area IAA, Pygmy Blue Whale – Distribution BIA and Wedge-tailed Shearwater – Breeding BIA which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probability for the low threshold was 100% for all seasons for these receptors. Probabilities of moderate exposure for these receptors ranged between 6% (summer) and 18% (transitional).

- The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m^2) was greatest during summer at 27%, while the minimum time before shoreline accumulation was 13.7 days and the maximum volume of condensate ashore above the low threshold was 29.0 m^3.

- No high (≥ 1,000 g/m^2) shoreline threshold accumulation was observed in the modelling results.

- During summer conditions, condensate had accumulated on 62 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA (19%). In comparison, during transitional and winter conditions condensate had accumulated on 10 and 4 shoreline receptors, respectively. During transitional conditions, the greatest probabilities had occurred at Cunningham Island (Imperieuse Reef), Argo-Rowley Terrace IAAs and Imperieuse Reef, all 3% probability. While for the winter season, the same three receptors recorded a 9% probability.

- There were several receptors exposed at or above the low threshold for dissolved hydrocarbons (≥ 10 ppb) during summer and winter, however they were all 1% occurrence.

- In the 0-10 m depth layer, a total of 34, 22 and 21 BIAs were shown to be exposed at or above the low threshold during summer, transitional and winter seasons respectively. Excluding the receptors that the release location resides within, the highest probabilities of exposure were shown for the Flatback Turtle – Internesting Buffer BIA during summer (100%), transitional (97%) and winter (90%) conditions.

- Across the three seasons, 6 Australian Marine Parks (AMP) were predicted to be exposed at, or above the low threshold for entrained hydrocarbons, with the highest probabilities predicted at the Gascoyne AMP (81% summer, 82% transitional and 74% winter).

- A total of 6 KEFs were shown to be exposed by entrained hydrocarbons at the low threshold, including the Continental Slope Demersal Fish Communities KEF that the release site is located within. Excluding that receptor, probabilities of exposure ranged between 6–80%, 1–92% and 1–80%, for summer, transitional and winter, respectively.

- A total of 37 IAAs were shown to be exposed to entrained hydrocarbons at low threshold.

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Semele field situated within the Northern Carnarvon Basin in Permit area WA-15-R, northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the Semele field, Chevron commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 2,441 stb/day (388.1 m^3/day) subsea release of condensate over 90 days (totalling 219,690 stb or 34,927 m^3) from a loss of well control (LOWC).

The release location used for the oil spill assessment is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the ‘outer boundaries’ of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis Program (SIMAP). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, RPS warrants that this work meets and exceeds the American Society for Testing and Materials (ASTM) Standard F2067-13 “*Standard Practice for Development and Use of Oil Spill Models*”.

Table 1.1 Coordinates of the Semele release location.

Location	Latitude	Longitude	Depth (mLAT)
Semele Well 5	19.99726° S	114.94312° E	800

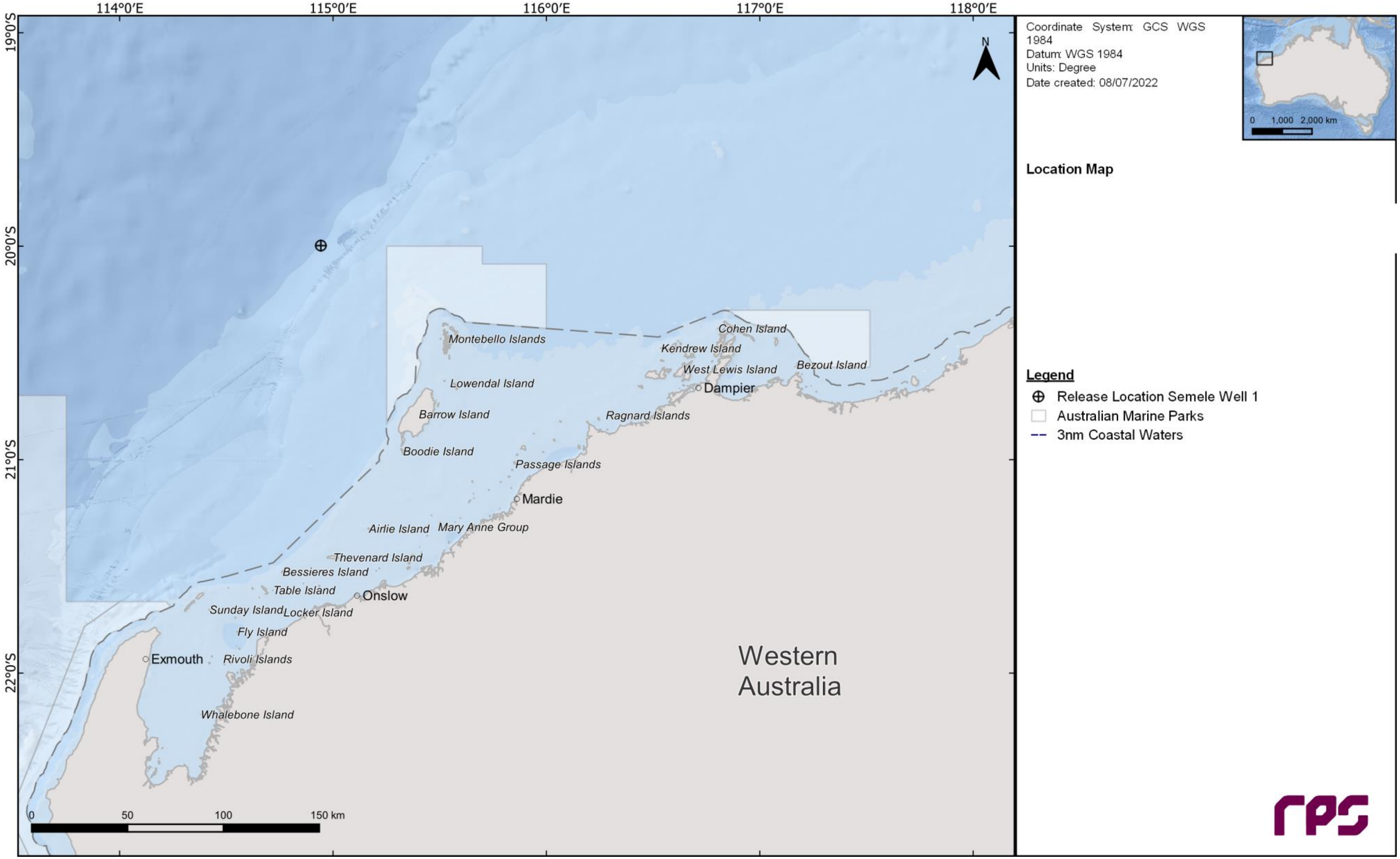


Figure 1.1 Semele hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate ten years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. Run 100 simulations for each season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds; and

5. From the 300 simulations modelled, identify and present the "worst case" deterministic runs, which can be used to inform response planning based on the following criteria:
    a. Largest swept area of floating hydrocarbon above 10 g/m^2
    b. Largest swept area of floating hydrocarbon above 50 g/m^2
    c. Largest volume of condensate ashore
    d. Longest length of shoreline accumulation above 100 g/m^2
    e. Largest area of entrained hydrocarbons above 100 ppb
    f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no floating hydrocarbons at or above 50 g/m^2 and no dissolved hydrocarbon exposure at or above 50 ppb, for any of the 300 simulations, the deterministic results are presented based on criteria a, c, d and e only.

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

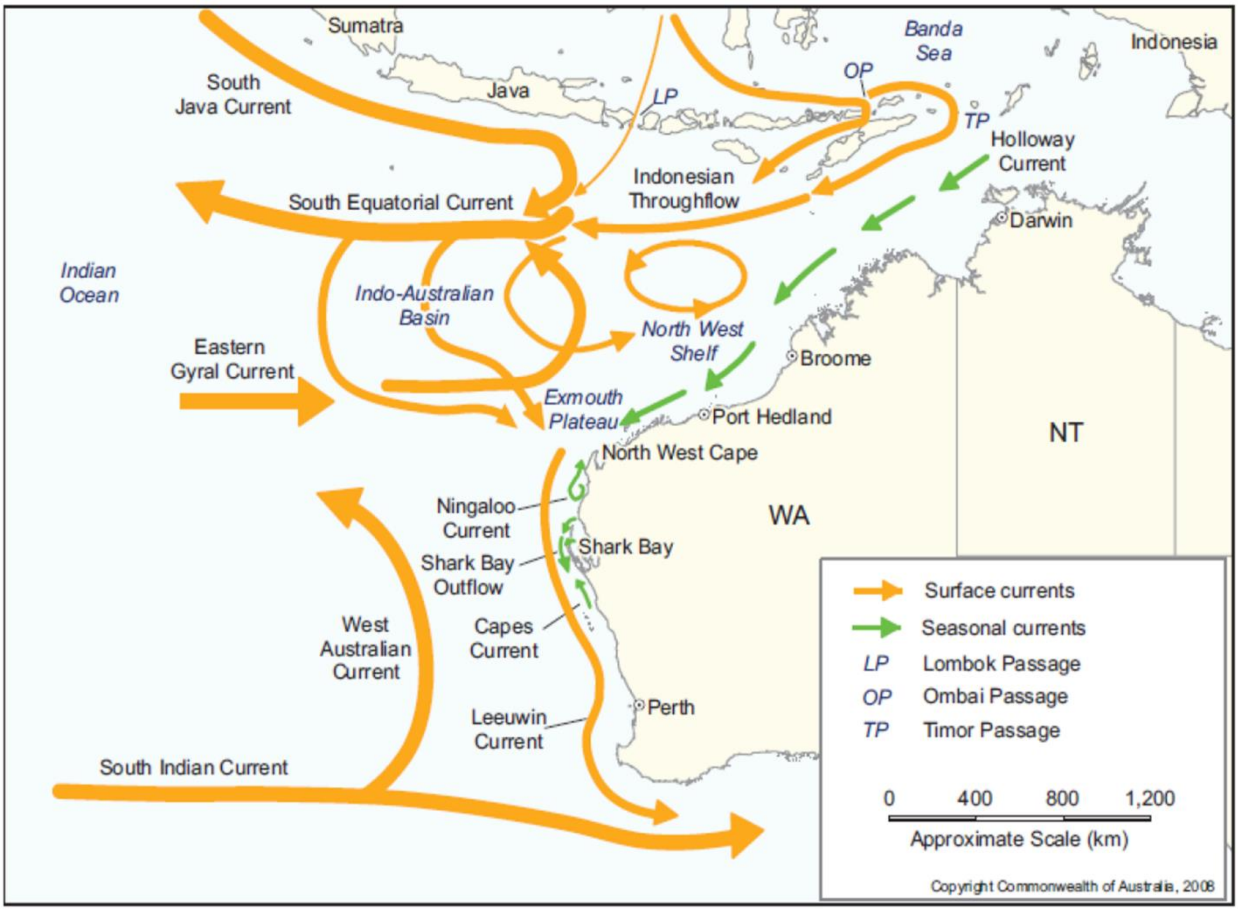


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

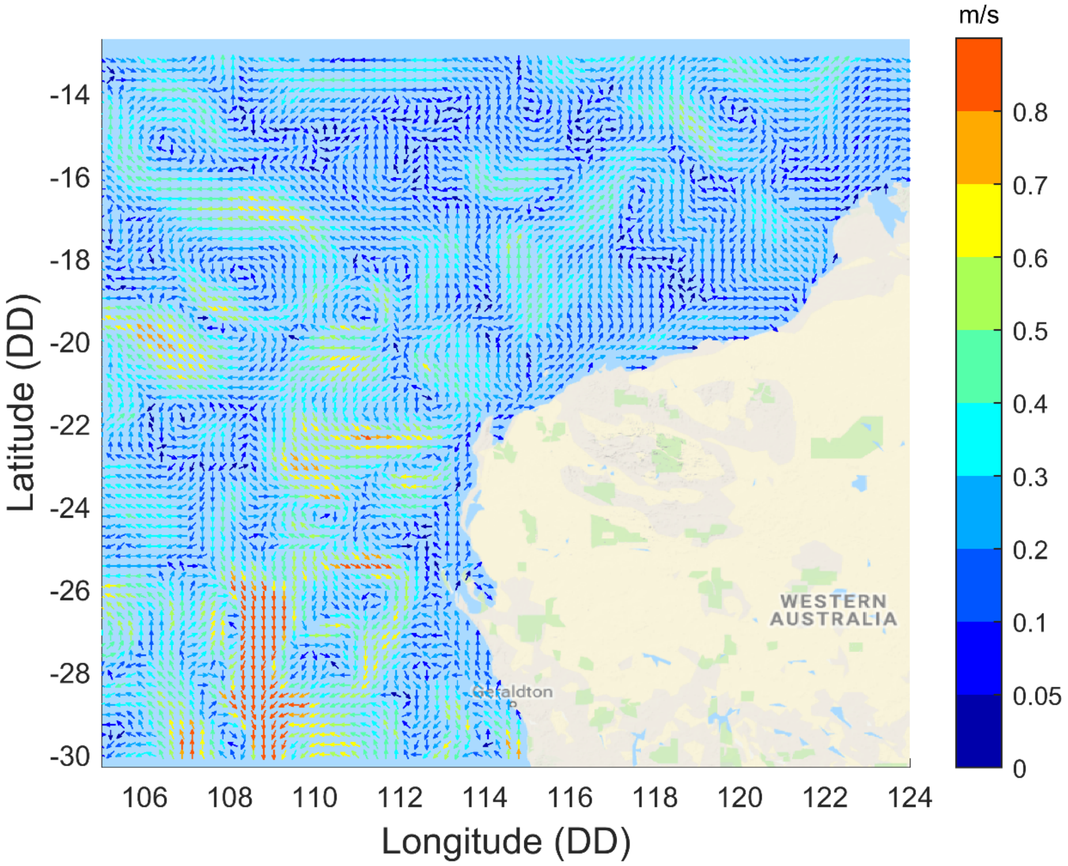


Figure 3.2 Typical ocean current circulation pattern during the summer months.

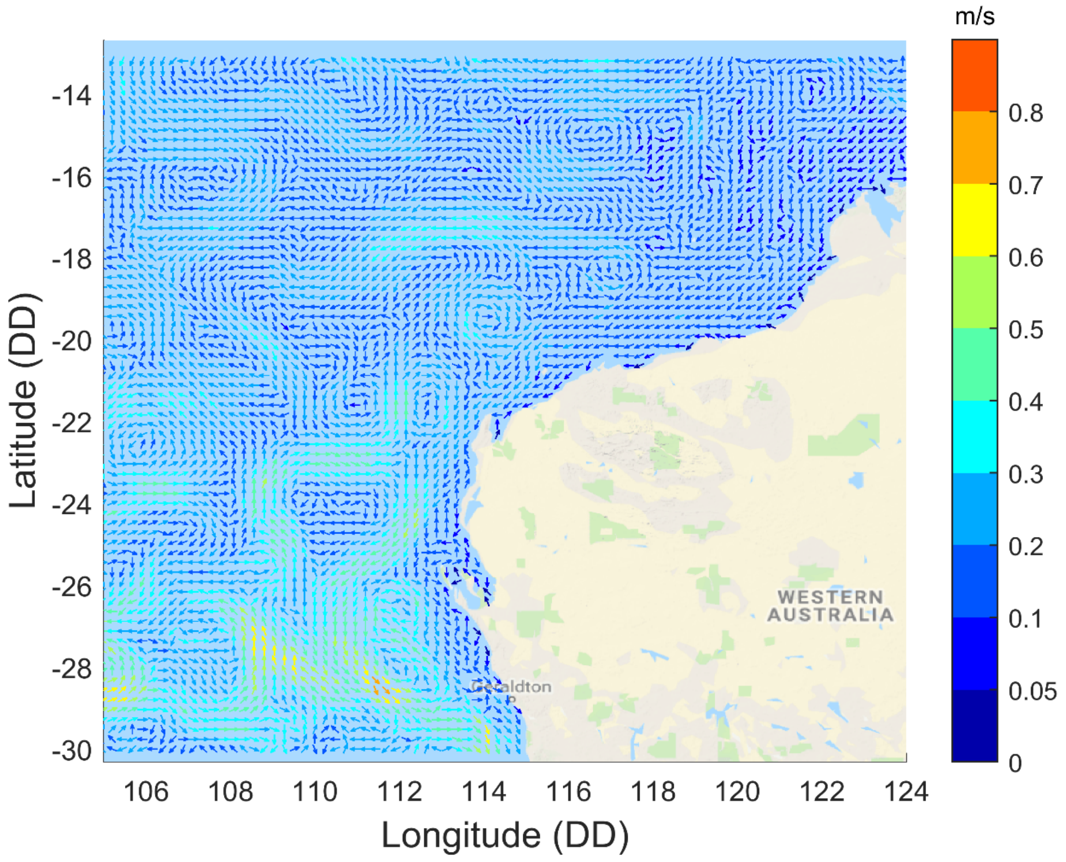


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grids were allocated in a step-wise fashion to resolve flows more accurately along the coastline, around islands and over regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

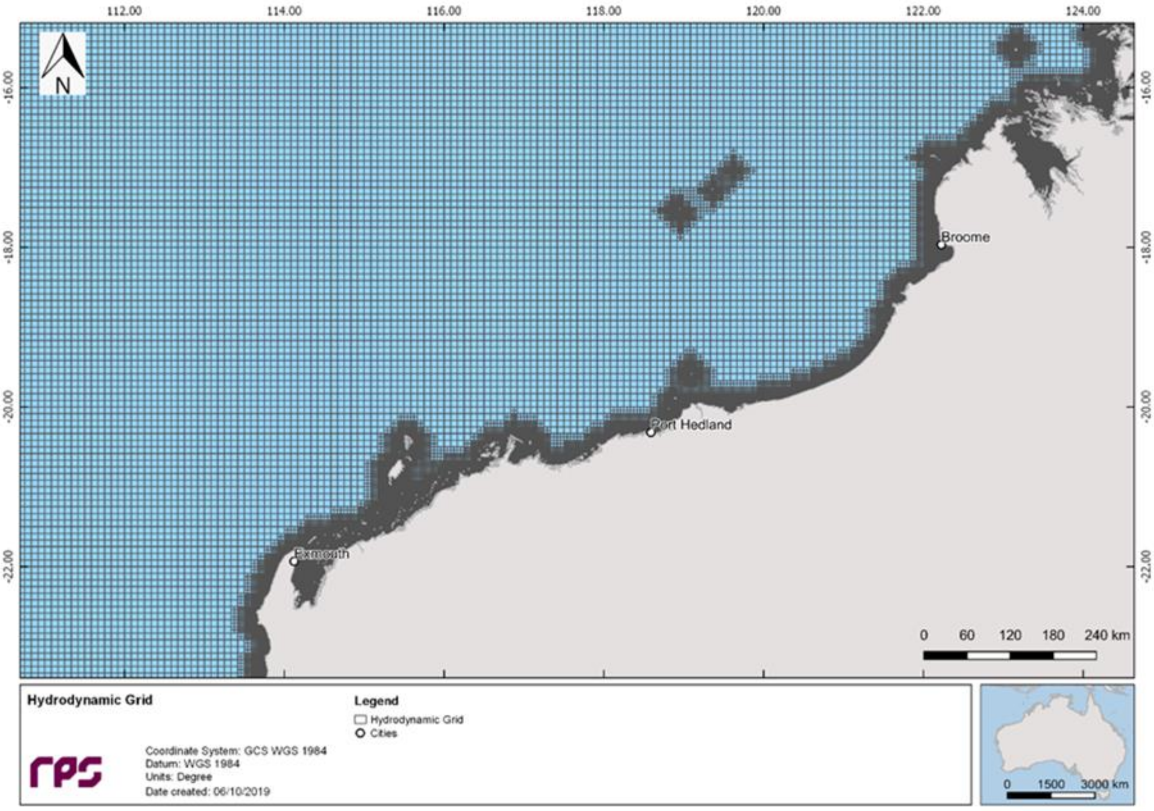


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

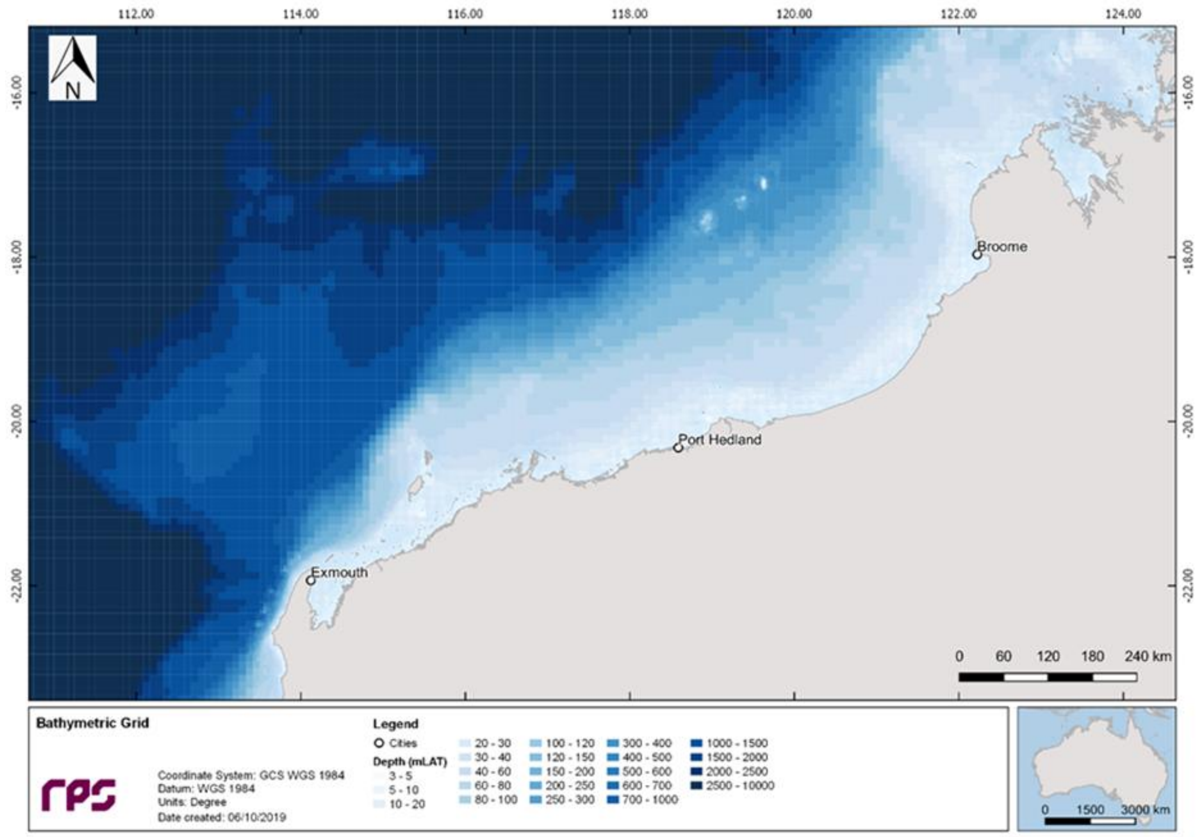


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.18 m/s (November) and 0.26 m/s (June). Additionally, the maximums ranged between 0.57 m/s (November) and 1.63 m/s (January). The general current directions were predominately southwest and then northeast throughout the year. Figure 3.6 and Figure 3.7 present the monthly and total current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.21	1.63	Northeast and Southwest
	February	0.19	1.09	Northeast and Southwest
	March	0.21	1.50	Southwest
Transitional	April	0.23	1.02	Southwest
Winter	May	0.24	0.78	Southwest
	June	0.26	1.01	Southwest
	July	0.22	0.98	Southwest
Transitional	August	0.19	0.60	Northeast and Southwest
Summer	September	0.20	0.87	Northeast and Southwest
	October	0.20	0.67	Northeast and Southwest
	November	0.18	0.57	Southwest
	December	0.20	0.69	Southwest
Minimum		**0.18**	**0.57**	
Maximum		**0.26**	**1.63**	

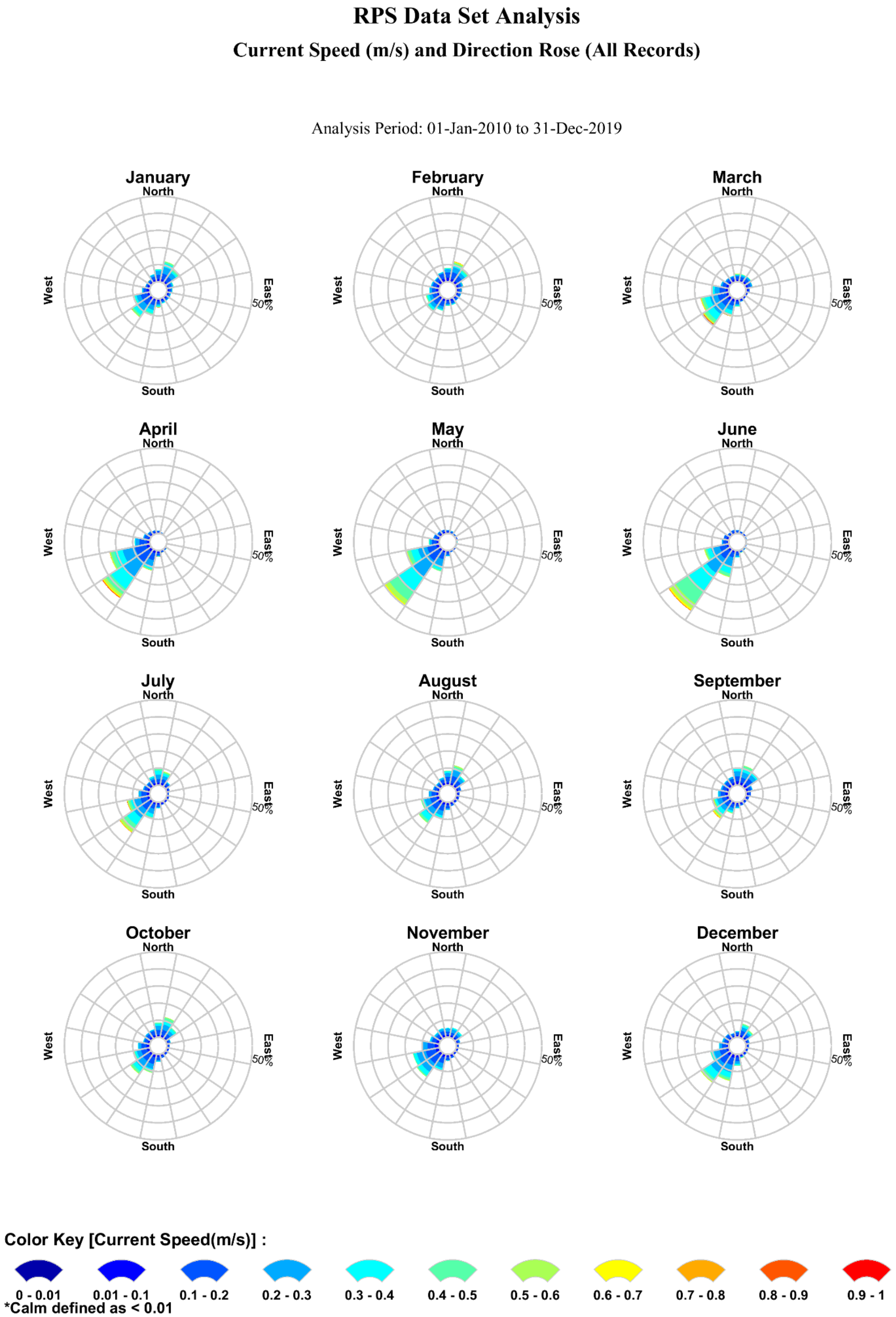


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

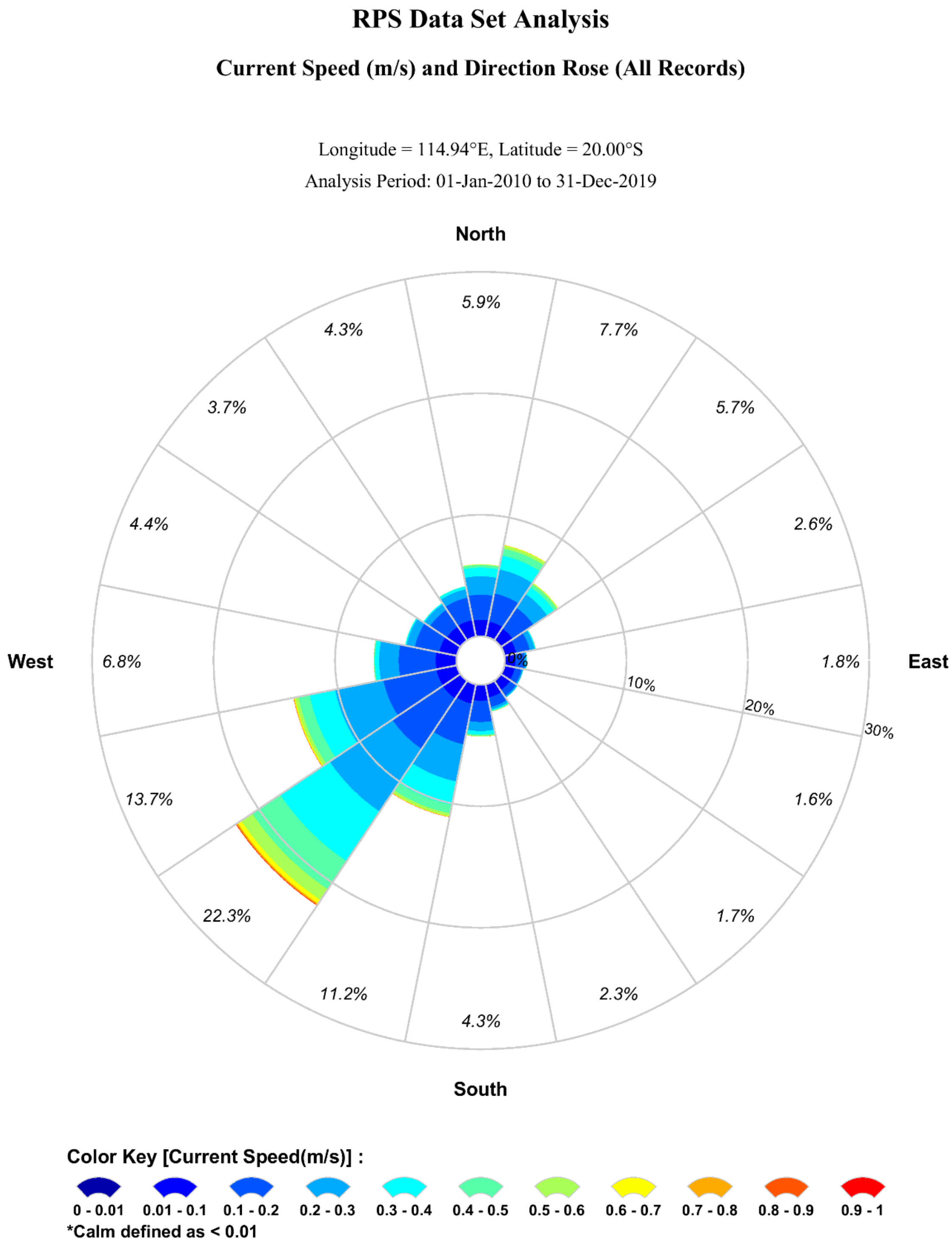


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 46 knots (February). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

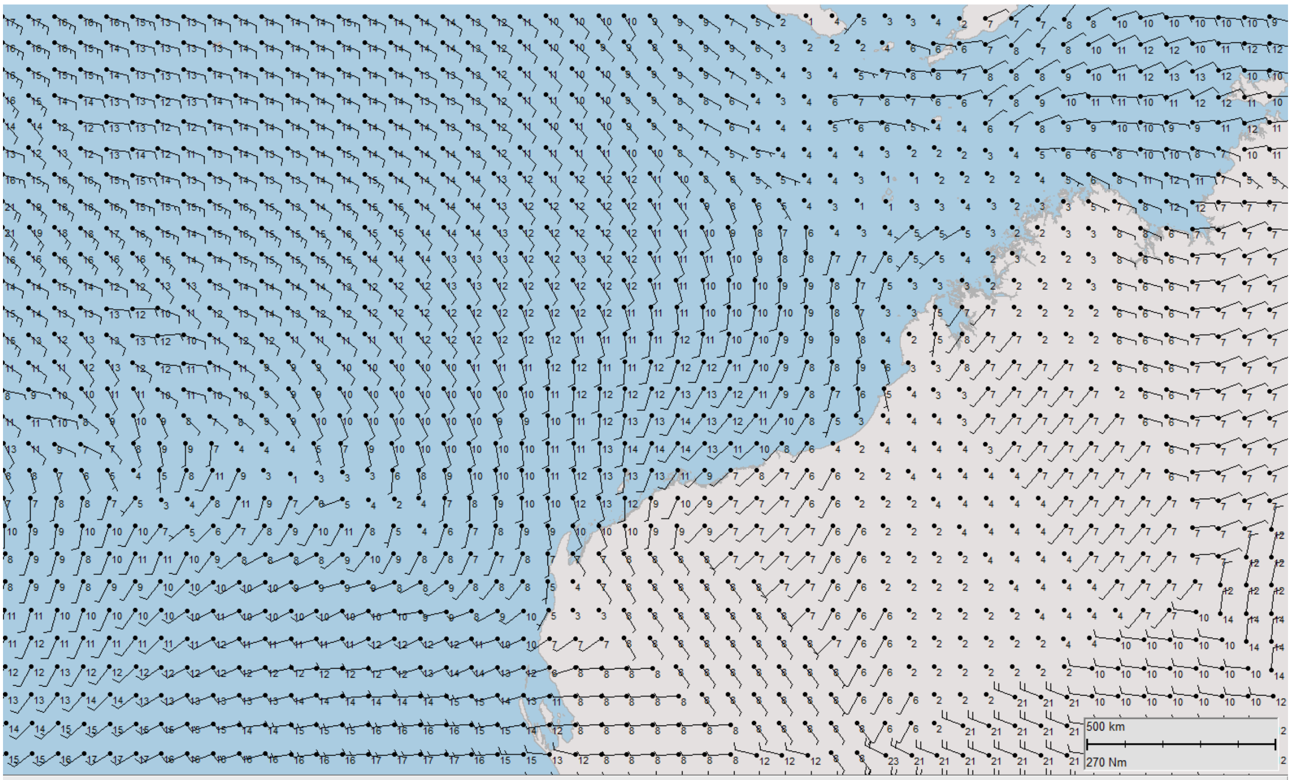


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	45	Southwest
	February	11	46	Southwest
	March	10	34	Southwest
Transitional	April	10	39	South
Winter	May	12	43	East
	June	14	29	East
	July	13	48	Southeast
Transitional	August	11	30	South
Summer	September	12	27	Southwest
	October	13	27	Southwest
	November	13	25	Southwest
	December	13	30	Southwest
Minimum		**10**	**25**	
Maximum		**14**	**46**	

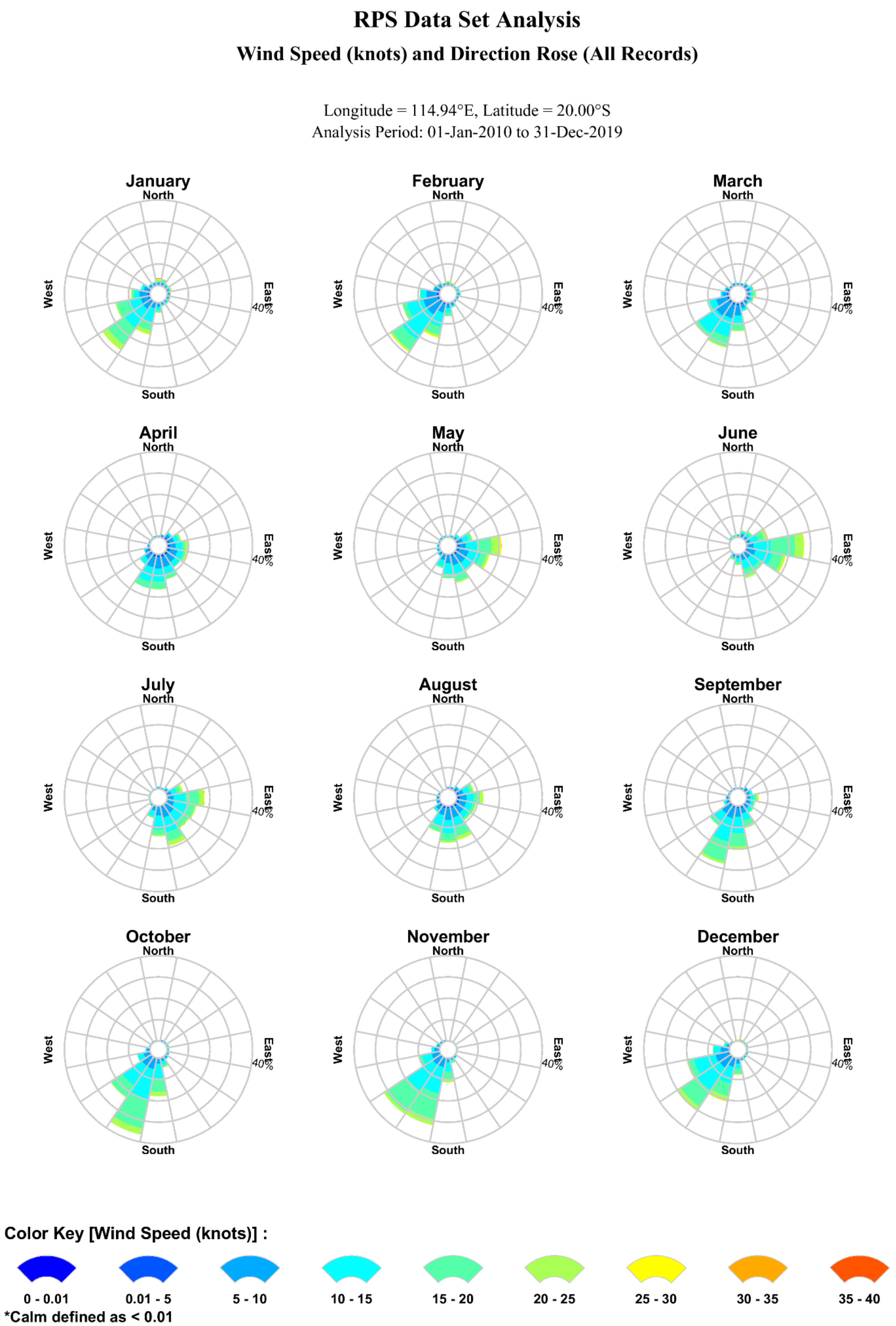


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

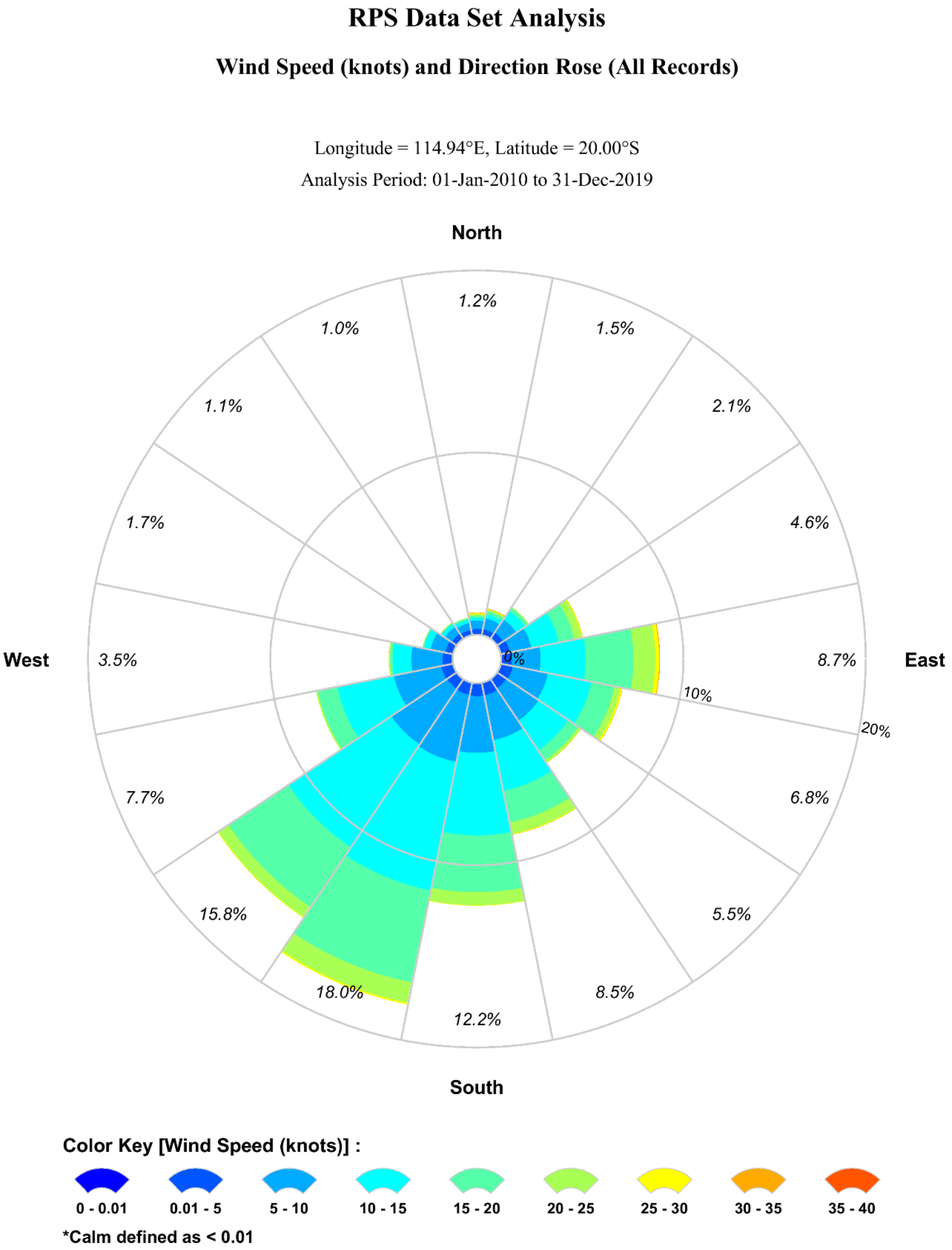


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from the HYbrid Coordinate Ocean Model (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.3°C (September) to 29.5°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.6–35.1 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	27.9	28.7	29.5	28.9	28.0	26.7	25.6	24.7	24.3	25.1	27.2	27.1
Salinity (psu)	35.1	34.7	34.8	34.9	35.1	35.1	34.9	34.8	34.8	34.8	34.6	34.9

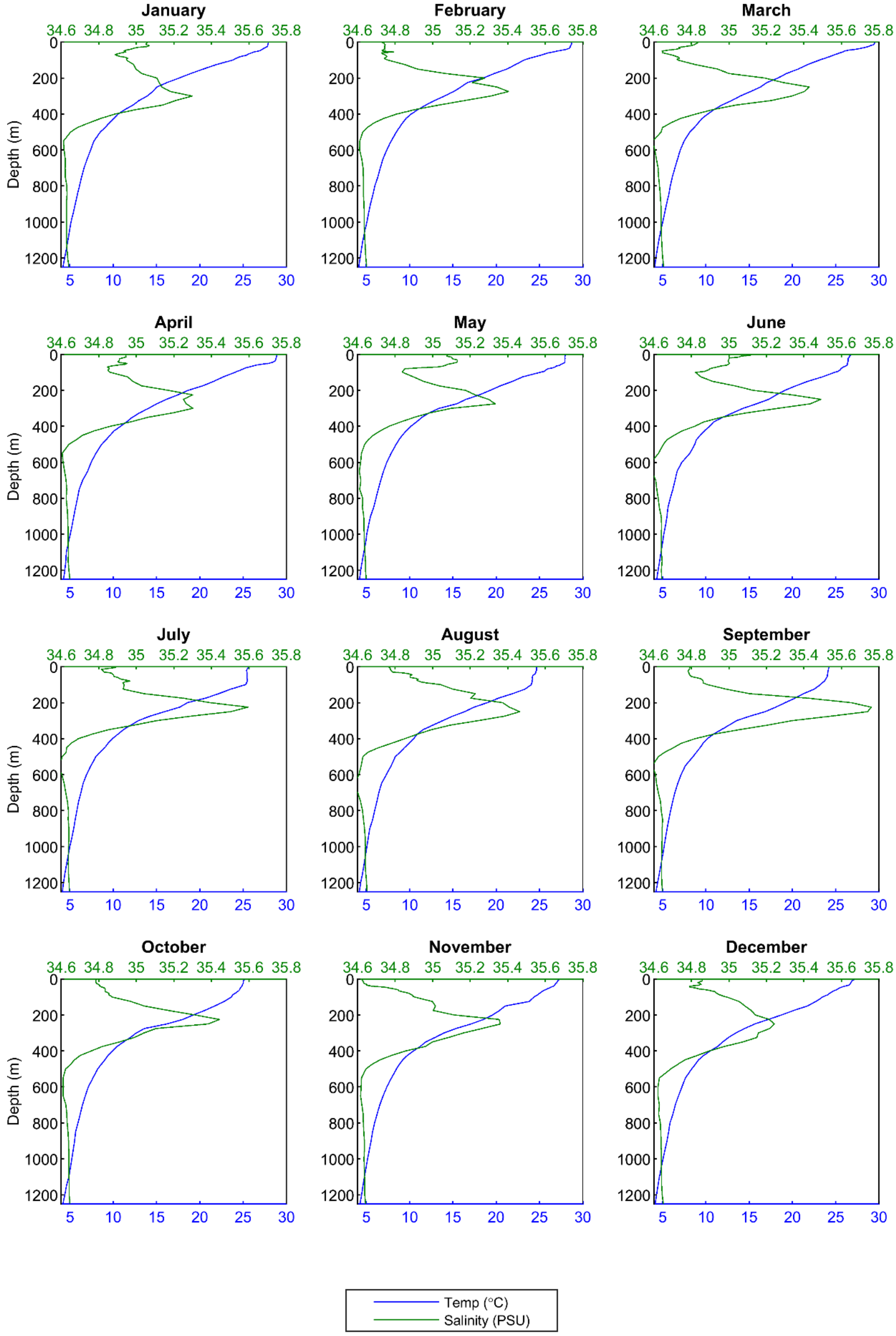


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 SUBSEA PLUME MODEL – OILMAP DEEP

The LOWC scenario is a high-pressure release of mostly gas and condensate and where gas is released with condensate, the buoyancy of the expanding gas cloud will entrain ambient seawater and propel the droplets towards the surface at a faster rate than would occur from the relative buoyancy of the condensate alone. Furthermore, the turbulence generated by such an intense discharge will tend to break the condensate up into droplets of various sizes.

To define the near-field plume dynamics, the subsea blowout model, OILMAP-DEEP, was applied. The model simulates the plume rise dynamics in two phases, the initial jet phase and the buoyant plume phase. The initial jet phase governs the plume dynamics directly above the subsurface release location and is predominately driven by the exit velocity. During this phase, the condensate droplet size and distribution is calculated. Next, the rise dynamics are dominated by the buoyant nature of the plume until the termination of the plume phase (known as the trapping depth). At this point, the results from OILMAP-DEEP (including plume trapping depth, plume diameter and droplet size distribution) are integrated into the far-field model SIMAP to simulate the rise and dispersion of the condensate droplets.

More details on the OILMAP-DEEP model, can be found in Spaulding et al. (2015). The model has been validated against observations from Deepwater Horizon as well as small and large-scale laboratory studies on subsurface oil releases (Brandvik et al., 2013, 2014; Belore, 2014; Spaulding et al., 2015; Li et al., 2017).

Table 6.1 presents the input parameters for the OILMAP-DEEP model and key results related to the near-field plume dynamics. The results indicated that the mixture of gas and condensate rose through the water column (whilst gradually losing momentum) to a trapping depth of approximately 424 m below mean sea level. After this point the condensate droplets would rise due to their own buoyancy, which are predicted to range in size from 115 to 496 μm.

Figure 6.1 illustrates the various stages of an example blowout plume.

Table 6.1 Input data and key results for the subsea plume modelling.

Input Variable	Value
Scenario	Loss of Well Control
Well name	Semele Well 5
Water depth (m)	800
Tubing diameter (inch) [m]	7 5/8 [0.194]
Condensate rate (stb/day)	2,441
Gas rate (MMscf/day)	428
Gas to condensate ratio (scf/bbl)	175,338
Formation water flow rate (stb/day)	0
Operating pressure (psia)	4,646
Key results	
Plume execution depth (m BMSL)	424
Droplet sizes (μm)	115 to 496

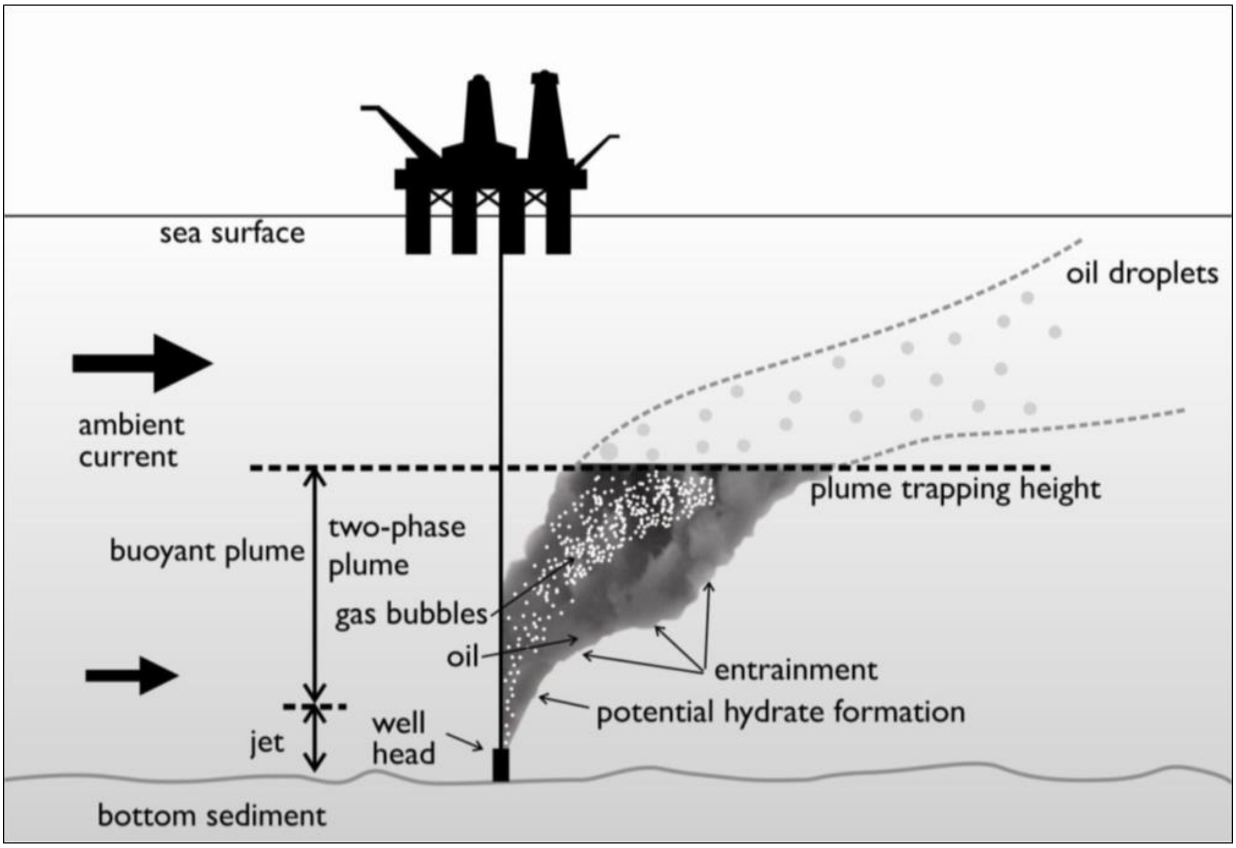


Figure 6.1 Example of a subsea plume and the various stages of the plume in the water column (Source: ASA, 2011).

7 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application.

The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

7.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 7.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and
- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

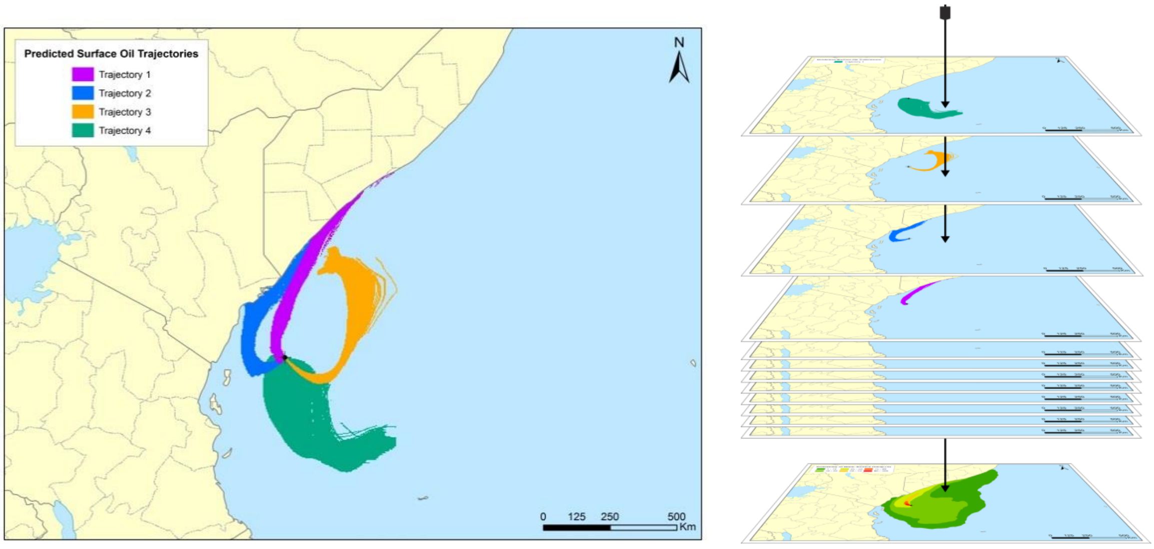


Figure 7.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

7.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 7.2.1 to 7.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

7.2.1 Floating condensate exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating condensate exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil exposure, was 1 g/m^2, which equates approximately to an average thickness of 1 µm, referred to as visible oil. Oil of this thickness is described as rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement, 2009; AMSA, 2014) (see Table 7.1). Figure 7.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. This threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to its visibility on the sea surface and potential to trigger temporary closures of areas (i.e. fishing grounds) as a precautionary measure. Table 7.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil exposure.

Ecological impact has been estimated to occur at 10 g/m^2 (a film thickness of approximately 10 µm or 0.01 mm) according to French et al. (1996) and French-McCay (2009) as this level of fresh oiling has been observed to mortally impact some birds through adhesion of oil to their feathers, exposing them to secondary effects such as hypothermia. The appearance of oil at this average thickness has been described as a metallic sheen (Bonn Agreement, 2009). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at oil concentrations on the sea surface of 25 g/m^2 (or greater), would be harmful for all birds that have landed in an oil film due to potential contamination of their feathers, with secondary effects such as loss of temperature regulation and ingestion of oil through preening. The appearance of oil at this thickness is also described as metallic sheen (Bonn Agreement, 2009). For this study the high exposure threshold was set to 50 g/m^2 and above based on NOPSEMA (2019). This threshold can also be used to inform response planning.

Table 7.2 defines the thresholds used to classify the zones of floating condensate exposure reported herein.

Table 7.1 The Bonn Agreement Oil Appearance Code.

Code	Description Appearance	Layer Thickness Interval (g/m^2 or µm)	Litres per km^2
1	Sheen (silvery/grey)	0.04 – 0.30	40 – 300
2	Rainbow	0.30 – 5.0	300 – 5,000
3	Metallic	5.0 – 50	5,000 – 50,000
4	Discontinuous True Oil Colour	50 – 200	50,000 – 200,000
5	Continuous True Oil Colour	≥ 200	≥ 200,000

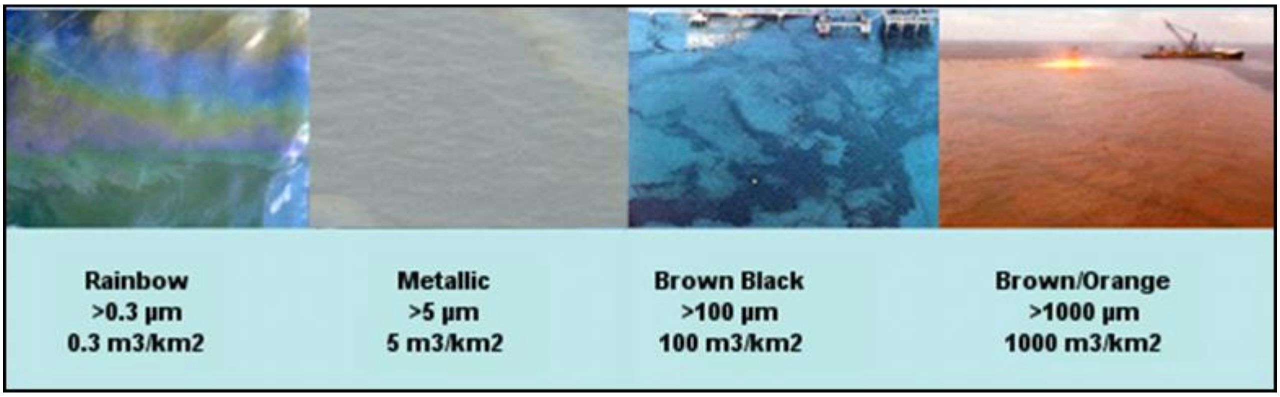


Figure 7.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 7.2 Floating condensate exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (g/m^2)	Description
Low	1	Approximates range of socioeconomic effects and establishes planning area for scientific monitoring
Moderate	10	Approximates lower limit for harmful exposures to birds and marine mammals
High	50*	Approximates surface oil slick and informs response planning

* 50 g/m^2 also used to define the threshold for actionable floating oil.

7.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential "low shoreline accumulation".

French et al. (1996) and French-McCay (2009) define a shoreline oil accumulation threshold of 100 g/m^2, or above, would potentially harm shorebirds and wildlife (furbearing aquatic mammals and marine reptiles on or along the shore) based on studies for sub-lethal and lethal impacts. This threshold has been used in previous environmental risk assessment studies (see French-McCay, 2003; French-McCay et al., 2004, French-McCay et al., 2011; 2012; NOAA, 2013). Additionally, a shoreline concentration of 100 g/m^2, or above, is the minimum limit that the oil can be effectively cleaned according to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential "moderate shoreline accumulation".

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential "high shoreline accumulation". It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 7.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 7.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	10	Predicts potential for some socio-economic impact
Moderate	100*	Loading predicts area likely to require clean-up effort
High	> 1,000	Loading predicts area likely to require intensive clean-up effort

* 100 g/m^2 also used to define the threshold for actionable shoreline oil.

7.2.3 In-water Exposure Thresholds

Oil is a mixture of thousands of hydrocarbons of varying physical, chemical, and toxicological characteristics, and therefore, demonstrate varying fates and impacts on organisms. As such, for in-water exposure, the SIMAP model provides separate outputs for dissolved and entrained hydrocarbons from oil droplets. The consequences of exposure to dissolved and entrained components will differ because they have different modes and magnitudes of effect.

Entrained hydrocarbon concentrations were calculated based on oil droplets that are suspended in the water column, though not dissolved. The composition of this oil would vary with the state of weathering (oil age) and may contain soluble hydrocarbons when the oil is fresh. Calculations for dissolved hydrocarbons specifically calculates oil components which are dissolved in water, which are known to be the primary source of toxicity exerted by oil.

7.2.3.1 Dissolved Hydrocarbons

Laboratory studies have shown that dissolved hydrocarbons exert most of the toxic effects of oil on aquatic biota (Carls et al., 2008; Nordtug et al., 2011; Redman, 2015). The mode of action is a narcotic effect, which is positively related to the concentration of soluble hydrocarbons in the body tissues of organisms (French-McCay, 2002). Dissolved hydrocarbons are taken up by organisms directly from the water column by absorption through external surfaces and gills, as well as through the digestive tract. Thus, soluble hydrocarbons are termed “bioavailable”.

Hydrocarbon compounds vary in water-solubility and the toxicity exerted by individual compounds is inversely related to solubility, however bioavailability will be modified by the volatility of individual compounds (Nirmalakhandan & Speece, 1988; Blum & Speece, 1990; McCarty, 1986; McCarty et al., 1992a, 1992b; Mackay et al., 1992; McCarty & Mackay, 1993; Verhaar et al., 1992, 1999; Swartz et al., 1995; French-McCay, 2002; McGrath et al., 2009). Of the soluble compounds, the greatest contributor to toxicity for water-column and benthic organisms are the lower-molecular-weight aromatic compounds, which are both volatile and soluble in water. Although they are not the most water-soluble hydrocarbons within most oil types, the polynuclear aromatic hydrocarbons (PAHs) containing 2-3 aromatic ring structures typically exert the largest narcotic effects because they are semi-soluble and not highly volatile, so they persist in the environment long enough for significant accumulation to occur (Anderson et al., 1974, 1987; Neff & Anderson, 1981; Malins & Hodgins, 1981; McAuliffe, 1987; NRC, 2003). The monoaromatic hydrocarbons (MAHs), including the BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), and the soluble alkanes (straight chain hydrocarbons) also contribute to toxicity, but these compounds are highly volatile, so that their contribution will be low when oil is exposed to evaporation and higher when oil is discharged at depth where volatilisation does not occur (French-McCay, 2002).

French-McCay (2002) reviewed available toxicity data, where marine biota was exposed to dissolved hydrocarbons prepared from oil mixtures, finding that 95% of species and life stages exhibited 50% population mortality (LC_{50}) between 6 and 400 ppb total PAH concentration after 96 hrs exposure, with an average of 50 ppb. Hence, concentrations lower than 6 ppb total PAH value should be protective of 97.5% of species and life stages even with exposure periods of days (at least 96 hours). Early life-history stages of fish appear to be more sensitive than older fish stages and invertebrates.

Exceedances of 10, 50 or 400 ppb over a 1 hour timestep (see Table 7.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on NOPSEMA (2019).

7.2.3.2 Entrained Hydrocarbons

Entrained hydrocarbons consist of oil droplets that are suspended in the water column and insoluble. As such, insoluble compounds in oil cannot be absorbed from the water column by aquatic organisms, hence are not bioavailable through absorption of compounds from the water. Exposure to these compounds would require routes of uptake other than absorption of soluble compounds. The route of exposure of organisms to whole oil alone include direct contact with tissues of organisms and uptake of oil by direct consumption, with potential for biomagnification through the food chain (NRC, 2003).

The 10 ppb threshold represents the very lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the ANZECC & ARMCANZ (2000) water quality guidelines. Due to the requirement for relatively long exposure times (> 24 hours) for these concentrations to be significant, they are likely to be more meaningful for juvenile fish, larvae and planktonic organisms that might be entrained (or otherwise moving) within the entrained plumes, or when entrained hydrocarbons adhere to organisms or trapped against a shoreline for periods of several days or more.

This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the entrained hydrocarbon at this level.

Thresholds of 10 ppb and 100 ppb were applied over a 1 hour time exposure (Table 7.4), to cover the range of thresholds outlined in the ANZECC & ARMCANZ (2000) water quality guidelines, the incremental change for greater potential effect and is per NOPSEMA (2019).

A complicating factor that should be considered when assessing the consequence of dissolved and entrained oil distributions is that there will be some areas where both physically entrained oil droplets and dissolved hydrocarbons co-exist. Higher concentrations of each will tend to occur close to the source where sea conditions can force mixing of relatively unweathered oil into the water column, resulting in more rapid dissolution of soluble compounds.

Table 7.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

8 CONDENSATE PROPERTIES

8.1 Properties

Semele condensate physical properties and boiling point distributions were provided by Chevron and are presented in Table 8.1 and Table 8.2, respectively.

Semele condensate has an API of 41.9, a density of 816 kg/m^3 (at 15ºC) and a viscosity value of 6.7 cP at 15 ºC. When exposed to the atmosphere at local temperatures, about 33% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 32.5% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (27.9%) should evaporate over a longer period (265°C < BP < 380°C). The remaining 6.5% of the condensate would persist in the marine environment for much longer periods and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity for the mixture to take up water to form water-in-oil emulsion.

Soluble aromatic hydrocarbons contribute approximately 3.9% by mass of the whole oil, which is contained in the volatile fractions and are highly soluble. The process of evaporation will be grater under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

The actual fate will depend greatly on the amount that reaches the surface, either through the initial release or by resurfacing.

Table 8.1 Physical properties of Semele condensate.

Characteristic	Semele Condensate
Density (kg/m^3)	816 (at 15°C)
API	41.9
Dynamic viscosity (cP)	6.7 (at 15°C)
Pour point (°C)	-9
Surface tension (dyne/cm)	22
Hydrocarbon property category	Group I
Hydrocarbon property classification	Non-persistent

Table 8.2 Boiling point ranges of Semele condensate.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 >C_{20}
Semele Condensate	% of total	33.0	32.5	27.9	6.5
	% of aromatics	3.9	0	0	0

8.2 Weathering Characteristics

8.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this condensate when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.

- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the condensate reaches the surface.

8.2.2 Results

The mass balance forecast for the calm-wind case (Figure 8.1) shows that 66% of the condensate is predicted to evaporate within 24 hours. The majority of the remaining condensate on the water surface will weather at a slower rate due to the low volatile components. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.2), where the winds are of greater strength on average, entrainment of Semele condensate into the water column was shown to increase. Approximately 24 hours after the spill, 49% of the condensate mass was shown to entrain and a further 49% had evaporated, leaving only a small portion of the condensate floating on the water surface (<0.8%). The residual compounds will tend to remain entrained during conditions that generate wind-waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case would result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and condensate droplets in the water column occurs at an approximate rate of ~1.5% per day with an accumulated total of ~11.5% after 7 days, in comparison to a rate of ~0.1% per day and an accumulated total of ~0.7% after 7 days in the constant-wind case. Given the portion of entrained condensate and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

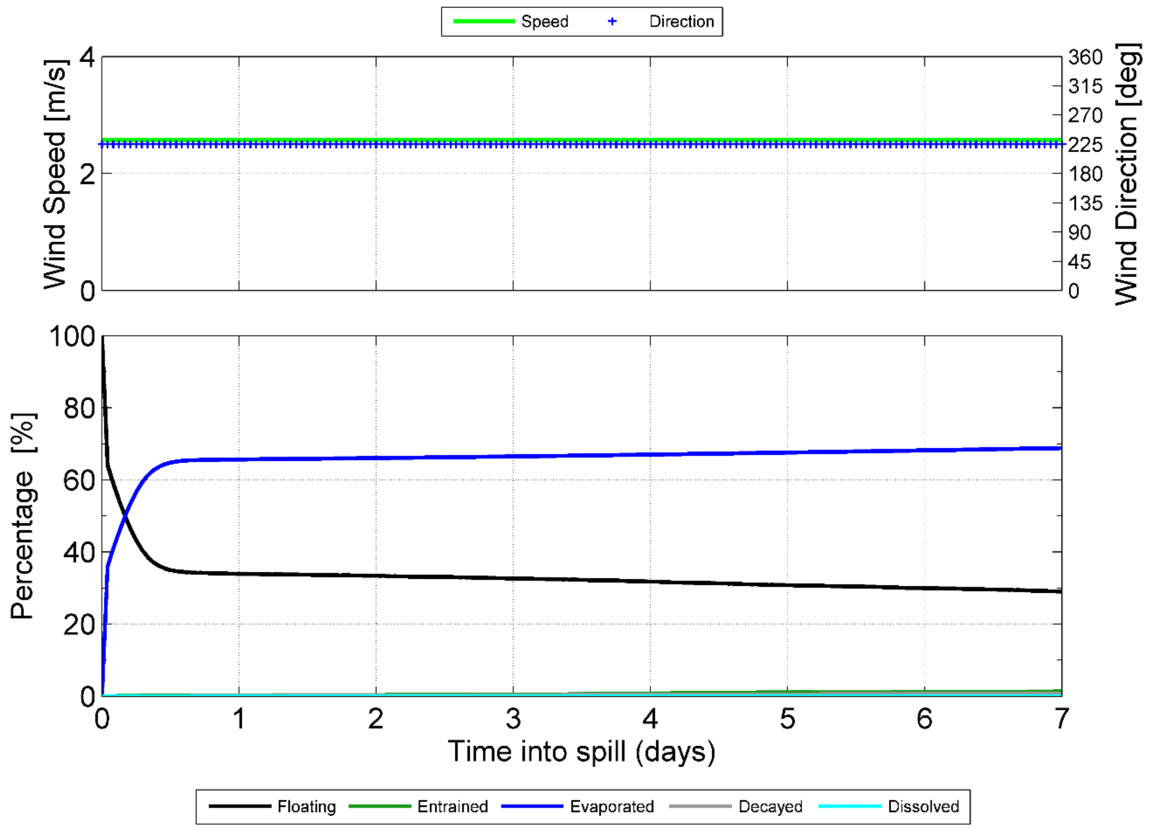


Figure 8.1 Proportional mass balance plot representing the weathering of Semele condensate spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature.

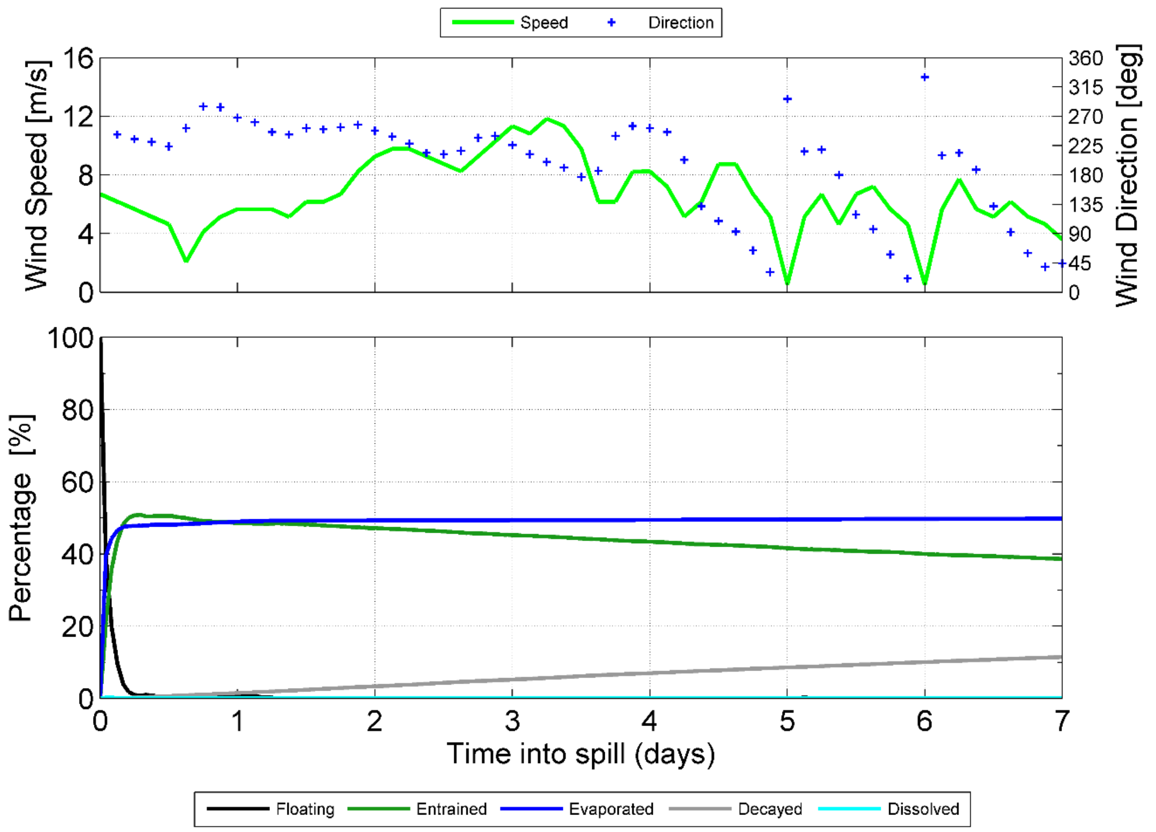


Figure 8.2 Proportional mass balance plot representing the weathering of Semele condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature.

9 MODEL SETTINGS

Table 9.1 provides a summary of the oil spill model settings.

Table 9.1 Summary of the oil spill model settings used in this assessment.

	Scenario
Location	Semele Well 5 (Semele)
Number of spill simulations with randomly selected start times	100 per season (300 total)
Spill volume (m^3) [bbl]	34,927 [219,690]
Condensate type	Semele condensate
Release type (depth)	Subsea (800 m)
Release duration (days)	90
Simulation length (days)	104
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour high exposure

10 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

10.1 Stochastic Analysis

10.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***Probability of condensate exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***Minimum time before condensate exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

10.2 Deterministic Trajectories

The deterministic results in Section 11.2 are based on the following criteria:

a. Largest swept area of floating hydrocarbon above 10 g/m^2
b. Largest swept area of floating hydrocarbon above 50 g/m^2
c. Largest volume of condensate ashore
d. Longest length of shoreline accumulation above 100 g/m^2
e. Largest area of entrained hydrocarbons above 100 ppb; and
f. Largest area of dissolved hydrocarbons above 50 ppb

10.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 10.1 to Figure 10.10). Receptor categories (see Table 10.1) include sections of shorelines and offshore islands. All other sensitive receptors other than submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

Table 10.2 summarises the receptors that the location resides within.

Table 10.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	✗
Biologically Important Area	BIA	✓	✓	✗
Impact Assessment Area	IAA	✓	✓	✓
Integrated Marine and Coastal Regionalisation of Australia	IMCRA	✓	✓	✗
Interim Biogeographic Regionalisation of Australia	IBRA	✓	✓	✗
Key Ecological Feature	KEF	✓	✓	✗
Marine Park	MP	✓	✓	✗
Marine Management Area	MMA	✓	✓	✗
Nature Reserve	NR	✓	✓	✗
Reefs, Shoals and Banks	RSB	✓	✓	✗
Ramsar Sites	Ramsar	✓	✓	✗
State Waters	State Waters	✓	✓	✗
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 10.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Pygmy Blue Whale - Distribution	BIA	✓
Wedge-tailed Shearwater - Breeding	BIA	✓
Offshore Area	IAA	✓
Continental Slope Demersal Fish Communities*	KEF	✓

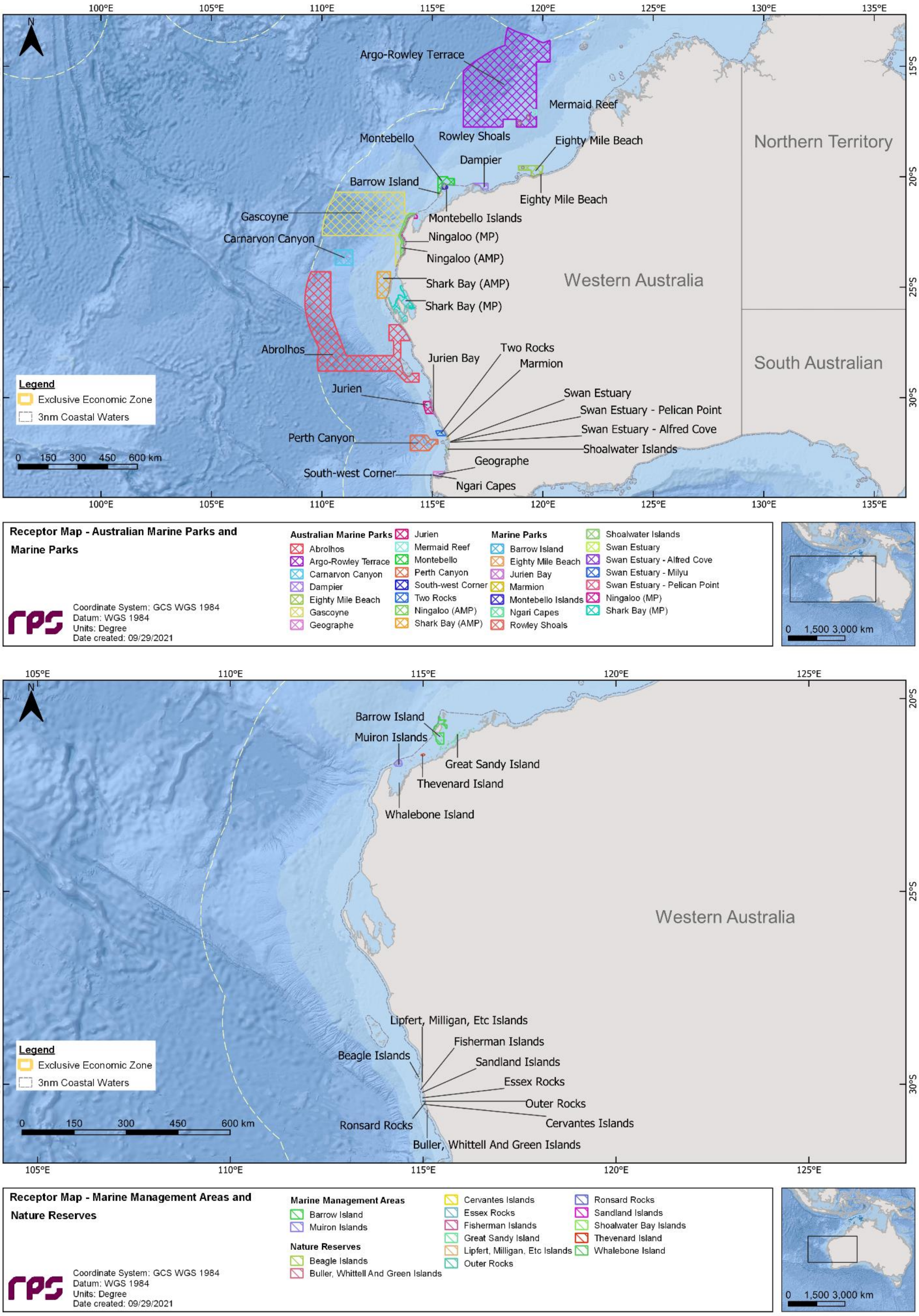
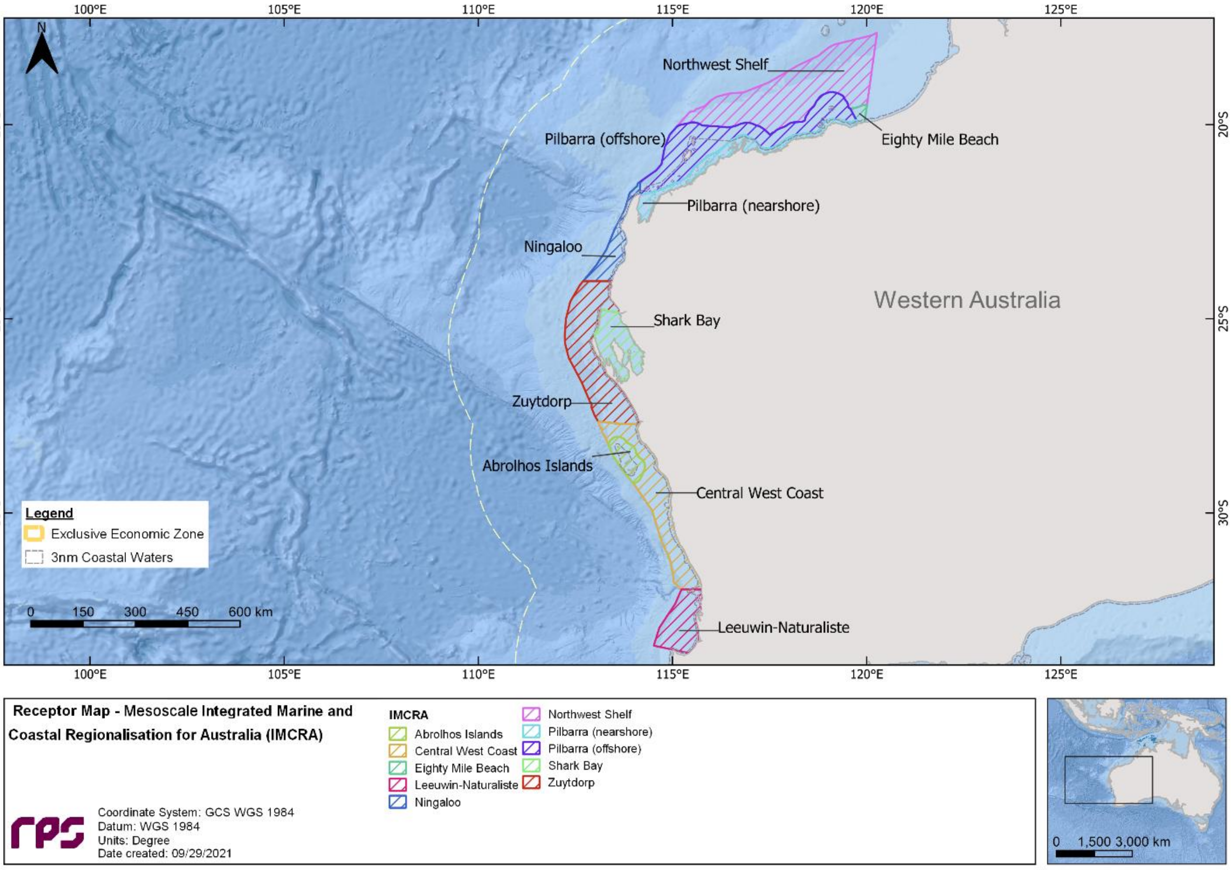


Figure 10.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).



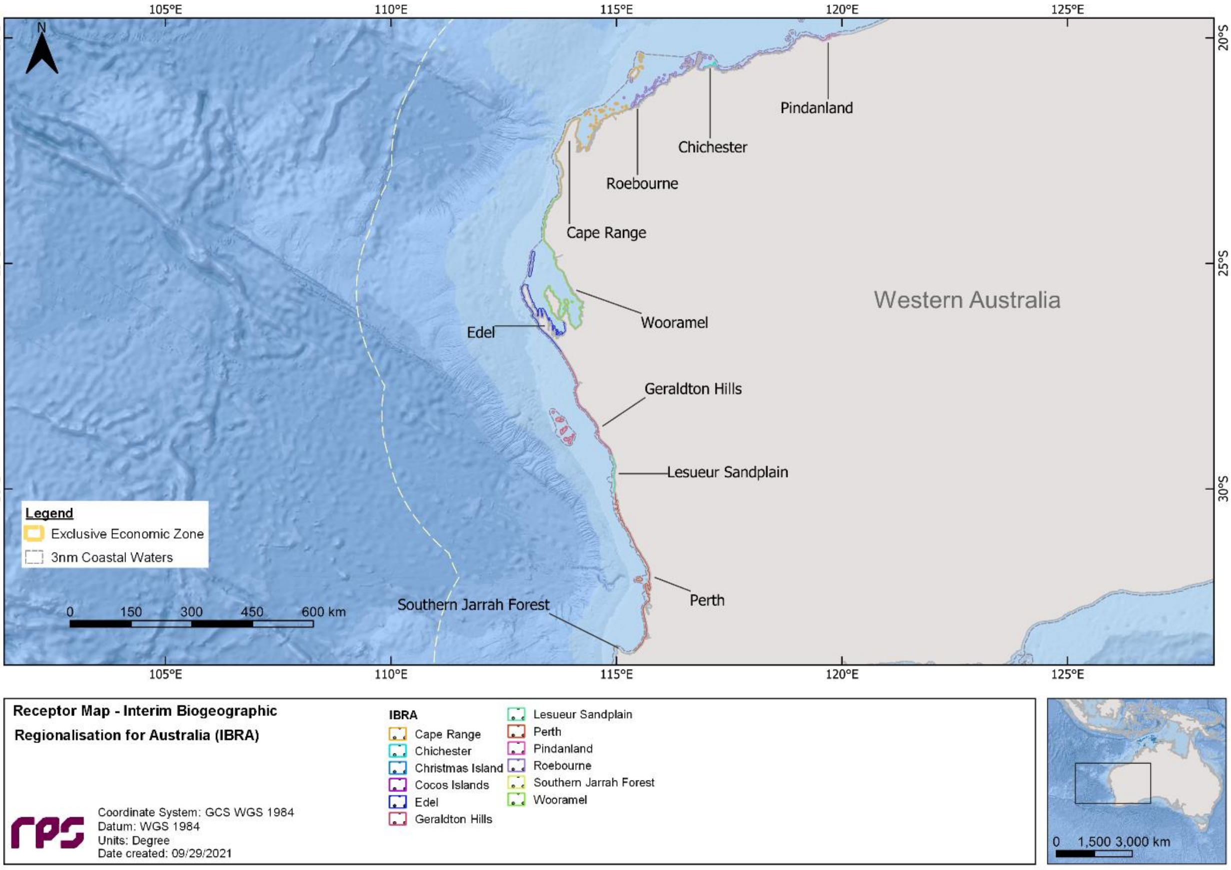
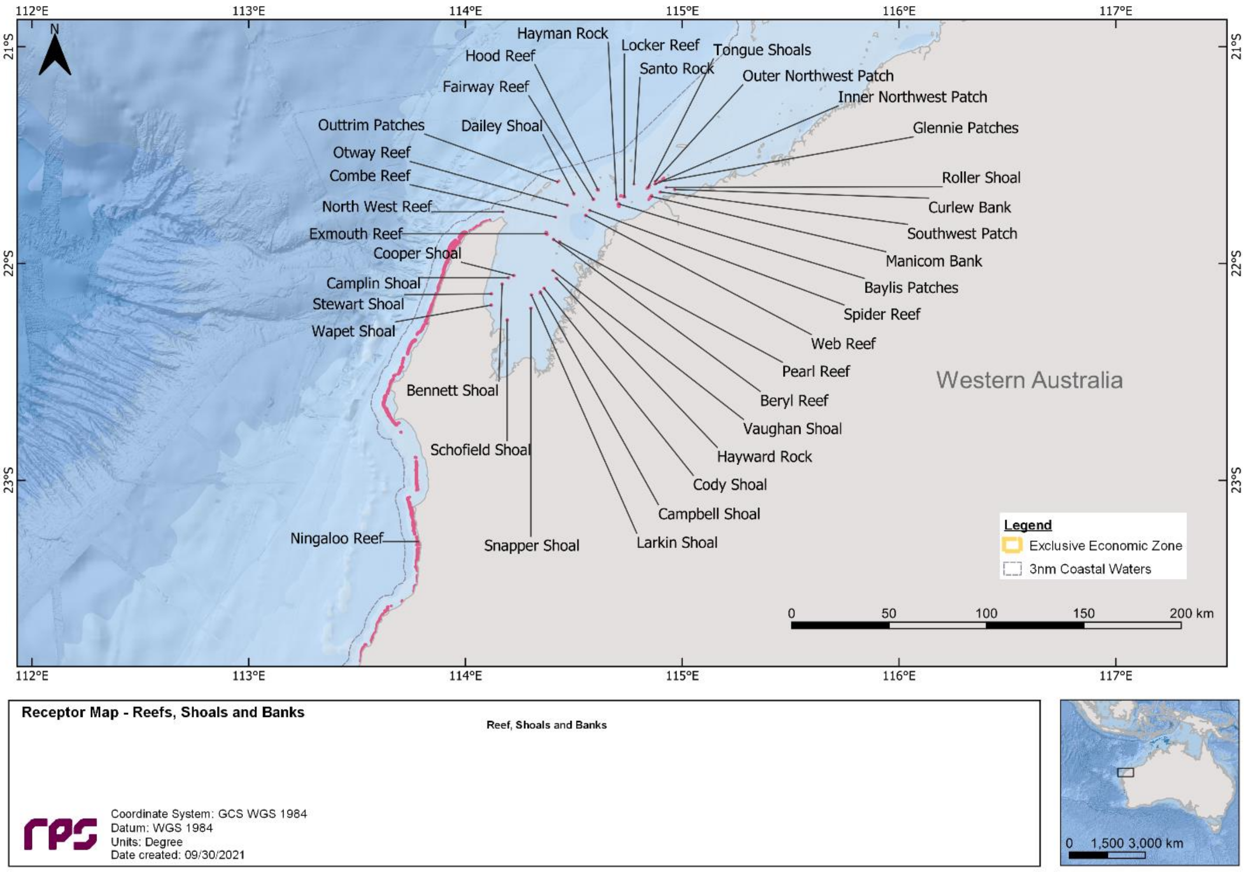


Figure 10.2 Receptor maps for Mesoscale Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).



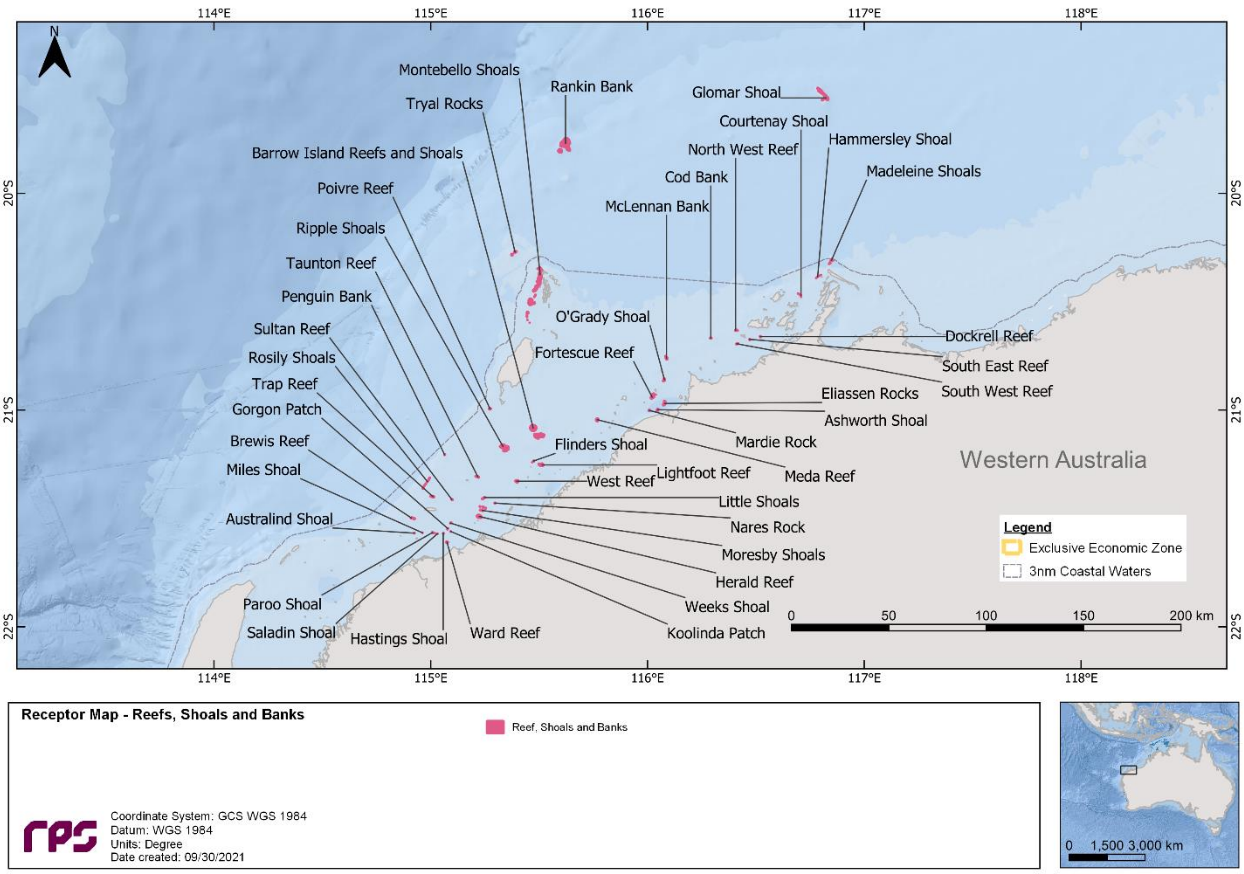


Figure 10.3 Receptor maps for Reefs, Shoals and Banks (RSB).

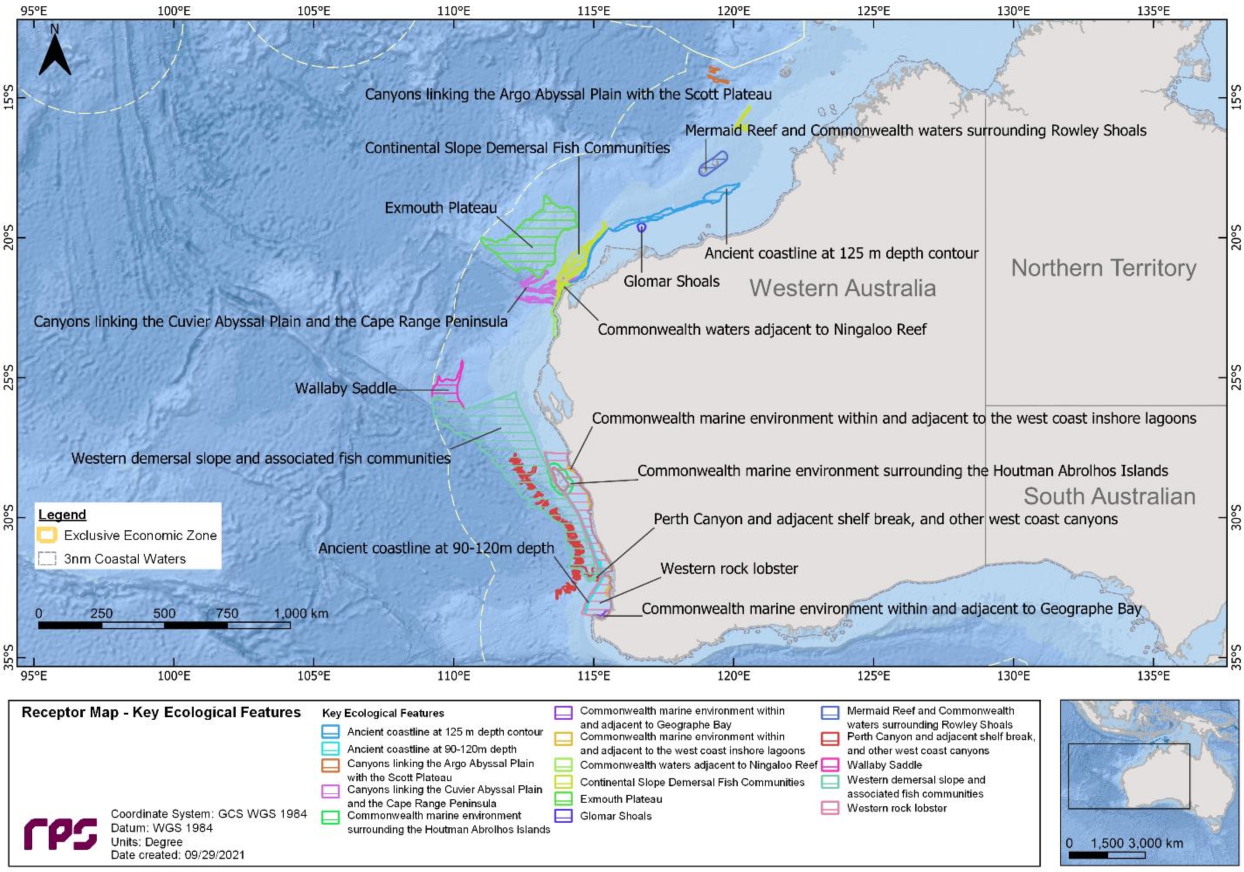


Figure 10.4 Receptor maps for Key Ecological Features (KEFs).

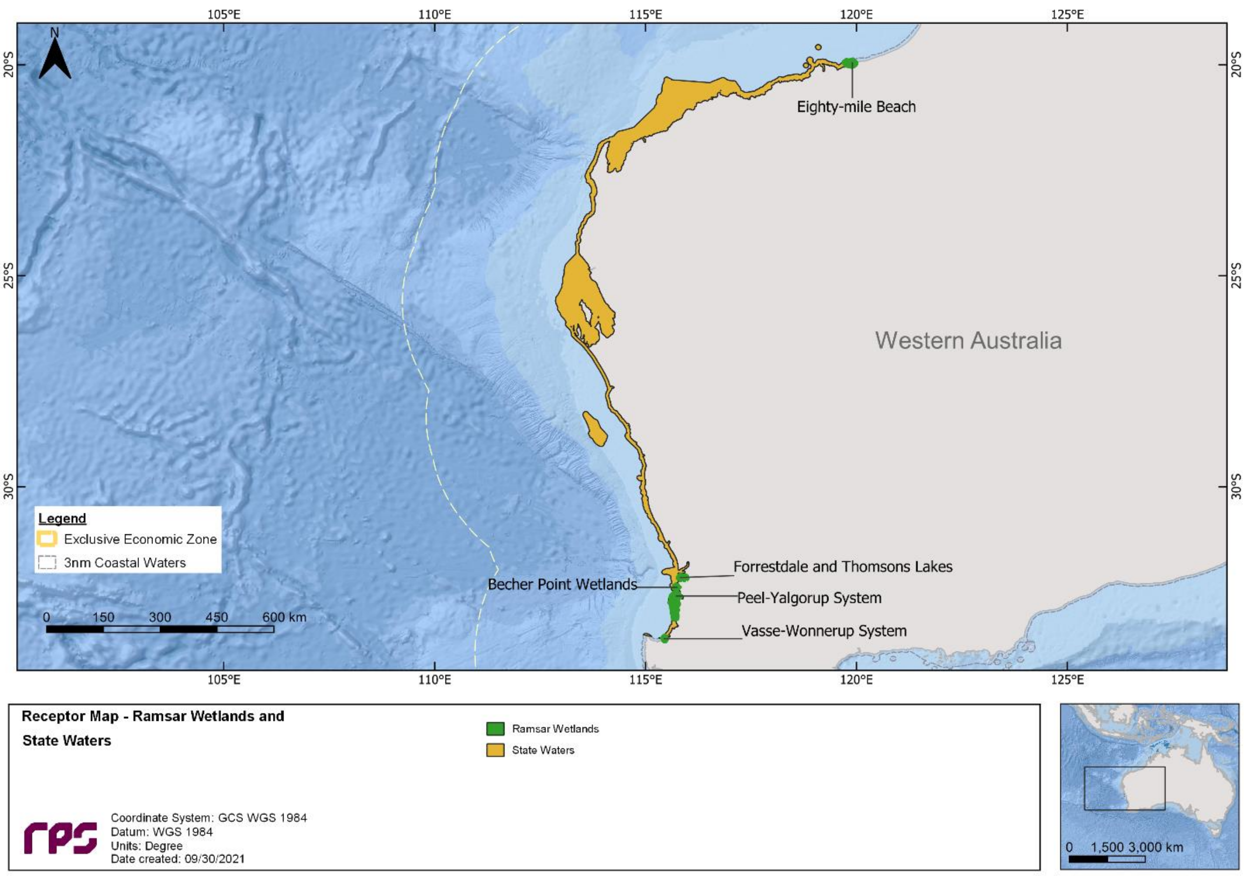
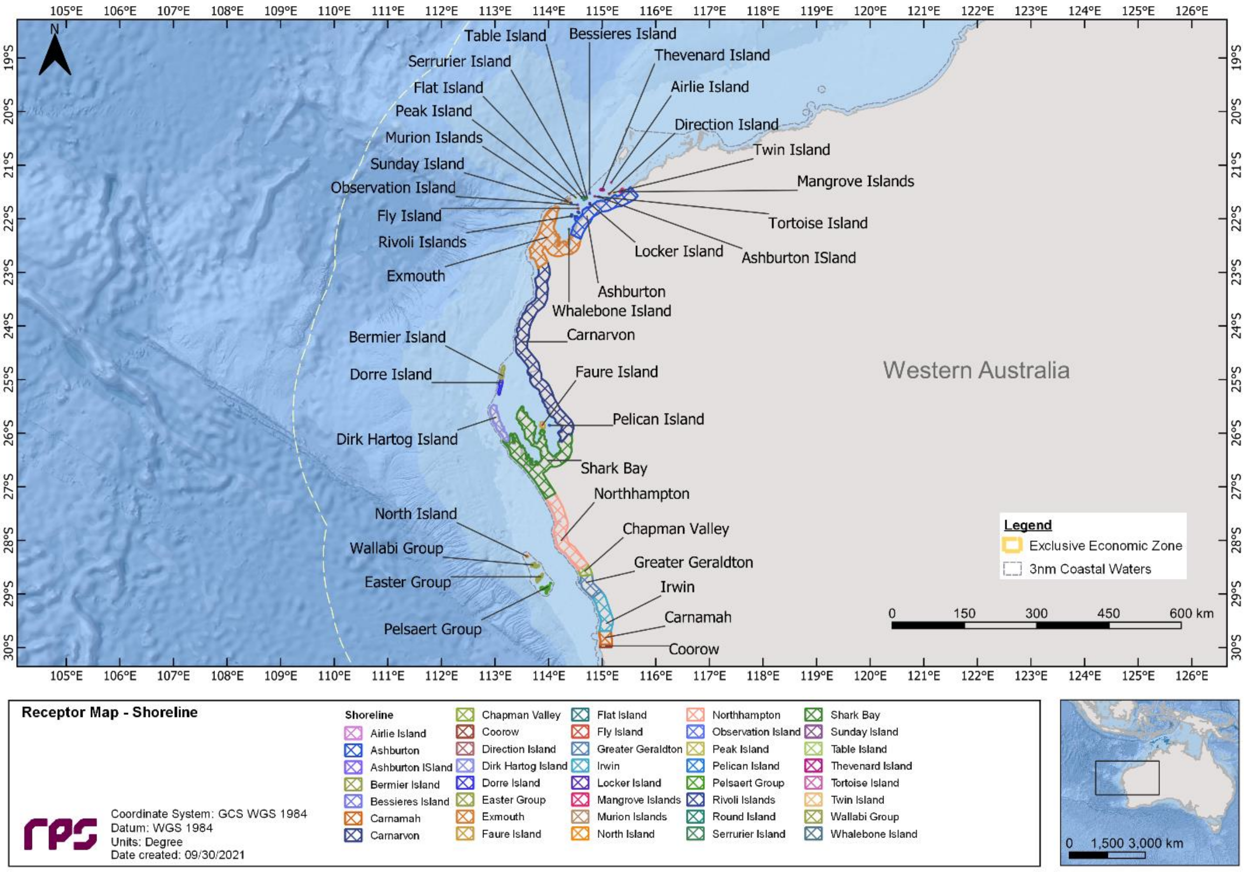


Figure 10.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.



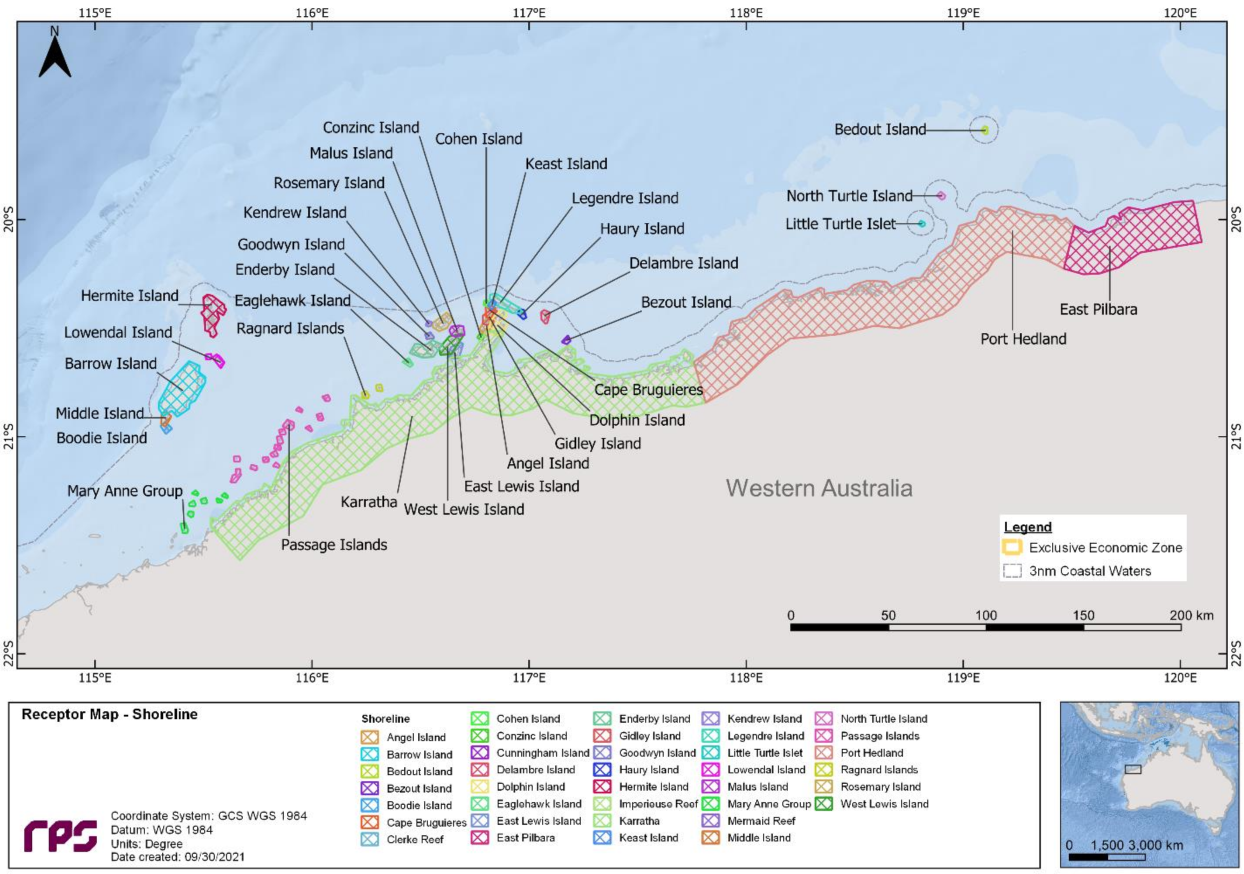


Figure 10.6 Receptor maps for Shorelines (1 of 2).

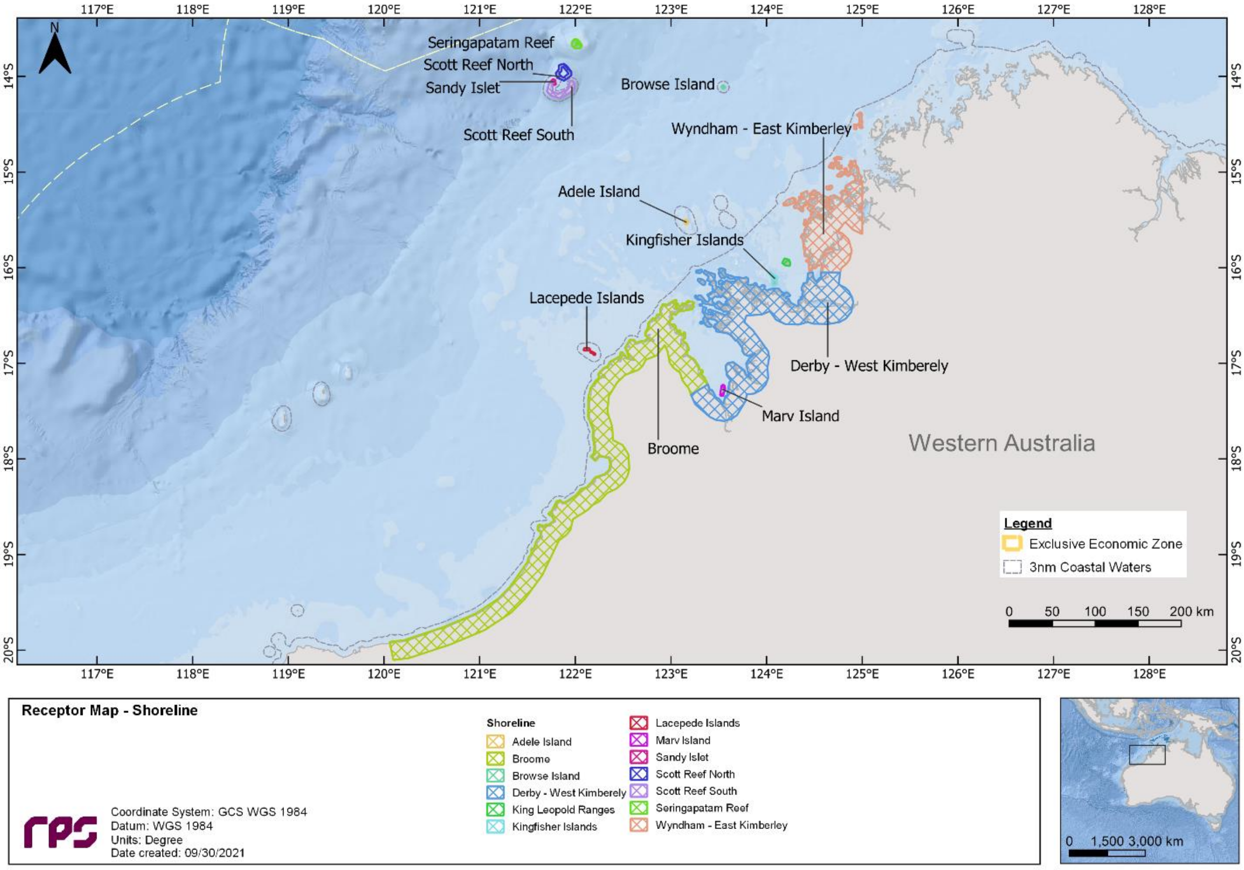


Figure 10.7 Receptor maps for Shorelines (2 of 2).

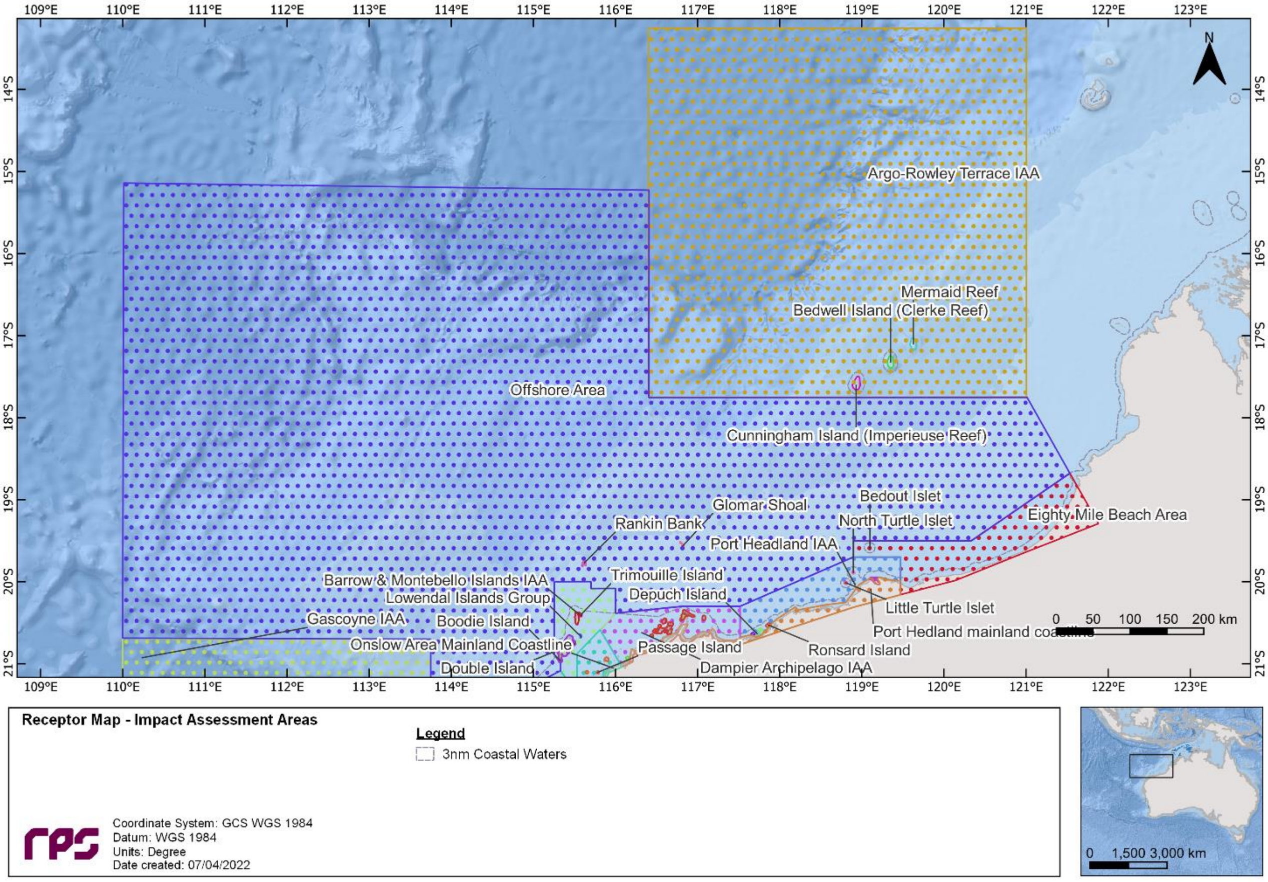


Figure 10.8 Receptor maps for Impact Assessment Areas (1 of 3).

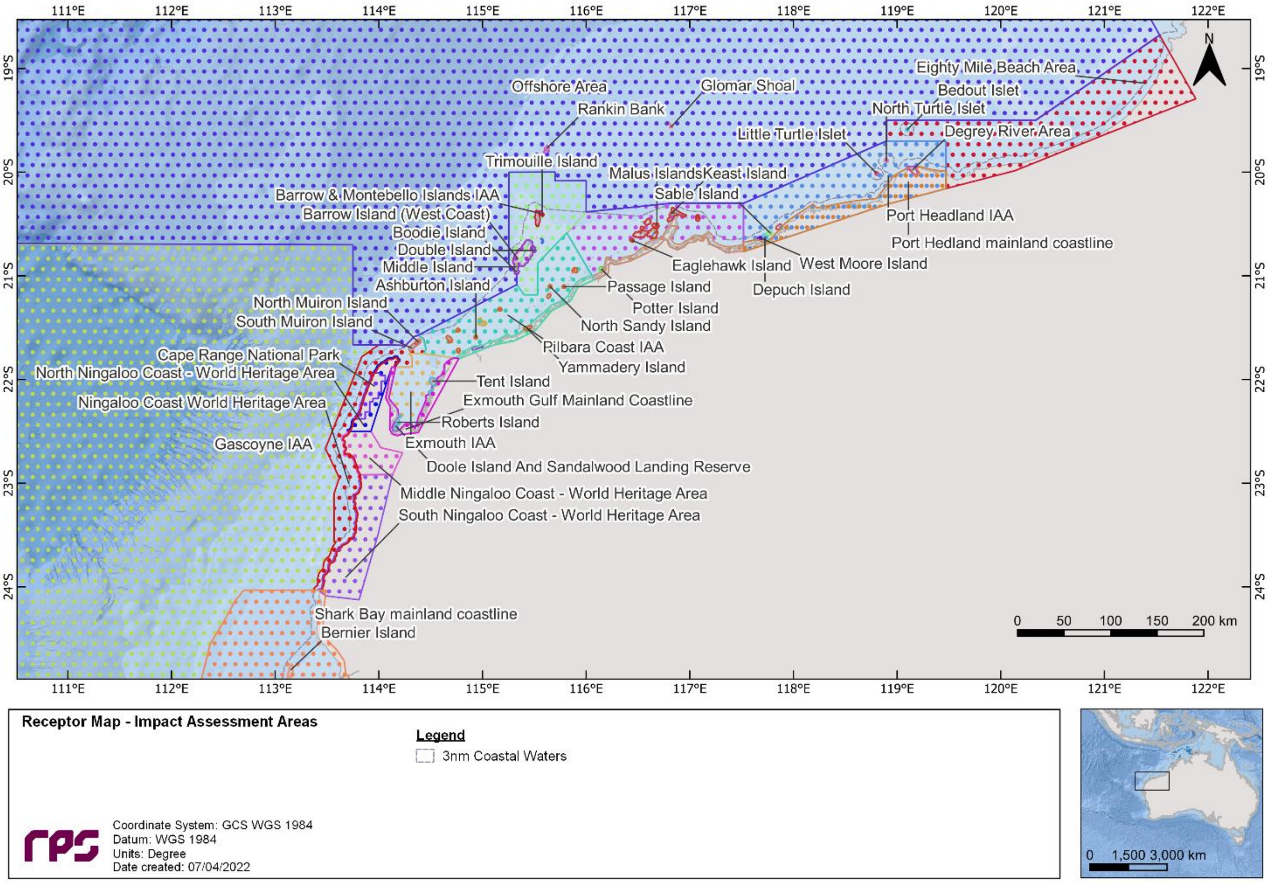


Figure 10.9 Receptor maps for Impact Assessment Areas (2 of 3).

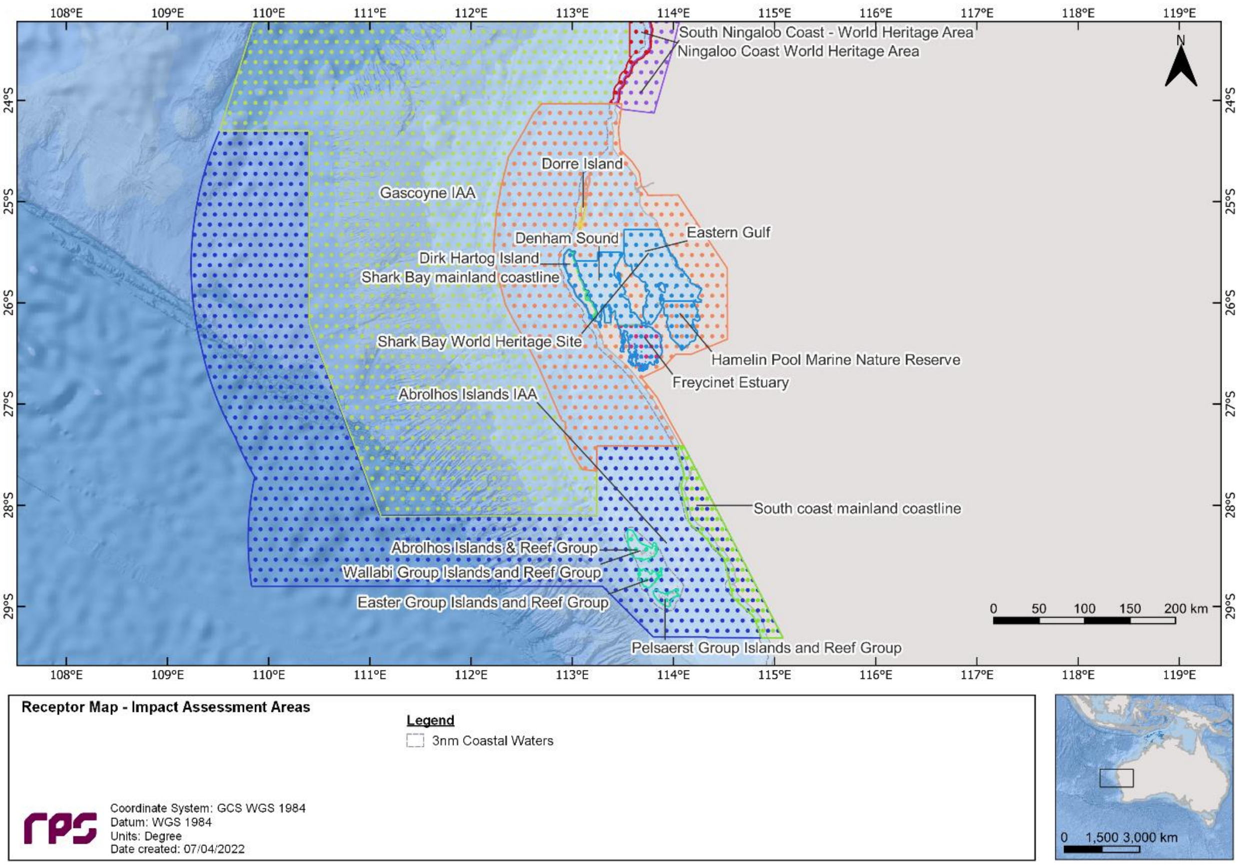


Figure 10.10 Receptor maps for Impact Assessment Areas (3 of 3).

11 RESULTS: SEMELE LOSS OF WELL CONTROL

This scenario examined a 219,690 bbl subsea release of condensate over 90 days, following a LOWC. A total of 300 spill simulations were run across the three seasons; summer, winter and transitional (i.e. 100 spills per season) and tracked for 104 days.

Section 11.1 presents the seasonal (or stochastic) analysis results, while Section 11.2 presents the deterministic results.

11.1 Stochastic Analysis

11.1.1 Floating Condensate Exposure

Table 11.1 summarises the maximum distances from the release location to floating condensate exposure zones for each season.

The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 144.5 km southwest (summer) and 2.2 km west southwest (winter and transitional), respectively. No exposure was predicted at the high (≥ 50 g/m^2) threshold.

Table 11.2 summarises the potential floating condensate exposure to individual receptors during each season.

The Offshore Area IAA, Pygmy Blue Whale – Distribution BIA and Wedge-tailed Shearwater – Breeding BIA which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probability for the low threshold was 100% for all seasons for these receptors. Probabilities of moderate exposure for these receptors ranged between 6% (summer) and 18% (transitional).

Figure 11.1 to Figure 11.3 present the zones of floating condensate exposure for each season.

Table 11.1 Maximum distances and directions travelled from the release location to floating condensate exposure for each season and threshold, following a subsea LOWC at Semele Well 5. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating condensate exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	144.5	1.4	-
	Max. distance from release site (km) (99th percentile)	80.6	1.4	-
	Direction	Southwest	Southwest	-
Transitional	Max. distance from release site (km)	134.6	2.2	-
	Max. distance from release site (km) (99th percentile)	73.9	2.2	-
	Direction	North-northeast	West-southwest	-
Winter	Max. distance from release site (km)	103.2	2.2	-
	Max. distance from release site (km) (99th percentile)	74.1	2.2	-
	Direction	Northeast	West-southwest	-

Table 11.2 Summary of the potential floating condensate exposure to individual receptors, following a LOWC at Semele Well 5. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
BIA	Flatback Turtle - Internesting Buffer	3	-	-	29.88	-	-	21	-	-	1.71	-	-	31	-	-	12.88	-	-
	Humpback Whale - Migration	2	-	-	46.25	-	-	1	-	-	20.63	-	-	1	-	-	78.96	-	-
	Pygmy Blue Whale – Distribution*	100	6	-	0.46	11.58	-	100	18	-	0.46	1.21	-	100	16	-	0.46	12.17	-
	Wedge-tailed Shearwater – Breeding*	100	6	-	0.46	11.58	-	100	18	-	0.46	1.21	-	100	16	-	0.46	12.17	-
	Whale Shark - Foraging	-	-	-	-	-	-	14	-	-	2.38	-	-	26	-	-	13.04	-	-
EEZ	Australian Exclusive Economic Zone*	100	6	-	0.46	11.58	-	100	18	-	0.46	1.21	-	100	16	-	0.46	12.17	-
IAA	Offshore Area*	100	6	-	0.46	11.58	-	100	18	-	0.46	1.21	-	100	16	-	0.46	12.17	-
IMCRA	Northwest Shelf	-	-	-	-	-	-	5	-	-	7.13	-	-	6	-	-	13.13	-	-
	Pilbara (offshore)	-	-	-	-	-	-	12	-	-	5.79	-	-	24	-	-	13.21	-	-
KEF	Ancient coastline at 125 m depth contour	-	-	-	-	-	-	5	-	-	8.92	-	-	11	-	-	28.67	-	-
	Continental Slope Demersal Fish Communities*	100	-	-	0.88	-	-	98	-	-	1.13	-	-	98	-	-	1.71	-	-

*The release location resides within the receptor boundaries.

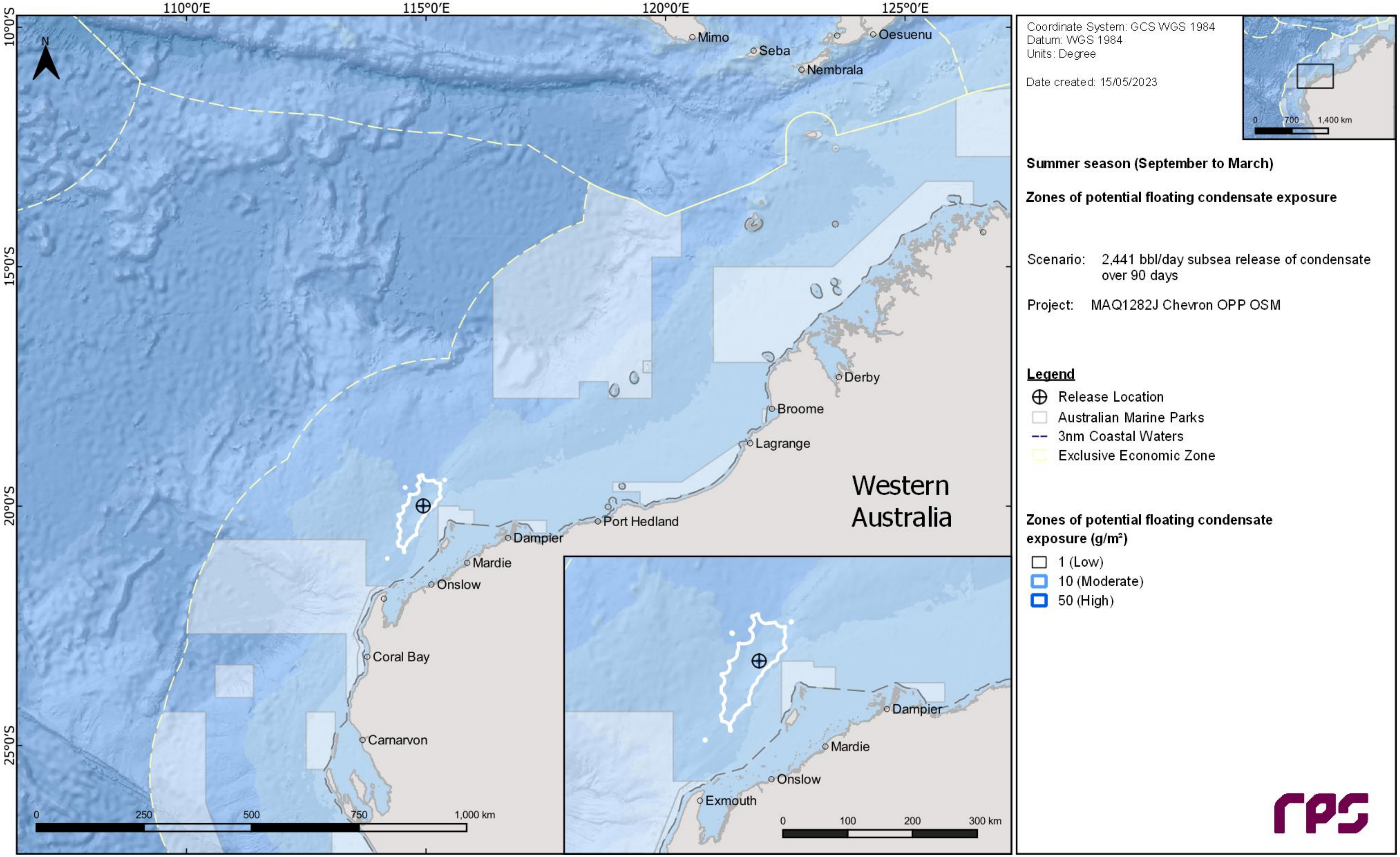


Figure 11.1 Zones of potential floating condensate exposure following a subsea LOWC at Semele Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

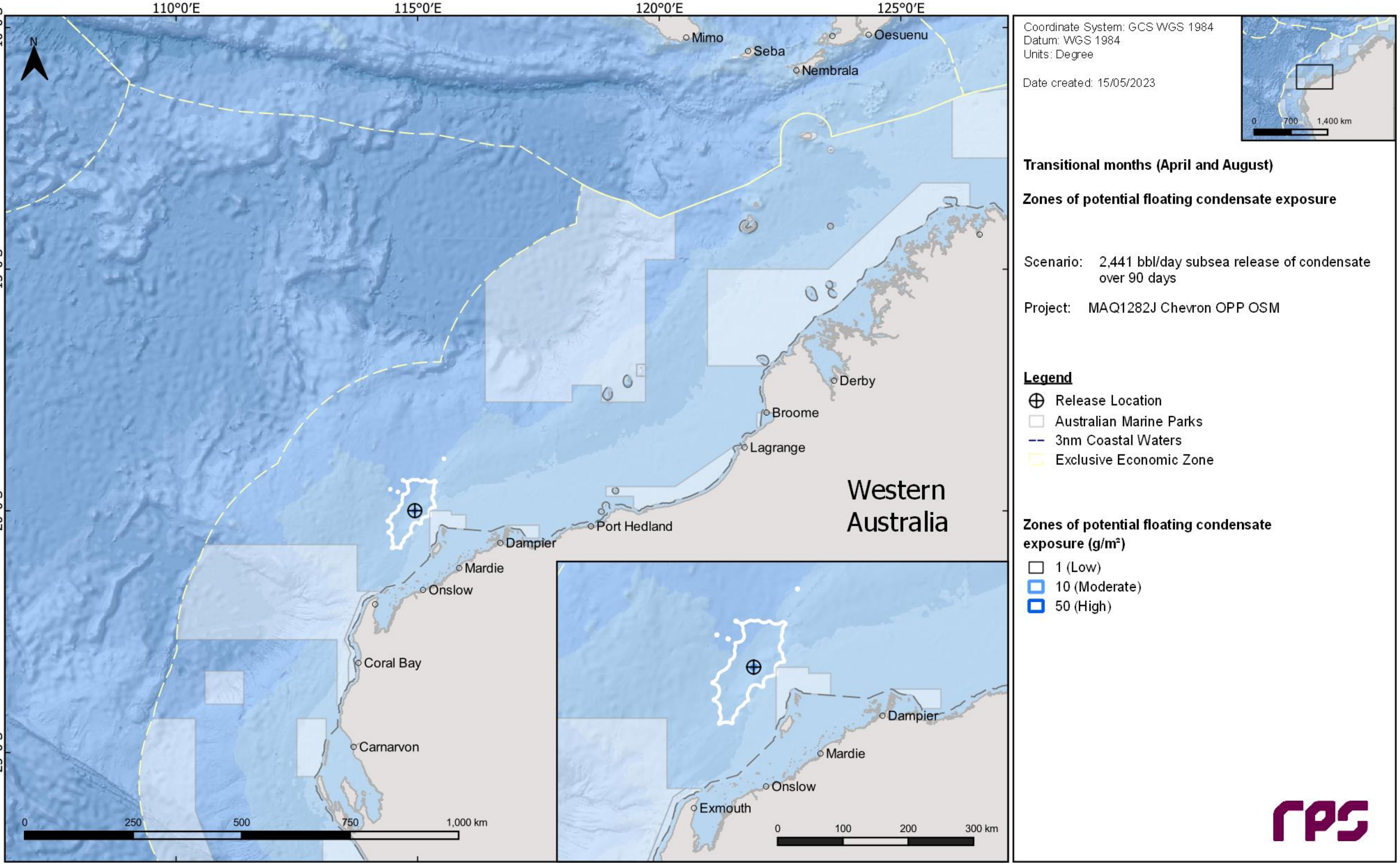


Figure 11.2 Zones of potential floating condensate exposure following a subsea LOWC at Semele Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

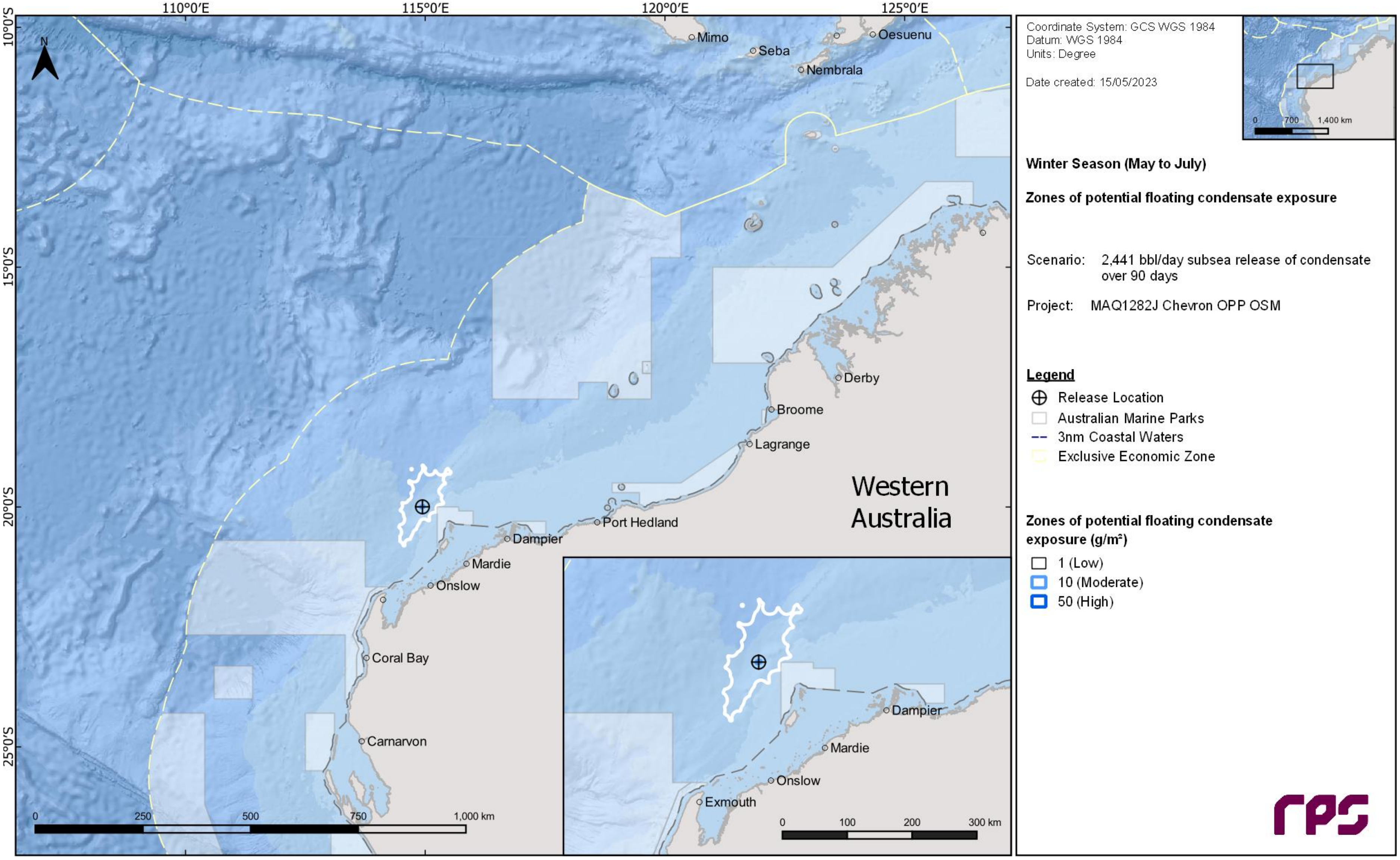


Figure 11.3 Zones of potential floating condensate exposure following a subsea LOWC at Semele Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.2 Shoreline Accumulation

Table 11.3 presents a summary of the predicted shoreline accumulation during summer, transitional and winter seasons. The probability of accumulation on any shoreline at, or above, the low threshold (≥ 10 g/m²) was greatest during summer at 27%, while the minimum time before shoreline accumulation was 13.7 days and the maximum volume of condensate ashore above the low threshold was 29.0 m³.

No accumulation at the high (≥ 1,000 g/m²) shoreline threshold was observed.

Table 11.4 to Table 11.6 summarises the shoreline accumulation on individual receptors for each season.

During summer conditions, condensate had accumulated on 62 shoreline receptors at, or above, the low threshold with the greatest probability predicted for Barrow & Montebello Islands IAA (19%). In comparison, during transitional and winter conditions condensate had accumulated on 10 and 4 shoreline receptors, respectively. During transitional conditions, the greatest probabilities had occurred at Cunningham Island (Imperieuse Reef), Argo-Rowley Terrace IAAs and Imperieuse Reef, all 3% probability. While for the winter season, the same three receptors recorded a 9% probability.

The maximum potential shoreline accumulation is presented for each season in Figure 11.4 to Figure 11.5.

Table 11.3 Summary of oil accumulation across all shorelines for each season and threshold, following a subsea LOWC at Semele Well 5. The results were calculated from 100 spill trajectories per season.

Shoreline Statistics	Summer	Transitional	Winter
Probability of accumulation on any shoreline (%)	27	4	9
Absolute minimum time for visible oil to shore (days)	13.7	29.0	45.4
Maximum volume of hydrocarbons ashore (m³) above the low threshold	29.0	2.1	2.4
Average volume of hydrocarbons ashore (m³) above the low threshold	6.9	0.3	0.5
Maximum length of the shoreline at **10 g/m²** (km)	142	8	7
Average shoreline length (km) at **10 g/m²** (km)	35.2	5	4.9
Maximum length of the shoreline at **100 g/m²** (km)	2.9	-	-
Average shoreline length (km) at **100 g/m²** (km)	2.1	-	-
Maximum length of the shoreline at **1,000 g/m²** (km)	-	-	-
Average shoreline length (km) at **1,000 g/m²** (km)	-	-	-

Table 11.4 Summary of shoreline oil accumulation to individual receptors, following a LOWC at Semele Well 5. The results were calculated from 100 spill trajectories days during summer (September to the following March) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	8	2	-	33.58	59.54	-	27	110	1	2.5	2.4	1	-	2.9	1	-
	Argo-Rowley Terrace IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow & Montebello Islands IAA	19	5	-	18.67	21.21	-	7	209	5	25.6	22.3	2.5	-	56.8	2.9	-
	Barrow Island (West Coast)	13	-	-	18.67	-	-	9	79	2.7	9.2	14.6	-	-	22.1	-	-
	Barrow Island Group	14	5	-	18.67	21.21	-	10	209	4.8	19.2	21.2	2.5	-	33.7	2.9	-
	Bessieres Island	7	-	-	15.08	-	-	9	45	0.3	0.9	2.1	-	-	2.9	-	-
	Boodie Island	12	5	-	20.25	21.21	-	24	209	1.4	5.1	3.3	1.2	-	3.8	1.9	-
	Cape Range National Park	8	-	-	15.08	-	-	4	38	1.1	4.4	9.1	-	-	15.4	-	-
	Cunningham Island (Imperieuse Reef)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago IAA	5	-	-	40.67	-	-	4	39	4.1	8.7	12.9	-	-	19.2	-	-
	Dampier Archipelago Island Group	3	-	-	44.67	-	-	4	17	1.3	2.5	3.8	-	-	4.8	-	-
	Dampier mainland coastline	4	-	-	45.88	-	-	5	21	2.4	3.2	4.3	-	-	4.8	-	-
	Eaglehawk Island	1	-	-	45.33	-	-	4	17	0.3	0.5	1	-	-	1	-	-
	Enderby Island	3	-	-	45.46	-	-	5	17	0.4	0.8	1.6	-	-	1.9	-	-
	Exmouth IAA	2	-	-	19.63	-	-	3	17	0.4	0.7	1.4	-	-	1.9	-	-
	Great Sandy Island	5	-	-	40.71	-	-	7	24	0.3	0.7	2.5	-	-	2.9	-	-
	Hermite Island	15	-	-	20.42	-	-	5	45	0.8	4.2	4.7	-	-	12.5	-	-
	Malus Islands	1	-	-	88.42	-	-	4	14	0.2	0.4	1	-	-	1	-	-
	Middle Island	10	4	-	20.63	21.75	-	18	143	1.6	5.9	6.7	1.7	-	7.7	1.9	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Middle Ningaloo Coast - World Heritage Area	8	-	-	14.75	-	-	4	29	1.3	2.9	4.3	-	-	9.6	-	-
	Montebello Islands Group	15	-	-	20.42	-	-	5	45	0.9	4.6	4.8	-	-	13.5	-	-
	Muiron Islands	15	-	-	13.67	-	-	8	97	1.4	7.7	4.7	-	-	15.4	-	-
	Ningaloo Coast World Heritage Area	16	-	-	13.67	-	-	5	97	2.7	16.5	13	-	-	41.4	-	-
	North Muiron Island	7	-	-	13.67	-	-	8	97	0.5	3	3.3	-	-	5.8	-	-
	North Ningaloo Coast - World Heritage Area	10	-	-	14.63	-	-	4	66	1.2	5.4	6.6	-	-	15.4	-	-
	North Sandy Island	6	-	-	44.13	-	-	9	21	0.2	0.5	1.3	-	-	1.9	-	-
	Onslow Area Mainland Coastline	3	-	-	43.38	-	-	3	13	0.9	2.9	1.9	-	-	3.8	-	-
	Passage Island	1	-	-	102.21	-	-	6	10	< 0.1	0.1	1	-	-	1	-	-
	Pilbara Coast IAA	11	2	-	14.88	59.54	-	5	110	3.2	13.5	15.6	1	-	32.7	1	-
	Pilbara Coast Islands Group	11	2	-	14.88	59.54	-	8	110	2.1	5.7	8.6	1	-	15.4	1	-
	Pilbara Mainland Coast	3	-	-	43.38	-	-	3	13	0.9	2.9	1.9	-	-	3.8	-	-
	Potter Island	2	-	-	50.54	-	-	7	13	0.3	0.4	1.4	-	-	1.9	-	-
	Rosemary Island	2	-	-	44.67	-	-	4	15	0.4	0.6	2.4	-	-	2.9	-	-
	Serrurier Island	9	-	-	14.88	-	-	5	30	0.6	1.6	2.7	-	-	7.7	-	-
	Sholl Island	5	-	-	40.67	-	-	7	30	0.5	1.2	3.1	-	-	5.8	-	-
	South Muiron Island	15	-	-	13.71	-	-	8	82	0.9	4.7	3.2	-	-	9.6	-	-
	Thevenard Island	9	-	-	22.5	-	-	6	36	0.5	1	2.1	-	-	3.8	-	-
	Trimouille Island	1	-	-	62.92	-	-	4	12	0.2	0.5	1	-	-	1	-	-
Shoreline	Airlie Island	8	2	-	33.58	59.54	-	27	110	1	2.5	2.4	1	-	2.9	1	-
	Barrow Island	13	-	-	18.67	-	-	8	94	3	10.6	15.8	-	-	24	-	-
	Bessieres Island	7	-	-	15.08	-	-	9	45	0.3	0.9	2.1	-	-	2.9	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Boodie Island	12	5	-	20.25	21.21	-	24	209	1.7	6.7	4.1	1.7	-	4.8	1.9	-
Cunningham Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eaglehawk Island	1	-	-	45.33	-	-	4	17	0.3	0.5	1	-	-	1	-	-
Enderby Island	3	-	-	45.46	-	-	5	17	0.4	0.8	1.6	-	-	1.9	-	-
Exmouth	10	-	-	14.63	-	-	4	66	2.3	12.4	17.4	-	-	35.6	-	-
Flat Island	5	-	-	16.46	-	-	5	17	0.2	0.4	1.2	-	-	1.9	-	-
Fly Island	2	-	-	19.63	-	-	8	17	0.2	0.3	1.4	-	-	1.9	-	-
Imperieuse Reef	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Karratha	4	-	-	43.38	-	-	3	29	2.3	6.4	7.5	-	-	8.7	-	-
Kendrew Island	3	-	-	55.5	-	-	6	12	0.1	0.2	1	-	-	1	-	-
Lowendal Island	7	-	-	22.38	-	-	5	47	0.4	1.5	2.2	-	-	3.8	-	-
Malus Island	1	-	-	88.42	-	-	4	14	0.2	0.4	1	-	-	1	-	-
Mary Anne Group	7	-	-	38.08	-	-	6	29	0.6	1.5	2.7	-	-	4.8	-	-
Middle Island	10	4	-	20.63	21.75	-	17	143	1.9	7.5	8.4	1.7	-	9.6	1.9	-
Montebello Islands	15	-	-	20.42	-	-	5	45	1.3	7.4	7.5	-	-	22.1	-	-
Murion Islands	15	-	-	13.67	-	-	8	97	1.4	7.7	4.7	-	-	15.4	-	-
Observation Island	1	-	-	35.54	-	-	4	10	< 0.1	0.2	1	-	-	1	-	-
Passage Islands	7	-	-	40.67	-	-	6	45	2	6	11.1	-	-	20.2	-	-
Peak Island	3	-	-	15.08	-	-	6	14	< 0.1	0.2	1	-	-	1	-	-
Ragnard Islands	4	-	-	50.17	-	-	8	22	0.5	0.6	1.4	-	-	1.9	-	-
Rosemary Island	3	-	-	44.67	-	-	4	15	0.4	0.7	1.9	-	-	2.9	-	-
Round Island	1	-	-	19.79	-	-	5	12	< 0.1	0.2	1	-	-	1	-	-
Serrurier Island	9	-	-	14.88	-	-	5	30	0.6	1.6	2.7	-	-	7.7	-	-
Sunday Island	5	-	-	30.42	-	-	7	21	0.2	0.5	1.2	-	-	1.9	-	-
Thevenard Island	9	-	-	22.5	-	-	6	36	0.5	1	2.1	-	-	3.8	-	-

Table 11.5 Summary of shoreline oil accumulation to individual receptors, following a LOWC at Semele Well 5. The results were calculated from 100 spill trajectories days during transitional (April and August) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Argo-Rowley Terrace IAA	3	-	-	29.04	-	-	3	23	0.7	2	5.8	-	-	7.7	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	1	-	-	31.58	-	-	3	10	< 0.1	0.2	1	-	-	1	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island (Imperieuse Reef)	3	-	-	29.04	-	-	5	23	0.7	1.7	5.8	-	-	7.7	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Malus Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passage Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	1	-	-	31.42	-	-	3	11	0.1	0.5	1.9	-	-	1.9	-	-
	Pilbara Coast Islands Group	1	-	-	31.58	-	-	3	10	< 0.1	0.2	1	-	-	1	-	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Potter Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	1	-	-	31.42	-	-	3	11	0.1	0.2	1	-	-	1	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoreline	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	1	-	-	31.58	-	-	3	10	< 0.1	0.2	1	-	-	1	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cunningham Island	2	-	-	39.46	-	-	5	20	0.4	0.9	2.9	-	-	3.8	-	-
Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flat Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fly Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imperieuse Reef	3	-	-	29.04	-	-	5	23	0.6	1.5	5.1	-	-	5.8	-	-
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kendrew Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murion Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Observation Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ragnard Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sunday Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thevenard Island	1	-	-	31.42	-	-	3	11	0.1	0.2	1	-	-	1	-	-

Table 11.6 Summary of shoreline oil accumulation to individual receptors, following a LOWC at Semele Well 5. The results were calculated from 100 spill trajectories days during winter (May to July) wind and current conditions.

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
IAA	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Argo-Rowley Terrace IAA	9	-	-	45.42	-	-	5	37	1.1	2.3	4.7	-	-	6.7	-	-
	Barrow & Montebello Islands IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island (West Coast)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barrow Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cape Range National Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cunningham Island (Imperieuse Reef)	9	-	-	45.42	-	-	6	37	1	1.8	4.7	-	-	6.7	-	-
	Dampier Archipelago IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier Archipelago Island Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dampier mainland coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Exmouth IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Great Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hermite Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Malus Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor		Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline above the low threshold (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
	Middle Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Montebello Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muiron Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ningaloo Coast World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Ningaloo Coast - World Heritage Area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Sandy Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Onslow Area Mainland Coastline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Passage Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast IAA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Coast Islands Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pilbara Mainland Coast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Potter Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sholl Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Muiron Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Trimouille Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Airlie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoreline	Barrow Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bessieres Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline above the low threshold (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Boodie Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cunningham Island	8	-	-	49	-	-	6	36	0.5	1	2.2	-	-	2.9	-	-
Eaglehawk Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Enderby Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exmouth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flat Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fly Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imperieuse Reef	9	-	-	45.42	-	-	7	37	0.8	1.5	4.1	-	-	5.8	-	-
Karratha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kendrew Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowendal Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malus Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mary Anne Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middle Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montebello Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murion Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Observation Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passage Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peak Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ragnard Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rosemary Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Serrurier Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sunday Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thevenard Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

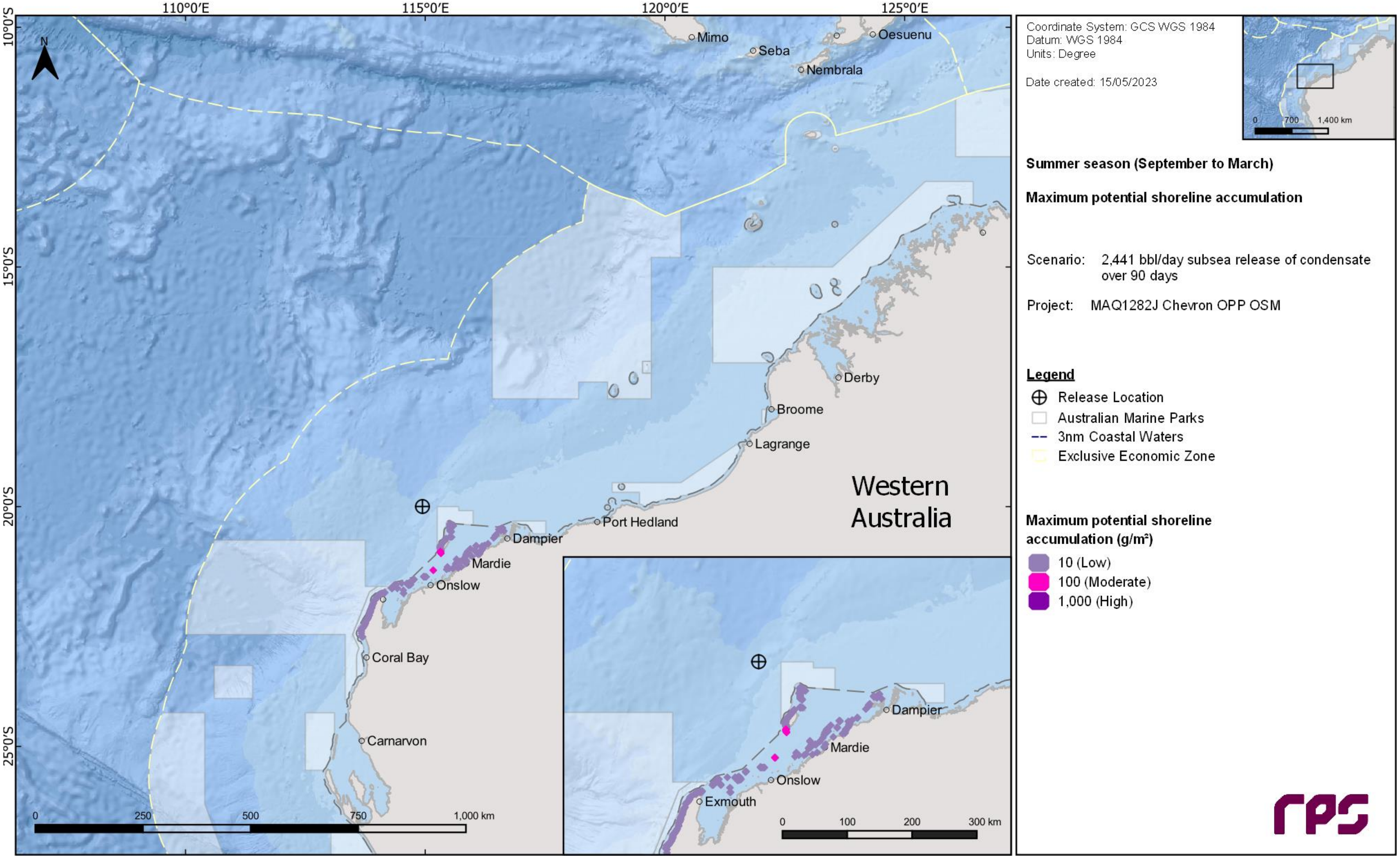


Figure 11.4 Maximum potential shoreline accumulation following a subsea LOWC at Semele Well 5 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

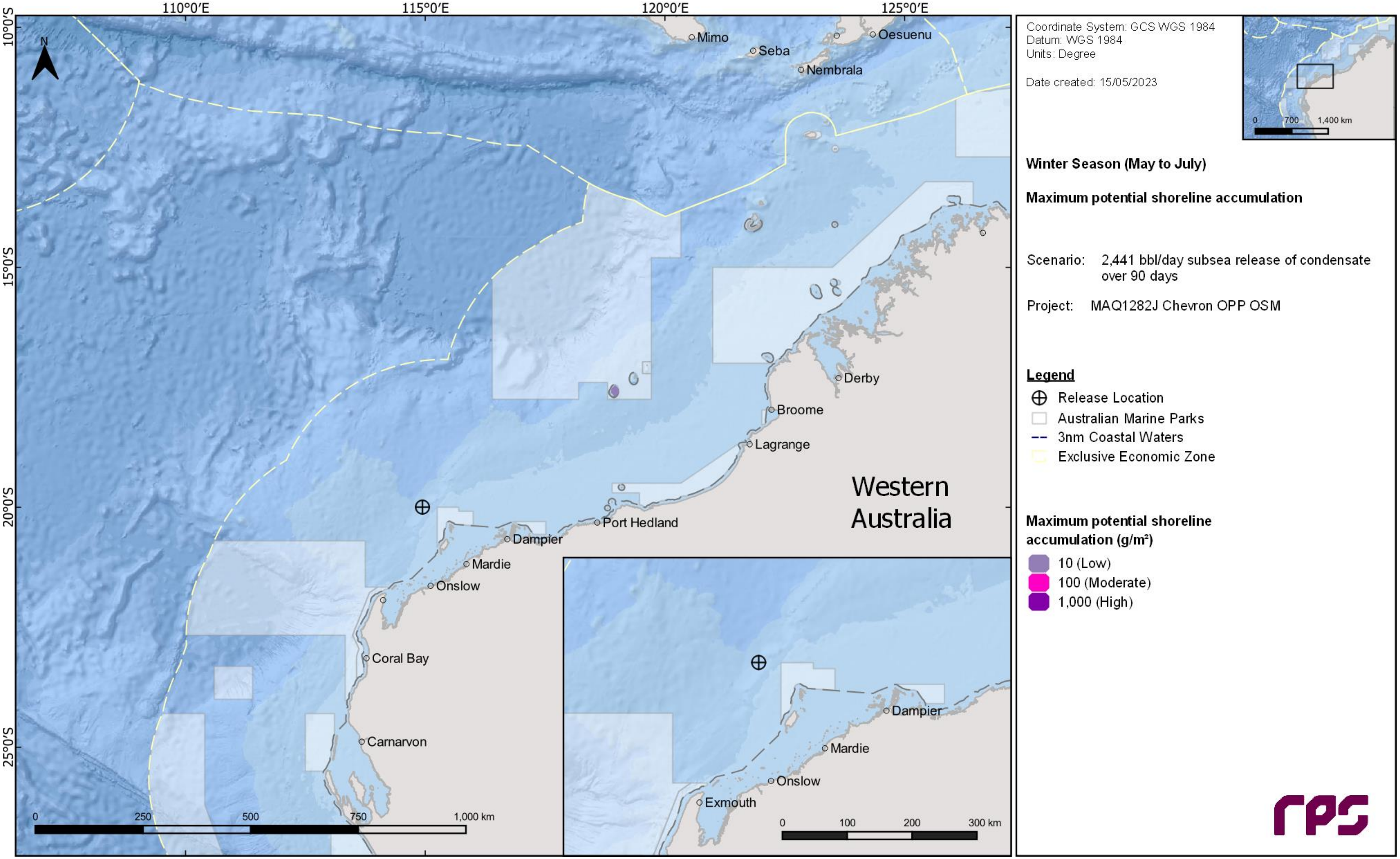


Figure 11.5 Maximum potential shoreline accumulation following a subsea LOWC at Semele Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3 Water Column Exposure

11.1.3.1 Dissolved Hydrocarbons

Table 11.7 summarises the maximum instantaneous exposure to dissolved hydrocarbons and the probability for individual receptors in the 0-10 m depth layer.

There were several receptors exposed at or above the low threshold during summer and winter, however they were all 1% occurrence.

Figure 11.6 to Figure 11.7 illustrate the extent of the predicted dissolved hydrocarbon exposure in the 0-10 m depth layer for each season.

Table 11.7 Predicted probability and maximum dissolved hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at Semele Well 5. The results were calculated from 100 spill simulations per season.

Receptor		Summer							Transitional							Winter						
		Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (Days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (Days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (Days)		
			Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High
BIA	Flatback Turtle - Internesting Buffer	10.8	1	-	-	5.46	-	-	2.6	-	-	-	4.08	7.63	-	13.8	1	-	-	4.29	-	-
	Flatback Turtle - Nesting	0.6	-	-	-	-	-	-	0.6	-	-	-	5.46	-	-	10.4	1	-	-	8.54	-	-
	Humpback Whale - Migration	0.6	-	-	-	-	-	-	1.5	-	-	-	6.33	-	-	13.8	1	-	-	6	-	-
	Pygmy Blue Whale – Distribution*	19.9	1	-	-	0.46	1.29	-	6.7	-	-	-	0.71	2.25	-	13.8	1	-	-	0.42	0.58	-
	Wedge-tailed Shearwater – Breeding*	19.9	1	-	-	0.46	1.29	-	6.7	-	-	-	0.71	2.25	-	13.8	1	-	-	0.42	0.58	-
	Whale Shark - Foraging	9	-	-	-	5.5	-	-	2.4	-	-	-	4.13	7.63	-	13.8	1	-	-	4.38	-	-
EEZ	Australian Exclusive Economic Zone	19.9	1	-	-	0.46	1.29	-	6.7	-	-	-	0.71	2.25	-	13.8	1	-	-	0.42	0.58	-
IAA	Offshore Area*	19.9	1	-	-	0.46	1.29	-	6.7	-	-	-	0.71	2.25	-	13.8	1	-	-	0.42	0.58	-
IMCRA	Pilbara (offshore)	9	-	-	-	7.04	-	-	2.2	-	-	-	4.42	9	-	13.8	1	-	-	4.38	-	-

*The release location resides within the receptor boundaries.

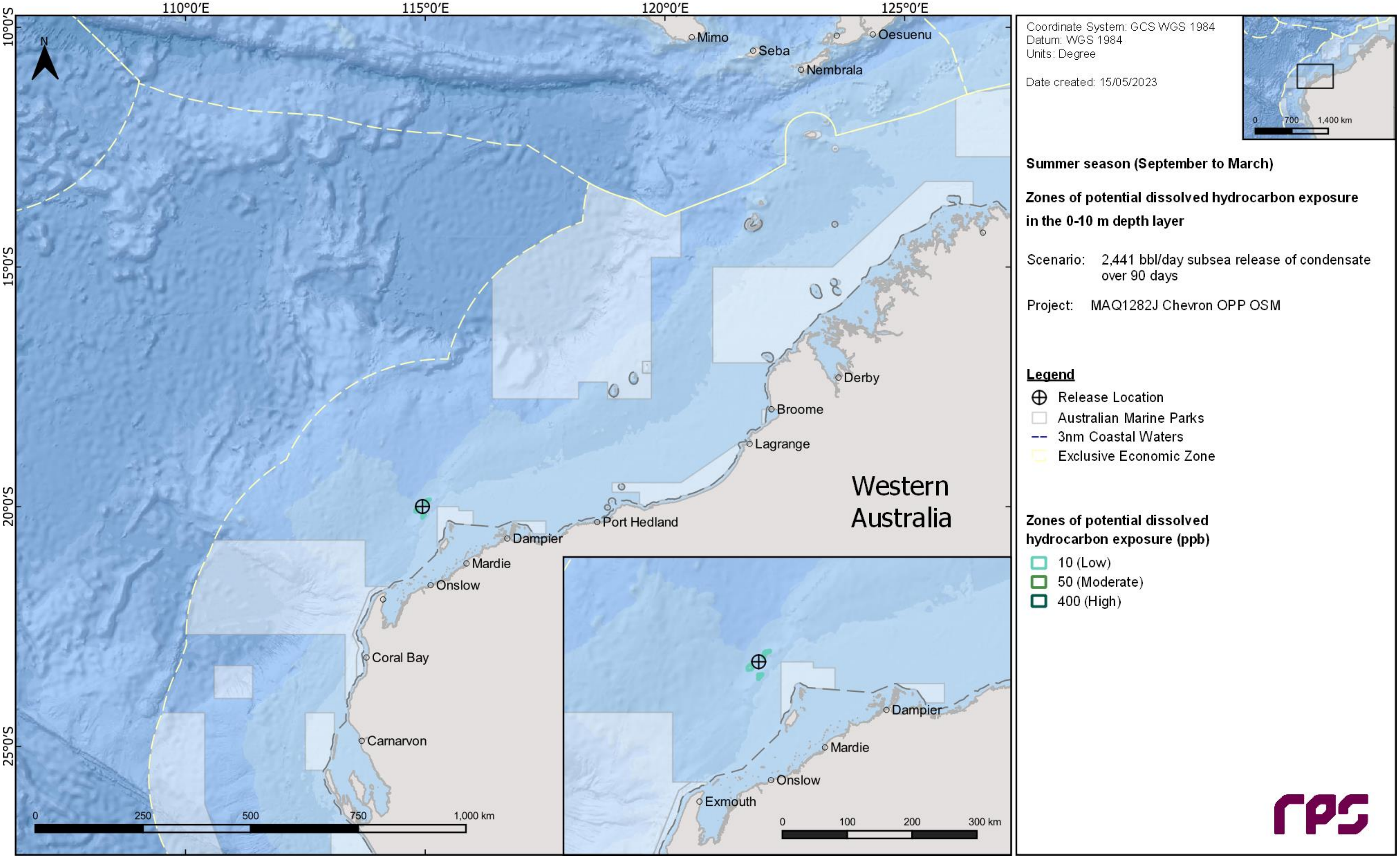


Figure 11.6 Zones of potential dissolved hydrocarbon exposure at 0-10 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

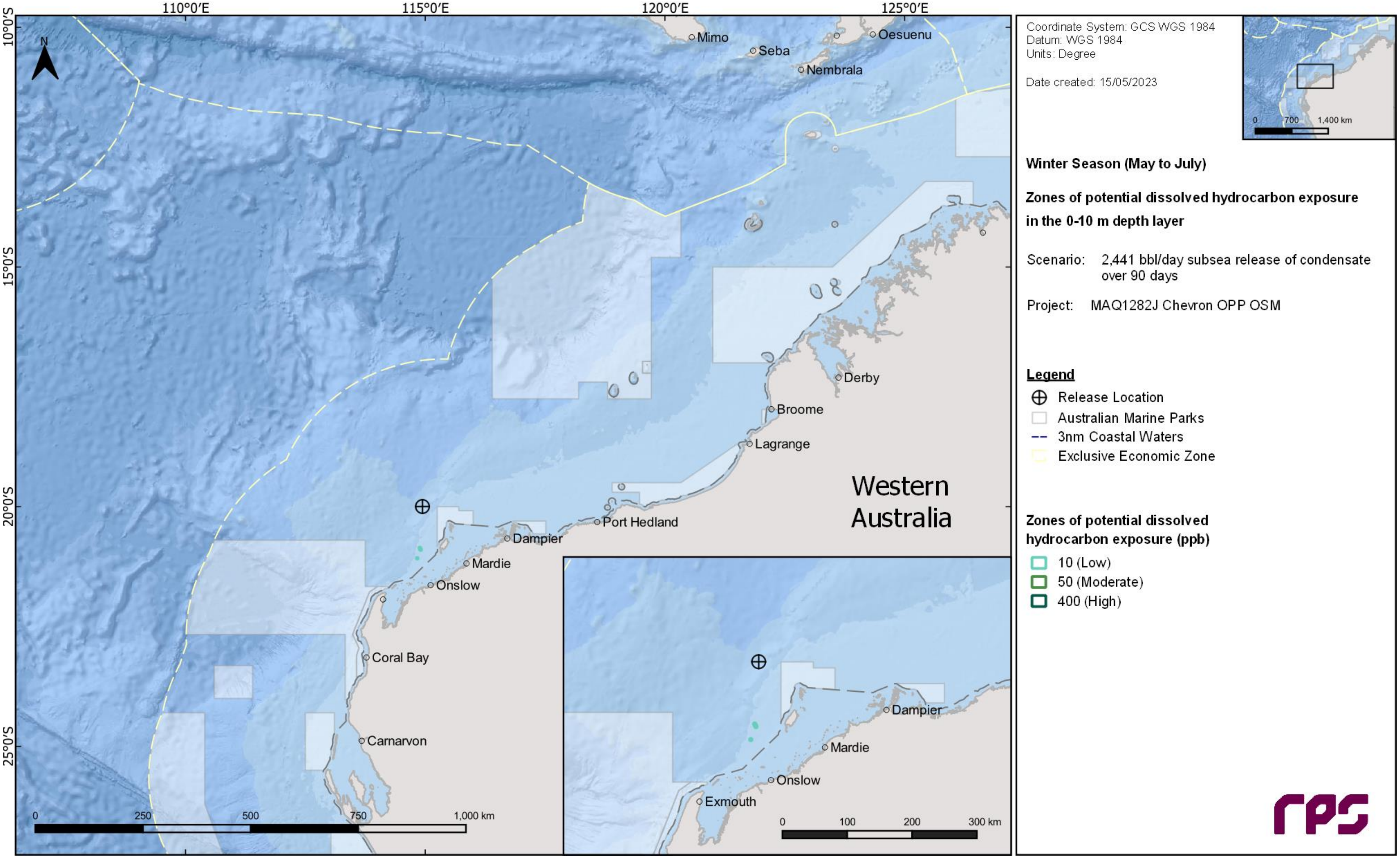


Figure 11.7 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at Semele Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3.2 Entrained Hydrocarbons

Table 11.8 summarises the maximum exposure to entrained hydrocarbons and the probability for individual receptors in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

A total of 34, 22 and 21 BIAs were shown to be exposed at or above the low threshold during summer, transitional and winter seasons respectively. Excluding the receptors that the release location resides within, the highest probabilities of exposure were shown for the Flatback Turtle – Internesting Buffer BIA during summer (100%), transitional (97%) and winter (90%) conditions.

Across the three seasons, 6 AMPs were predicted to be exposed at, or above the low threshold, with the highest probabilities predicted at the Gascoyne AMP (81% summer, 82% transitional and 74% winter).

A total of 6 KEFs were shown to be exposed by entrained hydrocarbons at the low threshold, including the Continental Slope Demersal Fish Communities KEF that the release site is located within. Excluding that receptor, probabilities of exposure ranged between 6–80%, 1–92% and 1–80%, for summer, transitional and winter, respectively.

Additionally, 37 IAA, were shown to be exposed to entrained hydrocarbons at low threshold.

Furthermore, 36 RSBs were shown to be exposed to entrained hydrocarbons at the low threshold.

Figure 11.8 to Figure 11.10 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

The same maps for the 10-20 m depth layer are presented in Figure 11.11 to Figure 11.13.

Table 11.8 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at Semele Well 5. The results were calculated from 100 spill simulations per season.

	Receptor	Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
AMP	Abrolhos	7.2	-	-	-	-	11.7	1	-	85.46	-	11	1	-	69.38	-
	Argo-Rowley Terrace	18.5	10	-	27.71	-	25.8	10	-	18.79	-	32.8	20	-	40.17	-
	Carnarvon Canyon	19	2	-	100.33	-	19.8	8	-	70.33	-	19.7	7	-	38.04	-
	Gascoyne	64	81	-	4.42	-	61	82	-	5.67	-	61.2	74	-	6	-
	Montebello	58.9	43	-	3.17	-	53.5	34	-	4.79	-	55.6	48	-	7.71	-
	Ningaloo	56.6	17	-	12.33	-	20.2	10	-	16.25	-	19.8	8	-	14.75	-
	Shark Bay	10.4	1	-	100.96	-	8.3	-	-	-	-	3.4	-	-	-	-
BIA	Dugong - Breeding	42.1	11	-	13.04	-	17.7	4	-	16.54	-	18.5	5	-	69.04	-
	Dugong - Calving	42.1	11	-	13.04	-	17.7	4	-	16.54	-	18.5	5	-	69.04	-
	Dugong - Foraging	42.1	11	-	13.04	-	17.7	4	-	16.54	-	18.5	5	-	69.04	-
	Dugong - Nursing	42.1	11	-	13.04	-	17.7	4	-	16.54	-	18.5	5	-	69.04	-
	Fairy Tern - Breeding	90.4	16	-	12.54	-	20.2	9	-	16.54	-	19.8	7	-	22.21	-
	Flatback Turtle - Aggregation	22	6	-	32.88	-	0.5	-	-	-	-	2.6	-	-	-	-
	Flatback Turtle - Foraging	41	13	-	17.33	-	0.6	-	-	-	-	2.9	-	-	-	-
	Flatback Turtle - Internesting	22	6	-	32.88	-	0.5	-	-	-	-	2.6	-	-	-	-
	Flatback Turtle - Internesting Buffer	149.6	100	12	1.04	9.75	130.3	97	6	1.5	5.79	200	90	17	1	6.75
	Flatback Turtle - Mating	41	13	-	17.33	-	0.6	-	-	-	-	2.9	-	-	-	-
	Flatback Turtle - Nesting	104.8	71	2	3.17	30.58	64.9	39	-	3.38	-	66.6	48	-	6.08	-
	Green Turtle - Aggregation	22	6	-	32.88	-	0.5	-	-	-	-	2.6	-	-	-	-
	Green Turtle - Basking	41	13	-	17.33	-	0.6	-	-	-	-	2.9	-	-	-	-
	Green Turtle - Foraging	41	13	-	17.33	-	0.7	-	-	-	-	2.9	-	-	-	-
	Green Turtle - Internesting	41	13	-	17.33	-	0.7	-	-	-	-	2.9	-	-	-	-
	Green Turtle - Internesting Buffer	66.4	18	-	4.54	-	16.8	8	-	10.21	-	23.6	11	-	9.63	-
	Green Turtle - Mating	41	13	-	17.33	-	0.7	-	-	-	-	2.9	-	-	-	-
	Green Turtle - Nesting	93.3	21	-	5	-	20.2	10	-	12.63	-	20.7	8	-	10.08	-
	Hawksbill Turtle - Foraging	41	13	-	17.33	-	0.6	-	-	-	-	2.9	-	-	-	-
	Hawksbill Turtle - Internesting	14.4	5	-	38.67	-	0.3	-	-	-	-	1.5	-	-	-	-
	Hawksbill Turtle - Internesting Buffer	90.4	20	-	4.67	-	20.2	10	-	11.13	-	24	12	-	8.63	-
	Hawksbill Turtle - Mating	41	13	-	17.33	-	0.6	-	-	-	-	2.9	-	-	-	-
	Hawksbill Turtle - Nesting	93.3	21	-	5	-	15.5	5	-	12.67	-	20.7	6	-	10.08	-
	Humpback Whale - Migration	122.1	97	6	2.96	29.75	97.4	86	-	2.96	-	91.6	94	-	2.42	-
	Humpback Whale - Resting	28.9	4	-	14.25	-	4.6	-	-	-	-	4.9	-	-	-	-
	Lesser Crested Tern - Breeding	93.3	22	-	12.63	-	14.3	1	-	28.29	-	9.2	-	-	-	-
	Little Tern - Resting	3.7	-	-	-	-	11.3	3	-	43.46	-	11.7	4	-	58.21	-
	Loggerhead Turtle - Internesting Buffer	66.4	20	-	10.88	-	20.2	10	-	14.42	-	19.8	12	-	13.25	-
	Loggerhead Turtle - Nesting	66.4	18	-	12.29	-	20.2	10	-	16	-	19.8	8	-	14.63	-
	Pygmy Blue Whale – Distribution*	495.3	100	99	0.04	0.25	485	100	100	0.04	0.25	467.9	100	100	0.04	0.25

	Receptor	Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Pygmy Blue Whale - Foraging	40.1	53	-	11.38	-	33.5	32	-	7.96	-	31.7	20	-	9.83	-
	Roseate Tern - Breeding	81.1	26	-	12.71	-	15.3	3	-	21.92	-	30.1	13	-	17.08	-
	Wedge-tailed Shearwater – Breeding*	495.3	100	99	0.04	0.25	485	100	100	0.04	0.25	467.9	100	100	0.04	0.25
	Whale Shark - Foraging	138.5	98	7	1.17	21.33	120.4	95	5	1.63	6.04	184.2	90	17	1.08	7.04
	White-tailed Tropicbird - Breeding	16	3	-	31.67	-	16.1	3	-	37.67	-	16.4	6	-	44.5	-
CP	Montebello Islands	15	4	-	33.54	-	0.2	-	-	-	-	1.7	-	-	-	-
EEZ	Australian Exclusive Economic Zone*	495.3	100	99	0.04	0.25	485	100	100	0.04	0.25	467.9	100	100	0.04	0.25
IAA	Abrolhos Islands IAA	7.2	-	-	-	-	11.7	1	-	85.46	-	11	1	-	69.38	-
	Airlie Island	52.2	6	-	33.46	-	1.6	-	-	-	-	1.7	-	-	-	-
	Argo-Rowley Terrace IAA	18.5	10	-	27.71	-	25.8	10	-	18.79	-	32.8	20	-	40.17	-
	Barrow & Montebello Islands IAA	58.9	43	-	3.17	-	53.5	34	-	4.79	-	55.6	48	-	7.71	-
	Barrow Island (East Coast)	23.5	10	-	23.83	-	0.2	-	-	-	-	2.4	-	-	-	-
	Barrow Island (West Coast)	37.9	11	-	22.96	-	0.6	-	-	-	-	2.9	-	-	-	-
	Barrow Island Group	37.9	12	-	17.75	-	0.6	-	-	-	-	2.9	-	-	-	-
	Bessieres Island	59.4	10	-	18.63	-	6.2	-	-	-	-	5.6	-	-	-	-
	Boodie Island	36.6	12	-	17.75	-	0.5	-	-	-	-	2.9	-	-	-	-
	Cape Range National Park	24.7	5	-	14.42	-	8.6	-	-	-	-	7.8	-	-	-	-
	Cunningham Island (Imperieuse Reef)	2.9	-	-	-	-	11.3	3	-	43.46	-	11.5	4	-	58.67	-
	Dampier Archipelago IAA	28.5	5	-	40.71	-	0.9	-	-	-	-	1	-	-	-	-
	Dampier mainland coastline	12.3	4	-	52.58	-	0.1	-	-	-	-	0.2	-	-	-	-
	Exmouth IAA	28.2	11	-	13.75	-	5.2	-	-	-	-	7	-	-	-	-
	Gascoyne IAA	64	81	-	4.42	-	61	82	-	5.67	-	61.2	74	-	6	-
	Glomar Shoal	16.1	5	-	22.21	-	0.8	-	-	-	-	1.4	-	-	-	-
	Great Sandy Island	16.4	5	-	40.71	-	0.2	-	-	-	-	0.4	-	-	-	-
	Hermite Island	16.3	4	-	53.04	-	0.3	-	-	-	-	1.7	-	-	-	-
	Middle Island	37.7	11	-	17.75	-	0.5	-	-	-	-	2.7	-	-	-	-
	Middle Ningaloo Coast - World Heritage Area	21.3	8	-	15.79	-	6.3	-	-	-	-	5.9	-	-	-	-
	Montebello Islands Group	16.3	4	-	53.04	-	0.3	-	-	-	-	1.7	-	-	-	-
	Muiron Islands	66.4	13	-	12.75	-	12.5	2	-	17.42	-	12.9	3	-	75.71	-
	Ningaloo Coast World Heritage Area	66.4	17	-	12.33	-	20.2	10	-	16.25	-	19.8	8	-	14.75	-
	North Muiron Island	60.5	13	-	12.75	-	12.5	2	-	17.42	-	12.9	3	-	75.71	-
	North Ningaloo Coast - World Heritage Area	27.5	5	-	13.75	-	5.6	-	-	-	-	5.9	-	-	-	-
	North Sandy Island	12.9	5	-	40.29	-	0.2	-	-	-	-	0.3	-	-	-	-
	Offshore Area*	495.3	100	99	0.04	0.25	485	100	100	0.04	0.25	467.9	100	100	0.04	0.25
	Onslow Area Mainland Coastline	15.7	4	-	49.54	-	0.4	-	-	-	-	0.4	-	-	-	-
	Pilbara Coast IAA	90.4	17	-	12.46	-	14.8	4	-	16.33	-	14.7	4	-	68.58	-
	Pilbara Coast Islands Group	59.4	10	-	17.33	-	7.1	-	-	-	-	5.6	-	-	-	-
	Pilbara Mainland Coast	15.7	4	-	49.54	-	0.4	-	-	-	-	0.4	-	-	-	-
	Potter Island	11.2	3	-	52.67	-	0.1	-	-	-	-	0.1	-	-	-	-

	Receptor	Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Rankin Bank	84.1	34	-	4.88	-	20.8	21	-	8.38	-	21.7	32	-	18.92	-
	Serrurier Island	35.4	9	-	17.33	-	7.1	-	-	-	-	5.1	-	-	-	-
	Shark Bay mainland coastline	10.8	1	-	36.38	-	9.2	-	-	-	-	4.5	-	-	-	-
	Sholl Island	20.9	5	-	42.29	-	0.1	-	-	-	-	0.3	-	-	-	-
	South Muiron Island	66.4	13	-	13.17	-	10.6	1	-	37.04	-	10	-	-	-	-
	Thevenard Island	59.5	9	-	32.46	-	6.3	-	-	-	-	3.2	-	-	-	-
	Trimouille Island	10.5	2	-	81.13	-	0.2	-	-	-	-	1	-	-	-	-
IBRA	Cape Range	66.4	13	-	12.75	-	12.5	2	-	17.42	-	12.9	3	-	75.71	-
	Roebourne	50.9	11	-	17.75	-	1.6	-	-	-	-	2.9	-	-	-	-
IMCRA	Ningaloo	48.5	21	-	12.08	-	19.5	13	-	10.71	-	18.5	8	-	14	-
	Northwest Shelf	111.5	62	4	1.71	41.71	125.1	62	6	3.04	30.29	127.5	81	6	6.25	60.08
	Pilbara (nearshore)	30.5	6	-	14.25	-	4.8	-	-	-	-	7	-	-	-	-
	Pilbara (offshore)	140.3	97	7	1.13	21.33	119	95	3	1.63	6.04	184.2	84	17	1.08	6.92
	Zuytdorp	10.8	1	-	36.38	-	9.2	-	-	-	-	4.5	-	-	-	-
KEF	Ancient coastline at 125 m depth contour	116.2	80	6	1.71	30.04	96.2	64	-	2.17	-	97.5	65	-	3.67	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	66.2	64	-	7.71	-	64.1	48	-	7.29	-	63.1	43	-	7.04	-
	Commonwealth waters adjacent to Ningaloo Reef	56.6	17	-	12.33	-	20.2	10	-	16.25	-	19.8	8	-	14.75	-
	Continental Slope Demersal Fish Communities*	212.3	100	39	0.67	4.29	243.6	100	49	0.75	4.46	266.7	100	48	0.75	4.42
	Exmouth Plateau	73.7	70	-	4.71	-	77.2	92	-	4.71	-	96.7	80	-	5.54	-
	Glomar Shoals	17.1	6	-	20.13	-	1.3	-	-	-	-	1.4	-	-	-	-
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	4.2	-	-	-	-	11.3	3	-	43.08	-	11.7	4	-	58.21	-
	Wallaby Saddle	7.2	-	-	-	-	11.7	1	-	85.46	-	11	1	-	69.38	-
MMA	Barrow Island	52.3	13	-	17.17	-	0.8	-	-	-	-	3.8	-	-	-	-
	Muiron Islands	66.4	15	-	12.54	-	13.3	5	-	17.38	-	13.3	5	-	69.92	-
MP	Barrow Island	20.1	11	-	23.92	-	0.5	-	-	-	-	2.5	-	-	-	-
	Montebello Islands	22	6	-	32.88	-	0.7	-	-	-	-	2.6	-	-	-	-
	Ningaloo	56.4	12	-	13.21	-	15.6	4	-	17.13	-	15.5	5	-	69.79	-
	Rowley Shoals	3.4	-	-	-	-	11.3	3	-	43.46	-	11.5	4	-	58.54	-
NR	Great Sandy Island	39	6	-	34.38	-	0.2	-	-	-	-	1	-	-	-	-
	Thevenard Island	43	6	-	32.96	-	3.2	-	-	-	-	2.4	-	-	-	-
RSB	Ashworth Shoal	13.8	4	-	51.17	-	0	-	-	-	-	0.2	-	-	-	-
	Australind Shoal	15.5	5	-	56.88	-	0.5	-	-	-	-	0.7	-	-	-	-
	Barrow Island Reefs and Shoals	41.7	6	-	34	-	0.3	-	-	-	-	1.2	-	-	-	-
	Brewis Reef	33	6	-	32.63	-	3.6	-	-	-	-	2	-	-	-	-
	Cod Bank	14.2	4	-	44.29	-	0.1	-	-	-	-	0.2	-	-	-	-
	Combe Reef	11.4	1	-	97.63	-	2.8	-	-	-	-	3.5	-	-	-	-
	Dailey Shoal	15.3	4	-	15.21	-	5.6	-	-	-	-	5.8	-	-	-	-
	Eliassen Rocks	12.1	3	-	51.63	-	0	-	-	-	-	0.1	-	-	-	-

	Receptor	Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Fairway Reef	11.7	2	-	33.38	-	3.5	-	-	-	-	2.2	-	-	-	-
	Flinders Shoal	20.5	6	-	37.13	-	0.2	-	-	-	-	0.5	-	-	-	-
	Fortescue Reef	16.3	4	-	47	-	0.1	-	-	-	-	0.2	-	-	-	-
	Glomar Shoal	16.1	5	-	22.21	-	0.8	-	-	-	-	1.4	-	-	-	-
	Hood Reef	13.6	8	-	17.92	-	5.5	-	-	-	-	3.9	-	-	-	-
	Imperieuse Reef	2.9	-	-	-	-	11.3	3	-	43.46	-	11.5	4	-	58.67	-
	Lightfoot Reef	20.8	6	-	38.17	-	0.2	-	-	-	-	0.5	-	-	-	-
	Little Shoals	14.5	4	-	59.58	-	0.2	-	-	-	-	0.4	-	-	-	-
	Mardie Rock	13	4	-	49.54	-	0	-	-	-	-	0.1	-	-	-	-
	McLennan Bank	25.8	5	-	42.21	-	0.1	-	-	-	-	0.2	-	-	-	-
	Meda Reef	11.1	1	-	89.96	-	0.1	-	-	-	-	0.2	-	-	-	-
	Montebello Shoals	20.1	6	-	32.96	-	0.7	-	-	-	-	2.2	-	-	-	-
	Moresby Shoals	11.1	2	-	60.71	-	0.3	-	-	-	-	0.4	-	-	-	-
	Ningaloo Reef	24.8	8	-	14.42	-	9.6	-	-	-	-	8.3	-	-	-	-
	North West Reef	29.9	9	-	13.67	-	6.3	-	-	-	-	6.6	-	-	-	-
	O'Grady Shoal	18.5	4	-	44.25	-	0.1	-	-	-	-	0.1	-	-	-	-
	Otway Reef	12.9	4	-	18.88	-	3.7	-	-	-	-	4.5	-	-	-	-
	Outtrim Patches	44.8	13	-	13.17	-	10	2	-	37.13	-	9.8	-	-	-	-
	Penguin Bank	50.3	11	-	18.67	-	2.9	-	-	-	-	5.7	-	-	-	-
	Poivre Reef	41.9	13	-	17.92	-	0.4	-	-	-	-	2.3	-	-	-	-
	Rankin Bank	84.1	34	-	4.88	-	23	21	-	8.13	-	21.7	32	-	18.92	-
	Ripple Shoals	40.7	6	-	33.04	-	0.5	-	-	-	-	1.6	-	-	-	-
	Rosily Shoals	73.8	14	-	20.75	-	11.9	1	-	31.29	-	6	-	-	-	-
	South West Reef	10.2	1	-	59.42	-	0.1	-	-	-	-	0	-	-	-	-
	Sultan Reef	31.5	6	-	33.5	-	0.9	-	-	-	-	1.5	-	-	-	-
	Taunton Reef	46.9	6	-	34.42	-	0.8	-	-	-	-	1.5	-	-	-	-
	Trap Reef	58.4	6	-	32.58	-	4.8	-	-	-	-	2.2	-	-	-	-
	Tryal Rocks	20.7	4	-	32.92	-	4.7	-	-	-	-	3.8	-	-	-	-
	West Reef	13.8	6	-	39.42	-	0.5	-	-	-	-	0.5	-	-	-	-
Nearshore Waters	Airlie Island	52.2	6	-	33.46	-	1.6	-	-	-	-	1.7	-	-	-	-
	Barrow Island	37.9	11	-	22.96	-	0.6	-	-	-	-	2.9	-	-	-	-
	Bessieres Island	59.4	10	-	18.63	-	6.2	-	-	-	-	5.6	-	-	-	-
	Boodie Island	36.1	11	-	17.75	-	0.4	-	-	-	-	2.9	-	-	-	-
	Cunningham Island	2.3	-	-	-	-	10.3	1	-	54.33	-	10	1	-	63.21	-
	Exmouth	27.5	8	-	13.75	-	9.6	-	-	-	-	7.8	-	-	-	-
	Flat Island	24.2	10	-	14.33	-	6.9	-	-	-	-	6.3	-	-	-	-
	Imperieuse Reef	2.3	-	-	-	-	10.5	1	-	54.88	-	11.2	3	-	59.17	-
	Karratha	15.7	4	-	45.46	-	0.1	-	-	-	-	0.4	-	-	-	-
	Lowendal Island	14.4	5	-	40.21	-	0.3	-	-	-	-	1.4	-	-	-	-

	Receptor	Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Mary Anne Group	20.4	6	-	37.54	-	0.2	-	-	-	-	0.5	-	-	-	-
	Middle Island	37.7	11	-	17.75	-	0.5	-	-	-	-	2.7	-	-	-	-
	Montebello Islands	17.6	4	-	33.42	-	0.5	-	-	-	-	2.1	-	-	-	-
	Murion Islands	66.4	13	-	12.75	-	12.5	2	-	17.42	-	12.9	3	-	75.71	-
	Observation Island	12	3	-	34.29	-	4.2	-	-	-	-	2.5	-	-	-	-
	Passage Islands	23	5	-	40.29	-	0.2	-	-	-	-	0.4	-	-	-	-
	Peak Island	25.5	9	-	13.29	-	8.6	-	-	-	-	8.4	-	-	-	-
	Ragnard Islands	12.4	4	-	56.21	-	0.1	-	-	-	-	0.1	-	-	-	-
	Round Island	21.4	9	-	19.75	-	5.2	-	-	-	-	3.8	-	-	-	-
	Serrurier Island	33.1	9	-	17.33	-	6.5	-	-	-	-	4.8	-	-	-	-
	Sunday Island	20	11	-	13.71	-	6	-	-	-	-	7.1	-	-	-	-
	Table Island	31.9	9	-	18.33	-	5.1	-	-	-	-	2.9	-	-	-	-
	Thevenard Island	47.4	7	-	32.96	-	3.4	-	-	-	-	1.9	-	-	-	-
	Tortoise Island	18.1	6	-	33.13	-	1.7	-	-	-	-	2.9	-	-	-	-
State Waters	Western Australia State Waters	90.4	17	-	12.46	-	15.6	5	-	16.63	-	15.5	5	-	58.54	-

*The release location resides within the receptor boundaries.

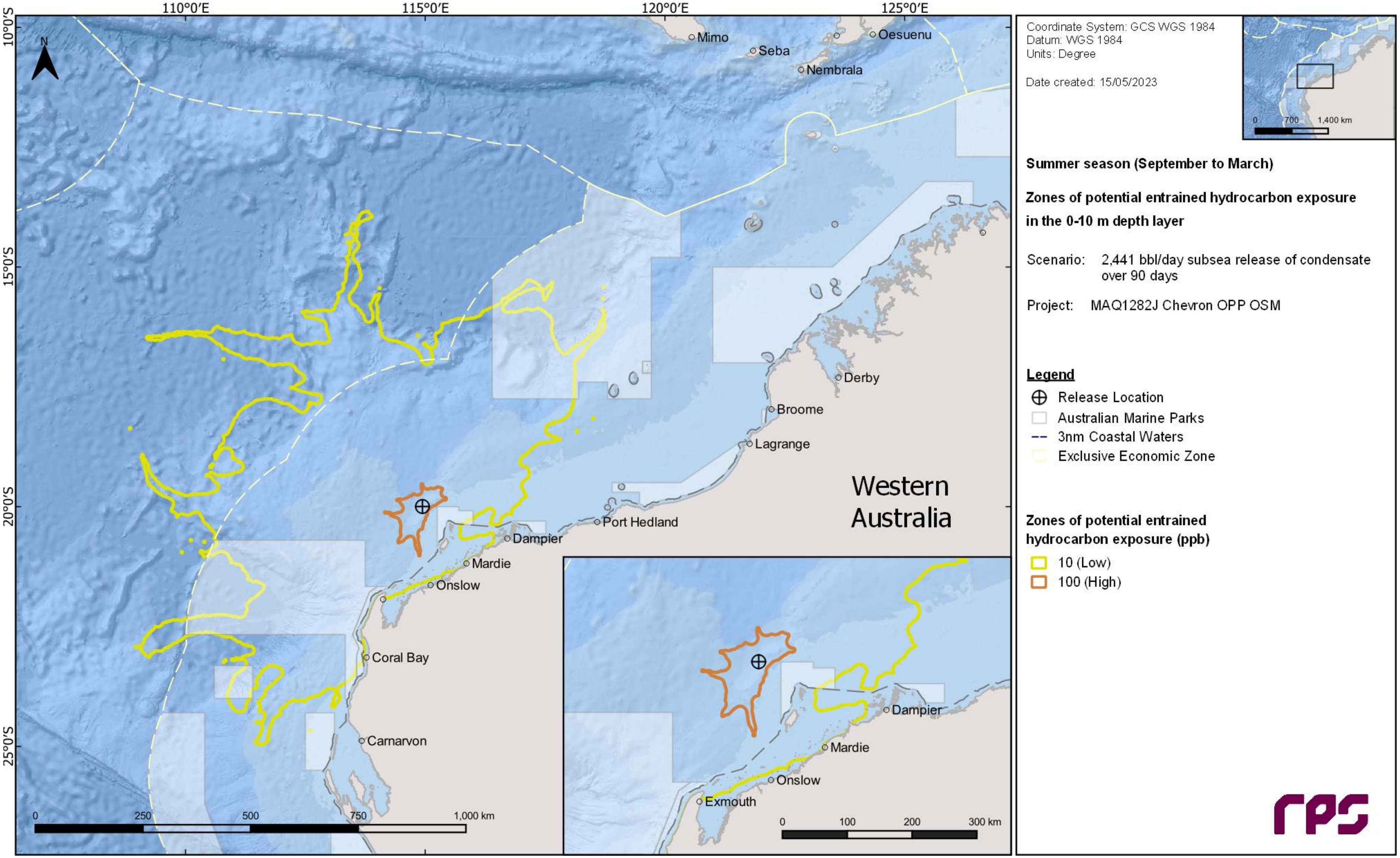


Figure 11.8 Zones of potential entrained hydrocarbon exposure at 0-10 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

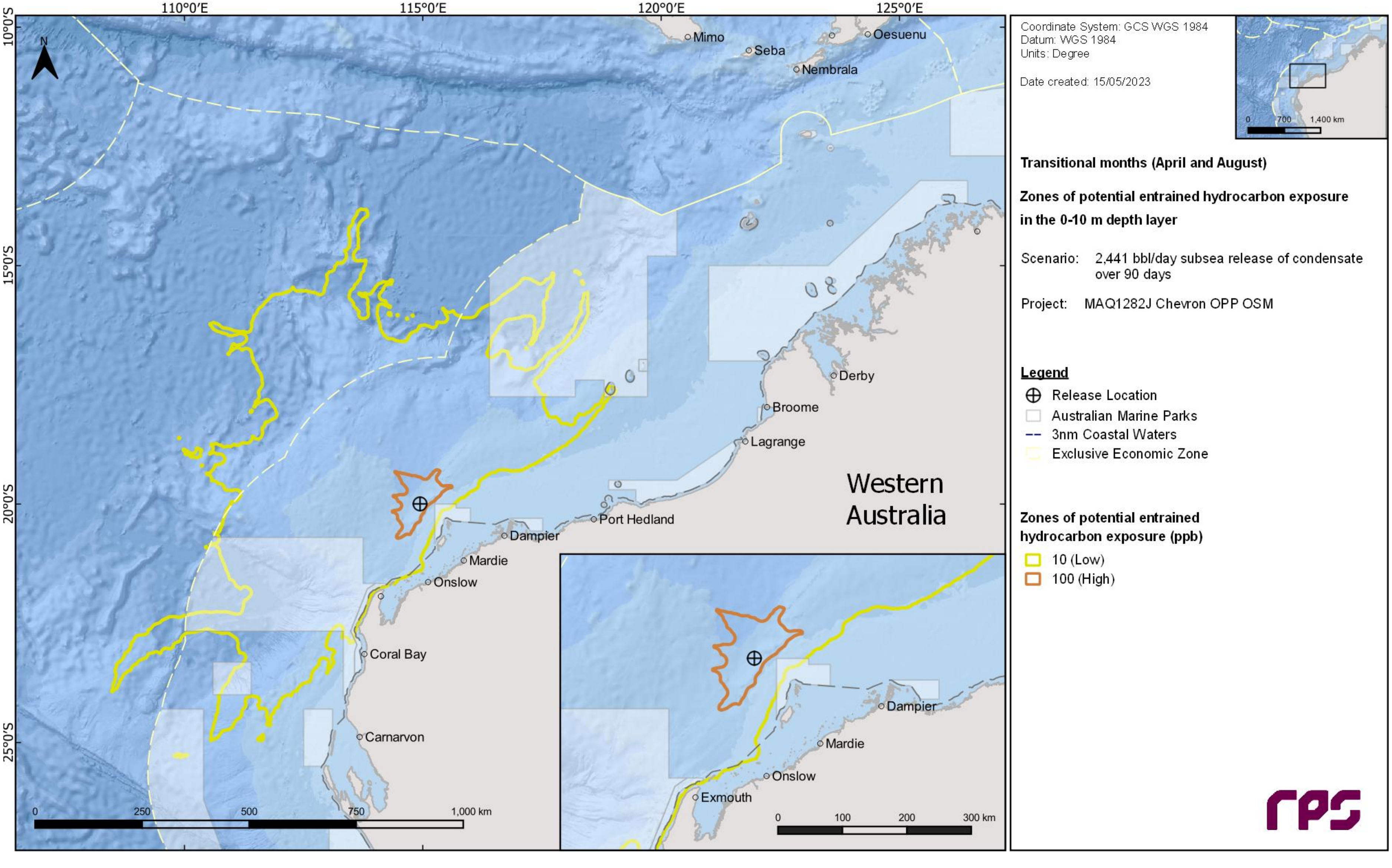


Figure 11.9 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Semele Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

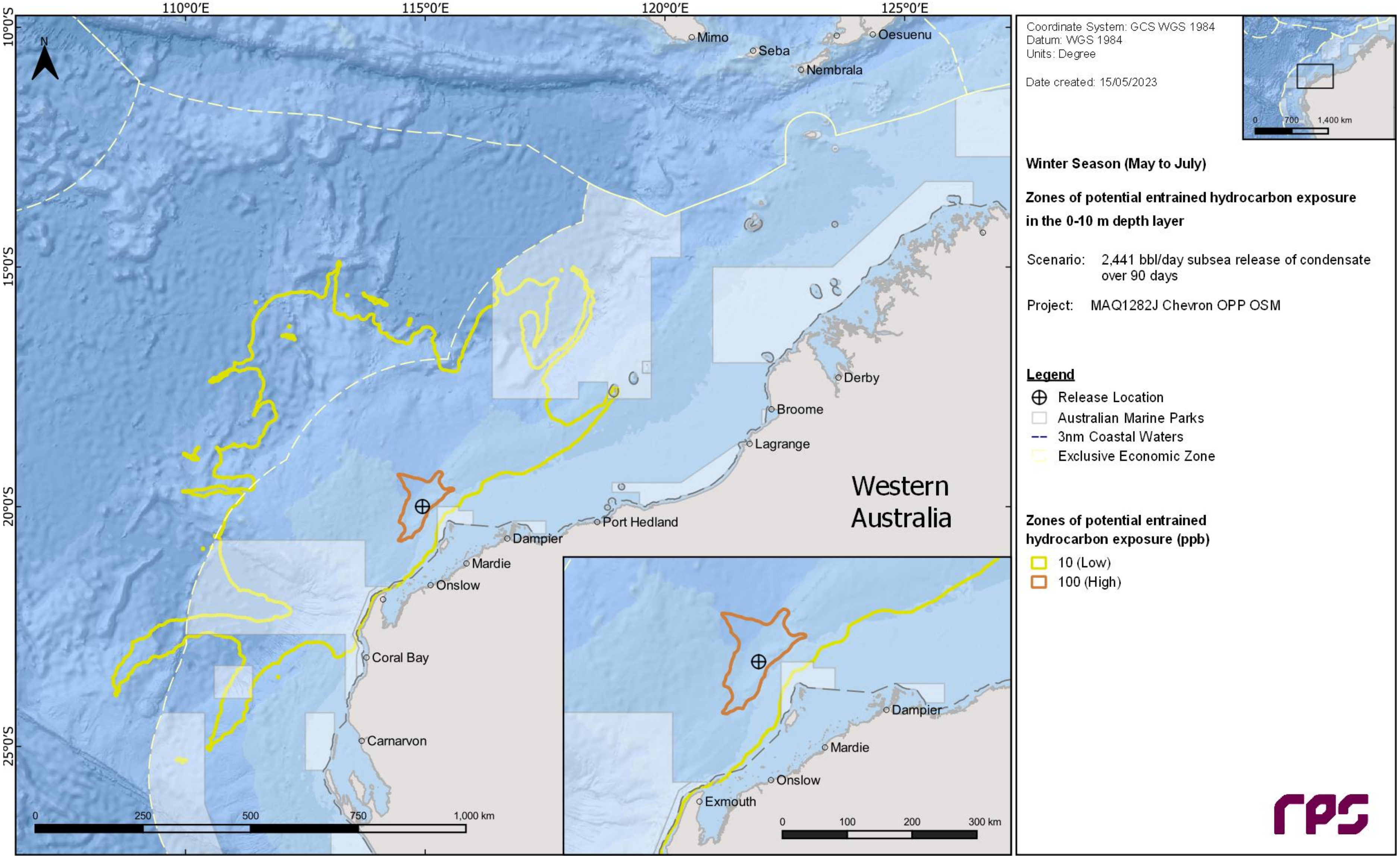


Figure 11.10 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Semele Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

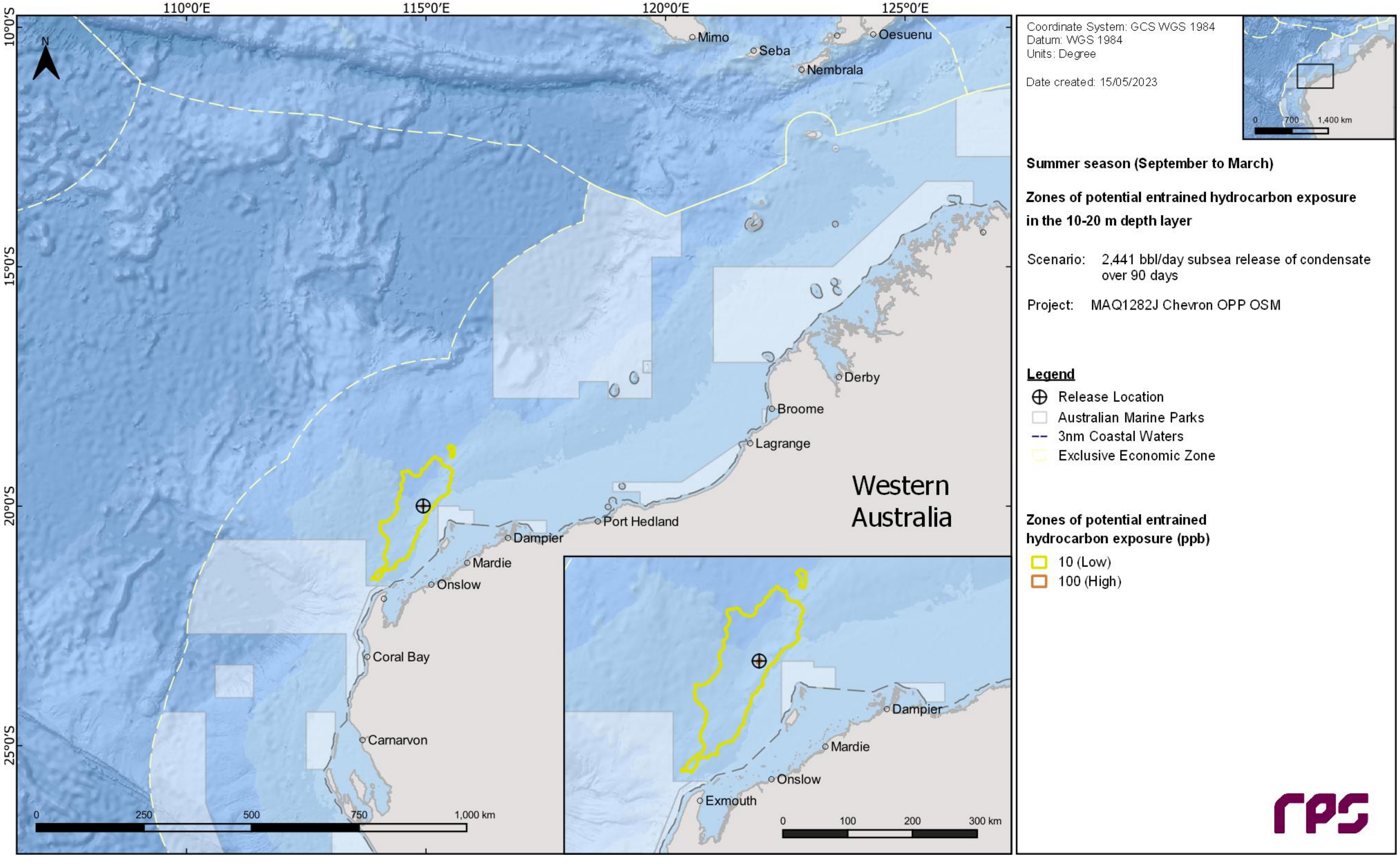


Figure 11.11 Zones of potential entrained hydrocarbon exposure at 10-20 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

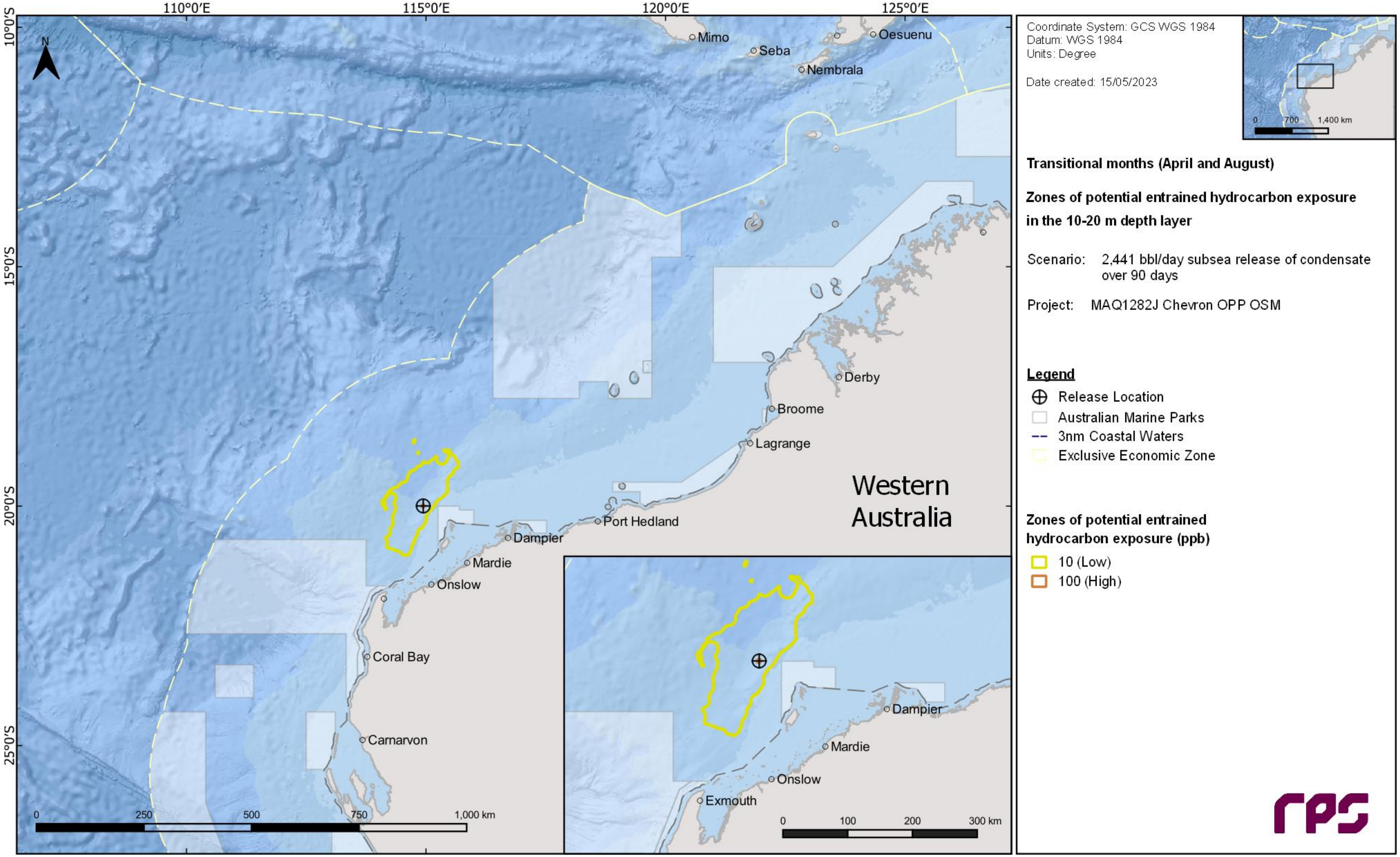


Figure 11.12 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Semele Well 5 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

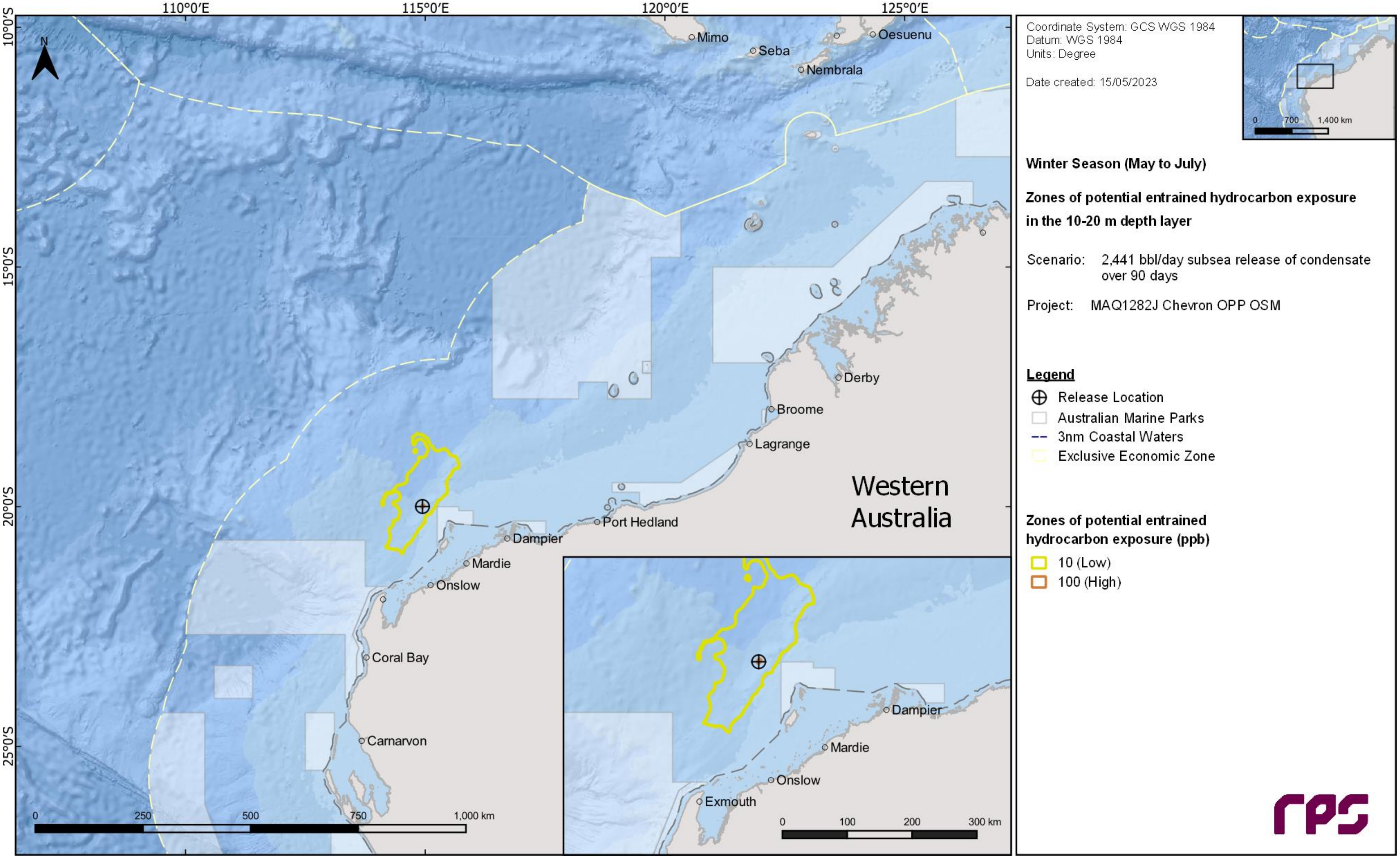


Figure 11.13 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Semele Well 5 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating condensate above 10 g/m^2 (see Section 11.2.1), and the largest volume of condensate ashore (see Section 11.2.2), the longest length of shoreline with accumulation above 100 g/m2 (see Section 11.2.3) and the largest area of entrained hydrocarbons above 100 ppb (see Section 11.2.4).

Table 11.9 presents a summary of all deterministic analysis criteria and the corresponding values at the assessed thresholds.

Note that there was no floating hydrocarbons at or above 50 g/m^2 and no dissolved hydrocarbon exposure at or above 50 ppb for any of the 300 simulations.

Interpretation of the deterministic analysis result table and timeseries plots:

The summary deterministic analysis results presented in the table below should be interpreted as **maximum values**, representing the total volume or swept area exposed by floating or in-water hydrocarbons throughout the entire simulation duration. In this particular case, the simulation showed that a maximum of 564 km^2 was exposed to floating oil above the low threshold over a period of 104 days.

However, it's important to note that the timeseries plots present **peak values** at specific points in time. For example, when considering shoreline volume, the peak value in the timeseries plot does not account for oil that may have reached the shore earlier in the simulation but was subsequently lost through evaporation or other weathering processes.

Continuing with the previous example, the timeseries plot indicates that the peak floating oil swept area above the low threshold reached 36 km^2. This value represents the highest swept area recorded at a single point in time during the simulation.

Table 11.9 Summary of the deterministic analysis following a subsea LOWC at Semele Well 5.

Variable	Threshold	Deterministic Analysis Criteria			
		Largest swept area of floating condensate above 10 g/m^2	Largest volume of condensate ashore	Longest length of shoreline with accumulation above 100 g/m^2	Largest area of entrained hydrocarbons above 100 ppb
Season		Winter	Summer	Summer	Winter
Run Number		43	18	8	48
Floating Oil (km^2)	1 g/m^2	564	489	814	598
	10 g/m^2	**4**	-	-	-
	50 g/m^2	-	-	-	-
Shoreline Length (km)	10 g/m^2	-	137	38	-
	100 g/m^2	-	1	**3**	-
	1,000 g/m^2	-	-	-	-
Minimum Time (days)		-	33	20.3	-
Maximum Volume (m^3)		-	**29**	8	-
Entrained Area (km^2)	10 ppb	68,367	78,433	75,220	96,269
	100 ppb	1,015	1,169	505	**2,351**
Dissolved Area (km^2)	10 ppb	4	5	-	-
	50 ppb	-	-	-	-
	400 ppb	-	-	-	-
Start Date		30 June 2011	16 November 2010	27 December 2011	31 July 2013

11.2.1 Deterministic Case: Largest swept area of floating condensate above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 (moderate threshold) was identified as run number 43 during the winter period.

Figure 11.14 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.15 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.16 presents the fates and weathering for the corresponding simulation and Table 11.10 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.10 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at Semele Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	325	43	1
Entrained (m^3)	2,703	90	1,561
Dissolved (m^3)	61	78	2
Evaporation (m^3)	23,577	104	23,577
Decay (m^3)	9,937	104	9,937
Ashore (m^3)	0	0	0

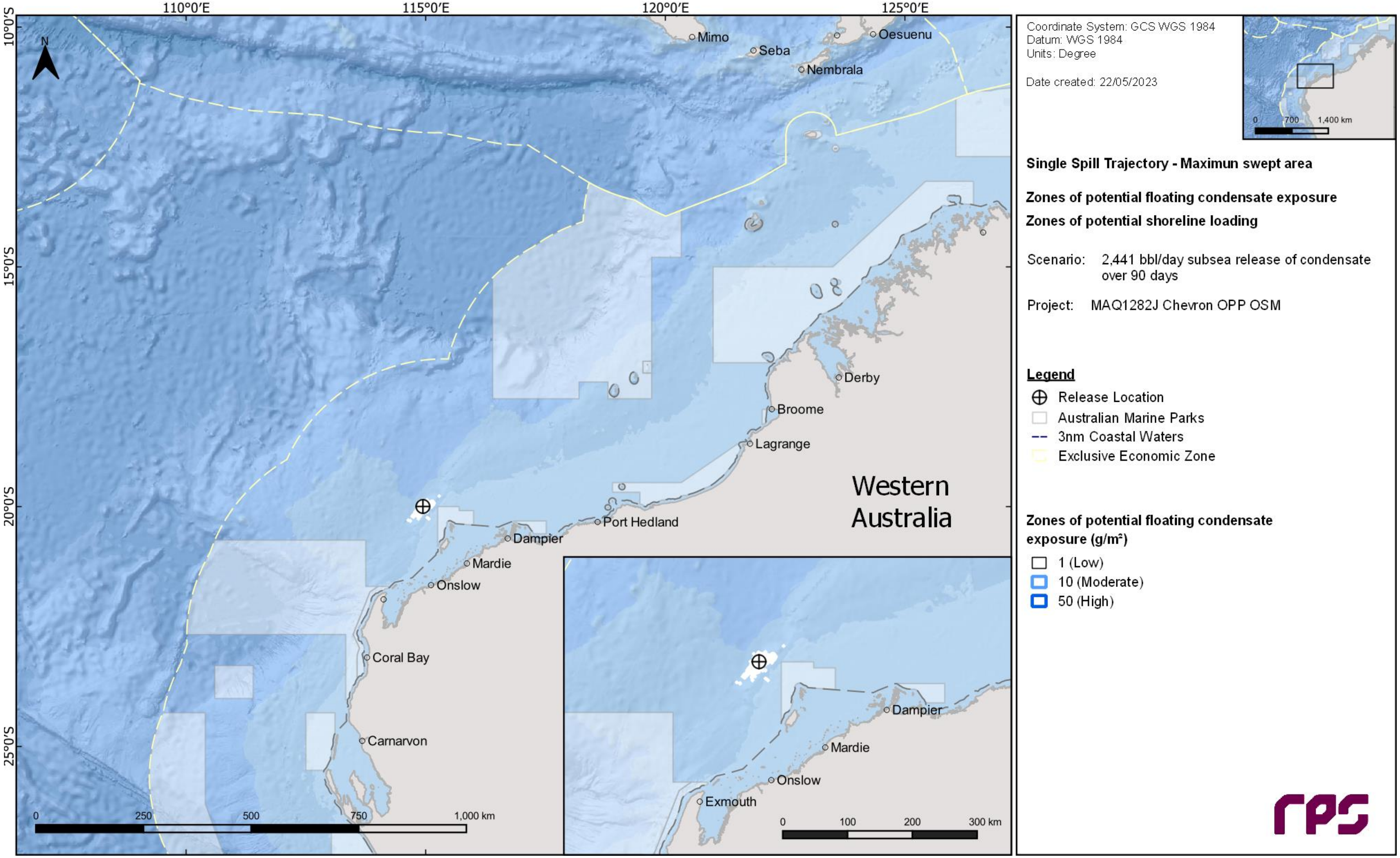


Figure 11.14 Zones of potential floating condensate exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at Semele Well 5.

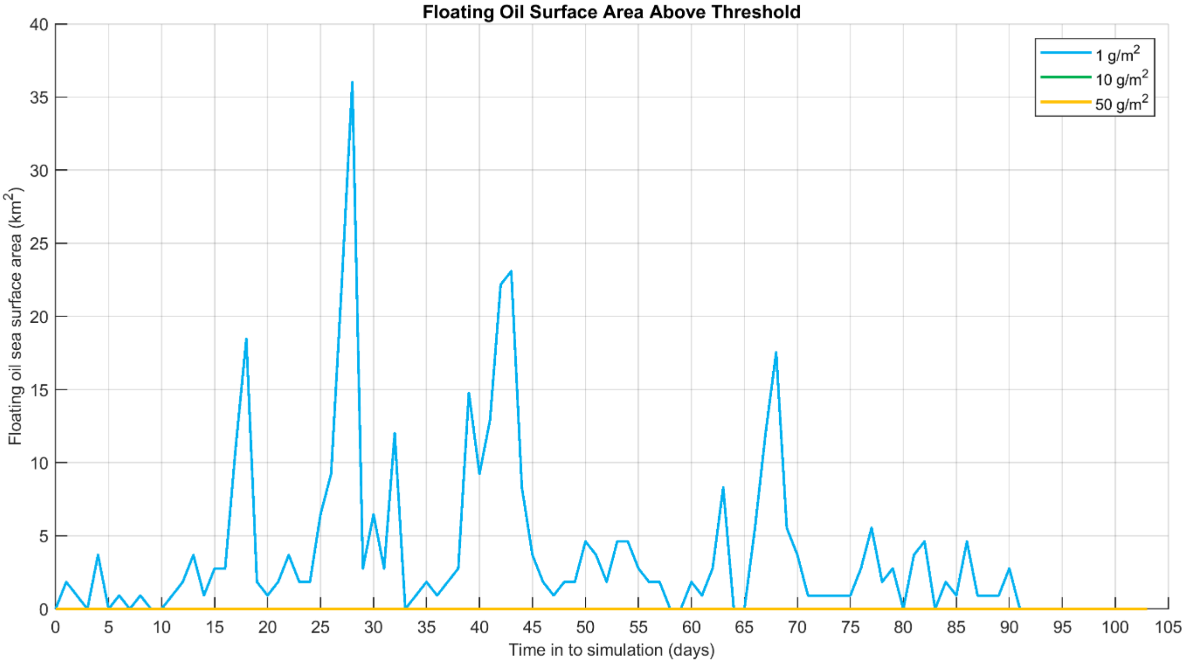


Figure 11.15 Predicted area of floating condensate exposure for each threshold, for the simulation with the largest swept area of floating condensate above 10 g/m² following a LOWC at Semele Well 5.

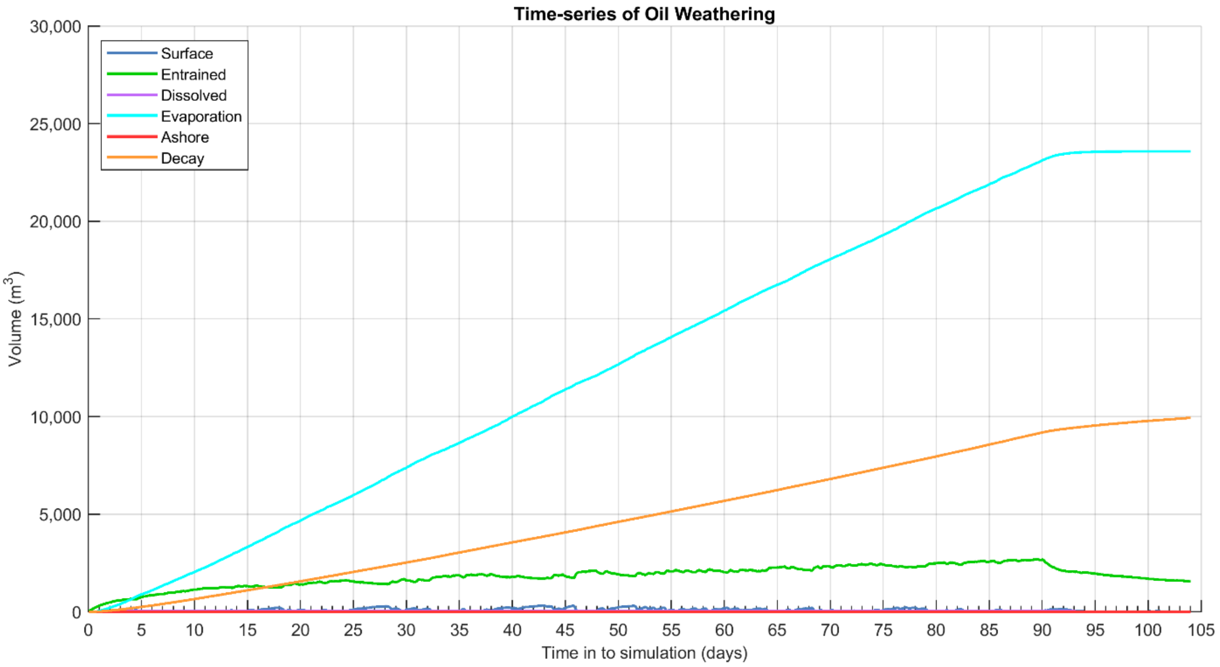


Figure 11.16 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 10 g/m² following a LOWC at Semele Well 5.

11.2.2 Deterministic Case: Largest volume of condensate ashore

The deterministic simulation that resulted in the largest volume of condensate ashore was identified as run number 18, during the summer season.

Figure 11.17 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.18 displays the time series of the volume of oil accumulating on shorelines at the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.19 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.11 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.11 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest volume of condensate ashore following a subsea LOWC at Semele Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	196	75	1
Entrained (m^3)	2,518	87	1,458
Dissolved (m^3)	61	52	2
Evaporation (m^3)	23,753	104	23,753
Decay (m^3)	9,826	104	9,826
Ashore (m^3)	43	103	43

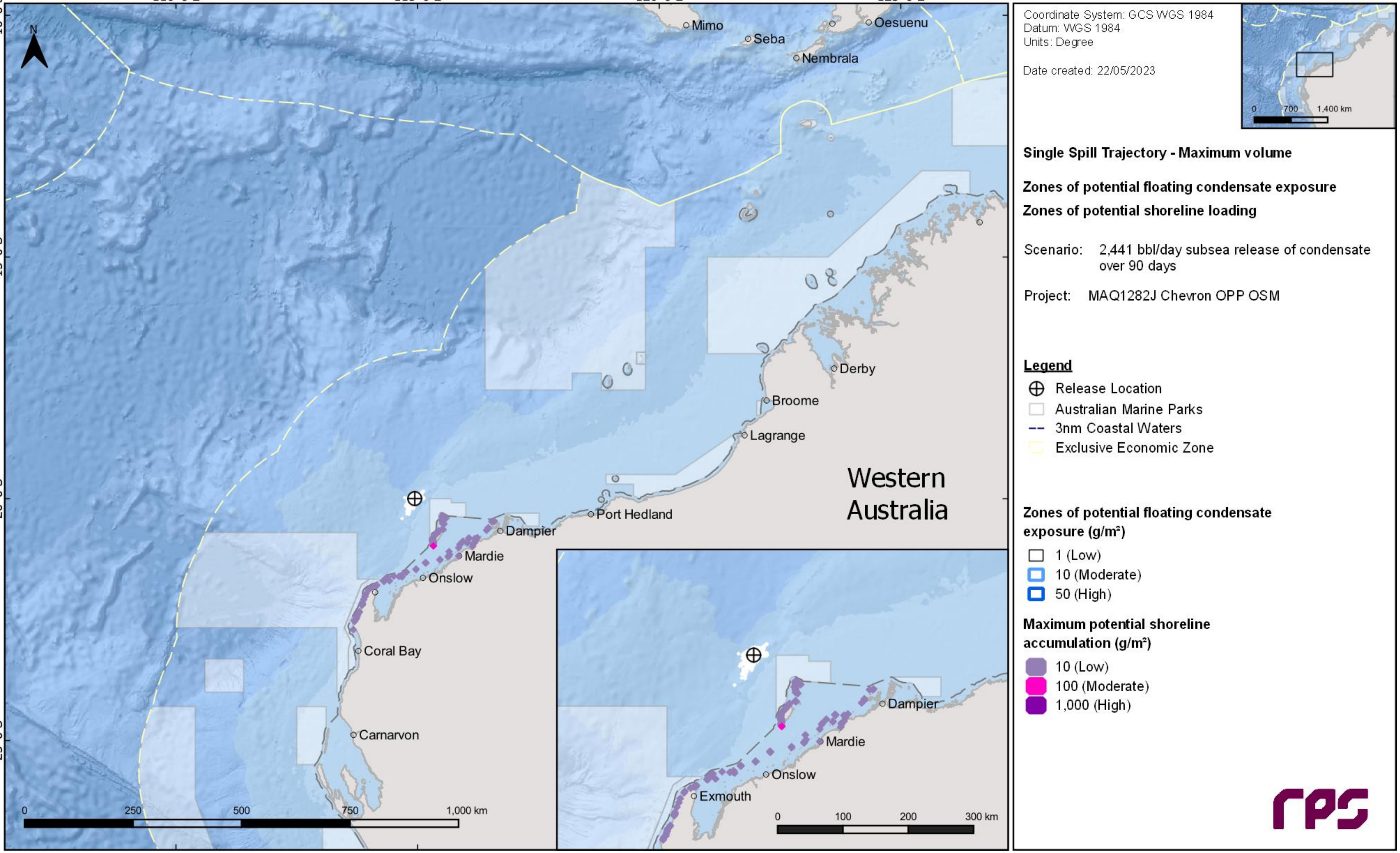


Figure 11.17 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the largest volume of condensate ashore following a LOWC at Semele Well 5.

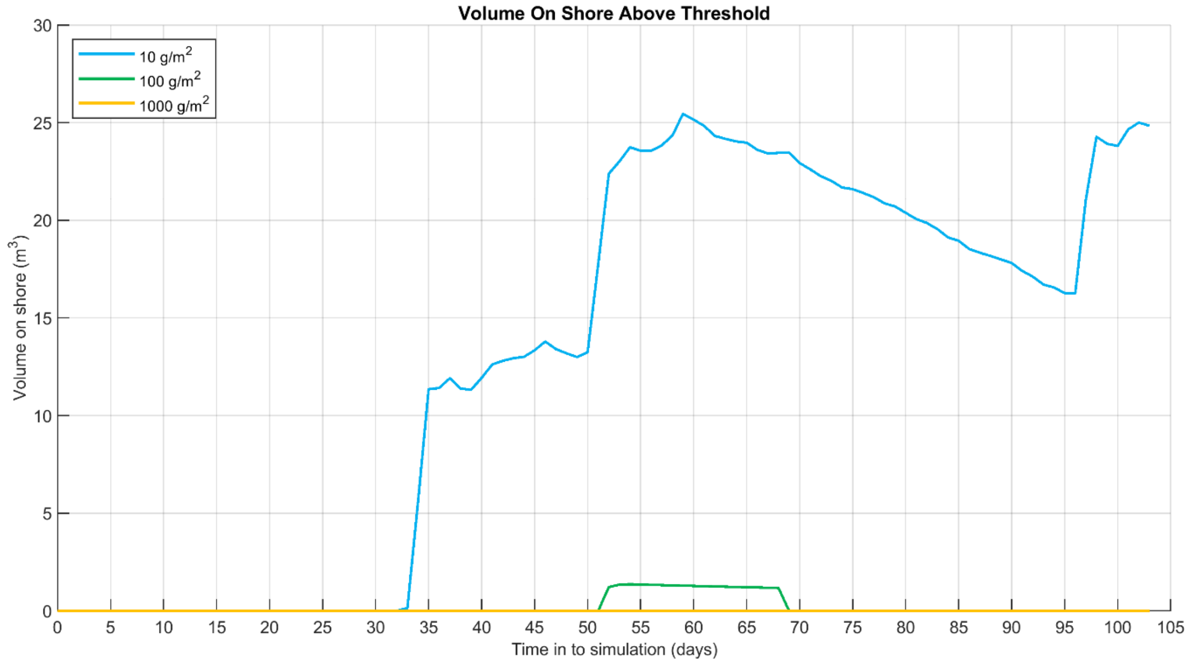


Figure 11.18 Time series of the volume of condensate ashore at each threshold for the simulation with the largest volume ashore following a LOWC at Semele Well 5.

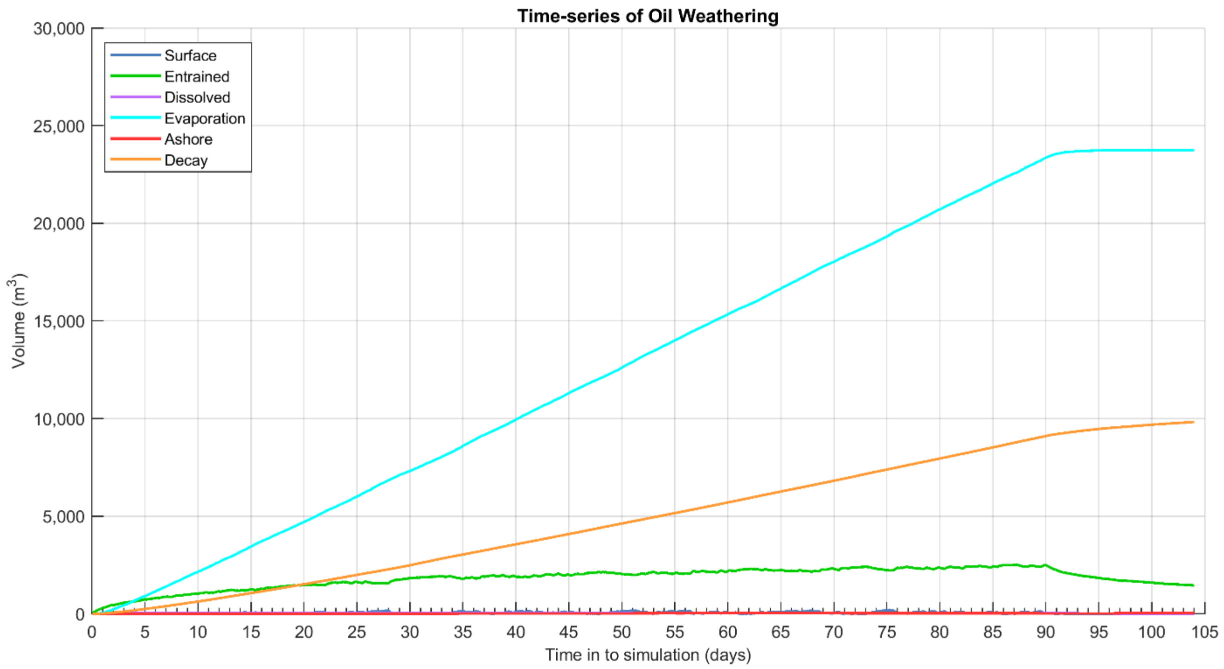


Figure 11.19 Predicted weathering and fates for the simulation with the largest volume of condensate ashore following a LOWC at Semele Well 5.

11.2.3 Deterministic Case: Longest length of shoreline with accumulation above 100 g/m^2

The deterministic simulation that resulted in the longest length of shoreline with accumulation above 100 g/m^2 (moderate threshold) was identified as run number 8 during the summer period.

Figure 11.17 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.18 displays the time series of the length of shoreline with accumulation above the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds over the 104-day simulation.

Figure 11.19 presents the fates and weathering graph for the corresponding single spill trajectory and Table 11.11 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.12 Summary peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a subsea LOWC at Semele Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	274	22	35
Entrained (m^3)	2,525	82	1,399
Dissolved (m^3)	61	73	2
Evaporation (m^3)	24,037	104	24,037
Decay (m^3)	9,599	104	9,599
Ashore (m^3)	19	42	10

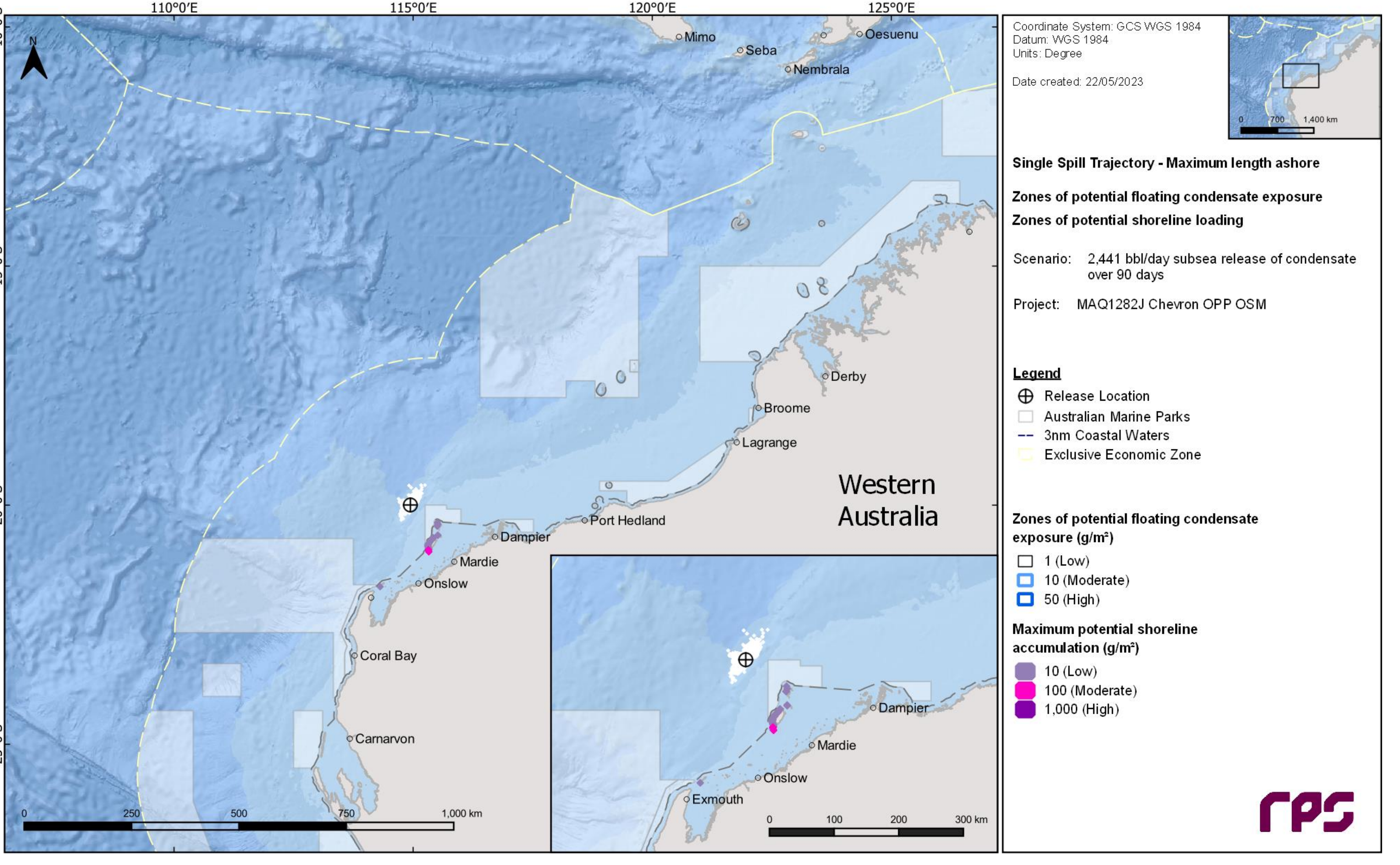


Figure 11.20 Zones of potential floating condensate exposure over the entire 104 days, for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a LOWC at Semele Well 5.

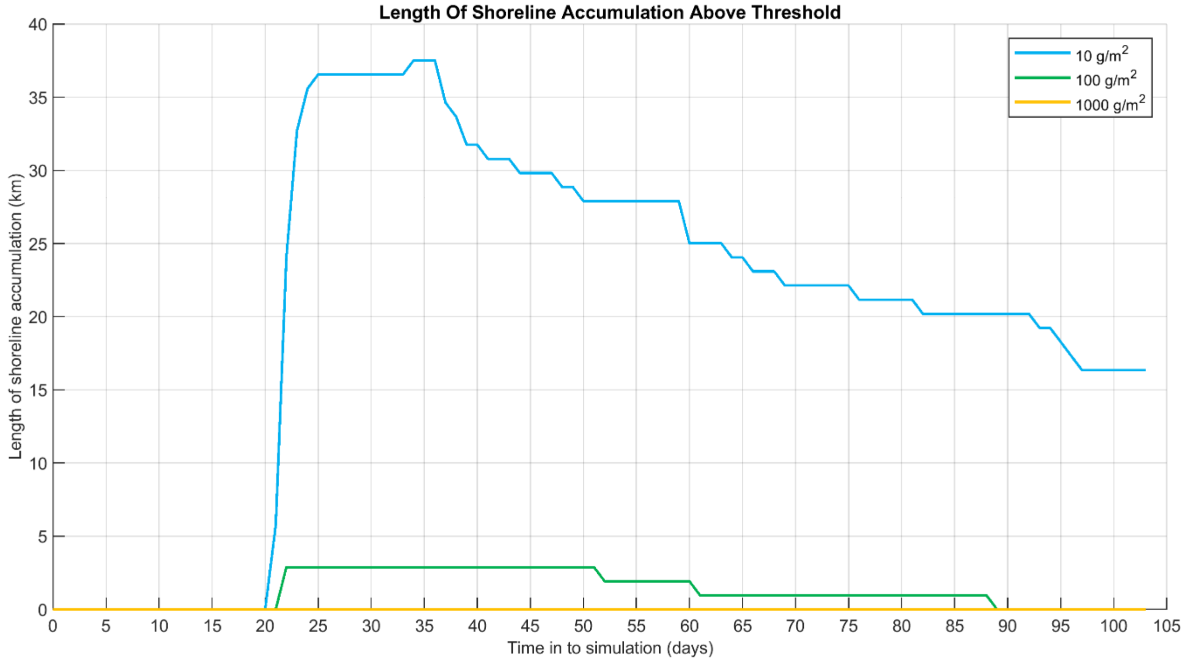


Figure 11.21 Time series of the length of shoreline at each threshold for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a LOWC at Semele Well 5.

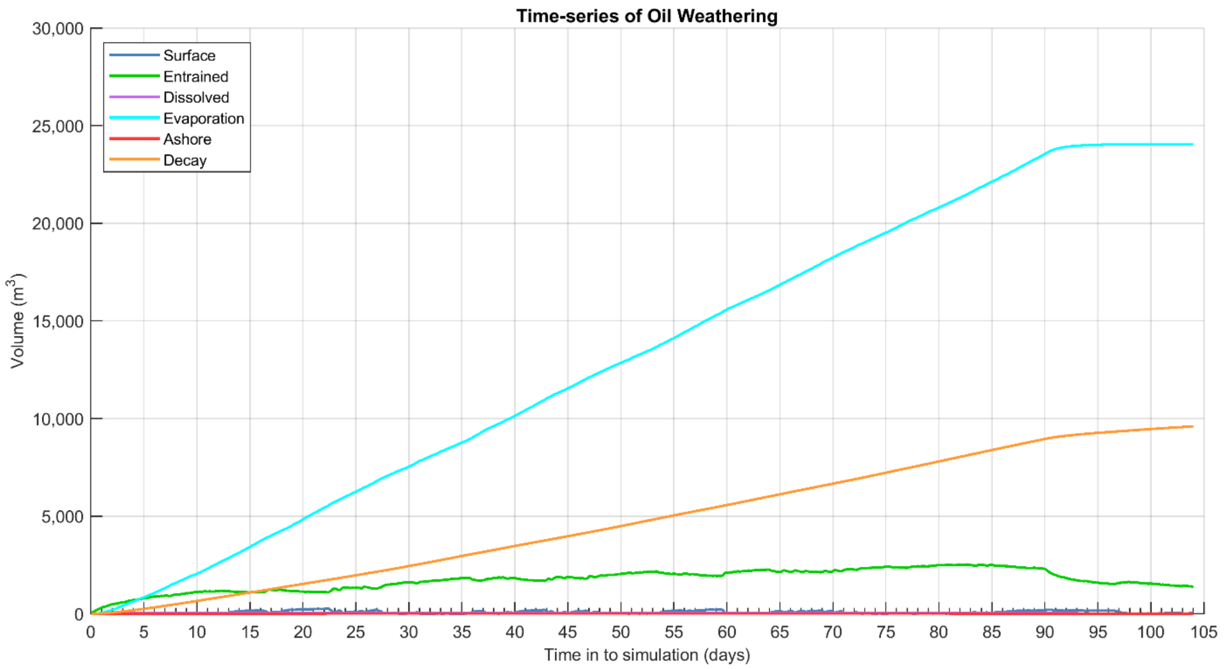


Figure 11.22 Predicted weathering and fates for the simulation with the longest length of shoreline with accumulation above 100 g/m^2 following a LOWC at Semele Well 5.

11.2.4 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (high threshold) was identified as run number 48 during the winter period.

Figure 11.23 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.24 displays the time series of the area of entrained hydrocarbons at the low (≥10 ppb) and high (≥100 ppb) thresholds over the 104-day simulation.

Figure 11.25 presents the fates and weathering for the corresponding single spill trajectory and Table 11.13 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.13 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Semele Well 5.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	244	15	7
Entrained (m^3)	2,860	87	1,701
Dissolved (m^3)	61	37	2
Evaporation (m^3)	23,134	104	23,134
Decay (m^3)	10,246	104	10,246
Ashore (m^3)	0	43	0

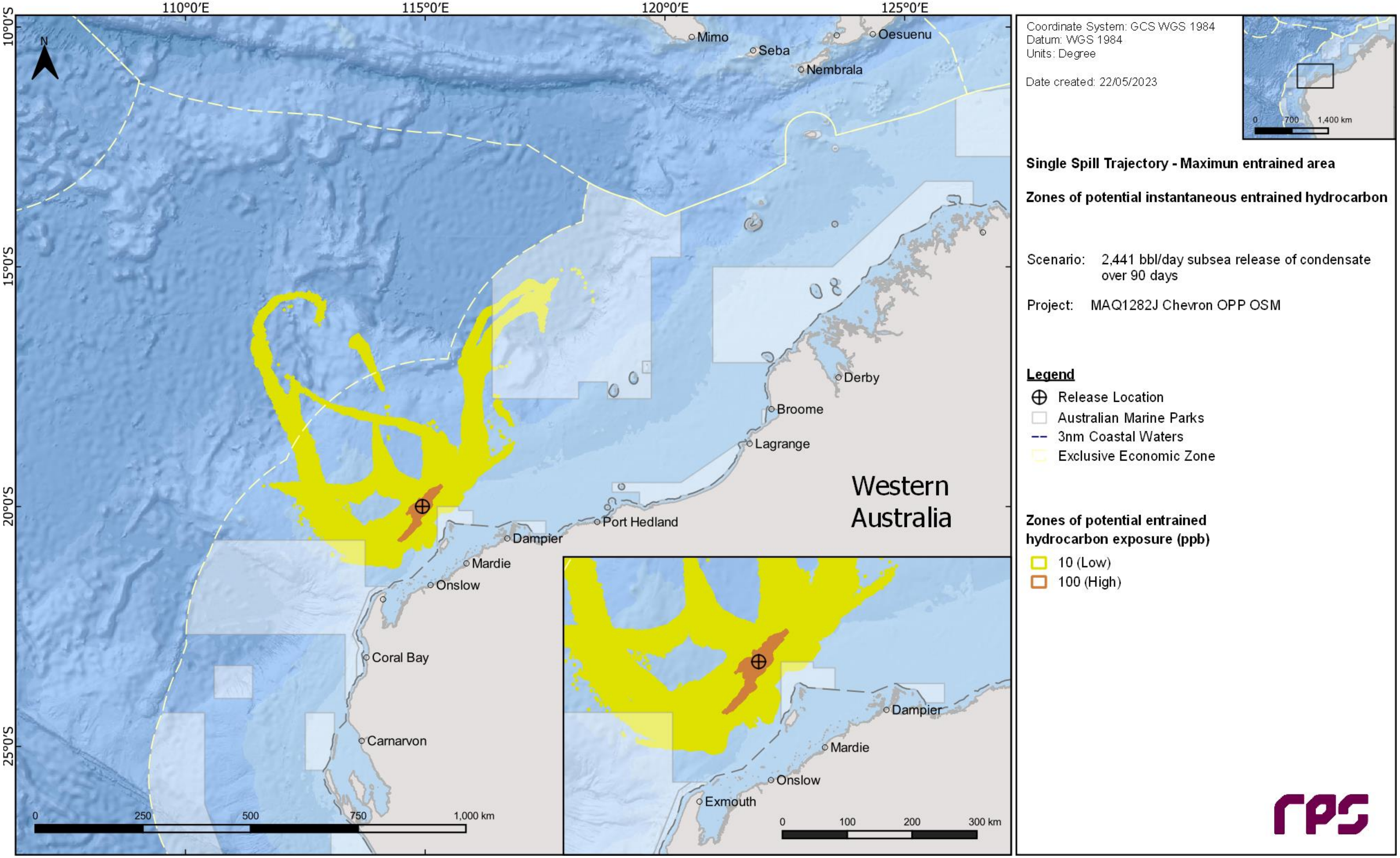


Figure 11.23 Zones of potential entrained hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Semele Well 5.

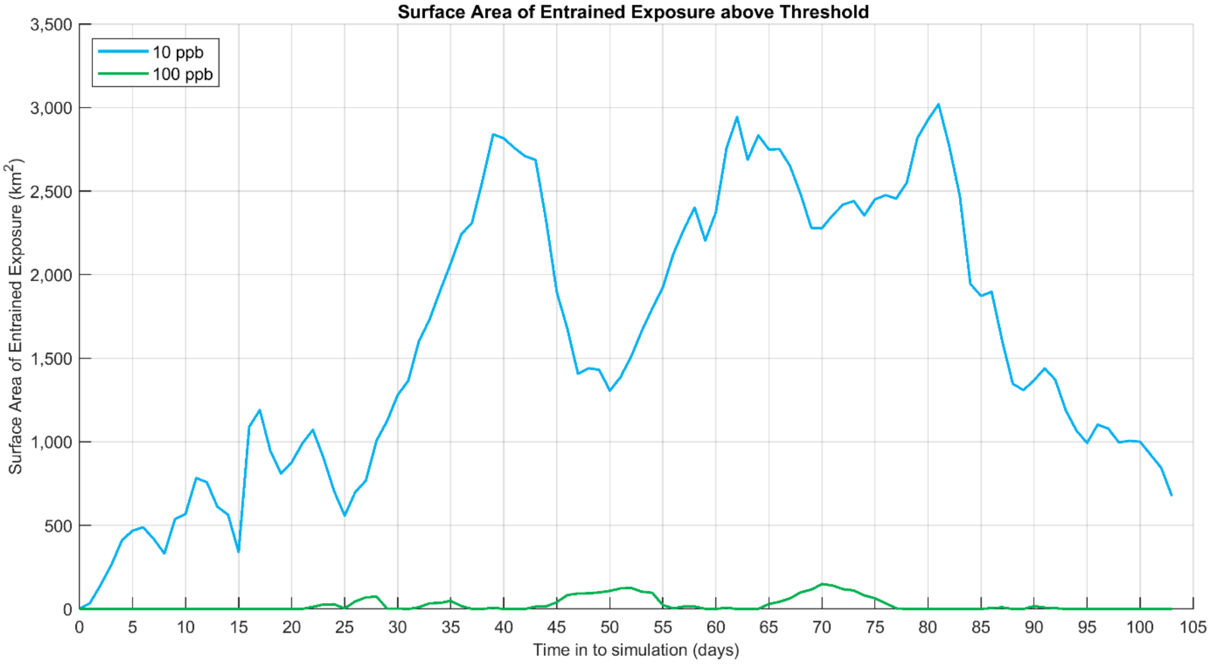


Figure 11.24 Time series of the area of entrained hydrocarbons for each threshold, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Semele Well 5.

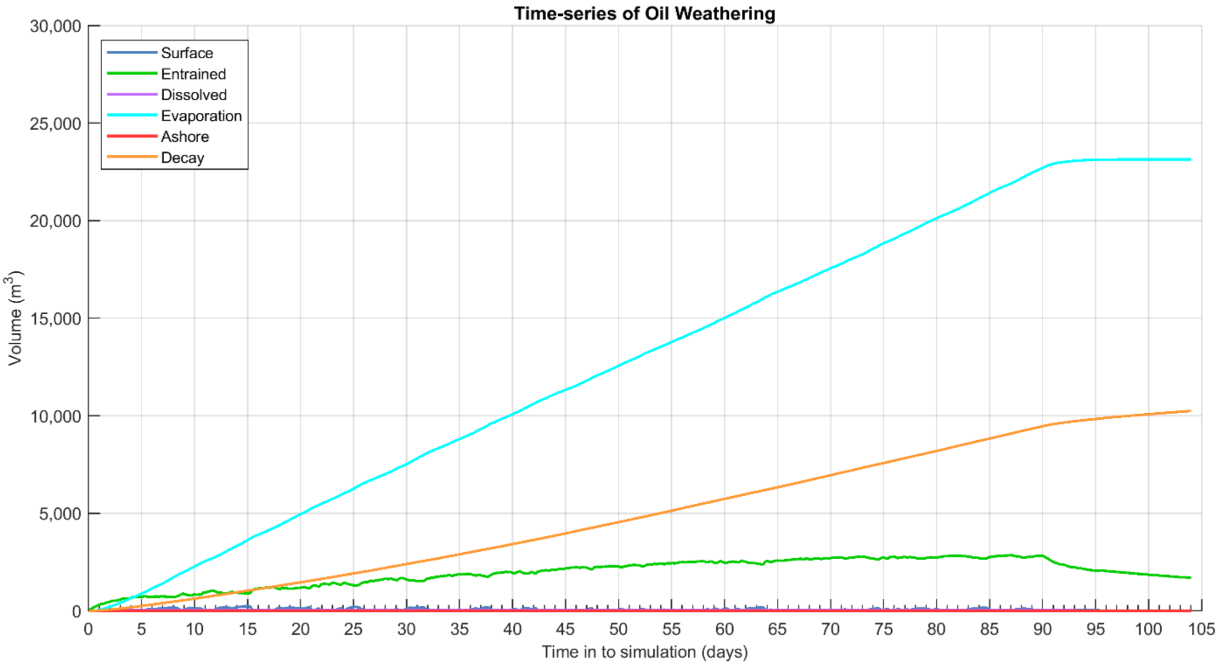


Figure 11.25 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Semele Well 5.

12 REFERENCES

American Society for Testing and Materials (ASTM) 2013, ‘F2067-13 Standard Practice for Development and Use of Oil-Spill Trajectory Models’, ASTM International, West Conshohocken (PA).

Andersen, OB 1995, ‘Global ocean tides from ERS 1 and TOPEX/POSEIDON altimetry’, *Journal of Geophysical Research: Oceans*, vol. 100, no. C12, pp. 25249–25259.

Anderson JW, Neff JM, Cox BA, Tatem HE & Hightower GM 1974, ‘Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish’, *Marine Biology*, vol. 27, no. 1, pp. 75–88.

Anderson JW, Riley R, Kiesser S & Gurtisen J 1987, ‘Toxicity of dispersed and undispersed Prudhoe Bay crude oil fractions to shrimp and fish’, Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 235–240.

Applied Science Associates (ASA) 2011, OILMAP-DEEP: Blowout Plume Model Technical Manual, Applied Science Associates Inc, South Kingstown, USA.

Asia-Pacific ASA 2010, ‘Montara well release monitoring study S7.2. Oil fate and effects assessment: modelling of chemical dispersant operation’, Prepared for PTTEP Australasia.

Australian Maritime Safety Authority (AMSA) 2014, ‘Identification of oil on water: Aerial observations and identification guide’, viewed 4 June 2020, https://www.amsa.gov.au/sites/default/files/2014-01-mp-amsa22-identification-oil-on-water.pdf

Australian Maritime Safety Authority (AMSA) 2015, ‘Australian Maritime Safety Authority Technical Guideline for the Preparation of Marine Pollution Contingency Plans for Marine and Coastal Facilities Australian Maritime Safety Authority’, viewed 20 June 2017, https://www.amsa.gov.au/forms-and-publications/Publications/AMSA413_Contingency_Planning_Guidelines.pdf

Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, ‘Australian and New Zealand Guidelines for Fresh and Marine Water’, Australian & New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Becker, JJ, Sandwell, DT, Smith, WHF, Braud, J, Binder, B, Depner, J, Fabre, D, Factor, J, Ingalls, S, Kim, S-H, Ladner, R, Marks, K, Nelson, S, Pharaoh, A, Trimmer, R, Von Rosenberg, J, Wallace, G & Weatherall, P 2009, ‘Global bathymetry and evaluation data at 30 arc seconds resolution: SRTM30_PLUS’, *Marine Geodesy*, vol. 32, no. 4, pp. 355–371.

Belore, UC 2014, Subsea chemical dispersant research. Proceedings of the 37th AMOP Technical Seminar on Environmental Contamination and Response, Environmental Canada, Canmore, Alberta, Canada pp 618–650.

Blum DJ & Speece RE 1990, ‘Determining chemical toxicity to aquatic species’, *Environmental Science & Technology*, vol. 24, no. 3, pp. 284–293.

Bonn Agreement 2009, ‘Bonn Agreement aerial operations handbook, 2009 - Publication of the Bonn Agreement’, London, viewed 13 January 2015, http://www.bonnagreement.org/site/assets/files/3947/ba-aoh_revision_2_april_2012.pdf.

Brandvik, PJ, Johansen, O, Leirvik, F, Farooq, U & Daling PS 2013, ‘Droplet Breakup in subsurface oil releases – Part 1: Experimental study of droplet breakup and effectiveness of dispersant injection’, *Marine Pollution Bulletin*, vol. 73, no. 1, pp 319–326.

Brandvik, PJ, Johansen, O, Farooq, U, Angell, G & Leirvik F 2014, ‘Sub-surface oil releases – Experimental study of droplet distributions and different dispersant injection techniques- version 2’, A scaled experimental approach using the SINTEF Tower basin. SINTEF report no: A25122. Trondheim Norway 2014. ISBN: 9788214057393

Carls, MG, Holland, L, Larsen, M, Collier, TK, Scholz, NL & Incardona, JP 2008, ‘Fish embryos are damaged by dissolved PAHs, not oil particles’, *Aquatic toxicology*, 88(2), pp.121–127.

Chassignet, EP, Hurlburt, HE, Smedstad, OM, Halliwell, GR, Hogan, PJ, Wallcraft, AJ, Baraille, R & Bleck, R 2007, ‘The HYCOM (hybrid coordinate ocean model) data assimilative system’, *Journal of Marine Systems*, vol. 65, no. 1, pp. 60–83.

Chassignet, E, Hurlburt, H, Metzger, E, Smedstad, O, Cummings, J & Halliwell, G 2009, ‘U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)’, *Oceanography*, vol. 22, no. 2, pp. 64–75.

Condie, SA., & Andrewartha, JR 2008, ‘Circulation and connectivity on the Australian Northwest Shelf’, *Continental Shelf Research*, 28, 1724–1739.

Davies, AM 1977a, ‘The numerical solutions of the three-dimensional hydrodynamic equations using a B-spline representation of the vertical current profile’, in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 1–25.

Davies, AM 1977b, ‘Three-dimensional model with depth-varying eddy viscosity’, in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 27–48.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2007, ‘Characterisation of the marine environment in the north marine region’, Marine Division, Department of the environment, water heritage and the arts.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2008, ‘The North-West Marine Bioregional Plan - Bioregional Profile’, Retrieved February 12, 2013, from Australian Government Department of Environment, Water, Heritage and the Arts: http://www.environment.gov.au/coasts/mbp/publications/north-west/pubs/bioregional-profile.pdf

French, D, Reed, M, Jayko, K., Feng, S, Rines, H & Pavignano, S 1996, ‘The CERCLA Type A Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME), Technical Documentation, Vol. I - Model Description’, Office of Environmental Policy and Compliance, U.S. Department of the Interior. Washington, D.C.: Contract No. 14-0001-91-C-11.

French, D, Schuttenberg, H & Isaji, T 1999, ‘Probabilities of oil exceeding thresholds of concern: examples from an evaluation for Florida Power and Light’, Proceedings of the 22nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Alberta, pp. 243–270.

French-McCay, DP 2002, ‘Development and application of an oil toxicity and exposure model, OilToxEx’, *Environmental Toxicology and Chemistry*, vol. 21, no. 10, pp. 2080–2094.

French-McCay, DP 2003, ‘Development and application of damage assessment modelling: example assessment for the North Cape oil spill’, *Marine Pollution Bulletin*, vol. 47, no. 9, pp. 9–12.

French-McCay, DP 2004, ‘Spill impact modelling: development and validation’, *Environmental Toxicology and Chemistry*, vol. 23, no.10, pp. 2441–2456.

French-McCay, DP 2009, ‘State-of-the-art and research needs for oil spill impact assessment modelling’, Proceedings of the 32nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 601–653.

French-McCay, D, Rowe, JJ, Whittier, N, Sankaranarayanan, S, & Etkin, DS 2004, ‘Estimate of potential impacts and natural resource damages of oil’, *Journal of Hazardous Materials*, vol. 107, no. 1, pp. 11–25.

French-McCay, D, Whittier, N, Dalton, C, Rowe, J, Sankaranarayanan, S & Aurand, D 2005a, 'Modeling the fates of hypothetical oil spills in Delaware, Florida, Texas, California, and Alaska waters, varying response options including use of dispersants', Proceedings of the International Oil Spill Conference 2005, American Petroleum Institute, Washington DC, paper 399.

French-McCay, D, Whittier, N, Rowe, J, Sankaranarayanan, S, Kim, H-S & Aurand, D 2005b, 'Use of probabilistic trajectory and impact modeling to assess consequences of oil spills with various response strategies,' Proceedings of the 28th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 253–271.

French-McCay, D, Reich, D, Rowe, J, Schroeder, M & Graham, E 2011, 'Oil spill modeling input to the offshore environmental cost model (OECM) for US-BOEMRE's spill risk and costs evaluations', Proceedings of the 34th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Reich, D, Michel, J, Etkin, DS, Symons, L, Helton, D, & Wagner J 2012, 'Oil spill consequence analysis of potentially-polluting shipwrecks', Proceedings of the 35th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Jayko, K, Li, Z, Horn, M, Kim, Y, Isaji, T, Crowley, D, Spaulding, M, Decker, L, Turner, C, Zamorski, S, Fontenault, J, Schmmkler, R & Rowe, J 2015, 'Technical Reports for Deepwater Horizon Water Column Injury Assessment: WC_TR.14: Modeling Oil Fate and Exposure Concentrations in the Deepwater Plume and Rising Oil Resulting from the Deepwater Horizon Oil Spill', RPS ASA, South Kingston, Rhode Island.

Gordon, R 1982, 'Wind driven circulation in Narragansett Bay' PhD thesis, Department of Ocean Engineering, University of Rhode Island.

Grant, DL, Clarke, PJ & Allaway, WG 1993, 'The response of grey mangrove (*Avicennia marina* (Forsk.) Vierh) seedlings to spills of crude oil,' *The Journal of Experimental Marine Biological Ecology*, vol. 171, no. 2, pp. 273–295.

Isaji, T & Spaulding, M 1984, 'A model of the tidally induced residual circulation in the Gulf of Maine and Georges Bank', *Journal of Physical Oceanography*, vol. 14, no. 6, pp. 1119–1126.

Isaji, T, Howlett, E, Dalton C, & Anderson, E 2001, 'Stepwise-continuous-variable-rectangular grid hydrodynamics model', Proceedings of the 24th Arctic and Marine Oil spill Program (AMOP) Technical Seminar (including 18th TSOCS and 3rd PHYTO), Environment Canada, Edmonton, pp. 597–610.

Koops, W, Jak, RG & van der Veen, DPC 2004, 'Use of dispersants in oil spill response to minimise environmental damage to birds and aquatic organisms', Proceedings of the Interspill 2004: Conference and Exhibition on Oil Spill Technology, Trondheim, presentation 429.

Kostianoy, AG, Ginzburg, AI, Lebedev, SA, Frankignoulle, M & Delille, B 2003, 'Fronts and mesoscale variability in the southern Indian Ocean as inferred from the TOPEX/POSEIDON and ERS-2 Altimetry data', *Oceanology*, vol. 43, no. 5, pp. 632–642.

Li, Z, Spaulding, M, French-McCay, D, Crowley, D & Payne JR 2017, 'Development of a unified oil droplet size distribution model with application to surface breaking waves and subsea blowout releases considering dispersant effects', *Marine Pollution Bulletin*, vol. 114, no. 1, pp 247–257.

Lin, Q & Mendelssohn, IA 1996, 'A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish and Salt Marshes', *Marine Pollution Bulletin*, vol. 32, no. 2, pp. 202–209.

Ludicone, D, Santoleri, R, Marullo, S & Gerosa, P 1998, 'Sea level variability and surface eddy statistics in the Mediterranean Sea from TOPEX/POSEIDON data', *Journal of Geophysical Research I*, vol. 103, no. C2, pp. 2995–3011.

Mackay D, Puig H & McCarty LS 1992, ‘An equation describing the time course and variability in uptake and toxicity of narcotic chemicals to fish’, *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, p.941–951.

Malins DC & Hodgins HO 1981, ‘Petroleum and marine fishes: a review of uptake, disposition, and effects’, *Environmental Science & Technology*, vol. 15, no. 11, pp.1272–1280.

Matsumoto, K, Takanezawa, T & Ooe, M 2000, ‘Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan’, *Journal of Oceanography*, vol. 56, no.5, pp. 567–581.

McAuliffe CD 1987, ‘Organism exposure to volatile/soluble hydrocarbons from crude oil spills – a field and laboratory comparison’, Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 275–288.

McCarty LS 1986, ‘The relationship between aquatic toxicity QSARs and bioconcentration for some organic chemicals’, *Environmental Toxicology and Chemistry*, vol. 5, no. 12, pp. 1071–1080.

McCarty LS & Mackay D 1993, ‘Enhancing ecotoxicological modelling and assessment. Body residues and modes of toxic action’, *Environmental Science & Technology*, vol. 27, no. 9, pp. 1718–1728.

McCarty LS, Dixon DG, MacKay D, Smith AD & Ozburn GW 1992a, ‘Residue-based interpretation of toxicity and bioconcentration QSARs from aquatic bioassays: Neutral narcotic organics’, *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, pp.917–930.

McCarty LP, Flannagan DC, Randall SA & Johnson KA 1992b, ‘Acute toxicity in rats of chlorinated hydrocarbons given via the intratracheal route’, *Human & Experimental Toxicology*, vol. 11, no. 3, pp.173–117.

McGrath JA, & Di Toro DM 2009, ‘Validation of the target lipid model for toxicity assessment of residual petroleum constituents: monocyclic and polycyclic aromatic hydrocarbons’, *Environmental Toxicology and Chemistry*, vol. 28, no. 6, pp. 1130–1148.

National Oceanic and Atmospheric Administration (NOAA) 2013, ‘Screening level risk assessment package Gulf state’, Office of National Marine Sanctuaries & Office of Response and Restoration, Washington DC.

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2018, ‘At a glance: Oil spill modelling’, viewed 15 November 2018, https://www.nopsema.gov.au/assets/Publications/A626200.pdf

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2019, ‘NOPSEMA Bulletin #1: Oil spill modelling’, viewed April 2019, https://www.nopsema.gov.au/assets/Bulletins/A652993.pdf

National Research Council (NRC) 2003, ‘Oil in the sea III: Inputs, fates and effects’, The National Academic Press, Washington D.C.

Neff JM, Anderson JW 1981, ‘Response of marine animals to petroleum and specific petroleum hydrocarbons’ United States Department of Energy, United States.

Nirmalakhandan N & Speece RE 1998, ‘Quantitative techniques for predicting the behaviour of chemicals in the ecosystem’, *Environmental Science & Technology*, vol. 22, no. 6, pp. 606–615.

Nordtug, T, Olsen, AJ, Altin, D, Overrein, I, Storøy, W, Hansen, BH & De Laender, F 2011, ‘Oil droplets do not affect assimilation and survival probability of first feeding larvae of North-East Arctic cod’, *Science of the Total Environment*, 412, pp.148–153.

Oil Spill Solutions 2015, ‘Evaluation - The Theory of Oil Slick Appearances’, viewed 6 January 2015, http://www.oilspillsolutions.org/evaluation.htm

Owen, A 1980, ‘A three-dimensional model of the Bristol Channel’, *Journal of Physical Oceanography*, vol. 10, no. 8, pp. 1290–1302.

Qiu, B & Chen, S 2010, ‘Eddy-mean flow interaction in the decadally modulating Kuroshio Extension system’, *Deep-Sea Research II*, vol. 57, no. 13, pp. 1098–1110.

Redman AD 2015, ‘Role of entrained droplet oil on the bioavailability of petroleum substances in aqueous exposures’, *Marine Pollution Bulletin*, vol. 97, no. (1–2), pp. 342–348.

Saha, S, Moorthi, S, Pan, H-L, Wu, X, Wang, J & Nadiga, S 2010, ‘The NCEP Climate Forecast System Reanalysis’, *Bulletin of the American Meteorological Society*, vol. 91, no. 8, pp. 1015–1057.

Scholten, MCTh, Kaag, NHBM, Dokkum, HP van, Jak, R.G., Schobben, HPM & Slob, W 1996, Toxische effecten van olie in het aquatische milieu, TNO report TNO-MEP – R96/230, Den Helder.

Spaulding, ML., Kolluru, VS, Anderson, E & Howlett, E 1994, ‘Application of three-dimensional oil spill model (WOSM/OILMAP) to hindcast the Braer Spill’, *Spill Science and Technology Bulletin*, vol. 1, no. 1, pp. 23–35.

Spaulding, MS, Mendelsohn, D, Crowley, D, Li, Z, and Bird A, 2015. Technical Reports for Deepwater Horizon Water Column Injury Assessment- WC_TR.13: Application of OILMAP DEEP to the Deepwater Horizon Blowout. RPS APASA, 55 Village Square Drive, South Kingstown, RE 02879.

Suprayogi, B & Murray, F 1999, ‘A field experiment of the physical and chemical effects of two oils on mangroves’, *Environmental and Experimental Botany*, vol. 42, no. 3, pp. 221–229.

Swartz RC, Schults DW, Ozretich RJ, Lamberson JO, Cole FA, Ferraro SP, Dewitt TH & Redmond MS 1995, ‘ΣPAH: A Model to predict the toxicity of polynuclear aromatic hydrocarbon mixtures in field-collected sediments’, *Environmental Toxicology and Chemistry*, vol. 14, no. 11, pp. 1977–1187.

Verhaar HJM, Van Leeuwen CJ & Hermens JLM 1992, ‘Classifying environmental pollutants’, *Chemosphere*, vol. 24, no. 4, pp. 471–491.

Verhaar HJM, de Jongh J & Hermens JLM 1999, ‘Modelling the bioconcentration of organic compounds by fish: A novel approach’, *Environmental Science & Technology*, vol. 33, no. 22, pp. 4069–4072.

Willmott, CJ 1981, ‘On the validation of models’, *Physical Geography*, vol. 2, no. 2, pp.184–194.

Willmott, CJ 1982, ‘Some comments on the evaluation of model performance’, *Bulletin of the American Meteorological Society*, vol. 63, no. 11, pp.1309–1313.

Willmott CJ, Ackleson SG, Davis RE, Feddema JJ, Klink, KM, Legates, DR, O’Donnell, J & Rowe, CM 1985, ‘Statistics for the evaluation of model performance’, *Journal of Geophysical Research*, vol. I 90, no. C5, pp. 8995–9005.

Willmott, CJ & Matsuura, K 2005, ‘Advantages of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance’, *Journal of Climate Research*, vol. 30, no. 1, pp. 79–82.

Yaremchuk, M & Tangdong, Q 2004, ‘Seasonal variability of the large-scale currents near the coast of the Philippines’, *Journal of Physical Oceanography*, vol. 34, no., 4, pp. 844–855.

Zigic, S, Zapata, M, Isaji, T, King, B, & Lemckert, C 2003, ‘Modelling of Moreton Bay using an ocean/coastal circulation model’, Proceedings of the 16th Australasian Coastal and Ocean Engineering Conference, the 9th Australasian Port and Harbour Conference and the Annual New Zealand Coastal Society Conference, Institution of Engineers Australia, Auckland, paper 170.

GREATER GORGON – CHANDON

Oil Spill Modelling

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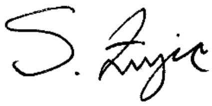
Dr. Sasha Zigic		5 July 2023

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Prepared by:

RPS

Jeremie Bernard
Senior Coastal Engineer

Lakeside Corporate Space, Suite 425
Level 2, 34-38 Glenferrie Drive
Robina, QLD, 4226, Australia

T +61 7 5553 6900
E Jeremie.Bernard@rpsgroup.com

Prepared for:

CHEVRON AUSTRALIA PTY LTD

Mike Daly
HSE Specialist - Environment

Level 13, 250 St Georges Tce
Perth WA 6000 Australia

T +61 418 488 728
E mike.daly@chevron.com

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TERMS AND ABBREVIATIONS

°	Degrees
‘	Minutes
“	Seconds
µm	Micrometre (unit of length; 1 µm = 0.001 mm)
Actionable oil	Oil which is thick enough for the effective use of mitigation strategies
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute gravity. A measure of how heavy or light a petroleum liquid is compared to water.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASTM	American Society for Testing and Materials
bbl	Barrel (unit of volume; 1 bbl = 0.159 m3)
bbl/d	Barrels per day
Bonn Agreement	An agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983, includes: Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union.
BP	Boiling point. The temperature at which the vapor pressure of the liquid is equal to the pressure exerted on it by the surrounding atmosphere
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
cP	Centipoise (unit of dynamic viscosity)
Decay	The process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions.
Dynamic viscosity	The dynamic viscosity of a fluid expresses its resistance to shearing flows, where adjacent layers move parallel to each other with different speeds.
Floating condensate exposure	Contact by floating oil on the sea surface at concentrations equal to or exceeding defined threshold concentrations. The consequence will vary depending on the threshold and the receptors
g/m^2	Grams per square meter (unit of surface area density)
GODAE	Global Ocean Data Assimilation Experiment
HYCOM	Hybrid Coordinate Ocean Model. A data-assimilative, three-dimensional ocean model
HYDROMAP	Advanced ocean/coastal tidal model used to predict tidal water levels, current speed and current direction.

IAA	Impact Assessment Area
IBRA	Interim Biogeographic Regionalisation for Australia
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
ITOPF	International Tanker Owners Pollution Federation Limited
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
LOWC	Loss of well control
m	Meter (unit of length)
m^3	Cubic meter (unit of volume)
m/s	Meter per Second (unit of speed)
MAHs	Monoaromatic Hydrocarbons
MNP	Marine National Park
MP	Marine Park
NASA	National Aeronautics and Space Administration (USA)
NCEP	National Centres for Environmental Prediction (USA)
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration (USA)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NP	National Park
NR	Nature Reserve
PAH	Polynuclear Aromatic Hydrocarbons
Pour Point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics
ppb	Parts per billion (concentration)
psu	Practical salinity nits
RSB	Reefs, Shoals and Banks
scf	Standard cubic feet (defined as one cubic foot of gas at 15.56 °C and at normal sea level air pressure)
Shoreline contact	Arrival of oil at or near shorelines at on-water concentrations equal to or exceeding defined threshold concentrations. Shoreline contact is judged for floating oil arriving within a 2 km buffer zone from any shoreline as a conservative measure
SIMAP	Spill Impact Model Application Package. SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for surface or subsea releases
Single Oil spill modelling	Oil spill modelling involving a computer simulation of a single hypothetical oil spill event subject to a single sequence of wind, current and other sea conditions over time. Single oil spill modelling, also referred to as “deterministic modelling” provides a simulation of one possible outcome of a given spill scenario, subject to the metocean conditions that are imposed. Single oil spill modelling is commonly used to consider the fate and effects of ‘worst-case’ oil spill scenarios that are carefully selected in consideration of the nature and scale of the offshore petroleum activity and the local environment (NOPSEMA, 2017). Because the outcomes of a single oil spill simulation can only represent the outcome of that scenario under one sequence of metocean conditions, worst-case conditions are often identified from stochastic modelling. It is impossible to calculate the likelihood of any outcome from a

	single oil spill simulation. Single oil spill modelling is generally used for response planning, preparedness planning and for supporting oil spill response operations in the event of an actual spill
SRTM	Shuttle Radar Topography Mission
Stochastic oil spill modelling	Stochastic oil spill modelling is created by overlaying and statistically analysing the outcomes of many single oil-spill simulations of a defined spill scenario, where each simulation was subject to a different sequence of metocean conditions, selected objectively (typically by random selection) from a long sequence of historic conditions for the study area. Analysis of this larger set of simulations provides a more accurate indication of the environment that maybe affected (EMBA) and indicates which locations are more likely to be affected (as well as other statistics). Stochastic oil spill modelling avoids biases that affect single oil spill modelling (due to the reliance on only one possible sequence of conditions). However, when interpreting stochastic modelling, which is based on a wide range of potential conditions that might happen to occur, it is essential to understand that calculations will encompass a much larger area than could be affected in any single spill event, where a more limited set of conditions will occur. Consequently, it is misleading to imply that the region derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2017) Stochastic modelling is generally used for risk assessment and preparedness planning by indicating locations that could be exposed and may require response or subsequent impact assessment
TOPEX/ Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USA	United States of America
US CG	United States Coast Guard
US EPA	United States Environmental Protection Agency
World Ocean Atlas	A collection of objectively analysed quality controlled physicochemical parameters (e.g. temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)
WGS 1984	World Geodetic System 1984 (WGS84); reference coordinate system

EXECUTIVE SUMMARY

Background

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Chandon field situated within the Northern Carnarvon Basin in Permit area WA-53-R, northwest of Barrow Island off the north-west coast of Western Australia.

Chevron commissioned RPS to undertake an oil spill modelling to support environmental approvals. The study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 5,214 stb/day (829 m^3/day) subsea release of condensate over 90 days (totalling 469,260 stb or 74,604 m^3) from a loss of well control (LOWC).

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

Methodology

The modelling study was carried out in stages. Firstly, a ten-year current dataset (2010–2019) that includes the combined influence of large-scale ocean and nearshore tidal currents was developed. Secondly, the currents, local winds and detailed hydrocarbon characteristics were used as inputs in the three-dimensional oil spill model (SIMAP) to simulate the drift, spread, weathering and fate of the spilled oil.

As spills can occur during any set of wind and current conditions, modelling was conducted using a stochastic (or probabilistic) approach, which involved running 100 spill simulations per season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but randomly selected start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Condensate Properties

Chandon condensate physical properties and boiling point distributions were provided by Chevron. The condensate has an API of 47.80, a density of 789 kg/m^3 (at 15ºC) and a viscosity value of 2.6 cP at 15 ºC. When exposed to the atmosphere at local temperatures, about 45.9% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 26.3% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (22.4%) should evaporate over a longer period (265°C < BP < 380°C). The remaining 5.4% of the condensate would persist in the marine environment for much longer periods and be subject to relatively slow degradation. The process of evaporation will be greater than under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity to take up water to form water-in-oil emulsion. For this condensate, the aromatic hydrocarbons contribute 2.5% and are all contained in the volatile fractions, which are highly soluble.

Key Findings

- The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 102.9 km south (transitional) and 5.2 km west (transitional and winter), respectively. No exposure was predicted at the high (≥ 50 g/m^2) threshold.

- Other than the receptors that the release location resides within (Offshore Area Impact Assessment Area (IAA), Pygmy Blue Whale – Distribution Biologically Important Area (BIA) and Exmouth Plateau Key Ecological Feature (KEF)), the Wedge-tailed Shearwater – Breeding BIA was the only other receptor to exposed above the low threshold, but only for the transitional season and a 1% probability.

- No shoreline accumulation at or above the low (≥ 10 g/m^2) shoreline contact threshold was recorded for any of the spill simulations.

- There was no exposure to any other receptors by dissolved hydrocarbons in the 0-10 m depth layer, other than those that the release location resides within, being Offshore Area IAA and Pygmy Blue Whale – Distribution BIA.

- In the 0-10 m depth layer, a total of 16 BIAs were shown to be exposed to entrained hydrocarbons at, or above, the low threshold (≥10 ppb) during all 3 seasons. Across the three seasons, 5 Australian Marine Parks (AMPs) were predicted to be exposed at, or above the low threshold, with the highest probabilities predicted at the Gascoyne AMP (63% summer, 65% transitional and 68% winter). Furthermore, during summer conditions the Gascoyne AMP was shown to be exposed to entrained hydrocarbons at the high threshold above 100 ppb (5%). Additionally, 5 KEFs were shown to be exposed to entrained hydrocarbons at or above the low threshold. Furthermore, the Rankin Bank was shown to be exposed to entrained hydrocarbons at the low threshold only during the summer season.

1 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) is the operator of the Greater Gorgon area, which includes the Chandon field situated within the Northern Carnarvon Basin in Permit area WA-53-R, northwest of Barrow Island off the north-west coast of Western Australia.

As part of the planned development for the Chandon field, Chevron commissioned RPS to undertake a comprehensive oil spill modelling study to support environmental approvals. The modelling study assessed the seasonal risk and potential exposure to the surrounding waters and contact to the shorelines from the following hypothetical scenario:

- **Scenario:** A 5,214 stb/day (829 m^3/day) subsea release of condensate over 90 days (totalling 469,260 stb or 74,604 m^3) from a loss of well control (LOWC).

The release location used for the oil spill assessment is presented in Table 1.1 and illustrated in Figure 1.1.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (September to the following March), (ii) the transitional periods (April and August) and (iii) winter (May to July). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

One of the purposes for the modelling is to define the 'outer boundaries' of the environment that may be affected (EMBA) in the unlikely event of hydrocarbon release. Therefore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis Program (SIMAP). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been peer reviewed and published in international journals. Further, RPS warrants that this work meets and exceeds the American Society for Testing and Materials (ASTM) Standard F2067-13 "*Standard Practice for Development and Use of Oil Spill Models*".

Table 1.1 Coordinates of the Chandon release location.

Location	Latitude	Longitude	Depth (mLAT)
Chandon Well 1	19.56712° S	114.12603° E	1,100

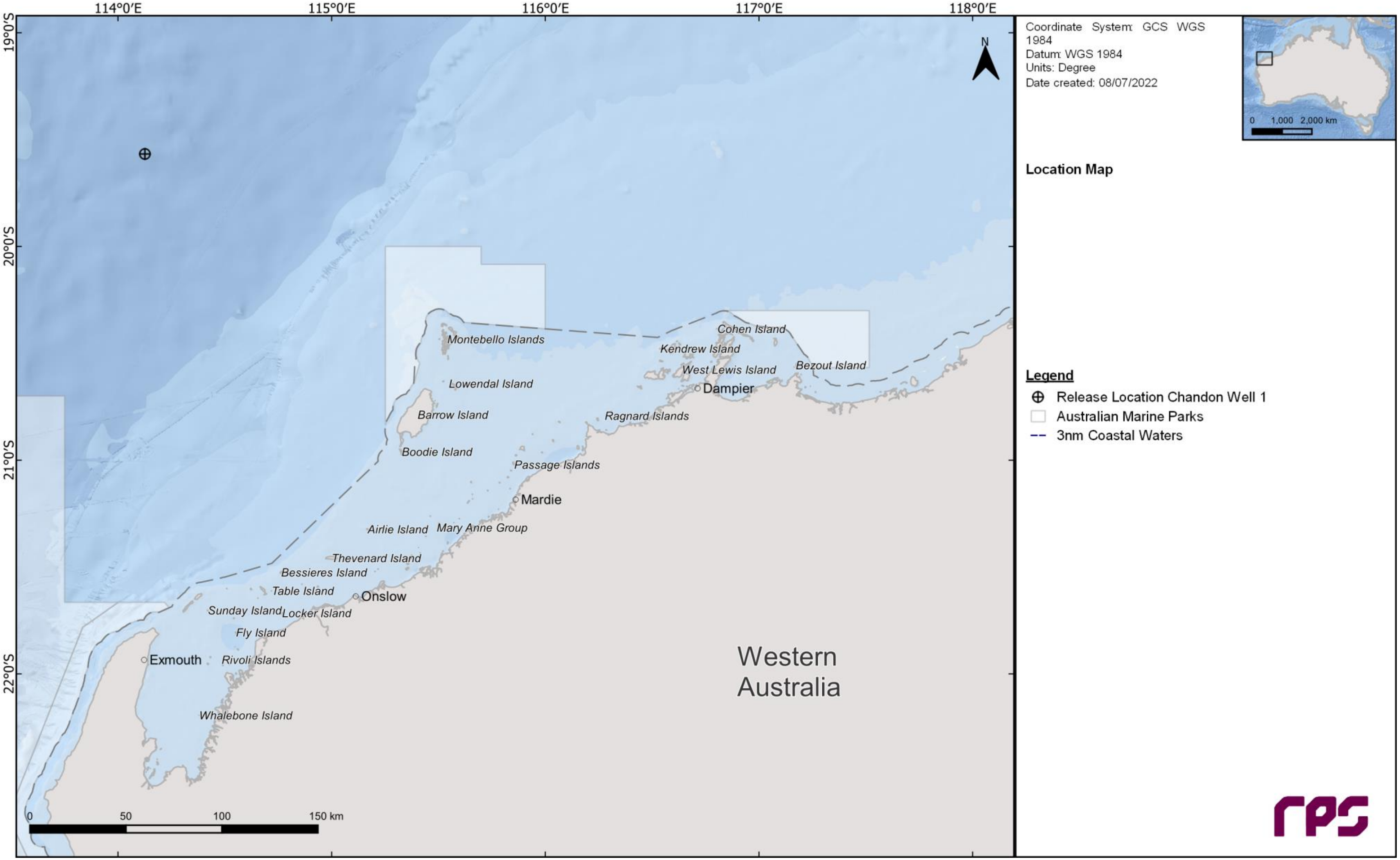


Figure 1.1 Chandon hydrocarbon spill modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate ten years (2010 to 2019 (inclusive)) of wind and current data. The three-dimensional current data includes the combined influence of ocean and tidal currents;

2. Include the wind data, current data and condensate properties characteristics into the three-dimensional oil spill model; SIMAP, to model the movement, spreading, entrainment, weathering and potential shoreline accumulation over time;

3. Run 100 simulations for each season (i.e. 300 simulations total), with each simulation having the same spill information (location, volume, duration and condensate properties) but randomly varying start times. This ensured that each spill simulation was subjected to unique wind and current conditions;

4. Combine the results from the 100 spill simulations to assess the exposure to waters and shoreline accumulation based upon the NOPSEMA thresholds; and

5. From the 300 simulations modelled, identify and present the “worst case” deterministic runs, which can be used to inform response planning based on the following criteria:
   a. Largest swept area of floating hydrocarbon above 10 g/m^2
   b. Largest swept area of floating hydrocarbon above 50 g/m^2
   c. Largest volume of oil ashore
   d. Longest length of shoreline accumulation above 100 g/m^2
   e. Largest area of entrained hydrocarbons above 100 ppb
   f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no floating hydrocarbons at or above 50 g/m^2, no dissolved hydrocarbon exposure at or above 50 ppb, and no shoreline accumulation at or above any threshold, for any of the 300 simulations, the deterministic results are presented based on criteria a, and e only.

3 REGIONAL CURRENTS

The study area is located within the Northern Carnarvon Basin, on the North West Shelf, a waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the North West Shelf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 3.1.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3.2 and Figure 3.3 present summer and winter current trends within the Carnarvon Basin and the North West Shelf.

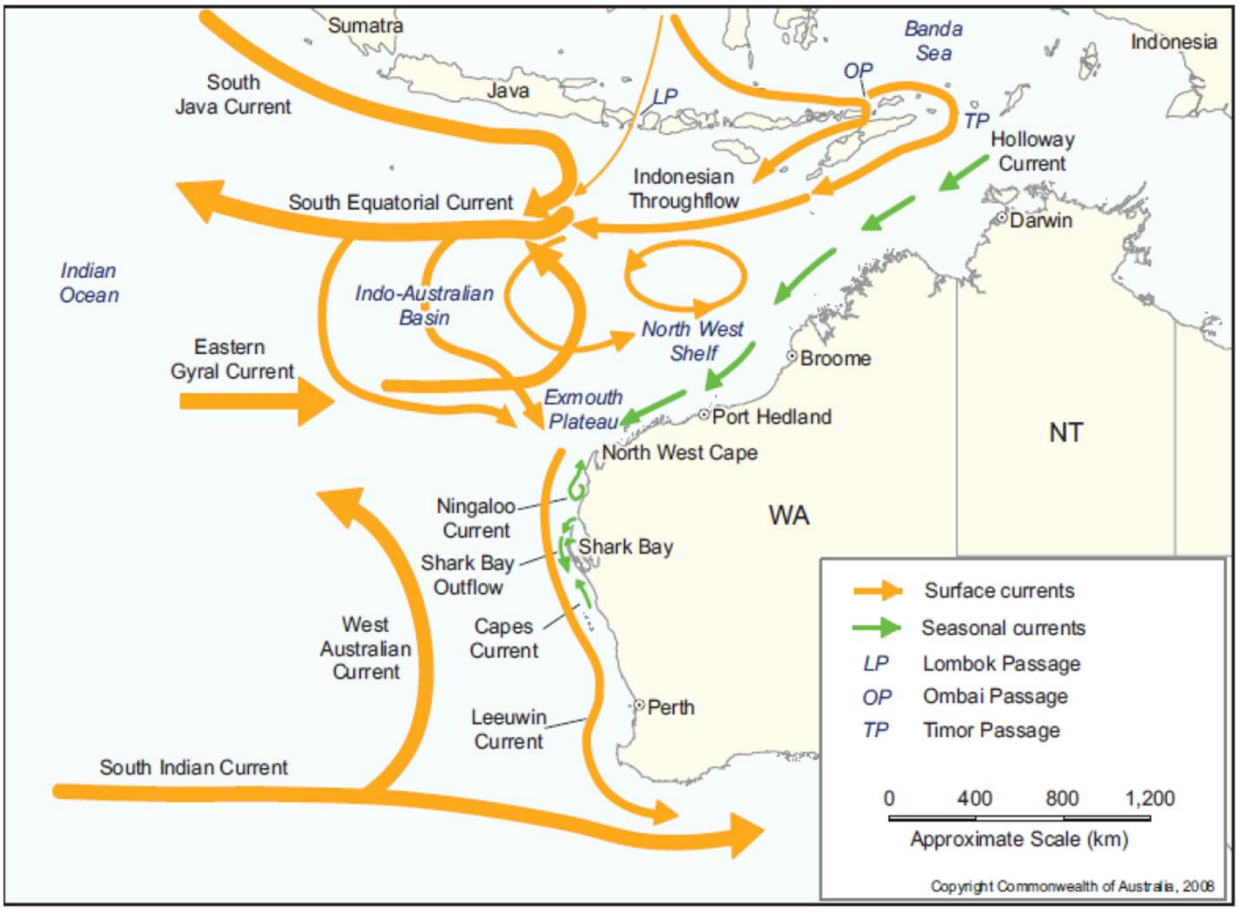


Figure 3.1 Schematic of ocean currents along the northwest Australian continental shelf. Image adapted from DEWHA (2008).

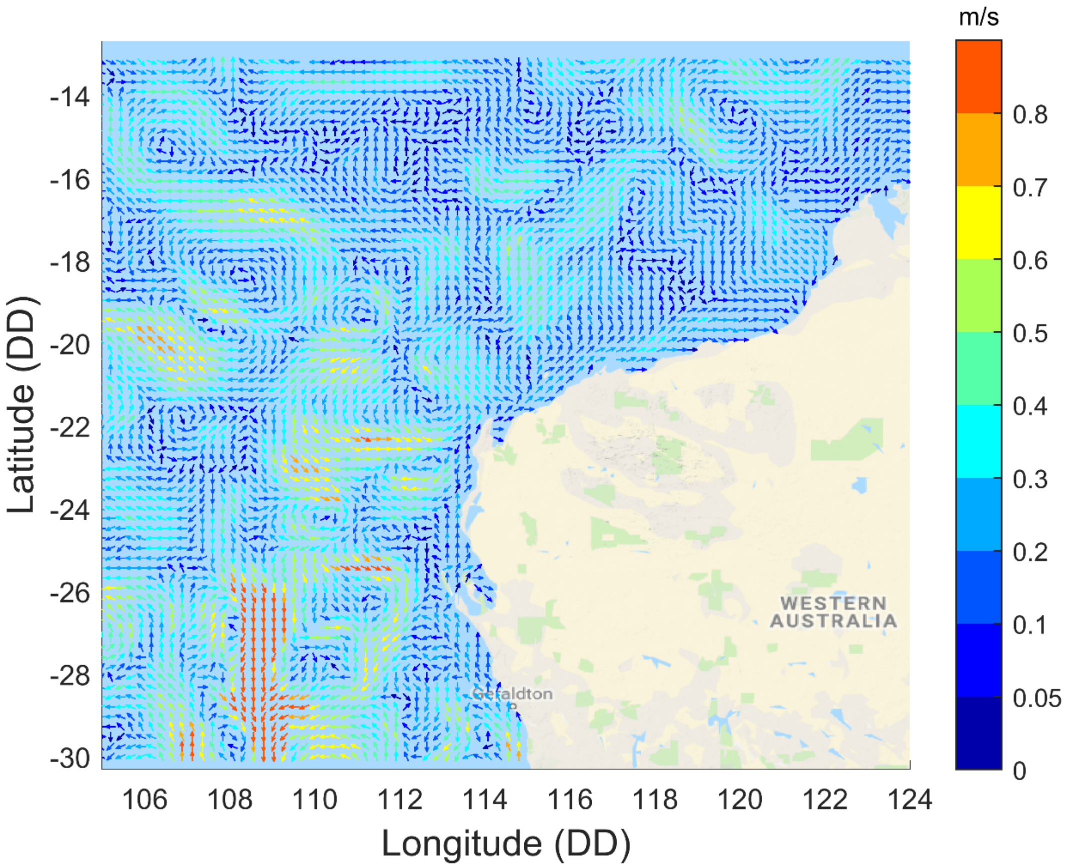


Figure 3.2 Typical ocean current circulation pattern during the summer months.

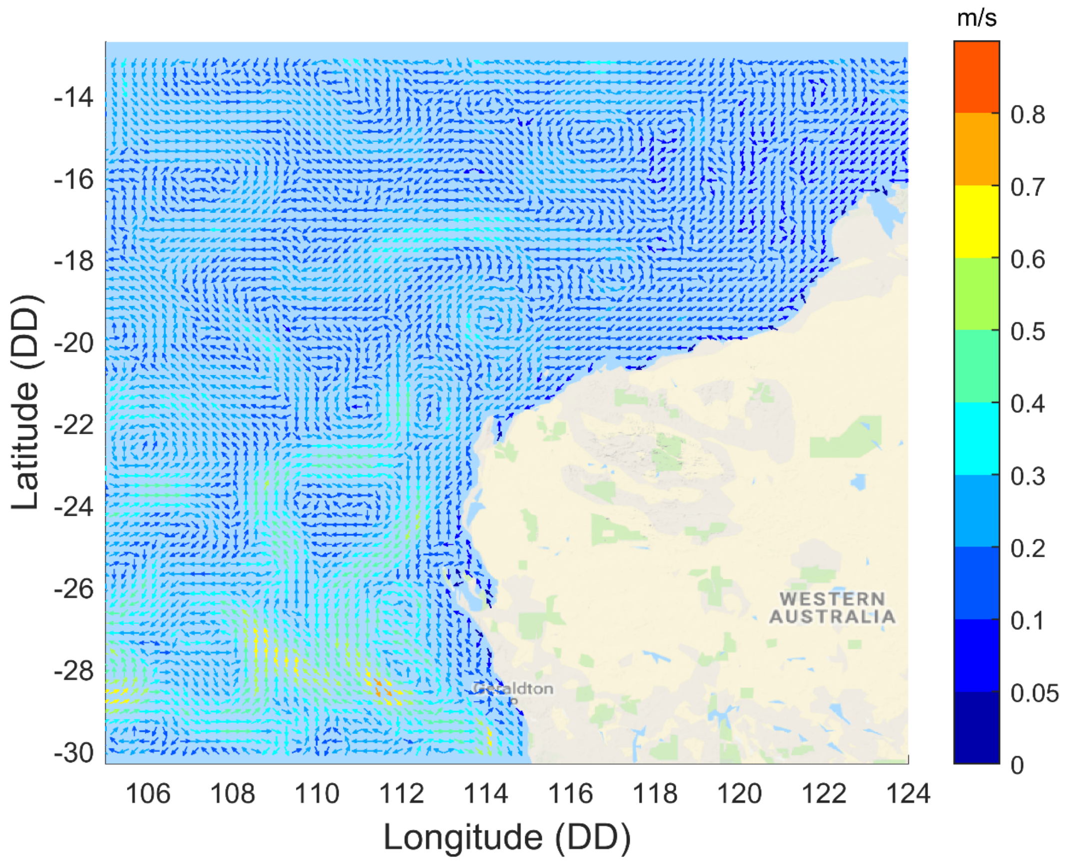


Figure 3.3 Typical ocean current circulation pattern during the winter months.

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 38 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

The tidal model domain has been sub-gridded to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grids were allocated in a step-wise fashion to resolve flows more accurately along the coastline, around islands and over regions with more complex bathymetry. Figure 3.4 shows the tidal model grid resolutions.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 3.5). These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

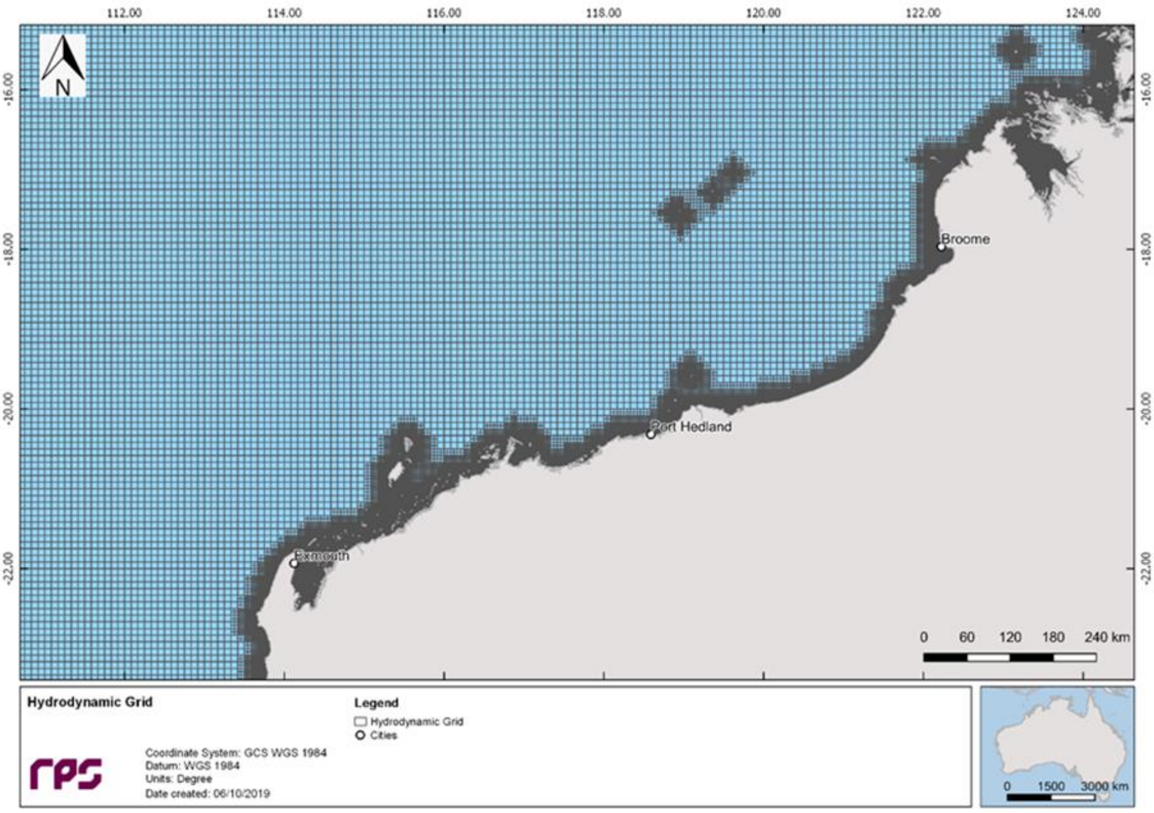


Figure 3.4 Zoomed in view of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

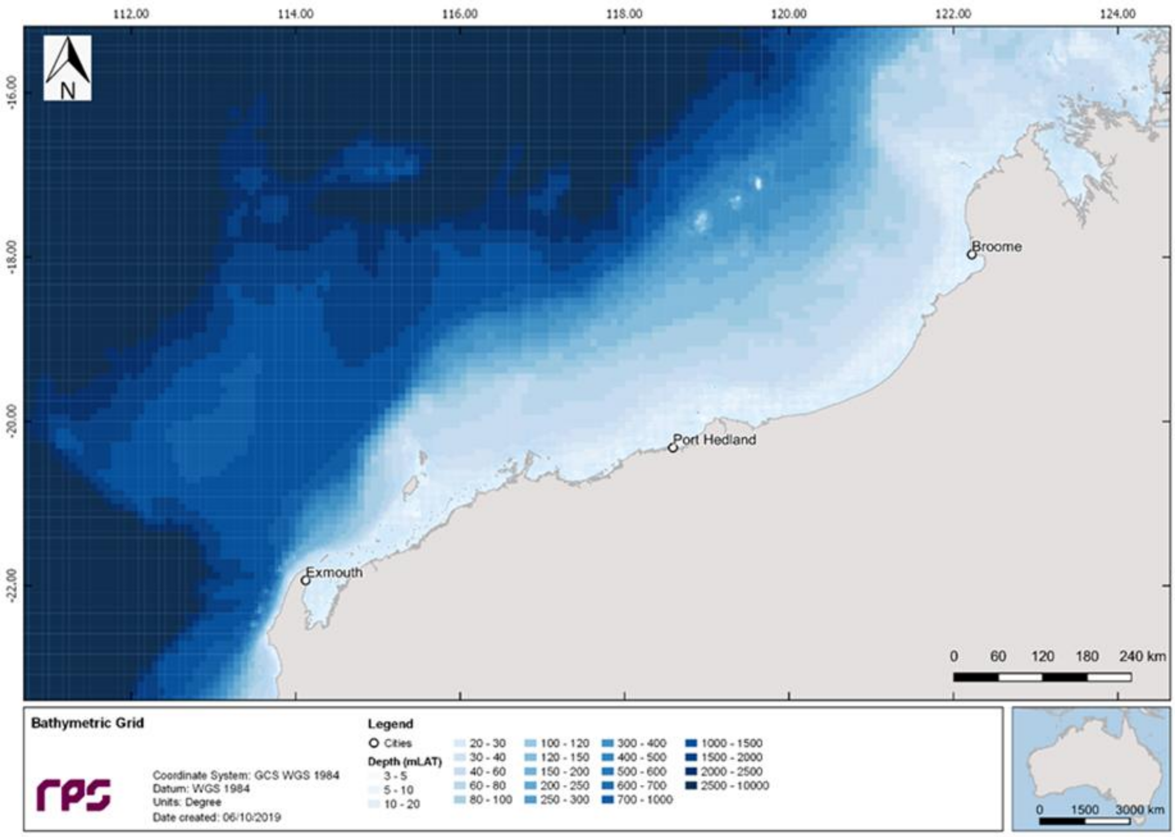


Figure 3.5 Bathymetry defined throughout the tidal model domain.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

For this study, the HYCOM hindcast currents were obtained for the years 2010 to 2019 (inclusive).

3.3 Surface Currents

Table 3.1 presents the predicted average and maximum monthly surface current speeds at the release location.

The month average surface current speeds ranged between 0.16 m/s (November) and 0.23 m/s (February). Additionally, the maximums ranged between 0.55 m/s (November) and 1.36 m/s (January). The general current directions were quite variable throughout the year. Figure 3.6 and Figure 3.7 present the monthly and total current rose distributions, respectively.

Note the convention for defining current direction throughout this report is the direction the current flows towards. Each branch of the current rose distribution represents the currents flowing to that direction, with north to the top of the diagram. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment within a branch is proportional to the frequency of currents flowing within the corresponding speed and direction.

Table 3.1 Predicted monthly average and maximum surface current speeds close to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2010-2019 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.22	1.36	Northeast
	February	0.23	0.97	Variable
	March	0.18	0.57	Westerly
Transitional	April	0.21	1.15	Westerly
Winter	May	0.22	0.90	Westerly
	June	0.21	0.60	Northwest
	July	0.20	0.90	Westerly
Transitional	August	0.17	0.59	North
Summer	September	0.19	0.93	Variable
	October	0.20	0.74	Northwest
	November	0.16	0.55	Variable
	December	0.21	0.73	North
Minimum		**0.16**	**0.55**	
Maximum		**0.23**	**1.36**	

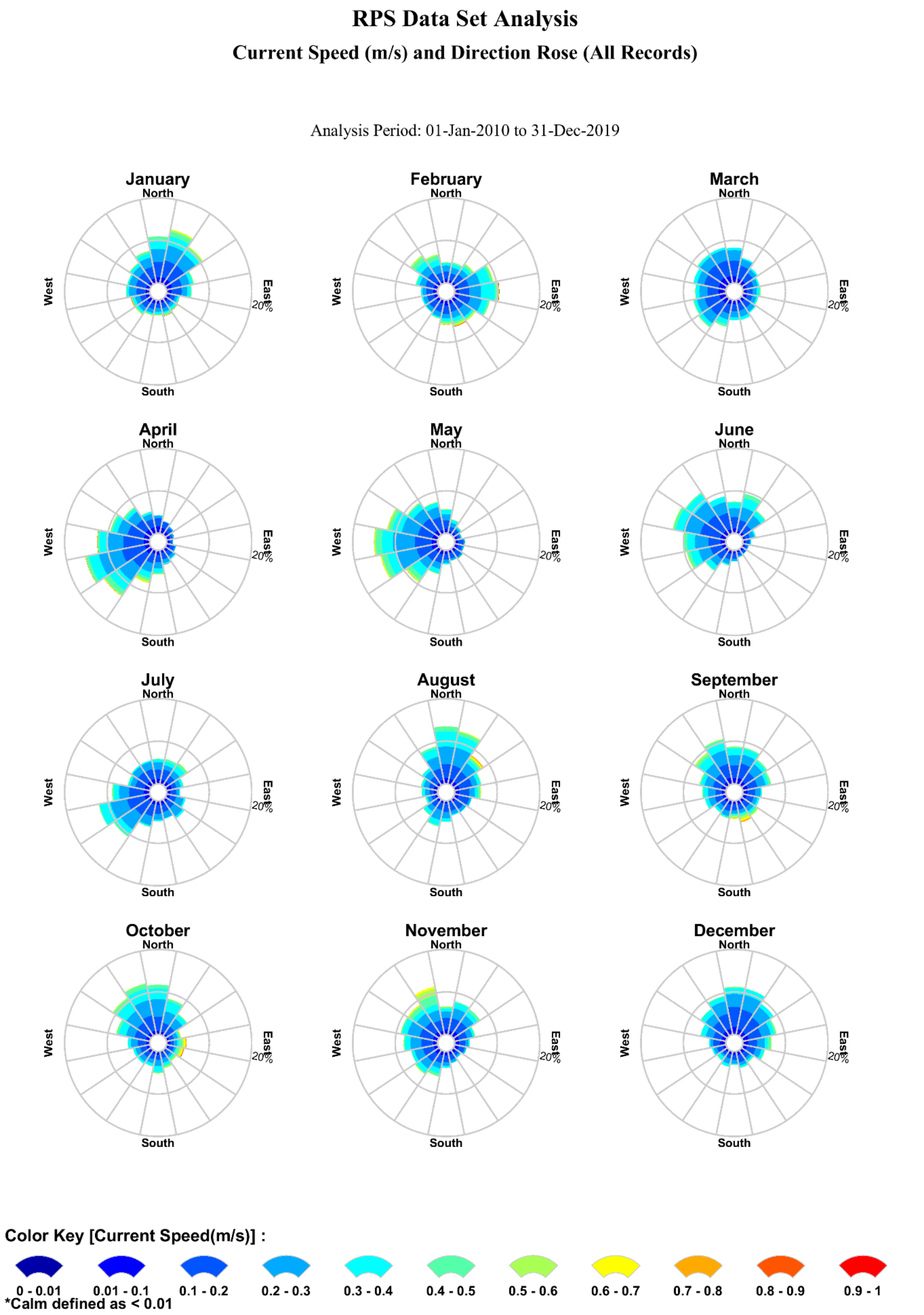


Figure 3.6 Monthly surface current rose distributions at the release location, derived from the 2010 to 2019 modelled dataset.

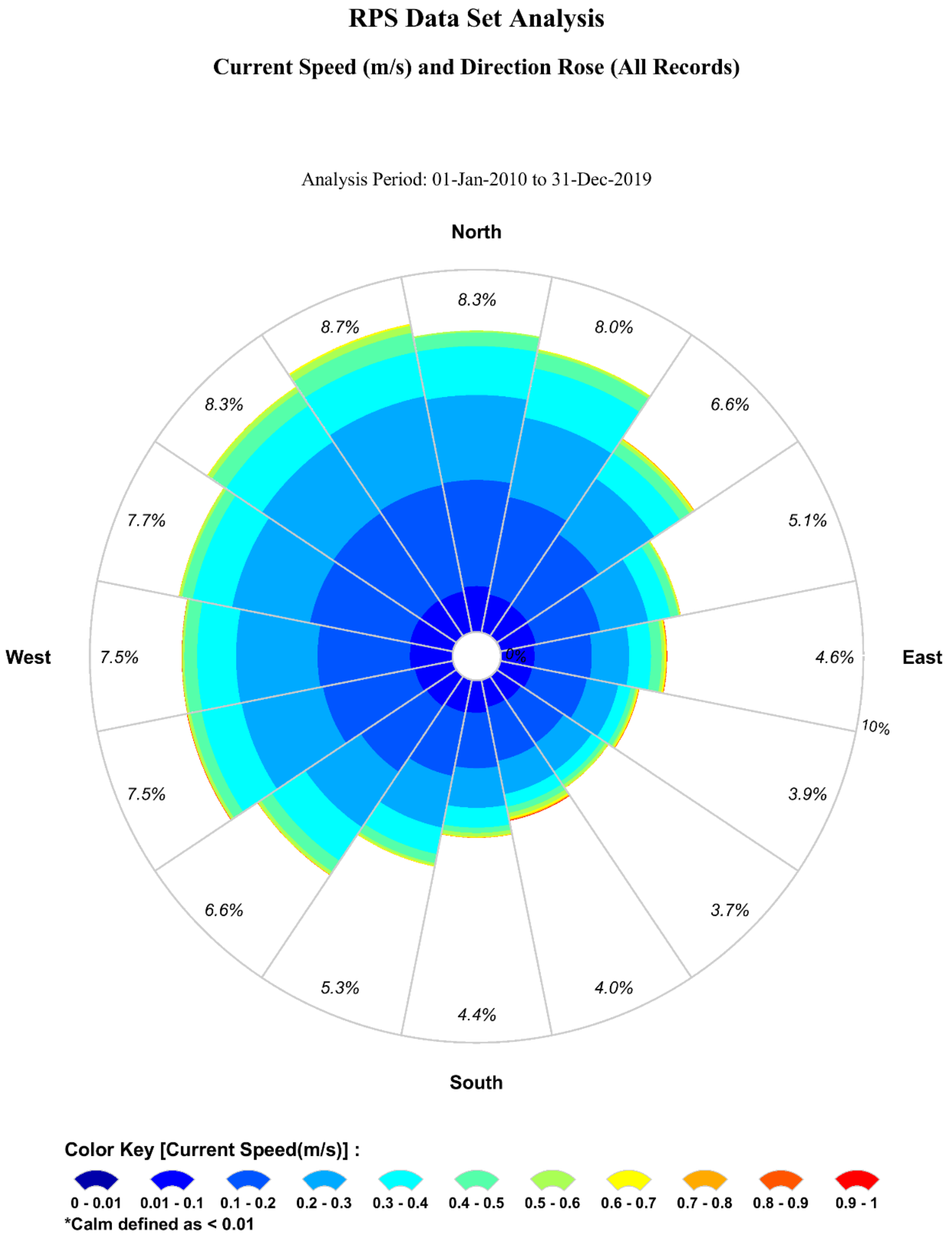


Figure 3.7 Total surface current rose plot at the release location, derived from the 2010 to 2019 modelled dataset.

4 WIND DATA

To account for the influence of the wind on the floating oil, wind data from 2010 to 2019 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 4.1 shows the spatial resolution of the wind field used as input into the oil spill model.

Table 4.1 shows the monthly average and maximum winds derived from the CFSR node closest to the release location. The model wind data demonstrated that this region typically experiences moderate winds all year round and although the monthly average wind speeds remain under 15 knots. The maximum wind speed was 45 knots (July). Winds typically blow from the southwest during the summer months, while winds are typically easterly during the winter months.

Figure 4.2 and Figure 4.3 illustrates the monthly and total wind rose distributions nearby the release location, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 5 knot intervals are typically used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

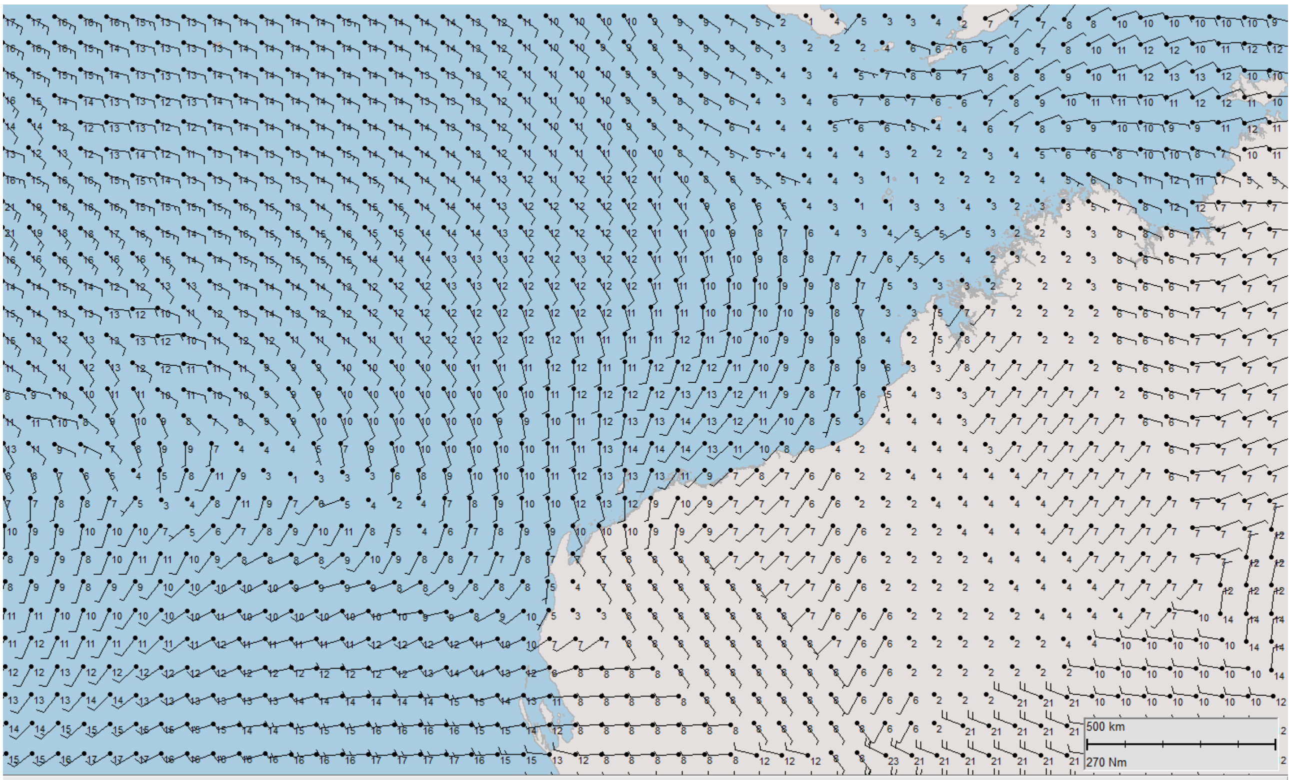


Figure 4.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model. Note, for ease viewing only every second wind vector is displayed on the map.

Table 4.1 Predicted average and maximum winds for the wind node closest to the release location. Data derived from CFSR hindcast model 2010 to 2019 (inclusive).

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	13	44	Southwest
	February	11	36	Southwest
	March	10	33	Southwest
Transitional	April	11	42	South
Winter	May	12	37	East
	June	14	30	East
	July	13	45	Southeast
Transitional	August	11	30	Southeast
Summer	September	12	25	South
	October	13	25	South
	November	13	24	South
	December	12	31	Southwest
Minimum		**10**	**24**	
Maximum		**14**	**45**	

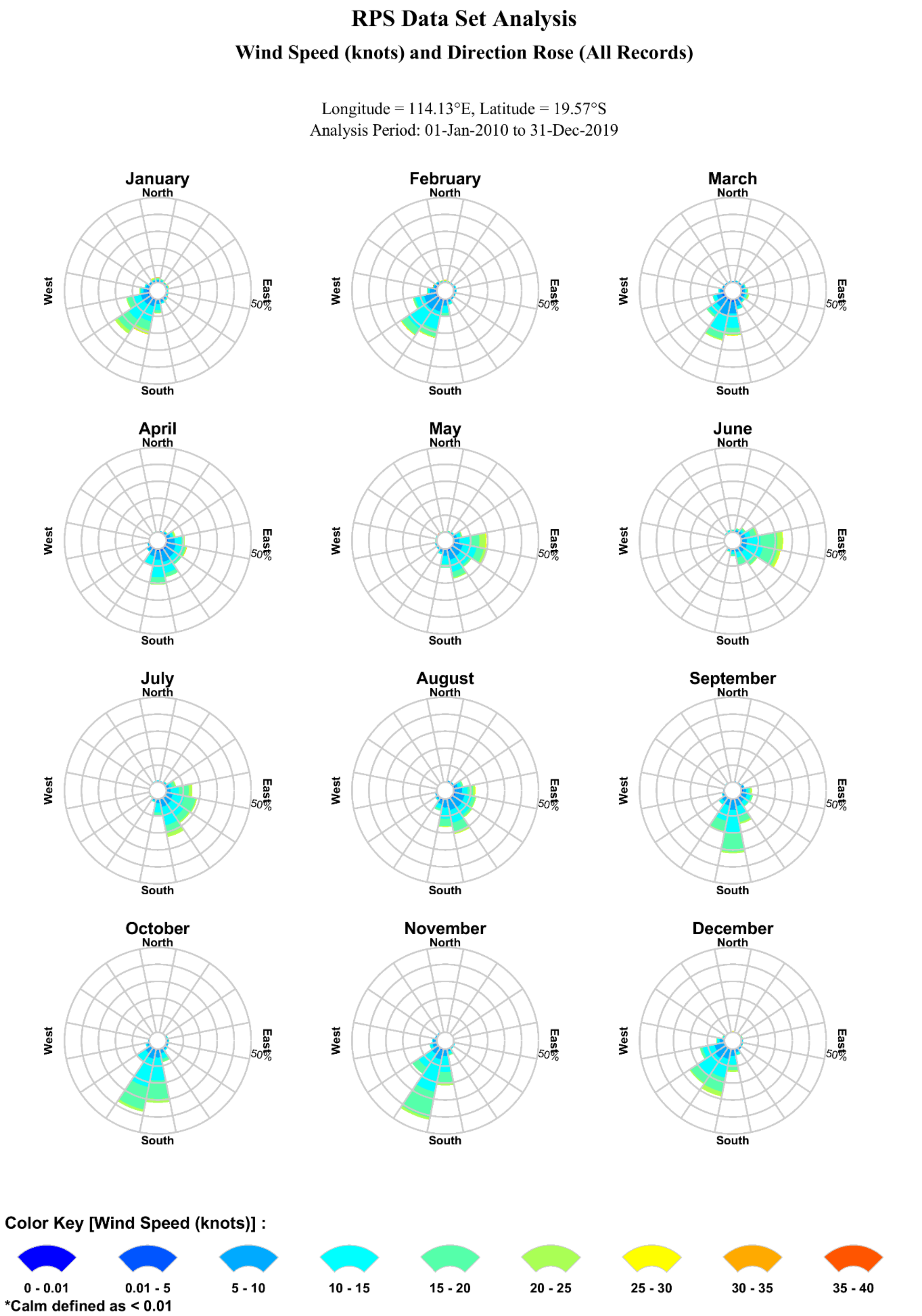


Figure 4.2 Monthly wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

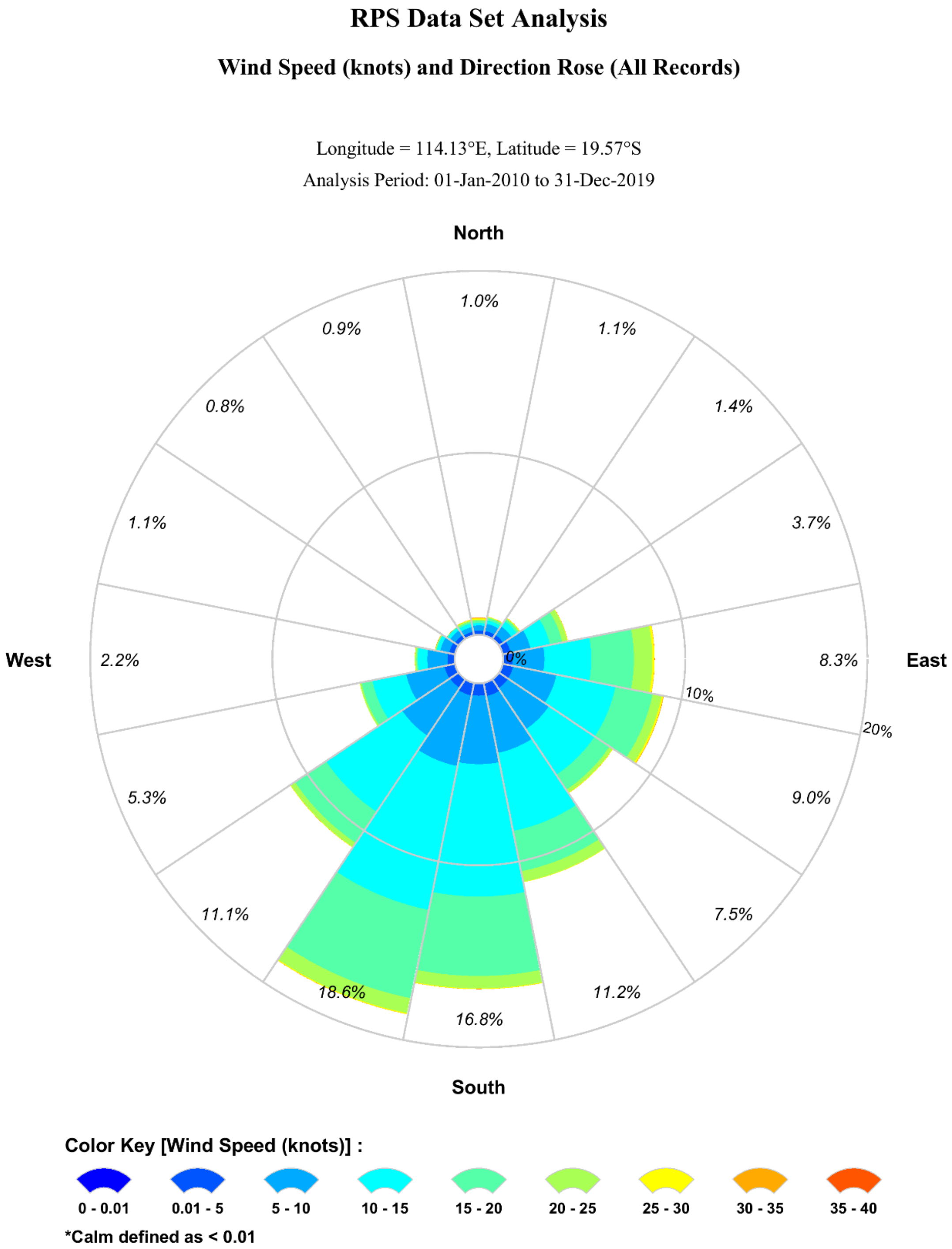


Figure 4.3 Total wind rose distributions adjacent to the release location, derived from the 2010 to 2019 modelled dataset.

5 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location was obtained from the HYbrid Coordinate Ocean Model (see Section 3.2 Ocean Currents).

The three-dimensional salinity and temperature datasets are used in the oil spill model domain to inform the weathering, movement, and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

Table 5.1 shows that the monthly average sea surface temperatures ranged from 24.3°C (September) to 29.4°C (March), whilst salinity remained relatively consistent throughout the year, ranging between 34.5–34.9 psu.

Figure 5.1 the vertical profile of sea temperature and salinity nearby the release location.

Table 5.1 Monthly average sea surface temperature and salinity near the release location in the 0-5 m depth layer.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	28.3	28.8	29.4	28.9	27.7	26.2	25.3	24.5	24.3	24.9	26.8	27.3
Salinity (psu)	34.9	34.6	34.6	34.5	34.7	34.8	34.6	34.7	34.7	34.7	34.7	34.7

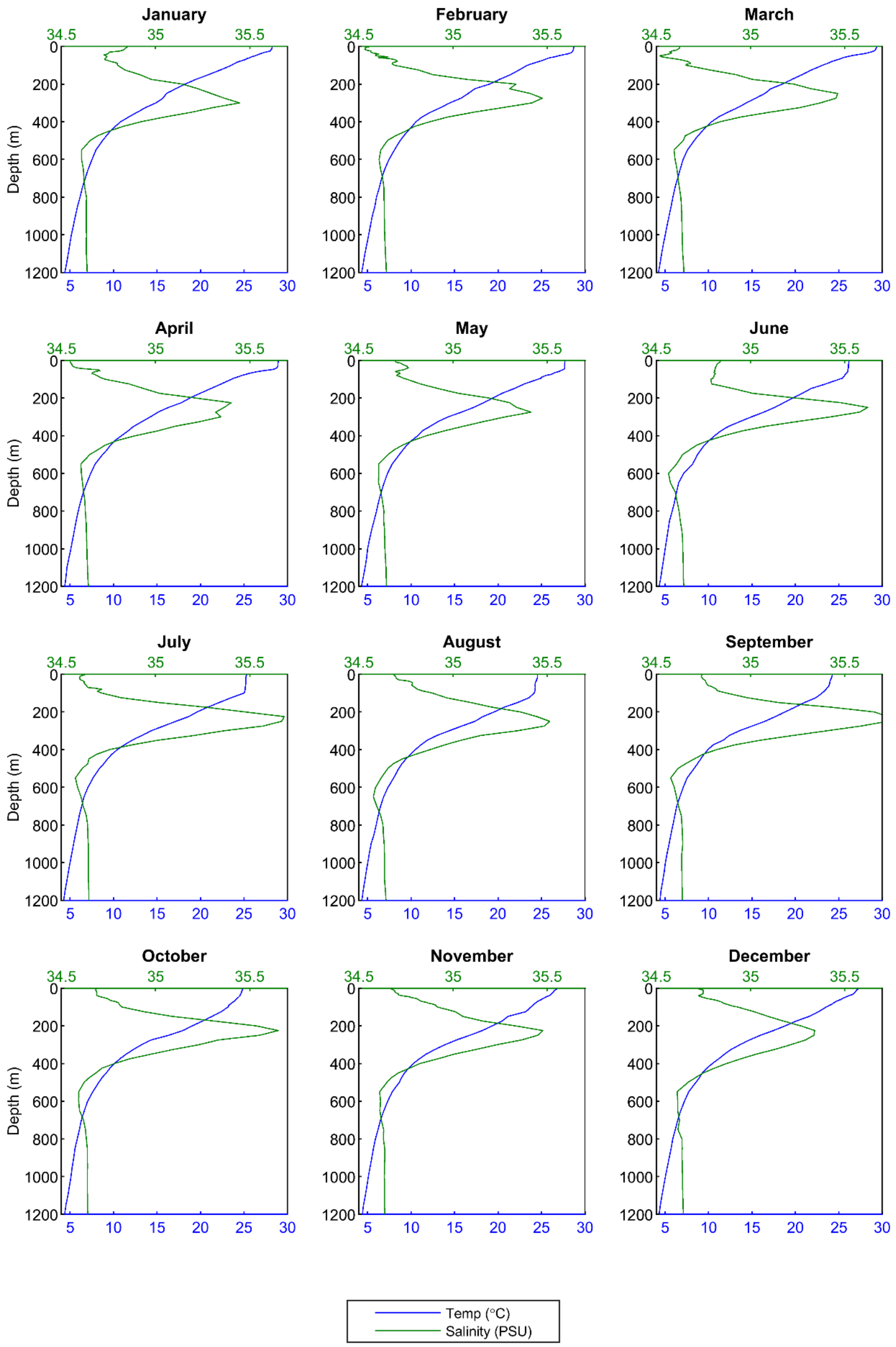


Figure 5.1 Monthly temperature and salinity profiles throughout the water column near the release location.

6 SUBSEA PLUME MODEL – OILMAP DEEP

The LOWC scenario is a high-pressure release of mostly gas and condensate and where gas is released with condensate, the buoyancy of the expanding gas cloud will entrain ambient seawater and propel the droplets towards the surface at a faster rate than would occur from the relative buoyancy of the condensate alone. Furthermore, the turbulence generated by such an intense discharge will tend to break the condensate up into droplets of various sizes.

To define the near-field plume dynamics, the subsea blowout model, OILMAP-DEEP, was applied. The model simulates the plume rise dynamics in two phases, the initial jet phase and the buoyant plume phase. The initial jet phase governs the plume dynamics directly above the subsurface release location and is predominately driven by the exit velocity. During this phase, the condensate droplet size and distribution is calculated. Next, the rise dynamics are dominated by the buoyant nature of the plume until the termination of the plume phase (known as the trapping depth). At this point, the results from OILMAP-DEEP (including plume trapping depth, plume diameter and droplet size distribution) are integrated into the far-field model SIMAP to simulate the rise and dispersion of the condensate droplets.

More details on the OILMAP-DEEP model, can be found in Spaulding et al. (2015). The model has been validated against observations from Deepwater Horizon as well as small and large-scale laboratory studies on subsurface oil releases (Brandvik et al., 2013, 2014; Belore, 2014; Spaulding et al., 2015; Li et al., 2017).

Table 6.1 presents the input parameters for the OILMAP-DEEP model and key results related to the near-field plume dynamics. The results indicated that the mixture of gas and condensate rose through the water column (whilst gradually losing momentum) to a trapping depth of approximately 753 m below mean sea level. After this point the condensate droplets would rise due to their own buoyancy, which are predicted to range in size from 135 to 548 μm.

Figure 6.1 illustrates the various stages of an example blowout plume.

Table 6.1 Input data and key results for the subsea plume modelling.

Input Variable	Value
Scenario	Loss of Well Control
Well name	Chandon Well 1
Water depth (m)	1,100
Tubing diameter (inch) [m]	7 5/8 [0.194]
Condensate rate (stb/day)	5,214
Gas rate (MMscf/day)	356
Gas to condensate ratio (scf/bbl)	68,278
Formation water flow rate (stb/day)	0
Operating pressure (psia)	4,296
Key results	
Plume execution depth (m BMSL)	753
Droplet sizes (μm)	135 to 584

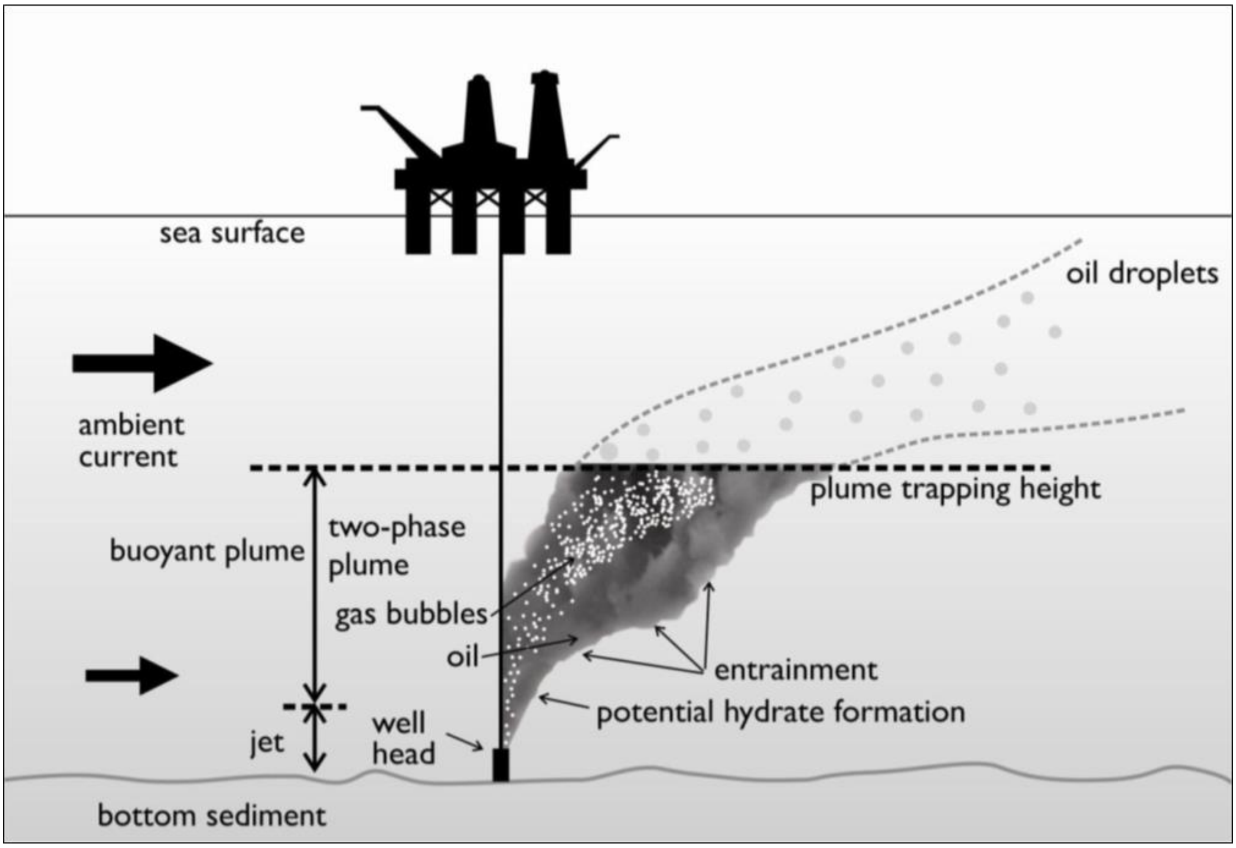


Figure 6.1 Example of a subsea plume and the various stages of the plume in the water column (Source: ASA, 2011).

7 OIL SPILL MODEL – SIMAP

Modelling of the fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application.

The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on five years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained oil and dissolved constituents in the water column, and oil in the sediments. For surface oil, water column oil and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

7.1 Stochastic Modelling

Stochastic oil spill modelling is created by overlaying a great number (often 100 hundred) simulated hypothetical oil spills (Figure 7.1). Stochastic modelling involves running numerous individual oil spill simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur.

For the stochastic modelling presented herein, **100 spills** were simulated per season using the same spill information (release location, spill volume, duration and condensate properties) but with varied start dates and times corresponding to the period represented by the available wind and current data. During each simulation, the model records whether any grid cells are exposed to any hydrocarbon concentrations, the concentrations involved and the elapsed time before exposure. For each scenario the results of all 100 condensate spill simulations were analysed to determine the following seasonal statistics for every grid cell:

- Exposure load (concentrations and volumes);
- Minimum time before exposure;
- Probability of contact above defined concentrations;
- Volume of condensate that may strand on shorelines from any single simulation;
- Concentration that might occur on sections of individual shorelines;
- Exposure (instantaneous and/or over a specified duration) to dissolved hydrocarbons in the water column; and
- Exposure (instantaneous and/or over a specified duration) to entrained hydrocarbons in the water column.

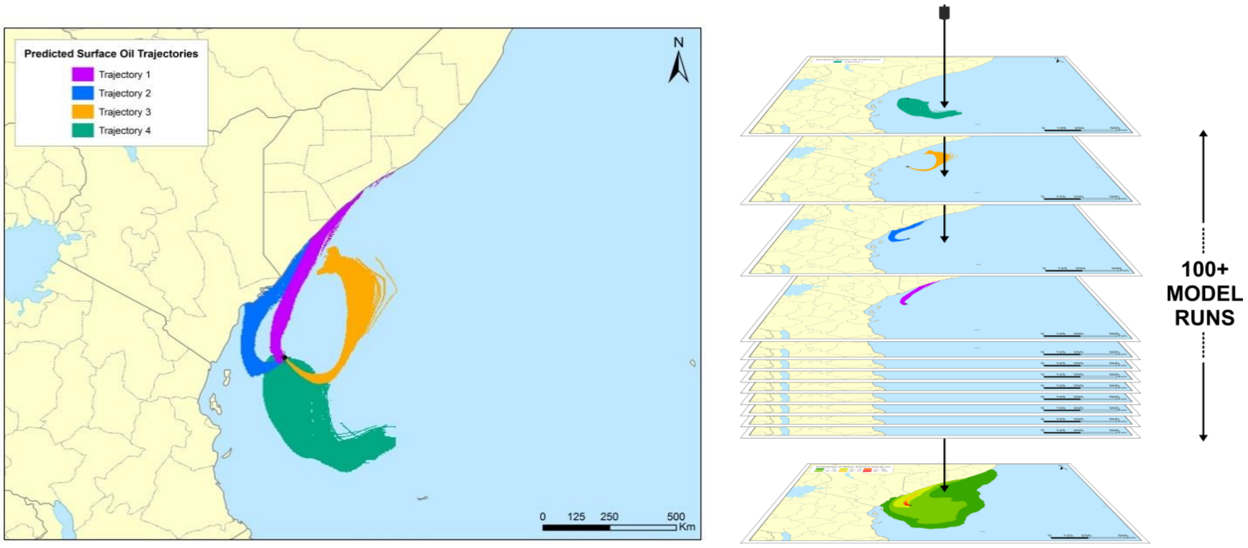


Figure 7.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

7.2 Floating, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 7.2.1 to 7.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

7.2.1 Floating condensate exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating condensate exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil exposure, was 1 g/m^2, which equates approximately to an average thickness of 1 µm, referred to as visible oil. Oil of this thickness is described as rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement, 2009; AMSA, 2014) (see Table 7.1). Figure 7.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. This threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to its visibility on the sea surface and potential to trigger temporary closures of areas (i.e. fishing grounds) as a precautionary measure. Table 7.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil exposure.

Ecological impact has been estimated to occur at 10 g/m^2 (a film thickness of approximately 10 µm or 0.01 mm) according to French et al. (1996) and French-McCay (2009) as this level of fresh oiling has been observed to mortally impact some birds through adhesion of oil to their feathers, exposing them to secondary effects such as hypothermia. The appearance of oil at this average thickness has been described as a metallic sheen (Bonn Agreement, 2009). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Scholten et al. (1996) and Koops et al. (2004) indicated that at oil concentrations on the sea surface of 25 g/m^2 (or greater), would be harmful for all birds that have landed in an oil film due to potential contamination of their feathers, with secondary effects such as loss of temperature regulation and ingestion of oil through preening. The appearance of oil at this thickness is also described as metallic sheen (Bonn Agreement, 2009). For this study the high exposure threshold was set to 50 g/m^2 and above based on NOPSEMA (2019). This threshold can also be used to inform response planning.

Table 7.2 defines the thresholds used to classify the zones of floating condensate exposure reported herein.

Table 7.1 The Bonn Agreement Oil Appearance Code.

Code	Description Appearance	Layer Thickness Interval (g/m^2 or µm)	Litres per km^2
1	Sheen (silvery/grey)	0.04 – 0.30	40 – 300
2	Rainbow	0.30 – 5.0	300 – 5,000
3	Metallic	5.0 – 50	5,000 – 50,000
4	Discontinuous True Oil Colour	50 – 200	50,000 – 200,000
5	Continuous True Oil Colour	≥ 200	≥ 200,000

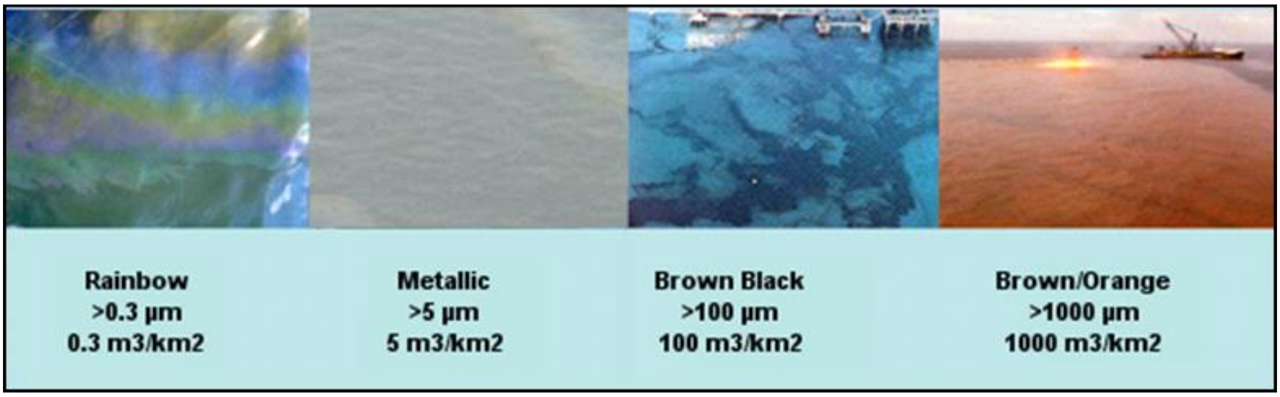


Figure 7.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 7.2 Floating condensate exposure thresholds used in this report (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (g/m^2)	Description
Low	1	Approximates range of socioeconomic effects and establishes planning area for scientific monitoring
Moderate	10	Approximates lower limit for harmful exposures to birds and marine mammals
High	50*	Approximates surface oil slick and informs response planning

* 50 g/m^2 also used to define the threshold for actionable floating oil.

7.2.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential “low shoreline accumulation”.

French et al. (1996) and French-McCay (2009) define a shoreline oil accumulation threshold of 100 g/m^2, or above, would potentially harm shorebirds and wildlife (furbearing aquatic mammals and marine reptiles on or along the shore) based on studies for sub-lethal and lethal impacts. This threshold has been used in previous environmental risk assessment studies (see French-McCay, 2003; French-McCay et al., 2004, French-McCay et al., 2011; 2012; NOAA, 2013). Additionally, a shoreline concentration of 100 g/m^2, or above, is the minimum limit that the oil can be effectively cleaned according to the AMSA (2015) guideline. This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential “moderate shoreline accumulation”.

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant et al., 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential “high shoreline accumulation”. It equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a hydrocarbon cover.

It is worth noting that the shoreline accumulation thresholds derived from extensive literature review (outlined in Table 7.3) agree with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 7.3 Thresholds used to assess shoreline accumulation.

Threshold level	Shoreline accumulation (g/m^2)	Description
Low (socioeconomic/sublethal)	10	Predicts potential for some socio-economic impact
Moderate	100*	Loading predicts area likely to require clean-up effort
High	> 1,000	Loading predicts area likely to require intensive clean-up effort

* 100 g/m^2 also used to define the threshold for actionable shoreline oil.

7.2.3 In-water Exposure Thresholds

Oil is a mixture of thousands of hydrocarbons of varying physical, chemical, and toxicological characteristics, and therefore, demonstrate varying fates and impacts on organisms. As such, for in-water exposure, the SIMAP model provides separate outputs for dissolved and entrained hydrocarbons from oil droplets. The consequences of exposure to dissolved and entrained components will differ because they have different modes and magnitudes of effect.

Entrained hydrocarbon concentrations were calculated based on oil droplets that are suspended in the water column, though not dissolved. The composition of this oil would vary with the state of weathering (oil age) and may contain soluble hydrocarbons when the oil is fresh. Calculations for dissolved hydrocarbons specifically calculates oil components which are dissolved in water, which are known to be the primary source of toxicity exerted by oil.

7.2.3.1 Dissolved Hydrocarbons

Laboratory studies have shown that dissolved hydrocarbons exert most of the toxic effects of oil on aquatic biota (Carls et al., 2008; Nordtug et al., 2011; Redman, 2015). The mode of action is a narcotic effect, which is positively related to the concentration of soluble hydrocarbons in the body tissues of organisms (French-McCay, 2002). Dissolved hydrocarbons are taken up by organisms directly from the water column by absorption through external surfaces and gills, as well as through the digestive tract. Thus, soluble hydrocarbons are termed “bioavailable”.

Hydrocarbon compounds vary in water-solubility and the toxicity exerted by individual compounds is inversely related to solubility, however bioavailability will be modified by the volatility of individual compounds (Nirmalakhandan & Speece, 1988; Blum & Speece, 1990; McCarty, 1986; McCarty et al., 1992a, 1992b; Mackay et al., 1992; McCarty & Mackay, 1993; Verhaar et al., 1992, 1999; Swartz et al., 1995; French-McCay, 2002; McGrath et al., 2009). Of the soluble compounds, the greatest contributor to toxicity for water-column and benthic organisms are the lower-molecular-weight aromatic compounds, which are both volatile and soluble in water. Although they are not the most water-soluble hydrocarbons within most oil types, the polynuclear aromatic hydrocarbons (PAHs) containing 2-3 aromatic ring structures typically exert the largest narcotic effects because they are semi-soluble and not highly volatile, so they persist in the environment long enough for significant accumulation to occur (Anderson et al., 1974, 1987; Neff & Anderson, 1981; Malins & Hodgins, 1981; McAuliffe, 1987; NRC, 2003). The monoaromatic hydrocarbons (MAHs), including the BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), and the soluble alkanes (straight chain hydrocarbons) also contribute to toxicity, but these compounds are highly volatile, so that their contribution will be low when oil is exposed to evaporation and higher when oil is discharged at depth where volatilisation does not occur (French-McCay, 2002).

French-McCay (2002) reviewed available toxicity data, where marine biota was exposed to dissolved hydrocarbons prepared from oil mixtures, finding that 95% of species and life stages exhibited 50% population mortality (LC_{50}) between 6 and 400 ppb total PAH concentration after 96 hrs exposure, with an average of 50 ppb. Hence, concentrations lower than 6 ppb total PAH value should be protective of 97.5% of species and life stages even with exposure periods of days (at least 96 hours). Early life-history stages of fish appear to be more sensitive than older fish stages and invertebrates.

Exceedances of 10, 50 or 400 ppb over a 1 hour timestep (see Table 7.4) was applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), based on NOPSEMA (2019).

7.2.3.2 Entrained Hydrocarbons

Entrained hydrocarbons consist of oil droplets that are suspended in the water column and insoluble. As such, insoluble compounds in oil cannot be absorbed from the water column by aquatic organisms, hence are not bioavailable through absorption of compounds from the water. Exposure to these compounds would require routes of uptake other than absorption of soluble compounds. The route of exposure of organisms to whole oil alone include direct contact with tissues of organisms and uptake of oil by direct consumption, with potential for biomagnification through the food chain (NRC, 2003).

The 10 ppb threshold represents the very lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the ANZECC & ARMCANZ (2000) water quality guidelines. Due to the requirement for relatively long exposure times (> 24 hours) for these concentrations to be significant, they are likely to be more meaningful for juvenile fish, larvae and planktonic organisms that might be entrained (or otherwise moving) within the entrained plumes, or when entrained hydrocarbons adhere to organisms or trapped against a shoreline for periods of several days or more.

This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the entrained hydrocarbon at this level.

Thresholds of 10 ppb and 100 ppb were applied over a 1 hour time exposure (Table 7.4), to cover the range of thresholds outlined in the ANZECC & ARMCANZ (2000) water quality guidelines, the incremental change for greater potential effect and is per NOPSEMA (2019).

A complicating factor that should be considered when assessing the consequence of dissolved and entrained oil distributions is that there will be some areas where both physically entrained oil droplets and dissolved hydrocarbons co-exist. Higher concentrations of each will tend to occur close to the source where sea conditions can force mixing of relatively unweathered oil into the water column, resulting in more rapid dissolution of soluble compounds.

Table 7.4 Dissolved and entrained hydrocarbon exposure values assessed over a 1-hour time step, as per NOPSEMA (2019).

Threshold level	Dissolved hydrocarbon concentration (ppb)	Entrained hydrocarbon concentrations (ppb)
Low	10	10
Moderate	50	-
High	400	100

8 CONDENSATE PROPERTIES

8.1 Properties

Chandon condensate physical properties and boiling point distributions were provided by Chevron and are presented in Table 8.1 and Table 8.2, respectively.

Chandon condensate has an API of 47.80, a density of 789 kg/m^3 (at 15ºC) and a viscosity value of 2.6 cP at 15 ºC. When exposed to the atmosphere at local temperatures, about 45.9% of the condensate volatile components should evaporate within the first 12 hours (BP < 180°C); a further 26.3% of the semi-volatiles should evaporate within the first 24 hours (180°C < BP < 265°C); and low volatile portion (22.4%) should evaporate over a longer period (265°C < BP < 380°C). The remaining 5.4% of the condensate would persist in the marine environment for much longer periods and be subject to relatively slow degradation.

This condensate has a low asphaltene content (< 0.05%), which is one indicator for a very low propensity for the mixture to take up water to form water-in-oil emulsion.

Soluble aromatic hydrocarbons contribute approximately 2.5% by mass of the whole oil, which is contained in the volatile fractions and are highly soluble. The process of evaporation will be grater under calm sea conditions, but increased entrainment can be expected under stronger winds due to the presence of small breaking waves (whitecaps).

The actual fate will depend greatly on the amount that reaches the surface, either through the initial release or by resurfacing.

Table 8.1 Physical properties of Chandon condensate.

Characteristic	Chandon Condensate
Density (kg/m^3)	789 (at 15°C)
API	47.8
Dynamic viscosity (cP)	2.6 (at 15°C)
Pour point (°C)	<-20
Surface tension (dyne/cm)	21
Hydrocarbon property category	Group I
Hydrocarbon property classification	Non-persistent

Table 8.2 Boiling point ranges of Chandon condensate.

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-265 C_{11} to C_{15}	265-380 C_{16} to C_{20}	>380 >C_{20}
Chandon Condensate	% of total	45.9	26.3	22.4	5.4
	% of aromatics	2.5	0	0	0

8.2 Weathering Characteristics

8.2.1 Overview

A series of weathering tests were conducted to illustrate the potential behaviour of this condensate when exposed to idealised and representative environmental conditions:

- Instantaneous 50 m^3 surface release under calm wind conditions (constant 5 knots), 27°C water temperature and currents.

- Instantaneous 50 m^3 surface release under variable moderate wind conditions, 27°C water temperature and currents.

The first case is indicative of weathering rates under calm conditions that would not generate entrainment, while the second case would be more representative of the moderate winds experienced over the region. Both scenarios provide examples of potential behaviour during periods of a spill event once the condensate reaches the surface.

8.2.2 Results

The mass balance forecast for the calm-wind case (Figure 8.1) shows that 72% of the condensate is predicted to evaporate within 24 hours. The majority of the remaining condensate on the water surface will weather at a slower rate due to the low volatile components. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 8.2), where the winds are of greater strength on average, entrainment of Chandon condensate into the water column was shown to increase. Approximately 24 hours after the spill, 38% of the condensate mass was shown to entrain and a further 60% had evaporated, leaving only a small portion of the condensate floating on the water surface (<0.3%). The residual compounds will tend to remain entrained during conditions that generate wind-waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case would result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and condensate droplets in the water column occurs at an approximate rate of ~1.1% per day with an accumulated total of ~8.6% after 7 days, in comparison to a rate of <0.1% per day and an accumulated total of 0.7% after 7 days in the constant-wind case. Given the portion of entrained condensate and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay over time scales of several weeks.

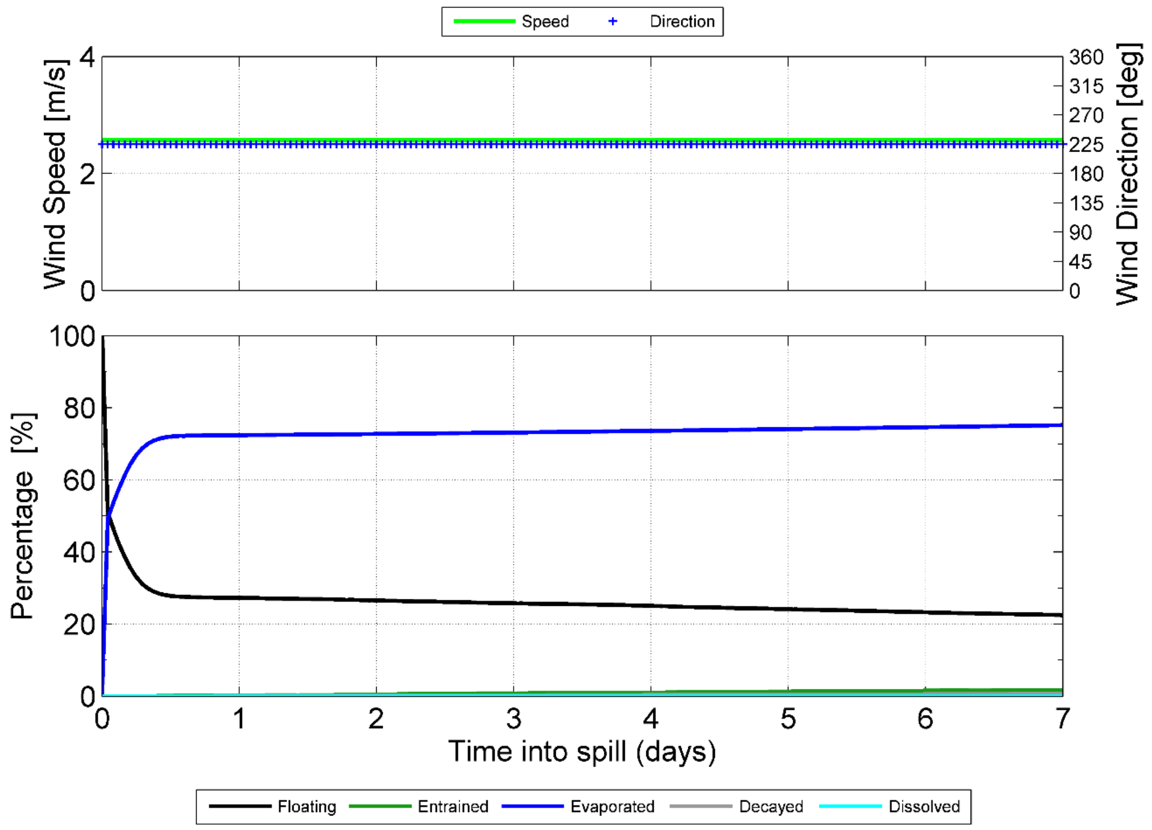


Figure 8.1 Proportional mass balance plot representing the weathering of Chandon condensate spilled onto the water surface as a one-off instantaneous release and subject to a constant 5 knots (2.6 m/s) wind at 27°C water temperature.

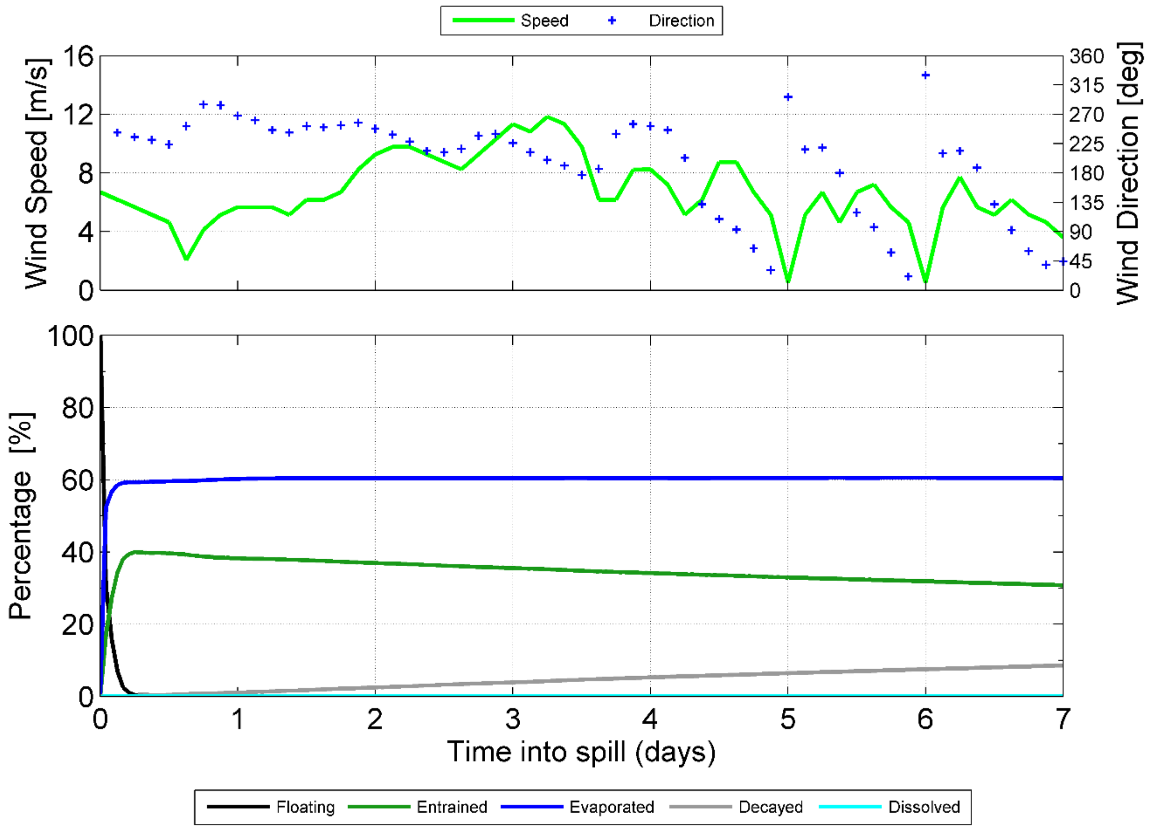


Figure 8.2 Proportional mass balance plot representing the weathering of Chandon condensate spilled onto the water surface as a one-off instantaneous release and subject to variable wind at 27°C water temperature.

9 MODEL SETTINGS

Table 9.1 provides a summary of the oil spill model settings.

Table 9.1 Summary of the oil spill model settings used in this assessment.

	Scenario
Location	Chandon Well 1 (Chandon)
Number of spill simulations with randomly selected start times	100 per season (300 total)
Spill volume (m^3) [bbl]	74,604 [469,260]
Condensate type	Chandon condensate
Release type (depth)	Subsea (1,100 m)
Release duration (days)	90
Simulation length (days)	104
Model period	Summer (September to the following March) Transitional (April and August) Winter (May to July)
Floating oil (NOPSEMA) thresholds	1 g/m^2, low exposure 10 g/m^2, moderate exposure 50 g/m^2, high exposure
Shoreline accumulation (NOPSEMA) thresholds	10 g/m^2, low exposure 100 g/m^2, moderate exposure 1,000 g/m^2, high exposure
Dissolved hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 50 ppb over 1 hour, moderate exposure 400 ppb over 1 hour, high exposure
Entrained hydrocarbon (NOPSEMA) thresholds	10 ppb over 1 hour, low exposure 100 ppb over 1 hour high exposure

10 PRESENTATION AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide an understanding of the predicted sea-surface and water column (subsurface) exposure and shoreline accumulation (if predicted).

10.1 Stochastic Analysis

10.1.1 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** – is determined by a) recording the maximum and b) second greatest distance travelled (or 99th percentile) by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***Probability of condensate exposure to a receptor*** – is determined by recording the number of spill trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***Minimum time before condensate exposure to a receptor*** – is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil accumulation at a receptor*** – is determined by recording the number of spill trajectories to reach a specified shoreline accumulation threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***maximum potential oil accumulation within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***dissolved and entrained hydrocarbon exposure*** – is determined by recording the maximum instantaneous concentrations at each grid cell assessed over a 1-hour time step.

10.2 Deterministic Trajectories

The deterministic results in Section 11.2 are based on the following criteria:

a. Largest swept area of floating hydrocarbon above 10 g/m^2
b. Largest swept area of floating hydrocarbon above 50 g/m^2
c. Largest volume of oil ashore
d. Longest length of shoreline accumulation above 100 g/m^2
e. Largest area of entrained hydrocarbons above 100 ppb
f. Largest area of dissolved hydrocarbons above 50 ppb

As there was no floating hydrocarbons at or above 50 g/m^2, no dissolved hydrocarbon exposure at or above 50 ppb, and no shoreline accumulation at or above any threshold, for any of the 300 simulations, the deterministic results are presented based on criteria a, and e only.

10.3 Receptors

A range of environmental receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved hydrocarbons) as part of the study (see Figure 10.1 to Figure 10.10). Receptor categories (see Table 10.1) include sections of shorelines and offshore islands. All other sensitive receptors other than the submerged reefs, shoals and banks (RSB) were sourced from http://www.environment.gov.au/. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

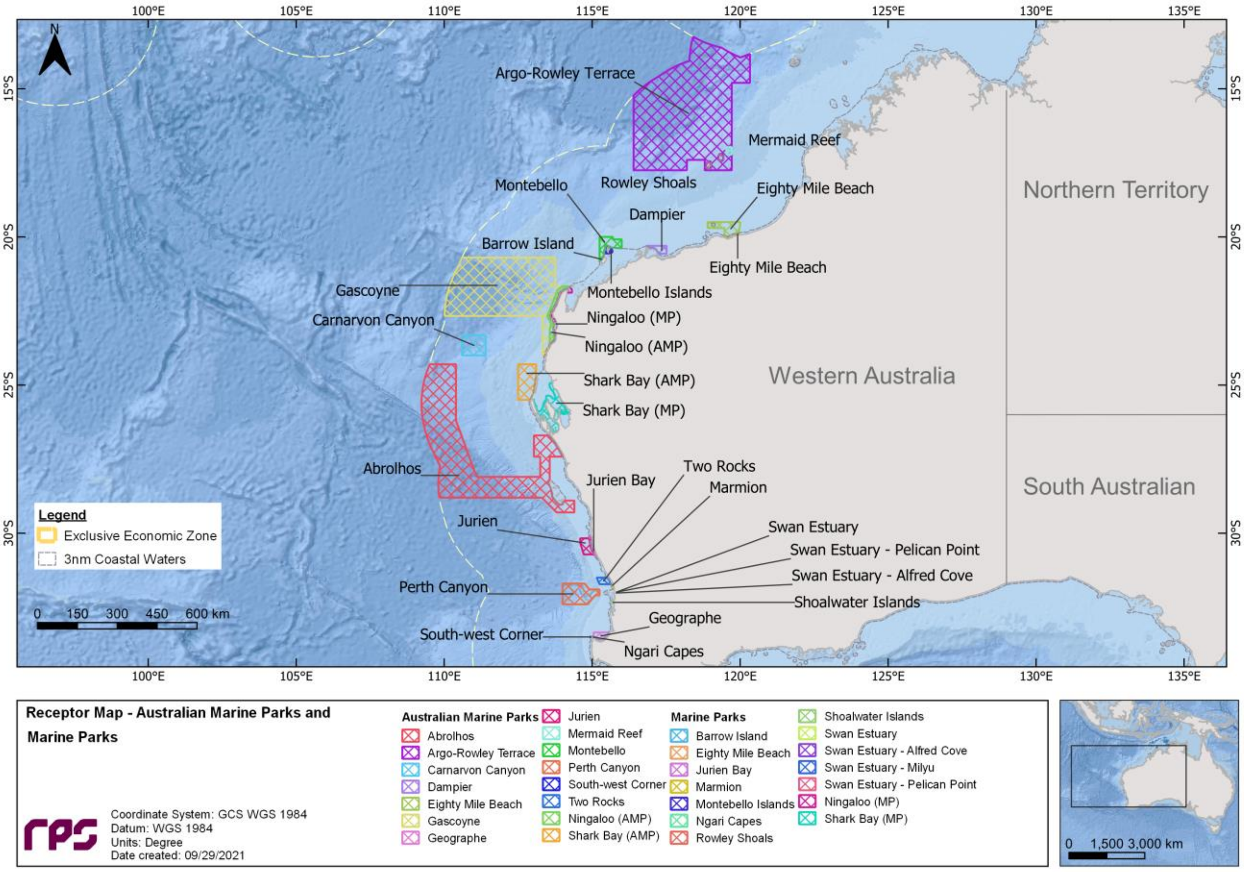
Table 10.2 summarises the receptors that the location resides within.

Table 10.1 Summary of receptors used to assess floating oil, shoreline and in-water exposure to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	✗
Biologically Important Area	BIA	✓	✓	✗
Impact Assessment Area	IAA	✓	✓	✓
Integrated Marine and Coastal Regionalisation of Australia	IMCRA	✓	✓	✗
Interim Biogeographic Regionalisation of Australia	IBRA	✓	✓	✗
Key Ecological Feature	KEF	✓	✓	✗
Marine Park	MP	✓	✓	✗
Marine Management Area	MMA	✓	✓	✗
Nature Reserve	NR	✓	✓	✗
Reefs, Shoals and Banks	RSB	✓	✓	✗
Ramsar Sites	Ramsar	✓	✓	✗
State Waters	State Waters	✓	✓	✗
Shoreline	Shore & Nearshore Waters	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Nearshore Waters)	✓ (Reported as: Shore)

Table 10.2 Summary of the receptors that each release location lies within.

Receptor category	Acronym	Scenario
Pygmy Blue Whale - Distribution	BIA	✓
Offshore Area	IAA	✓
Exmouth Plateau	KEF	✓



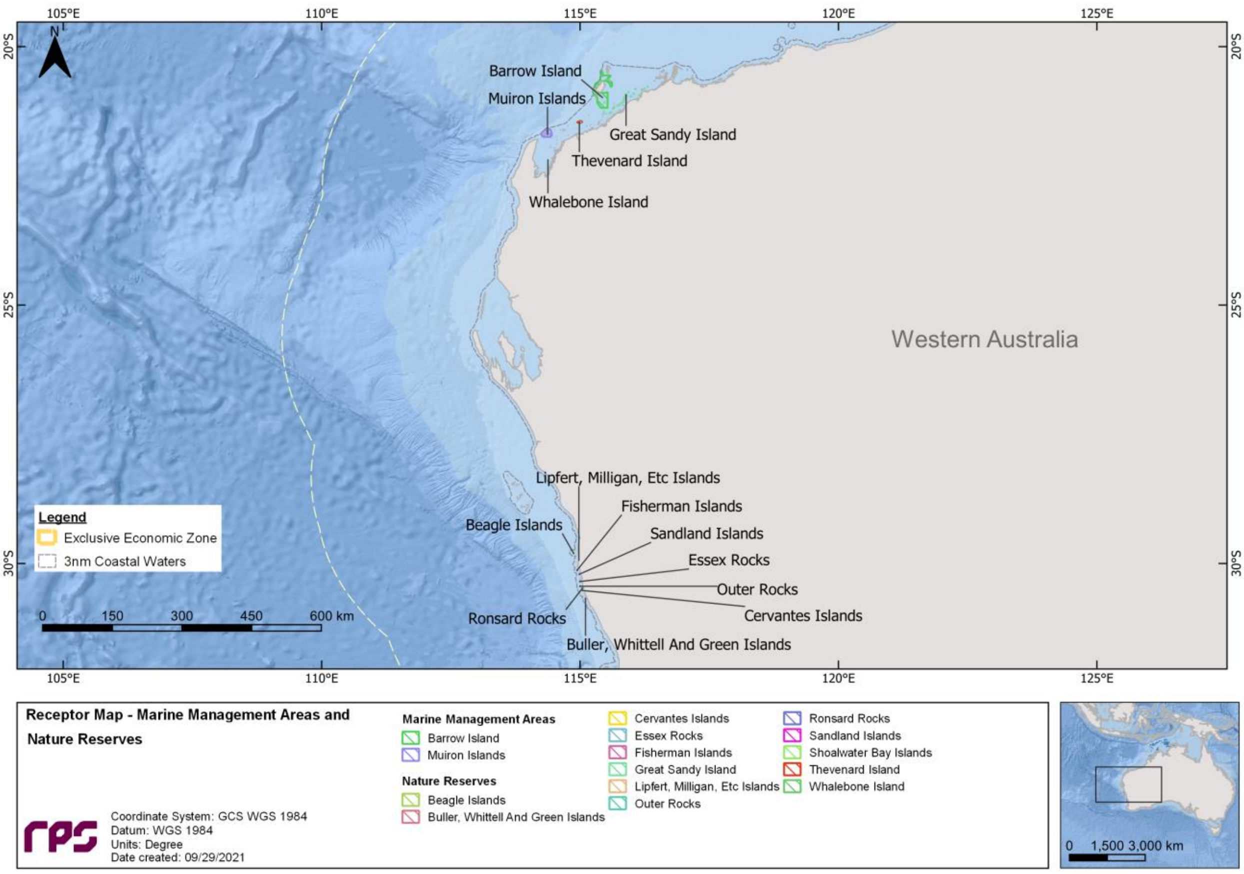


Figure 10.1 Receptor maps for Australian Marine Parks (AMPs) and Marine Parks (MPs) (Top) and Marine Management Areas (MMAs) and Nature Reserves (NRs) (Bottom).

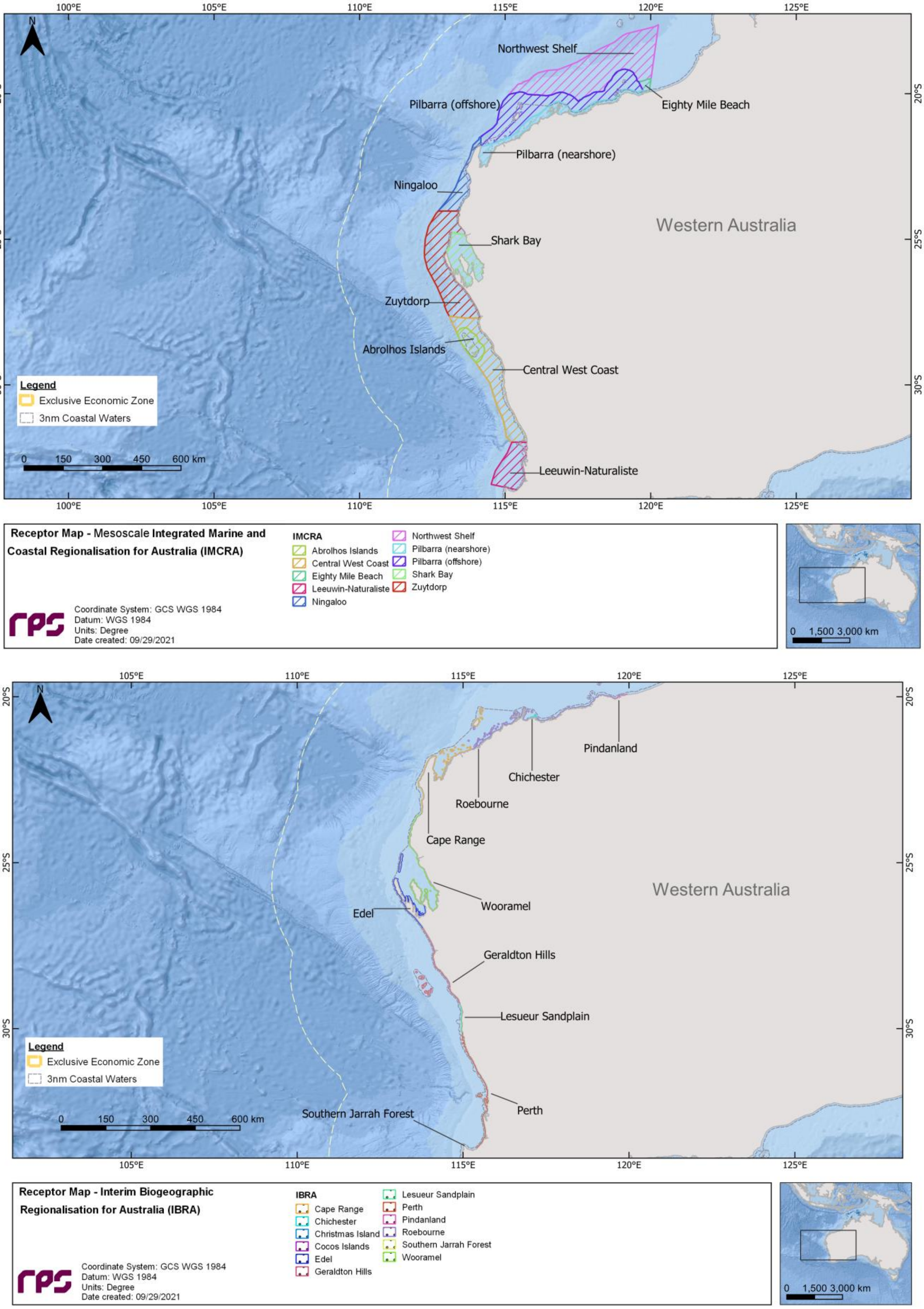


Figure 10.2 Receptor maps for Mesoscale Integrated Marine and Coastal Regionalisation of Australia (IMCRA; Top) and Interim Biogeographic Regionalisation for Australia (IBRA; Bottom).

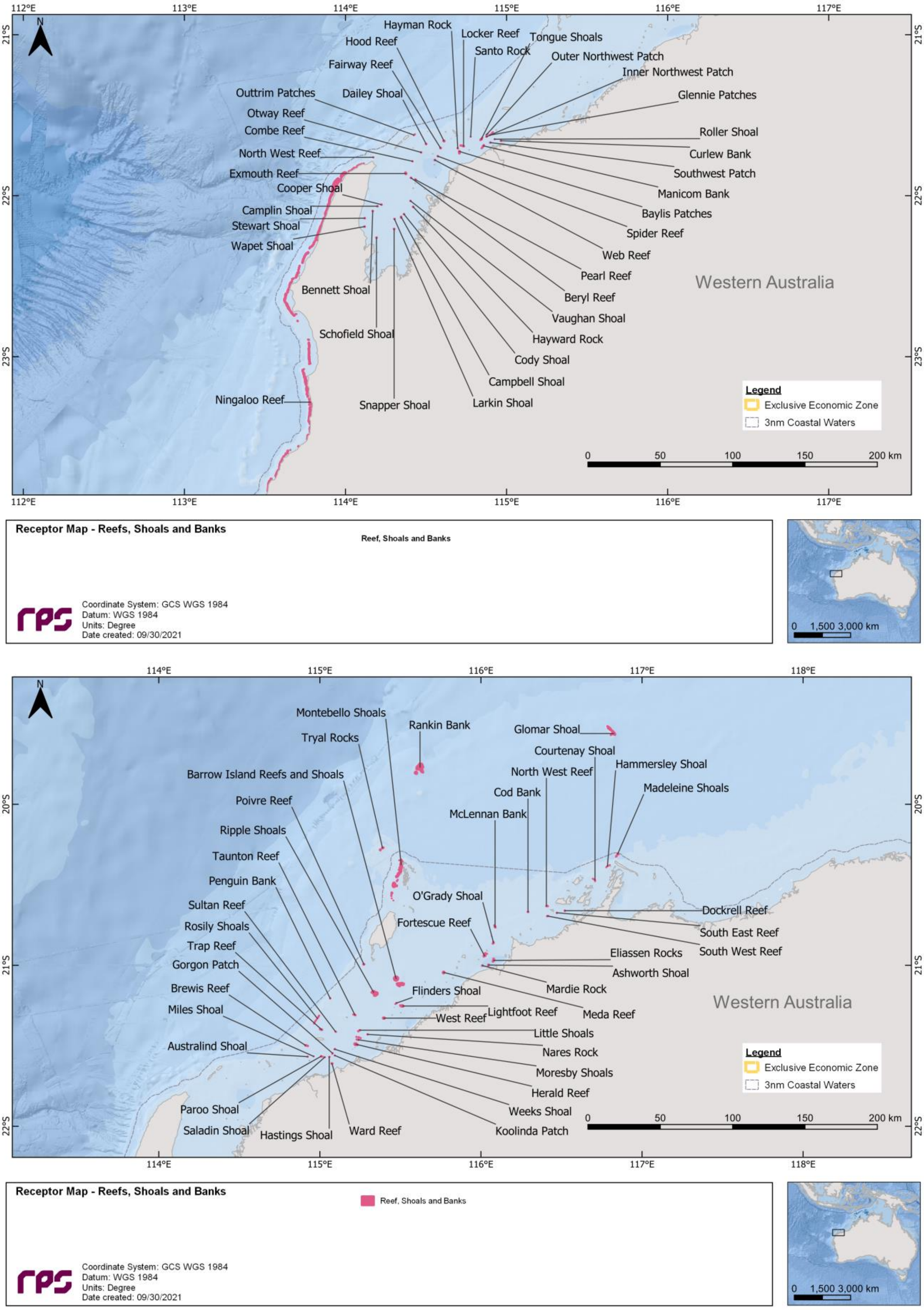


Figure 10.3 Receptor maps for Reefs, Shoals and Banks (RSB).

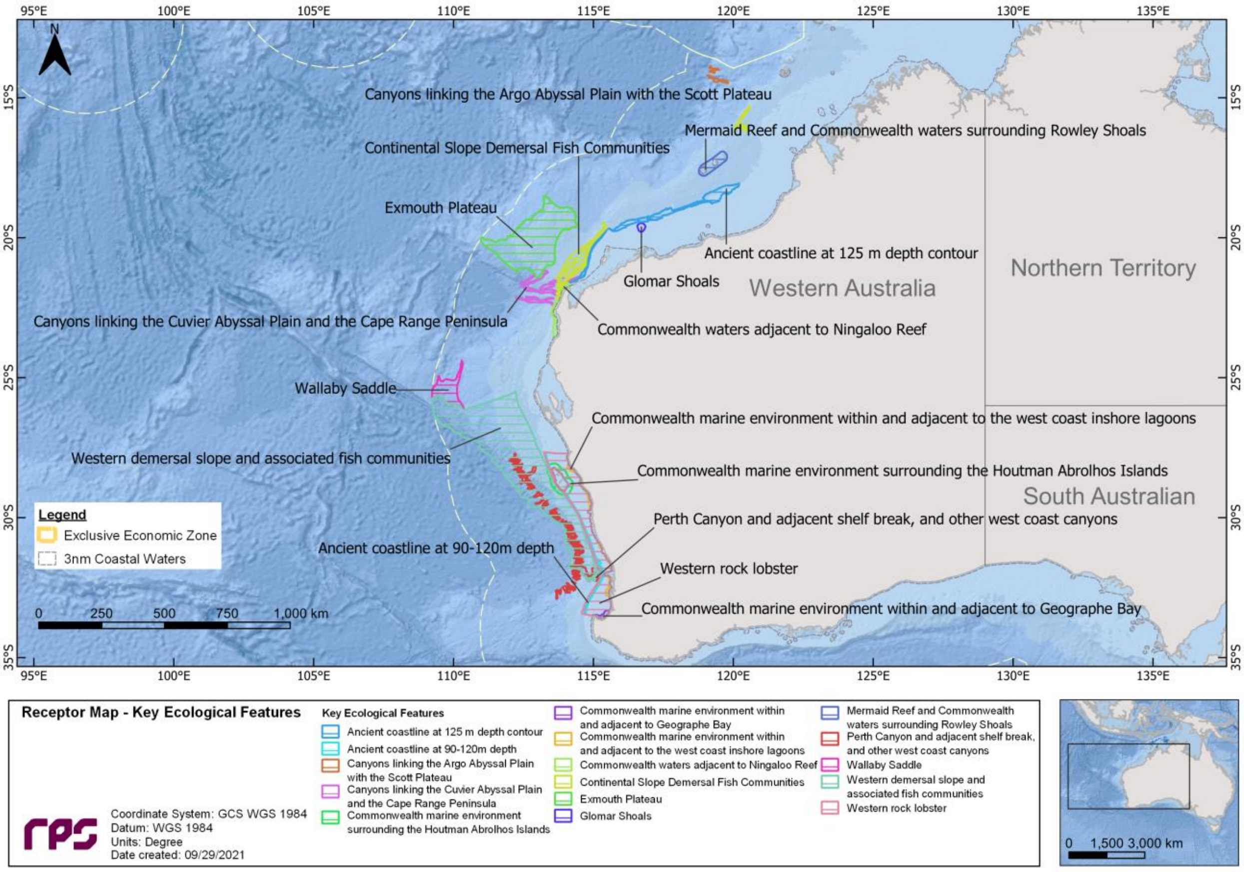


Figure 10.4 Receptor maps for Key Ecological Features (KEFs).

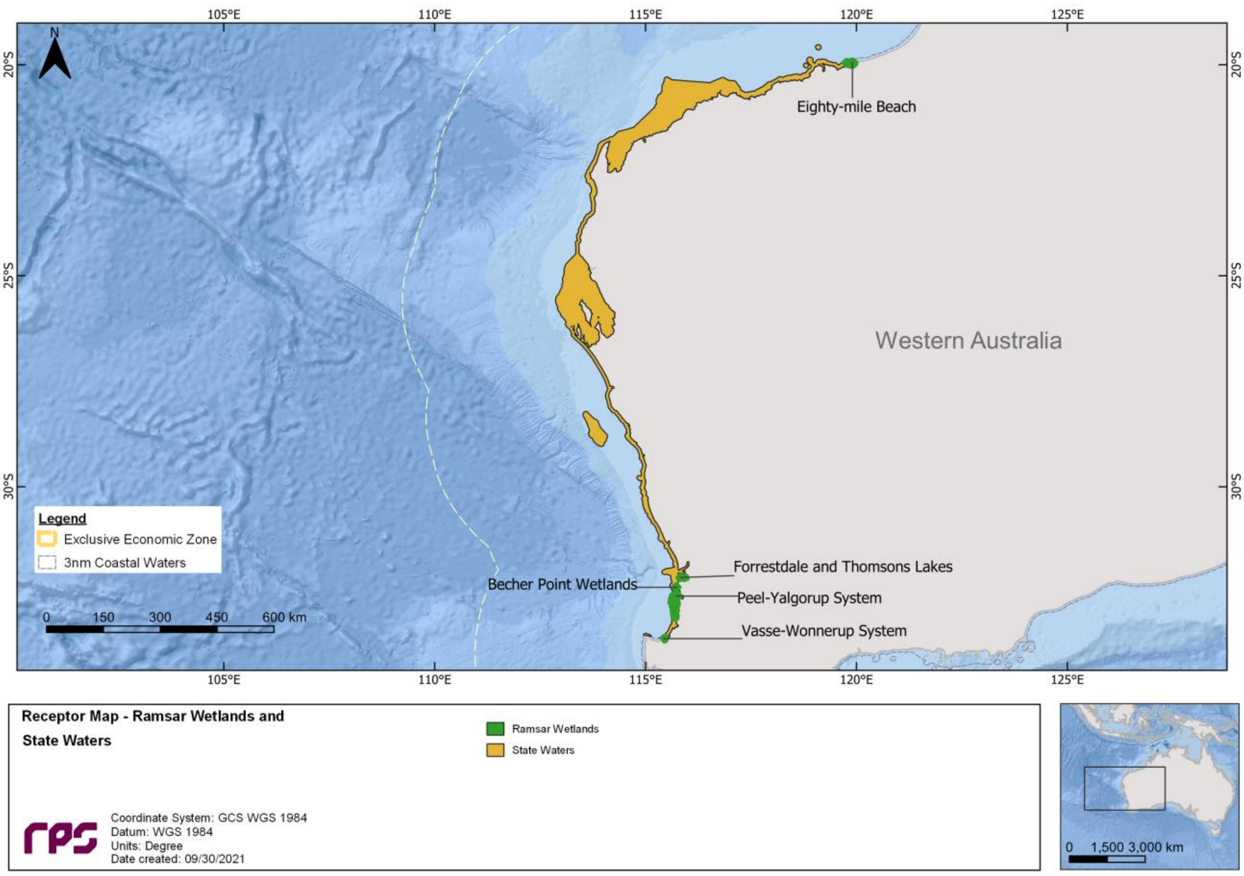
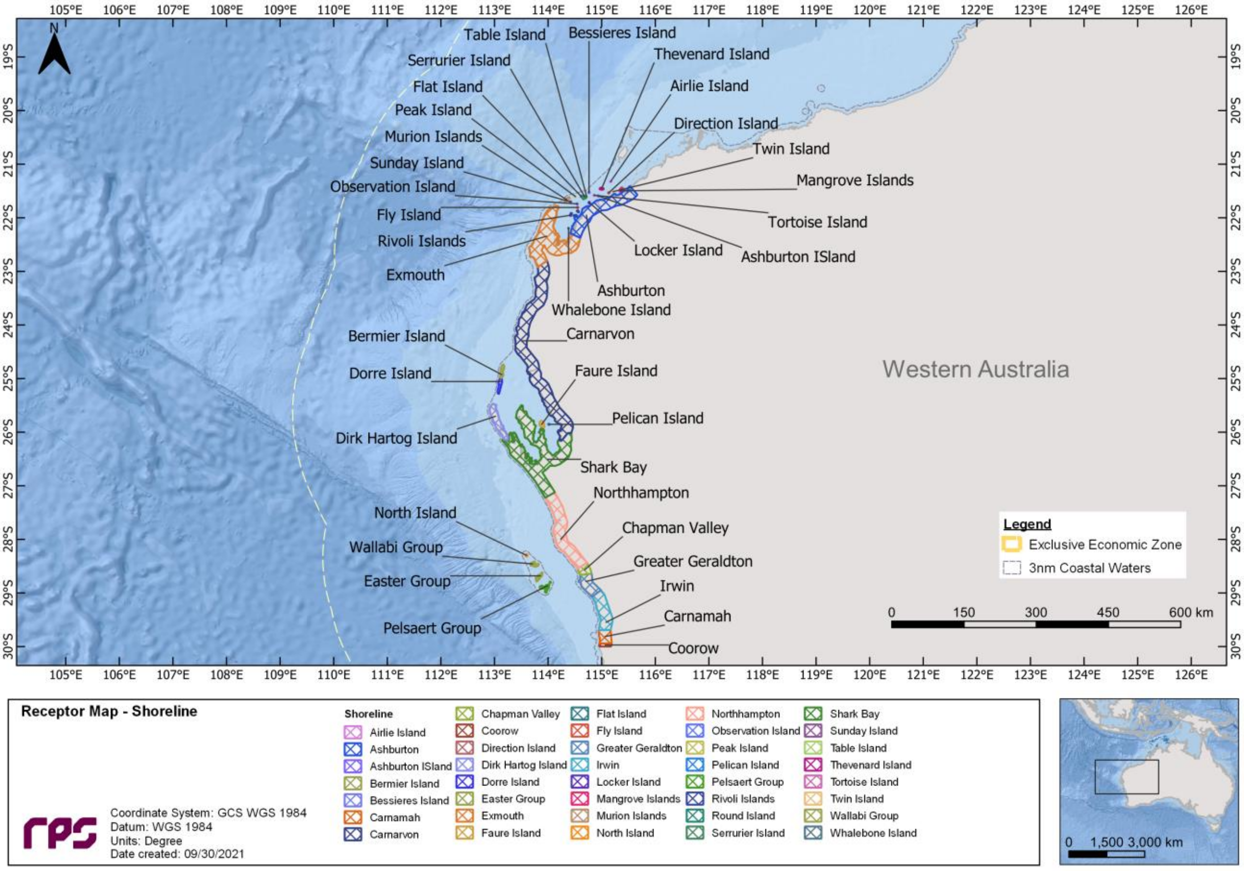


Figure 10.5 Receptor maps for Ramsar Sites (Ramsar) and State Waters.



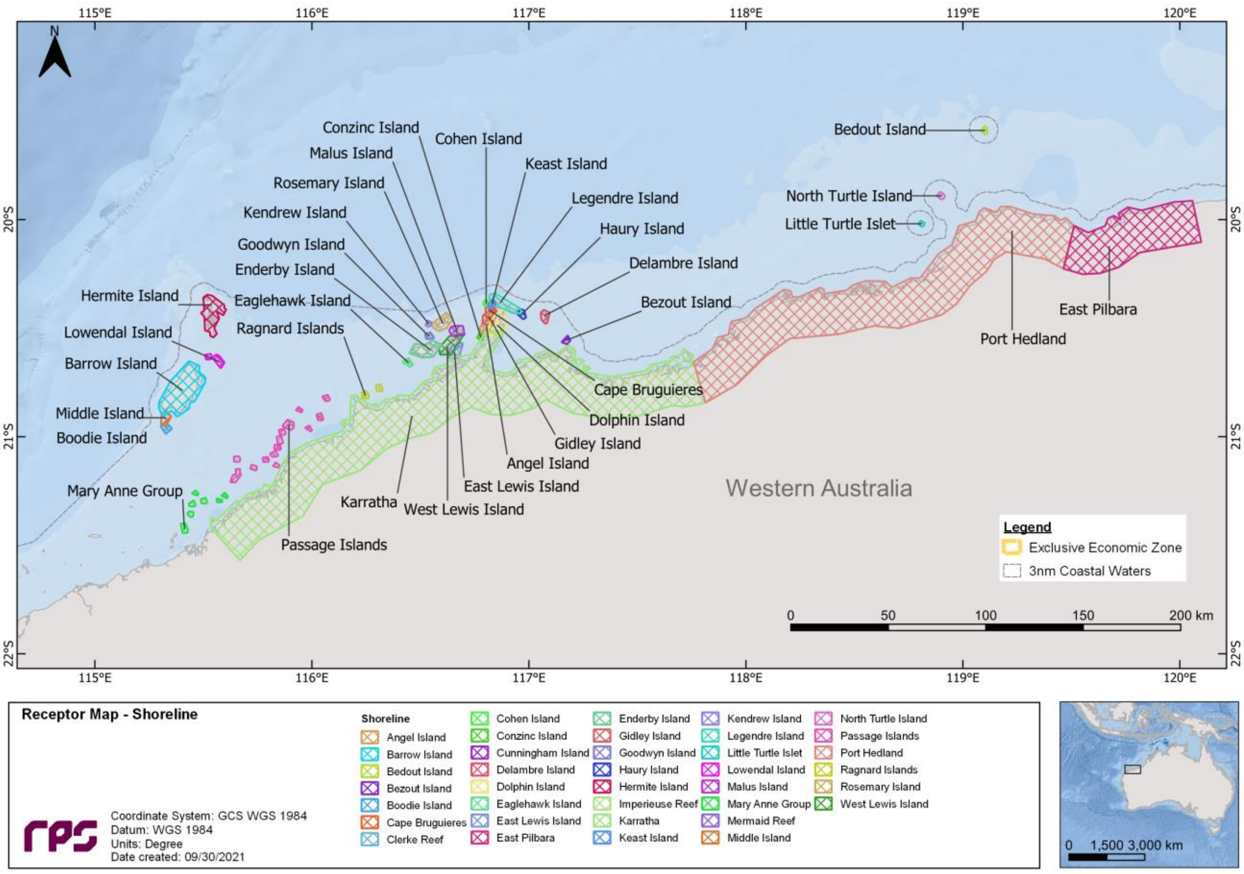


Figure 10.6 Receptor maps for Shorelines (1 of 2).

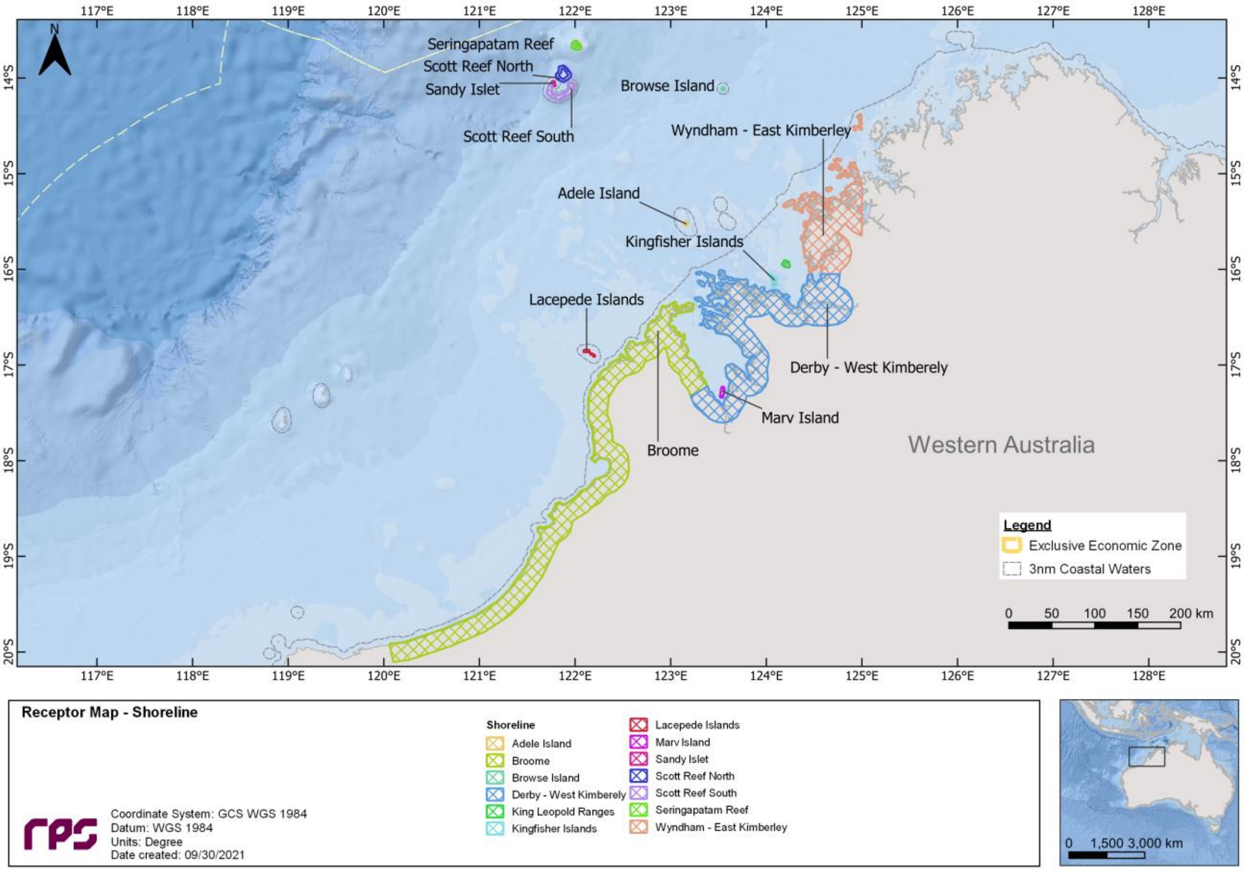


Figure 10.7 Receptor maps for Shorelines (2 of 2).

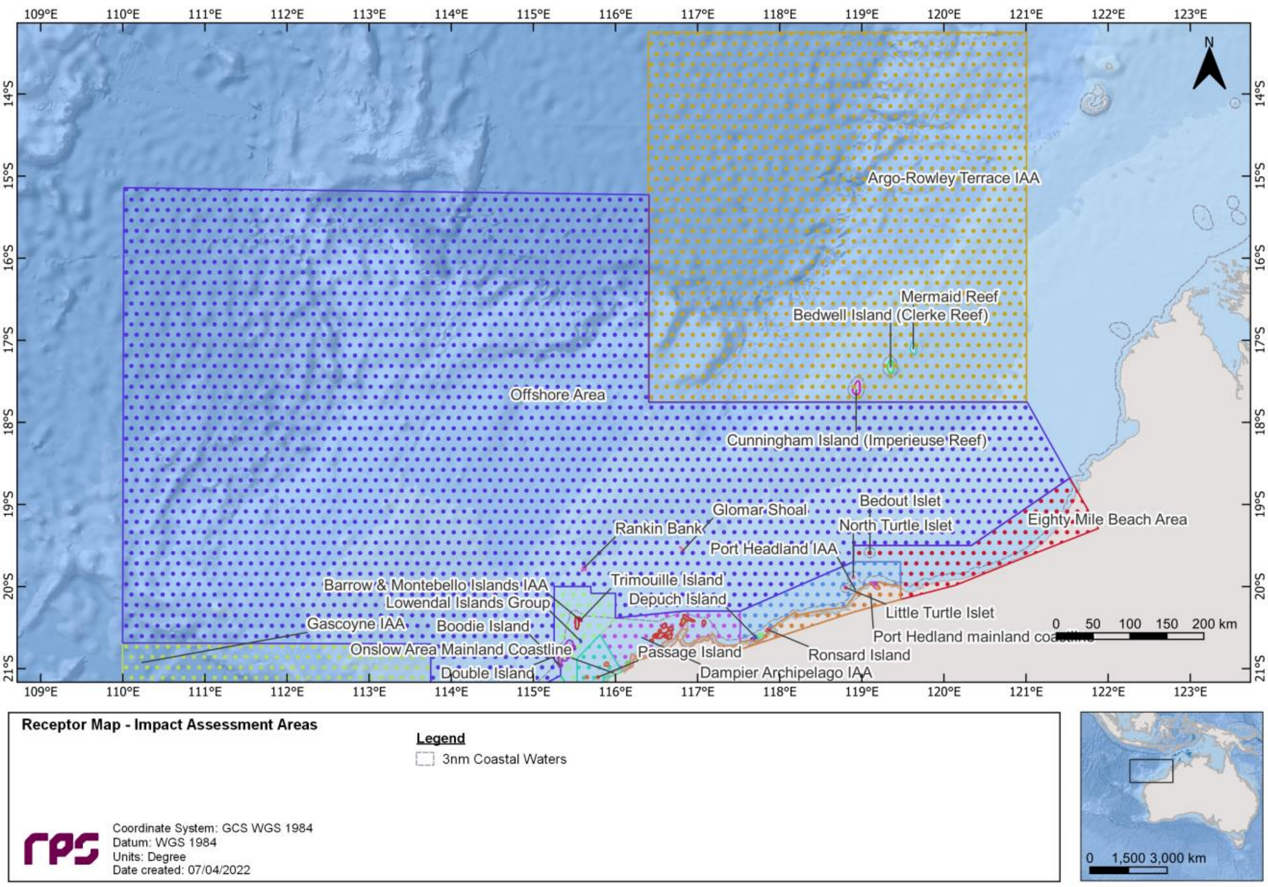


Figure 10.8 Receptor maps for Impact Assessment Areas (1 of 3).

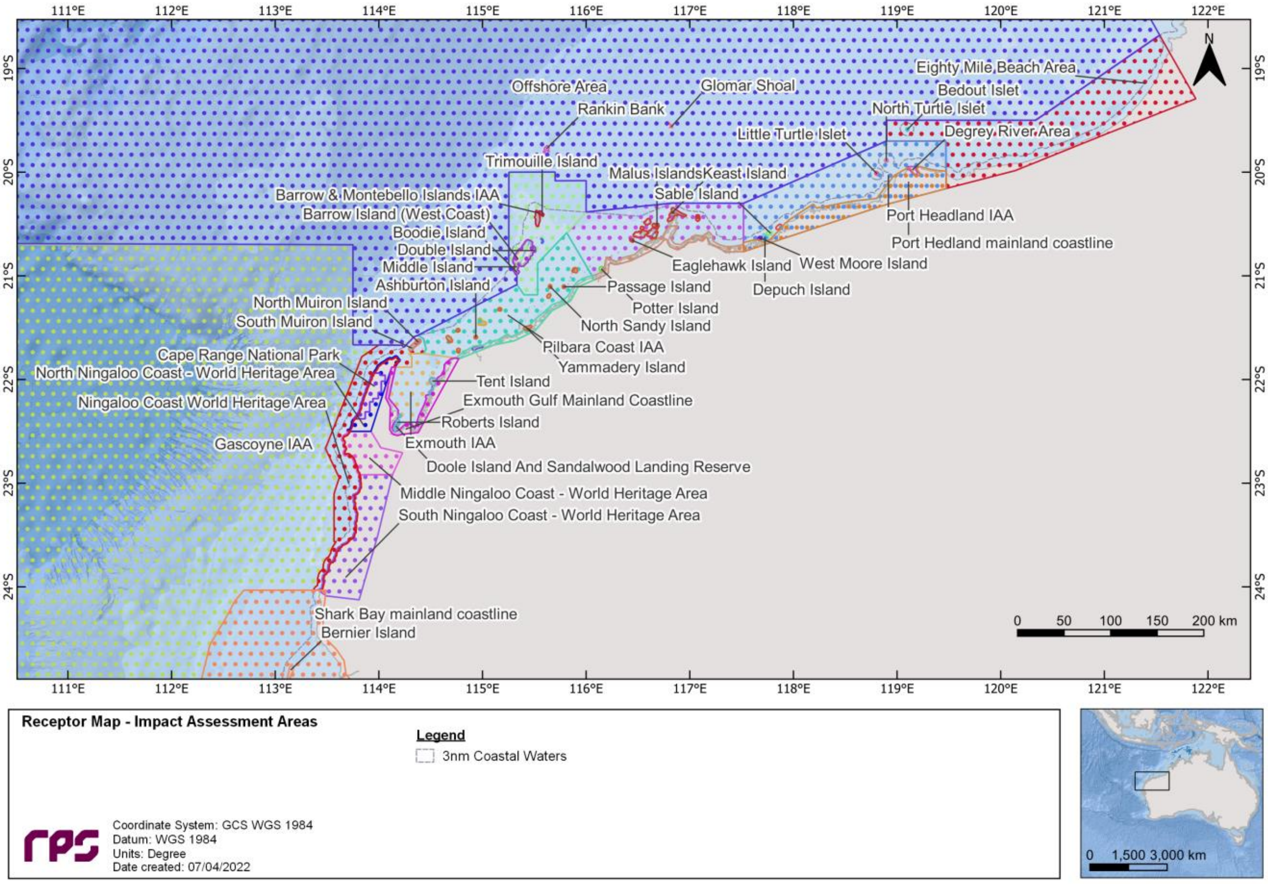


Figure 10.9 Receptor maps for Impact Assessment Areas (2 of 3).

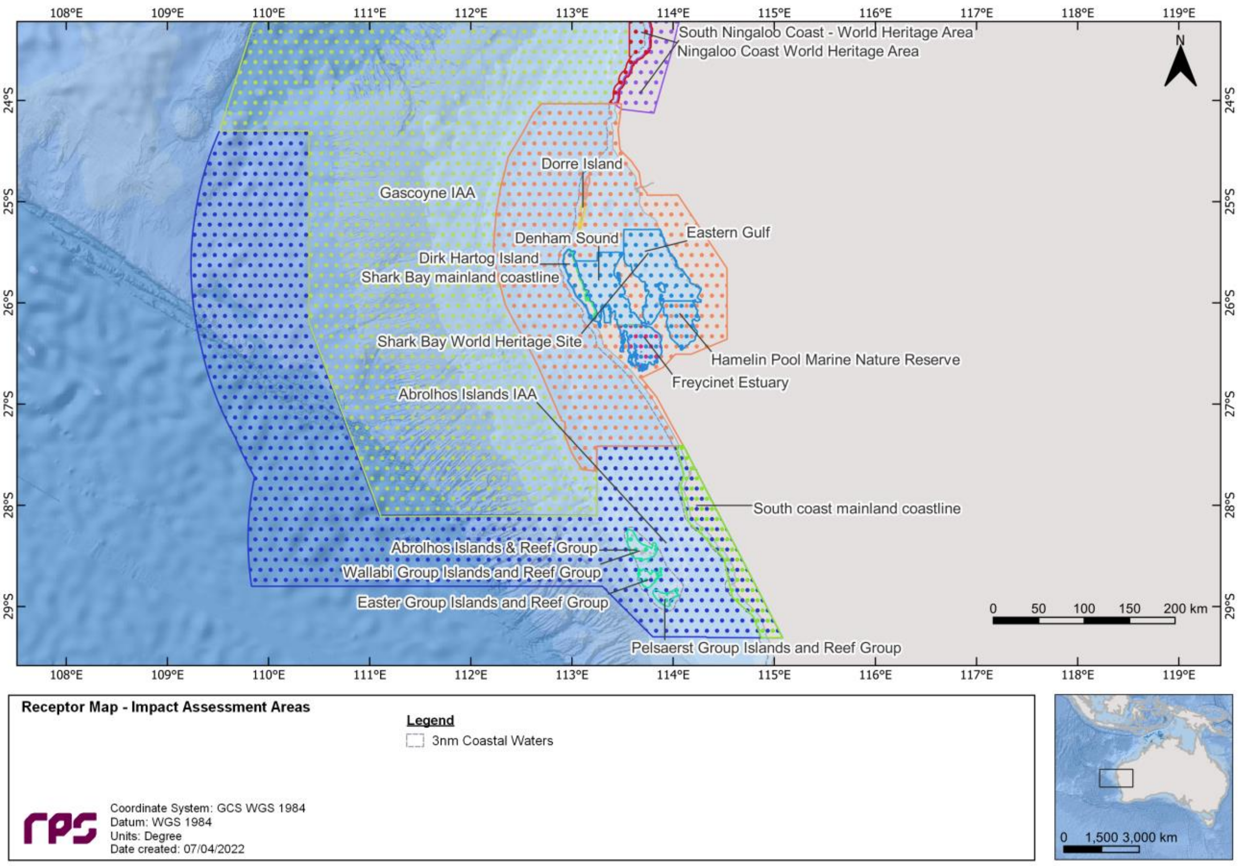


Figure 10.10 Receptor maps for Impact Assessment Areas (3 of 3).

11 RESULTS: CHANDON LOSS OF WELL CONTROL

This scenario examined a 469,260 stb (or 74,604 m^3) subsea release of condensate over 90 days, following a LOWC. A total of 300 spill simulations were run for each of the three seasons; summer (i.e. 100 spills per season) and tracked for 104 days.

Section 11.1 presents the seasonal (or stochastic) analysis results, while Section 11.2 presents the deterministic results.

11.1 Stochastic Analysis

11.1.1 Floating Condensate Exposure

Table 11.1 summarises the maximum distances from the release location to floating condensate exposure zones for each season. The maximum distance from the release location to the low (≥ 1 g/m^2) and moderate (≥ 10 g/m^2) thresholds was 102.9 km south (transitional) and 5.2 km west (transitional and winter), respectively.

No exposure was predicted at the high (≥ 50 g/m^2) threshold.

Table 11.2 summarises the potential floating condensate exposure to individual receptors during each season.

The Offshore Area IAA, Pygmy Blue Whale – Distribution BIA and Exmouth Plateau KEF, which the release location resides within, were the only receptors predicted to be exposed during all three seasons at the low and moderate thresholds. The probabilities for the low threshold was 100% for all seasons for these receptors. Probabilities of moderate exposure for these receptors ranged between 27% (winter) and 37% (summer and transitional).

Figure 11.1 to Figure 11.3 present the zones of floating condensate exposure for each season.

Table 11.1 Maximum distances and directions travelled from the release location to floating condensate exposure for each season and threshold, following a subsea LOWC at Chandon Well 1. The results were calculated from 100 spill trajectories per season.

Season	Distance and direction	Zones of potential floating condensate exposure		
		Low	Moderate	High
Summer	Max. distance from release site (km)	91.0	3.7	-
	Max. distance from release site (km) (99th percentile)	60.4	3.7	-
	Direction	West-northwest	North-northeast	-
Transitional	Max. distance from release site (km)	102.9	5.2	-
	Max. distance from release site (km) (99th percentile)	64.5	5.2	-
	Direction	Southwest	West	-
Winter	Max. distance from release site (km)	88.0	5.2	-
	Max. distance from release site (km) (99th percentile)	61.0	5.2	-
	Direction	West-northwest	West	-

Table 11.2 Summary of the potential floating condensate exposure to individual receptors, following a LOWC at Chandon Well 1. The results were calculated from 100 spill trajectories per season.

Receptor		Summer						Transitional						Winter					
		Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)			Probability of condensate exposure on the sea surface (%)			Minimum time before condensate exposure on the sea surface (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
BIA	Pygmy Blue Whale – Distribution*	100	37	-	0.5	4.46	-	100	37	-	0.5	1.21	-	100	27	-	0.5	2.67	-
EEZ	Australian Exclusive Economic Zone	100	37	-	0.5	4.46	-	100	37	-	0.5	1.21	-	100	27	-	0.5	2.67	-
IAA	Offshore Area*	100	37	-	0.5	4.46	-	100	37	-	0.5	1.21	-	100	27	-	0.5	2.67	-
KEF	Exmouth Plateau*	100	37	-	0.5	4.46	-	100	37	-	0.5	1.21	-	100	27	-	0.5	2.67	-

*The release location resides within the receptor boundaries.

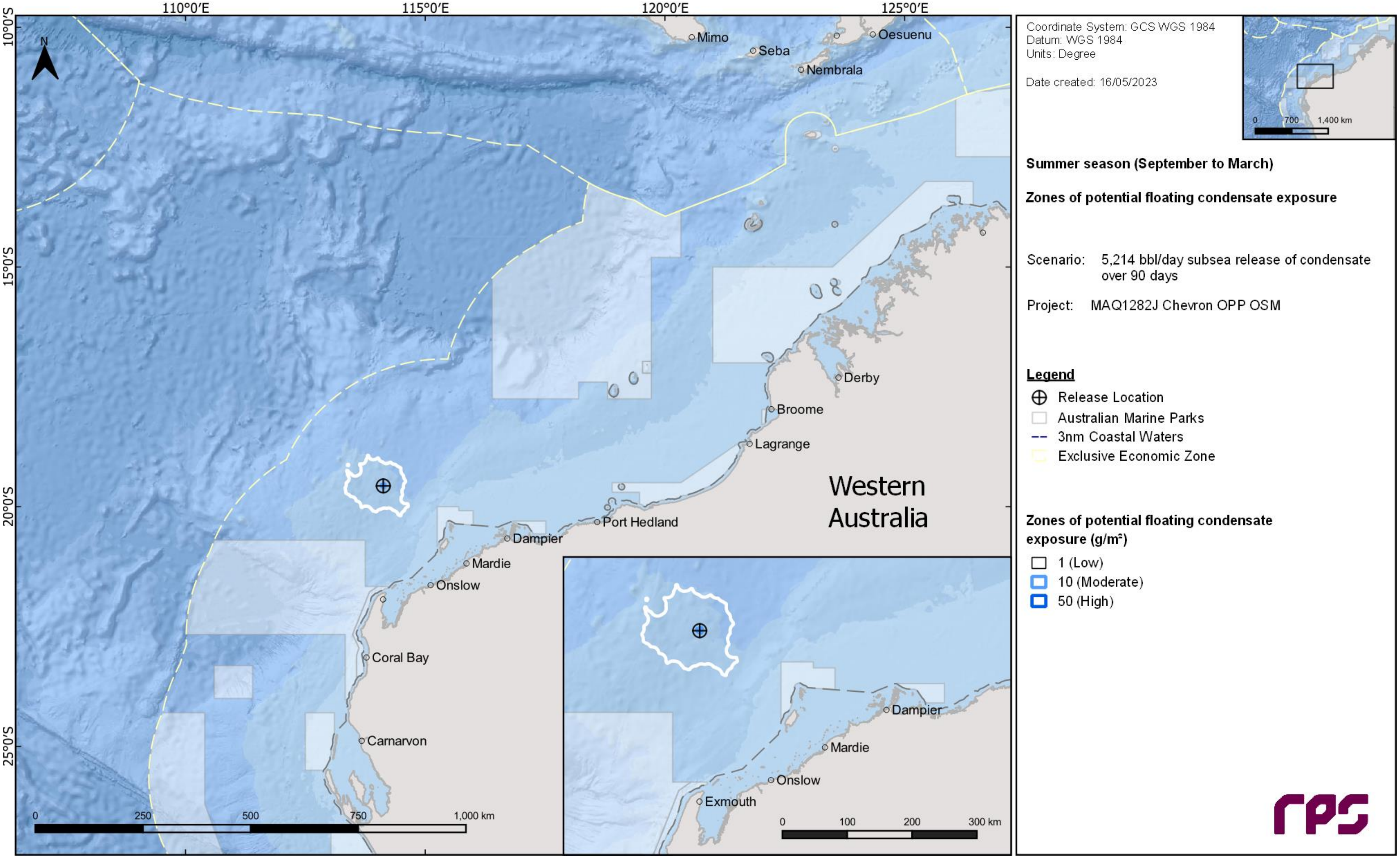


Figure 11.1 Zones of potential floating condensate exposure following a subsea LOWC at Chandon Well 1 during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

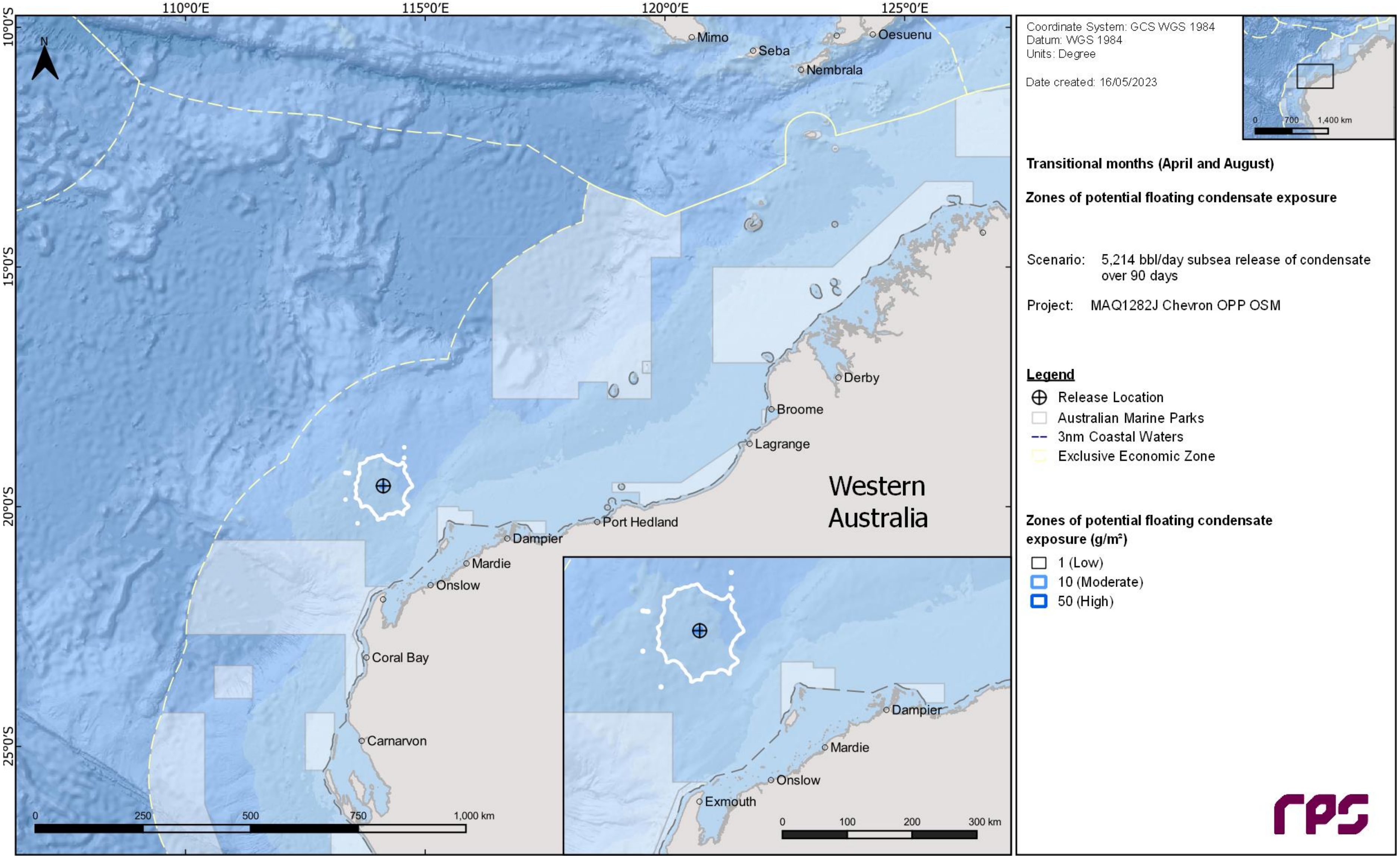


Figure 11.2 Zones of potential floating condensate exposure following a subsea LOWC at Chandon Well 1 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

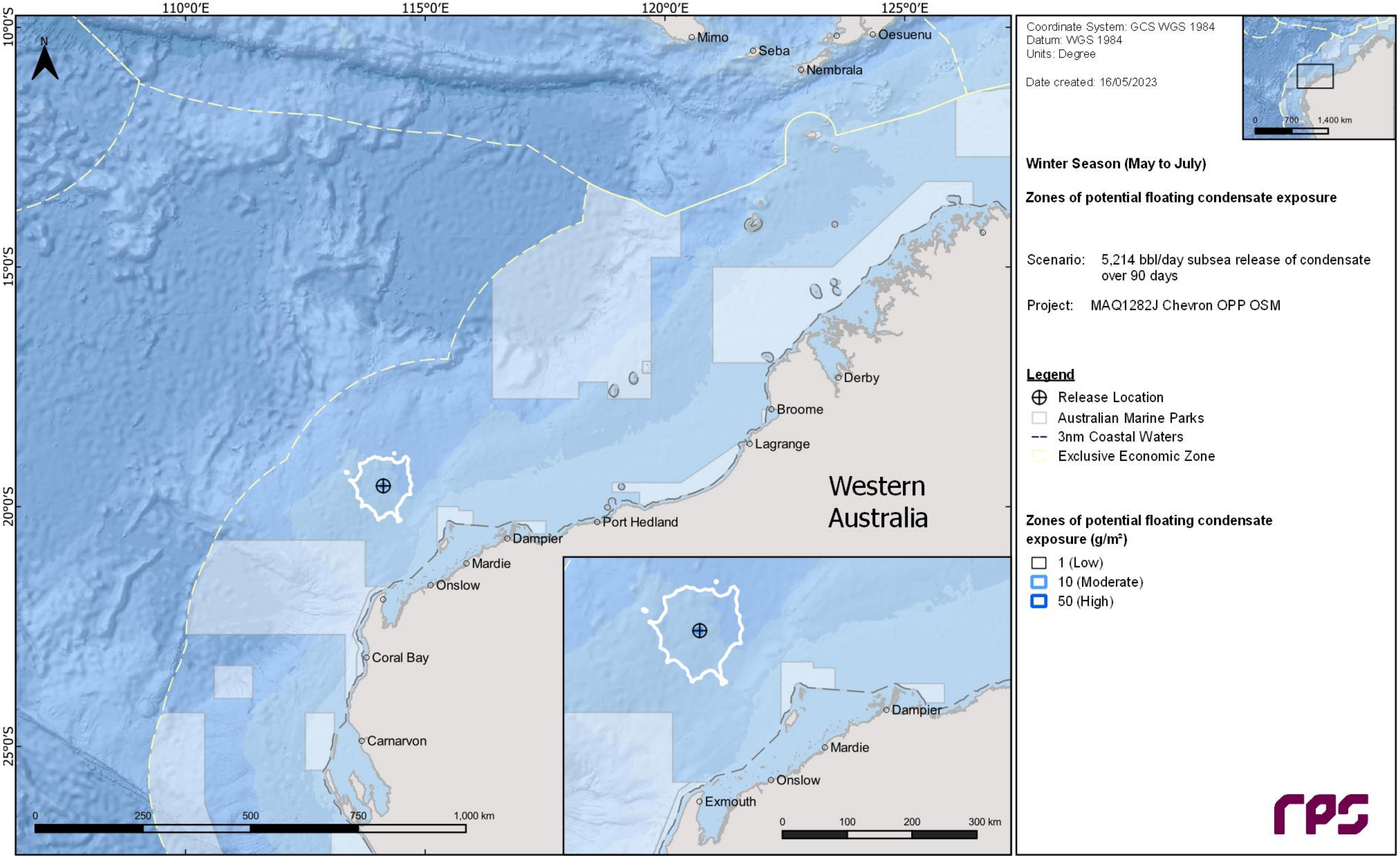


Figure 11.3 Zones of potential floating condensate exposure following a subsea LOWC at Chandon Well 1 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.2 Shoreline Accumulation

No shoreline accumulation was predicted for this scenario above the low reporting threshold (≥10 g/m^2) during any of the seasons modelled. Consequently, no results are reported.

11.1.3 Water Column Exposure

11.1.3.1 Dissolved Hydrocarbons

Table 11.3 summarises the maximum exposure to dissolved hydrocarbons and the probability for individual receptors in the 0-10 m depth layer.

The Offshore Area IAA and Pygmy Blue Whale – Distribution BIA, which the release location resides within, were the only receptors to be exposed at or above the low threshold exclusively in summer with 1% probability.

Figure 11.4 to Figure 11.5 illustrate the extent of the predicted dissolved hydrocarbon exposure in the 0-10 m depth layer for each season.

Table 11.3 Predicted probability and maximum dissolved hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at Chandon Well 1. The results were calculated from 100 spill simulations per season.

Receptor		Summer							Transitional							Winter						
		Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)			Maximum exposure to dissolved hydrocarbons (ppb)	Probability of exposure to dissolved hydrocarbons (%)			Minimum time before exposure to dissolved hydrocarbons (days)		
			Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High		Low	Mod.	High	Low	Mod.	High
BIA	Pygmy Blue Whale – Distribution*	20.4	1	-	-	0.75	1.5	-	2.5	-	-	-	1.08	2.83	-	3.3	-	-	-	0.79	0.88	-
EEZ	Australian Exclusive Economic Zone *	20.4	1	-	-	0.75	1.5	-	2.5	-	-	-	1.08	2.83	-	3.3	-	-	-	0.79	0.88	-
IAA	Offshore Area*	20.4	1	-	-	0.75	1.5	-	2.5	-	-	-	1.08	2.83	-	3.3	-	-	-	0.79	0.88	-
KEF	Exmouth Plateau*	20.4	1	-	-	0.75	1.5	-	2.5	-	-	-	1.08	2.83	-	3.3	-	-	-	0.79	0.88	-

*The release location resides within the receptor boundaries.

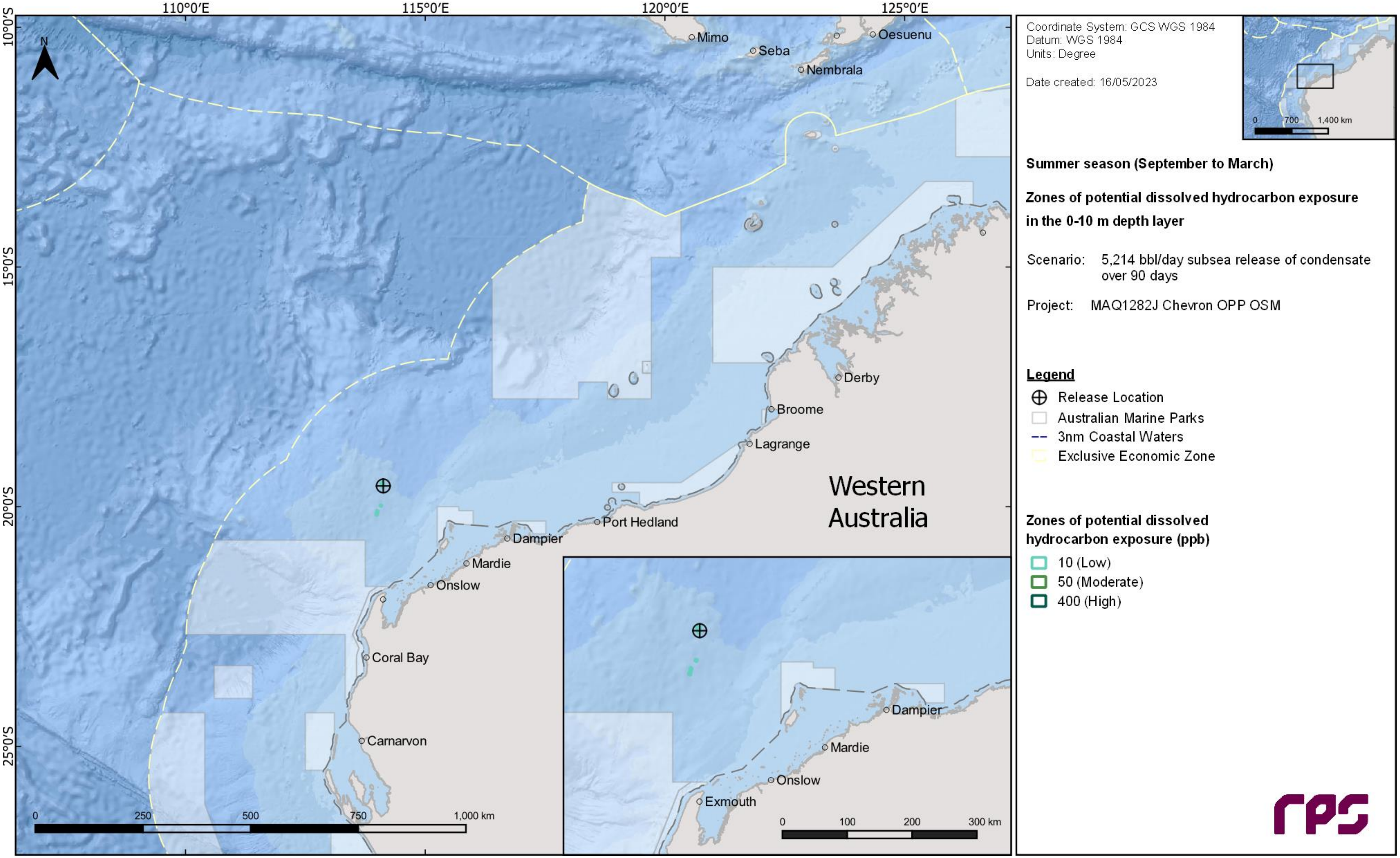


Figure 11.4 Zones of potential dissolved hydrocarbon exposure at 0-10 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

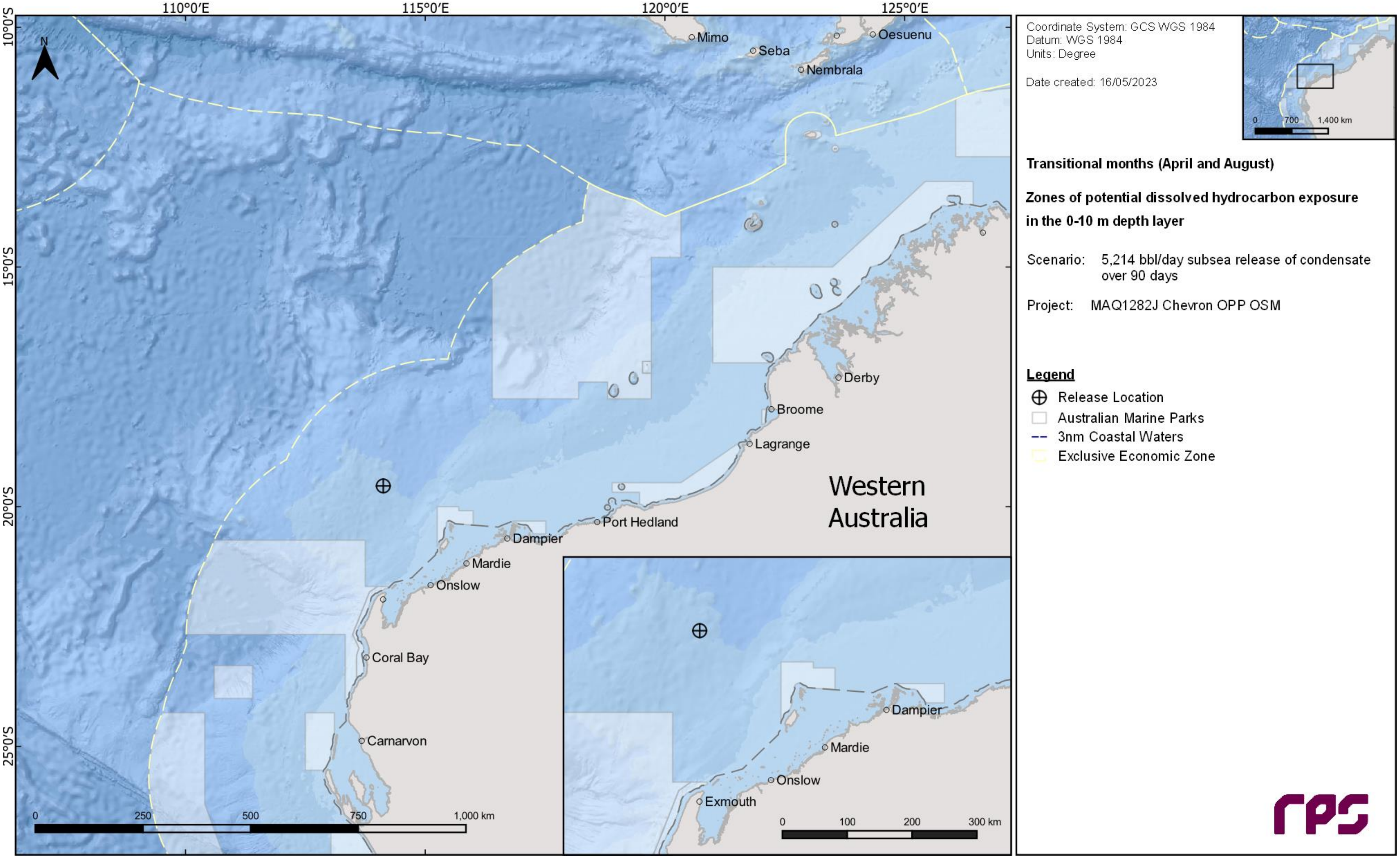


Figure 11.5 Zones of potential dissolved hydrocarbon exposure at 0-10 m following a subsea LOWC at Chandon Well 1 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

11.1.3.2 Entrained Hydrocarbons

Table 11.4 summarises the probability and minimum time before exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer, for each season, at the low (≥ 10 ppb) and high (≥ 100 ppb) thresholds.

A total of 16 BIAs were shown to be exposed at or above the low threshold during summer, compared to 11 and 8 during transitional and winter seasons respectively. Excluding the Pygmy Blue Whale - Distribution BIA, which the release location resides within, the highest probabilities of exposure were predicted for the Wedge-tailed Shearwater - Breeding BIA during summer (60%), transitional (61%) and winter (57%) conditions.

During summer, 5 AMPs were predicted to be exposed at, or above the low threshold, whilst only 3 were predicted to be exposed at the same threshold during transitional and winter conditions. The highest probabilities predicted occurred at the Gascoyne AMP (63% summer, 65% transitional and 68% winter). Furthermore, during summer conditions the Gascoyne AMP was shown to be exposed to entrained hydrocarbons at the high threshold (5%).

A total of 5 KEFs were shown to be exposed by entrained hydrocarbons at the low threshold, including the Exmouth Plateau KEF that the release site is located within. Excluding the Exmouth Plateau, probabilities of exposure ranged between 1–50%, 8–53% and 7–50%, for summer, transitional and winter, respectively.

Additionally, 6 IAA’s (including the Offshore IAA that the release site is located within), were shown to be exposed to entrained hydrocarbons at low threshold during summer season, compared to 3 during transitional and winter seasons. Excluding the Offshore IAA, the probabilities for each season ranged between 1–63%, 7–65% and 4–68% under summer, transitional and winter conditions, respectively.

Furthermore, the Rankin Bank RSB was shown to be exposed to entrained hydrocarbons at the low threshold only during the summer conditions and an 8% probability.

Figure 11.6 to Figure 11.8 illustrate the extent of the predicted entrained hydrocarbon exposure for the low and high thresholds in the 0-10 m depth layer for each season.

The same maps for the 10-20 m depth layer are presented in Figure 11.9 to Figure 11.11.

Table 11.4 Predicted probability and maximum entrained hydrocarbon exposure to individual receptors in the 0-10 m depth layer following a subsea LOWC at Chandon Well 1. The results were calculated from 100 spill simulations per season.

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
AMP	Argo-Rowley Terrace	47.6	12	-	22.29	-	25.6	7	-	41.17	-	24.7	4	-	53.04	-
	Carnarvon Canyon	13.1	1	-	101.42	-	14.2	8	-	61.92	-	14.2	3	-	40.83	-
	Gascoyne	115.8	63	5	5.25	22.13	109.2	65	2	4.29	45.21	81.6	68	-	6.25	-
	Montebello	22.4	8	-	8.83	-	1.6	-	-	-	-	3.4	-	-	-	-
	Ningaloo	10.1	1	-	85.42	-	8.9	-	-	-	-	6.7	-	-	-	-
BIA	Flatback Turtle - Internesting Buffer	31.6	15	-	8.08	-	35.4	12	-	40.29	-	34.3	20	-	11.29	-
	Flatback Turtle - Nesting	27.4	9	-	9	-	12.4	3	-	57.83	-	12.3	2	-	77.46	-
	Green Turtle - Internesting Buffer	17.6	5	-	10.5	-	6.1	-	-	-	-	6	-	-	-	-
	Green Turtle - Nesting	14.9	5	-	10.71	-	9.8	-	-	-	-	7.3	-	-	-	-
	Hawksbill Turtle - Internesting Buffer	29.5	5	-	10.42	-	11.2	1	-	71.33	-	8.9	-	-	-	-
	Hawksbill Turtle - Nesting	14.9	5	-	10.71	-	5.5	-	-	-	-	6.3	-	-	-	-
	Humpback Whale - Migration	58.7	15	-	8.21	-	38.1	14	-	44.04	-	39.3	8	-	68.92	-
	Little Tern - Resting	11.1	1	-	79.96	-	3.1	-	-	-	-	1.8	-	-	-	-
	Loggerhead Turtle - Internesting Buffer	29.5	3	-	52.29	-	11.2	1	-	71.33	-	8.9	-	-	-	-
	Loggerhead Turtle - Nesting	12.1	2	-	53.79	-	9.8	-	-	-	-	7.3	-	-	-	-
	Pygmy Blue Whale – Distribution*	654.6	100	99	0.04	0.17	589.8	100	100	0.04	0.17	590.2	100	99	0.04	0.17
	Pygmy Blue Whale - Foraging	97.3	23	-	14.13	-	27.3	23	-	16.67	-	24.8	15	-	21.21	-
	Roseate Tern - Breeding	88.5	12	-	24.58	-	12.8	2	-	45.38	-	9.8	-	-	-	-
	Wedge-tailed Shearwater - Breeding	112.5	60	4	3.88	22.58	89.8	61	-	3.08	-	99.3	57	-	5.38	-
	Whale Shark - Foraging	31.6	15	-	8.13	-	35.4	12	-	31.58	-	34.3	19	-	26.42	-
	White-tailed Tropicbird - Breeding	38.6	10	-	33.96	-	12	2	-	51.67	-	10.7	1	-	83.75	-
EEZ	Australian Exclusive Economic Zone *	654.6	100	99	0.04	0.17	589.8	100	100	0.04	0.17	590.2	100	99	0.04	0.17
	Christmas Island Exclusive Economic Zone	18.7	4	-	58.58	-	19.3	4	-	93.83	-	8.1	-	-	-	-
	Indonesian Exclusive Economic Zone	15	2	-	61.58	-	11.3	3	-	42.88	-	13.7	8	-	54.83	-
IAA	Argo-Rowley Terrace IAA	47.6	12	-	22.29	-	25.6	7	-	41.17	-	24.7	4	-	53.04	-
	Barrow & Montebello Islands IAA	22.4	8	-	8.83	-	1.6	-	-	-	-	3.4	-	-	-	-
	Gascoyne IAA	115.8	63	5	5.25	22.13	109.2	65	2	4.29	45.21	81.6	68	-	6.25	-
	Ningaloo Coast World Heritage Area	10.1	1	-	85.42	-	8.9	-	-	-	-	6.7	-	-	-	-
	Offshore Area*	654.6	100	99	0.04	0.17	589.8	100	100	0.04	0.17	590.2	100	99	0.04	0.17
	Rankin Bank	19.9	8	-	13.54	-	2.6	-	-	-	-	3.1	-	-	-	-
IMCRA	Northwest Shelf	28.2	15	-	8.63	-	25.9	6	-	31.67	-	24.2	11	-	63.17	-
	Pilbara (offshore)	31.6	10	-	8.13	-	33	12	-	44.29	-	34.3	19	-	26.38	-
KEF	Ancient coastline at 125 m depth contour	29.1	15	-	8.25	-	29.8	8	-	40.83	-	30.3	7	-	68.92	-
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	98.5	45	-	11.71	-	61.3	44	-	5.08	-	55.2	37	-	9.33	-
	Commonwealth waters adjacent to Ningaloo Reef	10.1	1	-	85.42	-	8.9	-	-	-	-	6.7	-	-	-	-
	Continental Slope Demersal Fish Communities	115	50	1	3.58	22.58	122.9	53	5	3.21	39.83	119.8	50	5	7.5	71.63

Receptor		Summer					Transitional					Winter				
		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)		Maximum exposure to entrained hydrocarbons (ppb)	Probability of exposure to entrained hydrocarbons (%)		Minimum time before exposure to entrained hydrocarbons (Days)	
			Low	High	Low	High		Low	High	Low	High		Low	High	Low	High
	Exmouth Plateau*	654.6	100	99	0.04	0.17	589.8	100	100	0.04	0.17	590.2	100	99	0.04	0.17
RSB	Rankin Bank	19.9	8	-	13.54	-	2.8	-	-	-	-	3.1	-	-	-	-

*The release location resides within the receptor boundaries.

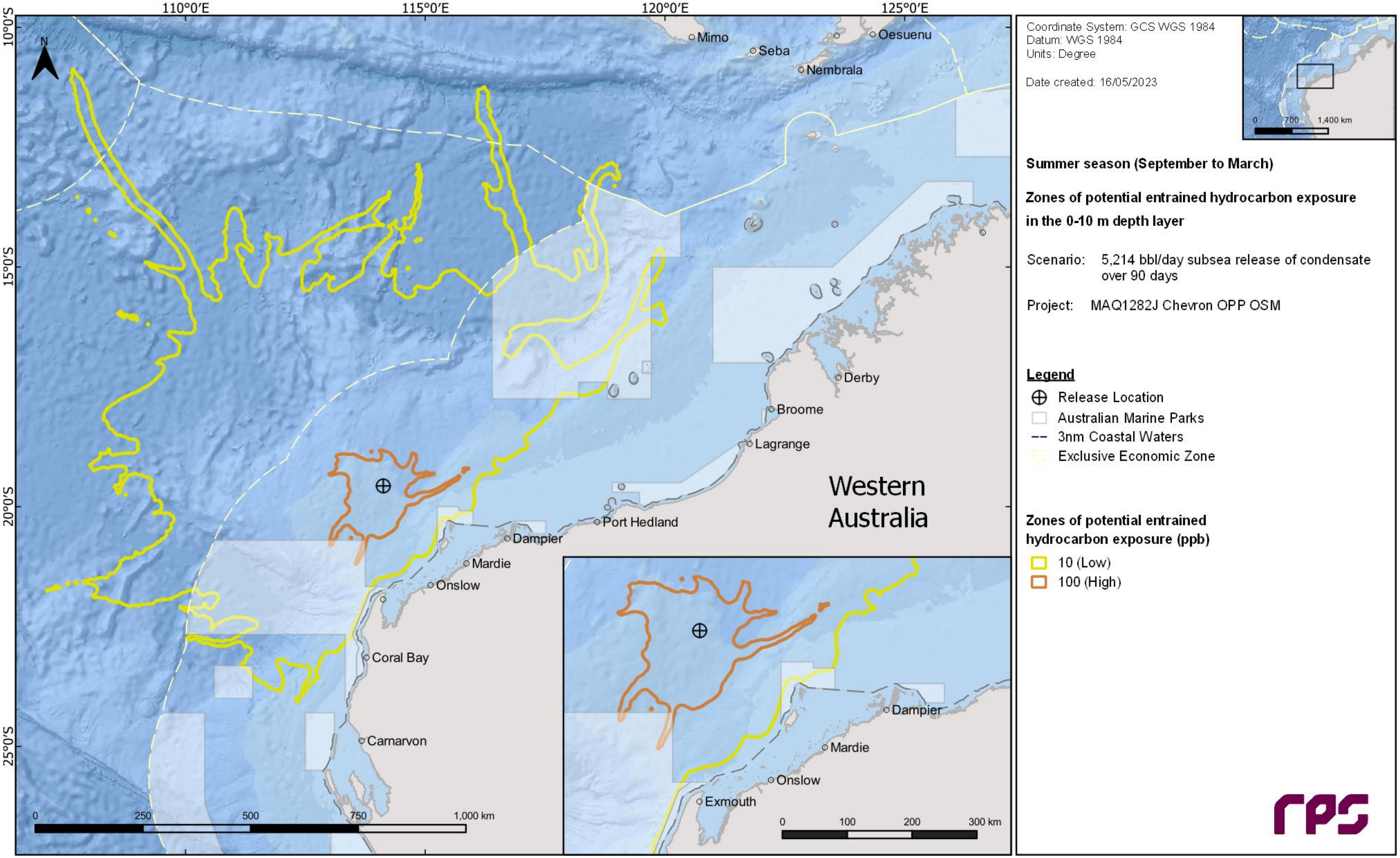


Figure 11.6 Zones of potential entrained hydrocarbon exposure at 0-10 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

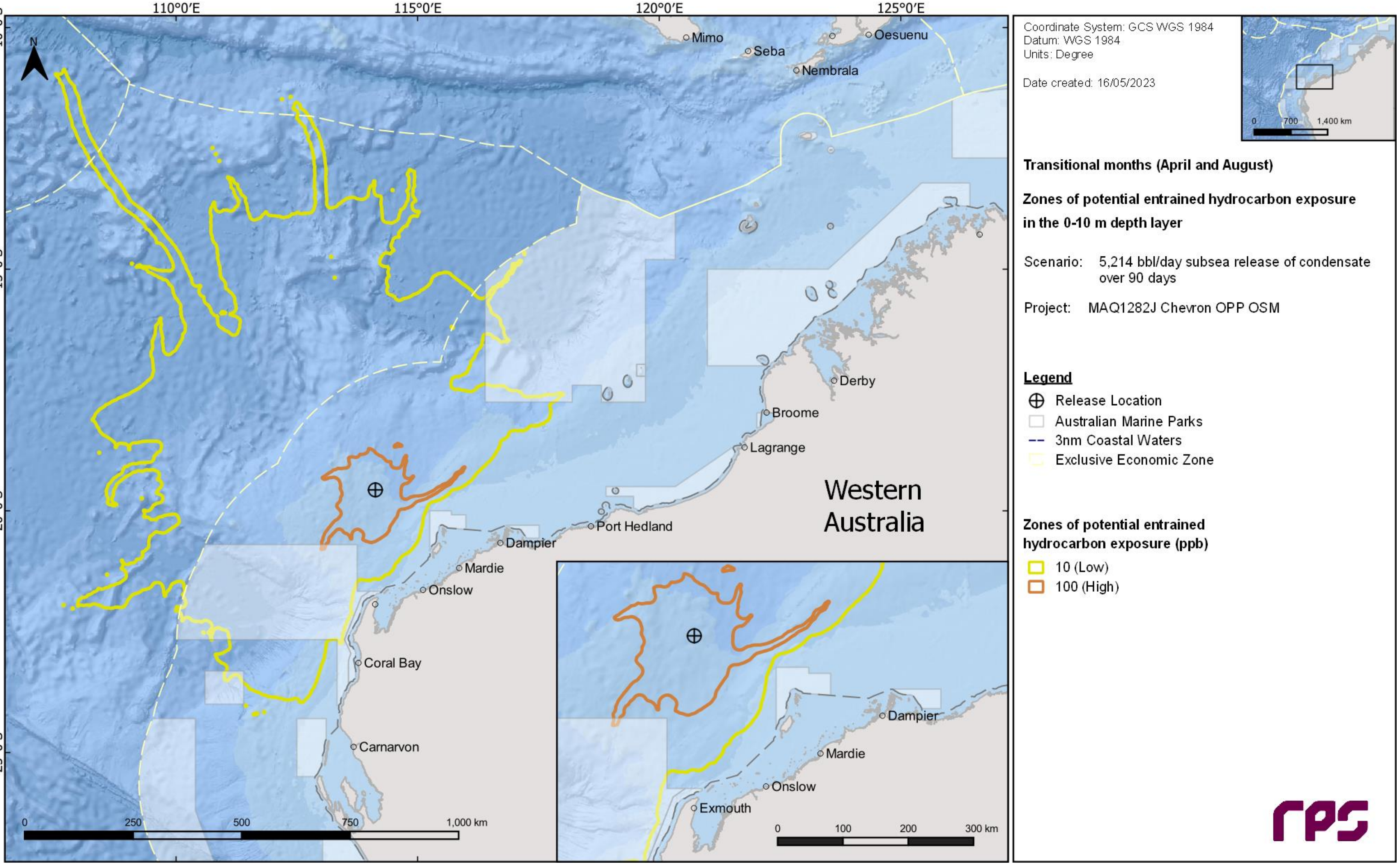


Figure 11.7 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Chandon Well 1 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

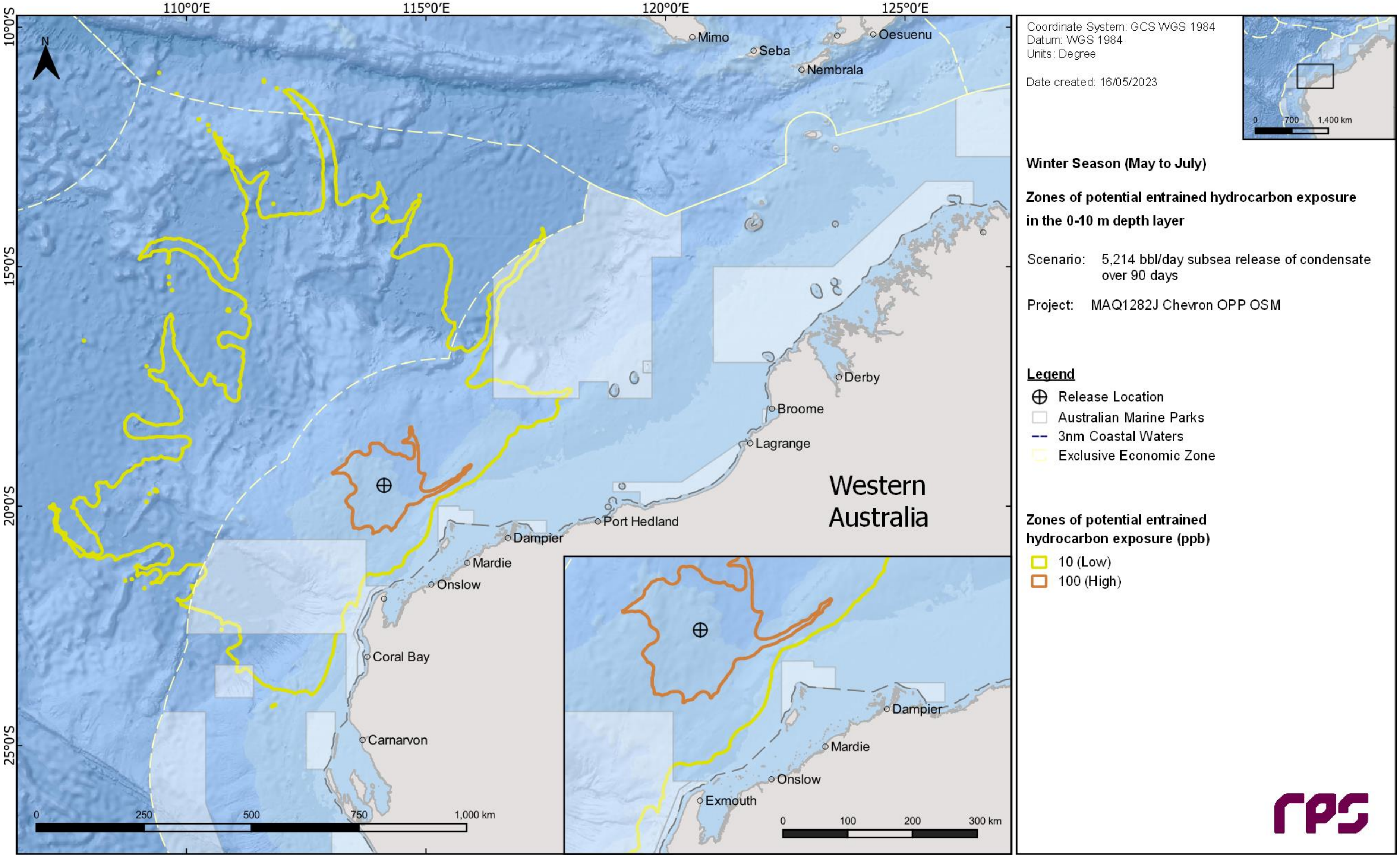


Figure 11.8 Zones of potential entrained hydrocarbon exposure at 0-10 m following a subsea LOWC at Chandon Well 1 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

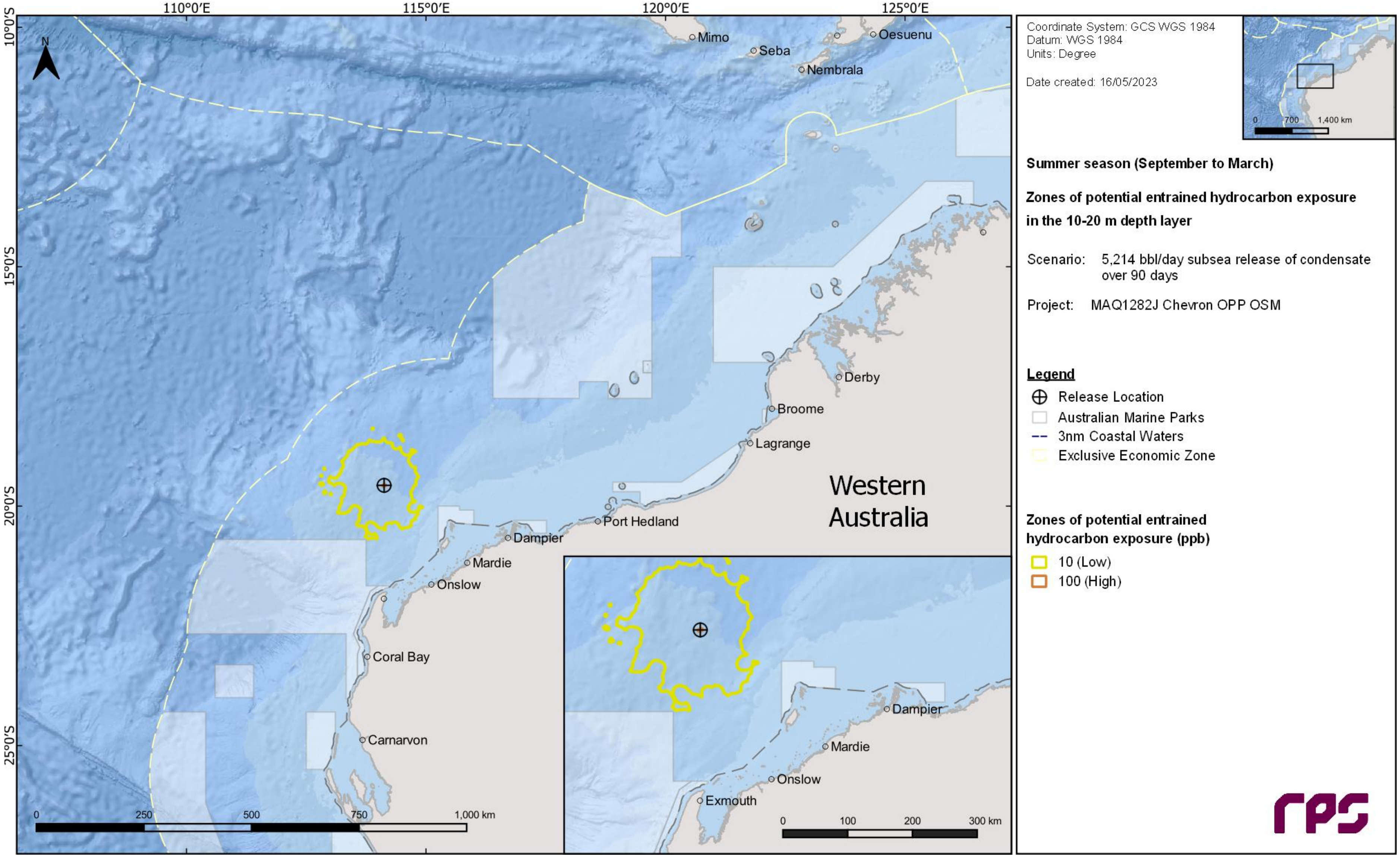


Figure 11.9 Zones of potential entrained hydrocarbon exposure at 10-20 m during summer (September to the following March) wind and current conditions. The results were calculated from 100 spill simulations.

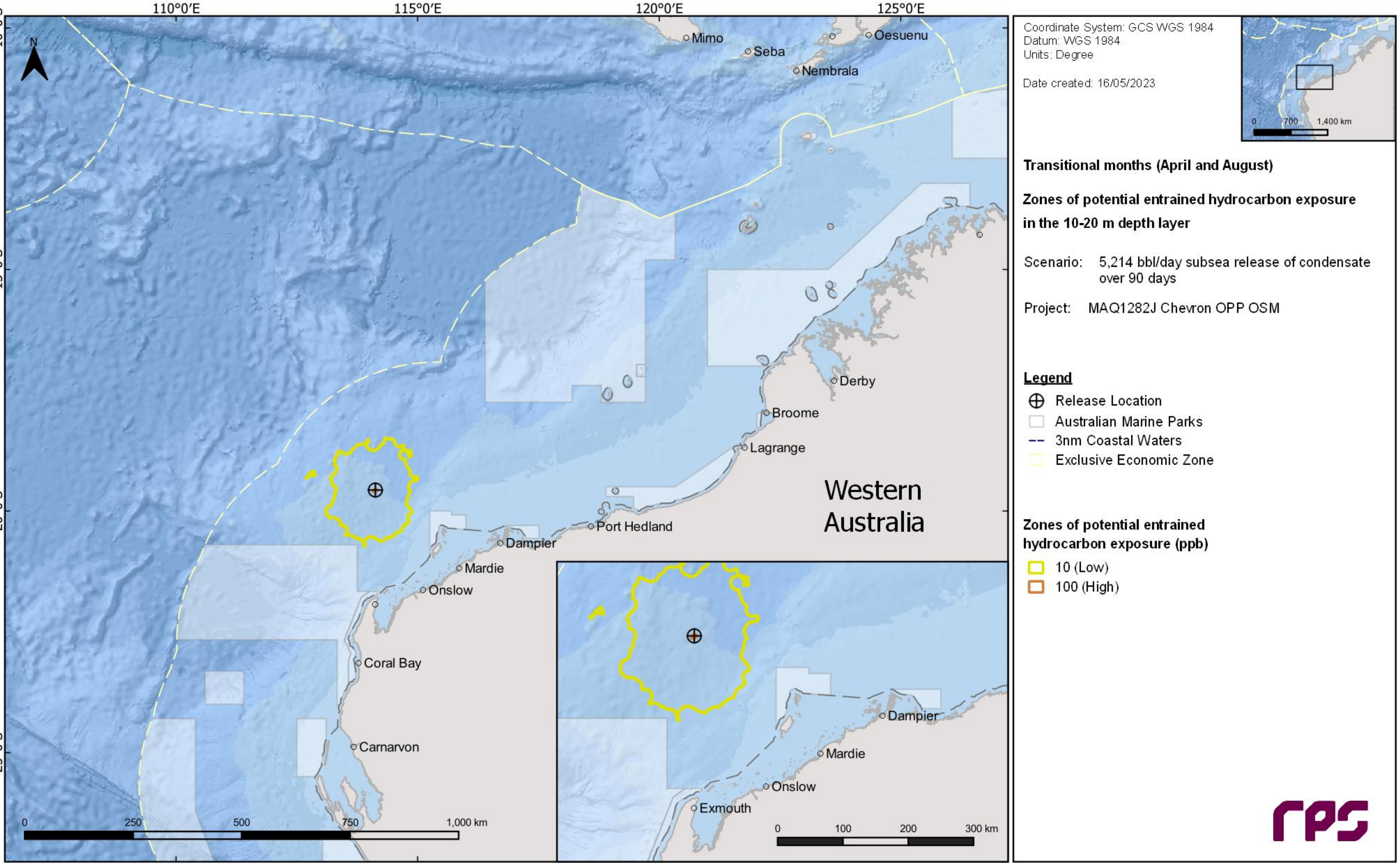


Figure 11.10 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Chandon Well 1 during transitional (April and August) wind and current conditions. The results were calculated from 100 spill simulations.

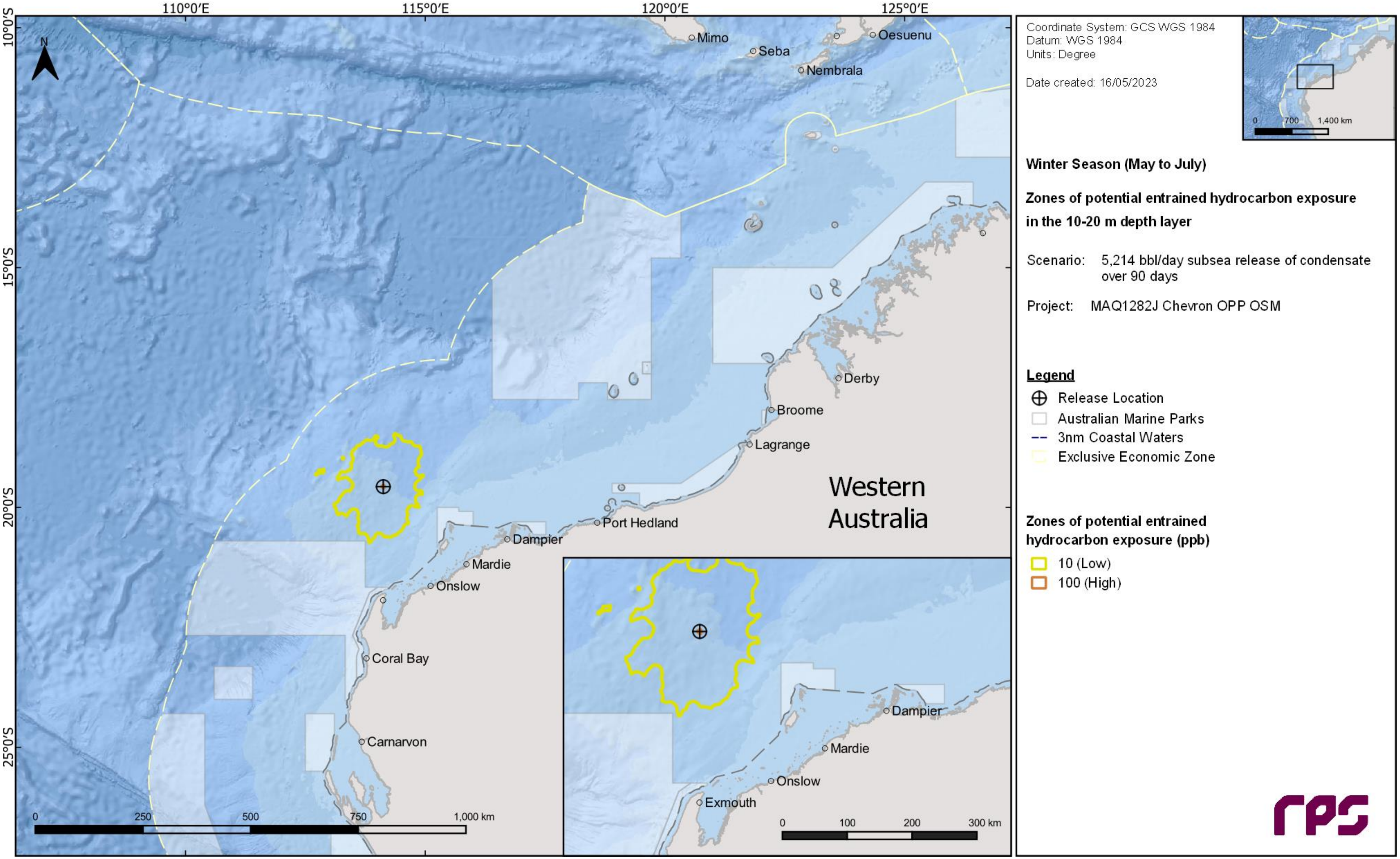


Figure 11.11 Zones of potential entrained hydrocarbon exposure at 10-20 m following a subsea LOWC at Chandon Well 1 during winter (May to July) wind and current conditions. The results were calculated from 100 spill simulations.

11.2 Deterministic Analysis

The deterministic analysis presented below, are based on simulations that resulted in the largest swept area of floating condensate above 10 g/m^2 (see Section 11.2.1), and the largest area of entrained hydrocarbons above 100 ppb (see Section 11.2.2).

Table 11.5 presents a summary of all deterministic analysis criteria and the corresponding values at the assessed thresholds.

Interpretation of the deterministic analysis result table and timeseries plots:

The summary deterministic analysis results presented in the table below should be interpreted as **maximum values**, representing the total volume or swept area exposed by floating or in-water hydrocarbons throughout the entire simulation duration. In this particular case, the simulation showed that a maximum of 793 km^2 was exposed to floating oil above the low threshold over a period of 104 days.

However, it's important to note that the timeseries plots present **peak values** at specific points in time. For example, when considering shoreline volume, the peak value in the timeseries plot does not account for oil that may have reached the shore earlier in the simulation but was subsequently lost through evaporation or other weathering processes.

Continuing with the previous example, the timeseries plot indicates that the peak floating oil swept area above the low threshold reached 40 km^2. This value represents the highest swept area recorded at a single point in time during the simulation.

Table 11.5 Summary of the deterministic analysis following a subsea LOWC at Chandon Well 1.

Variable	Threshold	Deterministic Analysis Criteria	
		Largest swept area of floating condensate above 10 g/m^2	Largest area of entrained hydrocarbons above 100 ppb
Season		Transitional	Winter
Run Number		41	57
Floating Oil (km^2)	1 g/m^2	793	1,012
	10 g/m^2	**10**	-
	50 g/m^2	-	-
Shoreline Length (km)	10 g/m^2	-	-
	100 g/m^2	-	-
	1,000 g/m^2	-	-
Minimum Time (days)		-	-
Maximum Volume (m^3)		-	-
Entrained Area (km^2)	10 ppb	98,614	99,261
	100 ppb	3,030	**6,094**
Dissolved Area (km^2)	10 ppb	9	-
	50 ppb	-	-
	400 ppb	-	-
Start Date		28 April 2015	25 June 2011

11.2.1 Deterministic Case: Largest swept area of floating condensate above 10 g/m^2

The deterministic simulation that resulted in the largest swept area of floating condensate above 10 g/m^2 (moderate threshold) was identified as run number 41 during the transitional period.

Figure 11.12 presents the extent of the predicted floating condensate exposure zones on the sea surface (swept area) and shoreline accumulation over the entire 104-day simulation.

Figure 11.13 displays the time series of the swept area of low (≥ 1 g/m^2), moderate (≥ 10 g/m^2) and high (≥ 50 g/m^2) floating condensate over the 104-day simulation.

Figure 11.14 presents the fates and weathering for the corresponding simulation and Table 11.6 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.6 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a subsea LOWC at Chandon Well 1.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	234	52	0
Entrained (m^3)	5,305	90	2,817
Dissolved (m^3)	84	82	3
Evaporation (m^3)	47,176	104	47,176
Decay (m^3)	25,177	104	25,177
Ashore (m^3)	0	0	0

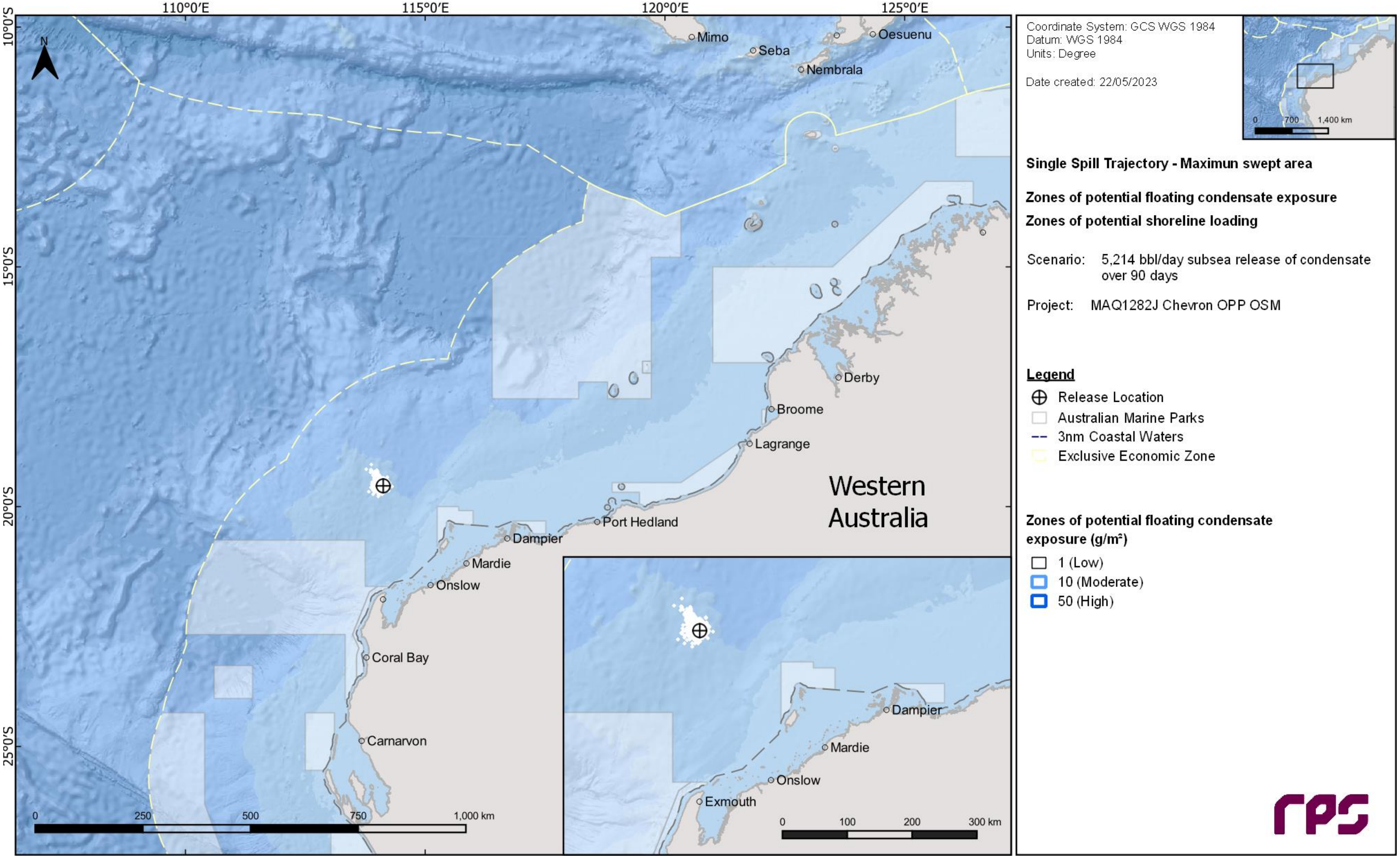


Figure 11.12 Zones of potential floating condensate exposure and shoreline accumulation over the entire 104 days, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at Chandon Well 1.

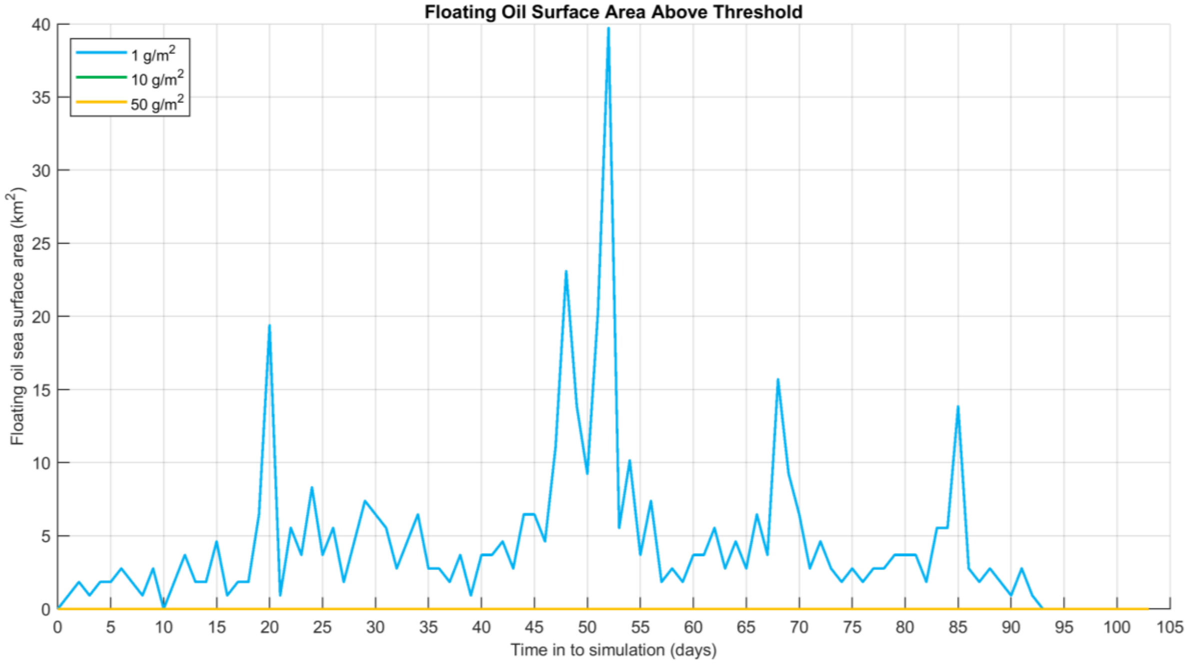


Figure 11.13 Predicted area of floating condensate exposure for each threshold, for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at Chandon Well 1.

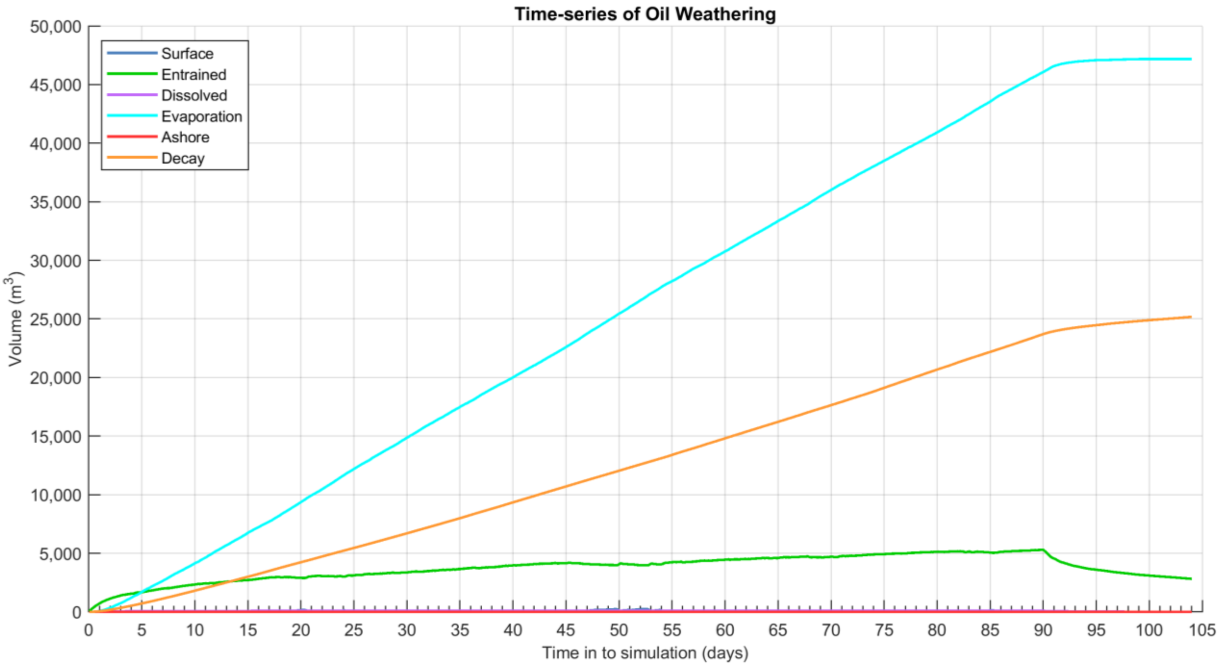


Figure 11.14 Predicted weathering and fates for the simulation with the largest swept area of floating condensate above 10 g/m^2 following a LOWC at Chandon Well 1.

11.2.2 Deterministic Case: Largest area of entrained hydrocarbons above 100 ppb

The deterministic simulation that resulted in the largest area of entrained hydrocarbons above 100 ppb (high threshold) was identified as run number 57 during the winter period.

Figure 11.15 presents the extent of the predicted entrained hydrocarbon exposure zones over the entire 104-day simulation.

Figure 11.16 displays the time series of the area of entrained hydrocarbons at the low (≥10 ppb) and high (≥100 ppb) thresholds over the 104-day simulation.

Figure 11.17 presents the fates and weathering for the corresponding single spill trajectory and Table 11.7 summarises the peak volumes and times of occurrence for each oil phase and volumes at the end of the 104-day simulation.

Table 11.7 Summary of peak volumes and times of occurrence for each oil phase and the volumes at the conclusion of the simulation (day 104), for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chandon Well 1.

Exposure Metrics	Peak Volume	Day of Occurrence	Volume at day 104
Surface (m^3)	298	51	0
Entrained (m^3)	5,025	89	2,684
Dissolved (m^3)	84	68	3
Evaporation (m^3)	47,918	104	47,918
Decay (m^3)	24,575	104	24,575
Ashore (m^3)	0	0	0

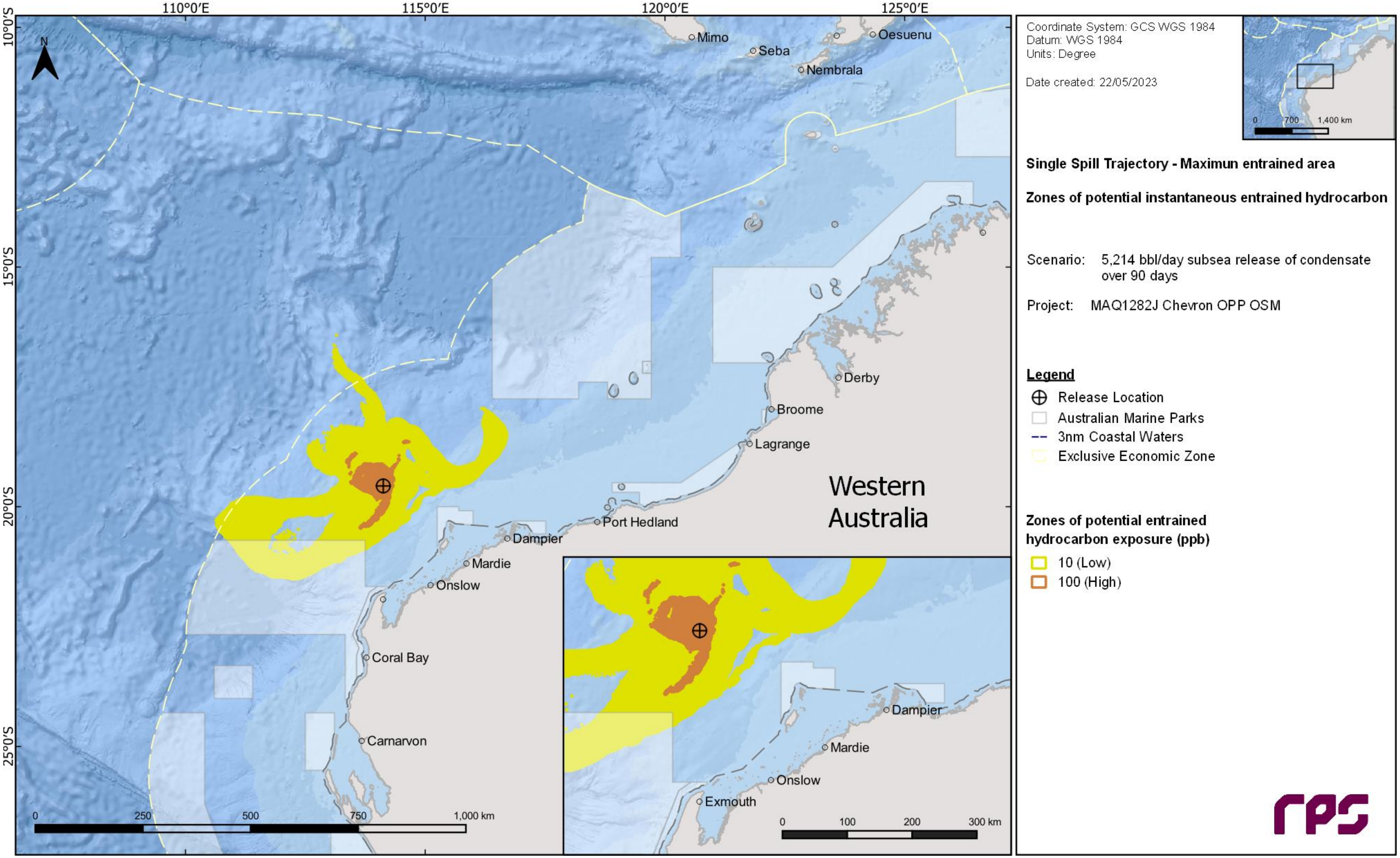


Figure 11.15 Zones of potential entrained hydrocarbon exposure over the entire 104 days, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chandon Well 1.

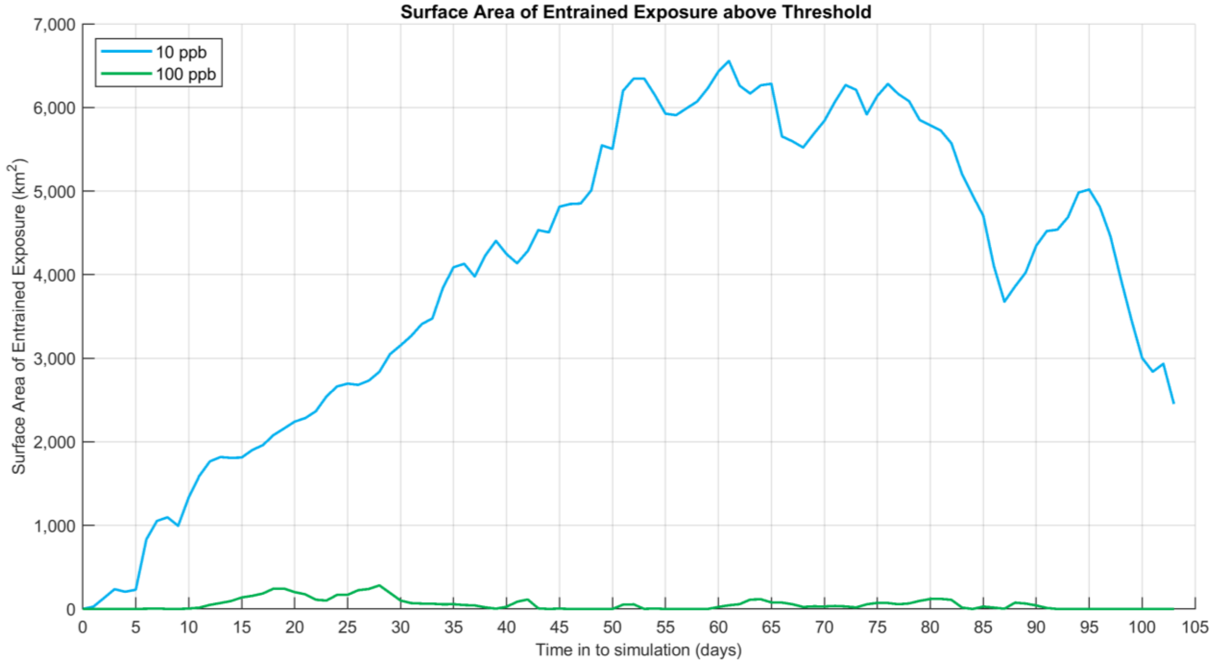


Figure 11.16 Time series of the area of entrained hydrocarbons for each threshold, for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chandon Well 1.

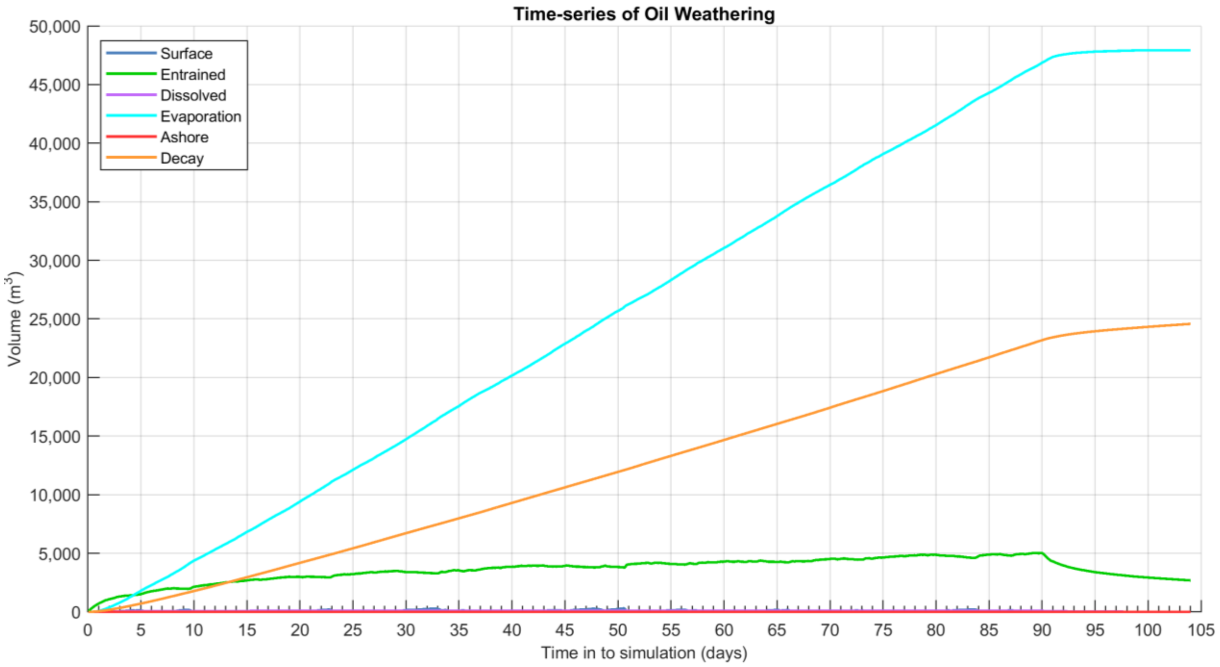


Figure 11.17 Predicted weathering and fates graph for the simulation with the largest area of entrained hydrocarbons above 100 ppb following a subsea LOWC at Chandon Well 1.

12 REFERENCES

American Society for Testing and Materials (ASTM) 2013, 'F2067-13 Standard Practice for Development and Use of Oil-Spill Trajectory Models', ASTM International, West Conshohocken (PA).

Andersen, OB 1995, 'Global ocean tides from ERS 1 and TOPEX/POSEIDON altimetry', *Journal of Geophysical Research: Oceans*, vol. 100, no. C12, pp. 25249–25259.

Anderson JW, Neff JM, Cox BA, Tatem HE & Hightower GM 1974, 'Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish', *Marine Biology*, vol. 27, no. 1, pp. 75–88.

Anderson JW, Riley R, Kiesser S & Gurtisen J 1987, 'Toxicity of dispersed and undispersed Prudhoe Bay crude oil fractions to shrimp and fish', Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 235–240.

Applied Science Associates (ASA) 2011, OILMAP-DEEP: Blowout Plume Model Technical Manual, Applied Science Associates Inc, South Kingstown, USA.

Asia-Pacific ASA 2010, 'Montara well release monitoring study S7.2. Oil fate and effects assessment: modelling of chemical dispersant operation', Prepared for PTTEP Australasia.

Australian Maritime Safety Authority (AMSA) 2014, 'Identification of oil on water: Aerial observations and identification guide', viewed 4 June 2020, https://www.amsa.gov.au/sites/default/files/2014-01-mp-amsa22-identification-oil-on-water.pdf

Australian Maritime Safety Authority (AMSA) 2015, 'Australian Maritime Safety Authority Technical Guideline for the Preparation of Marine Pollution Contingency Plans for Marine and Coastal Facilities Australian Maritime Safety Authority', viewed 20 June 2017, https://www.amsa.gov.au/forms-and-publications/Publications/AMSA413_Contingency_Planning_Guidelines.pdf

Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, 'Australian and New Zealand Guidelines for Fresh and Marine Water', Australian & New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Becker, JJ, Sandwell, DT, Smith, WHF, Braud, J, Binder, B, Depner, J, Fabre, D, Factor, J, Ingalls, S, Kim, S-H, Ladner, R, Marks, K, Nelson, S, Pharaoh, A, Trimmer, R, Von Rosenberg, J, Wallace, G & Weatherall, P 2009, 'Global bathymetry and evaluation data at 30 arc seconds resolution: SRTM30_PLUS', *Marine Geodesy*, vol. 32, no. 4, pp. 355–371.

Belore, UC 2014, Subsea chemical dispersant research. Proceedings of the 37th AMOP Technical Seminar on Environmental Contamination and Response, Environmental Canada, Canmore, Alberta, Canada pp 618–650.

Blum DJ & Speece RE 1990, 'Determining chemical toxicity to aquatic species', *Environmental Science & Technology*, vol. 24, no. 3, pp. 284–293.

Bonn Agreement 2009, 'Bonn Agreement aerial operations handbook, 2009 - Publication of the Bonn Agreement', London, viewed 13 January 2015, http://www.bonnagreement.org/site/assets/files/3947/ba-aoh_revision_2_april_2012.pdf.

Brandvik, PJ, Johansen, O, Leirvik, F, Farooq, U & Daling PS 2013, 'Droplet Breakup in subsurface oil releases – Part 1: Experimental study of droplet breakup and effectiveness of dispersant injection', *Marine Pollution Bulletin*, vol. 73, no. 1, pp 319–326.

Brandvik, PJ, Johansen, O, Farooq, U, Angell, G & Leirvik F 2014, 'Sub-surface oil releases – Experimental study of droplet distributions and different dispersant injection techniques- version 2', A scaled experimental approach using the SINTEF Tower basin. SINTEF report no: A25122. Trondheim Norway 2014. ISBN: 9788214057393

Carls, MG, Holland, L, Larsen, M, Collier, TK, Scholz, NL & Incardona, JP 2008, 'Fish embryos are damaged by dissolved PAHs, not oil particles', *Aquatic toxicology*, 88(2), pp.121–127.

Chassignet, EP, Hurlburt, HE, Smedstad, OM, Halliwell, GR, Hogan, PJ, Wallcraft, AJ, Baraille, R & Bleck, R 2007, 'The HYCOM (hybrid coordinate ocean model) data assimilative system', *Journal of Marine Systems*, vol. 65, no. 1, pp. 60–83.

Chassignet, E, Hurlburt, H, Metzger, E, Smedstad, O, Cummings, J & Halliwell, G 2009, 'U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)', *Oceanography*, vol. 22, no. 2, pp. 64–75.

Condie, SA., & Andrewartha, JR 2008, 'Circulation and connectivity on the Australian Northwest Shelf', *Continental Shelf Research*, 28, 1724–1739.

Davies, AM 1977a, 'The numerical solutions of the three-dimensional hydrodynamic equations using a B-spline representation of the vertical current profile', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 1–25.

Davies, AM 1977b, 'Three-dimensional model with depth-varying eddy viscosity', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 27–48.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2007, 'Characterisation of the marine environment in the north marine region', Marine Division, Department of the environment, water heritage and the arts.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2008, 'The North-West Marine Bioregional Plan - Bioregional Profile', Retrieved February 12, 2013, from Australian Government Department of Environment, Water, Heritage and the Arts: http://www.environment.gov.au/coasts/mbp/publications/north-west/pubs/bioregional-profile.pdf

French, D, Reed, M, Jayko, K., Feng, S, Rines, H & Pavignano, S 1996, 'The CERCLA Type A Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME), Technical Documentation, Vol. I - Model Description', Office of Environmental Policy and Compliance, U.S. Department of the Interior. Washington, D.C.: Contract No. 14-0001-91-C-11.

French, D, Schuttenberg, H & Isaji, T 1999, 'Probabilities of oil exceeding thresholds of concern: examples from an evaluation for Florida Power and Light', Proceedings of the 22nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Alberta, pp. 243–270.

French-McCay, DP 2002, 'Development and application of an oil toxicity and exposure model, OilToxEx', *Environmental Toxicology and Chemistry*, vol. 21, no. 10, pp. 2080–2094.

French-McCay, DP 2003, 'Development and application of damage assessment modelling: example assessment for the North Cape oil spill', *Marine Pollution Bulletin*, vol. 47, no. 9, pp. 9–12.

French-McCay, DP 2004, 'Spill impact modelling: development and validation', *Environmental Toxicology and Chemistry*, vol. 23, no.10, pp. 2441–2456.

French-McCay, DP 2009, 'State-of-the-art and research needs for oil spill impact assessment modelling', Proceedings of the 32nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 601–653.

French-McCay, D, Rowe, JJ, Whittier, N, Sankaranarayanan, S, & Etkin, DS 2004, 'Estimate of potential impacts and natural resource damages of oil', *Journal of Hazardous Materials*, vol. 107, no. 1, pp. 11–25.

French-McCay, D, Whittier, N, Dalton, C, Rowe, J, Sankaranarayanan, S & Aurand, D 2005a, 'Modeling the fates of hypothetical oil spills in Delaware, Florida, Texas, California, and Alaska waters, varying response options including use of dispersants', Proceedings of the International Oil Spill Conference 2005, American Petroleum Institute, Washington DC, paper 399.

French-McCay, D, Whittier, N, Rowe, J, Sankaranarayanan, S, Kim, H-S & Aurand, D 2005b, 'Use of probabilistic trajectory and impact modeling to assess consequences of oil spills with various response strategies,' Proceedings of the 28th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, pp. 253–271.

French-McCay, D, Reich, D, Rowe, J, Schroeder, M & Graham, E 2011, 'Oil spill modeling input to the offshore environmental cost model (OECM) for US-BOEMRE's spill risk and costs evaluations', Proceedings of the 34th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Reich, D, Michel, J, Etkin, DS, Symons, L, Helton, D, & Wagner J 2012, 'Oil spill consequence analysis of potentially-polluting shipwrecks', Proceedings of the 35th Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa.

French-McCay, D, Jayko, K, Li, Z, Horn, M, Kim, Y, Isaji, T, Crowley, D, Spaulding, M, Decker, L, Turner, C, Zamorski, S, Fontenault, J, Schmmkler, R & Rowe, J 2015, 'Technical Reports for Deepwater Horizon Water Column Injury Assessment: WC_TR.14: Modeling Oil Fate and Exposure Concentrations in the Deepwater Plume and Rising Oil Resulting from the Deepwater Horizon Oil Spill', RPS ASA, South Kingston, Rhode Island.

Gordon, R 1982, 'Wind driven circulation in Narragansett Bay' PhD thesis, Department of Ocean Engineering, University of Rhode Island.

Grant, DL, Clarke, PJ & Allaway, WG 1993, 'The response of grey mangrove (*Avicennia marina* (Forsk.) Vierh) seedlings to spills of crude oil,' *The Journal of Experimental Marine Biological Ecology*, vol. 171, no. 2, pp. 273–295.

Isaji, T & Spaulding, M 1984, 'A model of the tidally induced residual circulation in the Gulf of Maine and Georges Bank', *Journal of Physical Oceanography*, vol. 14, no. 6, pp. 1119–1126.

Isaji, T, Howlett, E, Dalton C, & Anderson, E 2001, 'Stepwise-continuous-variable-rectangular grid hydrodynamics model', Proceedings of the 24th Arctic and Marine Oil spill Program (AMOP) Technical Seminar (including 18th TSOCS and 3rd PHYTO), Environment Canada, Edmonton, pp. 597–610.

Koops, W, Jak, RG & van der Veen, DPC 2004, 'Use of dispersants in oil spill response to minimise environmental damage to birds and aquatic organisms', Proceedings of the Interspill 2004: Conference and Exhibition on Oil Spill Technology, Trondheim, presentation 429.

Kostianoy, AG, Ginzburg, AI, Lebedev, SA, Frankignoulle, M & Delille, B 2003, 'Fronts and mesoscale variability in the southern Indian Ocean as inferred from the TOPEX/POSEIDON and ERS-2 Altimetry data', *Oceanology*, vol. 43, no. 5, pp. 632–642.

Li, Z, Spaulding, M, French-McCay, D, Crowley, D & Payne JR 2017, 'Development of a unified oil droplet size distribution model with application to surface breaking waves and subsea blowout releases considering dispersant effects', *Marine Pollution Bulletin*, vol. 114, no. 1, pp 247–257.

Lin, Q & Mendelssohn, IA 1996, 'A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish and Salt Marshes', *Marine Pollution Bulletin*, vol. 32, no. 2, pp. 202–209.

Ludicone, D, Santoleri, R, Marullo, S & Gerosa, P 1998, 'Sea level variability and surface eddy statistics in the Mediterranean Sea from TOPEX/POSEIDON data', *Journal of Geophysical Research I*, vol. 103, no. C2, pp. 2995–3011.

Mackay D, Puig H & McCarty LS 1992, ‘An equation describing the time course and variability in uptake and toxicity of narcotic chemicals to fish’, *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, p.941–951.

Malins DC & Hodgins HO 1981, ‘Petroleum and marine fishes: a review of uptake, disposition, and effects’, *Environmental Science & Technology*, vol. 15, no. 11, pp.1272–1280.

Matsumoto, K, Takanezawa, T & Ooe, M 2000, ‘Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan’, *Journal of Oceanography*, vol. 56, no.5, pp. 567–581.

McAuliffe CD 1987, ‘Organism exposure to volatile/soluble hydrocarbons from crude oil spills – a field and laboratory comparison’, Proceedings of the 1987 International Oil Spill Conference, American Petroleum Institute, pp. 275–288.

McCarty LS 1986, ‘The relationship between aquatic toxicity QSARs and bioconcentration for some organic chemicals’, *Environmental Toxicology and Chemistry*, vol. 5, no. 12, pp. 1071–1080.

McCarty LS & Mackay D 1993, ‘Enhancing ecotoxicological modelling and assessment. Body residues and modes of toxic action’, *Environmental Science & Technology*, vol. 27, no. 9, pp. 1718–1728.

McCarty LS, Dixon DG, MacKay D, Smith AD & Ozburn GW 1992a, ‘Residue-based interpretation of toxicity and bioconcentration QSARs from aquatic bioassays: Neutral narcotic organics’, *Environmental Toxicology and Chemistry: An International Journal*, vol. 11, no. 7, pp.917–930.

McCarty LP, Flannagan DC, Randall SA & Johnson KA 1992b, ‘Acute toxicity in rats of chlorinated hydrocarbons given via the intratracheal route’, *Human & Experimental Toxicology*, vol. 11, no. 3, pp.173–117.

McGrath JA, & Di Toro DM 2009, ‘Validation of the target lipid model for toxicity assessment of residual petroleum constituents: monocyclic and polycyclic aromatic hydrocarbons’, *Environmental Toxicology and Chemistry*, vol. 28, no. 6, pp. 1130–1148.

National Oceanic and Atmospheric Administration (NOAA) 2013, ‘Screening level risk assessment package Gulf state’, Office of National Marine Sanctuaries & Office of Response and Restoration, Washington DC.

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2018, ‘At a glance: Oil spill modelling’, viewed 15 November 2018, https://www.nopsema.gov.au/assets/Publications/A626200.pdf

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2019, ‘NOPSEMA Bulletin #1: Oil spill modelling’, viewed April 2019, https://www.nopsema.gov.au/assets/Bulletins/A652993.pdf

National Research Council (NRC) 2003, ‘Oil in the sea III: Inputs, fates and effects’, The National Academic Press, Washington D.C.

Neff JM, Anderson JW 1981, ‘Response of marine animals to petroleum and specific petroleum hydrocarbons’ United States Department of Energy, United States.

Nirmalakhandan N & Speece RE 1998, ‘Quantitative techniques for predicting the behaviour of chemicals in the ecosystem’, *Environmental Science & Technology*, vol. 22, no. 6, pp. 606–615.

Nordtug, T, Olsen, AJ, Altin, D, Overrein, I, Storøy, W, Hansen, BH & De Laender, F 2011, ‘Oil droplets do not affect assimilation and survival probability of first feeding larvae of North-East Arctic cod’, *Science of the Total Environment*, 412, pp.148–153.

Oil Spill Solutions 2015, ‘Evaluation - The Theory of Oil Slick Appearances’, viewed 6 January 2015, http://www.oilspillsolutions.org/evaluation.htm

Owen, A 1980, ‘A three-dimensional model of the Bristol Channel’, *Journal of Physical Oceanography*, vol. 10, no. 8, pp. 1290–1302.

Qiu, B & Chen, S 2010, ‘Eddy-mean flow interaction in the decadally modulating Kuroshio Extension system’, *Deep-Sea Research II*, vol. 57, no. 13, pp. 1098–1110.

Redman AD 2015, ‘Role of entrained droplet oil on the bioavailability of petroleum substances in aqueous exposures’, *Marine Pollution Bulletin*, vol. 97, no. (1–2), pp. 342–348.

Saha, S, Moorthi, S, Pan, H-L, Wu, X, Wang, J & Nadiga, S 2010, ‘The NCEP Climate Forecast System Reanalysis’, *Bulletin of the American Meteorological Society*, vol. 91, no. 8, pp. 1015–1057.

Scholten, MCTh, Kaag, NHBM, Dokkum, HP van, Jak, R.G., Schobben, HPM & Slob, W 1996, Toxische effecten van olie in het aquatische milieu, TNO report TNO-MEP – R96/230, Den Helder.

Spaulding, ML., Kolluru, VS, Anderson, E & Howlett, E 1994, ‘Application of three-dimensional oil spill model (WOSM/OILMAP) to hindcast the Braer Spill’, *Spill Science and Technology Bulletin*, vol. 1, no. 1, pp. 23–35.

Spaulding, MS, Mendelsohn, D, Crowley, D, Li, Z, and Bird A, 2015. Technical Reports for Deepwater Horizon Water Column Injury Assessment- WC_TR.13: Application of OILMAP DEEP to the Deepwater Horizon Blowout. RPS APASA, 55 Village Square Drive, South Kingstown, RE 02879.

Suprayogi, B & Murray, F 1999, ‘A field experiment of the physical and chemical effects of two oils on mangroves’, *Environmental and Experimental Botany*, vol. 42, no. 3, pp. 221–229.

Swartz RC, Schults DW, Ozretich RJ, Lamberson JO, Cole FA, Ferraro SP, Dewitt TH & Redmond MS 1995, ‘ΣPAH: A Model to predict the toxicity of polynuclear aromatic hydrocarbon mixtures in field-collected sediments’, *Environmental Toxicology and Chemistry*, vol. 14, no. 11, pp. 1977–1187.

Verhaar HJM, Van Leeuwen CJ & Hermens JLM 1992, ‘Classifying environmental pollutants’, *Chemosphere*, vol. 24, no. 4, pp. 471–491.

Verhaar HJM, de Jongh J & Hermens JLM 1999, ‘Modelling the bioconcentration of organic compounds by fish: A novel approach’, *Environmental Science & Technology*, vol. 33, no. 22, pp. 4069–4072.

Willmott, CJ 1981, ‘On the validation of models’, *Physical Geography*, vol. 2, no. 2, pp.184–194.

Willmott, CJ 1982, ‘Some comments on the evaluation of model performance’, *Bulletin of the American Meteorological Society*, vol. 63, no. 11, pp.1309–1313.

Willmott CJ, Ackleson SG, Davis RE, Feddema JJ, Klink, KM, Legates, DR, O’Donnell, J & Rowe, CM 1985, ‘Statistics for the evaluation of model performance’, *Journal of Geophysical Research*, vol. I 90, no. C5, pp. 8995–9005.

Willmott, CJ & Matsuura, K 2005, ‘Advantages of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance’, *Journal of Climate Research*, vol. 30, no. 1, pp. 79–82.

Yaremchuk, M & Tangdong, Q 2004, ‘Seasonal variability of the large-scale currents near the coast of the Philippines’, *Journal of Physical Oceanography*, vol. 34, no., 4, pp. 844–855.

Zigic, S, Zapata, M, Isaji, T, King, B, & Lemckert, C 2003, ‘Modelling of Moreton Bay using an ocean/coastal circulation model’, Proceedings of the 16th Australasian Coastal and Ocean Engineering Conference, the 9th Australasian Port and Harbour Conference and the Annual New Zealand Coastal Society Conference, Institution of Engineers Australia, Auckland, paper 170.

Appendix D Gorgon Gas Development: Backfill Fields Acoustic and Animal Movement Modelling for Assessing Marine Fauna Sound Exposures

Gorgon Gas Development: Backfill Fields

Acoustic and Animal Movement Modelling for Assessing Marine Fauna Sound Exposures

JASCO Applied Sciences (Australia) Pty Ltd

28 April 2023

Submitted to:

Naomi Kerp
Xodus Group

Authors:

Victoria E. Warren
Matthew W. Koessler
Alina M. Muellenmeister
Dion H. Stroot
Craig R. McPherson

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Executive Summary

JASCO Applied Sciences (JASCO) undertook a modelling study of underwater sound levels associated with vessel activities and vertical seismic profiling (VSP) for the construction of the Chevron Gorgon Gas Development: Backfill Fields ('the Development'). This study considers representative noise sources in five representative areas across the Development (Areas 1 to 5). The five nominal areas were designated based upon bathymetry and proximity to each other to assist with the study. Some activities in Area 1, and all activities within Areas 2, 3 and 4 are within the pygmy blue whale migratory Biologically Important Area (BIA). Vessel activities comprise continuous non-impulsive noise sources, while VSP is an impulsive noise source.

Acoustic Modelling – Vessel Noise

The modelling study considers 36 individual vessel activity scenarios across the five Areas:

- Area 1 – Exmouth Plateau, furthest offshore
    - Scenario 1 - Drillship under dynamic positioning (DP)
    - Scenario 2 – Drillship under DP with an Offshore Support Vessel (OSV) (for 8 hours)
    - Scenario 3 – Pipelay under DP
    - Scenario 4 – Pipelay under DP with one resupply vessel
    - Scenario 5 – Pipelay under DP with one resupply vessel and one OSV
    - Scenario 6 – Inspection, Maintenance and Repair (IMR) vessel under DP
    - Scenario 7 – Offshore Construction Vessel (OCV) under DP
    - Scenario 8 – OCV under DP with three support vessels
- Area 2 – Between the Exmouth Plateau and the continental slope
    - Scenario 9 - Drillship under dynamic positioning (DP)
    - Scenario 10 – Drillship under DP with an OSV (for 8 hours)
    - Scenario 11 – Pipelay under DP
    - Scenario 12 – Pipelay under DP with one resupply vessel
    - Scenario 13 – Pipelay under DP with one resupply vessel and one OSV
    - Scenario 14 – IMR vessel under DP
    - Scenario 15 – OCV under DP
    - Scenario 16 – OCV under DP with three support vessels
- Area 3 – Immediately offshore of the continental slope
    - Scenario 17 - Drillship under dynamic positioning (DP)
    - Scenario 18 – Drillship under DP with an OSV (for 8 hours)
    - Scenario 19 – Pipelay under DP
    - Scenario 20 – Pipelay under DP with one resupply vessel
    - Scenario 21 – Pipelay under DP with one resupply vessel and one OSV
    - Scenario 22 – IMR vessel under DP
    - Scenario 23 – OCV under DP
    - Scenario 24 – OCV under DP with three support vessels
- Area 4 – Continental slope
    - Scenario 25 – Pipelay under DP
    - Scenario 26 – Pipelay under DP with one resupply vessel
    - Scenario 27 – Pipelay under DP with one resupply vessel and one OSV

  - Scenario 28 – IMR vessel under DP
- Area 5 – Continental shelf
  - Scenario 29 - Drillship under dynamic positioning (DP)
  - Scenario 30 – Drillship under DP with an OSV (for 8 hours)
  - Scenario 31 – Pipelay under DP
  - Scenario 32 – Pipelay under DP with one resupply vessel
  - Scenario 33 – Pipelay under DP with one resupply vessel and one OSV
  - Scenario 34 – IMR vessel under DP
  - Scenario 35 – OCV under DP
  - Scenario 36 – OCV under DP with three support vessels

Further to the 36 individual vessel activity scenarios, four combined scenarios have also been modelled, which consist of multiple vessel activities. The four combined scenarios consider the aggregate contribution of noise emissions from concurrent vessel activities, namely:

- Scenario 37 – Scenario 5 and 18 (Area 1 Pipelay with resupply vessel and OSV + Area 3 Drillship with OSV)
- Scenario 38 – Scenario 8, 14, and 18 (Area 1 OCV with three support vessels + Area 2 IMR vessel + Area 3 Drillship with OSV)
- Scenario 39 – Scenario 18 and 33 (Area 3 Drillship with OSV, Area 5 Pipelay with resupply vessel and OSV)
- Scenario 40 – Scenario 30 and 33 (Area 5 Drillship with OSV, Area 5 Pipelay with resupply vessel and OSV)

The study assessed distances from vessel activities where underwater sound levels reached thresholds corresponding to various levels of potential impact to marine fauna. The animals considered here included marine mammals, turtles, and fish. Due to the variety of species considered, there are several different thresholds for evaluating effects, including: mortality, injury, temporary reduction in hearing sensitivity, and behavioural disturbance. The modelling methodology considered scenario specific source levels and range-dependent environmental properties. Estimated underwater acoustic levels for non-impulsive (continuous) noise sources presented as sound pressure levels (SPL, L_p), and as accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria. In this report, the duration of the SEL accumulation is defined as integrated over a 24 h period.

The SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The corresponding SEL_{24h} radii represent an unlikely worst-case scenario. More realistically, marine mammals (as well as fish and turtles) would not stay in the same location for 24 hours. Therefore, a reported radius for SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with impairment if it remained in that location for 24 hours.

Maps are provided in the report to assist with contextualising tabulated distances. The key results of this acoustic modelling study are summarised in Tables 1–5.

In Areas 1, 2, 3 and 5, the OCV with construction support vessels resulted in the longest distances to effect thresholds (Table 1). The 120 dB SPL marine mammal behavioural effect zone from construction activities with support vessels featured a radius of 15.7 km in Area 1, 15.4 km in Area 2, 14.0 km in Area 3, and 17.3km in Area 5. Construction activities were not modelled in Area 4, and in this Area the pipelay vessel with two support vessels resulted in the longest distances to effect thresholds (120 dB marine mammal behavioural effect radii of 18.3 km). In every modelled Area, and for each activity, additional support vessels generated larger distances to effect thresholds (Table 1).

The smallest horizontal distances to effect thresholds were associated with scenarios that modelled a single IMR vessel; the largest marine mammal behavioural response zone for the IMR vessel was 3.76 km and the largest low-frequency (LF) cetacean TTS zone was 0.63 km (both in Area 5) (Table 1).

Offshore activities over deep water in Areas 1 and 2 generally featured smaller effect zones than equivalent activities in Areas 3, 4 and 5 where the continental shelf environment was conducive to effective sound propagation downslope (Table 1).

To consider the aggregate contribution of noise emissions from the four combined scenarios, ensonified areas were examined for Scenarios 37 – 40, rather than maximum radii. In the combined scenarios, only Scenario 40 resulted in overlapping ensonified areas such that the two behavioural effect zones of the drilling and pipelay activities combined into one larger area (with 12.9% greater ensonified area compared to the two individual scenarios) (Table 2). The SEL_{24h} areas for Scenario 40, and all effect areas for Scenarios 37, 38 and 39, did not result in merged effect zones and the percentage change in ensonified areas therefore remained low (<5%) (Table 2). The lack of change in ensonified area for Scenarios 37, 38 and 39 was primarily due to the distances between concurrent activities being larger than the sum of the effect radii of the individual activities. While the modelled sound fields presented here are specific to the modelled site locations, the effect radii provide some guidance to the spacing between individual scenarios that will result in overlapping, or merged, effect zones.

Table 1. Summary of maximum (R_{max}) horizontal distances (in km) from all scenarios considered to the marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) and frequency-weighted LF-cetacean SEL_{24h} TTS and PTS thresholds (179 and 199 dB re 1 µPa²·s, respectively) based on Southall et al. (2019).

Scenario Number	Description	Marine Mammal Behavioural Response [a]	LF-cetacean TTS [b]	LF-cetacean PTS [c]
		R_{max} (km)	R_{max} (km)	R_{max} (km)
1	Area 1, Drillship	5.62	0.78	0.08
2	Area 1, Drillship with OSV	5.87	0.83	0.10
3	Area 1, Pipelay vessel	6.30	0.84	0.05
4	Area 1, Pipelay vessel with resupply vessel	6.56	0.99	0.10
5	Area 1, Pipelay vessel with resupply vessel and support OSV	6.72	1.07	0.12
6	Area 1, IMR vessel	1.99	0.36	0.04
7	Area 1, OCV	15.5	1.71	0.18
8	Area 1, OCV with 3 support vessels	15.7	1.82	0.21
9	Area 2, Drillship	5.60	0.78	0.07
10	Area 2, Drillship with OSV	5.85	0.84	0.11
11	Area 2, Pipelay vessel	6.42	0.85	0.06
12	Area 2, Pipelay vessel with resupply vessel	6.70	0.99	0.09
13	Area 2, Pipelay vessel with resupply vessel and support OSV	6.88	1.08	0.12
14	Area 2, IMR vessel	1.74	0.36	0.04
15	Area 2, OCV	15.1	1.70	0.19
16	Area 2, OCV with 3 support vessels	15.4	1.81	0.21
17	Area 3, Drillship	5.30	0.78	0.08
18	Area 3, Drillship with OSV	12.1	0.84	0.11
19	Area 3, Pipelay vessel	5.78	0.84	0.05
20	Area 3, Pipelay vessel with resupply vessel	12.8	0.99	0.09
21	Area 3, Pipelay vessel with resupply vessel and support OSV	13.0	1.08	0.12
22	Area 3, IMR vessel	2.64	0.36	0.04
23	Area 3, OCV	14.0	1.96	0.19
24	Area 3, OCV with 3 support vessels	14.0	2.10	0.21
25	Area 4, Pipelay vessel	7.87	0.88	0.05
26	Area 4, Pipelay vessel with resupply vessel	9.72	1.20	0.10
27	Area 4, Pipelay vessel with resupply vessel and support OSV	18.3	1.47	0.12
28	Area 4, IMR vessel	2.24	0.37	0.04
29	Area 5, Drillship	10.0	1.56	0.08
30	Area 5, Drillship with OSV	10.4	1.66	0.11
31	Area 5, Pipelay vessel	12.2	1.69	0.06
32	Area 5, Pipelay vessel with resupply vessel	12.8	1.99	0.10
33	Area 5, Pipelay vessel with resupply vessel and support OSV	12.9	2.18	0.12
34	Area 5, IMR vessel	3.76	0.63	0.04
35	Area 5, OCV	17.0	4.39	0.19
36	Area 5, OCV with 3 support vessels	17.3	4.58	0.21

Noise exposure criteria: [a] NOAA (2019) and [b and c] Southall et al. (2019).
A dash indicates the level was not reached within the limits of the modelled resolution (20 m)

Table 2. Summary of percentage change in ensonified area between multiple individual scenarios and combined scenarios based on the marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) and frequency-weighted LF-cetacean SEL_{24h} TTS and PTS thresholds based on Southall et al. (2019).

Scenario Number	Description	Marine Mammal Behavioural Response [a]	LF-cetacean TTS [b]	LF-cetacean PTS [c]
		Percentage change in ensonified area from individual scenarios to combined (%)	*Percentage change in ensonified area from individual scenarios to combined (%)*	*Percentage change in ensonified area from individual scenarios to combined (%)*
37	Area 1 pipelay vessel with resupply vessel and support OSV + Area 3 drillship with OSV	+ 0.37	*	*
38	Area 1 OCV with 3 support vessels + Area 2 IMR vessel + Area 3 drillship with OSV	+ 3.21	+ 0.21	*
39	Area 3 drillship with OSV + Area 5 pipelay vessel with resupply vessel and support OSV	+ 4.03	+ 0.18	*
40	Area 5 drillship with OSV + Area 5 pipelay vessel with resupply vessel and support OSV	+ 12.9	+ 2.98	*

Noise exposure criteria: [a] NOAA (2019) and [b and c] Southall et al. (2019).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km^2)

Acoustic Modelling – Vertical Seismic Profiling

In addition to vessel noise modelling, the modelling study also considers Vertical Seismic Profiling (VSP) at three sites with a maximum of 300 shots over a 24 hour period. The three VSP locations were identified by Chevron to be representative of the range of water depths across the Development area. Site A lies on the Continental Shelf (Area 5) in the shallowest water (142.6 m), Site B is situated in Area 3, above the Continental Slope, with a water depth of 923.7 m, and Site C is situated in the deepest water, 1153 m, in Area 1.

As VSP is an impulsive noise source, the noise effect criteria are different to those in the vessel scenarios.

Of the three modelled sites, Site A generally resulted in the largest maximum horizontal distances to noise effect criteria thresholds.

Marine mammals:

The results for marine mammal injury applied the criteria from Southall et al. (2019), which requires two metrics (PK and SEL_{24h}) to be considered when assessing marine mammal PTS and TTS, with the longest distance associated with either metric being required to be applied. Table 3 summarises the maximum distances for TTS and PTS, along with the relevant metric associated with the maximum distance for the VSP results. The maximum distance where the NOAA (2019) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) is also presented in Table 3.

Table 3. Summary of maximum (R_{max}) horizontal distances (in km) from any modelled site to behavioural response thresholds and temporary threshold shift (TTS) and permanent threshold shift (PTS) for marine mammals.

Hearing group	Modelled distance to effect threshold (R_{max} km)		
	Behavioural response [a]	Impairment: TTS [b]	Impairment: PTS [b]
Low-frequency (LF) cetaceans	2.37	3.20[c]	0.48[c]
High-frequency (HF) cetaceans		–	–
Very high-frequency (VHF) cetaceans		0.13[d]	0.06[d]

Noise exposure criteria: [a] NOAA (2019) and [b] Southall et al. (2019)
[c] Longest distance to threshold from SEL_{24h} results
[d] Longest distance to threshold from PK results
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Sea turtles:

- The PK sea turtle injury criteria of 232 dB re 1 µPa for PTS and 226 dB re 1 µPa for TTS from Finneran et al. (2017) was not exceeded at a distance longer than 20 m from the acoustic centre of the source.
- The maximum distance to the SEL_{24h} metrics for PTS and TTS (Finneran et al. 2017) of 204 dB re 1 µPa^{2}s for PTS and 189 dB re 1 µPa^{2}s for TTS (summarised in Table 4) was 0.03 km for PTS onset and 0.24 km for TTS onset for the 750 in^3 seismic source. As is the case with marine mammals, a reported radius for SEL_{24h} criteria does not mean that sea turtles travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with either PTS or TTS if it remained in that location for 24 hours.
- The maximum distances to the behavioural response criteria for sea turtles of 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) threshold for behavioural disturbance (McCauley et al. 2000) were 1.03 km and 0.27 km, respectively for the 750 in^3 seismic source (summarised in Table 4).

Table 4. Summary of maximum horizontal distances (in km) from any modelled site to behavioural response thresholds and temporary threshold shift (TTS) and permanent threshold shift (PTS) for marine turtles.

Hearing group	Behavioural response[1]	Behavioural disturbance[1]	Impairment: TTS[2]	Impairment: PTS[2]
Sea Turtles	1.03 (SPL)	0.27 (SPL)	0.24 (SEL_{24h})	0.03 (SEL_{24h})

Noise exposure criteria: [1] McCauley et al. (2000), and [2] Finneran et al. (2017)

Fish, fish eggs, and fish larvae:

This modelling study assessed the ranges for quantitative criteria based on Popper et al. (2014) and considered both PK and SEL_{24h} metrics associated with mortality and potential mortal injury as well as impairment in the following groups:

- Fish without a swim bladder (also appropriate for sharks in the absence of other information),
- Fish with a swim bladder that do not use it for hearing,
- Fish that use their swim bladders for hearing, and
- Fish eggs and fish larvae.

Table 5 summarises the maximum distances to effect criteria for fish, fish eggs, and fish larvae along with the relevant metric for both modelled locations.

Table 5. Summary of maximum fish, fish eggs, and larvae injury and temporary threshold shift (TTS) onset distances for any modelled site, for single impulse and 24 h sound exposure level (SEL_{24h}) modelled scenarios.

Relevant hearing group	Effect criteria	Water column	
		Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Recoverable injury	–	–
	TTS	SEL_{24h}	0.57
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Recoverable injury	SEL_{24h}	0.05
	TTS	SEL_{24h}	0.57
Fish eggs, and larvae	Injury	SEL_{24h}	0.05

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Benthic invertebrates:

To assist with assessing the potential effects on crustaceans from VSP operations, the following results were determined:

- The sound level of 202 dB re 1 µPa PK-PK from Payne et al. (2008), which is representative of no effects, was considered for seafloor sound levels; the sound level was reached at 60.8 m from the acoustic centre of the VSP array.
- Sound levels of 209–212dB re 1 µPa PK-PK from Day et al. (2016b) and 213 dB re 1 µPa from Day et al. (2016a), which are related to impairment in crustaceans, was considered; the level was not reached for any VSP modelling site at a depth of 5 cm above the seafloor.

Animal Movement Modelling

A more realistic representation of the potential exposures for migrating pygmy blue whales in the migration BIA was undertaken using animal movement modelling (‘animat modelling’) for five of the vessel scenarios, with the results presented separately below. While acoustic modelling inherently assumes static animals, the JASCO Animal Simulation Model Including Noise Exposure (JASMINE) combines modelled sound fields with realistic animal movements to predict how animals might be impacted through sound exposure. The exposure ranges account for animats sampling the sound field vertically and horizontally based on species-specific diving and movement parameters. JASMINE provides a framework for understanding and predicting sound exposure for species of interest and for calculating ranges to relevant regulatory thresholds. The distribution of distances to the source of simulated animals (‘animats’) predicted to be exposed to sound levels above relevant thresholds was used to calculate the horizontal distance that includes 95% of the animat distances that exceeded a given effect threshold ($ER_{95\%}$). Within the $ER_{95\%}$, there is generally some proportion of animats that do not exceed the threshold criteria. This occurs for several reasons, including the spatial and temporal characteristics of the sound field and the way in which the animats are exposed to the sound field over time, both vertically and horizontally. The probability that an animat within the $ER_{95\%}$ was exposed above threshold was also computed (P_{exp}) to provide additional context. Due to insufficient density data availability, the modelling results are not related to real-world density estimates for pygmy blue whales within the BIA.

Animat modelling was undertaken for a total of nine scenarios to provide an overview of the construction activities across the range of bathymetric and geological variation within the Development footprint.

The animat modelling study considered six individual vessel activity scenarios across four Areas:

- Scenario 8 – Construction (with three support vessels) in Area 1.
- Scenario 14 – IMR vessel under DP in Area 2.
- Scenario 18 – Drillship under DP with an offshore support vessel (OSV) (for 8 hours) in Area 3.
- Scenario 21 – Pipelay (with two support vessels) in Area 3.
- Scenario 30 – Drillship under DP with an offshore support vessel (OSV) (for 8 hours) in Area 5.
- Scenario 33 – Pipelay under DP with one resupply vessel and one OSV in Area 5.

Further to the six individual vessel activity scenarios, three combined scenarios have also been modelled, which consist of multiple vessel activities:

- Scenario 38 – Construction (with three support vessels) in Area 1, IMR in Area 2, and drilling (with OSV) in Area 3.
- Scenario 39 – Drilling (with OSV) in Area 3 and pipelay (with two support vessels) in Area 5.
- Scenario 40 – Drilling (with OSV) in Area 5 and pipelay (with two support vessels) in Area 5.

The key results of the animat modelling are outlined below and summarised Table 6.

- In general, exposure ranges from animal movement modelling for PTS and TTS criteria (Southall et al. 2019) are typically shorter than those predicted using acoustic propagation modelling because of the shorter time (‘dwell time’) to accumulate sound energy of the moving animats. In this study, there were no exposures above PTS threshold for any of the pygmy blue whale scenarios. The maximum $ER_{95\%}$ for TTS of 0.04 km with a corresponding exposure probability for animats travelling within that range of 67%.
- Exposure ranges ($ER_{95\%}$) for single exposure metrics, such as the SPL behavioural response criteria, are generally comparable to the predicted acoustic ranges. In this study, exposure ranges

were slightly lower than the R_{max} acoustic ranges based on the vertical distribution of the sound field.

- Unrestricted animat seeding resulted in exposures above the SPL behavioural response threshold (NOAA (2019)) for all considered scenarios. Of these, the maximum $ER_{95\%}$ to the threshold was 12.4 km. The probability of an animat within the $ER_{95\%}$ being exposed above the threshold was 99%.

Table 6. Summary of animat simulation results for the marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) and frequency-weighted LF-cetacean SEL_{24h} PTS and TTS thresholds for pygmy blue whales with unrestricted and restricted seeding. Maximum exposure ranges show $ER_{95\%}$ (km) first and probability of exposure of animats travelling within the $ER_{95\%}$ (P_{exp} (%)) in parentheses. A dash (-) indicates that no animat was exposed above the threshold.

Scenario Number	Description	Behavioural response (SPL)[2]	LF-cetacean TTS (SEL_{24h})[1]	LF-cetacean PTS (SEL_{24h})[1]
8	Area 1, OCV with 3 support vessels	12.4 (99%)	0.04 (67%)	–
14	Area 2, IMR vessel	0.73 (88%)	0.02 (87%)	–
18	Area 3, Drillship with OSV	3.02 (73%)	0.02 (76%)	–
21	Area 3, Pipelay vessel with resupply and support OSVs	5.03 (73%)	0.02 (91%)	–
30	Area 5, Drillship with OSV	8.03 (>99%)	0.02 (80%)	–
33	Area 5, Pipelay vessel with resupply vessel and support OSV	9.56 (>99%)	0.02 (77%)	–
38	Area 1, OCV with 3 support vessels + Area 2, IMR vessel + Area 3, drillship with OSV	12.3 (50%)	0.03 (61%)	–
39	Area 3, drillship with OSV + Area 5, pipelay vessel with 2 OSVs	9.47 (63%)	0.02 (77%)	–
40	Area 5, drillship with OSV + Area 5, pipelay vessel with 2 OSVs	9.55 (98%)	0.02 (79%)	–

[1] Southall et al. (2019) criteria for marine fauna.
[2] NOAA (2019) recommended unweighted behavioural criteria for marine mammals.

1. Introduction

JASCO Applied Sciences (JASCO) undertook a modelling study of underwater sound levels associated with vessel activities and vertical seismic profiling (VSP) for the construction of the Chevron Gorgon Gas Development: Backfill Fields, incorporating site-specific environmental parameters that affect the propagation of underwater sound. The modelling study considers 36 individual vessel scenarios (Scenarios 1–36) across five representative areas (Areas 1–5) within the Development footprint (Figure 1), four combined vessel scenarios incorporating multiple individual scenarios (Scenarios 37–40) (Section 1.1.1), and three VSP scenarios (Scenarios A, B and C) (Section 1.1.2). Vessel activities comprise continuous non-impulsive noise sources, while VSP is an impulsive noise source. The vessels considered within the study are nominal vessels representing the type and class of vessel likely to be used for the Development.

The modelling study predicted the distances from construction activities at which underwater sound levels reached noise effect thresholds and criteria for marine mammals, sea turtles and fish. The corresponding marine mammal thresholds include levels associated with behavioural response, permanent threshold shift (PTS) and temporary threshold shift (TTS), and the marine mammal functional hearing groups considered were low, high, and very-high-frequency cetaceans. Estimated underwater acoustic levels associated with vessel scenarios are presented as sound pressure levels (SPL, L_p), and accumulated sound exposure levels (over 24 hours) (SEL_{24h}, $L_{E,24h}$), as appropriate for non-impulsive (continuous) noise sources. Estimated underwater acoustic levels associated with VSP scenarios are presented as SEL_{24h}, for multiple pulses (5, 10, 25, 50, 100, 150, 200, 250, 300) over a 24 hour period, as well as single-impulse (i.e., per-pulse) metrics, including SPL, per-pulse sound exposure levels (SEL, L_E), zero-to-peak pressure levels (PK, L_{pk}), peak-to-peak pressure levels (PK-PK, $L_{pk\text{-}pk}$), as appropriate for impulsive noise sources.

The representative areas within the Development footprint are as follows:

- Area 1 – Exmouth Plateau, furthest offshore
- Area 2 – Between the Exmouth Plateau and the continental slope
- Area 3 – Immediately offshore of the continental slope
- Area 4 – Continental slope
- Area 5 – Continental shelf

The modelled vessel activity sites within each area are shown in Figure 1.

Some activities in Area 1, and all activities within Areas 2, 3, and 4 lie within the pygmy blue whale (*Balaenoptera musculus brevicauda*) migratory Biologically Important Area (BIA). Therefore, the acoustic modelling results for some vessel scenarios were used in conjunction with animal movement modelling (‘animat modelling’) simulations to predict the distance at which migrating pygmy blue whales are expected to be exposed above threshold criteria for PTS, TTS, and behavioural response. Sound exposure distribution estimates are determined by moving large numbers of simulated animals (animats) through a modelled time-evolving sound field, computed using specialised sound source and sound propagation models. This approach provides the most realistic prediction of the maximum expected SPL and SEL_{24h} for comparison against the relevant thresholds. Animal movement modelling was undertaken for nine vessel scenarios (Section 1.1.3) to provide an overview of the construction activities across the range of bathymetric and geological variation within the Development footprint.

This report is structured as follows: the remainder of Section 1 provides details on the scenarios considered for modelling, Section 2 explains the metrics used to represent underwater acoustic fields and the effect criteria considered. Sections 3.1 to 3.4 detail the methodology for predicting the source levels and modelling the sound propagation, including the specifications of the considered sound sources and the environmental parameters. Section 3.5 details the methodology for animat modelling of pygmy blue whales. Section 4.1 presents the acoustic results as tabulated ranges to thresholds, Sections 4.2.1 and 0 provide sound level contour maps, and Section 4.3 includes animal movement modelling results. The acoustic and animat modelling results are then discussed in Section 5.

1.1. Details of Modelling Scenarios

1.1.1. Vessel Noise Sources

This acoustic and exposure study considered the sound-producing activities associated with thirty individual vessel scenarios (outlined in Table 7), each describing a unique combination of sound sources.

Table 7. Summary of modelled scenarios

Scenario	Associated Site(s)	Area	Scenario description
1	1	1 – Exmouth Plateau, furthest offshore	Drillship under DP
2	1 + 2		Drillship under DP + Offshore Support Vessel (OSV) under DP 8hr
3	3		Pipelay vessel under DP
4	3 + 4		Pipelay vessel + resupply vessel, both under DP
5	3 + 4 + 5		Pipelay vessel + resupply vessel + OSV, all under DP
6	6		IMR vessel under DP
7	7		Offshore Construction Vessel (OCV) under DP
8	7 + 8 + 9 + 10		OCV + 3 support vessels, all under DP
9	11	2 – Between the Exmouth Plateau and the continental slope	Drillship under DP
10	11 + 12		Drillship under DP + OSV under DP 8hr
11	13		Pipelay vessel under DP
12	13 + 14		Pipelay vessel + resupply vessel, both under DP
13	13 + 14 + 15		Pipelay vessel + resupply vessel + OSV, all under DP
14	16		IMR vessel under DP
15	17		OCV under DP
16	17 + 18 + 19 + 20		OCV + 3 support vessels, all under DP
17	21	3 – Immediately offshore of the continental slope	Drillship under DP
18	21 + 22		Drillship under DP + OSV under DP 8hr
19	23		Pipelay vessel under DP
20	23+24		Pipelay vessel + resupply vessel, both under DP
21	23+24+25		Pipelay vessel + resupply vessel + OSV, all under DP
22	26		IMR vessel under DP
23	27		OCV under DP
24	27+28+29+30		OCV + 3 support vessels, all under DP
25	31	4 – Continental slope	Pipelay vessel under DP
26	31+32		Pipelay vessel + resupply vessel, both under DP
27	31+32+33		Pipelay vessel + resupply vessel + OSV, all under DP
28	34		IMR vessel under DP
29	35	5 – Continental shelf	Drillship under DP
30	35+36		Drillship under DP + OSV under DP 8hr
31	37		Pipelay vessel under DP
32	37+38		Pipelay vessel + resupply vessel, both under DP
33	37+38+39		Pipelay vessel + resupply vessel + OSV, all under DP
34	40		IMR vessel under DP
35	41		OCV under DP
36	41+42+43+44		OCV + 3 support vessels, all under DP

Scenarios 1 and 2, 9 and 10, 17 and 18, and 29 and 30 represent the operation of a drillship (nominally, the *Dhirubhai Deepwater KG2*), with and without the addition of an Offshore Support Vessel (OSV), respectively, across Area 1, 2, 3 and 5. The drillship has been assumed to operate continuously (24 h), under dynamic positioning (DP) in a static location. The OSV has been modelled using a representative generic vessel, the *MMA Leeuwin*, which has been considered on DP attendance alongside the drillship for 8 hours per day.

Scenarios 3–5, 11–13, 19–21, 25–27, and 31–33 represent the operation of a pipelay vessel in each of the five Areas with none, one, or two support vessels, respectively. The *Allseas Solitaire* has been considered as a representative pipelay vessel. Scenarios with one support vessel include a resupply vessel (nominally *Allseas Alegria*) alongside the pipelay vessel, and scenarios with two support vessels include the resupply vessel and a generic OSV (again represented by the *MMA Leeuwin*) alongside the pipelay vessel. All vessels are assumed to operate under DP for 24 h per day, travelling at 0.3 km per day along the supplied track-lines.

Scenarios 6, 14, 22, 28 and 34 represent the activities of an Inspection, Maintenance and Repair (IMR) vessel, which has been represented by the *Skandi Hercules*. This vessel is modelled in each of the five Areas for 24 h per day under static DP.

Scenarios 7, 15, 23 and 35 represent the operation of an Offshore Construction Vessel (OCV) (nominally the *Skandi Africa*) in Areas 1, 2, 3 and 5, respectively. Scenarios 8, 16, 24 and 36 represent the OCV with the addition of three support vessels; a tug (represented by *Mermaid Sound*), and two OSVs (represented by *MMA Chieftain* and *MMA Coral)*. In these scenarios, all vessels are assumed to operate statically under DP for 24 h per day.

Figure 1 displays an overview of the modelling area showing the locations of the modelled sites within their respective Areas, the pygmy blue whale BIA (and the humpback whale migratory BIA for reference), and the regional bathymetry.

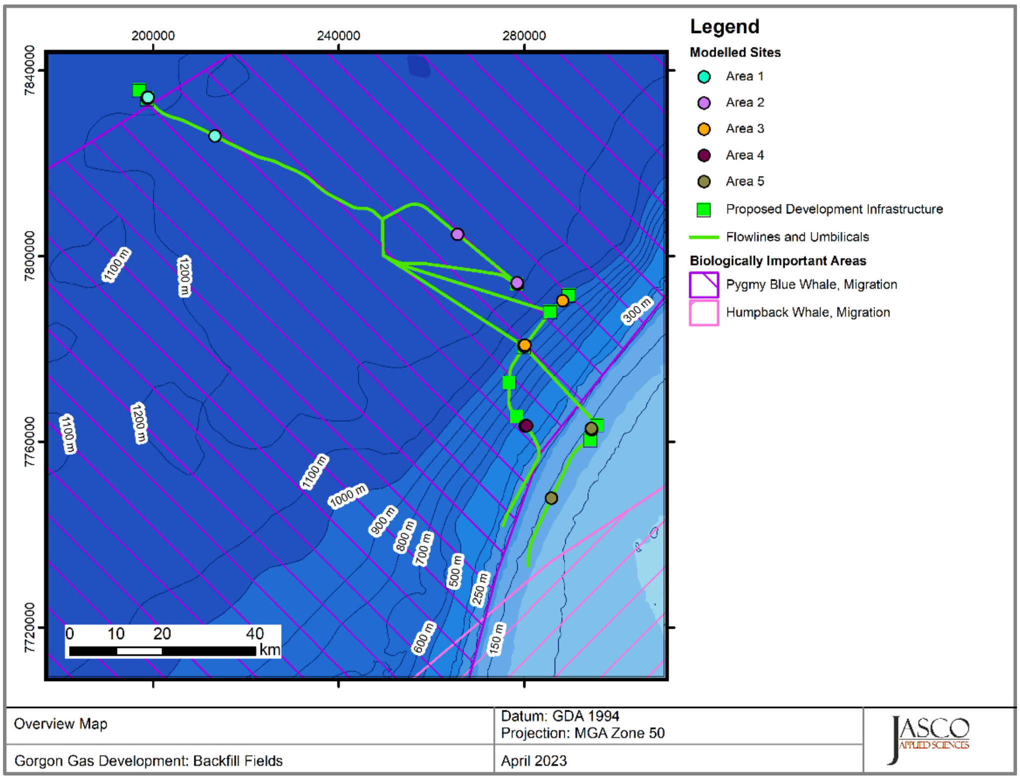

Figure 1. Overview map of the Chevron 'Gorgon Gas Development: Backfill Fields' showing the modelled vessel activity site locations within each representative Development area.

The 36 scenarios outlined in Table 7 comprise a total of 44 acoustic modelling sites that were selected to represent the extent of the construction activities, and these are listed in Table 8. Detailed maps illustrating the site locations within each of the five Areas are included as Figures 2 to 6.

Table 8. Location details for the vessel acoustic modelling sites

Site	Area	Vessel Type	Latitude (S)	Longitude (E)	MGA[1] Zone 50		Water Depth (m)
					X (m)	Y (m)	
1	1	Drillship	19° 34' 00.82"	114° 07' 42.61"	198715	7833915	1153
2		Drillship OSV	19° 34' 00.86"	114° 07' 45.01"	198785	7833915	1153
3		Pipelay	19° 38' 30.23"	114° 15' 58.64"	213313	7825864	1292
4		Pipelay OSV 1 (resupply)	19° 38' 29.23"	114° 15' 59.22"	213330	7825895	1291
5		Pipelay OSV 2 (support)	19° 38' 31.23"	114° 15' 58.04"	213296	7825833	1292
6		IMR vessel	19° 33' 51.07"	114° 07' 42.79"	198715	7834215	1149
7		OCV	19° 33' 51.07"	114° 07' 42.79"	198715	7834215	1149
8		Support tug	19° 33' 51.06"	114° 07' 41.94"	198690	7834215	1149
9		OCV OSV 1	19° 33' 51.09"	114° 07' 43.78"	198744	7834215	1149
10		OCV OSV 2	19° 33' 52.46"	114° 07' 47.90"	198865	7834175	1149
11	2	Drillship	19° 56' 18.05"	114° 52' 59.29"	278440	7793945	1210
12		Drillship OSV	19° 56' 18.08"	114° 53' 01.70"	278510	7793945	1209
13		Pipelay	19° 50' 22.41"	114° 45' 43.14"	265609	7804719	1328
14		Pipelay OSV 1 (resupply)	19° 50' 21.55"	114° 45' 43.94"	265632	7804746	1328
15		Pipelay OSV 2 (support)	19° 50' 23.28"	114° 45' 42.34"	265586	7804692	1328
16		IMR vessel	19° 56' 08.30"	114° 52' 59.42"	278440	7794245	1211
17		OCV	19° 56' 18.05"	114° 52' 59.29"	278440	7793945	1210
18		Support tug	19° 56' 18.04"	114° 52' 58.43"	278415	7793945	1210
19		OCV OSV 1	19° 56' 18.06"	114° 53' 00.29"	278469	7793945	1210
20		OCV OSV 2	19° 56' 19.41"	114° 53' 04.43"	278590	7793905	1208
21	3	Drillship	20° 03' 33.49"	114° 53' 45.53"	279953	7780570	923
22		Drillship OSV	20° 03' 33.52"	114° 53' 47.94"	280023	7780570	921
23		Pipelay	19° 58' 17.92"	114° 58' 34.84"	288243	7790379	972
24		Pipelay OSV 1 (resupply)	19° 58' 18.80"	114° 58' 35.62"	288266	7790352	971
25		Pipelay OSV 2 (support)	19° 58' 17.06"	114° 58' 34.05"	288220	7790405	974
26		IMR vessel	20° 03' 23.74"	114° 53' 45.66"	279953	7780870	932
27		OCV	20° 03' 33.49"	114° 53' 45.53"	279953	7780570	923
28		Support tug	20° 03' 33.48"	114° 53' 44.67"	279928	7780570	924
29		OCV OSV 1	20° 03' 33.50"	114° 53' 46.53"	279982	7780570	922
30		OCV OSV 2	20° 03' 34.85"	114° 53' 50.67"	280103	7780530	918
31	4	Pipelay	20° 12' 49.63"	114° 53' 44.27"	280133	7763465	400
32		Pipelay OSV 1 (resupply)	20° 12' 48.89"	114° 53' 45.19"	280159	7763488	399
33		Pipelay OSV 2 (support)	20° 12' 50.38"	114° 53' 43.35"	280106	7763442	400
34		IMR vessel	20° 12' 49.75"	114° 53' 54.60"	280433	7763465	389
35	5	Drillship	20° 13' 22.18"	115° 01' 56.74"	294442	7762640	142
36		Drillship OSV	20° 13' 22.20"	115° 01' 59.16"	294512	7762640	142
37		Pipelay	20° 21' 18.61"	114° 56' 53.00"	285807	7747880	141
38		Pipelay OSV 1 (resupply)	20° 21' 19.13"	114° 56' 54.09"	285838	7747865	141
39		Pipelay OSV 2 (support)	20° 21' 18.11"	114° 56' 51.91"	285775	7747895	141
40		IMR vessel	20° 13' 12.42"	115° 01' 56.87"	294442	7762940	145
41		OCV	20° 13' 22.18"	115° 01' 56.74"	294442	7762640	142
42		Support tug	20° 13' 22.17"	115° 01' 55.88"	294417	7762640	142
43		OCV OSV 1	20° 13' 22.19"	115° 01' 57.74"	294471	7762640	142
44		OCV OSV 2	20° 13' 23.53"	115° 02' 01.89"	294592	7762600	141

[1] Map Grid of Australia (MGA)

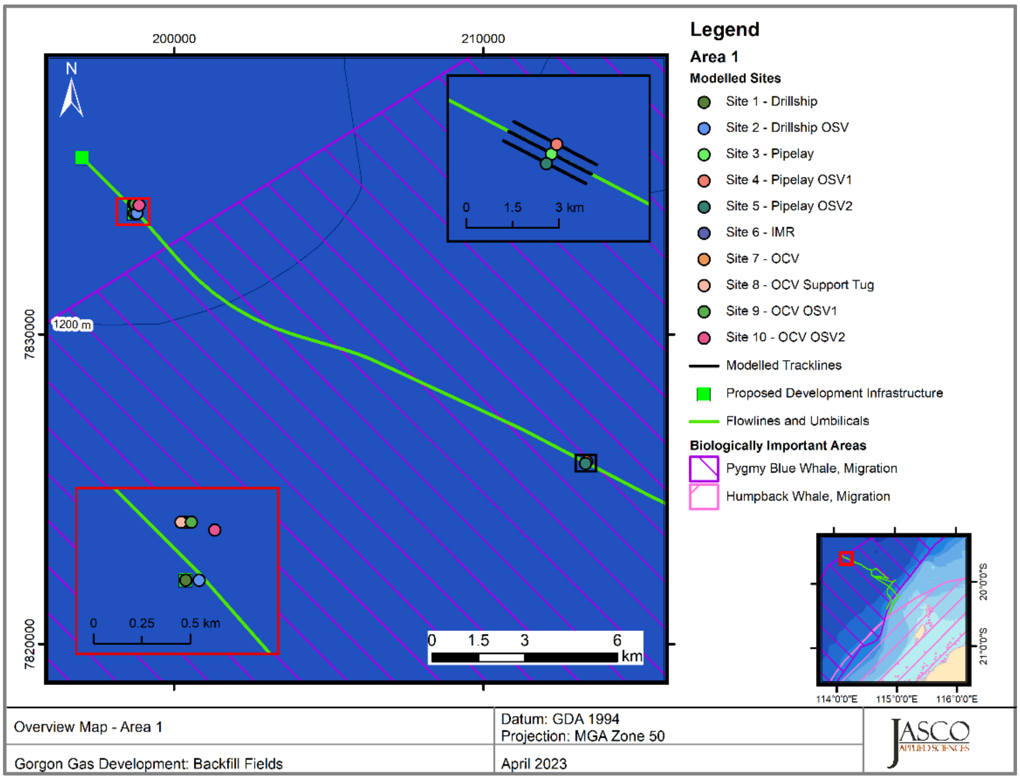

Figure 2. Overview map of Area 1 modelled sites for the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios with two zoom inserts focusing on the stationary modelled sites (red, bottom left) and the modelled pipelay tracklines (black, top right).

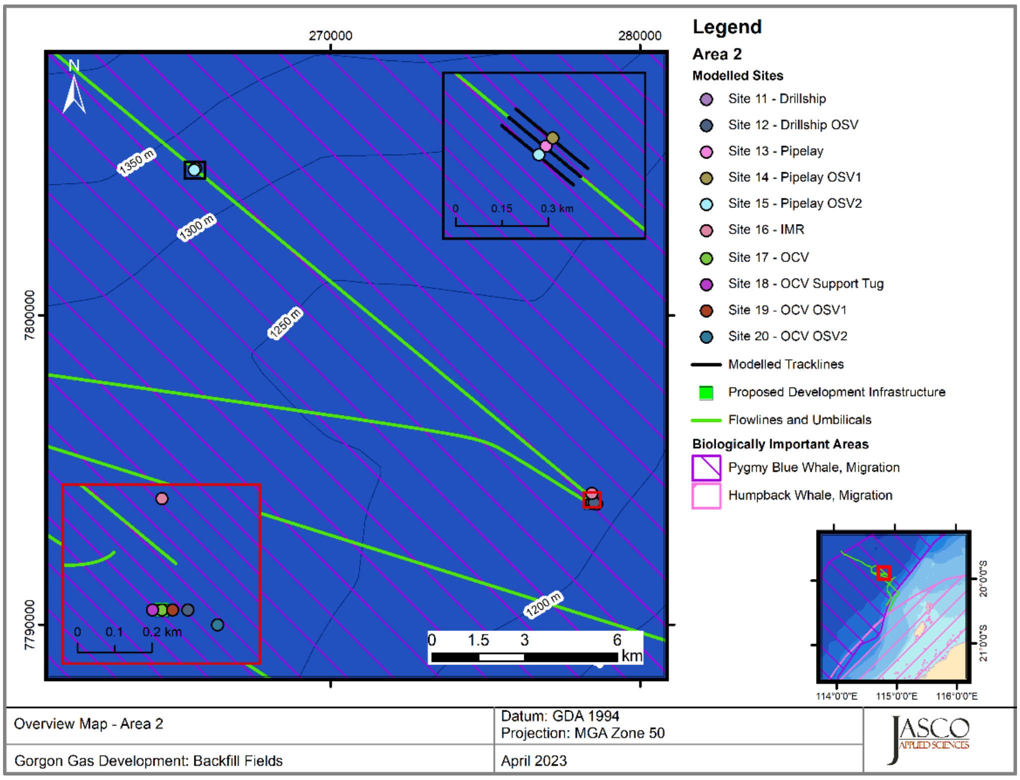

Figure 3. Overview map of Area 2 modelled sites for the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios with two zoom inserts focusing on the stationary modelled sites (red, bottom left) and the modelled pipelay tracklines (black, top right).

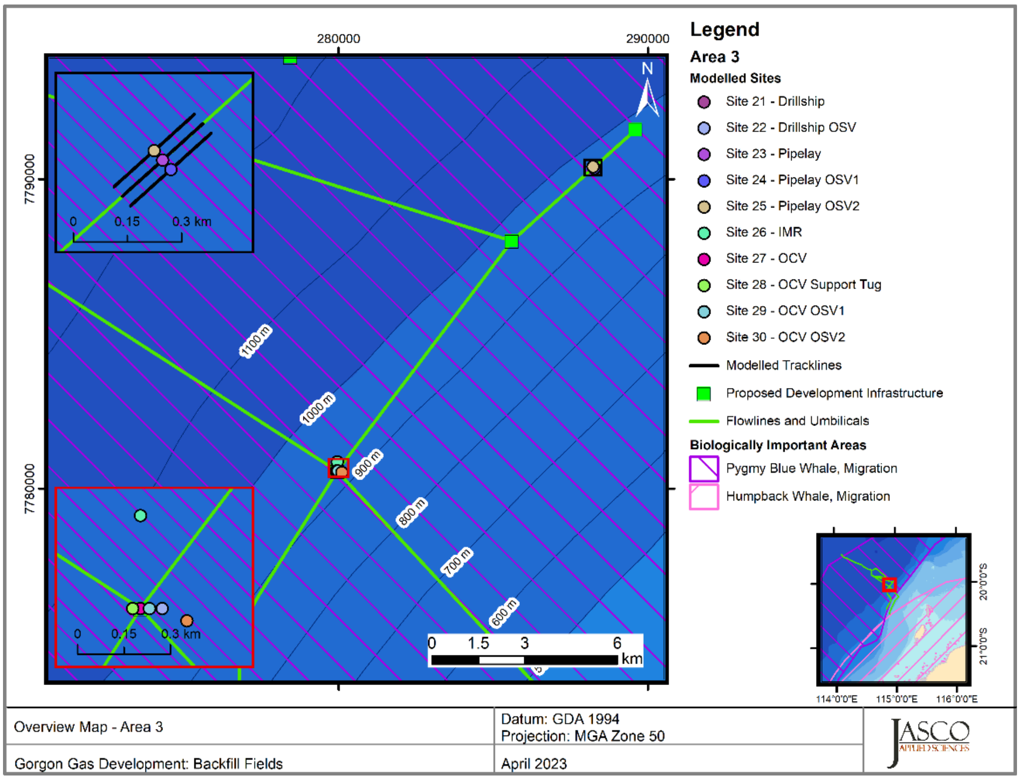

Figure 4. Overview map of Area 3 modelled sites for the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios with two zoom inserts focusing on the stationary modelled sites (red, bottom left) and the modelled pipelay tracklines (black, top left).

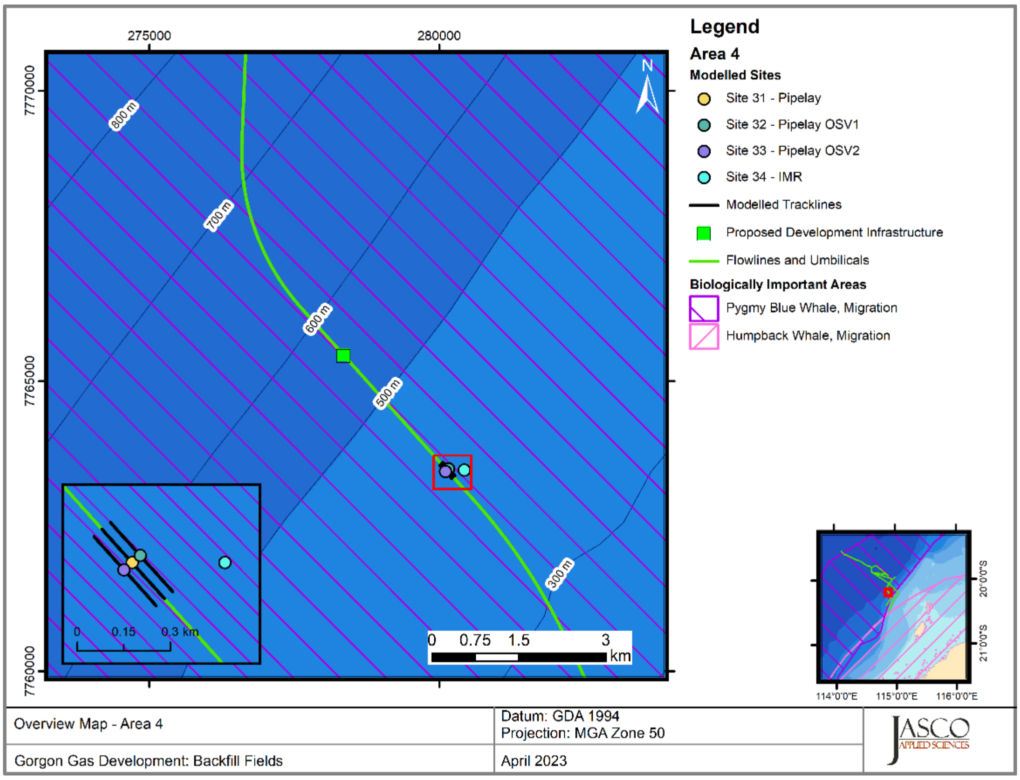

Figure 5. Overview map of Area 4 modelled sites for the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios.

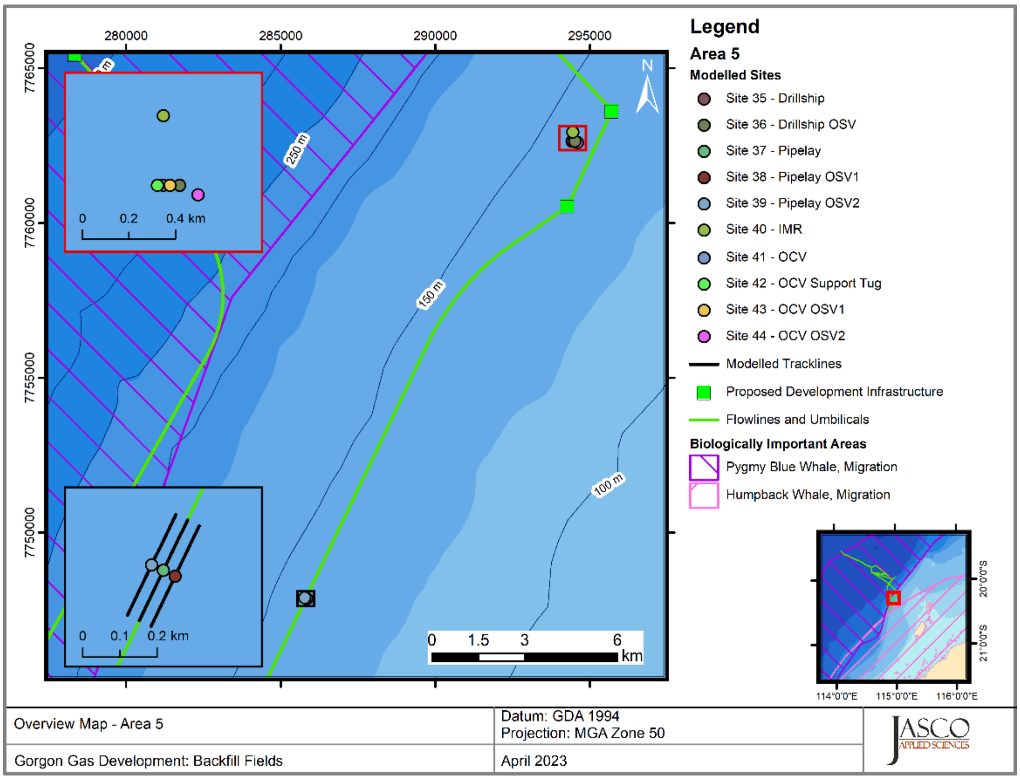

Figure 6. Overview map of Area 5 modelled sites for the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios with two zoom inserts focusing on the stationary modelled sites (red, top left) and the modelled pipelay tracklines (black, bottom left).

In addition to the 36 individual vessel scenarios, four combined scenarios have also been modelled, which consider the aggregate contribution of noise emissions from concurrent works. The four combined scenarios are summarised in Table 9.

Table 9. Summary of modelled combined scenarios.

Combined scenario	Associated individual scenarios	Associated sites	Scenario description
37	5, 18	3, 4, 5, 21, 22	Area 1, pipelay vessel with 2 support vessels + Area 3, drillship with OSV
38	8, 14, 18	7, 8, 9, 10, 16, 21, 22	Area 1, OCV with 3 support vessels + Area 2, IMR vessel + Area 3, drillship with OSV
39	18, 33	21, 22, 37, 38, 39	Area 3, drillship with OSV + Area 5, pipelay vessel with 2 support vessels
40	30, 33	35, 36, 37, 38, 39	Area 5, drillship with OSV + Area 5, pipelay vessel with 2 support vessels

1.1.2. Vertical Seismic Profiling Acoustic Source

The modelling study considers three VSP scenarios occurring at three sites as shown in Figure 7 and detailed in Table 10. The three VSP locations were identified by Chevron to be representative of the range of water depths across the Development area. Site A lies on the Continental Shelf (Area 5) in the shallowest water (142.6 m), Site B is situated in Area 3, above the Continental Slope, with a water depth of 923.7 m, and Site C is situated in the deepest water, 1153 m, in Area 1.

Table 10. Location details for VSP acoustic modelling sites

Site	Area	Latitude (S)	Longitude (E)	MGA[1] Zone 50		Water depth (m)
				X (m)	Y (m)	
A	5	20° 13' 20.9892" S	115° 1' 56.172" E	294424.9	7762676	142.6
B	3	20° 3' 33.3684" S	114° 53' 45.3372" E	279947.4	7780574	923.7
C	1	19° 34' 0.822" S	114° 7' 42.5784" E	198714	7833915	1153

[1] Map Grid of Australia (MGA)

The proposed VSP array has a total volume of 750 in^3 in a delta cluster configuration. A set of nine aggregate exposure (SEL_{24h}) scenarios were modelled at each VSP location with 5, 10, 25, 50, 100, 200, 250, and 300 shots over 24 hours to realistically represent a range of potential operations.

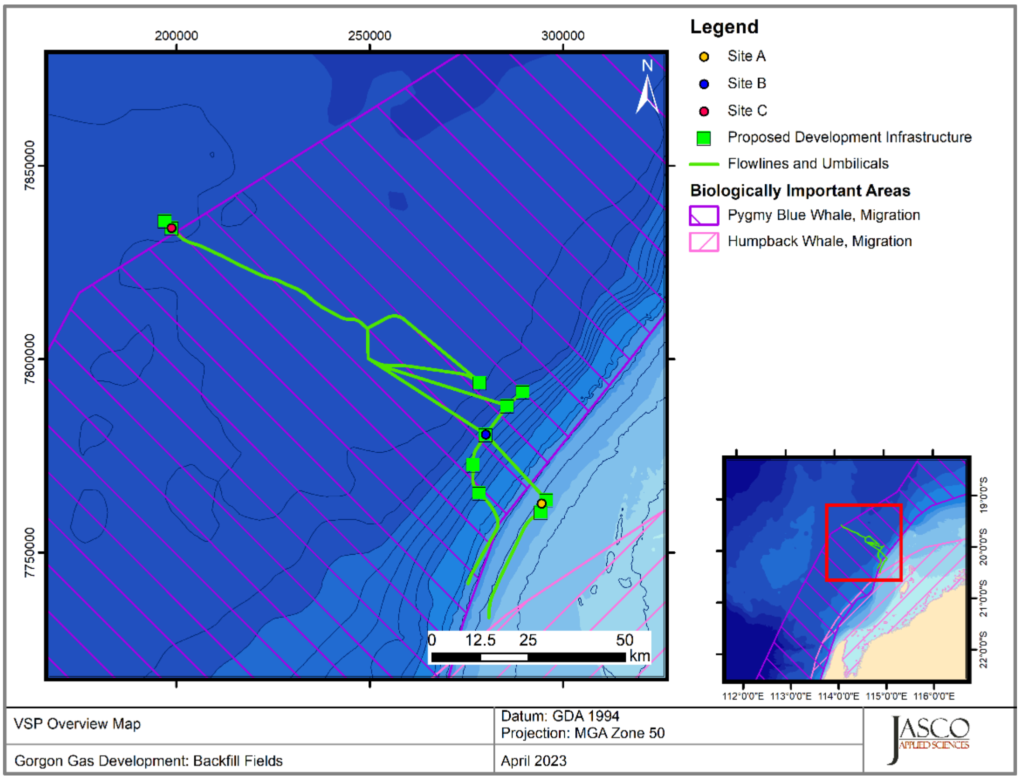

Figure 7. VSP Overview Map.

1.1.3. Animal Movement Modelling

Animal movement modelling simulations were run for migrating pygmy blue whales for vessel Scenarios 8, 14, 18, 21, 30, 33, 38, 39 and 40, as summarised in Table 7 and Table 9. Each of the animat simulations were run for a representative 24 h duration. The simulation area was selected to encompass a buffer of approximately 30 km from either modelled site, in any direction, based on the maximum acoustic range. Figure 8 shows an overview of the animat modelling simulation extents, along with the scenario locations and the pygmy blue whale BIA.

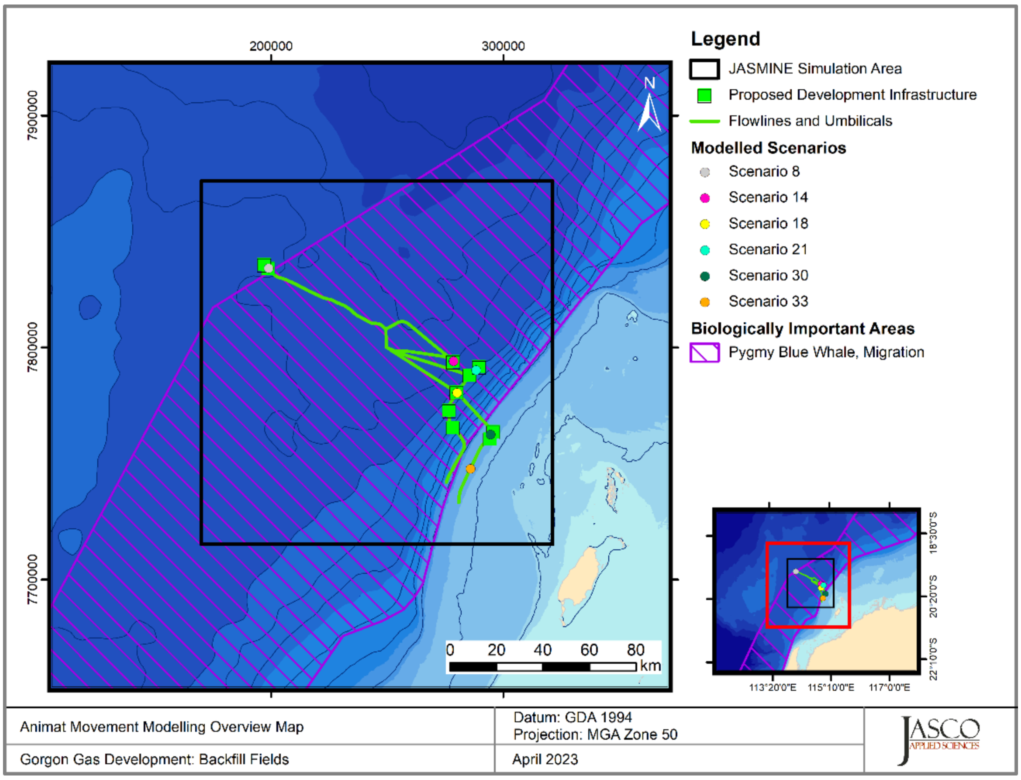

Figure 8. Overview map of the Chevron 'Gorgon Gas Development: Backfill Fields' construction scenarios, showing the animat movement modelling simulation extents along with the scenario locations and the pygmy blue whale BIAs.

2. Noise Effect Criteria

To assess the potential effects of a sound-producing activity, it is necessary to first establish exposure criteria and associated thresholds for which sound levels may be expected to have an adverse effect on animals. Whether acoustic levels might injure or disturb marine fauna is an active research topic. Since 2007, several expert groups have developed SEL-based assessment approaches for evaluating auditory injury, with key works including Southall et al. (2007), Finneran and Jenkins (2012), Popper et al. (2014), United States National Marine Fisheries Service (NMFS 2018) and Southall et al. (2019). The number of studies that investigate the level of behavioural disturbance to marine fauna by anthropogenic sound has also increased substantially.

Two sound level metrics, SPL and SEL, are commonly used to evaluate non-impulsive noise and its effects on marine life. In this report, the duration of the SEL accumulation is defined as integrated over a 24-hour period. The acoustic metrics in this report reflect the ANSI and ISO standards for acoustic terminology, ANSI S1.1 (S1.1-2013) and ISO 18405:2017 (2017).

The following thresholds and guidelines for this study were chosen because they represent the best available science:

1. Marine mammals:
    a. Peak pressure levels (PK; L_{pk}) and frequency–weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Southall et al. (2019) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in marine mammals for non–impulsive and impulsive sources.
    b. Marine mammal behavioural thresholds based on the current interim U.S. National Oceanic and Atmospheric Administration (NOAA) (2019) unweighted criterion for marine mammals of 120 dB re 1 µPa (SPL; L_p) and 160 dB re 1 µPa (SPL; L_p) for non–impulsive and impulsive sound sources.
2. Fish, fish eggs, and larvae:
    a. Sound exposure guidelines for fish, fish eggs, and larvae (Popper et al. 2014).
3. Sea turtles:
    a. Frequency–weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Finneran et al. (2017) for the onset of PTS and TTS in turtles for non–impulsive and impulsive sound sources.
    b. Sea turtle behavioural response threshold of 166 dB re 1 µPa (SPL; L_p) for impulsive noise, along with a sound level associated with behavioural disturbance 175 dB re 1 µPa (SPL; L_p) (McCauley et al. 2000).
4. Invertebrates:
    a. Peak-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$) and particle acceleration (ms^{-2}) at the seafloor to help assess effects of noise on crustaceans through comparing to results in Day et al. (2016a), Day et al. (2019), Day et al. (2016b), Day et al. (2017) and Payne et al. (2008).

Section 2.1, along with Appendix A.3 and A.4, expand on the thresholds, guidelines, and sound levels for marine mammals.

2.1. Marine Mammals

Cetaceans represent a potentially sensitive receptor group of marine mammals and were the focus of this assessment. The criteria applied in this study to assess possible effects of non-impulsive noise sources on marine mammals are summarised in Table 11, with impulsive noise criteria summarised in Table 12.

2.1.1. Injury and Hearing Sensitivity Changes

There are two categories of auditory threshold shifts or hearing loss: permanent threshold shift (PTS), a physical injury to an animal's hearing organs; and temporary threshold shift (TTS), a temporary reduction in an animal's hearing sensitivity as the result of receptor hair cells in the cochlea becoming fatigued.

To assist in assessing the potential for effect on marine mammals, this report applies the criteria recommended by Southall et al. (2019), considering both PTS and TTS (see Table 11). Appendix A.3 provides more information about the Southall et al. (2019) criteria, with frequency weighting explained in detail in Appendix A.4.

2.1.2. Behavioural Response

The NMFS noise criterion was selected for this assessment because it represents the most commonly applied behavioural response criterion by regulators. Whilst the newly published Southall et al. (2021) provides recommendations and discusses the nuances of assessing behavioural response, the authors of the study do not present new numerical thresholds for onset of behavioural responses for marine mammals, so the previously established guidelines from the US National Oceanic and Atmospheric Administration (NOAA) (2019) have been used. Accordingly, behavioural responses were assumed to occur in areas ensonified above an unweighted SPL of 120 dB re 1 µPa for continuous noise sources (Table 11), and 160 dB re 1 µPa for impulsive noise sources (Table 12) (NOAA 2019). Appendix A.3 provides more information about the development of this criteria.

Table 11. Criteria for effects of non-impulsive noise exposure, including vessel noise, for marine mammals: Unweighted SPL and SEL_{24h} thresholds.

Hearing group	NOAA (2019)	Southall et al. (2019)	
	Behaviour	PTS onset thresholds (received level)	TTS onset thresholds (received level)
	SPL (Lp; dB re 1 µPa)	Weighted SEL24h (LE,24h; dB re 1 µPa2·s)	Weighted SEL24h (LE,24h; dB re 1 µPa2·s)
Low-frequency (LF) cetaceans	120	199	179
High-frequency (HF) cetaceans		198	178
Very High-frequency (VHF) cetaceans		173	153

L_p denotes sound pressure level period and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa^2·s.

Table 12. Criteria for effects of impulsive noise exposure for marine mammals: Unweighted sound pressure level (SPL), 24 h sound exposure level (SEL_{24h}), and peak (PK) thresholds.

Hearing group	NOAA (2019) Behaviour	Southall et al. (2019) PTS onset thresholds [a] (received level)		Southall et al. (2019) TTS onset thresholds [a] (received level)	
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Low-Frequency (LF) cetaceans	160	183	219	168	213
High-frequency (HF) cetaceans		185	230	170	224
Very high-frequency (VHF) cetaceans		155	202	140	196
Otariid seals		183	232	168	226

[a] Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period.
$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted.
L_E denotes cumulative sound exposure over a 24 h period.

2.2. Fish, Sea Turtles, Fish Eggs, and Fish Larvae

In 2006, the Working Group on the Effects of Sound on Fish and Sea Turtles was formed to continue developing noise exposure criteria for fish and sea turtles, work begun by a NOAA panel two years earlier. The Working Group developed guidelines with specific thresholds for different levels of effects for several species groups (Popper et al. 2014). The guidelines define quantitative thresholds for three types of immediate effects:

- Mortality, including injury leading to death,
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma, and
- TTS.

Masking and behavioural effects can be assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. However, as these depend upon activity-based subjective ranges, these effects are not addressed in this report and are included in Section 2.2.1 for completeness only. Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure depends on the species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds were proposed for fish without a swim bladder (also appropriate for sharks and applied to whale sharks in the absence of other information), fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing. The criteria for fish, fish eggs, fish larvae and sea turtles are presented below.

2.2.1. Fish, Eggs, and Larvae

Table 13 lists the relevant effects thresholds from Popper et al. (2014) for non-impulsive noise. Some evidence suggests that fish sensitive to acoustic pressure show a recoverable loss in hearing sensitivity, or injury when exposed to high levels of noise (Scholik and Yan 2002, Amoser and Ladich 2003, Smith et al. 2006); this is reflected in the SPL thresholds for fish with a swim bladder involved in hearing.

Table 13. Criteria for non-impulsive (vessel and drilling) noise exposure for fish and sea turtles, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	(N) Low (I) Low (F) Low	170 dB SPL for 48 h	158 dB SPL for 12 h	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Sea turtles	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low
Fish eggs and fish larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low

Sound pressure level dB re 1 µPa.
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

Impulsive noise from airguns (i.e., from VSP) was assessed in this study based on the relevant effects thresholds from Popper et al. (2014) listed in Table 14. In general, whether an impulsive sound adversely effects fish behaviour depends on the species, the state of the individual exposed, and other factors.

The SEL metric integrates noise intensity over some period of exposure. Because the period of integration for regulatory assessments is not well defined for sounds that do not have a clear start or end time, or for very long-lasting exposures, an exposure evaluation time must be defined. Southall et al. (2007) defines the exposure evaluation time as the greater of 24 h or the duration of the activity. Popper et al. (2014) recommend a standard period of the duration of the activity; however, the publication also includes caveats about considering the actual exposure times if fish move. Integration times in this study for VSP operations have been applied over the total number of impulses per day.

Table 14. Criteria for impulsive noise exposure for fish, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	> 219 dB SEL_{24h} or > 213 dB PK	> 216 dB SEL_{24h} or > 213 dB PK	>> 186 dB SEL_{24h}	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL_{24h} or > 207 dB PK	203 dB SEL_{24h} or > 207 dB PK	>> 186 dB SEL_{24h}	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24h} or > 207 dB PK	203 dB SEL_{24h} or > 207 dB PK	186 dB SEL_{24h}	Pile driving: (N, I) High (F) Moderate Seismic: (N, I) Low (F) Moderate	(N, I) High (F) Moderate
Fish eggs and fish larvae	> 210 dB SEL_{24h} or > 207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) Moderate (I, F) Low

Peak sound pressure level dB re 1 µPa; SEL_{24h} dB re 1µPa^2·s.
All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist.
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

2.2.2. Sea Turtles

There is a paucity of data regarding responses of turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. Popper et al. (2014) suggested thresholds for onset of mortal injury (including PTS) and mortality for sea turtles and, in absence of taxon-specific information, adopted the levels for fish that do not hear well (suggesting that this likely would be conservative for sea turtles) (Table 13). Finneran et al. (2017) presented revised thresholds for turtle injury, considering frequency weighted SEL, which have been applied in this study for vessels (Table 15). Their rationale is that sea turtles have best sensitivity at low frequencies and are known to have poor auditory sensitivity (Bartol and Ketten 2006, Dow Piniak et al. 2012). Accordingly, TTS and PTS thresholds for turtles are likely more similar to those of fishes than to marine mammals (Popper et al. 2014).

Table 15. Acoustic effects of non-impulsive noise on sea turtles, weighted SEL_{24h}, Finneran et al. (2017).

PTS onset thresholds* (received level)	TTS onset thresholds* (received level)
220	200

[a] L_E, cumulative sound exposure over a 24 h period, with a reference value of 1 µPa^2·s.

McCauley et al. (2000) observed the behavioural response of caged sea turtles (green (*Chelonia mydas*) and loggerhead (*Caretta caretta*)) to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the sea turtles increased their swimming activity, and above 175 dB re 1 µPa they began to behave erratically, which was interpreted as an agitated state. The Recovery Plan for Marine Turtles in Australia (Department of the Environment and Energy et al. 2017) acknowledges the 166 dB re 1 µPa SPL reported (McCauley et al. 2000) as the level that may result in a behavioural response to marine turtles. The 175 dB re 1 µPa level from McCauley et al. (2000) is recommended as a criterion for behavioural disturbance. These thresholds are shown in Table 16.

Table 16. Acoustic effects of impulsive noise on sea turtles: Unweighted sound pressure level (SPL), 24 h sound exposure level (SEL_{24h}), and peak pressure (PK) thresholds.

Effect type	Criterion	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Behavioural response	McCauley et al. (2000)	166	NA	
Behavioural disturbance		175		
PTS onset thresholds [a] (received level)	Finneran et al. (2017)	NA	204	232
TTS onset thresholds [a] (received level)			189	226

[a] Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS and TTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.

L_p denotes sound pressure level period and has a reference value of 1 µPa.

$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted and has a reference value of 1 µPa.

L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa²s.

2.3. Invertebrates

Research is ongoing into the relationship between sound and its effects on crustaceans, including the relevant metrics for both effect and impact. Available literature suggests particle motion, rather than sound pressure, is a more important factor for crustacean and bivalve hearing. Water depth and seismic source size are related to the particle motion levels at the seafloor, with larger arrays and shallower water being related to higher particle motion levels, more likely relevant to effects on crustaceans and bivalves. Information is only available to define levels for assessment for impulsive sources.

At the seafloor interface, crustaceans and bivalves are subject to particle motion stimuli from several acoustic or acoustically induced waves. These include the particle motion associated with an impinging sound pressure wave in the water column (the incident, reflected, and transmitted portions), substrate acoustic waves, and interface waves of the Scholte type. However, it is unclear which aspect(s) of these waves is/are most relevant to the animals, either when they normally sense the environment or their physiological responses to loud sounds so there is not enough information to establish similar criteria and thresholds as done for marine mammals and fish. Including recent research, such as Day et al. (2016b), current literature does not clearly define an appropriate metric or identify relevant levels (pressure or particle motion) for an assessment. This includes the consideration of what particle motion levels lead to a behavioural response, or mortality. Therefore, at this stage, we cannot propose authoritative thresholds to inform the impact assessment. However, levels can be determined for pressure metrics presented in literature to assist the assessment.

The pressure and acceleration examples provided in Day et al. (2016a)) indicate that the acceleration and pressure signals occurred simultaneously, which was interpreted as an indication that the waterborne sounds were responsible for the accelerations measured by the geophones. For clarity, it is important to distinguish that the acceleration from waterborne sound energy is not ground roll, which Day et al. (2016a) correctly define as the sound that propagates along the interface at a speed lower than the shear wave speed of the sediment. However, the report subsequently uses ground roll for all further discussions of particle acceleration. While Day et al. (2016a) discuss that they chose the simplest measure of ground roll, it should have been referred to as “the acceleration from waterborne sound energy”, or ‘waterborne acceleration’ for short.

For crustaceans, a PK-PK sound level of 202 dB re 1 µPa (Payne et al. 2008) is considered to be associated with no effect, and it was therefore applied in this assessment. Additionally for context related to different levels of potential impairment, the PK-PK sound levels determined for crustaceans in Day et al. (2016b), 209–212 dB re 1 µPa and 213 dB re 1 µPa from Day et al. (2019), are also included.

3. Methods

The modelled sites have been split into five representative Areas to capture the variability of the marine environment across the Development footprint (refer to Figure 1 and the wide regional bathymetry in Appendix B.1.1). Area 1 is furthest from shore and the modelled sites are located in water depths of 1,149 m to 1,292 m. The modelled drilling, IMR and construction activities in Area 1 (Scenarios 1, 2, 6, 7 and 8) lie outside of the pygmy blue whale BIA. The modelled pipelaying activities in Area 1 (Scenarios 3, 4 and 5) lie within the pygmy blue whale BIA.

All activities in Areas 2 to 4 lie within the pygmy blue whale BIA. The water depths of modelled sites in Area 2 range from 1208 m to 1328 m. Area 3 is located over the foot of the continental slope; the water depths of modelled sites in Area 3 range from 918 m to 974 m. Area 4 considers modelled sites directly above the continental shelf, in 400 m of water. The water depth of the modelled sites for Area 4 was chosen based on a sensitivity analysis of seven slope locations of varying water depth; the chosen location resulted in the largest ranges to considered isopleth criteria.

Finally, Area 5 represents vessel activities on the continental shelf, in water depths of 141m to 145 m. Area 5 activities are located outside of the pygmy blue whale BIA.

To allow for operational flexibility, the sound speed profile implemented within the modelling was selected through a sensitivity analysis considering all months of the year. The month of August was found to be the most favourable for sound propagation, resulting in the largest ranges to considered isopleths criteria. As such, August was selected as the conservative choice for modelling. Additional detail can be found in Appendix B.1.2.

Geoacoustics information for Areas 1, 2, 3 and 4 were taken from Duncan and Erbe (2019) as provided by the client. For Area 1, the seabed geoacoustic model was characterised by 5 m of silt overlaying a 200 m thick package of silt and sand sediments underlain by a sedimentary rock half space. Areas 2 and 3 were modelled with a geoacoustic profile characterised by ~300m thick package of silt and sand sediments underlain by a sedimentary rock half space. Area 4 utilised a ‘Slope’ geoacoustic profile characterised by 50 m of silt overlaying a 150 m thick package of silt and sand sediments underlain by a sedimentary rock half space. Area 5, on the continental shelf, was adjacent to drill core site obtained during IODP Cruise 356 (Gallagher et al. 2017). The geoacoustic profile from the sampled core was therefore utilised during modelling of sites in Area 5; a 450 m thick package of unconsolidated sediments underlain by a sedimentary rock half space. Further details on the associated geoacoustic properties used in this modelling study are provided in Appendix B.1.3.

The following sections provide a high-level description of the inputs used for this underwater noise modelling study. The sections are divided into subsections detailing the source inputs for the different vessels (Section 3.1) and VSP activities (Section 3.2), with Sections 3.3 and 3.4 providing details on the applied modelling techniques and model configuration information. Section 3.5 provides details on the animal movement modelling methodology.

3.1. Vessel Noise Sources

Underwater sound that radiates from vessels is produced mainly by propeller and thruster cavitation, with a smaller fraction of noise produced by sound transmitted through the hull, such as by engines, gearing, and other mechanical systems. Sound levels tend to be the highest when thrusters are used to position the vessel and when the vessel is transiting at high speeds. A vessel's sound signature depends on the vessel's size, power output, propulsion system (e.g., conventional propellers vs. Voith Schneider propulsion), and the design characteristics of the given system (e.g., blade shape and size). A vessel produces broadband noise emissions with most of the energy emitted below a few kilohertz. Sound from onboard machinery, particularly sound below 200 Hz, dominates the sound spectrum before cavitation begins (Spence et al. 2007).

For the modelled vessels, Figures 9 to 11 present summary plots of considered source spectra for comparison purposes; additional detail on the sources is provided in Sections 3.1.1 to 3.1.4.

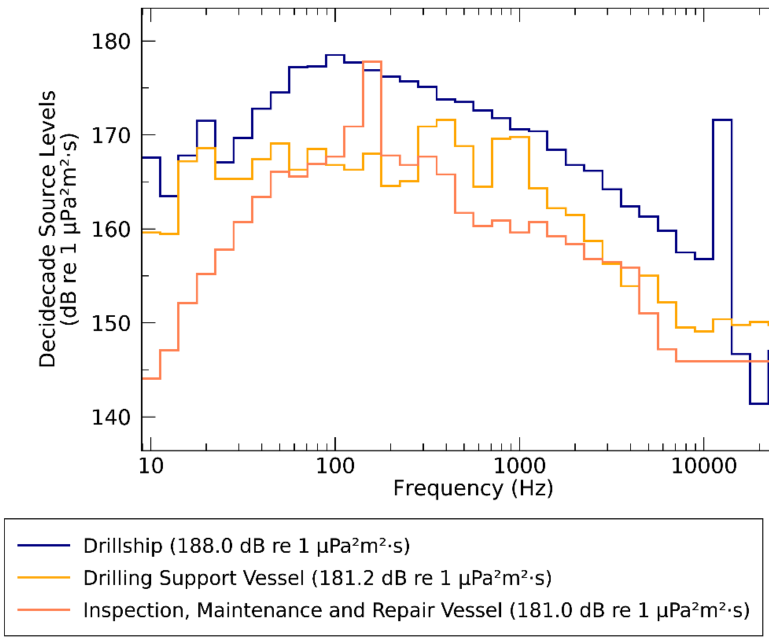

Figure 9. Energy source level (ESL) spectra (in decidecade frequency-band) for the three sound sources associated with Scenarios 1, 2, 6, 9, 10, 14, 17, 18, 22, 28, 29, 30, and 34: the drillship; the drillship support vessel (drillship OSV); and Inspection, Maintenance and Repair (IMR) vessel. All vessels are modelled under dynamic positioning.

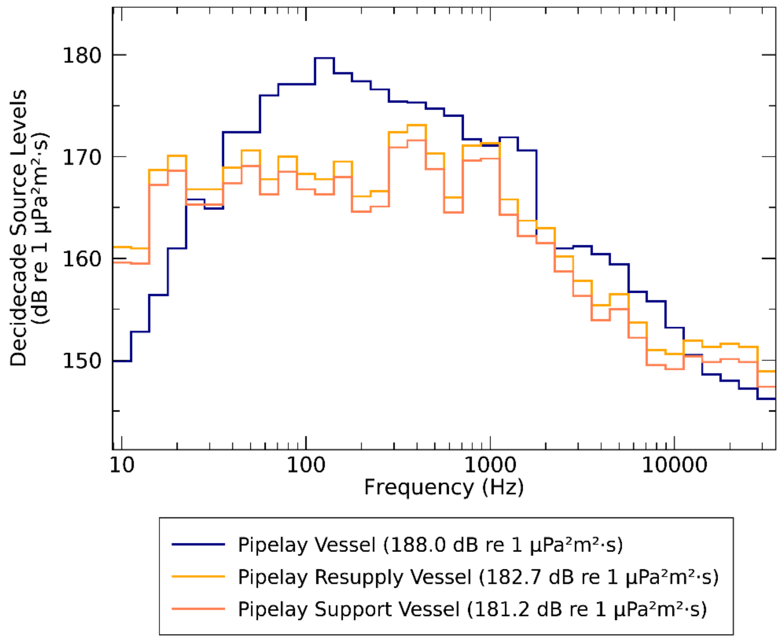

Figure 10. Energy source level (ESL) spectra (in decidecade frequency-band) for the three sound sources associated with Scenarios 3-5, 11-13, 19-21, 25-27, and 31-33: the pipelay vessel; the pipelay resupply vessel (pipelay OSV 1); and the pipelay support vessel (pipelay OSV 2). All vessels are modelled under dynamic positioning.

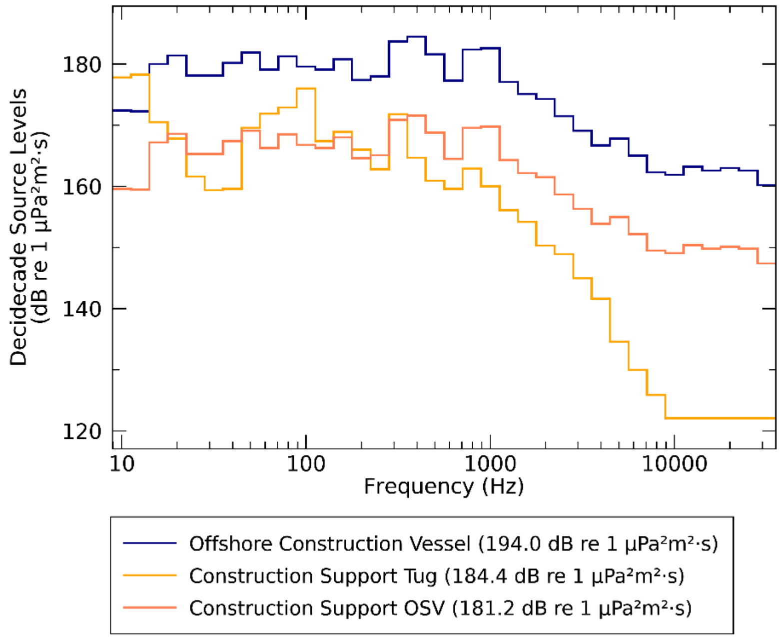

Figure 11. Energy source level (ESL) spectra (in decidecade frequency-band) for the sound sources associated with Scenarios 7, 8, 15, 16, 23, 24, 35, and 36 the offshore construction vessel (OCV), OCV support tug, and OCV support vessels (OSV), of which there are two. All vessels are modelled under dynamic positioning.

Each vessel considered here was modelled as a single source, with source levels detailed in the legends of Figures 9 to 11. Apart from the drillship and pipelay vessels, which have been modelled with source depths equal to their drafts (per the location of their thrusters), all source depths were based on the approximate location of noise emissions using a depth of 0.7 × ship draft, which aligns with current international standards, ISO 17208-1 (2016).

The following sections (Sections 3.1.1 to 3.1.4) detail the example vessels identified by Chevron as suitable representative vessels for the type/class of vessels that would be required to undertake the operations.

3.1.1. Drilling

3.1.1.1. Drillship

The vessel nominated as a representative drillship for this modelling study is the *Dhirubhai Deepwater KG2* (Figure 12). This vessel has an overall length, beam and draft of 228 m, 42 m, and 11.9 m, respectively. The thrusters of this vessel are located at the extent of its draft, and this vessel has been modelled with a source depth of 11.9 m.

Figure 12. *Dhirubhai Deepwater KG2*, the representative drillship.

As there are currently no publicly available underwater sound measurements of the *Dhirubhai Deepwater KG2*, measurements obtained for a similar vessel, the *Stena IceMAX*, have been used as a proxy. The *Stena IceMAX* is an identical size to the *Dhirubhai Deepwater KG2*. Underwater noise measurements of the *Stena IceMAX* were obtained from MacDonnell (2017). The broadband (10 Hz to 31 kHz) source level of this vessel has been modelled as 188.0 dB re 1 µPa^{2}m^2·s, with the spectral shape for this vessel also available from MacDonnell (2017) (Figure 9).

3.1.1.2. Drilling Offshore Support Vessel (OSV)

In some drilling scenarios, the drillship has been modelled with an offshore support vessel (OSV) alongside under DP for 8 hours. We have considered the *MMA Leeuwin* as a generic OSV in this capacity. The average broadband (10 Hz to 31 kHz) source level of the *MMA Leeuwin* undertaking DP exercises has been measured as 181.2 dB re 1 μPa^{2}m^2·s (Esso and ExxonMobil 2021). A publicly available spectral shape of another generic OSV, the *Siem Sapphire* (McPherson et al. 2021), has been scaled to the *MMA Leeuwin* broadband source level (Figure 9). The source depth of the *MMA Leeuwin* has been modelled as 70% of the vessel draft (draft of 6.5 m, resulting in a source depth of 4.6 m), per ISO 17208-1 (2016).

3.1.2. Inspection, Maintenance and Repair (IMR)

The multi-purpose vessel, *Skandi Hercules*, has been nominated as a representative IMR vessel for this Development. This vessel has a length of 110 m, beam of 24 m, and draft of 7.8 m (source depth of 5.5 m). This vessel has been modelled using sound measurements from the similarly sized construction vessel, *Deep Orient*, which has a publicly available broadband source level and source spectra (Quijano and McPherson 2021). The broadband (10 Hz to 31 kHz) source level has been modelled as 181.0 dB re 1 μPa^{2}m^2·s (Figure 9).

3.1.3. Pipelay

3.1.3.1. Pipelay Vessel

The *Allseas Solitaire* (Figure 13) has been considered as a representative pipelay vessel in each of the five modelling Areas. This vessel has a length of 368 m (including stinger), beam of 41 m, and draft of 14.5 m (source depth of 14.5 m as thrusters are located at extent of draft).

Figure 13. *Allseas Solitaire*, the representative pipelay vessel

Underwater noise levels related to the *Allseas Solitaire* are publicly available from Tougaard and Griffiths (2020).

The broadband (10 Hz to 31 kHz) source level of the *Allseas Solitaire* is reported in Table 3.1 by Tougaard and Griffiths (2020) for several measurement occasions. This study considers a broadband source level of 188.0 dB re 1 µPa^{2}m^2·s, which is the median level of those supplied in the referenced table. The source spectra for the *Allseas Solitaire* was also obtained from Tougaard and Griffiths (2020) (Figure 10).

3.1.3.2. Pipelay Resupply Offshore Support Vessel (OSV)

A pipelay resupply OSV has been modelled alongside the pipelay vessel in Scenarios 4, 5, 12, 13, 20, 21, 26, 27, 32 and 33. The resupply vessel has been represented by the *Allseas Alegria*, an OSV, which has an overall length of 83 m, beam of 19 m and draft of 6.3 m (source depth of 4.4m).

As there are no publicly available measurements of the source level of the *Allseas Alegria*, the source level of the OSV *MMA Leeuwin* (Esso and ExxonMobil 2021) was scaled up to correspond with a suitable source level for the *Allseas Alegria*. The overall power of the *MMA Leeuwin* is 4,960 kw, while the *Allseas Alegria* has an overall power of 7000 kW, hence the need to scale up the publicly available source level. The broadband (10 Hz to 31 kHz) source level of the *Allseas Alegria* has been modelled as 182.7 dB re 1 µPa^{2}m^2·s. As per the drilling OSV (Section 3.1.1.2), the spectra for this vessel has been represented *via* scaling the spectra of the *Siem Sapphire* (McPherson et al. 2021) (Figure 10).

3.1.3.3. Pipelay Offshore Support Vessel (OSV)

In addition to the pipelay resupply OSV, a second concurrent support OSV has been considered alongside the pipelay vessel in Scenarios 5, 13, 21, 27 and 33. This vessel was specified as a generic OSV and is identical to the drilling OSV specified in Section 3.1.1.2.

3.1.4. Construction

3.1.4.1. Offshore Construction Vessel (OCV)

An offshore construction vessel (OCV) is considered in Scenarios 7, 8, 15, 16, 23, 24, 35 and 36. A representative vessel of this vessel class has been considered as the *Skandi Africa.* This vessel has an overall length of 161 m, a beam of 32 m, and a draft of 9.3 m (resulting in a source depth of 6.5 m) (Figure 14). In this modelling study, the *Skandi Africa* has been represented by the OSV *Siem Sapphire*, which is a similarly sized (91m long, 22m beam, 8.0m draft) vessel, with similar installed power (21,100 kW for the *Skandi Africa*, 22,840 kW for the *Siem Sapphire*). The publicly available source level and spectra of the *Siem Sapphire* (McPherson et al. 2021) have been scaled down slightly (based on installed power) to represent the *Skandi Africa*, resulting in a broadband (10 Hz to 31 kHz) source level of 194.0 dB re 1 µPa^{2}m^2·s (Figure 11).

3.1.4.2. Construction Support Tug

In Scenarios 8, 16, 24 and 36, the OCV has been considered with support from three other vessels in close proximity. The first of these is a support tug, which has been represented by the *Mermaid Sound*. The *Mermaid Sound* has a length of 50 m, a beam of 13.4 m, and a draft of 4.9 m (resulting in a source depth of 3.4 m). As there are no publicly available measurements of the sound produced by the *Mermaid Sound*, this vessel has been directly represented by another Tug, the *Katun*. The source level and spectra of the *Katun* has been measured by JASCO Applied Sciences (Hannay et al. 2004). The broadband (10 Hz to 31 kHz) source level has been modelled as 184.4 dB re 1 µPa^{2}m^2·s (Figure 11).

3.1.4.3. Construction Offshore Support Vessels (OSV 1 and OSV 2)

In addition to the Support Tug, Scenarios 8, 16, 24 and 36 also include two construction support OSVs modelled alongside the OCV. The two OSVs have been represented by the *MMA Chieftain* and the *MMA Coral*. Both OSVs are 70 m long, with drafts of 6.1 m (source depths modelled as 4.3 m). The beam of the *MMA Chieftain* is 16 m, and the beam of the *MMA Coral* is 17 m.

For modelling purposes, both OSVs have been represented with the source level associated with the *MMA Leeuwin*, a similarly sized OSV, which was measured while undertaking comparable activities (Esso and ExxonMobil 2021). The broadband (10 Hz to 31 kHz) source level of each OSV has therefore been modelled as 181.2 dB re 1 $\mu Pa^2m^2{\cdot}s$. As per the other OSVs considered in this modelling study, the spectra for these two vessels has been represented *via* scaling the spectra of the *Siem Sapphire* (McPherson et al. 2021) (Figure 11).

Figure 14. *Skandi Africa*, the representative Offshore Construction Vessel.

3.2. Vertical Seismic Profiling Acoustic Source

The pressure signature of the individual airguns and the composite decidecade band point-source equivalent directional levels (i.e., source levels) of the 750 in^3 Vertical Seismic Profiling (VSP) source suspended at a depth of 5 m were modelled with JASCO's Airgun Array Source Model (AASM; Appendix C). A set of nine aggregate exposure (SEL_{24h}) scenarios were modelled at each VSP location with 5, 10, 25, 50, 100, 200, 250 and 300 shots over 24 hours to realistically represent a range of potential operations.

3.2.1. Acoustic Source Model

AASM accounts for the notional pressure signatures of each source element with respect to the effects of surface-reflected signals on bubble oscillations and inter-bubble interactions, the surface-reflected signal (known as surface ghost) is not included in the far-field source signatures. The acoustic propagation models account for those surface reflections, which are a property of the propagating medium rather than the source. AASM considers:

- Array layout;
- Volume, depth, and firing pressure of each airgun; and
- Interactions between different airguns in the array.

3.3. Geometry and Modelled Regions

JASCO's Marine Operations Noise Model (MONM-BELLHOP; see Appendix B.2.2) was used to predict the acoustic field at frequencies of 10 Hz to 25 kHz for all vessels. To supplement the MONM results, high-frequency results for propagation loss were modelled using Bellhop (Porter and Liu 1994) for frequencies from 1.26 to 25 kHz . The MONM and BELLHOP results were combined to produce results for the full frequency range of interest. The sound field modelling calculated propagation losses up to 100 km from the source, with a horizontal separation of 20 m between receiver points along the modelled radials. The sound fields were modelled with a horizontal angular resolution of $\Delta\theta$ = 2.5° for a total of N = 144 radial planes. Receiver depths were chosen to span the entire water column over the modelled areas, from 2 m to a maximum of 3250 m, with step sizes that increased with depth.

To produce the maps of received sound level isopleths, and to calculate distances to specified sound level thresholds, the maximum-over-depth level was calculated at each sampling point within the modelled region. The radial grids of maximum-over-depth levels were then resampled (by linear triangulation) to produce a regular Cartesian grid. The contours and threshold ranges were calculated from these grids of the modelled acoustic fields.

3.4. Accumulated SEL

In this study, the sound sources were considered to be continuously operating with new sound energy constantly being introduced to the environment. The reported source levels are usually in terms of sound pressure levels (SPL), representing the average instantaneous acoustic level of a considered source. The evaluation of the cumulative sound field (i.e., in terms of SEL_{24h}) depends on the number of seconds of operation during the accumulation period.

For all stationary sources, the SPL modelling results were converted to SEL by the duration of the measurement, which is appropriate for a non-impulsive noise source. As SEL was assessed over 24 h and for a stationary vessel over a day, the conversion from SPL was obtained by increasing the levels by $10*\log_{10}(T)$, where T is 86400 (the number of seconds in 24 h). For scenarios where a vessel was transiting along a track a similar adjustment to the SPL was applied, however the time factor was determined based on the step size along the track and the vessel's speed, see Appendix B.4 for details.

3.5. Animal Movement and Exposure Modelling

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to predict the exposure of animats to sound arising from the vessel activity scenarios (Tables 7 and 9). JASMINE integrates the predicted sound field with biologically meaningful movement rules for each marine mammal species (pygmy blue whales for the current analysis) that results in an exposure history for each animat in the model. An overview of the exposure modelling process using JASMINE is shown in Figure 15.

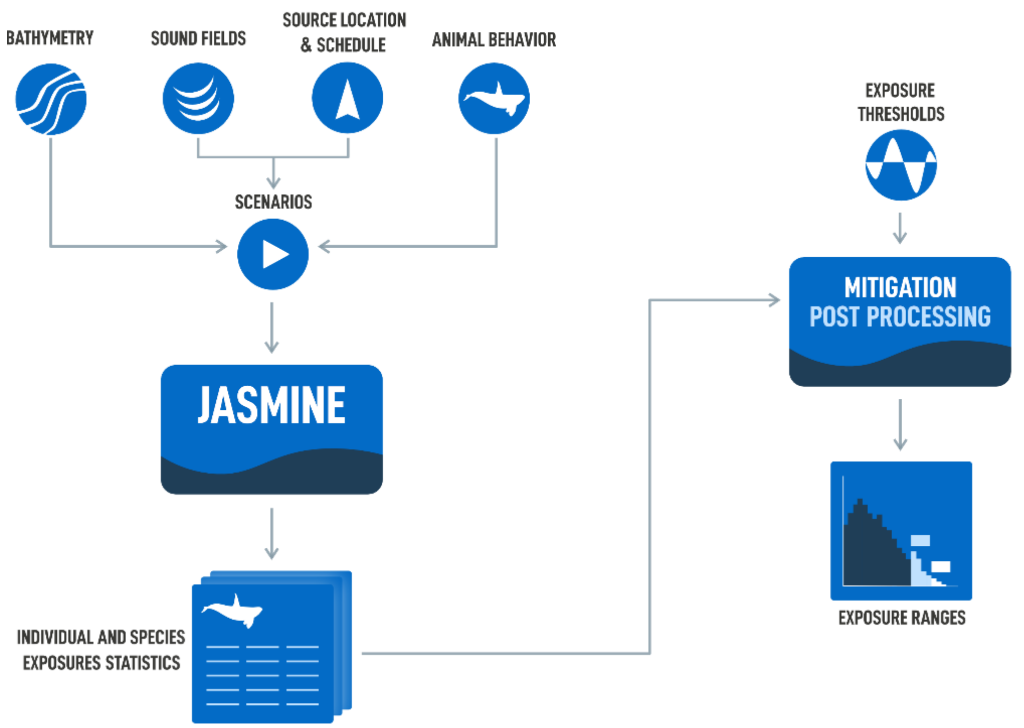

Figure 15. Exposure modelling process overview.

In JASMINE, the sound received by the animats is determined by the proposed vessel activities. As illustrated in Figure 16, animats are programmed to behave like the marine animals that may be present in an area. The parameters used for forecasting realistic behaviours (e.g., diving and foraging depth, swim speed, surface times) are determined and interpreted from marine mammal studies (e.g., tagging studies) where available, or reasonably extrapolated from related or comparable species. For cumulative metrics, an individual animat's sound exposure levels are summed over a 24 h duration to determine its total received energy, and then compared to the relevant threshold criteria. For single-exposure metrics, the maximum exposure is evaluated against threshold criteria for each 24 h period. For additional information on JASMINE, see Appendix D.

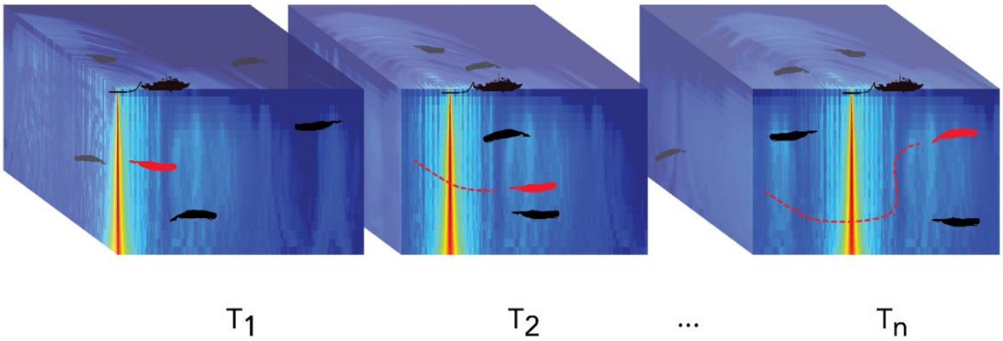

Figure 16. Depiction of animats in a moving sound field. Example animat (red) shown moving with each time step (T_n). The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

The exposure criteria for non-impulsive sounds (described in Section 2) were used to determine the number of animats that exceeded thresholds. To generate statistically reliable probability density functions, model simulations were run with animat sampling densities of 4 animats/km^2. Due to insufficient density data availability, the modelling results are not related to real-world density estimates for pygmy blue whales within the BIA. To evaluate PTS, TTS and behavioural response, exposure results were obtained using detailed behavioural information for migrating pygmy blue whales (described in Section 3.5.2). The simulation was run for a representative period of 24 h to coincide with the acoustic modelling effort. A subset of acoustic modelling scenarios was considered for animal movement modelling. Animat scenarios included acoustic modelling Scenarios 8, 19, 32, 33 and 34 (see Tables 7 and 9). Due to their locations within or close to the migratory pygmy blue whale BIA, all considered scenarios were run for migrating pygmy blue whales restricted to the BIA as well as unrestricted.

Despite the Development's proximity to the humpback whale BIA, animal movement modelling was not considered for humpback whales as the acoustic footprints of the corresponding vessel activities did not reach the BIA.

Figure 17 shows an example animat track (generated for information purposes only and not related to the results presented in this report) with associated received levels from a stationary point source. The top panel displays the animat track relative to the point source, and the bottom panel displays the accumulation of SEL_{24h} for TTS and PTS criteria. At approximately 50 seconds, the animat is exposed so that the TTS threshold is exceeded, and at approximately 700 seconds the animat is exposed so that the PTS threshold is exceeded.

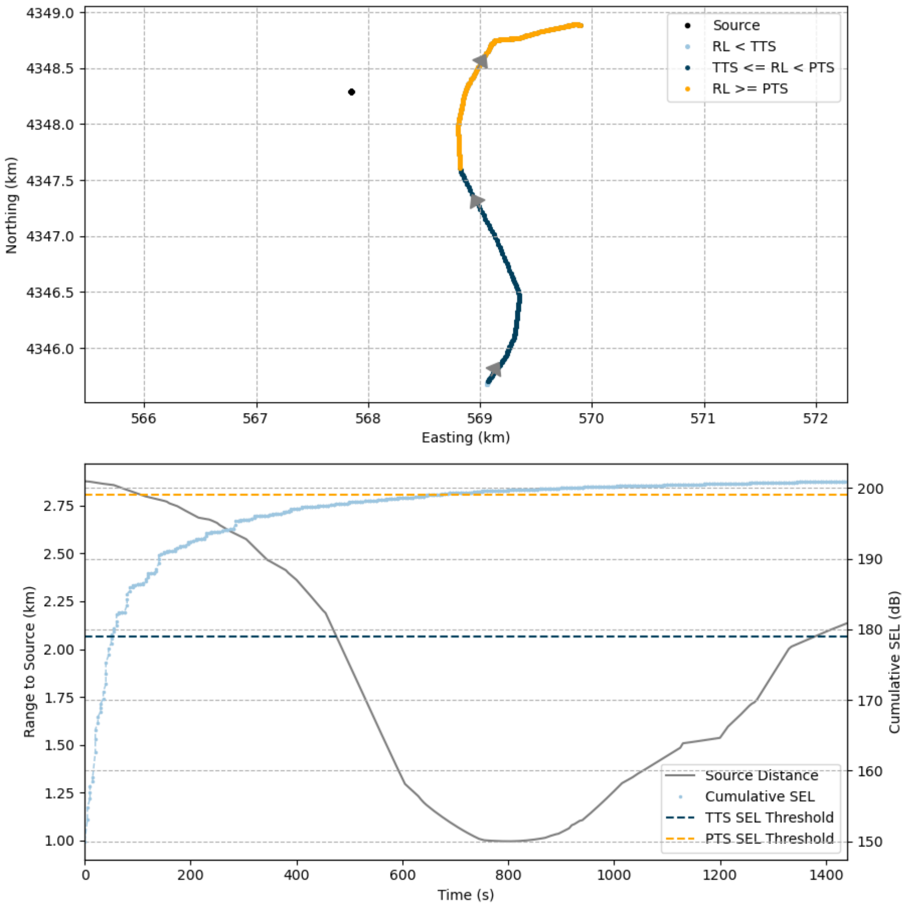

Figure 17. Animat track from an example simulation showing northward movement over a 1400 s duration. The upper panel shows a plan view of both a stationary point source and a foraging animat. Animat steps are coloured to indicate whether the accumulated sound energy at that point has exceeded either TTS or PTS threshold criteria. The lower panel shows horizontal distance in kilometres to the source (grey line; left y-axis) and cumulative 24-h SEL ($L_{E,24h}$, dB re 1 µPa²·s; right y-axis) as a function of time. Note that this example does not use data from the current study.

3.5.1. Exposure-based Radial Distance Estimation

The results from the animal movement and exposure modelling provided a way to estimate radial distances to effect thresholds. The distance to the closest point of approach (CPA) for each of the animats was recorded. The $ER_{95\%}$ (95% Exposure Range) is the horizontal distance that includes 95% of the animat CPAs that exceeded a given effect threshold (Figure 18). Within the $ER_{95\%}$, there is generally some proportion of animats that do not exceed threshold criteria. This occurs for several reasons, including the spatial and temporal characteristics of the sound field and the way in which animats sample the sound field over time, both vertically and horizontally. The sound field varies as a function of range, depth, and azimuth based on a variety of factors such as bathymetry, sound speed profile, and geoacoustic parameters. The way the animats sample the sound field depends upon species-typical swimming and diving characteristics (e.g., swim speed, dive depth, surface intervals, and reversals). Furthermore, even within a particular species definition, these characteristics vary with behavioral state (e.g., feeding, migrating). As this results in some animats not exceeding threshold criteria even within the $ER_{95\%}$, the probability that an animat within that distance was exposed above threshold within the $ER_{95\%}$ was also computed (P_{exp}) to provide additional context.

Acoustic ranges are reported for both $R_{95\%}$ and R_{max}, however, exposure ranges are reported for $ER_{95\%}$ only since, statistically, ER_{max} is not defined. JASMINE is a Monte Carlo simulation, and the results are probabilistic in nature. This is in contrast with acoustic modelling, where there is a specific maximum isopleth range for a given source/environment setup.

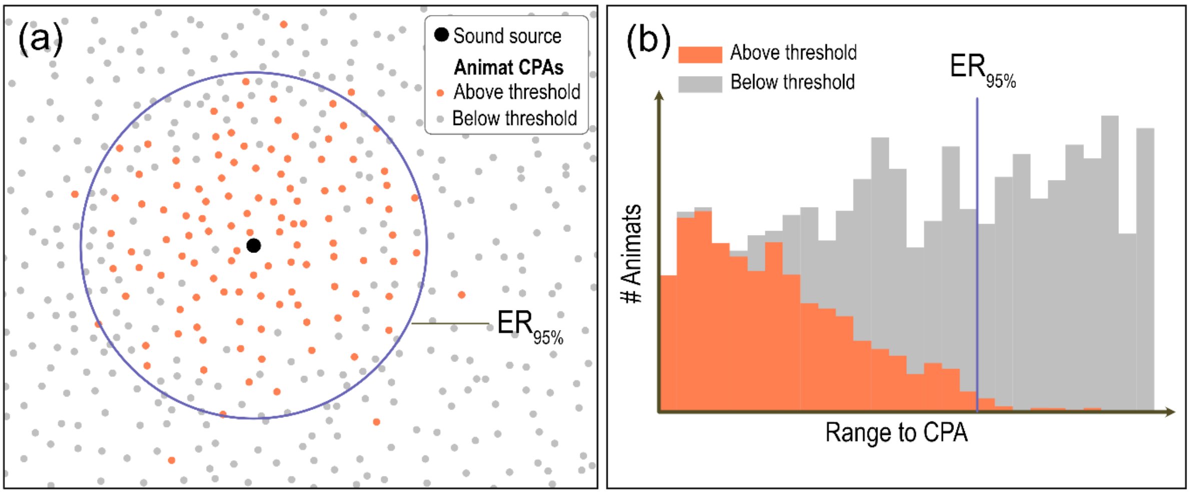

Figure 18. Example distribution of animat closest points of approach (CPAs). Panel (a) shows the horizontal distribution of animats near a sound source. Panel (b) shows the distribution of distances to animat CPAs. The 95% exposure range ($ER_{95\%}$) is indicated in both panels.

3.5.2. Pygmy Blue Whale Behaviour

Animal movement modelling scenarios are located within or adjacent to the migration BIA for pygmy blue whales, therefore migration was the only behavioural profile considered. The north-bound migration was selected for modelling because previous work (McPherson 2022) showed that this behavioural profile resulted in more conservative PTS and TTS exposure range estimates. Detailed information on pygmy blue whales was derived from a range of sources that used multi-sensor tags to record fine-scale dive and movement behaviour (Owen et al. 2016, AIMS unpublished data 2021), as well as satellite tags to record travel speed (Thums and Ferreira 2021).

Multi-sensor tags typically record the depth of an animal along with various movement parameters such as swim speed and their body's orientation. Owen et al. (2016) equipped a sub-adult pygmy blue whale with a multi-sensor tag off Western Australia. They identified dives for the tagged animal as migratory, feeding, or exploratory (i.e., no lunges recorded which would indicate feeding). Pygmy blue whales in the simulation area are presumed to be migrating, and so feeding was not included in the model. Exploratory dives were considered to be part of migratory behaviour, and so the two dive types were modelled together such that the animats were migrating 95% of the time and engaged in exploratory dives 5% of the time (Owen et al. 2016).

Using data from Owen et al. (2016), the approximate length of a bout of exploratory dives could be determined, as well as the average (± SD) depth of this dive type. The speed of travel for both dive behaviours was calculated from data presented in Thums and Ferreira (2021), who analysed data from satellite tags deployed on pygmy blue whales in the Northwest Marine Region. All remaining parameters were calculated from two multi-sensor tags deployed on pygmy blue whales off Western Australia (AIMS unpublished data 2021).

The behaviour of migrating pygmy blue whales was modelled to reflect animats transiting through the modelling area on a 45° track for the northward migration. This represents the animals migrating along the west coast of Australia to their breeding grounds in Indonesia (Double et al. 2014, Thums and Ferreira 2021).

4. Results

4.1. Vessel Activities – Acoustic Modelling Tabulated Results

Tables 17 to 21 present the maximum and 95% distances (defined in Appendix B.3) to SPL levels for each of the five Areas.

To consider the aggregate contribution of noise emissions from the four combined scenarios, ensonified areas were examined for Scenarios 37 – 40, rather than maximum radii. Tables 22 and 23 present the ensonified areas for the four combined scenarios and compare the total ensonified area to the summed areas of the corresponding individual scenarios. The changes in ensonified areas are presented as km^2 and as percentage change.

Tables 24 to 28 present the maximum distances to frequency-weighted SEL_{24h} thresholds, as well as total ensonified areas. Tables 29 and 30 present the changes in ensonified areas for the combined scenarios compared to their corresponding individual scenarios.

For the results below, the distances to isopleths/thresholds were reported from either the centroid of several sources, from the most dominant single source, or from a track. When an isopleth completely envelopes multiple sources the centroid was used, and when several closed isopleths exist the most dominant source was used. Maps are provided in Section 4.2 to assist with contextualising tabulated distances.

Table 17. SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL) for Area 1. A dash indicates the threshold is not reached within the limits of the modelled resolution (20 m). Scenario descriptions are given in Table 7.

SPL (L_p; dB re 1 µPa)	Scenario 1 – Drillship		Scenario 2 – Drillship with OSV		Scenario 3 – Pipelay vessel		Scenario 4 – Pipelay vessel with resupply vessel		Scenario 5 – Pipelay vessel with resupply vessel and support vessel		Scenario 6 – IMR vessel		Scenario 7 – OCV		Scenario 8 – OCV with 3 support vessels	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.03	0.03
170[a]	–	–	–	–	–	–	0.04	0.04	0.05	0.05	–	–	–	–	0.04	0.04
160	0.04	0.04	0.06	0.06	0.04	0.04	0.05	0.04	0.05	0.05	–	–	0.06	0.06	0.07	0.07
158[b]	0.05	0.05	0.08	0.08	0.05	0.05	0.06	0.06	0.06	0.06	–	–	0.08	0.08	0.09	0.08
150	0.11	0.11	0.15	0.14	0.12	0.12	0.13	0.13	0.14	0.14	0.05	0.05	0.20	0.20	0.23	0.22
140	0.36	0.35	0.41	0.38	0.38	0.37	0.43	0.41	0.44	0.43	0.17	0.17	0.63	0.62	0.67	0.65
130	1.11	1.07	1.21	1.15	1.17	1.13	1.29	1.23	1.35	1.30	0.53	0.51	2.51	2.43	2.66	2.57
120[c]	5.62	5.38	5.87	5.61	6.30	6.00	6.56	6.24	6.72	6.39	1.99	1.91	15.5	13.7	15.7	13.9
110	20.6	17.4	28.7	17.9	22.1	17.8	28.6	18.8	29.6	20.3	5.80	5.60	36.6	31.1	42.6	31.6

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).

Table 18. SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL) for Area 2. A dash indicates the threshold is not reached within the limits of the modelled resolution (20 m). Scenario descriptions are given in Table 7.

SPL (L_p; dB re 1 µPa)	Scenario 9 – Drillship		Scenario 10 – Drillship with OSV		Scenario 11 – Pipelay vessel		Scenario 12 – Pipelay vessel with resupply vessel		Scenario 13 – Pipelay vessel with resupply vessel and support vessel		Scenario 14 – IMR vessel		Scenario 15 – OCV		Scenario 16 – OCV with 3 support vessels	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	–	–	0.03	0.03	–	–	–	–	–	–	0.03	0.03
170[a]	–	–	–	–	–	–	0.03	0.03	0.03	0.03	–	–	–	–	0.04	0.04
160	0.04	0.04	0.07	0.07	0.03	0.03	0.05	0.04	0.05	0.05	–	–	0.06	0.06	0.07	0.07
158[b]	0.04	0.04	0.07	0.07	0.05	0.05	0.06	0.06	0.07	0.06	0.02	0.02	0.08	0.08	0.09	0.09
150	0.11	0.11	0.15	0.14	0.12	0.11	0.14	0.13	0.14	0.14	0.05	0.05	0.20	0.20	0.23	0.22
140	0.36	0.35	0.41	0.38	0.38	0.37	0.43	0.41	0.44	0.43	0.17	0.17	0.63	0.62	0.67	0.65
130	1.11	1.07	1.21	1.15	1.17	1.12	1.29	1.23	1.34	1.30	0.53	0.52	2.06	1.98	2.60	2.49
120[c]	5.60	5.34	5.85	5.56	6.42	6.06	6.70	6.31	6.88	6.46	1.74	1.68	15.1	11.0	15.4	11.5
110	18.7	17.1	19.6	17.7	26.2	19.5	33.7	21.9	34.9	23.9	7.50	6.60	35.9	31.2	36.6	31.7

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).

Table 19. SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL) for Area 3. A dash indicates the threshold is not reached within the limits of the modelled resolution (20 m). Scenario descriptions are given in Table 7.

SPL (L_p; dB re 1 µPa)	Scenario 17 – Drillship		Scenario 18 – Drillship with OSV		Scenario 19 – Pipelay vessel		Scenario 20 – Pipelay vessel with resupply vessel		Scenario 21 – Pipelay vessel with resupply vessel and support vessel		Scenario 22 – IMR vessel		Scenario 23 – OCV		Scenario 24 – OCV with 3 support vessels	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	–	–	–	–	0.04	0.04	–	–	–	–	0.02	0.02
170[a]	–	–	–	–	–	–	0.03	0.03	0.04	0.04	–	–	–	–	0.04	0.04
160	0.04	0.04	0.06	0.06	0.04	0.04	0.05	0.05	0.06	0.05	–	–	0.06	0.06	0.07	0.06
158[b]	0.05	0.05	0.08	0.08	0.05	0.05	0.06	0.06	0.06	0.06	–	–	0.08	0.08	0.09	0.08
150	0.12	0.11	0.15	0.14	0.12	0.12	0.14	0.13	0.14	0.14	0.05	0.05	0.20	0.20	0.23	0.22
140	0.36	0.35	0.41	0.38	0.38	0.37	0.43	0.41	0.44	0.43	0.17	0.17	0.63	0.62	0.67	0.65
130	1.11	1.07	1.21	1.15	1.17	1.13	1.28	1.23	1.36	1.30	0.53	0.52	3.05	2.62	3.39	3.16
120[c]	5.30	4.94	12.1	5.23	5.78	5.41	12.8	5.78	13.0	6.12	2.64	2.46	14.0	12.8	14.0	12.9
110	26.9	24.5	27.1	24.9	28.3	26.1	28.5	26.4	28.6	26.5	8.38	7.53	41.5	36.4	41.7	37.8

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).

Table 20. SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL) for Area 4. A dash indicates the threshold is not reached within the limits of the modelled resolution (20 m). Scenario descriptions are given in Table 7.

SPL (L_p; dB re 1 µPa)	Scenario 25 – Pipelay vessel		Scenario 26 – Pipelay vessel with resupply vessel		Scenario 27 – Pipelay vessel with resupply vessel and support vessel		Scenario 28 – IMR vessel	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	0.03	0.03	–	–
170[a]	–	–	0.03	0.03	0.05	0.05	–	–
160	0.04	0.04	0.05	0.04	0.07	0.07	–	–
158[b]	0.05	0.05	0.06	0.06	0.09	0.08	0.02	0.02
150	0.12	0.12	0.14	0.14	0.20	0.19	0.05	0.05
140	0.39	0.38	0.44	0.41	0.64	0.61	0.17	0.17
130	1.94	1.80	2.10	1.95	2.92	2.69	0.55	0.52
120[c]	7.87	7.19	9.72	7.37	18.3	16.6	2.24	2.04
110	39.5	29.7	40.2	32.3	58.0	47.0	9.85	9.24

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).

Table 21. SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL) for Area 5. A dash indicates the threshold is not reached within the limits of the modelled resolution (20 m). Scenario descriptions are given in Table 7.

SPL (L_p; dB re 1 µPa)	Scenario 29 – Drillship		Scenario 30 – Drillship with OSV		Scenario 31 – Pipelay vessel		Scenario 32 – Pipelay vessel with resupply vessel		Scenario 33 – Pipelay vessel with resupply vessel and support vessel		Scenario 34 – IMR vessel		Scenario 35 – OCV		Scenario 36 – OCV with 3 support vessels	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	–	–	0.03	0.03	0.03	0.03	–	–	–	–	0.03	0.03
170[a]	–	–	–	–	–	–	0.04	0.04	0.05	0.05	–	–	–	–	0.03	0.03
160	0.04	0.04	0.07	0.07	0.04	0.04	0.05	0.05	0.05	0.05	–	–	0.07	0.06	0.07	0.07
158[b]	0.05	0.05	0.07	0.07	0.05	0.05	0.06	0.06	0.06	0.06	–	–	0.08	0.08	0.09	0.08
150	0.12	0.11	0.15	0.14	0.12	0.12	0.15	0.14	0.15	0.14	0.06	0.05	0.21	0.20	0.23	0.22
140	0.64	0.61	0.69	0.66	0.67	0.64	0.73	0.69	0.75	0.72	0.18	0.17	1.14	1.07	1.23	1.15
130	2.96	2.64	3.26	2.75	3.18	2.75	3.33	3.09	3.55	3.24	0.91	0.83	4.85	4.48	5.18	4.73
120[c]	10.0	8.63	10.4	9.10	12.2	10.1	12.8	10.5	12.9	10.9	3.76	3.43	17.0	13.8	17.3	14.5
110	32.4	25.3	32.7	27.2	35.8	28.3	36.6	29.9	38.4	31.0	13.2	9.94	56.8	46.1	69.1	49.8

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).

Table 22. SPL: Total ensonified area (km^2) above sound pressure levels (SPLs) for combined scenarios 37 and 38. The ensonified areas for the corresponding individual scenarios are provided, as well as the percentage difference in area. Scenario descriptions are given in Table 9.

SPL (L_p; dB re 1 µPa)	Scenario 37 – Area 1, pipelay vessel with 2 support vessels + Area 3, drillship with OSV				Scenario 38 – Area 1, OCV with 3 support vessels + Area 2, IMR vessel + Area 3, drillship with OSV			
	Ensonified area, combined scenario (km^2)	*Sum of ensonified areas of individual scenarios (km^2)*	*Change in ensonified area from individual scenarios to combined (km^2)*	*Percentage change in ensonified area from individual scenarios to combined (%)*	*Ensonified area, combined scenario (km^2)*	*Sum of ensonified areas of individual scenarios (km^2)*	*Change in ensonified area from individual scenarios to combined (km^2)*	*Percentage change in ensonified area from individual scenarios to combined (%)*
180	0.001	0.001	/	*	0.003	0.003	/	*
170[a]	0.01	0.01	/	*	0.01	0.01	/	*
160	0.01	0.01	/	*	0.02	0.02	/	*
158[b]	0.02	0.02	/	*	0.04	0.04	/	*
150	0.11	0.11	/	*	0.22	0.22	/	*
140	1.08	1.08	/	*	1.95	1.95	-0.002	- 0.09
130	9.97	9.97	- 0.006	- 0.06	27.1	27.1	0.03	+ 0.11
120[c]	218.4	217.6	+ 0.80	+ 0.37	668.3	647.5	20.8	+ 3.21
110	2387.8	2218.8	+ 168.9	+ 7.62	4563.5	4370.4	193.1	+ 4.42

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).
/ Indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km^2).

Table 23. SPL: Total ensonified area (km²) above sound pressure levels (SPLs) for combined scenarios 39 and 40. The ensonified areas for the corresponding individual scenarios are provided, as well as the difference in area and percentage change. Scenario descriptions are given in Table 9.

SPL (L_p; dB re 1 µPa)	Scenario 39 - Area 3, drillship with OSV + Area 5, pipelay vessel with 2 support vessels				Scenario 40 - Area 5, drillship with OSV + Area 5, pipelay vessel with 2 support vessels			
	Ensonified area, combined scenario (km²)	*Sum of ensonified areas of individual scenarios (km²)*	*Change in ensonified area from individual scenarios to combined (km²)*	*Percentage change in ensonified area from individual scenarios to combined (%)*	*Ensonified area, combined scenario (km²)*	*Sum of ensonified areas of individual scenarios (km²)*	*Change in ensonified area from individual scenarios to combined (km²)*	*Percentage change in ensonified area from individual scenarios to combined (%)*
180	0.002	0.002	/	*	0.002	0.002	/	*
170[a]	0.01	0.01	/	*	0.01	0.01	/	*
160	0.01	0.01	/	*	0.01	0.01	/	*
158[b]	0.02	0.02	/	*	0.02	0.02	/	*
150	0.12	0.12	/	*	0.12	0.12	/	*
140	2.20	2.20	/	*	3.15	3.14	+ 0.01	+ 0.33
130	38.6	38.6	+ 0.05	+ 0.13	60.4	58.6	+ 1.76	+ 3.01
120[c]	466.3	448.2	+ 18.1	+ 4.03	707.1	626.2	+ 80.9	+ 12.9
110	4377.7	3800.8	+ 576.9	+ 15.2	4847.5	4723.1	+ 124.4	+ 2.63

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Criteria for marine mammal behavioural response to non-impulsive noise (NOAA 2019).
/ Indicates that the area is less than an area associated with the modelled resolution (0.0013 km²).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km²).

Table 24. Area 1, *Weighted SEL24h*: Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km²). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km²). Scenario descriptions are given in Table 7.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 1 - Drillship		Scenario 2 – Drillship with OSV		Scenario 3 – Pipelay vessel		Scenario 4 – Pipelay vessel with resupply vessel		Scenario 5 – Pipelay vessel with resupply vessel and support vessel		Scenario 6 – IMR vessel		Scenario 7 – OCV		Scenario 8 – OCV with 3 support vessels	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	R_{max} (km)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
PTS																	
Low-Frequency (LF) cetaceans	199	0.08	0.02	0.10	0.02	0.05	0.03	0.10	0.05	0.12	0.06	0.04	0.01	0.18	0.11	0.21	0.13
High-frequency (HF) cetaceans	198	0.02	0.002	0.04	0.002	–	/	0.04	0.002	0.04	0.002	–	/	0.02	0.002	0.15	0.003
Very High-frequency (VHF) cetaceans	173	0.18	0.10	0.21	0.10	0.03	0.01	0.06	0.03	0.11	0.04	0.03	0.003	0.18	0.10	0.21	0.12
Sea Turtles	220	0.02	/	0.02	0.002	–	/	0.05	0.01	0.04	0.01	–	/	0.02	0.00	0.04	0.003
TTS																	
Low-Frequency (LF) cetaceans	179	0.78	1.88	0.83	2.05	0.84	2.32	0.99	2.97	1.07	3.46	0.36	0.41	1.71	9.03	1.82	10.2
High-frequency (HF) cetaceans	178	0.13	0.05	0.16	0.06	0.03	0.01	0.06	0.02	0.09	0.04	0.02	0.002	0.14	0.06	0.19	0.07
Very High-frequency (VHF) cetaceans	153	3.27	29.1	3.31	29.3	0.62	1.16	0.76	1.90	1.02	3.09	0.27	0.24	2.46	19.0	2.61	21.3
Sea Turtles	200	0.09	0.02	0.12	0.03	0.06	0.04	0.10	0.05	0.11	0.05	0.05	0.01	0.13	0.06	0.18	0.07

Table 25. Area 2, *Weighted SEL24h*: Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km²). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km²). Scenario descriptions are given in Table 7.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 9 - Drillship		Scenario 10 – Drillship with OSV		Scenario 11 – Pipelay vessel		Scenario 12 – Pipelay vessel with resupply vessel		Scenario 13 – Pipelay vessel with resupply vessel and support vessel		Scenario 14 – IMR vessel		Scenario 15 – OCV		Scenario 16 – OCV with 3 support vessels	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	R_{max} (km)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
PTS																	
Low-Frequency (LF) cetaceans	199	0.07	0.02	0.11	0.02	0.06	0.04	0.09	0.05	0.12	0.06	0.04	0.01	0.19	0.11	0.21	0.13
High-frequency (HF) cetaceans	198	–	/	0.05	0.001	–	/	–	/	–	/	–	/	–	/	0.04	0.002
Very High-frequency (VHF) cetaceans	173	0.18	0.10	0.21	0.10	0.02	0.01	0.06	0.03	0.11	0.04	0.03	0.003	0.18	0.10	0.21	0.12
Sea Turtles	220	–	/	–	/	–	/	0.04	0.01	0.05	0.01	–	/	–	/	0.04	0.002
TTS																	
Low-Frequency (LF) cetaceans	179	0.78	1.88	0.84	2.05	0.85	2.33	0.99	2.97	1.08	3.46	0.36	0.41	1.70	8.99	1.81	10.2
High-frequency (HF) cetaceans	178	0.13	0.05	0.17	0.06	0.02	0.01	0.05	0.03	0.09	0.04	–	/	0.14	0.06	0.19	0.07
Very High-frequency (VHF) cetaceans	153	3.27	29.1	3.31	29.3	0.62	1.15	0.76	1.91	1.02	3.09	0.27	0.24	2.46	19.0	2.61	21.3
Sea Turtles	200	0.09	0.02	0.11	0.03	0.07	0.04	0.10	0.05	0.12	0.05	0.05	0.01	0.13	0.05	0.17	0.07

Table 26. Area 3, *Weighted SEL_{24h}*: Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2). Scenario descriptions are given in Table 7.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 17 - Drillship		Scenario 18 – Drillship with OSV		Scenario 19 – Pipelay vessel		Scenario 20 – Pipelay vessel with resupply vessel		Scenario 21 – Pipelay vessel with resupply vessel and support vessel		Scenario 22 – IMR vessel		Scenario 23 – OCV		Scenario 24 – OCV with 3 support vessels	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	R_{max} (km)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
PTS																	
Low-Frequency (LF) cetaceans	199	0.08	0.02	0.11	0.02	0.05	0.04	0.09	0.05	0.12	0.06	0.04	0.004	0.19	0.11	0.21	0.13
High-frequency (HF) cetaceans	198	0.02	0.001	0.04	0.002	–	/	–	/	–	/	–	/	0.01	0.001	0.16	0.004
Very High-frequency (VHF) cetaceans	173	0.18	0.10	0.21	0.10	0.03	0.02	0.06	0.03	0.10	0.04	0.03	0.003	0.18	0.10	0.21	0.12
Sea Turtles	220	0.02	0.001	0.02	0.001	0.02	0.01	0.04	0.01	0.04	0.01	0.02	0.001	0.01	0.001	0.14	0.004
TTS																	
Low-Frequency (LF) cetaceans	179	0.78	1.89	0.84	2.06	0.84	2.34	0.99	3.00	1.08	3.50	0.36	0.41	1.96	10.3	2.10	12.3
High-frequency (HF) cetaceans	178	0.13	0.05	0.16	0.05	0.03	0.02	0.06	0.03	0.09	0.04	0.02	0.001	0.14	0.06	0.18	0.07
Very High-frequency (VHF) cetaceans	153	3.28	29.1	3.31	29.3	0.62	1.16	0.80	1.93	1.02	3.13	0.27	0.23	2.46	18.9	2.62	21.4
Sea Turtles	200	0.09	0.03	0.12	0.03	0.06	0.04	0.10	0.05	0.12	0.05	0.05	0.01	0.13	0.05	0.18	0.07

Table 27. Area 4, *Weighted SEL24h*: Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2). Scenario descriptions are given in Table 7.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 25 – Pipelay vessel		Scenario 26 – Pipelay vessel with resupply vessel		Scenario 27 – Pipelay vessel with resupply vessel and support vessel		Scenario 28 – IMR vessel	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	R_{max} (km)
PTS									
Low-Frequency (LF) cetaceans	199	0.05	0.04	0.10	0.05	0.12	0.06	0.04	0.004
High-frequency (HF) cetaceans	198	–	/	0.03	/	0.04	/	–	/
Very High-frequency (VHF) cetaceans	173	0.02	0.01	0.06	0.03	0.10	0.04	0.03	0.004
Sea Turtles	220	–	/	0.05	0.01	0.04	0.01	0.02	0.001
TTS									
Low-Frequency (LF) cetaceans	179	0.88	2.52	1.20	4.08	1.47	6.13	0.37	0.41
High-frequency (HF) cetaceans	178	0.02	0.01	0.05	0.02	0.09	0.04	0.02	0.002
Very High-frequency (VHF) cetaceans	153	0.63	1.19	0.83	2.03	1.06	3.39	0.27	0.24
Sea Turtles	200	0.07	0.04	0.10	0.05	0.12	0.05	0.05	0.01

Table 28. Area 5, *Weighted SEL24h*: Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2). Scenario descriptions are given in Table 7.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 29 - Drillship		Scenario 30 – Drillship with OSV		Scenario 31 – Pipelay vessel		Scenario 32 – Pipelay vessel with resupply vessel		Scenario 33 – Pipelay vessel with resupply vessel and support vessel		Scenario 34 – IMR vessel		Scenario 35 – OCV		Scenario 36 – OCV with 3 support vessels	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	R_{max} (km)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
PTS																	
Low-Frequency (LF) cetaceans	199	0.08	0.02	0.11	0.02	0.06	0.04	0.10	0.05	0.12	0.06	0.04	0.01	0.19	0.11	0.21	0.13
High-frequency (HF) cetaceans	198	0.02	0.002	0.05	0.002	-	/	0.03	0.002	0.05	0.002	–	/	–	/	–	/
Very High-frequency (VHF) cetaceans	173	0.18	0.10	0.21	0.10	0.03	0.01	0.06	0.05	0.12	0.04	0.03	0.003	0.18	0.11	0.21	0.12
Sea Turtles	220	0.02	0.001	0.02	0.001	–	/	0.04	0.01	0.05	0.01	0.02	0.001	–	/	0.03	0.002
TTS																	
Low-Frequency (LF) cetaceans	179	1.56	6.43	1.66	7.16	1.69	7.73	1.99	11.2	2.18	14.2	0.63	1.21	4.39	51.5	4.58	59.1
High-frequency (HF) cetaceans	178	0.13	0.05	0.16	0.06	0.03	0.01	0.06	0.03	0.09	0.04	0.02	0.002	0.14	0.06	0.19	0.07
Very High-frequency (VHF) cetaceans	153	3.30	31.4	3.33	32.7	0.63	1.20	0.83	2.12	1.12	3.67	0.28	0.24	2.66	22.1	2.80	23.3
Sea Turtles	200	0.09	0.02	0.12	0.03	0.06	0.04	0.11	0.05	0.12	0.06	0.05	0.01	0.13	0.06	0.17	0.07

Table 29. Combined scenarios 37 and 38, *Weighted SEL24h*: Total ensonified area (km²) above frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017). The ensonified areas for the corresponding individual scenarios are provided, as well as the difference in area and percentage change. Scenario descriptions are given in Table 9.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 37 - Area 1, pipelay vessel with 2 support vessels + Area 3, drillship with OSV				Scenario 38 - Area 1, OCV with 3 support vessels + Area 2, IMR vessel + Area 3, drillship with OSV			
		Ensonified area, combined scenario (km²)	Sum of ensonified areas of individual scenarios (km²)	Change in ensonified area from individual scenarios to combined (km²)	Percentage change in ensonified area from individual scenarios to combined (%)	Ensonified area, combined scenario (km²)	Sum of ensonified areas of individual scenarios (km²)	Change in ensonified area from individual scenarios to combined (km²)	Percentage change in ensonified area from individual scenarios to combined (%)
PTS									
Low-Frequency (LF) cetaceans	199	0.08	0.08	/	*	0.15	0.15	/	*
High-frequency (HF) cetaceans	198	0.003	0.004	/	*	0.01	0.01	/	*
Very High-frequency (VHF) cetaceans	173	0.14	0.14	/	*	0.22	0.22	+ 0.002	+ 0.91
Sea Turtles	220	0.01	0.01	/	*	0.01	0.01	/	*
TTS									
Low-Frequency (LF) cetaceans	179	5.52	5.53	/	*	12.7	12.7	+ 0.03	+ 0.21
High-frequency (HF) cetaceans	178	0.09	0.09	/	*	0.13	0.13	/	*
Very High-frequency (VHF) cetaceans	153	32.4	32.4	- 0.002	- 0.006	50.9	50.9	+ 0.004	+ 0.008
Sea Turtles	200	0.08	0.08	/	*	0.10	0.10	/	*

/ Indicates that the area is less than an area associated with the modelled resolution (0.0013 km²).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km²).

Table 30. Combined 39 and 40, *Weighted SEL₂₄ₕ*: Total ensonified area (km²) above frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017). The ensonified areas for the corresponding individual scenarios are provided, as well as the difference in area and percentage change. Scenario descriptions are given in Table 9.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 39 - Area 3, drillship with OSV + Area 5, pipelay vessel with 2 support vessels				Scenario 40 - Area 5, drillship with OSV + Area 5, pipelay vessel with 2 support vessels			
		Ensonified area, combined scenario (km²)	Sum of ensonified areas of individual scenarios (km²)	Change in ensonified area from individual scenarios to combined (km²)	Percentage change in ensonified area from individual scenarios to combined (%)	Ensonified area, combined scenario (km²)	Sum of ensonified areas of individual scenarios (km²)	Change in ensonified area from individual scenarios to combined (km²)	Percentage change in ensonified area from individual scenarios to combined (%)
PTS									
Low-Frequency (LF) cetaceans	199	0.08	0.08	/	*	0.08	0.08	/	*
High-frequency (HF) cetaceans	198	0	0	/	*	0	0	/	*
Very High-frequency (VHF) cetaceans	173	0.14	0.14	/	*	0.14	0.14	/	*
Sea Turtles	220	0.01	0.01	/	*	0.01	0.01	/	*
TTS									
Low-Frequency (LF) cetaceans	179	16.3	16.3	+ 0.03	+ 0.18	22.0	21.4	+ 0.64	+ 2.98
High-frequency (HF) cetaceans	178	0.09	0.09	/	*	0.09	0.09	/	*
Very High-frequency (VHF) cetaceans	153	33.0	33.0	+ 0.009	+ 0.03	36.6	36.4	+ 0.14	+ 0.38
Sea Turtles	200	0.08	0.08	/	*	0.08	0.08	/	*

/ Indicates that the area is less than an area associated with the modelled resolution (0.0013 km²).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km²).

4.2. Vessel Activities - Sound Field Maps and Graphs

Maps of the estimated sound fields, threshold contours, and isopleths of interest for SPL and SEL_{24h} sound fields are presented for the vessel activity scenarios. The SPL results for individual and combined scenarios are presented in Figures 19 to Figure 58 (Section 4.2.1), whilst the SEL_{24h} results for individual scenarios are presented in Figures 59 to 92 (Section 4.2.2). SEL_{24h} results for combined scenarios are not illustrated as these effect zones remain identical to their corresponding individual scenarios.

4.2.1. Instantaneous SPL Sound Level Contour Maps

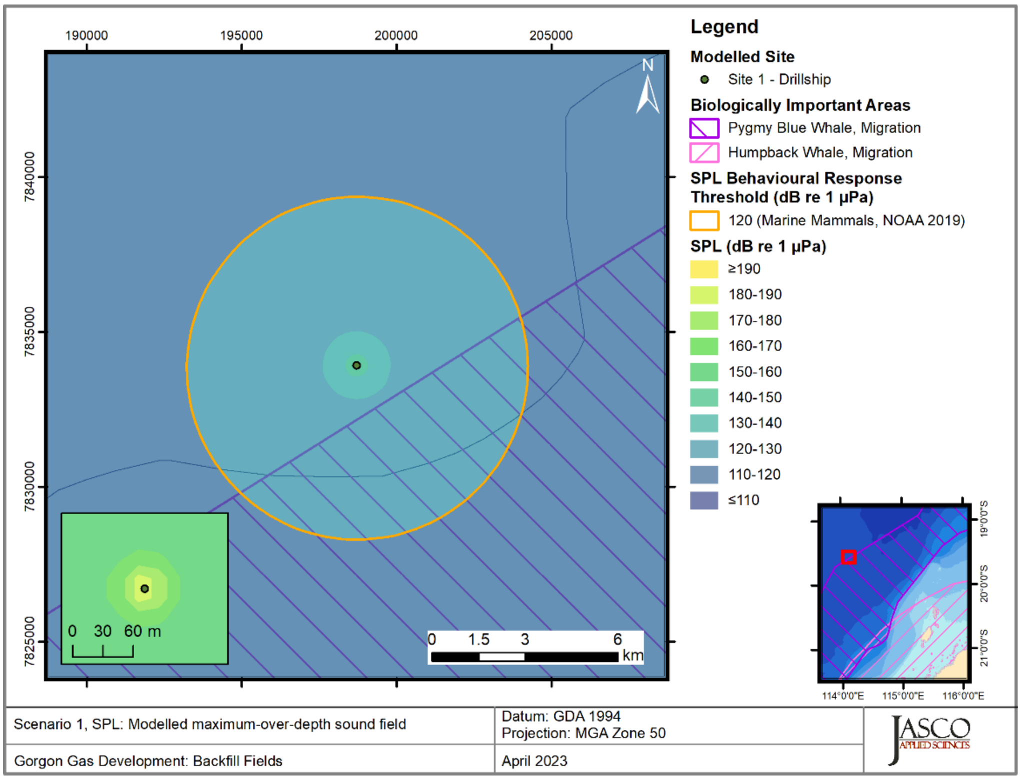

Figure 19. *Scenario 1, Area 1 Drillship, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

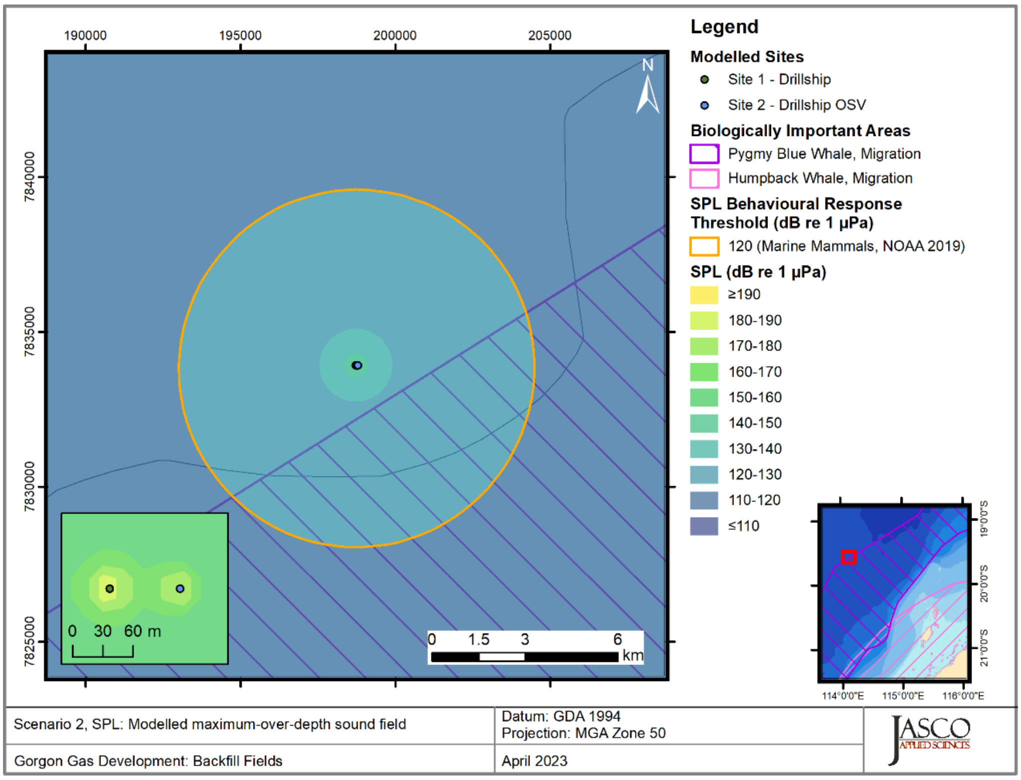

Figure 20. *Scenario 2, Area 1 Drillship with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

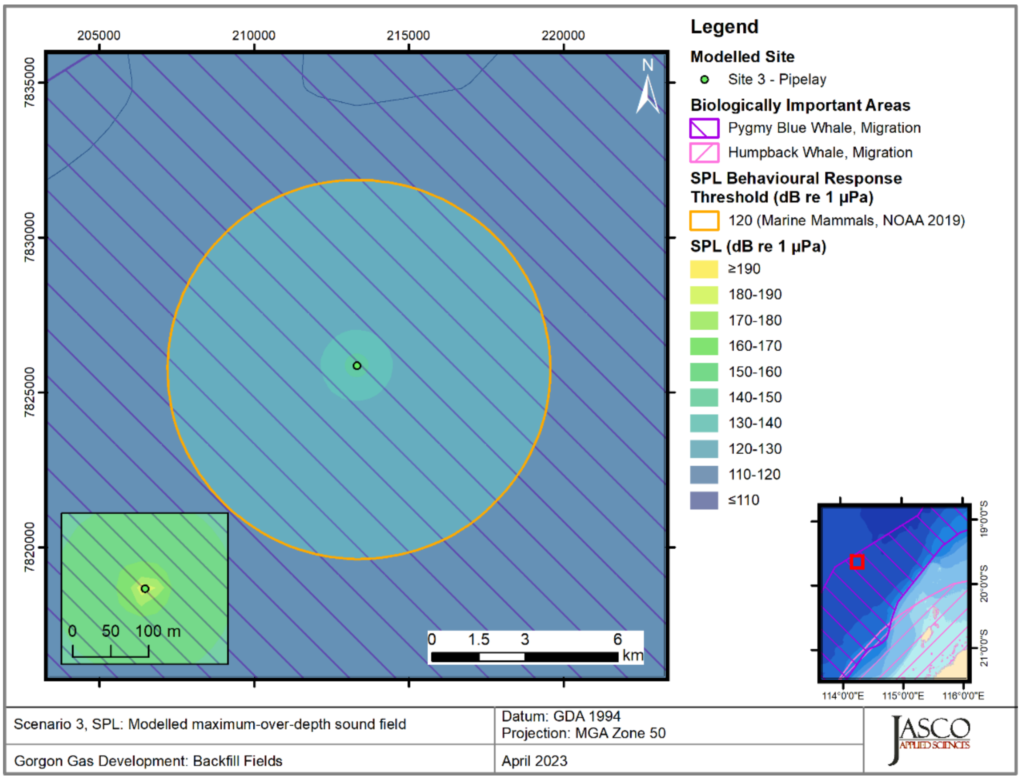

Figure 21. *Scenario 3, Area 1 Pipelay vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

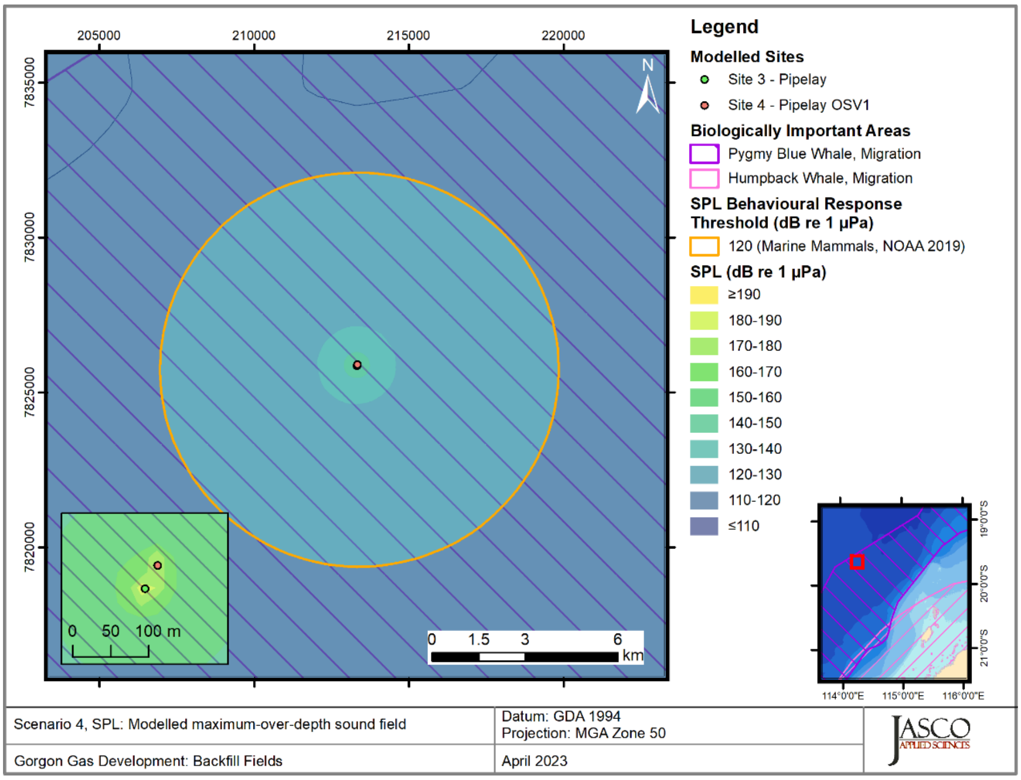

Figure 22. *Scenario 4, Area 1 Pipelay vessel with resupply OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

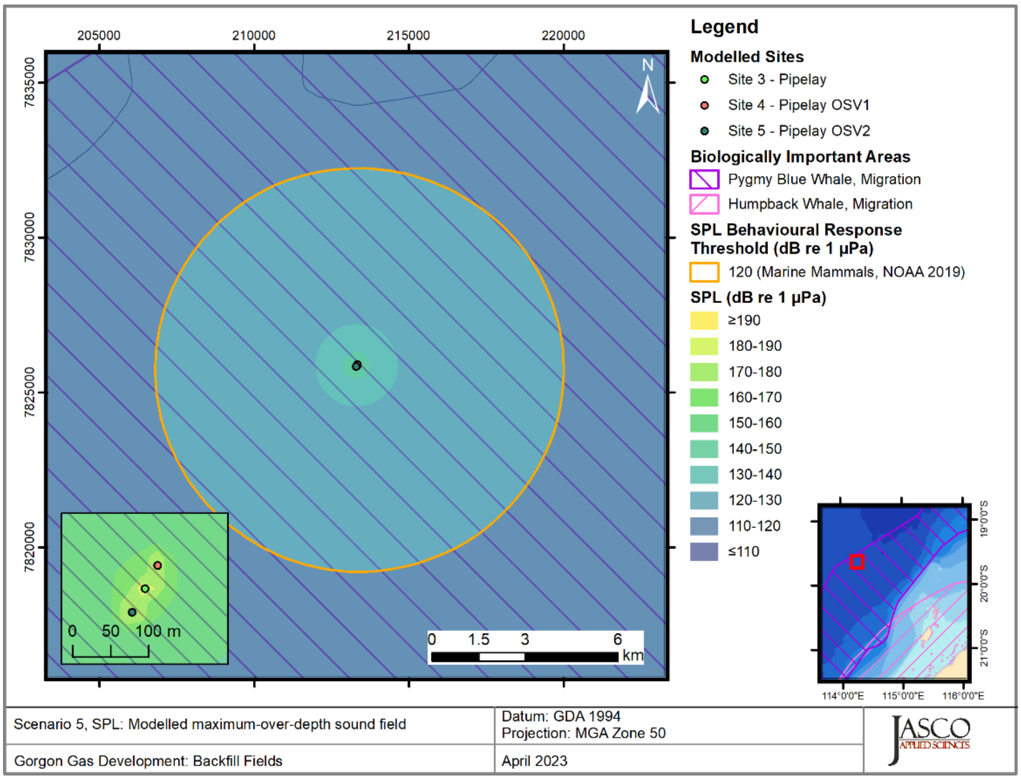

Figure 23. *Scenario 5, Area 1 Pipelay vessel with resupply OSV and support OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

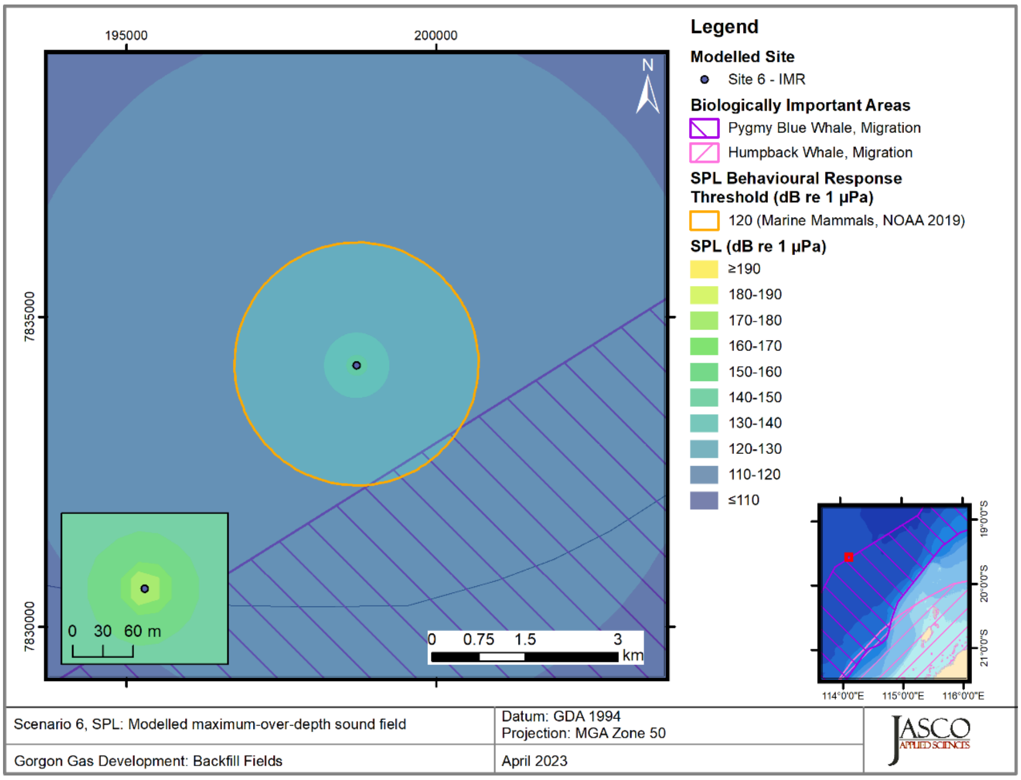

Figure 24. *Scenario 6, Area 1 IMR vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

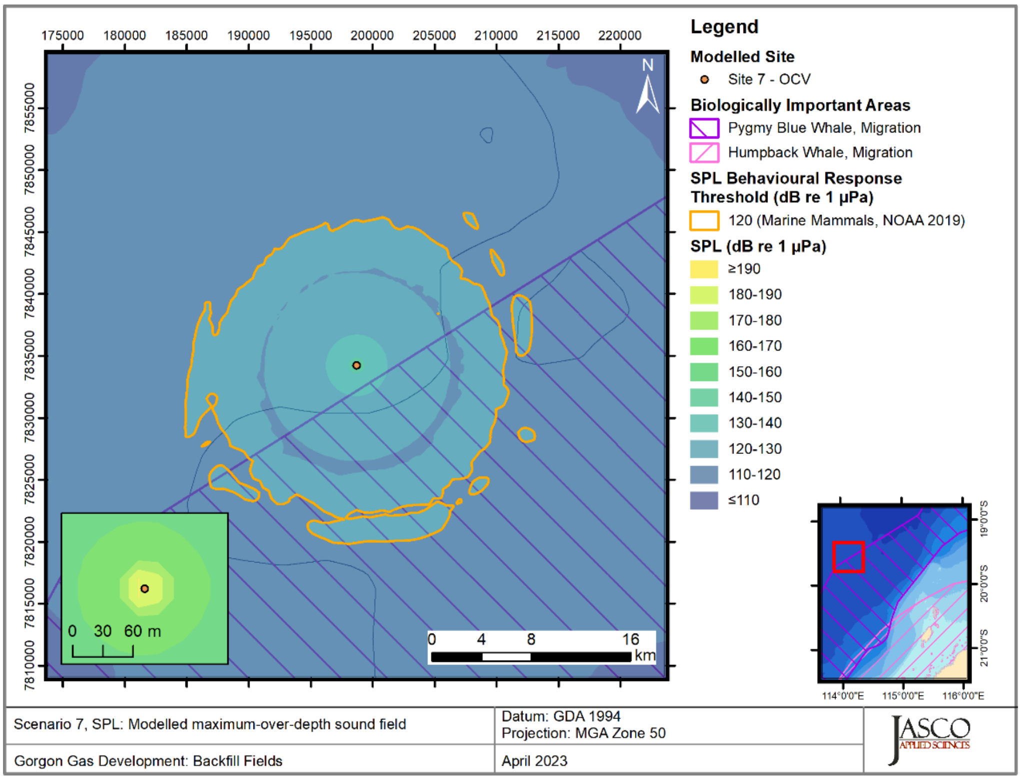

Figure 25. *Scenario 7, Area 1 OCV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

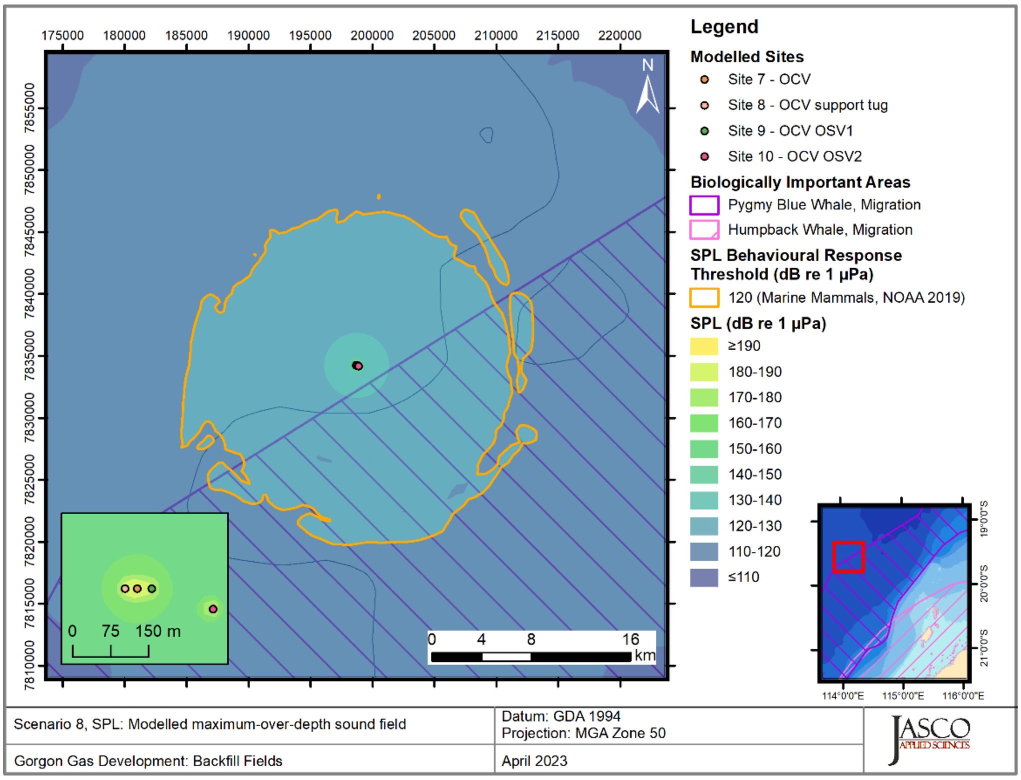

Figure 26. *Scenario 8, Area 1 OCV with three support vessels, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

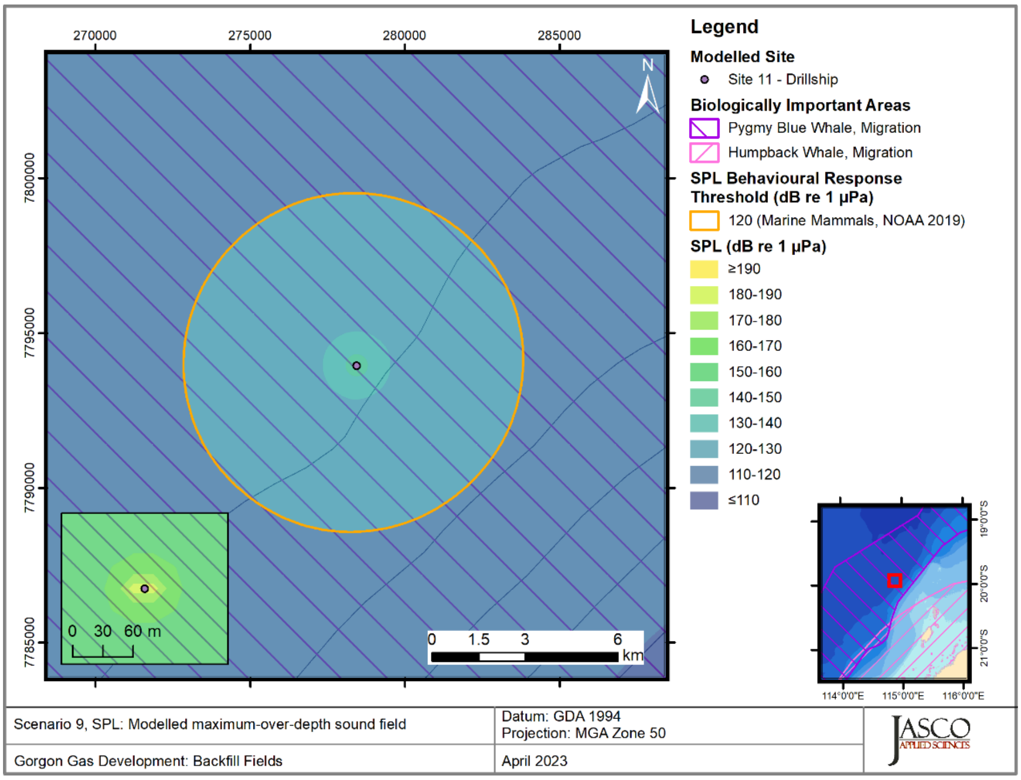

Figure 27. *Scenario 9, Area 2 Drillship, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

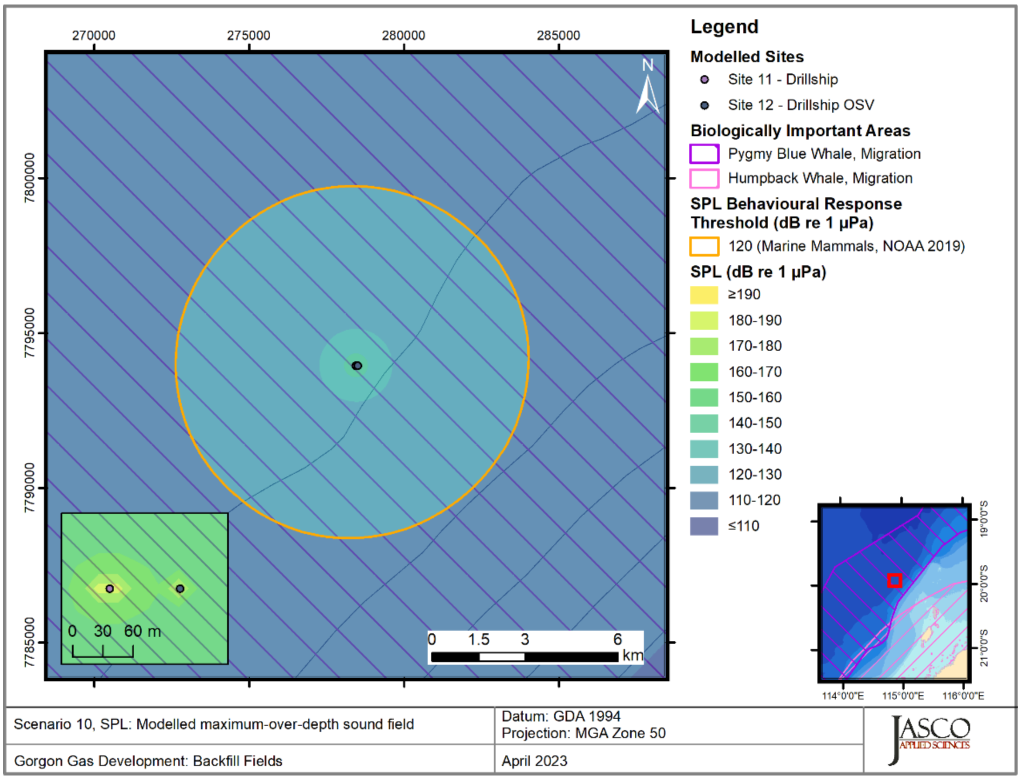

Figure 28. *Scenario 10, Area 2 Drillship with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

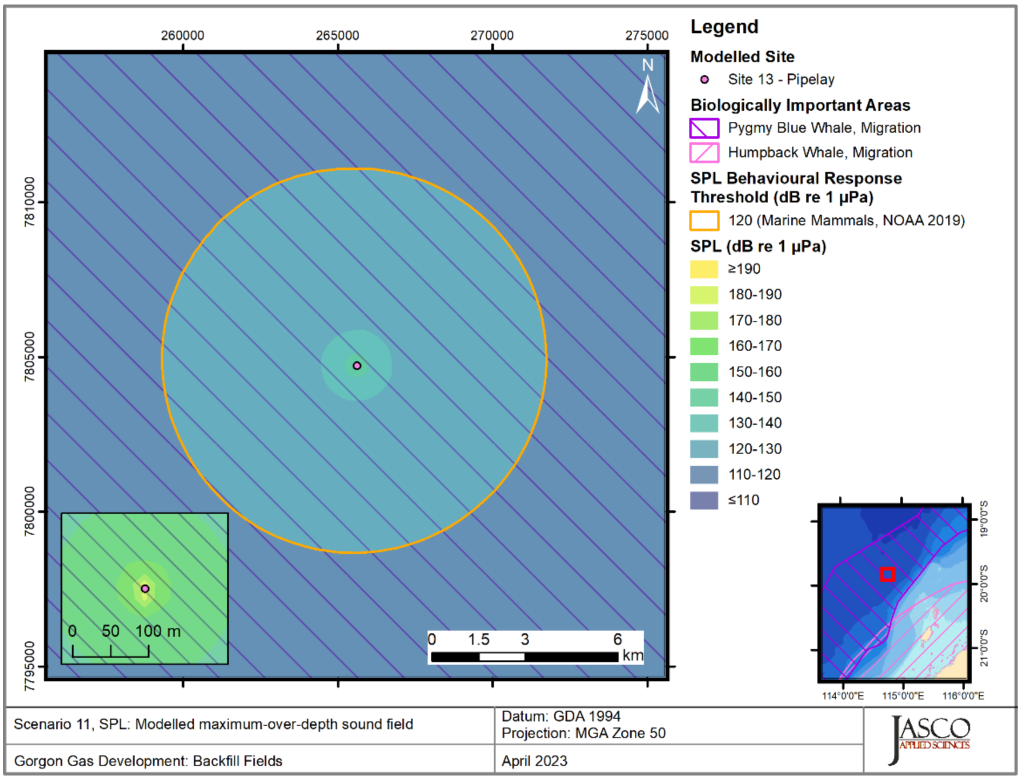

Figure 29. *Scenario 11, Area 2 Pipelay vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

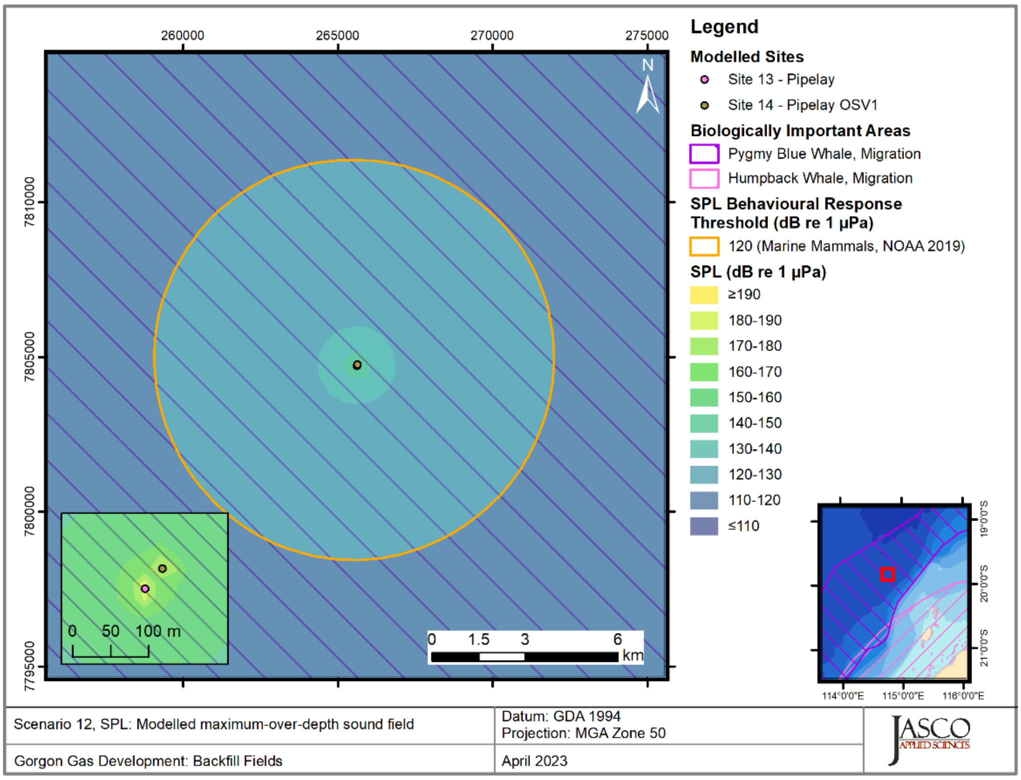

Figure 30. *Scenario 12, Area 2 Pipelay vessel with resupply OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

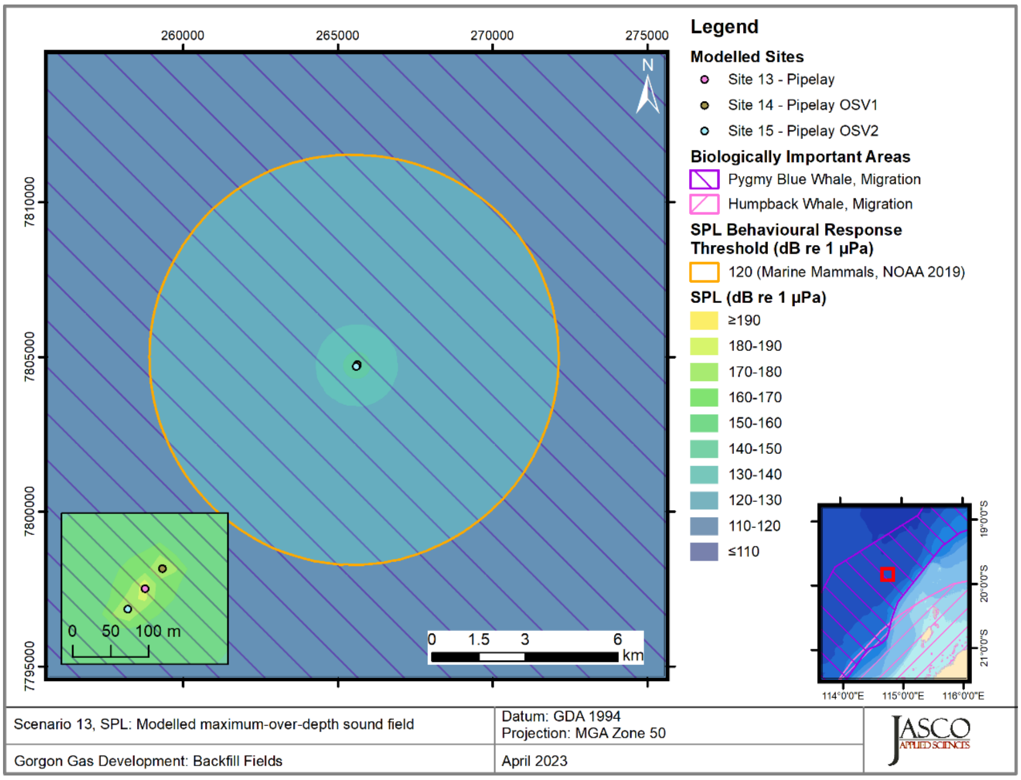

Figure 31. *Scenario 13, Area 2 Pipelay vessel with resupply OSV and support OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

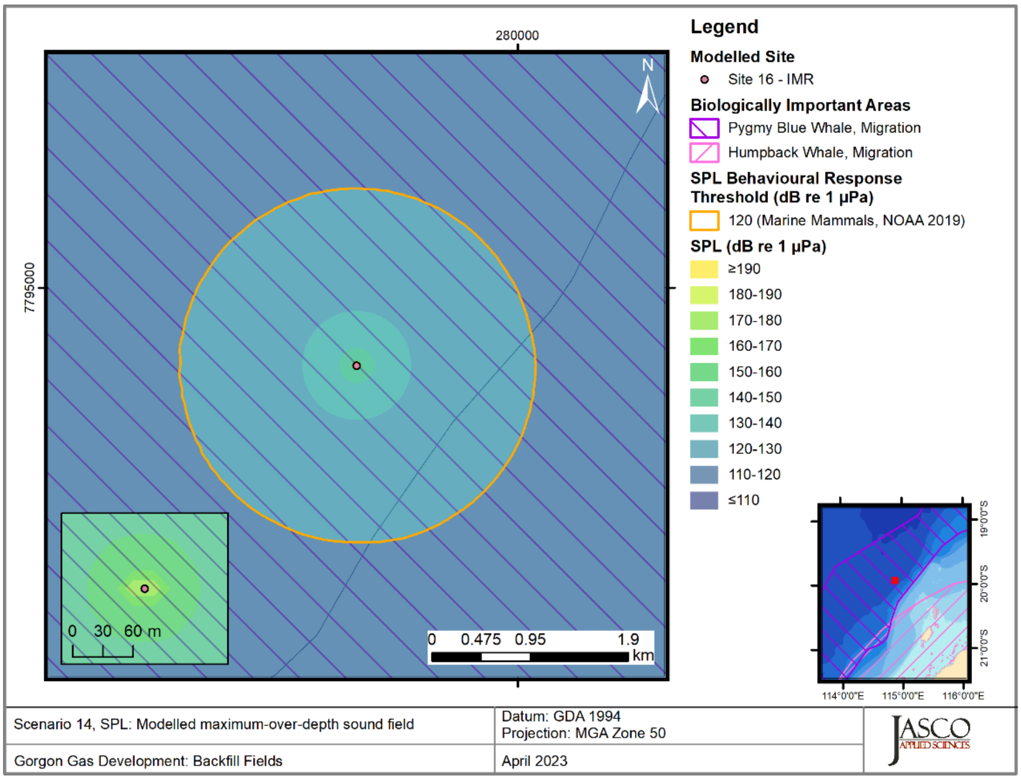

Figure 32. *Scenario 14, Area 2 IMR vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

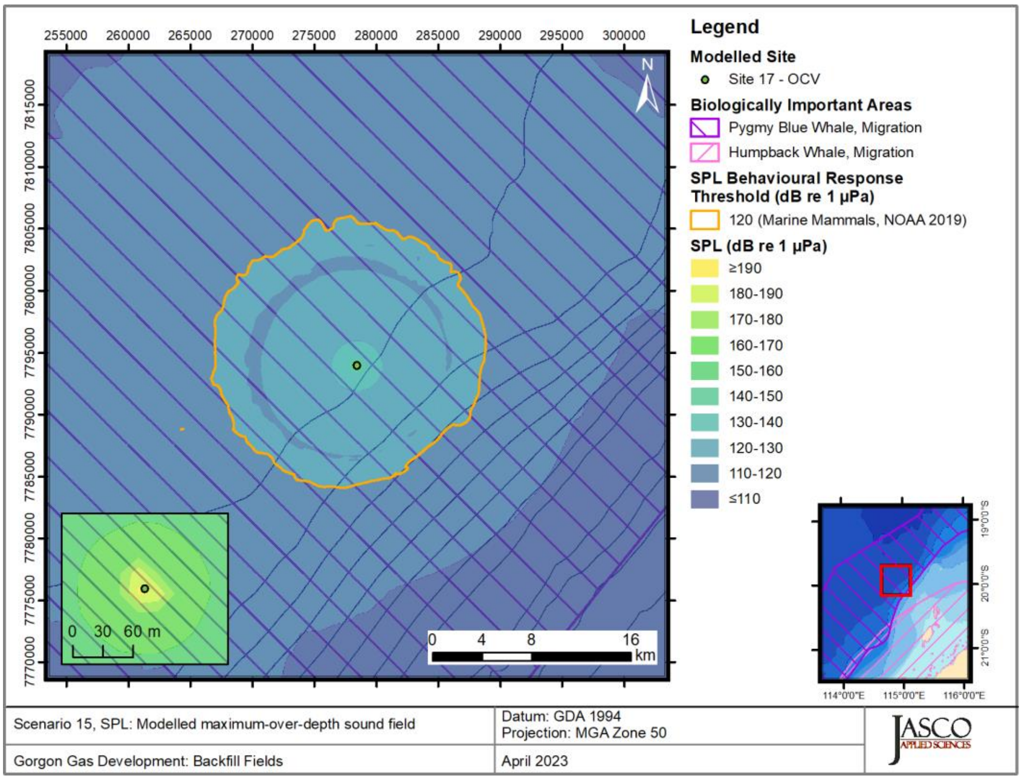

Figure 33. *Scenario 15, Area 2 OCV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

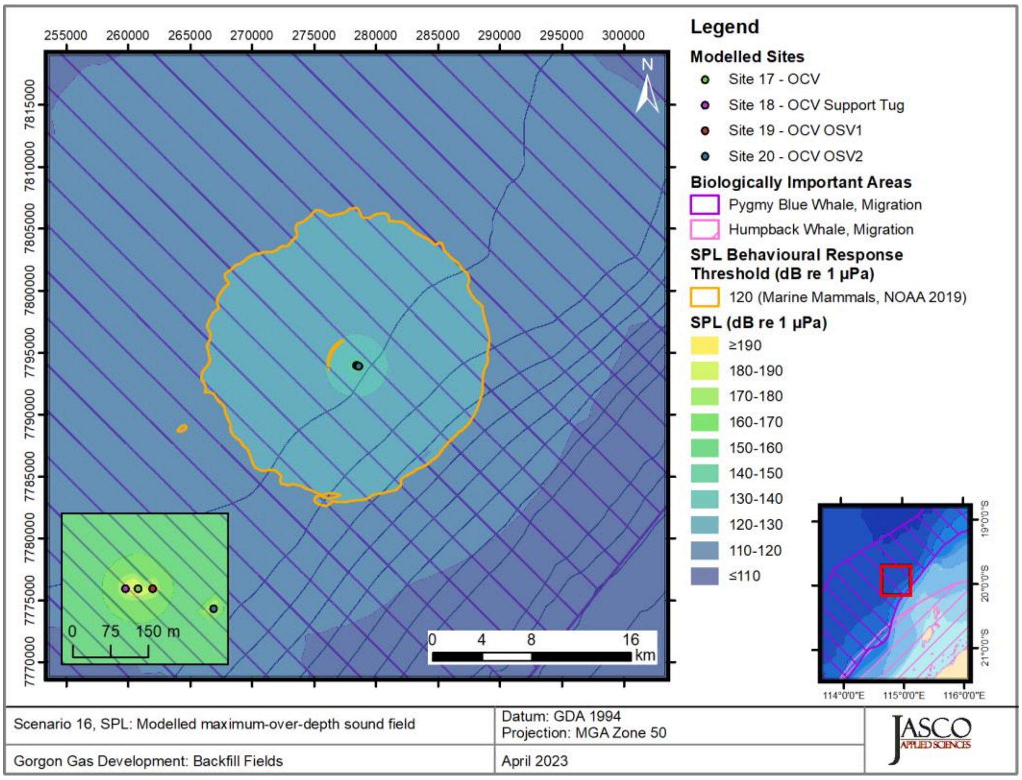

Figure 34. *Scenario 16, Area 2 OCV with three support vessels, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

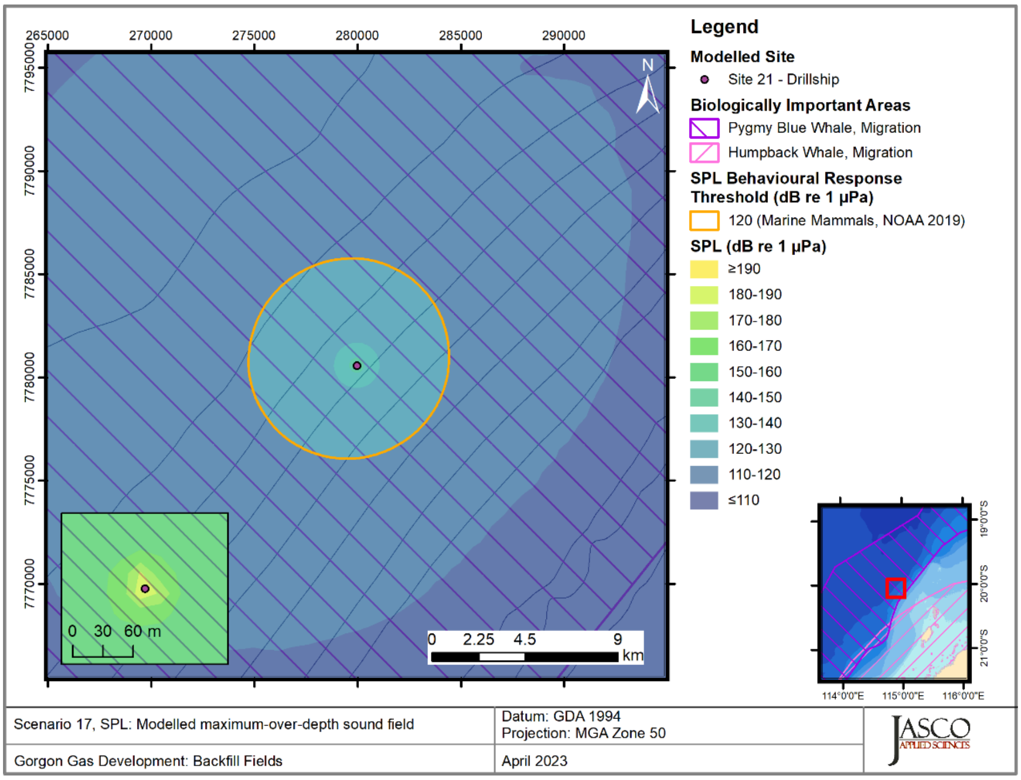

Figure 35. *Scenario 17, Area 3 Drillship, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

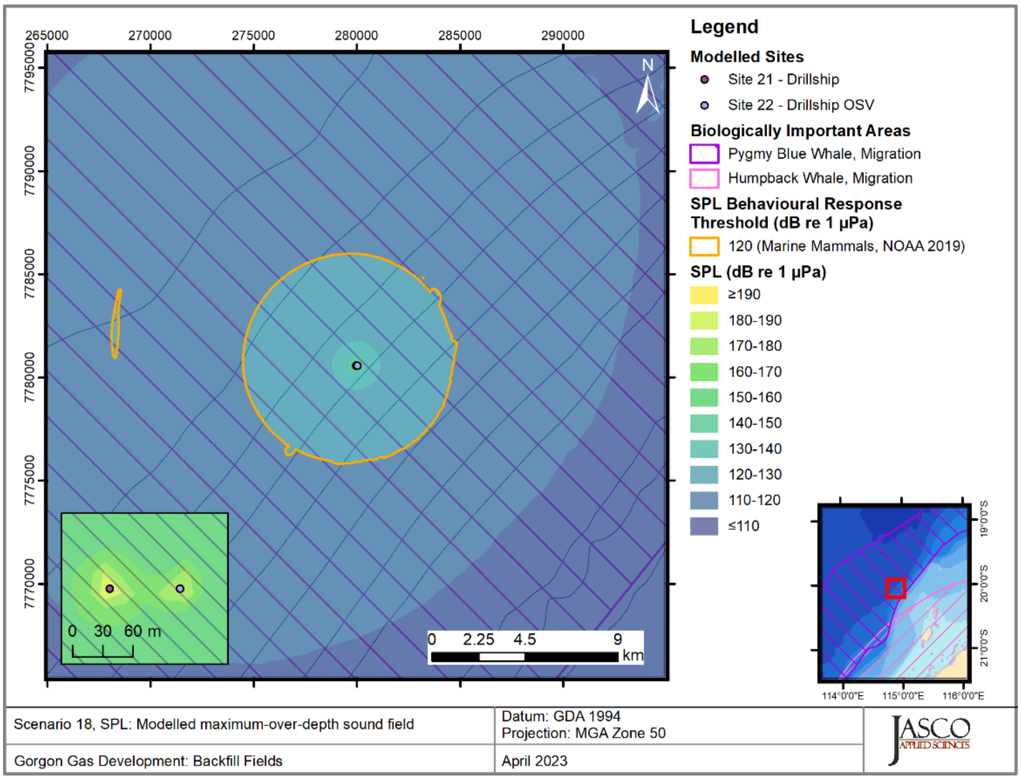

Figure 36. *Scenario 18, Area 3 Drillship with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

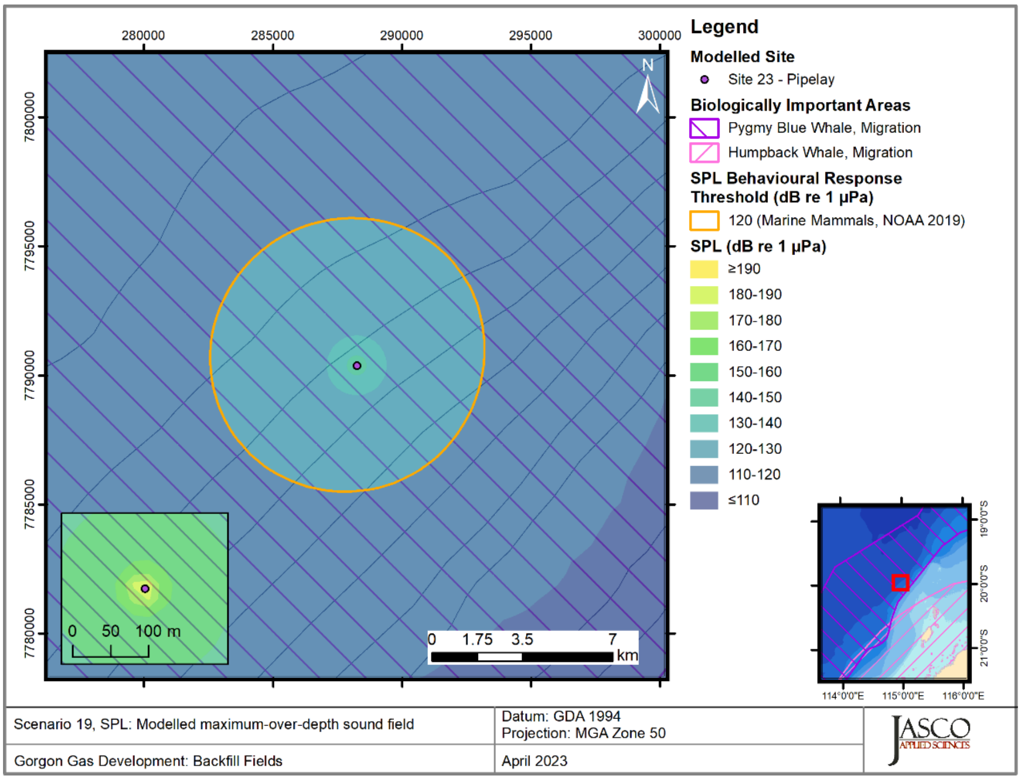

Figure 37. *Scenario 19, Area 3 Pipelay vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

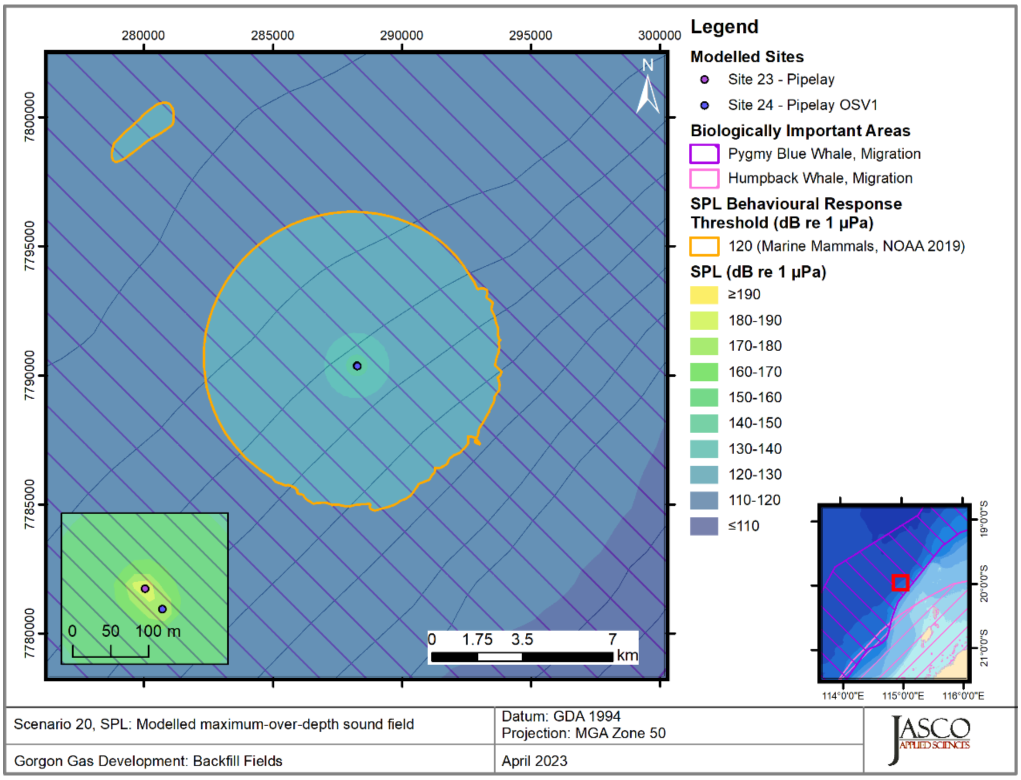

Figure 38. *Scenario 20, Area 3 Pipelay vessel with resupply OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

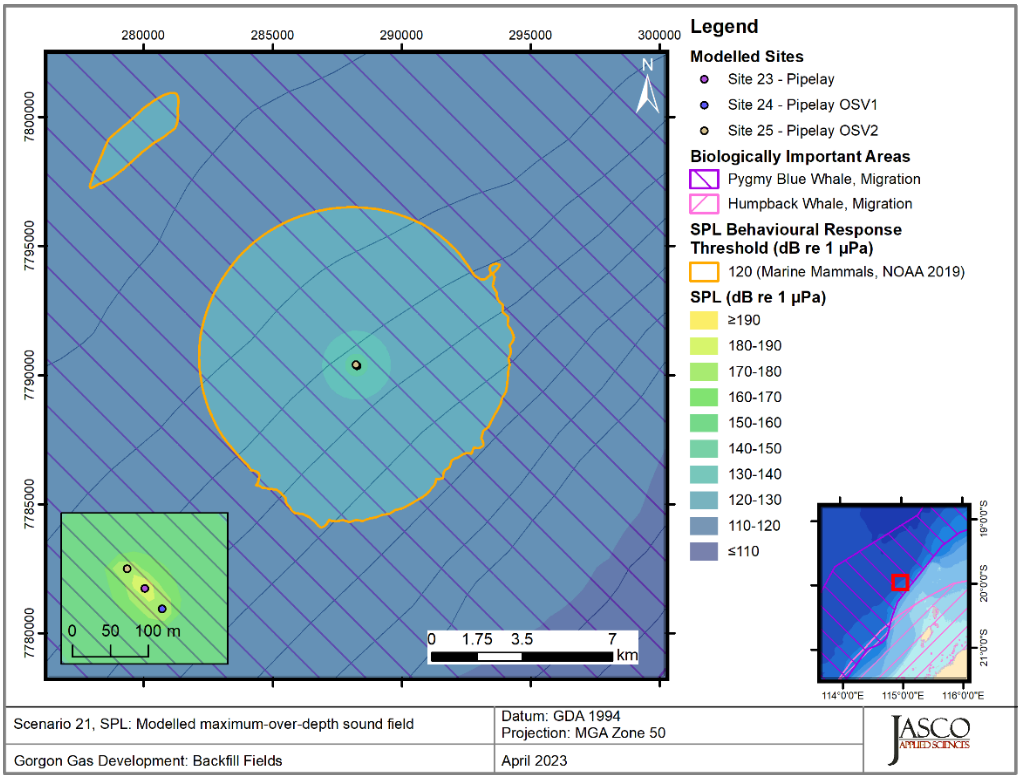

Figure 39. *Scenario 21, Area 3 Pipelay vessel with resupply OSV and support OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

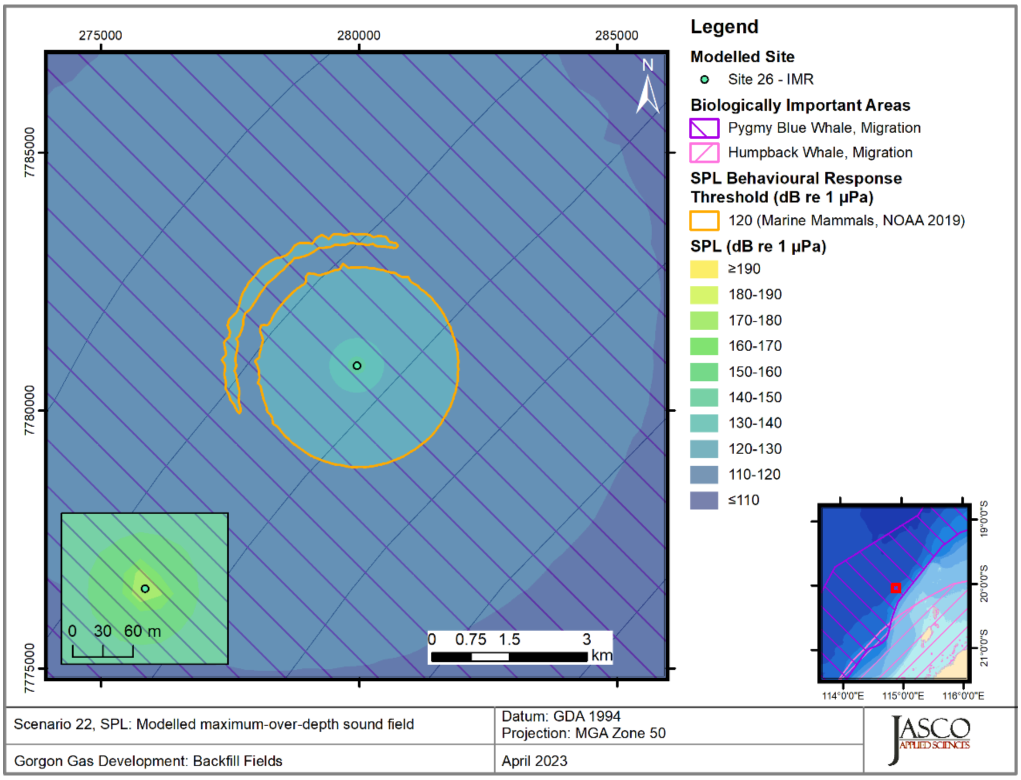

Figure 40. *Scenario 22, Area 3 IMR vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

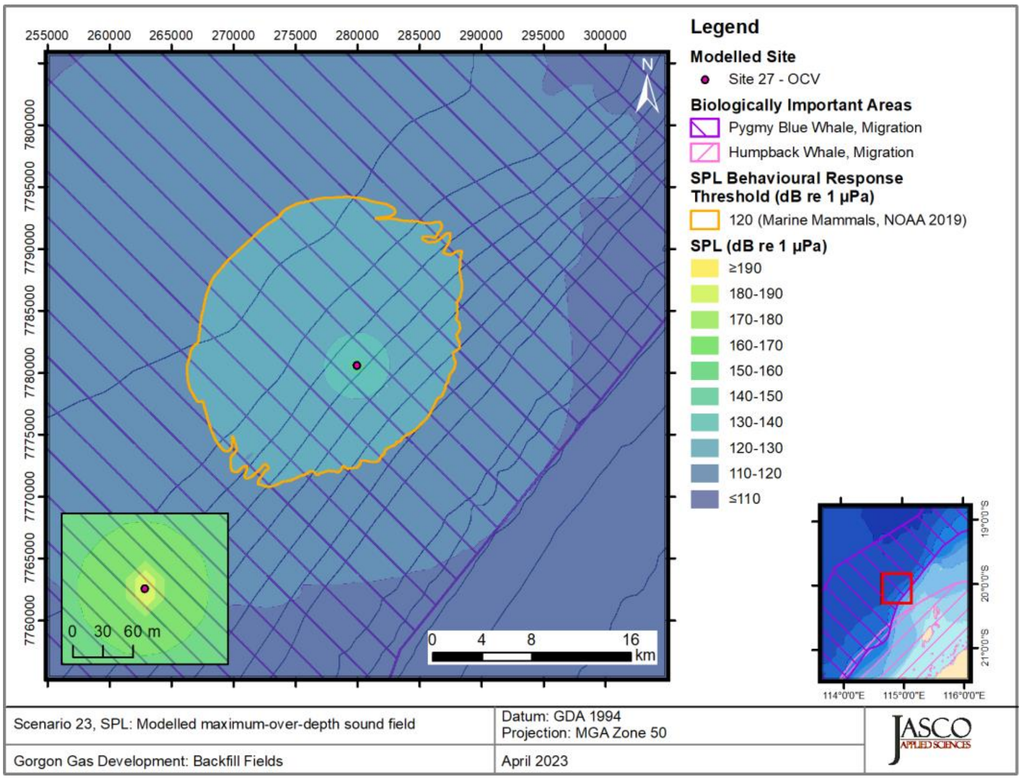

Figure 41. *Scenario 23, Area 3 OCV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

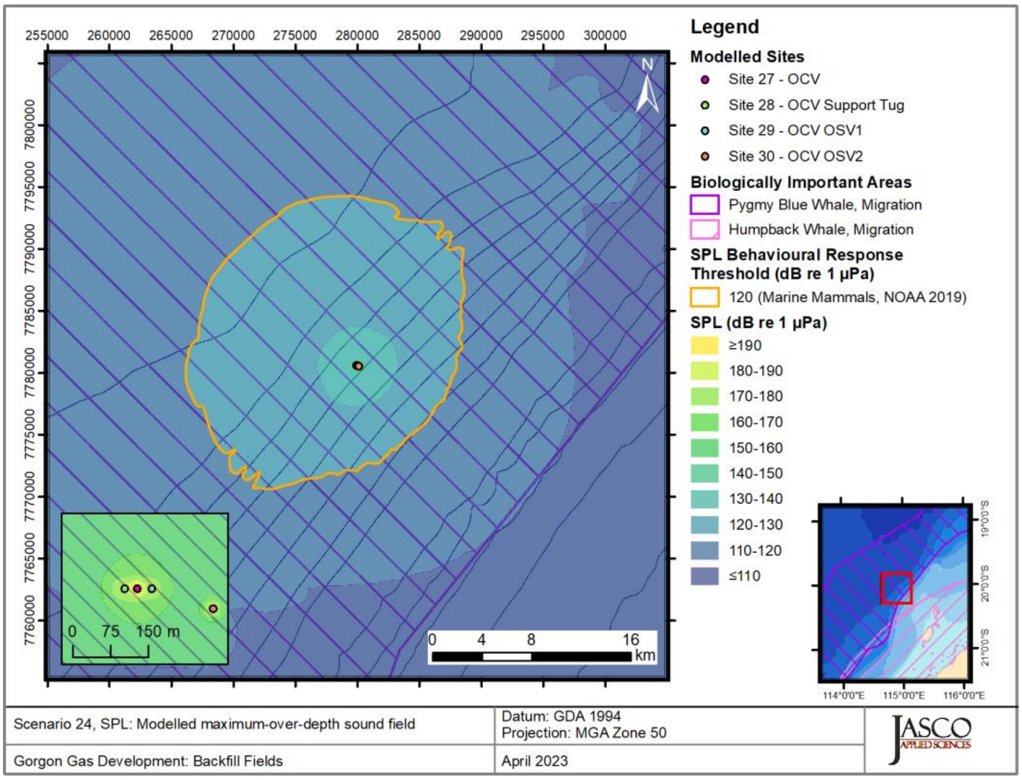

Figure 42. *Scenario 24, Area 3 OCV with three support vessels, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

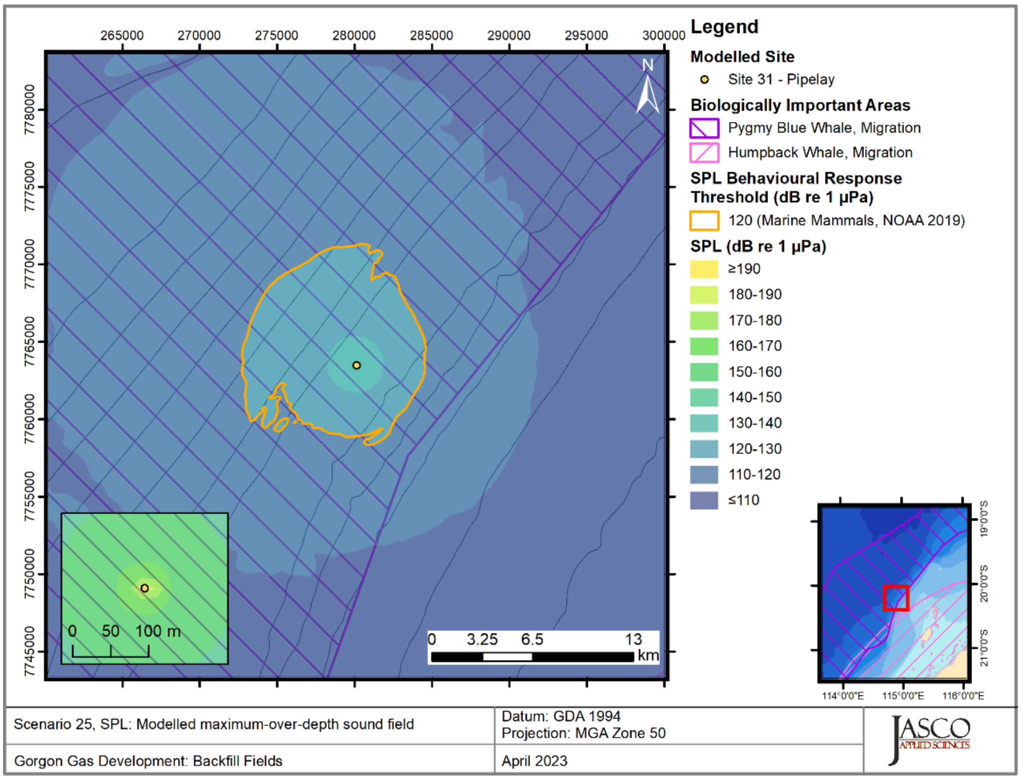

Figure 43. *Scenario 25, Area 4 Pipelay vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

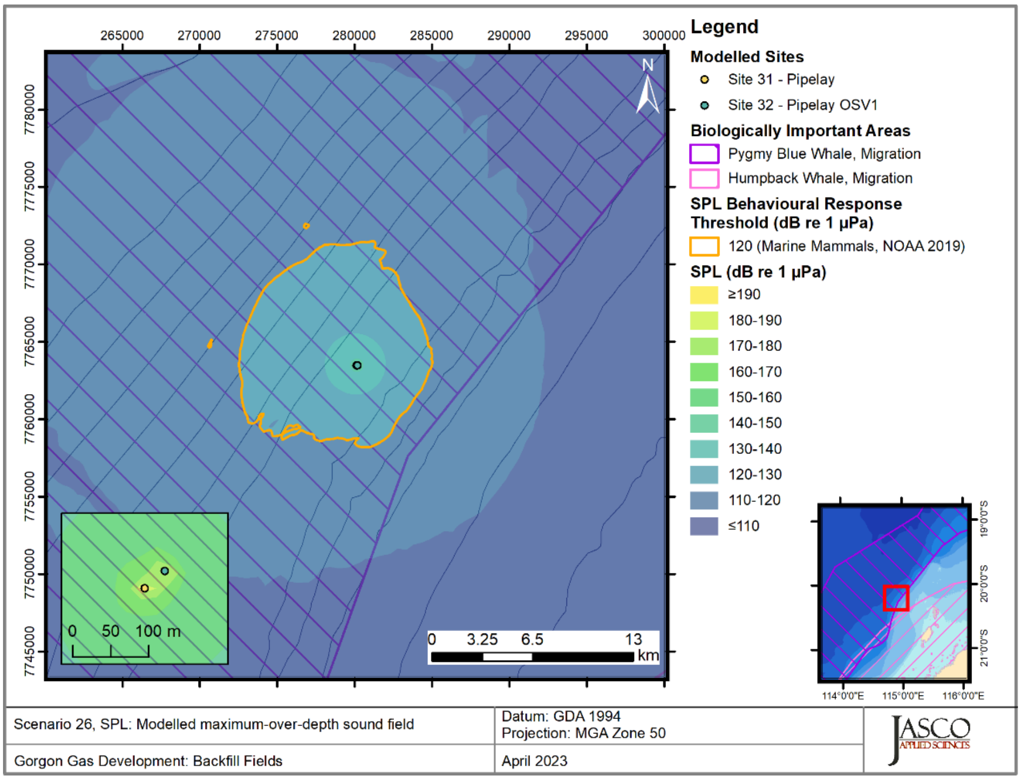

Figure 44. *Scenario 26, Area 4 Pipelay vessel with resupply OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

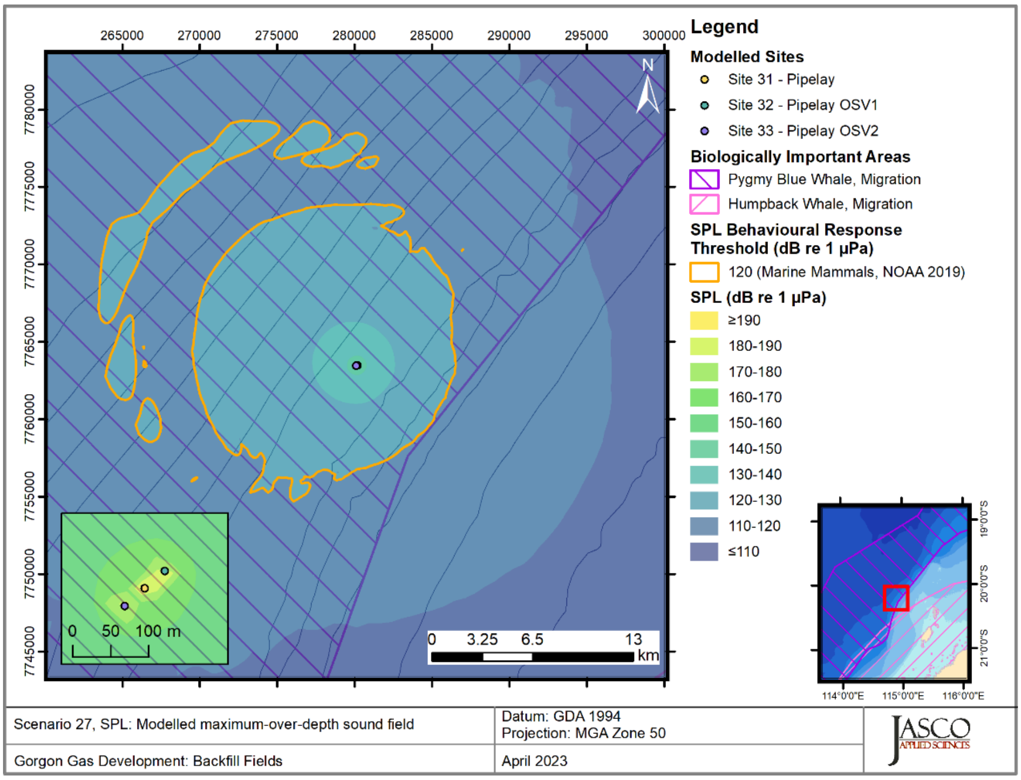

Figure 45. *Scenario 27, Area 4 Pipelay vessel with resupply OSV and support OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

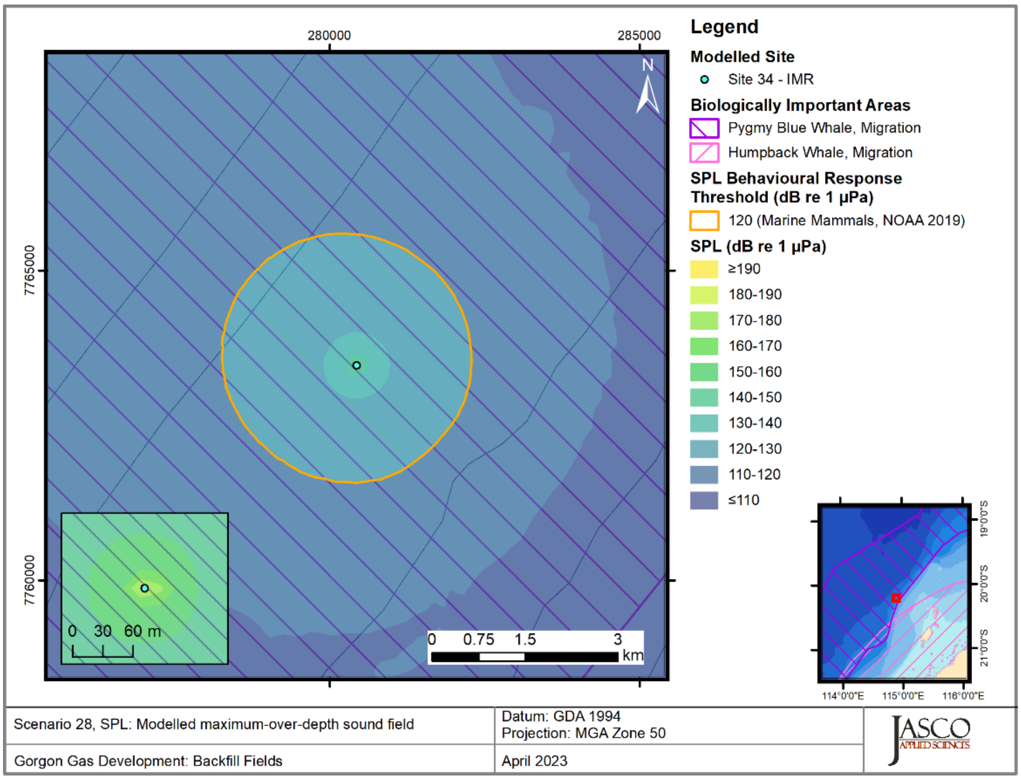

Figure 46. *Scenario 28, Area 4 IMR vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

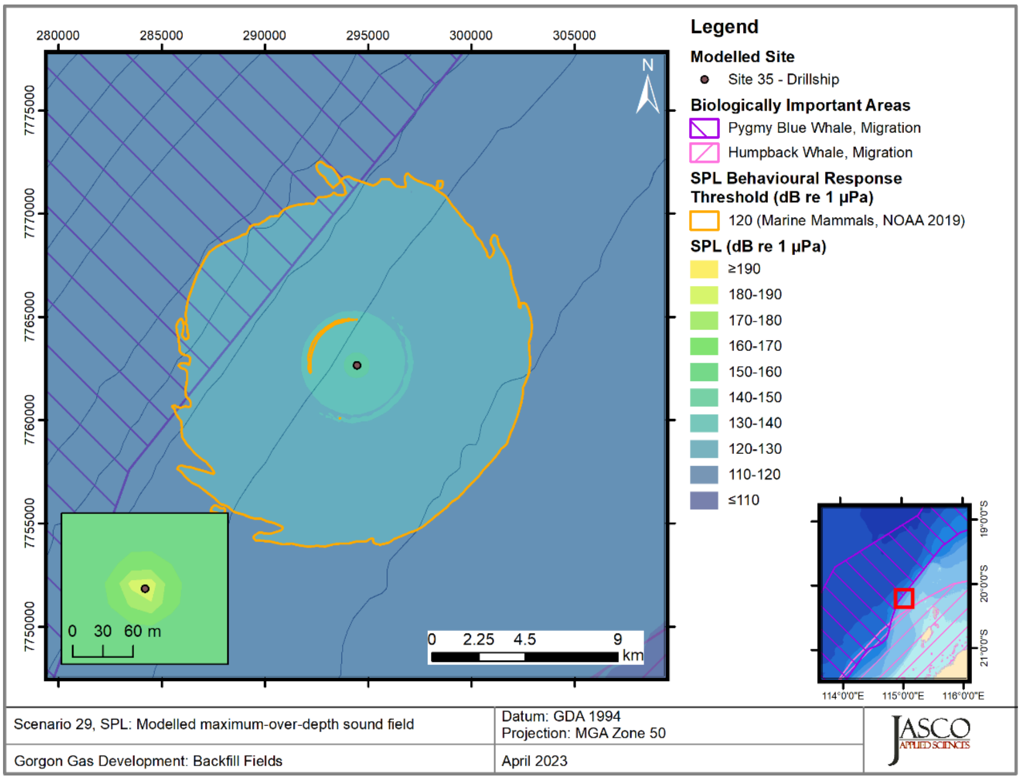

Figure 47. *Scenario 29, Area 5 Drillship, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

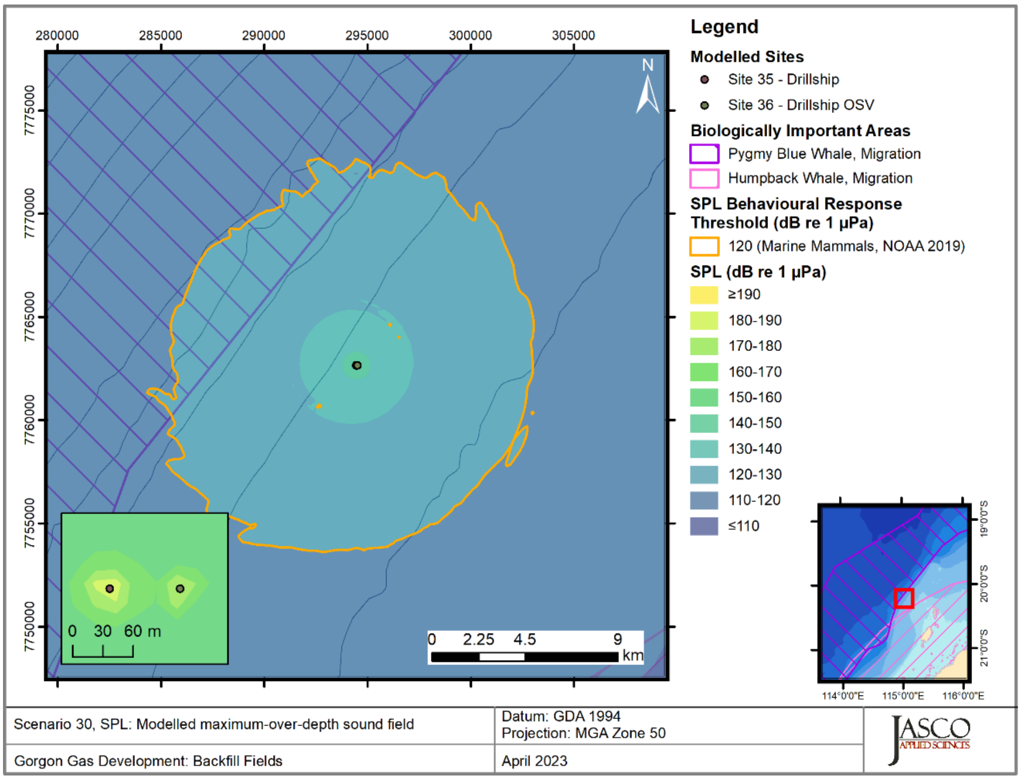

Figure 48. *Scenario 30, Area 5 Drillship with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

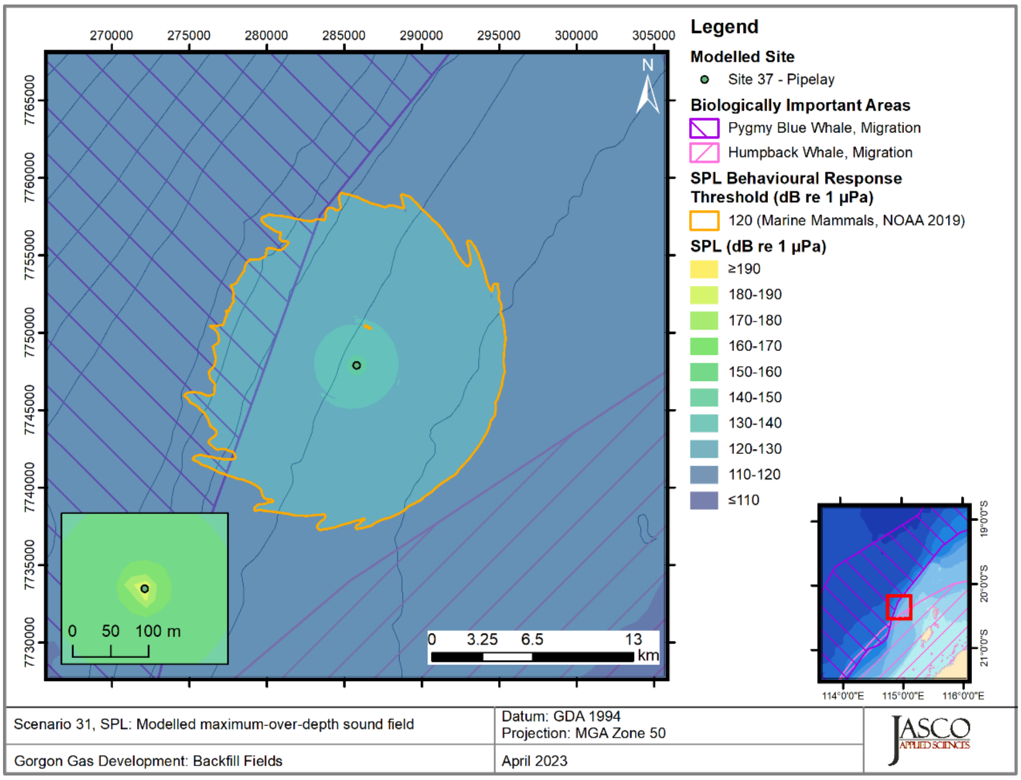

Figure 49. *Scenario 31, Area 5 Pipelay vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

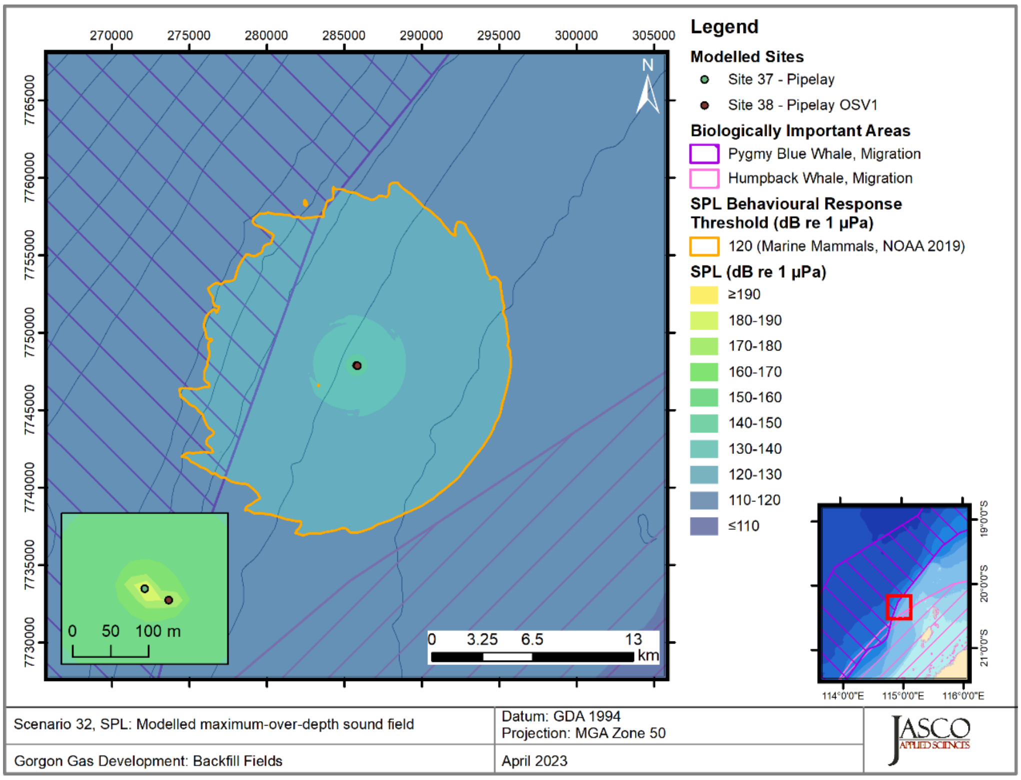

Figure 50. *Scenario 32, Area 5 Pipelay vessel with resupply OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

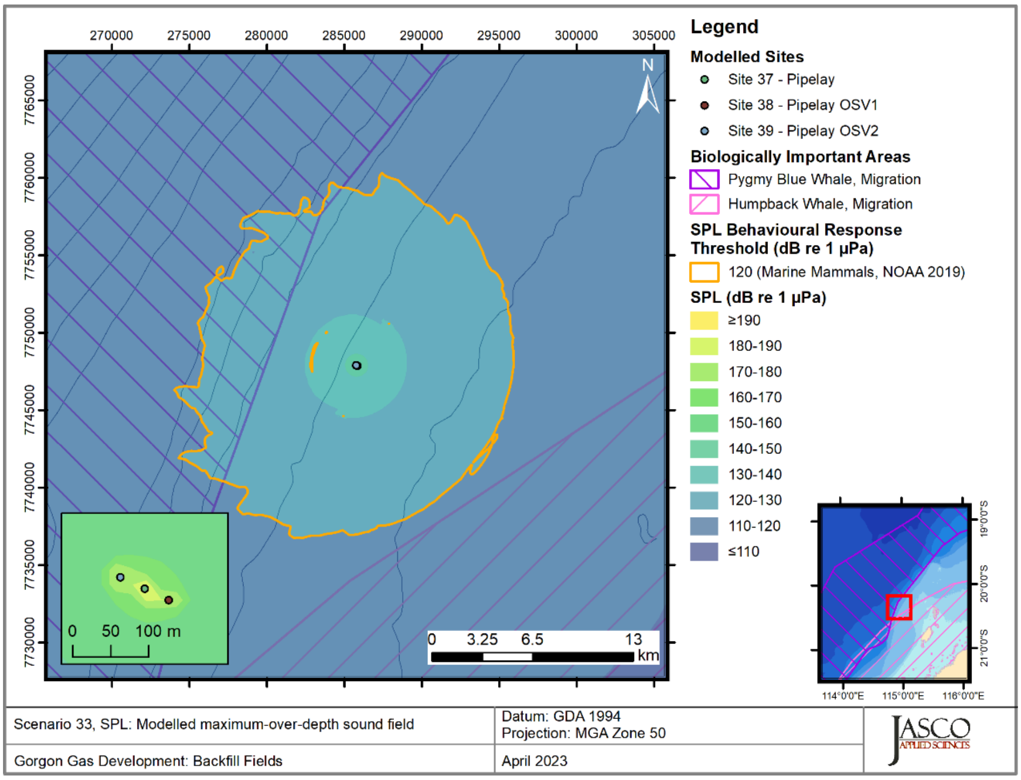

Figure 51. *Scenario 33, Area 5 Pipelay vessel with resupply OSV and support OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

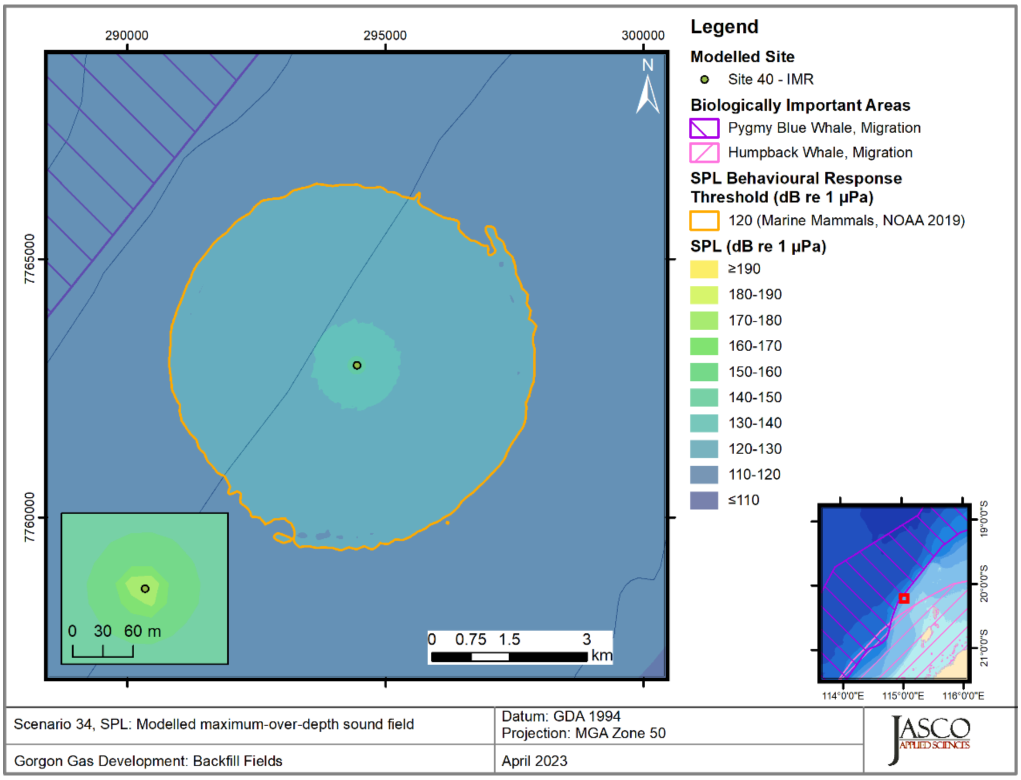

Figure 52. *Scenario 34, Area 5 IMR vessel, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

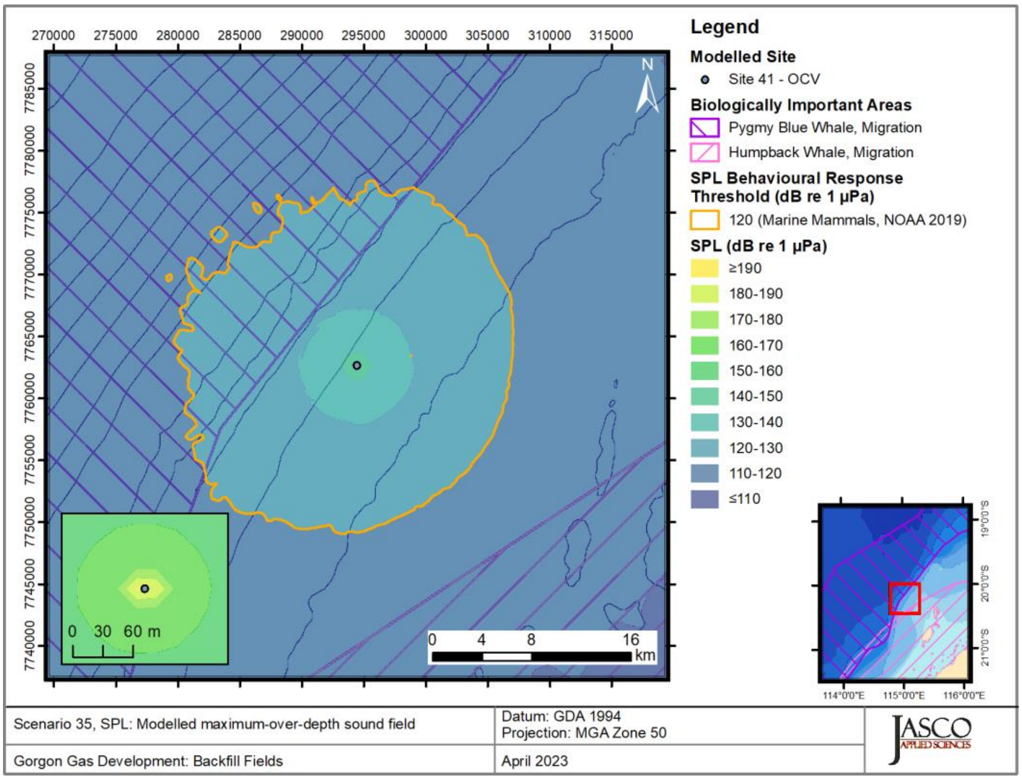

Figure 53. *Scenario 35, Area 5 OCV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

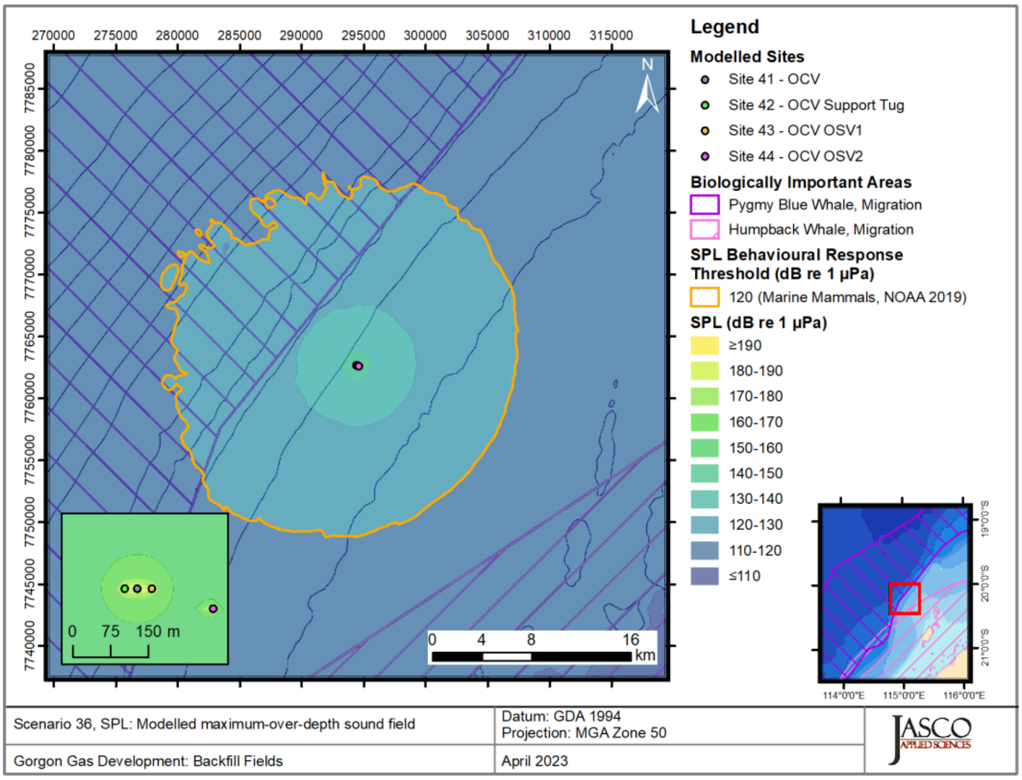

Figure 54. *Scenario 36, Area 5 OCV with three support vessels, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

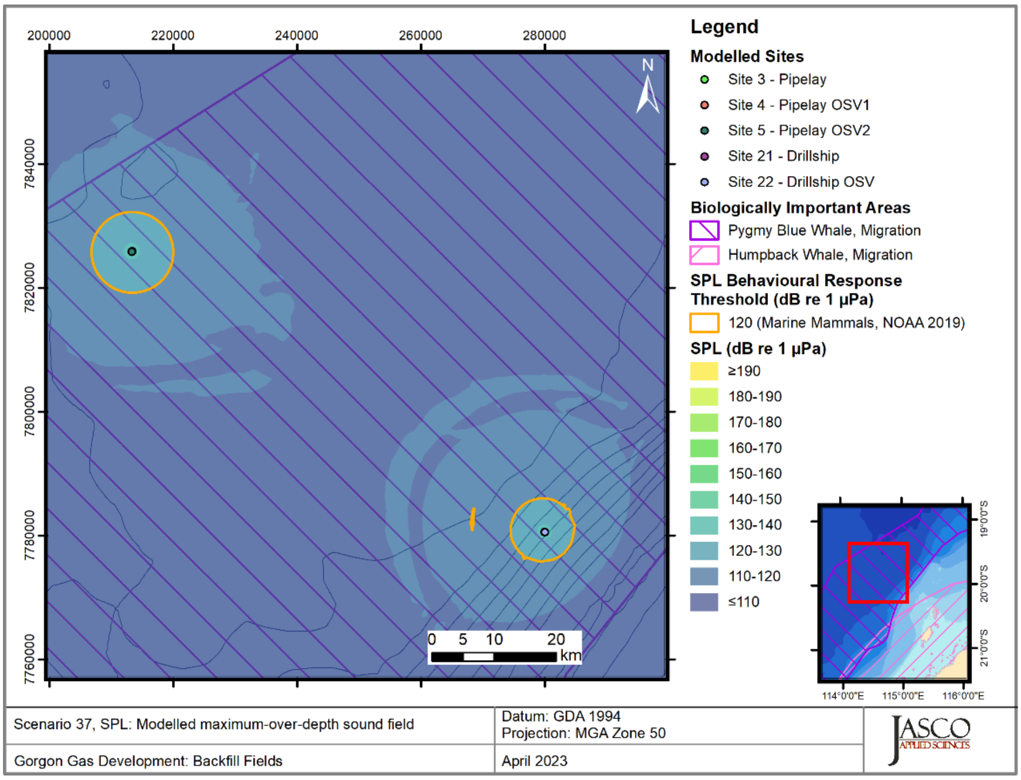

Figure 55. *Scenario 37, Combined scenario: Area 1 pipelay with OSVs and Area 3 drilling with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

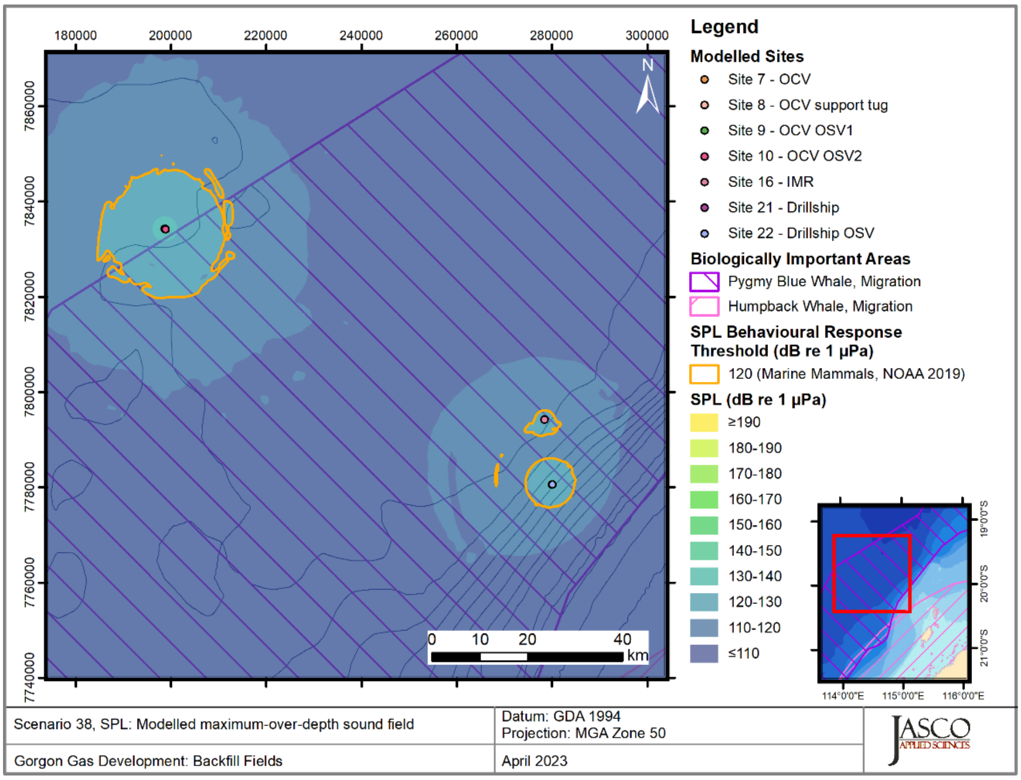

Figure 56. *Scenario 38 Combined scenario: Area 1 Construction with support vessels, Area 2 IMR vessel, and Area 3 drilling with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

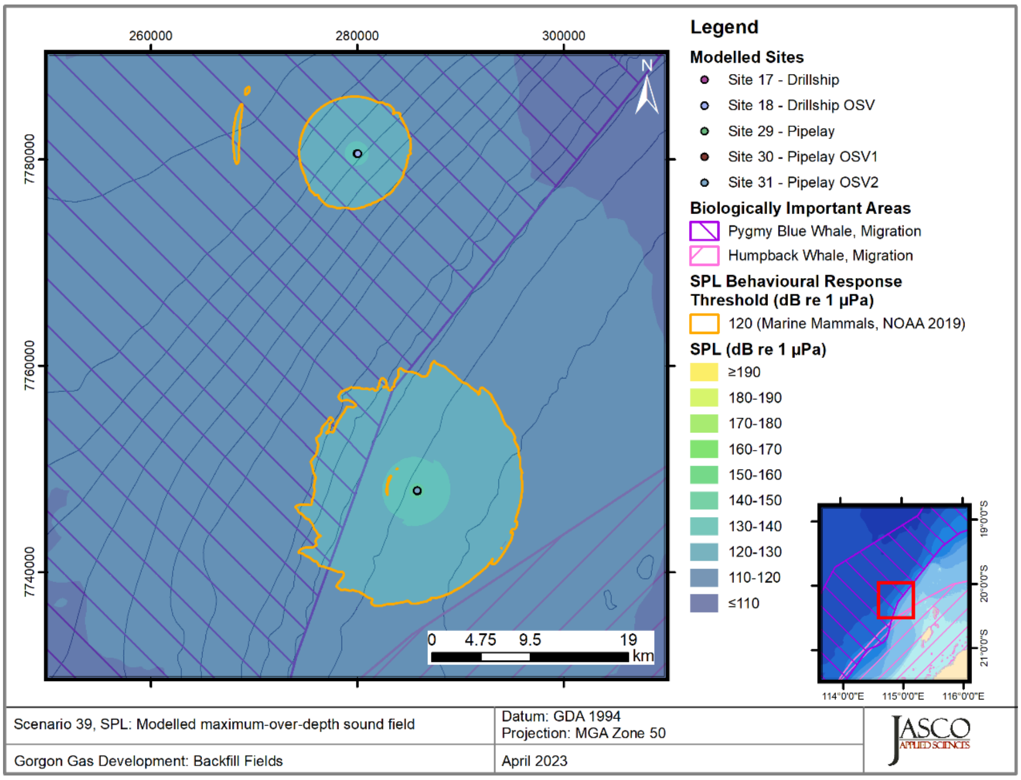

Figure 57. *Scenario 39, Combined scenario: Area 5 pipelay with OSVs and Area 3 drilling with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

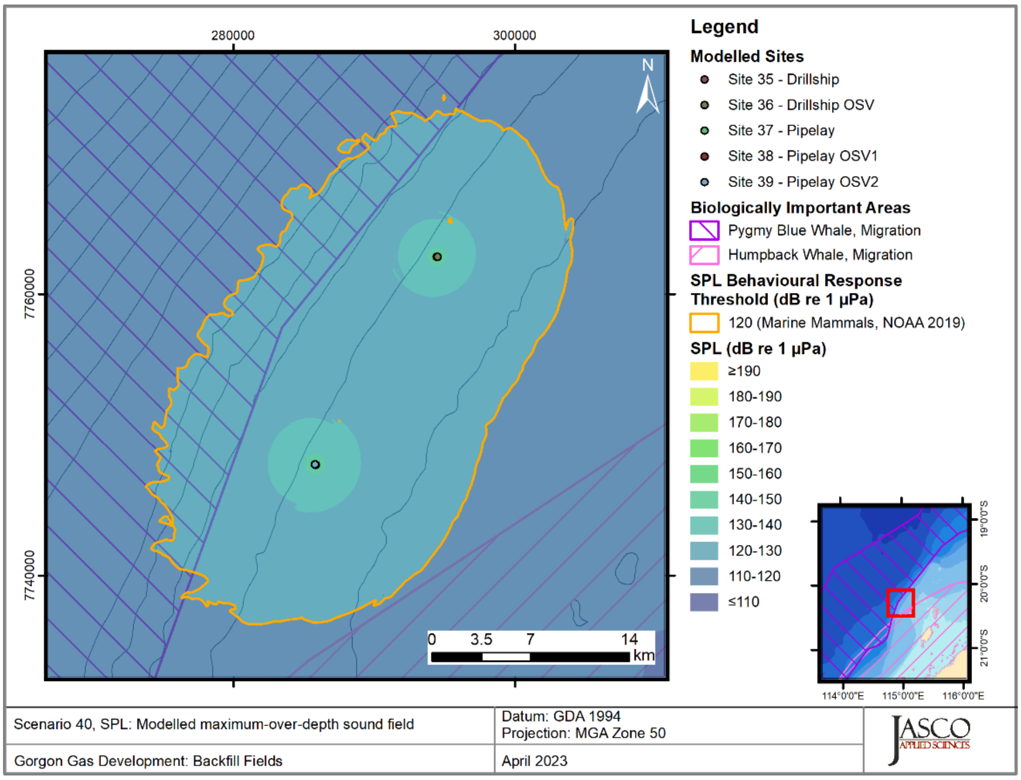

Figure 58. *Scenario 40, Combined scenario: Area 5 pipelay with OSVs and Area 5 drilling with OSV, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth for behavioural response threshold for marine mammals.

4.2.2. Accumulated SEL_{24h} Sound Level Contour Maps

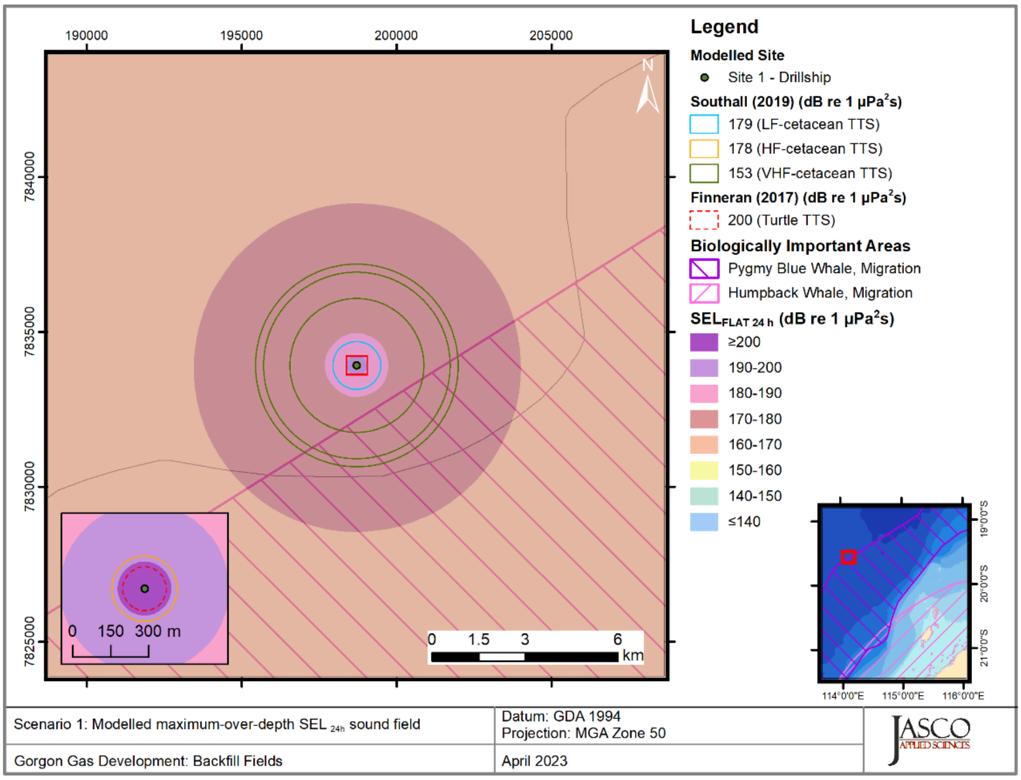

Figure 59. *Scenario 1, Area 1 Drillship*, *SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

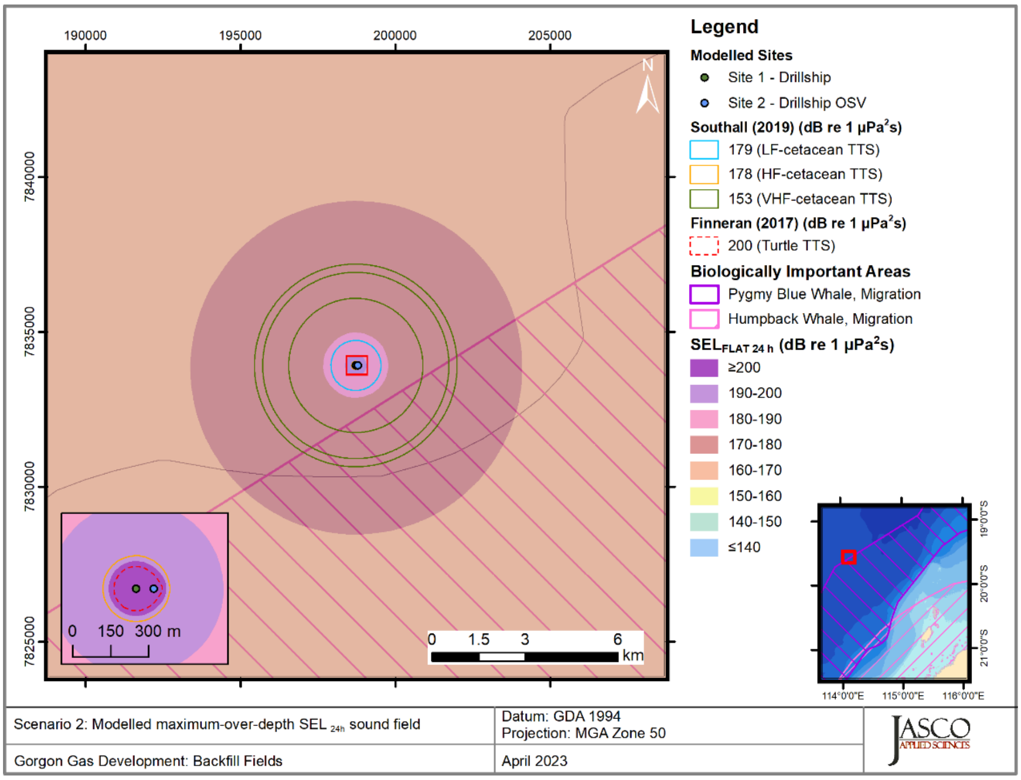

Figure 60. *Scenario 2, Area 1 Drillship with OSV*, SEL_{24h}: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

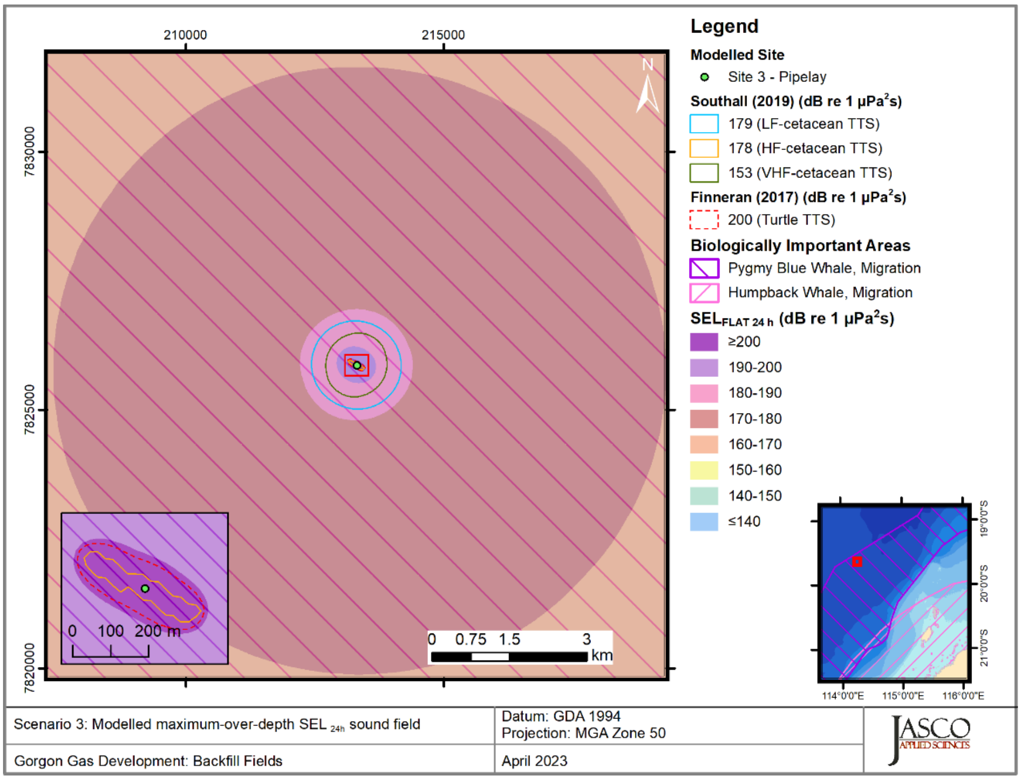

Figure 61. *Scenario 3, Area 1 Pipelay vessel*, SEL_{24h}: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

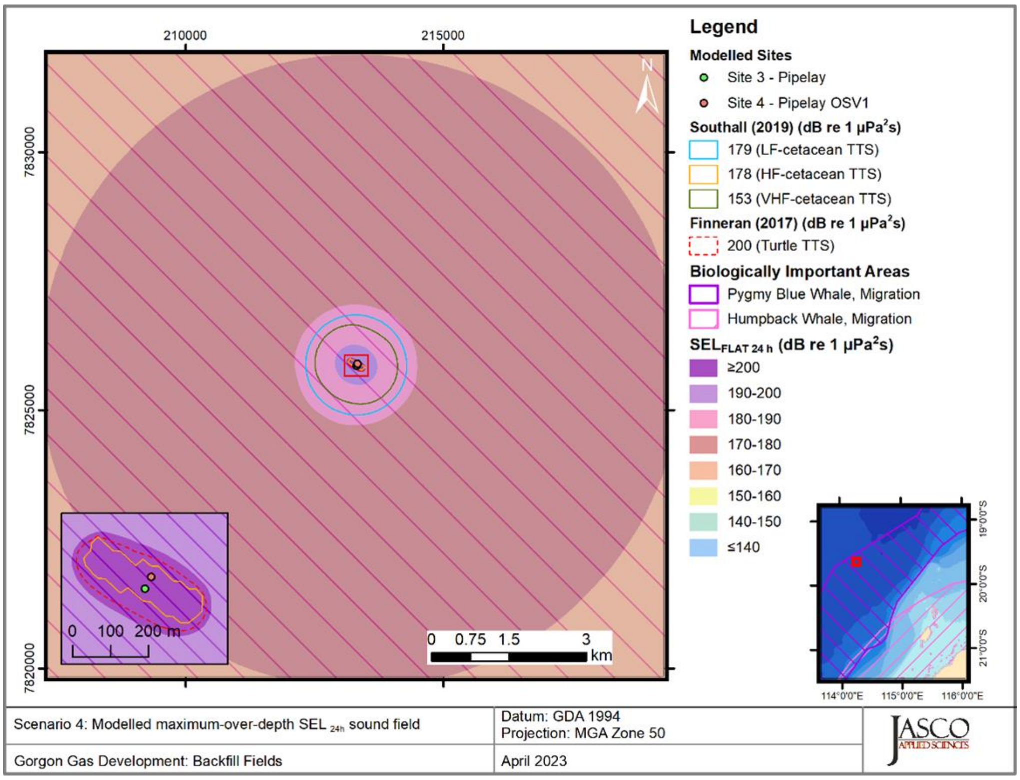

Figure 62. *Scenario 4, Area 1 Pipelay vessel with resupply OSV*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

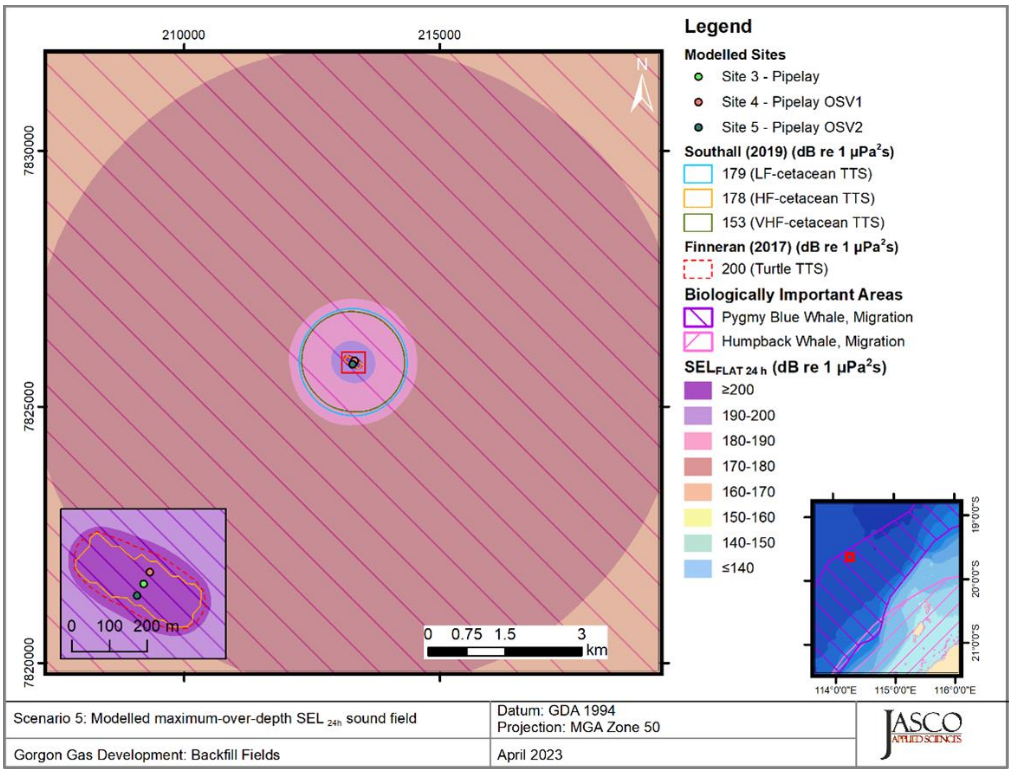

Figure 63. *Scenario 5, Area 1 Pipelay vessel with resupply OSV and support OSV, SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

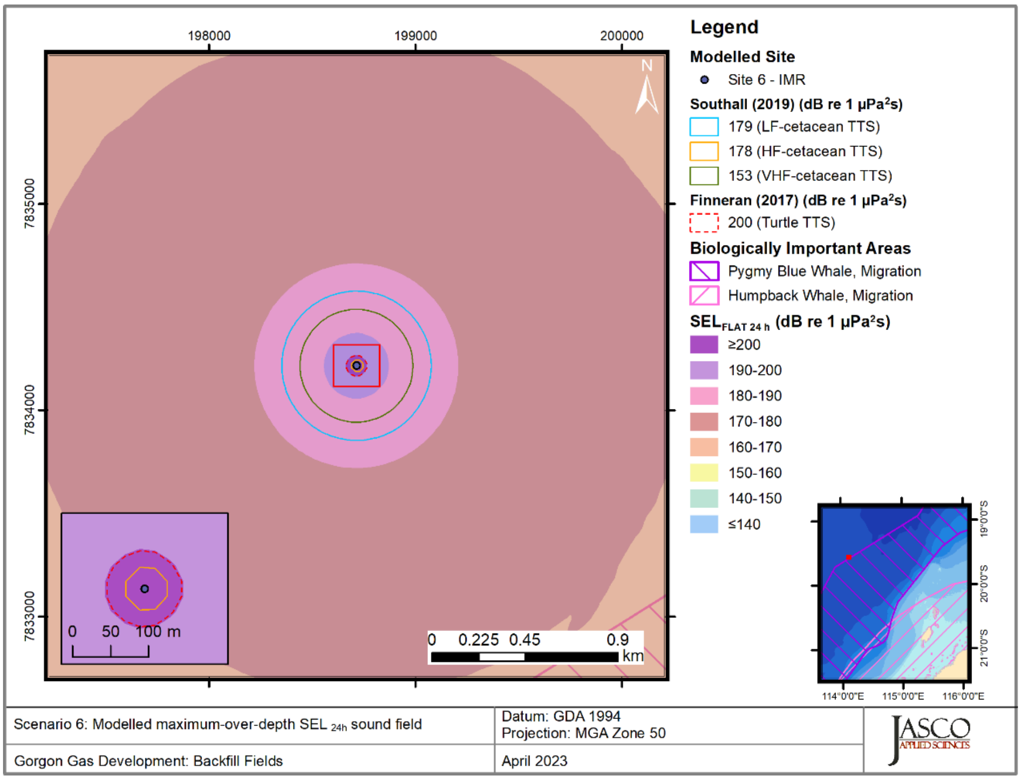

Figure 64. *Scenario 6, Area 1 IMR vessel*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

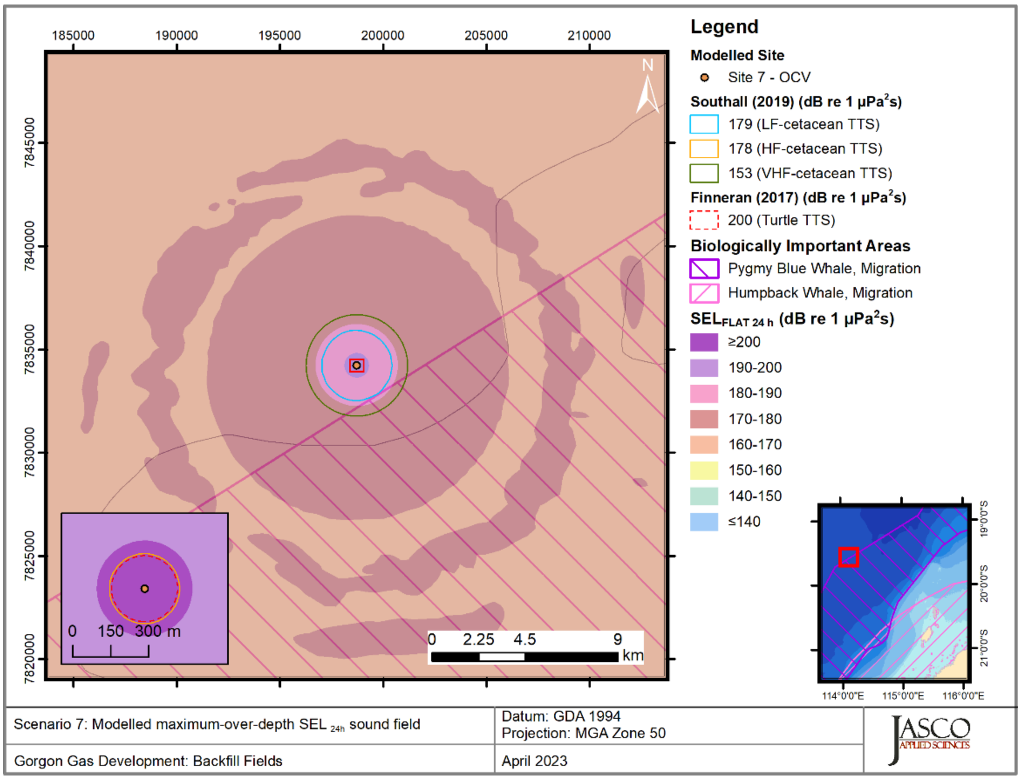

Figure 65. *Scenario 7, Area 1 OCV, SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

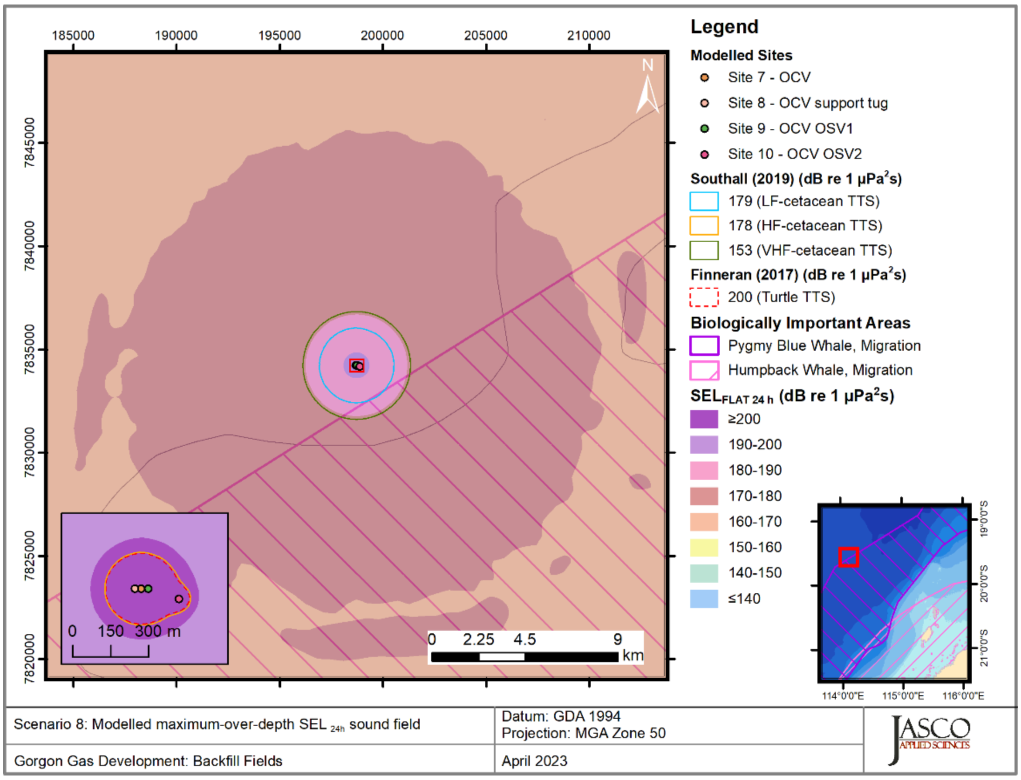

Figure 66. *Scenario 8, Area 1 OCV with three support vessels*, *SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

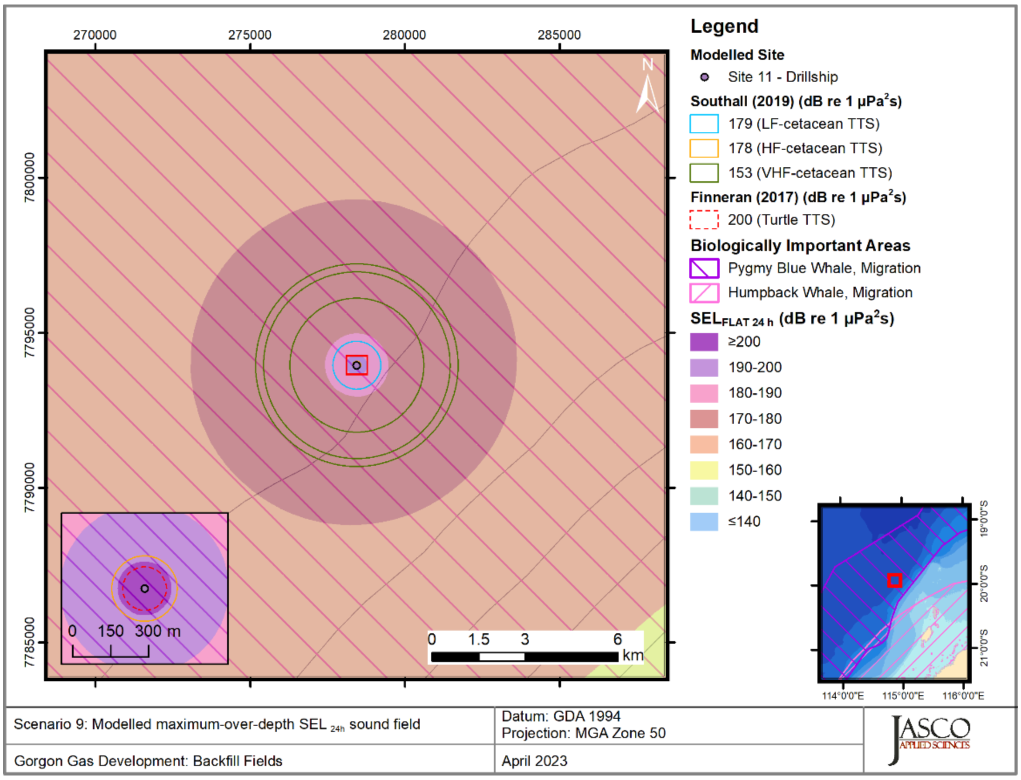

Figure 67. *Scenario 9, Area 2 Drillship*, *SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

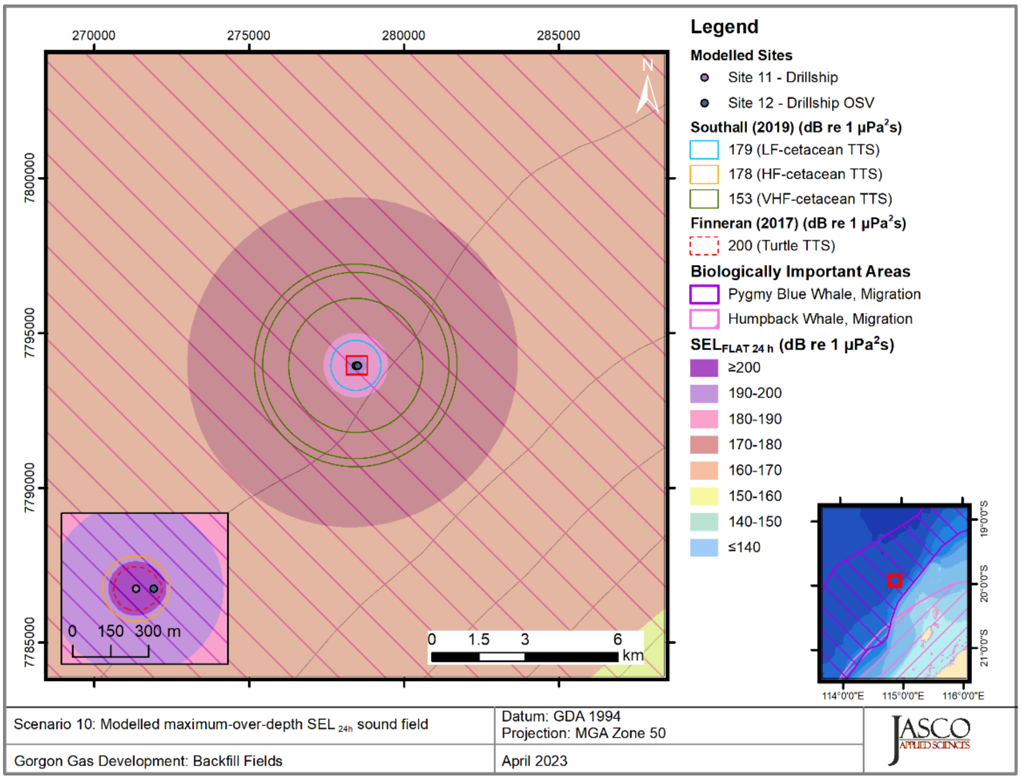

Figure 68. *Scenario 10, Area 2 Drillship with OSV*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

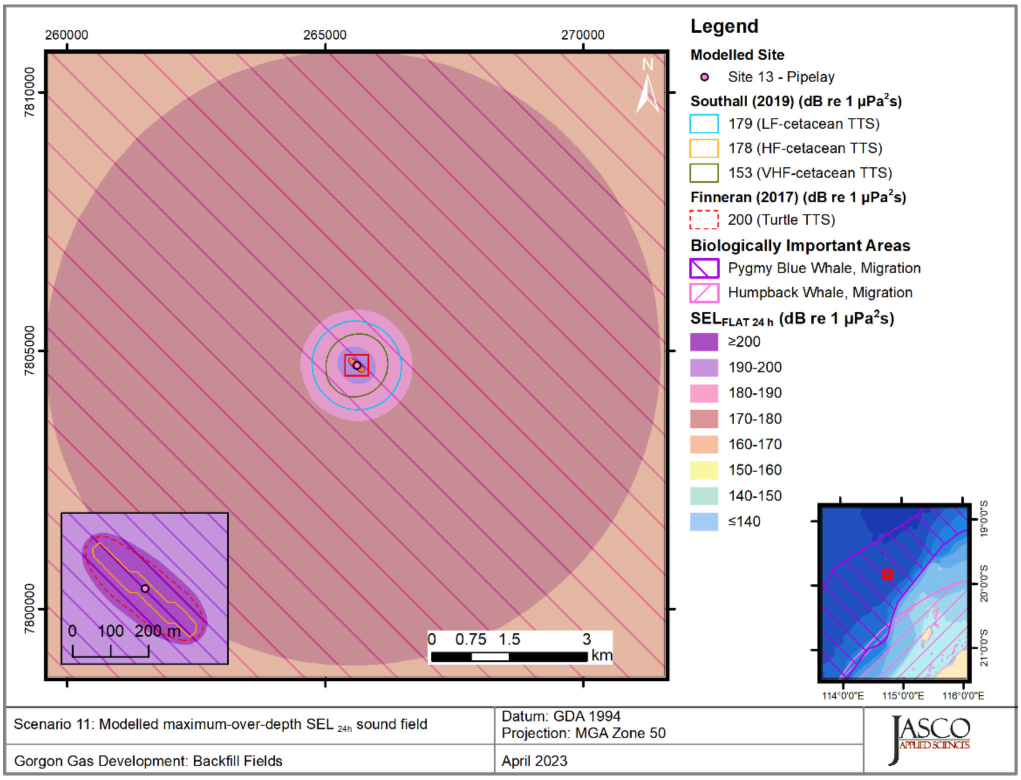

Figure 69. *Scenario 11, Area 2 Pipelay vessel*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

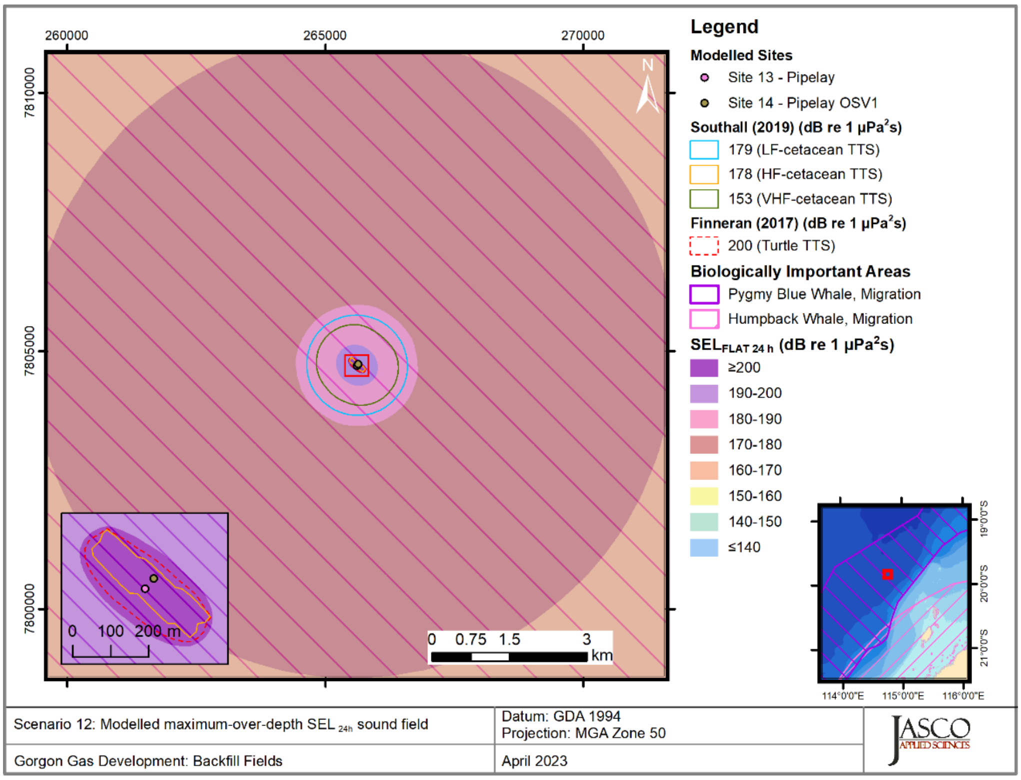

Figure 70. *Scenario 12, Area 2 Pipelay vessel with resupply OSV*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

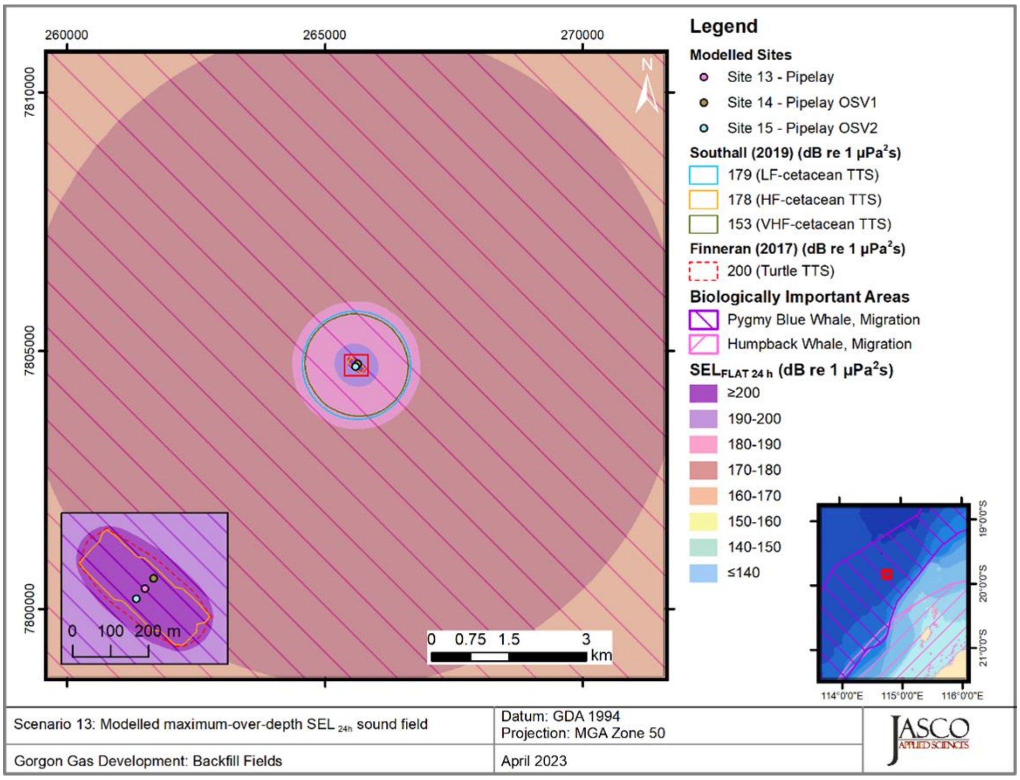

Figure 71. Scenario 13, Area 2 Pipelay vessel with resupply OSV and support OSV, SEL24h: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

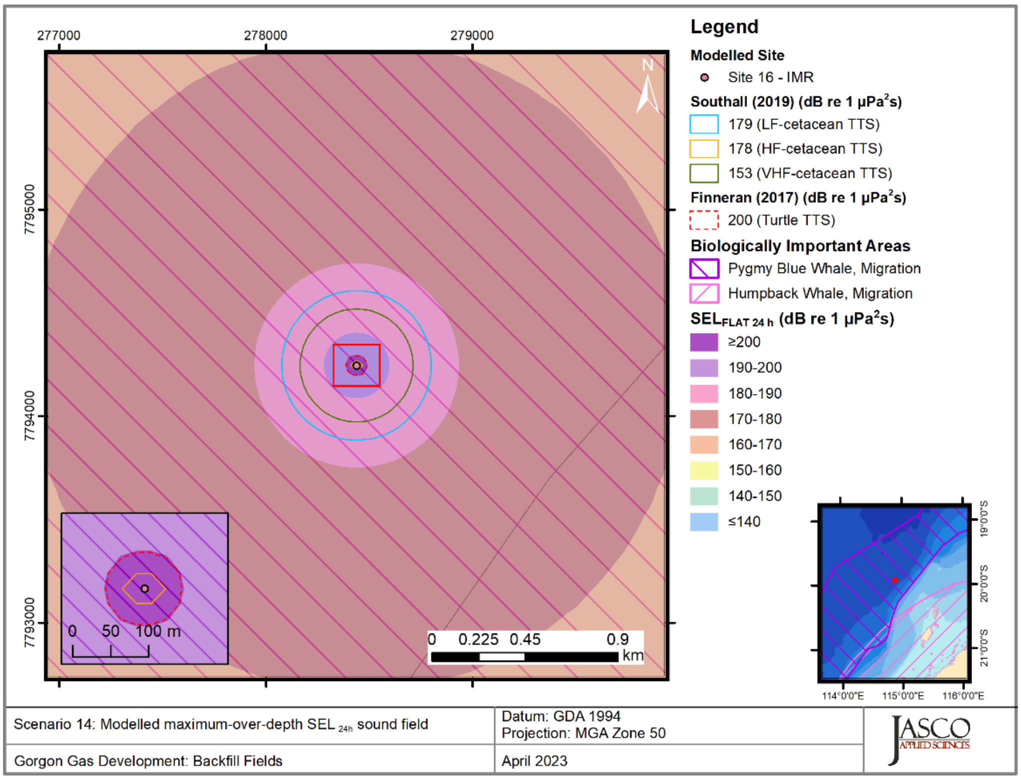

Figure 72. *Scenario 14, Area 2 IMR vessel*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

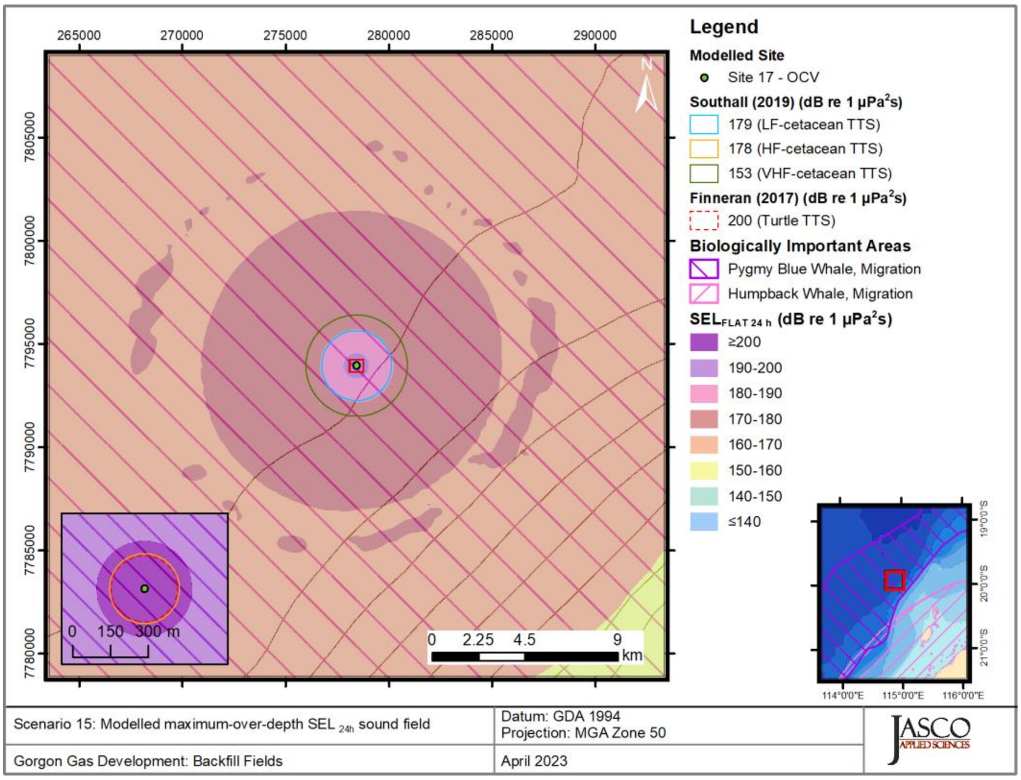

Figure 73. *Scenario 15, Area 2 OCV, SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

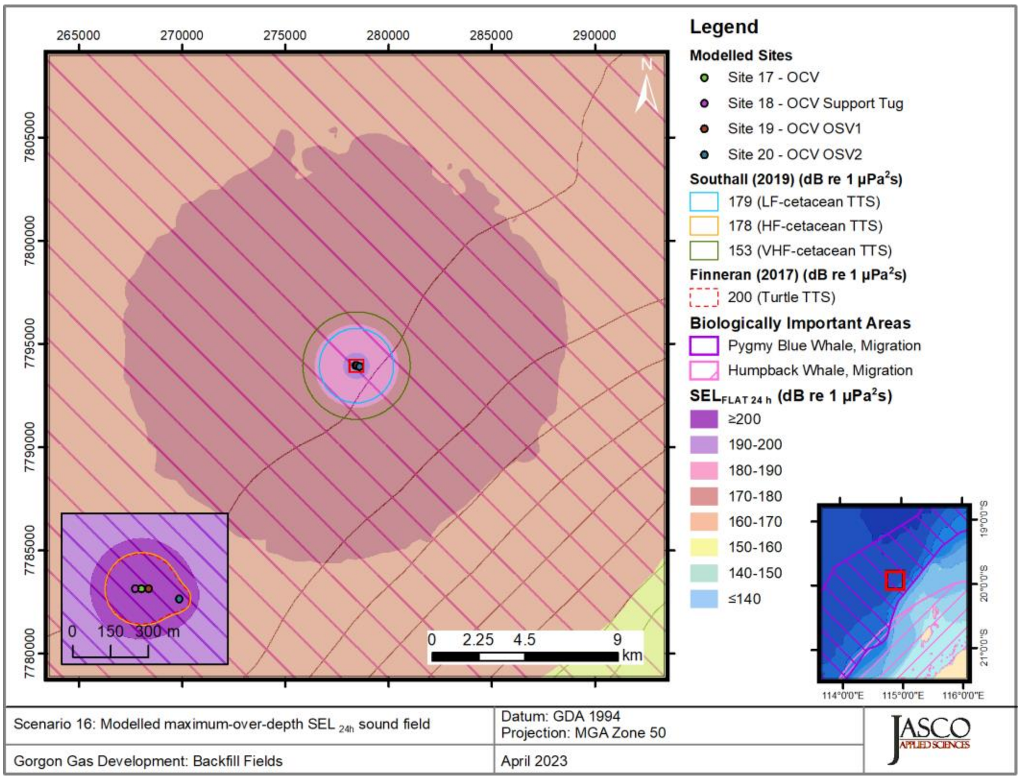

Figure 74. *Scenario 16, Area 2 OCV with three support vessels*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

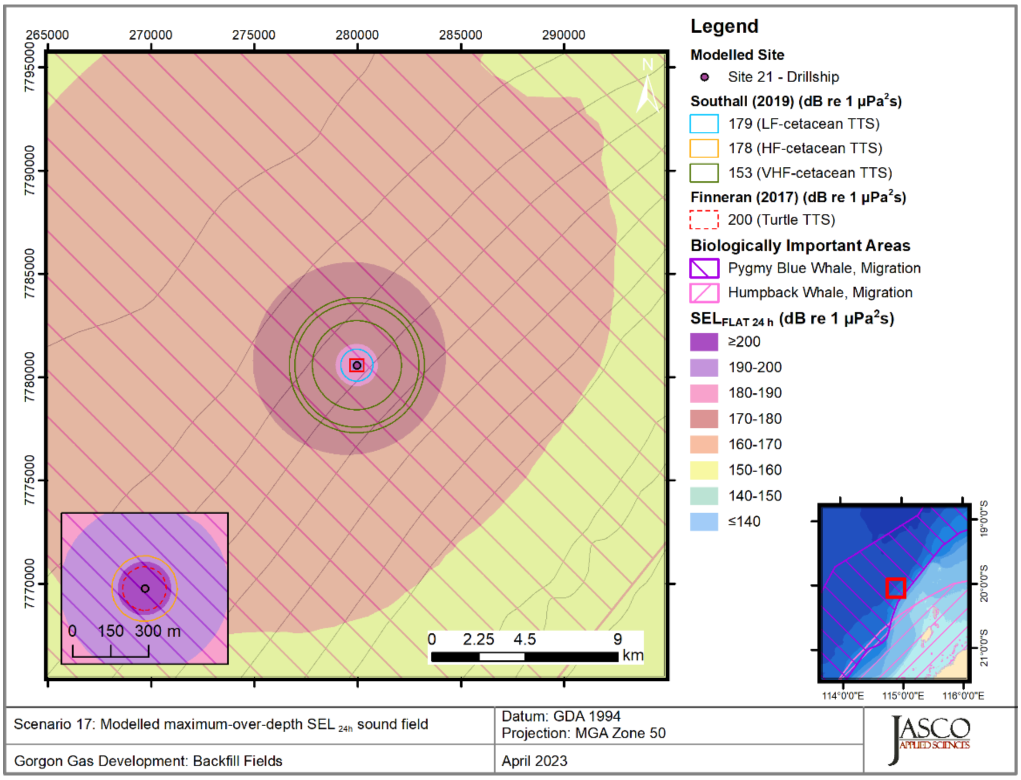

Figure 75. *Scenario 17, Area 3 Drillship*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

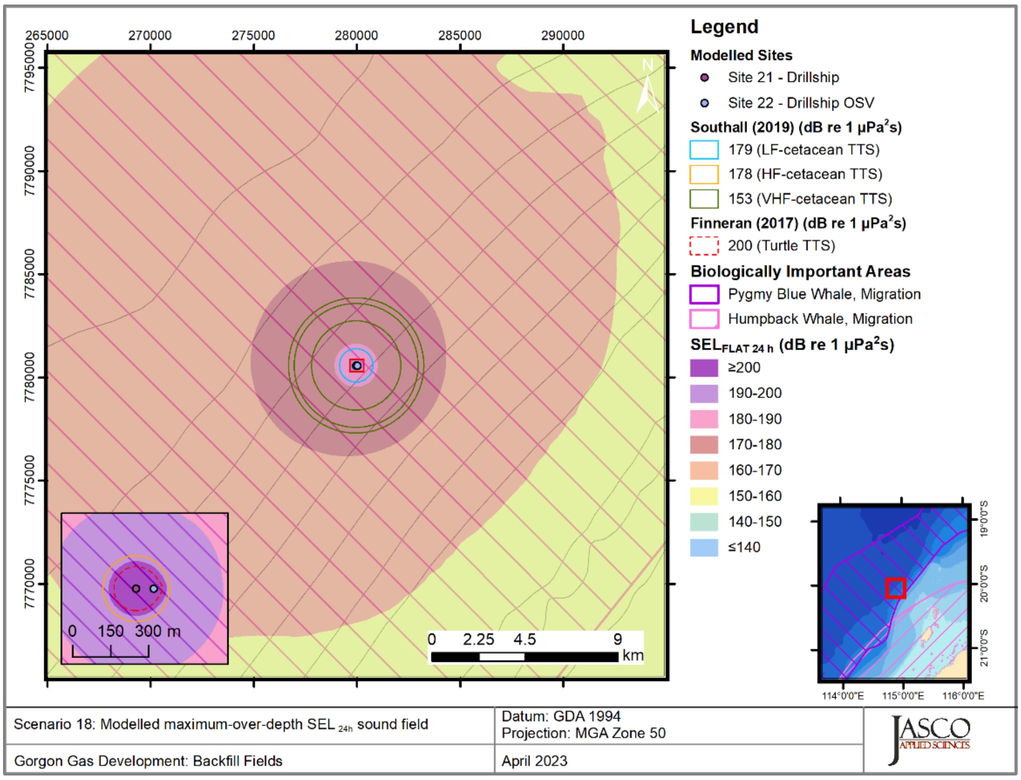

Figure 76. Scenario 18, Area 3 Drillship with OSV, SEL24h: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

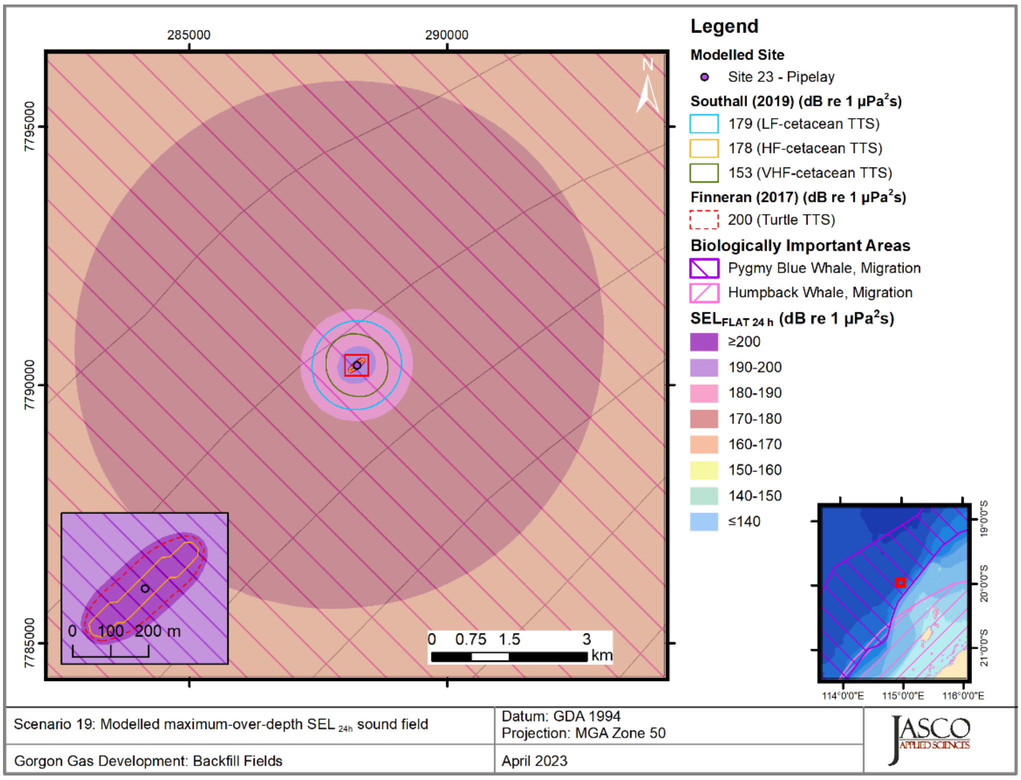

Figure 77. *Scenario 19, Area 3 Pipelay vessel*, *SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

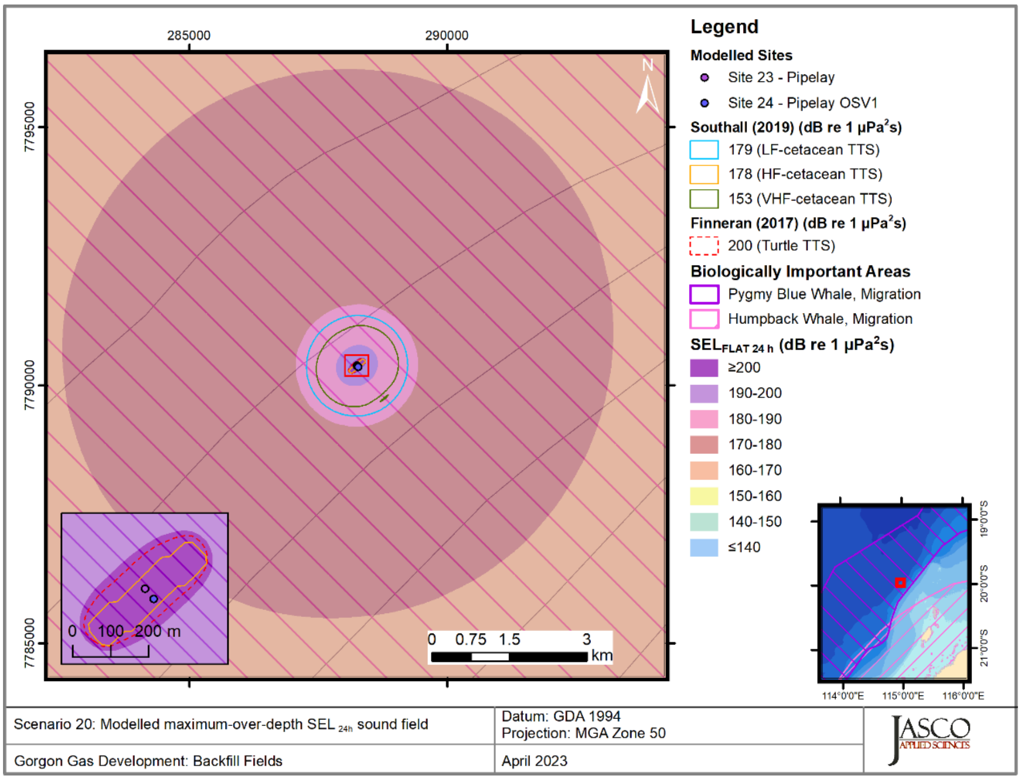

Figure 78. *Scenario 20, Area 3 Pipelay vessel with resupply OSV*, *SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

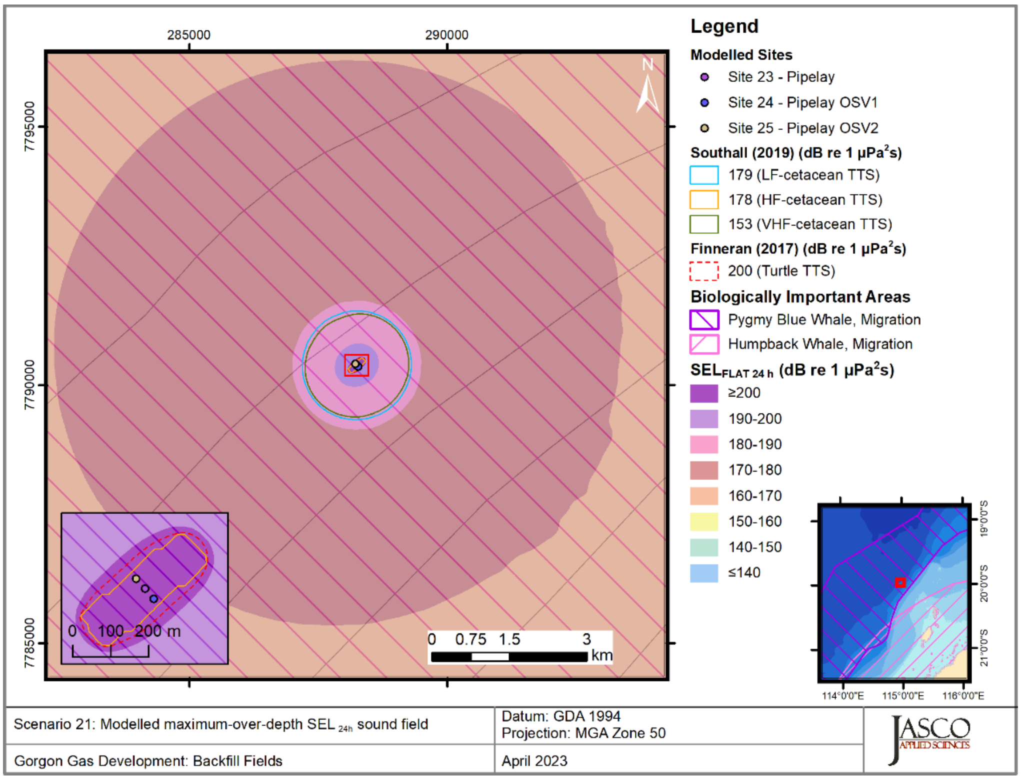

Figure 79. Scenario 21, Area 3 Pipelay vessel with resupply OSV and support OSV, SEL_{24h}: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

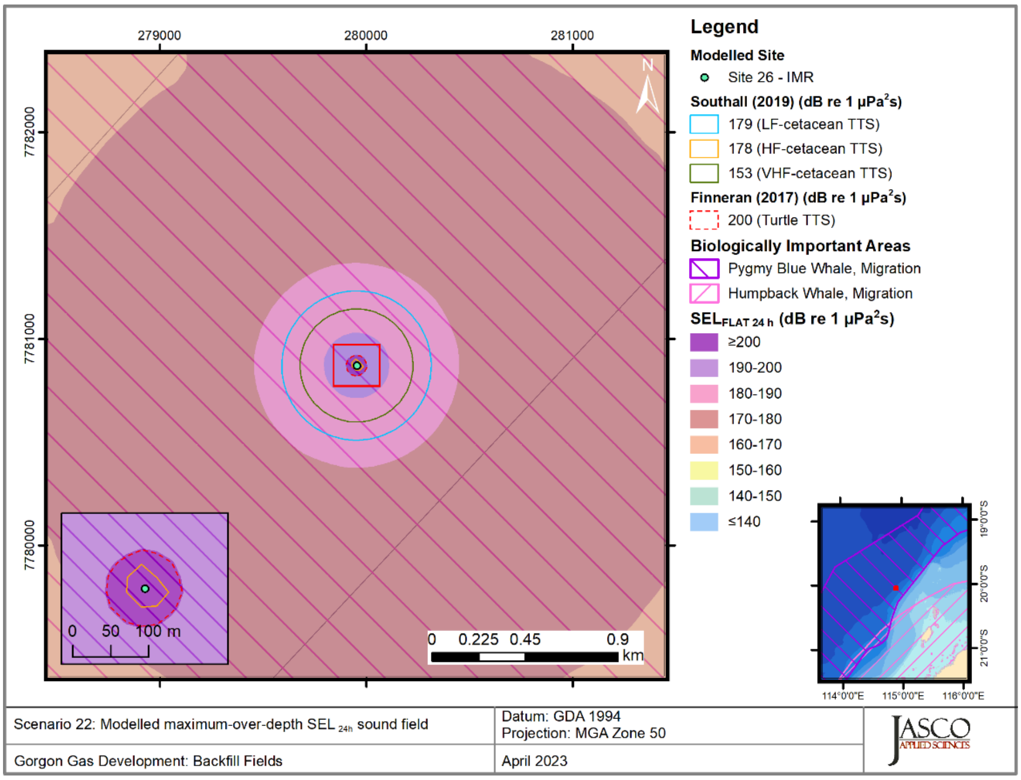

Figure 80. *Scenario 22, Area 3 IMR vessel*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

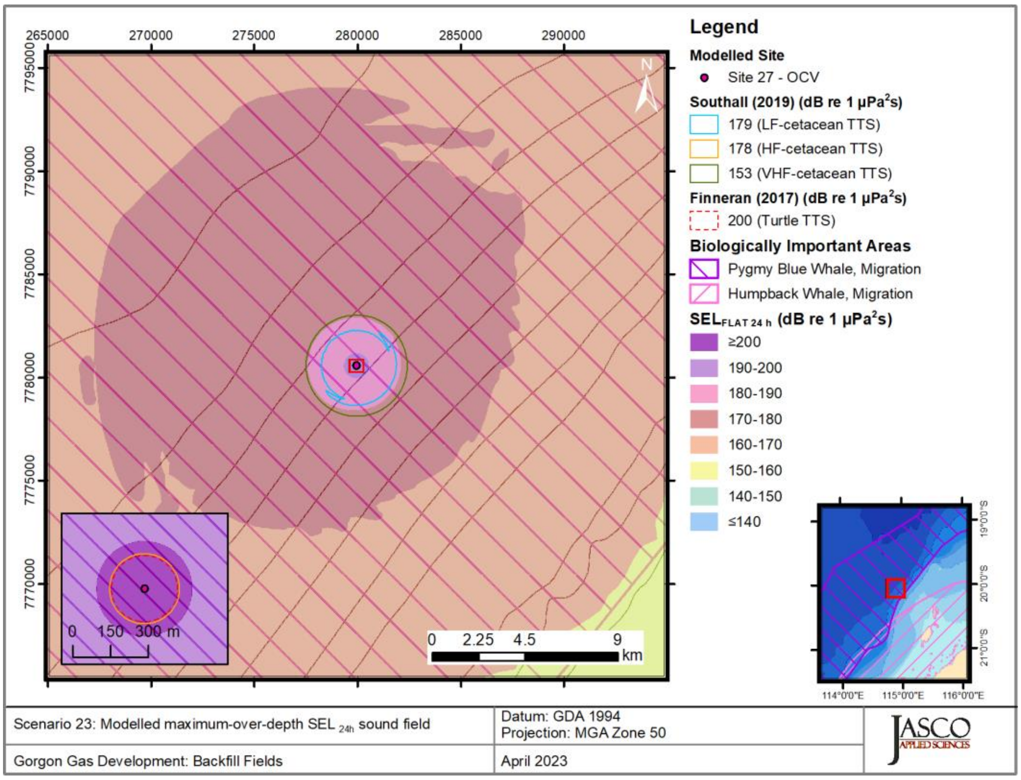

Figure 81. *Scenario 23, Area 3 OCV, SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

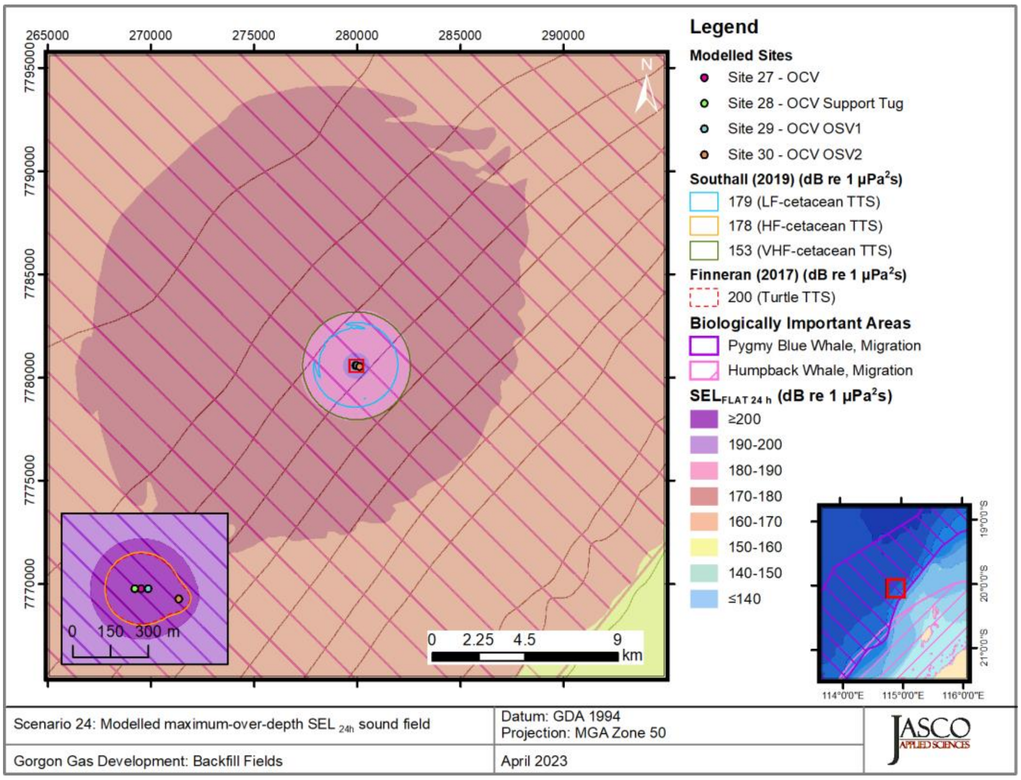

Figure 82. *Scenario 24, Area 3 OCV with three support vessels*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

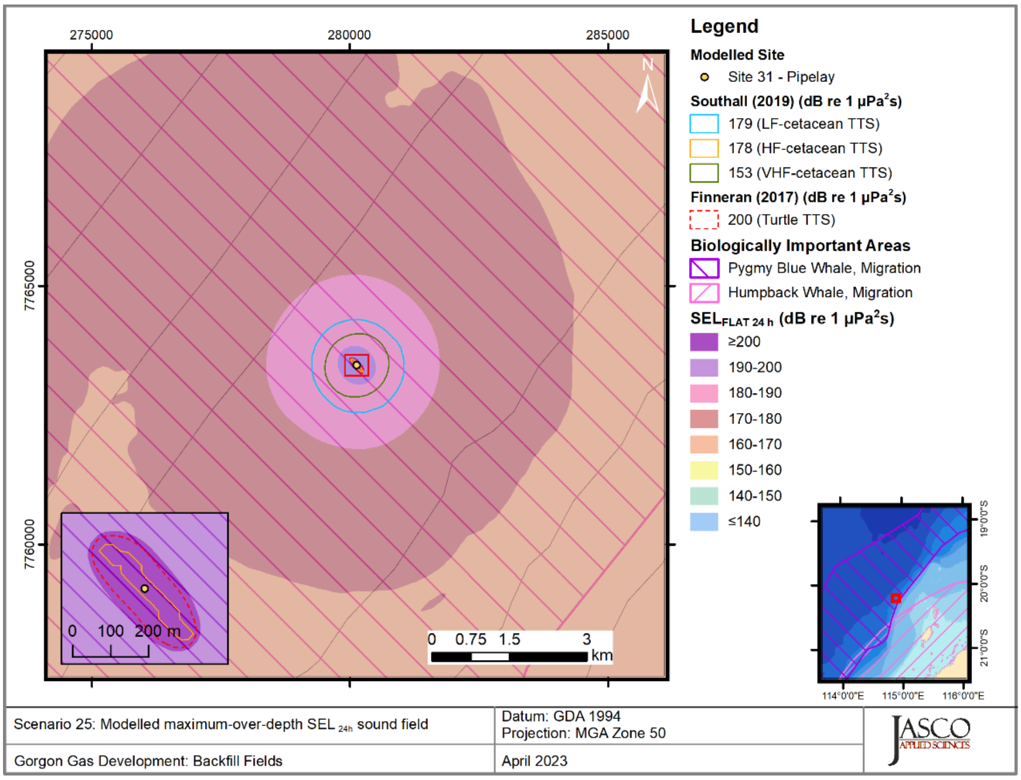

Figure 83. *Scenario 25, Area 4 Pipelay vessel*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

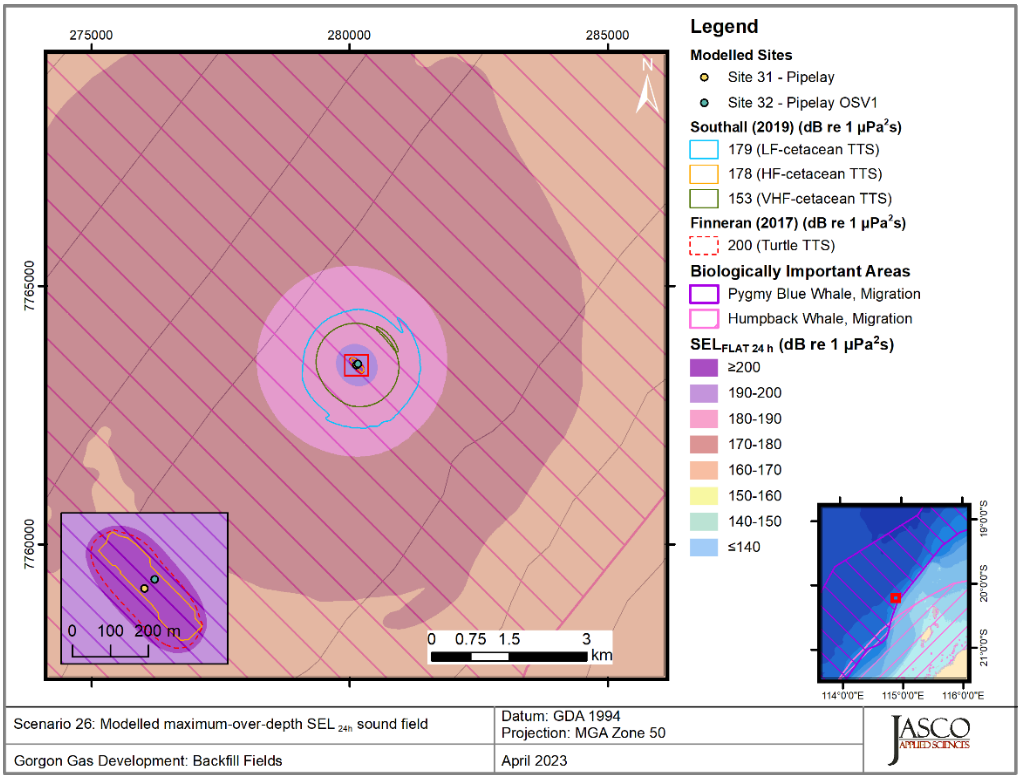

Figure 84. *Scenario 26, Area 4 Pipelay vessel with resupply OSV*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

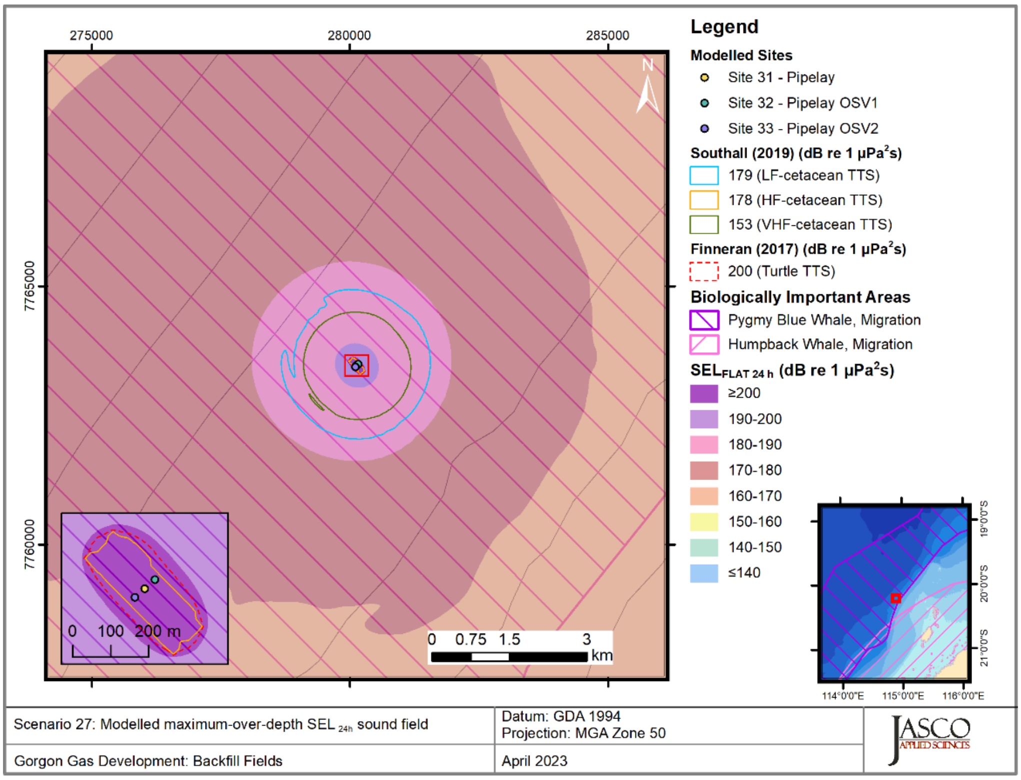

Figure 85. Scenario 27, Area 4 Pipelay vessel with resupply OSV and support OSV, SEL24h: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

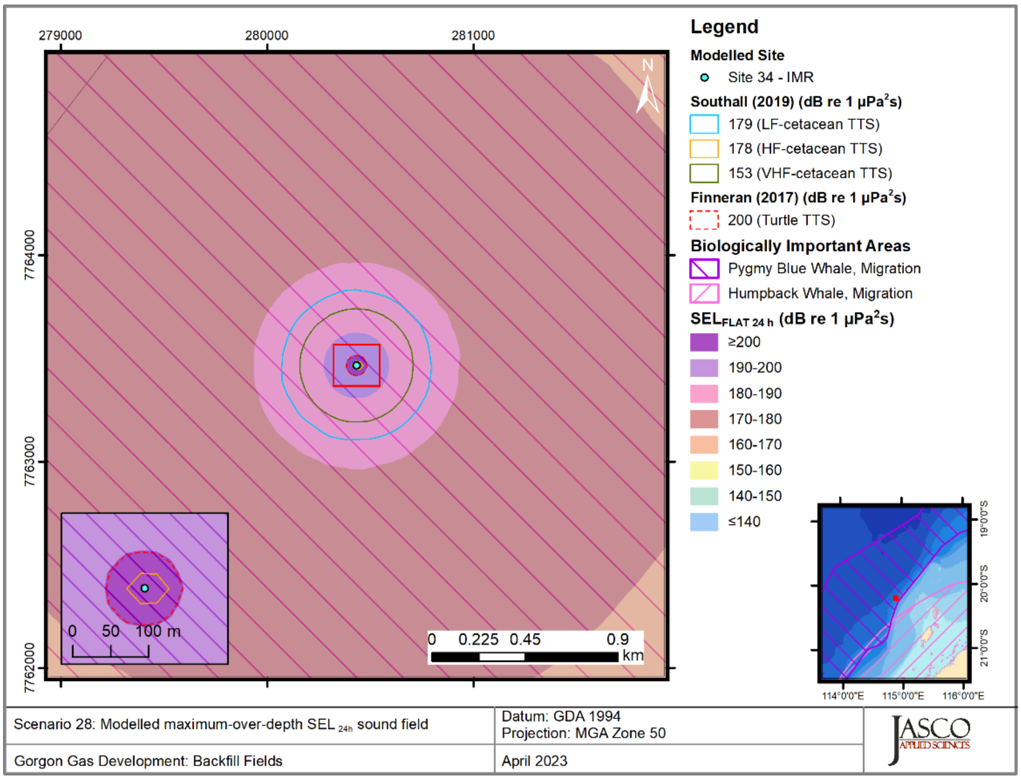

Figure 86. *Scenario 28, Area 4 IMR vessel*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

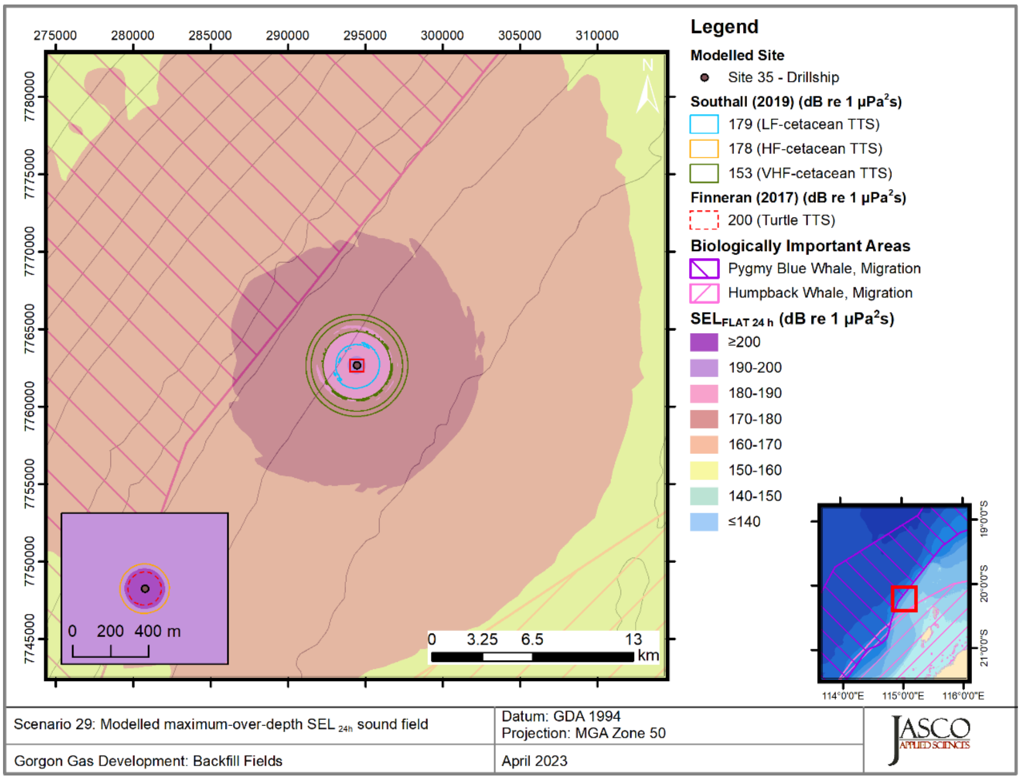

Figure 87. *Scenario 29, Area 5 Drillship*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

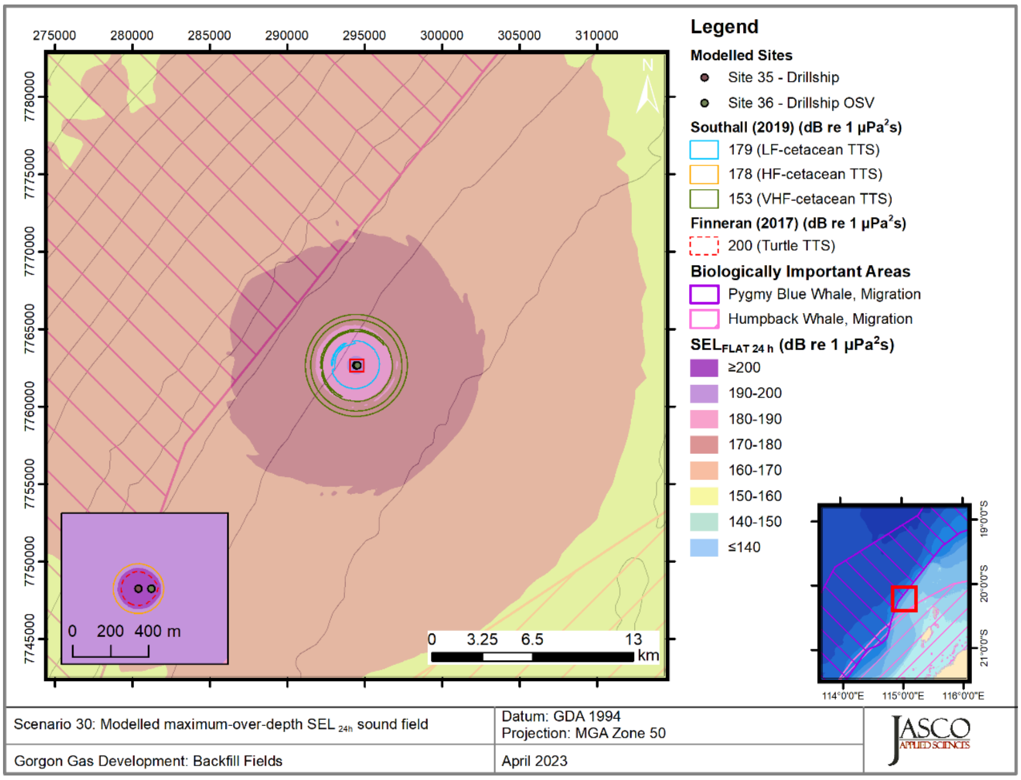

Figure 88. *Scenario 30, Area 5 Drillship with OSV*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

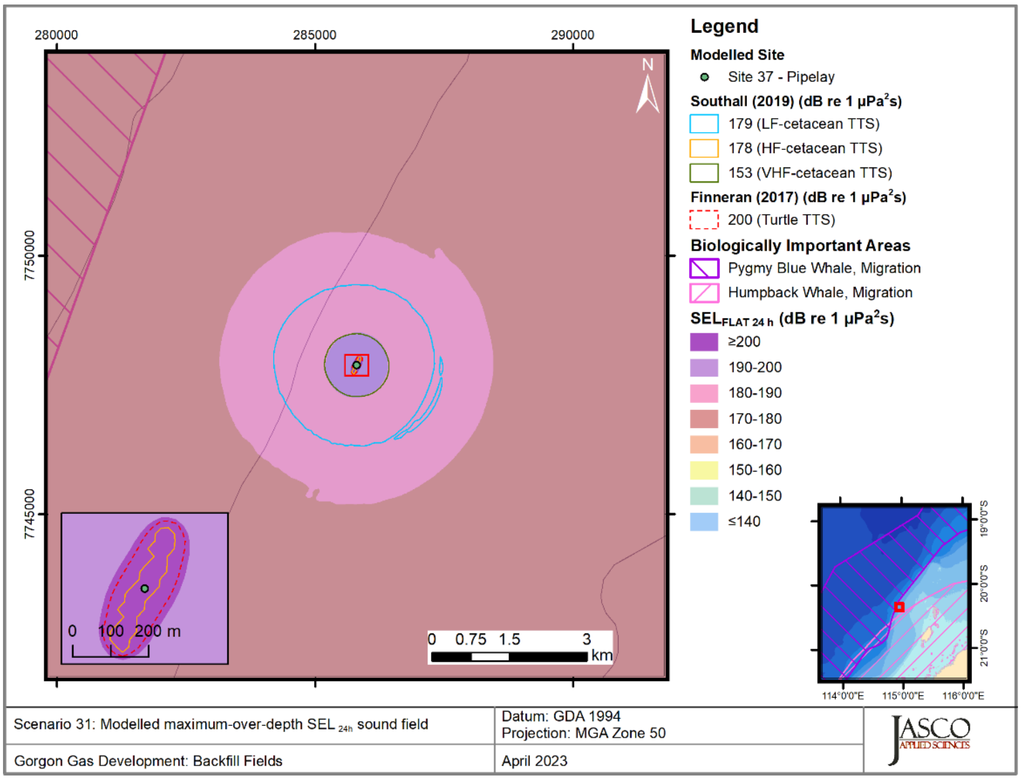

Figure 89. *Scenario 31, Area 5 Pipelay vessel*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

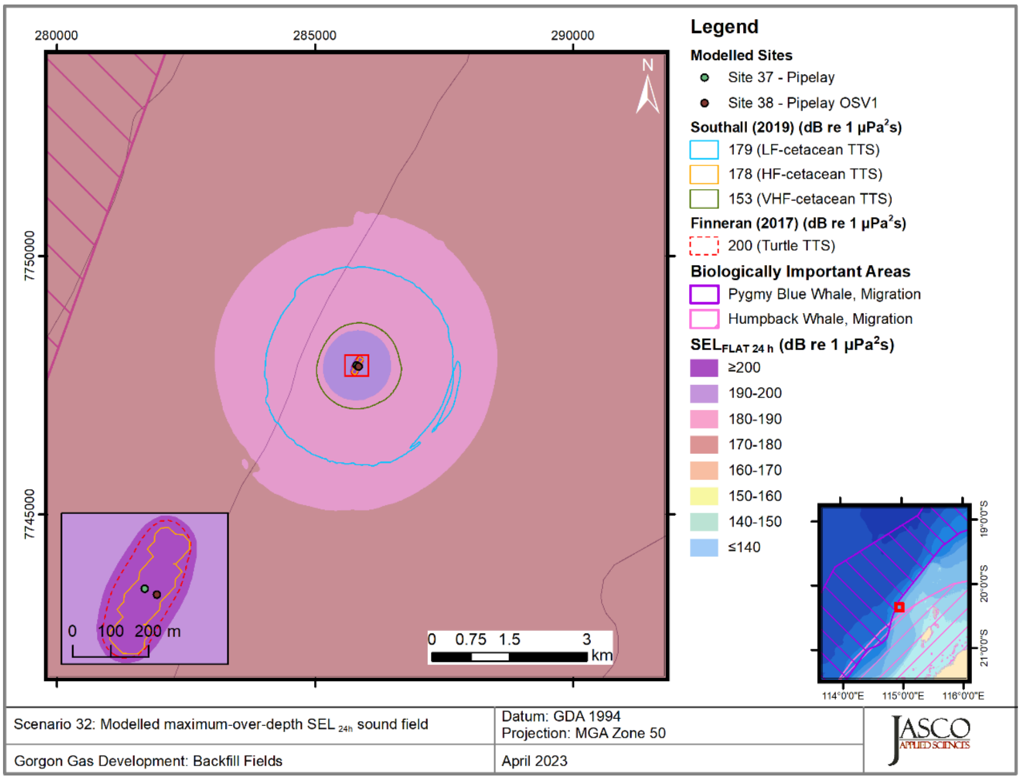

Figure 90. *Scenario 32, Area 5 Pipelay vessel with resupply OSV*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

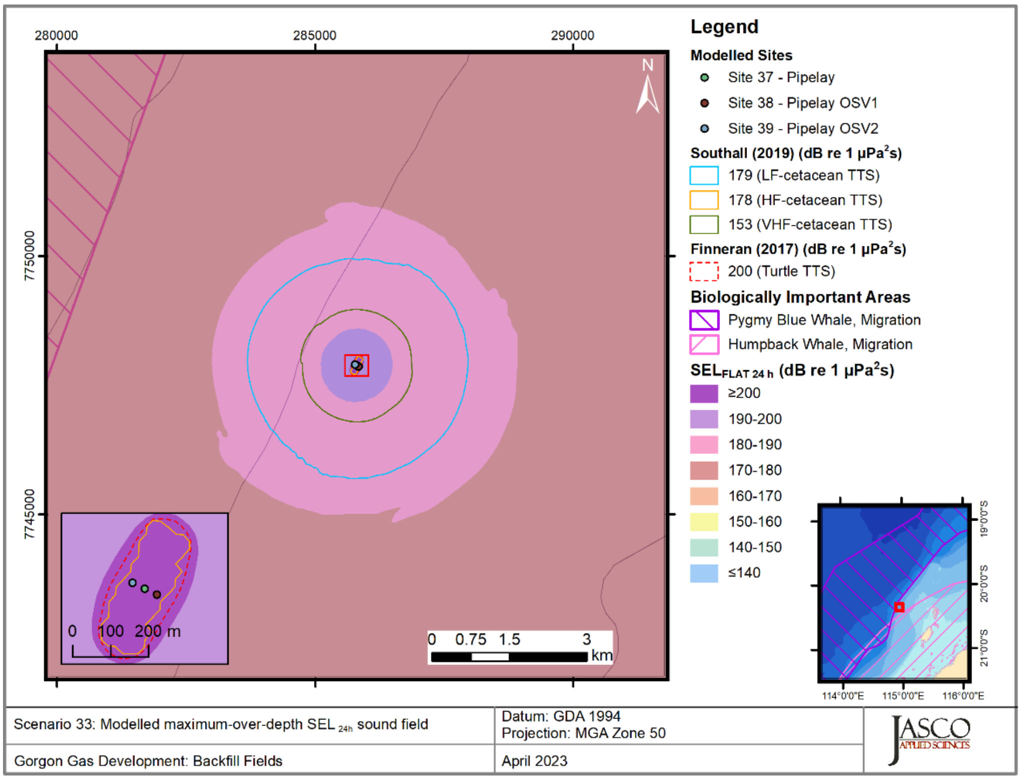

Figure 91. Scenario 33, Area 5 Pipelay vessel with resupply OSV and support OSV, SEL24h: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

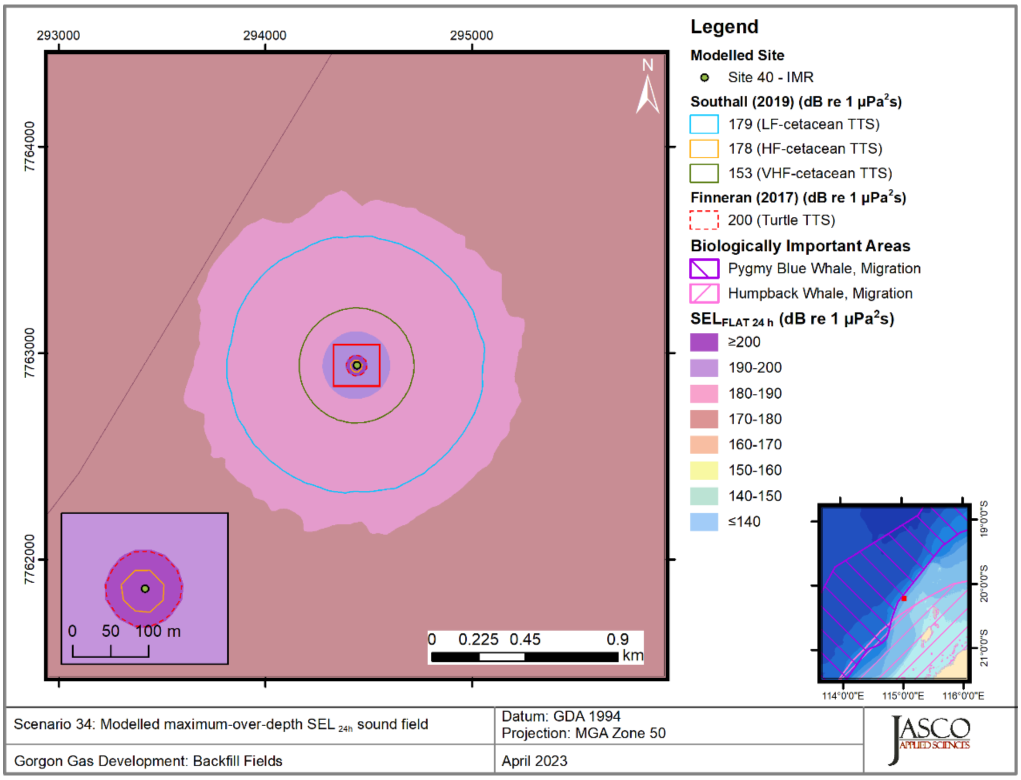

Figure 92. *Scenario 34, Area 5 IMR vessel*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

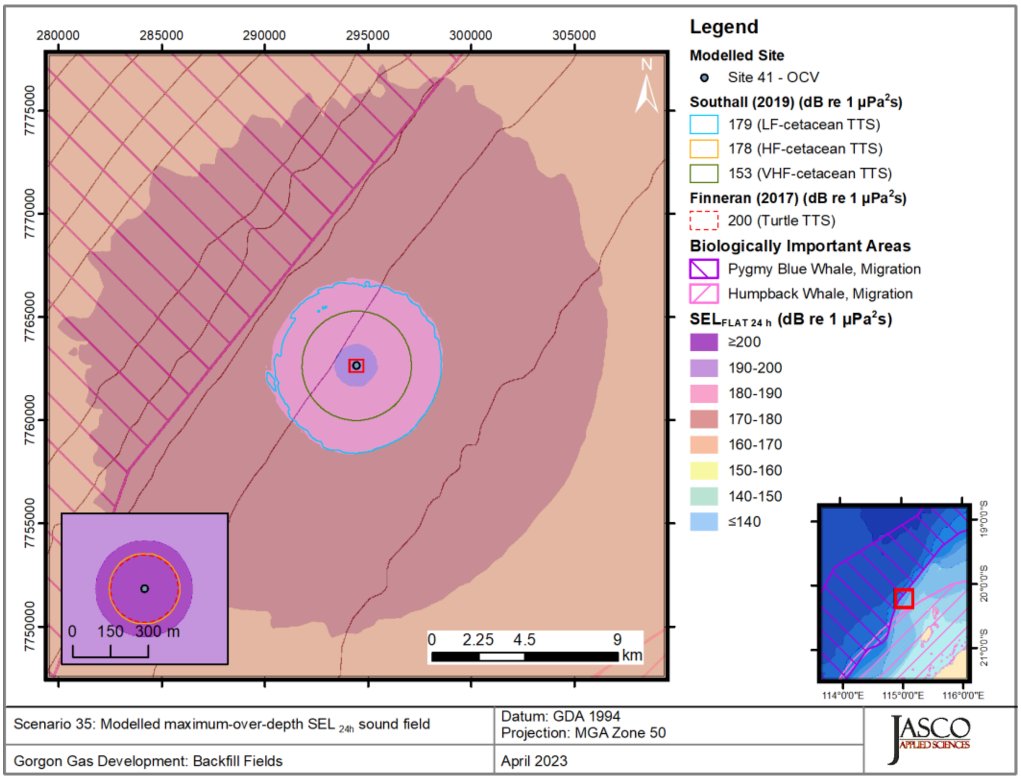

Figure 93. *Scenario 35, Area 5 OCV, SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

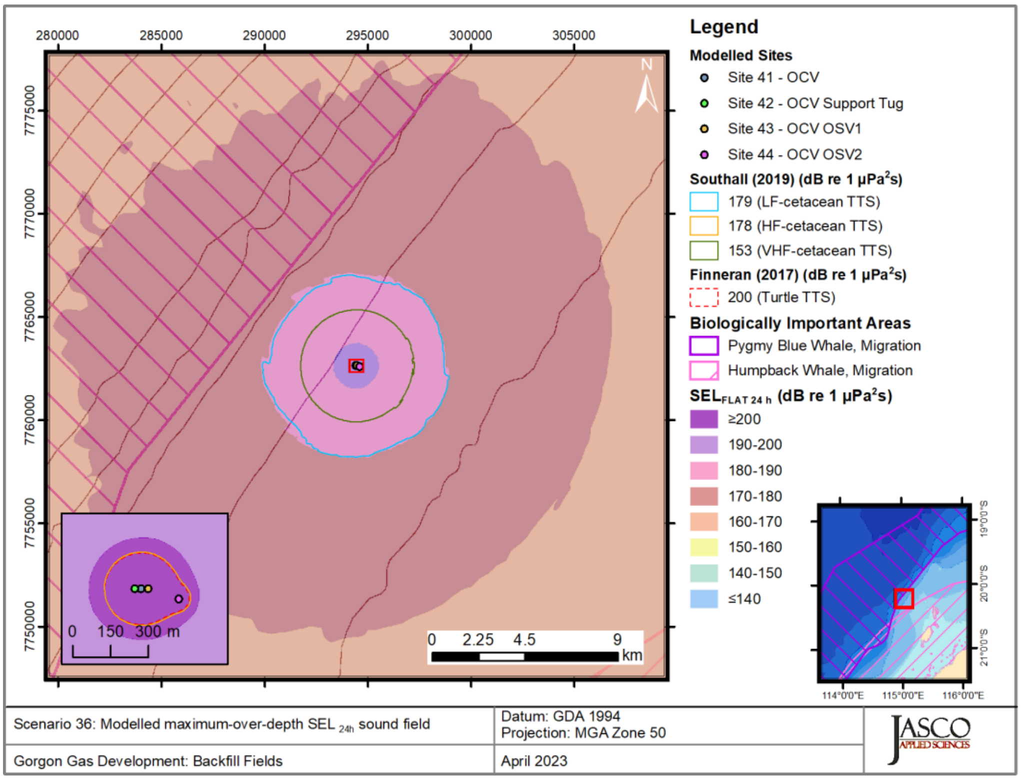

Figure 94. *Scenario 36, Area 5 OCV with three support vessels*, *SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with the isopleths for TTS in low, high- and very-high-frequency cetaceans and turtles. Thresholds omitted here were either not reached or were not long enough to display graphically.

4.3. Vertical Slice Plots

Vertical slice plots (Figures 95 to 99) are provided to illustrate the underwater propagation of the most significant noise source in each of the five Areas. In Areas 1, 2, 3 and 5, the most significant noise is the OCV; as the OCV was not modelled in Area 4, the pipelay vessel is illustrated.

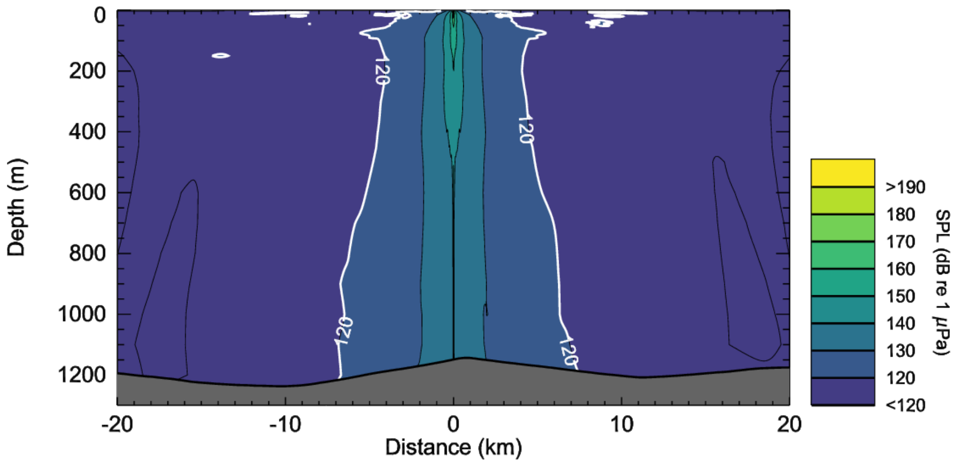

Figure 95. Vertical slice plot of Sound Pressure Levels (SPLs) for the OCV in Area 1 (Site 7).

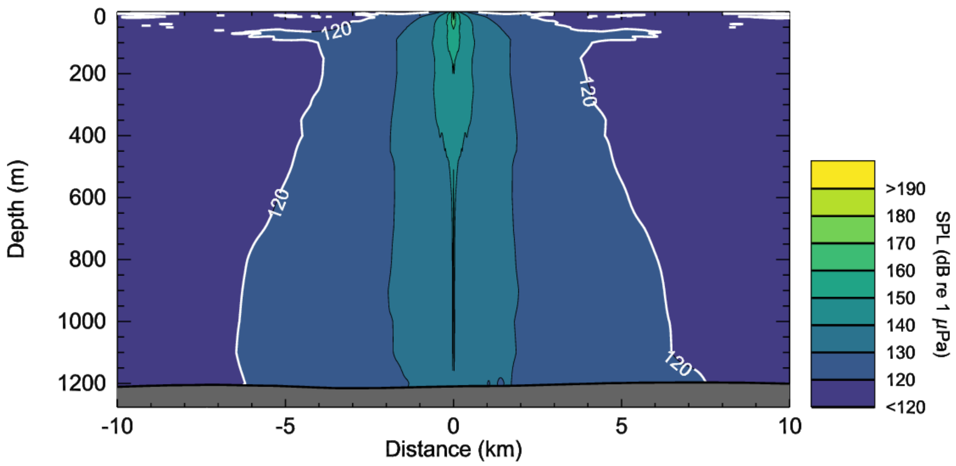

Figure 96. Vertical slice plot of Sound Pressure Levels (SPLs) for the OCV in Area 2 (Site 17).

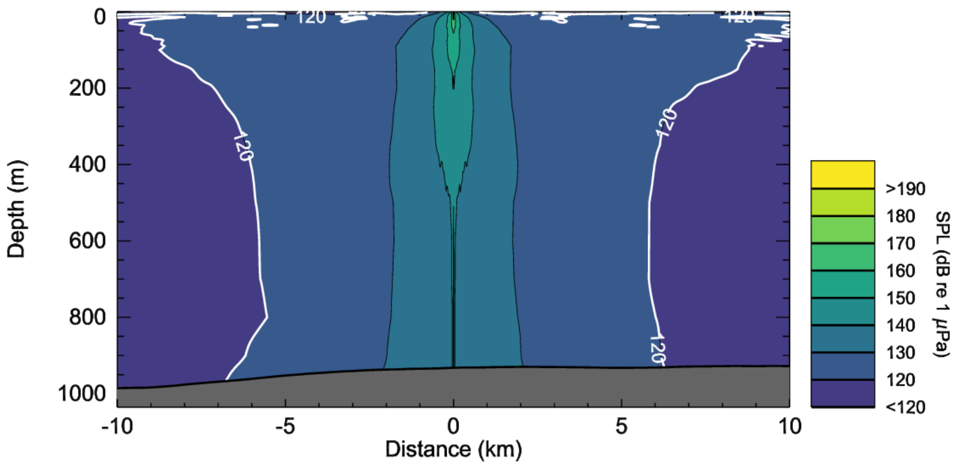

Figure 97. Vertical slice plot of Sound Pressure Levels (SPLs) for the OCV in Area 3 (Site 27).

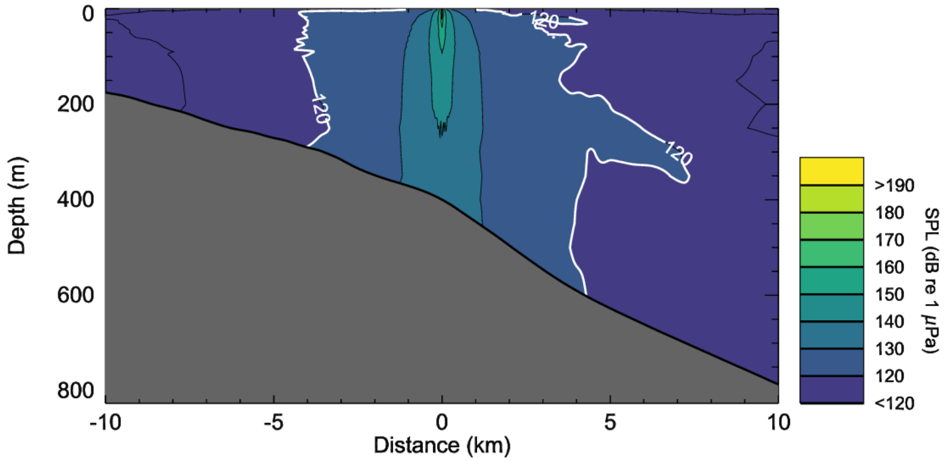

Figure 98. Vertical slice plot of Sound Pressure Levels (SPLs) for the pipelay vessel in Area 4 (Site 31).

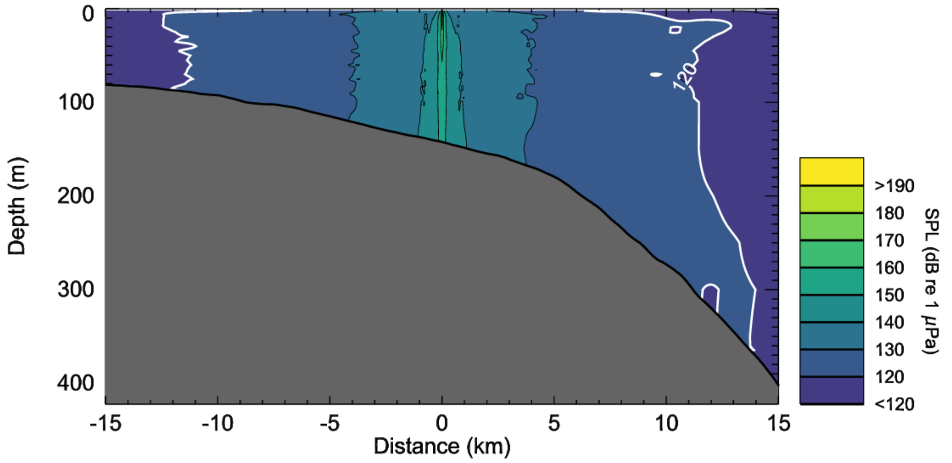

Figure 99. Vertical slice plot of Sound Pressure Levels (SPLs) for the OCV in Area 5 (Site 41).

4.4. VSP Tabulated Results and Maps

4.4.1. Acoustic Source Levels and Directivity

AASM (Section 3.2.1) was used to predict the horizontal and vertical overpressure signatures and corresponding power spectrum levels for the seismic source at the well centre, with results provided in Appendix C along with the horizontal directivity plots.

Table 31 shows the PK and per-pulse SEL source levels in the horizontal-plane broadside (perpendicular to the sagittal plane of the array), endfire (parallel to the sagittal plane of the array), and vertical directions. The vertical source level that accounts for the “surface ghost” (the out of phase reflected pulse from the water surface) is also presented to make it easier to compare the output of other seismic source models.

Appendix C.3 shows the broadside, endfire, and vertical overpressure signature and corresponding power spectrum levels for the source. The signature consists of a strong primary peak, related to the initial release of high-pressure air, followed by a series of pulses associated with bubble oscillations. Most energy was produced at frequencies below 300 Hz. Frequency-dependent peaks and nulls in the spectrum result from interference among airguns in the source and correspond with the volumes and relative locations of the airguns to each other.

Table 31. Far-field source level specifications for the 750 in^3 Vertical Seismic Profiling (VSP) array, for a 5 m source depth. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted.

Direction	Peak source pressure level ($L_{S,pk}$; dB re 1 µPa m)	Per-pulse source SEL ($L_{S,E}$; dB 1 µPa^{2}m^{2}s)	
		10–2000 Hz	2000–25000 Hz
Broadside	239.2	214.5	168.8
Endfire	239.4	214.5	165.8
Vertical	239.2	214.5	173.6
Vertical (surface affected source level)	239.3	216.1	176.6

4.4.2. Per-Pulse Sound Fields

This section presents the per-pulse sound fields in terms of maximum-over-depth SPL, SEL, PK, and seafloor PK and PK-PK. The different metrics are presented for the following reasons:

- Per-pulse SEL sound fields (Table 32) are used as inputs into the 24 h SEL scenario and to provide context for the range to 160 dB re 1 µPa^2·s, relevant for the EPBC Act Policy Statement 2.1 (DEWHA 2008).
- SPL sound fields (Table 33) were used to determine the distances to marine mammal and turtle behavioural thresholds (see Sections 2.1 and 2.2).
- PK metrics within the water column (Table 34) are relevant to thresholds and guidelines for marine mammals, sea turtles, fish, fish eggs and larvae (as well as plankton; see Sections 2.1 and 2.2).
- PK metrics at the seafloor (Table 35) are relevant to guidelines for fish, fish eggs and larvae (Section 2.2).
- PK-PK metrics at the seafloor (Table 36) are relevant to sound levels used in assessing effect on benthic invertebrates (see Section 2.3).

The SPL sound fields, and distances to relevant isopleths can be visualised on the contour maps presented in Section 4.4.4.1.

Table 32. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 750 in³ Vertical Seismic Profiling (VSP) array to modelled maximum-over-depth unweighted per-pulse sound exposure level (SEL) isopleths.

Per-pulse SEL (L_E; dB re 1 µPa²·s)	Site A		Site B		Site C	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	0.04	0.04	0.04	0.04	0.04	0.04
170	0.14	0.14	0.13	0.13	0.13	0.13
160[a]	0.61	0.58	0.42	0.41	0.42	0.41
150	2.76	2.50	1.56	1.51	1.63	1.56
140	7.99	7.04	4.49	4.16	4.85	4.61
130	22.5	20.0	18.7	17.6	14.4	12.1
120	>100	/	50.1	41.9	36.2	29.8
110	>100	/	96.2	84.8	70.0	60.2

[a] Low power zone assessment criteria DEWHA (2008).
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).
A slash indicates that $R_{95\%}$ is not reported when the R_{max} was greater than the maximum modelling extent.

Table 33. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 750 in³ Vertical Seismic Profiling (VSP) array to modelled maximum-over-depth unweighted per-pulse sound pressure level (SPL) isopleths.

SPL (L_p; dB re 1 µPa)	Site A		Site B		Site C	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
190	0.03	0.03	0.03	0.03	0.03	0.03
180	0.12	0.12	0.12	0.12	0.12	0.12
175[a]	0.27	0.25	0.21	0.20	0.21	0.20
170	0.58	0.55	0.374	0.362	0.372	0.36
166[b]	1.03	0.79	0.59	0.57	0.59	0.57
160[c]	2.37	2.09	1.33	1.28	1.35	1.30
150	6.20	5.50	4.23	3.90	4.48	4.26
140	20.2	16.2	13.5	12.5	11.0	10.0
130	98.1	83.0	44.5	39.7	31.3	27.1
120	>100	/	90.6	80.7	61.0	51.5

[a] Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000).
[b] Threshold for turtle behavioural response to impulsive noise (McCauley et al. 2000).
[c] Marine mammal behavioural threshold for impulsive sound sources (NOAA 2019).
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).
A slash indicates that $R_{95\%}$ is not reported when the R_{max} was greater than the maximum modelling extent.

Table 34. *VSP, PTS, and TTS PK thresholds*: Maximum (R_{max}) horizontal distances (m) from the 750 in^3 Vertical Seismic Profiling (VSP) array to modelled maximum-over-depth peak pressure level (PK) PTS and TTS thresholds for marine mammals (Southall et al. 2019), fish (Popper et al. 2014), and sea turtles (Finneran et al. 2017).

Hearing group		PK threshold (L_{pk}; dB re 1 µPa)	Site A	Site B	Site C
			Distance R_{max} (km)	Distance R_{max} (km)	Distance R_{max} (km)
LF cetaceans	PTS	219	–	–	–
	TTS	213	–	–	–
HF cetaceans	PTS	230	–	–	–
	TTS	224	–	–	–
VHF cetaceans	PTS	202	0.06	0.06	0.06
	TTS	196	0.13	0.13	0.13
Sea turtles	PTS	232	–	–	–
	TTS	226	–	–	–
Fish: No swim bladder (also applied to sharks)		213	–	–	–
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae		207	–	–	–

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 35. *VSP, seafloor PK*: Maximum (R_{max}) horizontal distances (in m) from the 750 in^3 Vertical Seismic Profiling (VSP) array to modelled seafloor peak pressure level thresholds (Popper et al. 2014) (PK).

Hearing group/animal type	PK threshold (L_{pk}; dB re 1 µPa)	Site A	Site B	Site C
		Distance R_{max} (m)	Distance R_{max} (m)	Distance R_{max} (m)
Fish: No swim bladder (also applied to sharks)	213	*	*	*
Fish: Swim bladder not involved in hearing; Swim bladder involved in hearing Sea turtles, fish eggs, and larvae	207	*	*	*

An asterisk indicates that the sound level was not reached.

Table 36. Maximum (R_{max}) horizontal distances (in m) from the 750 in^3 Vertical Seismic Profiling (VSP) array to modelled seafloor peak-peak pressure levels (PK-PK).

PK-PK ($L_{pk\text{-}pk}$; dB re 1 µPa)	Site A	Site B	Site C
	Distance R_{max} (m)	Distance R_{max} (m)	Distance R_{max} (m)
213[a,b,c]	*	*	*
212[b,c]	*	*	*
210[a,b]	*	*	*
209[a,b]	*	*	*
202[d]	60.8	*	*

[a] Day et al. (2019), lobster
[b] Day et al. (2016a), lobster and scallops
[c] Day et al. (2017), scallops.
[d] Payne et al. (2008), lobster
An asterisk indicates that the sound level was not reached.

4.4.3. Multiple Pulse Sound Fields

This section presents the sound fields in terms of SEL accumulated over 24 h of activity, for the modelled scenarios (Table 10). A set of nine aggregate exposure (SEL_{24h}) scenarios were modelled at each VSP location with 5, 10, 25, 50, 100, 200, 250 and 300 shots over 24 hours to realistically represent a range of potential operations Frequency-weighted SEL_{24h} sound fields were used to estimate the maximum and 95% distances (R_{max} and $R_{95\%}$; calculated as detailed in B.3) to marine mammals and turtle PTS and TTS thresholds (listed in Table 37), and to estimate maximum distance and the area to injury and TTS guidelines for fish (Table 14). (Southall et al. 2019)

Table 37. *VSP, multiple-pulse SEL, Site A*: Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based PTS and TTS thresholds for marine mammals (Southall et al. 2019) and sea turtles (Finneran et al. 2017) from Vertical Seismic Profiling (VSP) operations, assuming different numbers of impulses during a 24 h period.

Hearing group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
PTS										
LF cetaceans	183	0.03	0.05	0.07	0.11	0.15	0.19	0.23	0.45	0.48
HF cetaceans	185	–	–	–	–	–	–	–	–	–
VHF cetaceans	155	–	–	–	–	–	–	–	–	0.02
Sea turtles	204	–	–	–	–	0.02	0.03	0.03	0.03	0.03
TTS										
LF cetaceans	168	0.20	0.49	0.67	1.03	1.68	2.13	2.62	2.91	3.20
HF cetaceans	170	–	–	–	–	–	–	–	–	–
VHF cetaceans	140	–	0.02	0.03	0.05	0.07	0.09	0.10	0.12	0.13
Sea turtles	189	0.03	0.03	0.06	0.09	0.12	0.16	0.18	0.21	0.24

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 38. *VSP, multiple-pulse SEL, Site B*: Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based PTS and TTS thresholds for marine mammals Southall et al. (2019) and sea turtles (Finneran et al. 2017) from Vertical Seismic Profiling (VSP) operations, assuming different numbers of impulses during a 24 h period.

Hearing group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
PTS										
LF cetaceans	183	0.03	0.05	0.07	0.10	0.15	0.18	0.21	0.23	0.26
HF cetaceans	185	–	–	–	–	–	–	–	–	–
VHF cetaceans	155	–	–	–	–	–	–	–	–	0.02
Sea turtles	204	–	–	–	–	0.02	0.03	0.03	0.03	0.03
TTS										
LF cetaceans	168	0.19	0.27	0.42	0.60	0.84	1.02	1.20	1.46	1.68
HF cetaceans	170	–	–	–	–	–	–	–	–	–
VHF cetaceans	140	–	0.02	0.03	0.05	0.07	0.09	0.10	0.12	0.13
Sea turtles	189	0.03	0.03	0.06	0.09	0.12	0.15	0.17	0.19	0.21

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 39. *VSP, multiple-pulse SEL, Site C*: Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based PTS and TTS thresholds for marine mammals (Southall et al. 2019) and sea turtles (Finneran et al. 2017) from Vertical Seismic Profiling (VSP) operations, assuming different numbers of impulses during a 24 h period.

Hearing group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
PTS										
LF cetaceans	183	0.03	0.05	0.07	0.10	0.15	0.18	0.21	0.23	0.26
HF cetaceans	185	–	–	–	–	–	–	–	–	–
VHF cetaceans	155	–	–	–	–	–	–	–	–	0.02
Sea turtles	204	–	–	–	–	0.02	0.03	0.03	0.03	0.03
TTS										
LF cetaceans	168	0.19	0.27	0.42	0.59	0.83	1.03	1.19	1.34	1.47
HF cetaceans	170	–	–	–	–	–	–	–	–	–
VHF cetaceans	140	–	0.02	0.03	0.05	0.07	0.09	0.10	0.12	0.13
Sea turtles	189	0.03	0.03	0.06	0.09	0.12	0.15	0.17	0.19	0.21

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 40. *VSP, multiple-pulse SEL, Site A:* Maximum-over-depth distances to SEL_{24h} based fish criteria (Popper et al. 2014) from VSP operations, assuming different numbers of impulses during a 24 h period.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
Mortality and potential mortal injury										
I	219	–	–	–	–	–	–	–	–	–
II, fish eggs and fish larvae	210	–	–	–	–	–	–	–	0.02	0.02
III	207	–	–	–	–	–	0.02	0.03	0.03	0.03
Fish recoverable injury										
I	216	–	–	–	–	–	–	–	–	–
II, III	203	–	–	–	0.02	0.03	0.03	0.04	0.05	0.05
Fish TTS										
I, II, III	186	0.05	0.06	0.11	0.16	0.27	0.43	0.50	0.54	0.57

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 41. *VSP, multiple-pulse SEL, Site B:* Maximum-over-depth distances to SEL_{24h} based fish criteria (Popper et al. 2014) from VSP operations, assuming different numbers of impulses during a 24 h period.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
Mortality and potential mortal injury										
I	219	–	–	–	–	–	–	–	–	–
II, fish eggs and fish larvae	210	–	–	–	–	–	–	–	0.02	0.02
III	207	–	–	–	–	–	0.02	0.03	0.03	0.03
Fish recoverable injury										
I	216	–	–	–	–	–	–	–	–	–
II, III	203	–	–	–	0.02	0.03	0.03	0.04	0.05	0.05
Fish TTS										
I, II, III	186	0.05	0.06	0.10	0.15	0.22	0.27	0.31	0.34	0.37

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 42. *VSP, multiple-pulse SEL, Site C:* Maximum-over-depth distances to SEL_{24h} based fish criteria (Popper et al. 2014) from VSP operations, assuming different numbers of impulses during a 24 h period.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Distance R_{max} (km)								
		Number of impulses								
		5	10	25	50	100	150	200	250	300
Mortality and potential mortal injury										
I	219	–	–	–	–	–	–	–	–	–
II, fish eggs and fish larvae	210	–	–	–	–	–	–	–	0.02	0.02
III	207	–	–	–	–	–	0.02	0.03	0.03	0.03
Fish recoverable injury										
I	216	–	–	–	–	–	–	–	–	–
II, III	203	–	–	–	0.02	0.03	0.03	0.04	0.05	0.05
Fish TTS										
I, II, III	186	0.05	0.06	0.10	0.15	0.22	0.27	0.31	0.34	0.37

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

4.4.4. Sound Field Maps

Maps of the estimated sound fields, threshold contours, and isopleths of interest for the VSP operations are presented for Sites A-C. The per-pulse SPL sound fields are presented as contour maps in Figures 100–102. The SEL_{24h} sound fields are presented as contour maps in Figures 103–105 for 300 impulses per day. This figure presents the unweighted SEL_{24h} in 10 dB steps, as well as the isopleths corresponding to thresholds or guidelines for which R_{max} is greater than 20 m, the modelling resolution.

4.4.4.1. Maximum-over-depth Per-Pulse Sound Fields

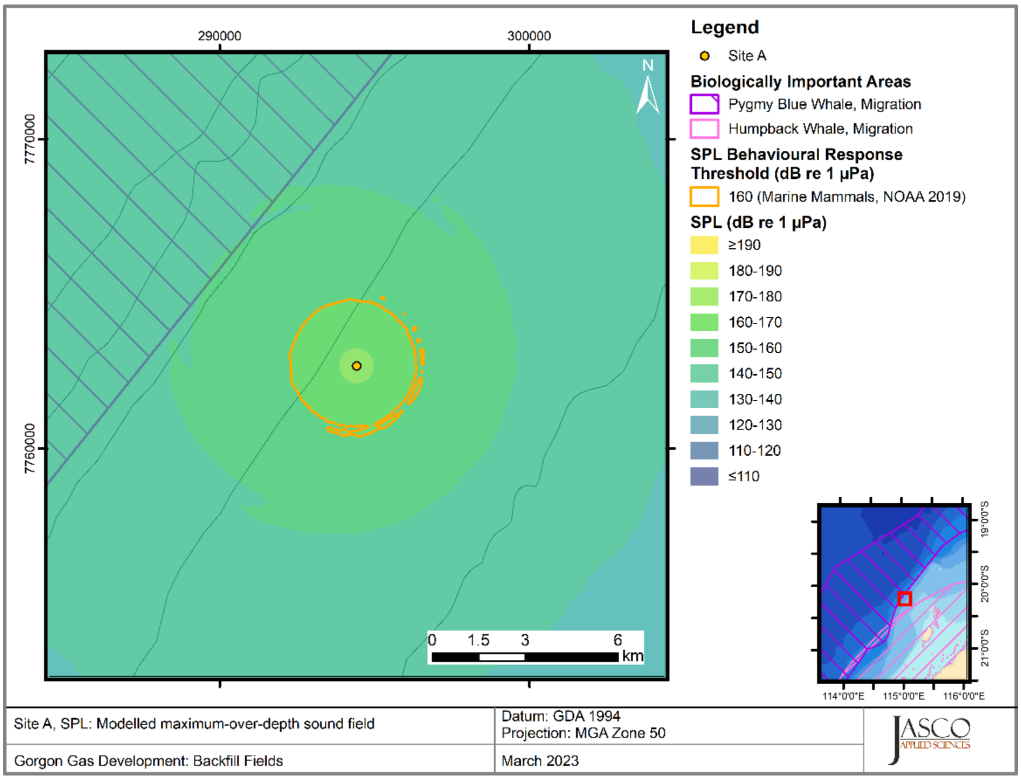

Figure 100. *VSP, Site A, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth of behavioural response thresholds for marine mammals and turtles.

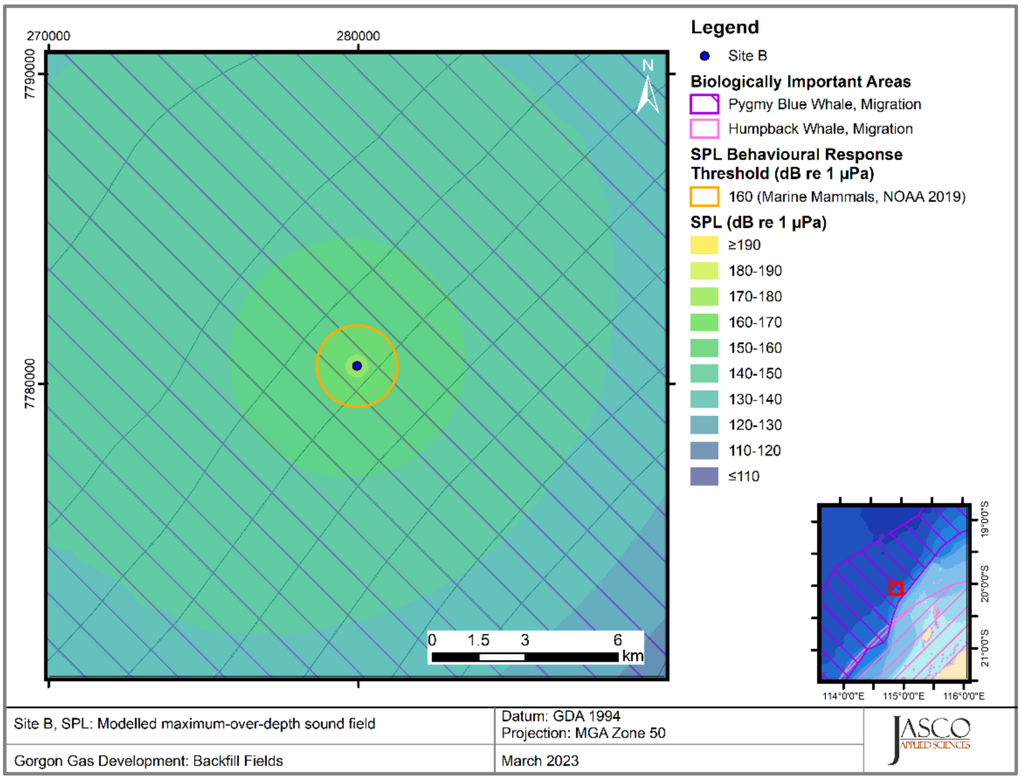

Figure 101. *VSP, Site B, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth of behavioural response thresholds for marine mammals and turtles.

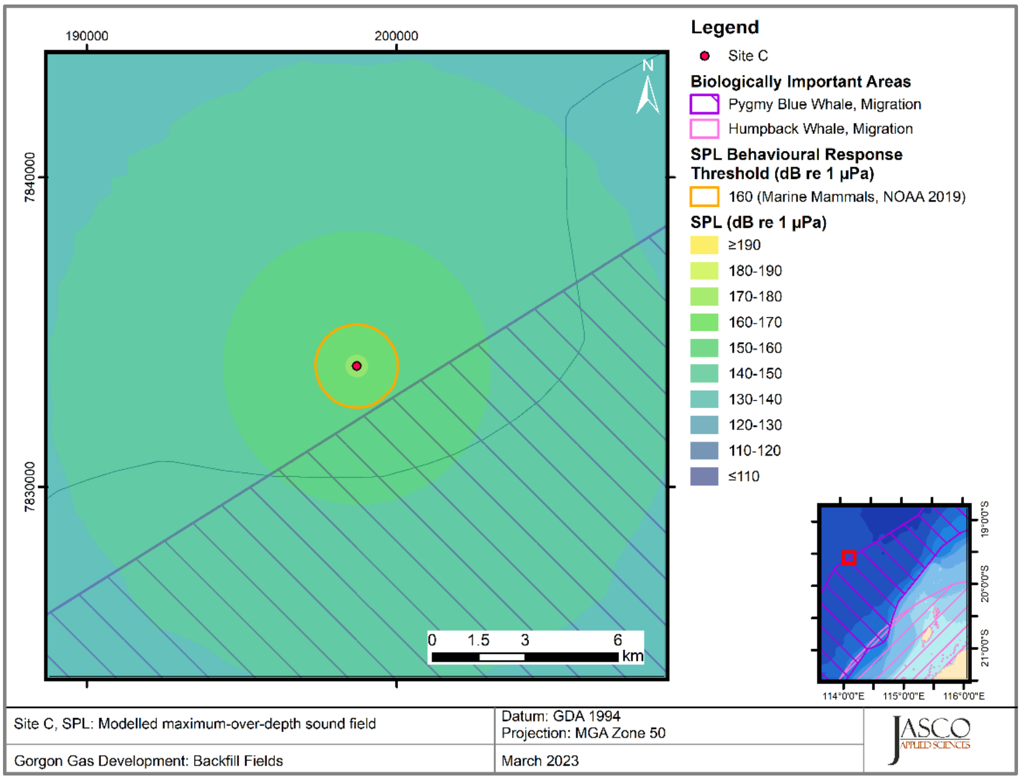

Figure 102. *VSP, Site C, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleth of behavioural response thresholds for marine mammals and turtles.

4.4.4.2. Accumulated Multi-Pulse Sound Fields

Thresholds for permanent threshold shift (PTS) and some thresholds for TTS were either not reached or were small enough such that they could not be displayed on a map. Refer to the radii tables in Section 4.4.3 for distances.

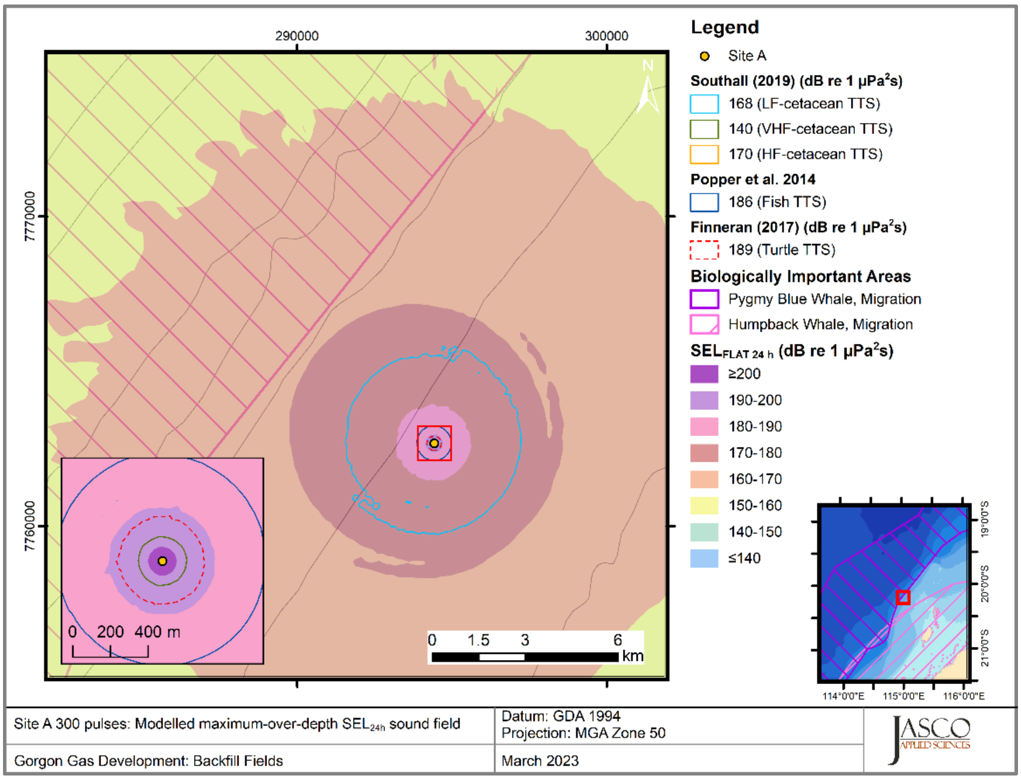

Figure 103. *VSP, Site A, multiple-pulse SEL, 300 impulses*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for temporary threshold shift (TTS) thresholds.

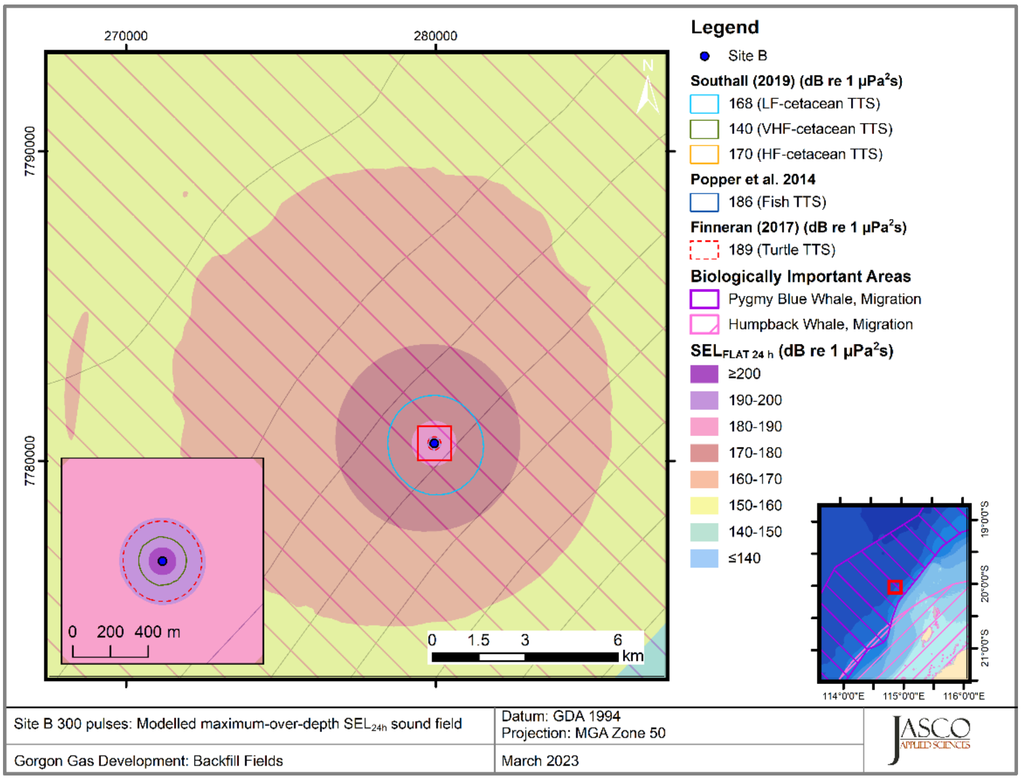

Figure 104. *VSP, Site B, multiple-pulse SEL, 300 impulses*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for temporary threshold shift (TTS) thresholds.

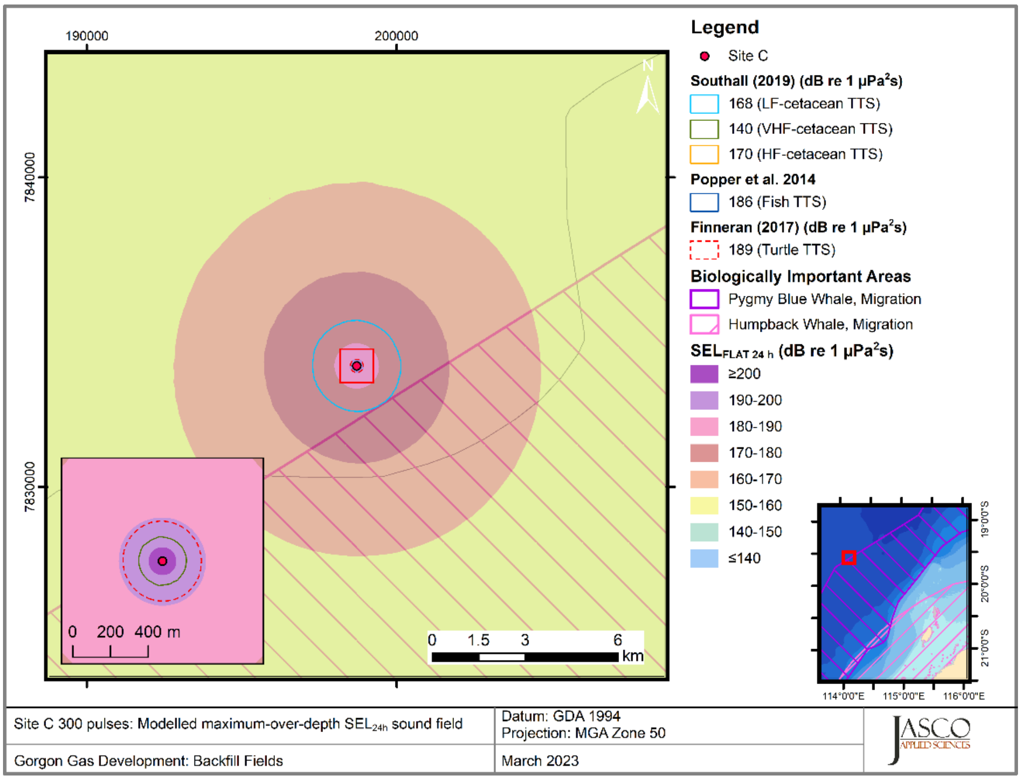

Figure 105. *VSP, Site C, multiple-pulse SEL, 300 impulses*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for temporary threshold shift (TTS) thresholds.

4.5. Animal Movement Exposure Ranges

Table 45 shows results for scenarios with unrestricted animat seeding. Results include $ER_{95\%}$ exposure ranges calculated for the 120 dB behavioural response threshold and SEL_{24h} thresholds for both TTS and PTS, and the probability of an animat being exposed above the threshold within the $ER_{95\%}$.

Section 4.5.1 includes histograms of CPA ranges to SEL_{24h} TTS, and the behavioural response threshold for pygmy blue whales with BIA-restricted and unrestricted animat seeding where exposures above threshold occurred. Note that no pygmy blue whale animats were exposed above threshold for PTS for any of the scenarios. Additionally, no pygmy blue whale animats were exposed above threshold for TTS for Scenarios 8, 30, 33 and 40 with BIA-restricted animat seeding. Due to the lack of exposures in these scenarios, no histograms of CPA ranges are presented for these cases.

Table 43. Summary of animat simulation results for north-bound migrating pygmy blue whales with animats restricted to the BIA. The 95th percentile exposures ranges ($ER_{95\%}$) in km and probability of animats being exposed above threshold within the $ER_{95\%}$ (P_{exp} (%)) are provided. Dashes indicate no animats were exposed above threshold.

Noise Effect Criteria Description	Pygmy blue whale, north-bound migration, restricted											
	Scenario 8		Scenario 14		Scenario 18		Scenario 21		Scenario 30		Scenario 33	
	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)
PTS (SEL_{24h})[1]	–	–	–	–	–	–	–	–	–	–	–	–
TTS (SEL_{24h})[2]	–	–	0.02	87	0.02	53	0.02	85	–	–	–	–
Behavioural response (SPL)[3]	12.3	99	0.70	89	3.02	73	4.99	73	8.02	>99	9.34	>99

[1] LF-weighted SEL_{24h} (199 dB re 1 µPa²·s) (Southall et al.)
[2] LF-weighted SEL_{24h} (179 dB re 1 µPa²·s) (Southall et al.)
[3] SPL (120 dB re 1 µPa) (NOAA (2019)

Table 44. Summary of animat simulation results for combined scenarios for north-bound migrating pygmy blue whales with animats restricted to the BIA. The 95th percentile exposures ranges ($ER_{95\%}$) in km and probability of animats being exposed above threshold within the $ER_{95\%}$ (P_{exp} (%)) are provided. Dashes indicate no animats were exposed above threshold.

Noise Effect Criteria Description	Pygmy blue whale, north-bound migration, restricted					
	Scenario 38		Scenario 39		Scenario 40	
	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)
PTS (SEL_{24h})[1]	–	–	–	–	–	–
TTS (SEL_{24h})[2]	0.02	77	0.02	53	–	–
Behavioural response (SPL)[3]	12.1	40	9.16	60	8.89	>99

[1] LF-weighted SEL_{24h} (199 dB re 1 µPa²·s) (Southall et al.)
[2] LF-weighted SEL_{24h} (179 dB re 1 µPa²·s) (Southall et al.)
[3] SPL (120 dB re 1 µPa) (NOAA (2019)

Table 45. Summary of animat simulation results for north-bound migrating pygmy blue whales with animats not restricted to the BIA. The 95th percentile exposures ranges ($ER_{95\%}$) in km and probability of animats being exposed above threshold within the $ER_{95\%}$ (P_{exp} (%)) are provided. Dashes indicate no animats were exposed above threshold.

Noise Effect Criteria Description	Pygmy blue whale, north-bound migration, unrestricted											
	Scenario 8		Scenario 14		Scenario 18		Scenario 21		Scenario 30		Scenario 33	
	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)
PTS (SEL_{24h})[1]	–	–	–	–	–	–	–	–	–	–	–	–
TTS (SEL_{24h})[2]	0.04	67	0.02	87	0.02	76	0.02	91	0.02	80	0.02	77
Behavioural response (SPL)[3]	12.4	99	0.73	88	2.76	77	5.03	73	8.03	>99	9.56	>99

1 LF-weighted SEL_{24h} (199 dB re 1 µPa²·s) (Southall et al.)
2 LF-weighted SEL_{24h} (179 dB re 1 µPa²·s) (Southall et al.)
3 SPL (120 dB re 1 µPa) (NOAA (2019)

Table 46. Summary of animat simulation results for combined scenarios for north-bound migrating pygmy blue whales with animats not restricted to the BIA. The 95th percentile exposures ranges ($ER_{95\%}$) in km and probability of animats being exposed above threshold within the $ER_{95\%}$ (P_{exp} (%)) are provided. Dashes indicate no animats were exposed above threshold.

Noise Effect Criteria Description	Pygmy blue whale, north-bound migration, unrestricted					
	Scenario 38		Scenario 39		Scenario 40	
	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)	$ER_{95\%}$ (km)	P_{exp} (%)
PTS (SEL_{24h})[1]	–	–	–	–	–	–
TTS (SEL_{24h})[2]	0.03	61	0.02	77	0.02	79
Behavioural response (SPL)[3]	12.3	50	9.47	63	9.55	98

1 LF-weighted SEL_{24h} (199 dB re 1 µPa²·s) (Southall et al.)
2 LF-weighted SEL_{24h} (179 dB re 1 µPa²·s) (Southall et al.)
3 SPL (120 dB re 1 µPa) (NOAA (2019)

4.5.1. Exposure Range Histograms

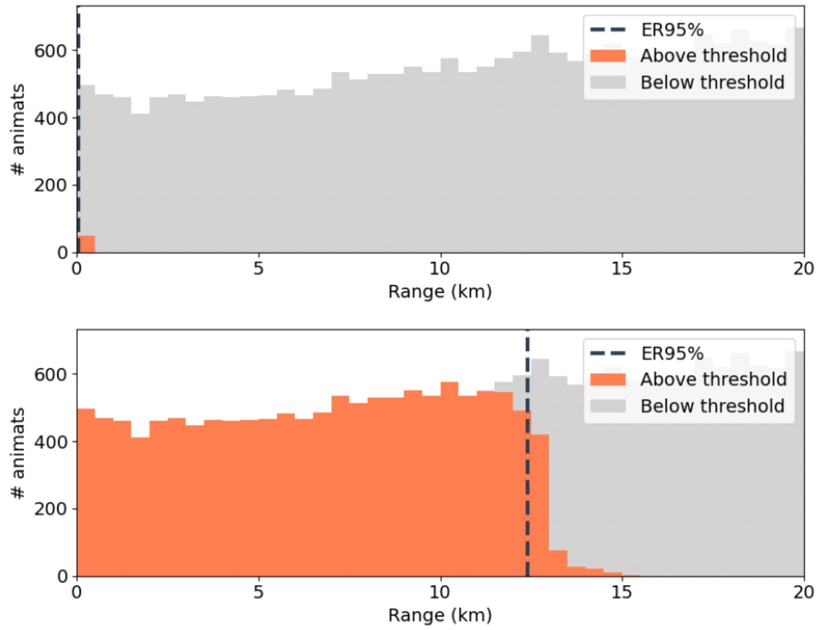

Figure 106. *Scenario 8, pygmy blue whale, north-bound migrating animats, unrestricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

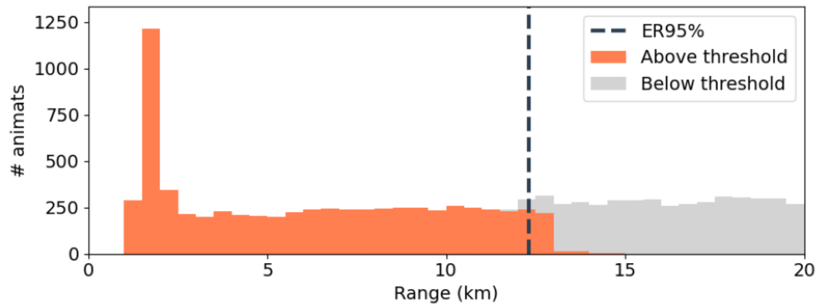

Figure 107. *Scenario 8, pygmy blue whale, north-bound migrating animats, restricted seeding:* CPA range histogram for animats, SPL behavioural threshold. Bar colours indicate whether the animats exceeded the threshold. Please refer to Section 5.3.1 for further details.

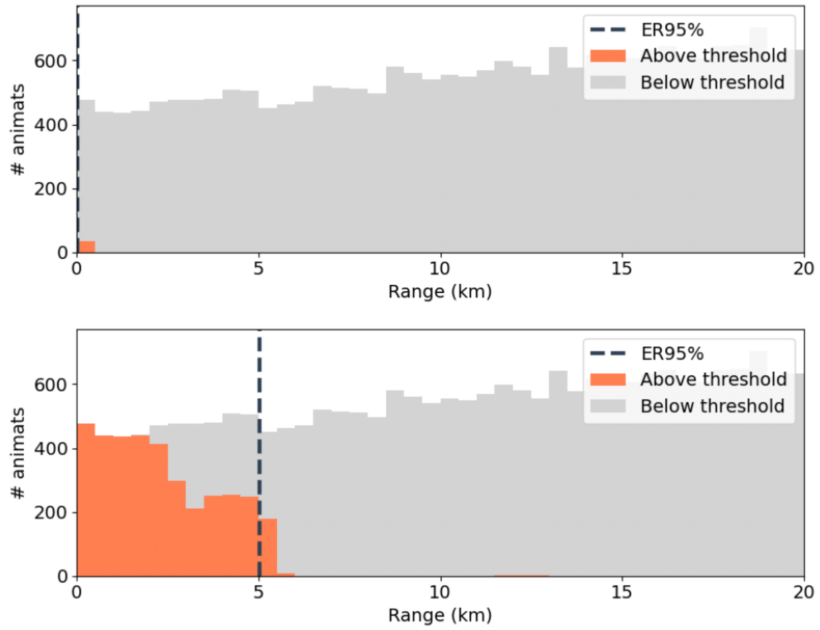

Figure 108. *Scenario 21, pygmy blue whale, north-bound migrating animats, unrestricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

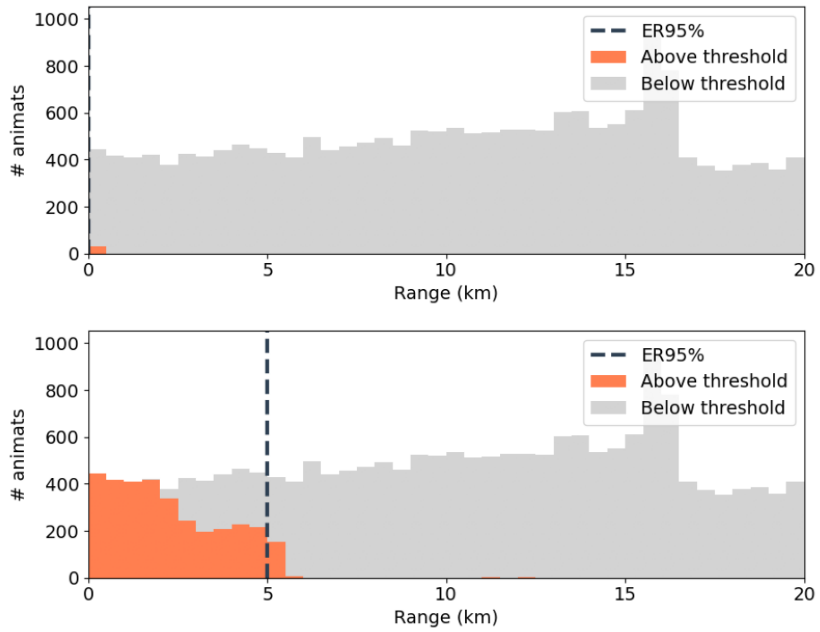

Figure 109. *Scenario 21, pygmy blue whale, north-bound migrating animats, restricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold. Please refer to Section 5.3.1 for further details.

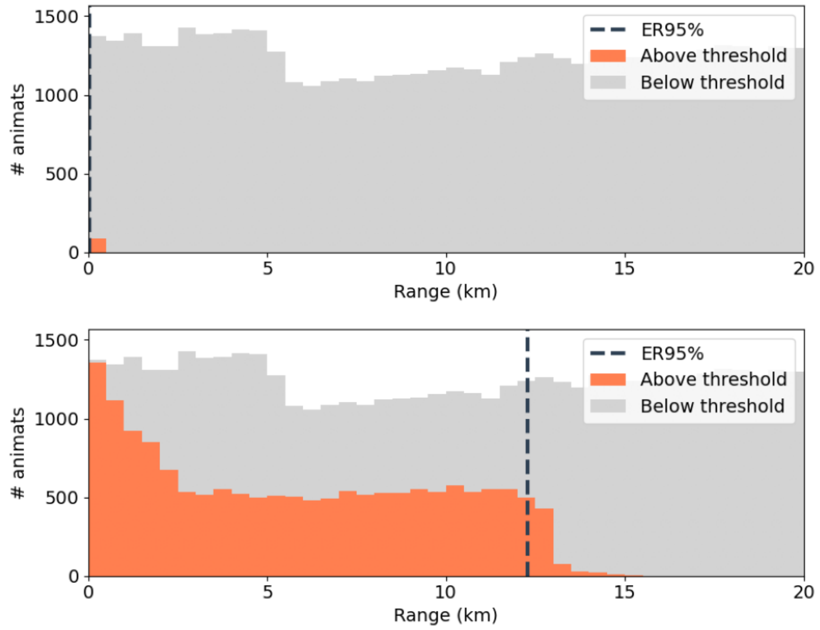

Figure 110. *Scenario 38, pygmy blue whale, north-bound migrating animats, unrestricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

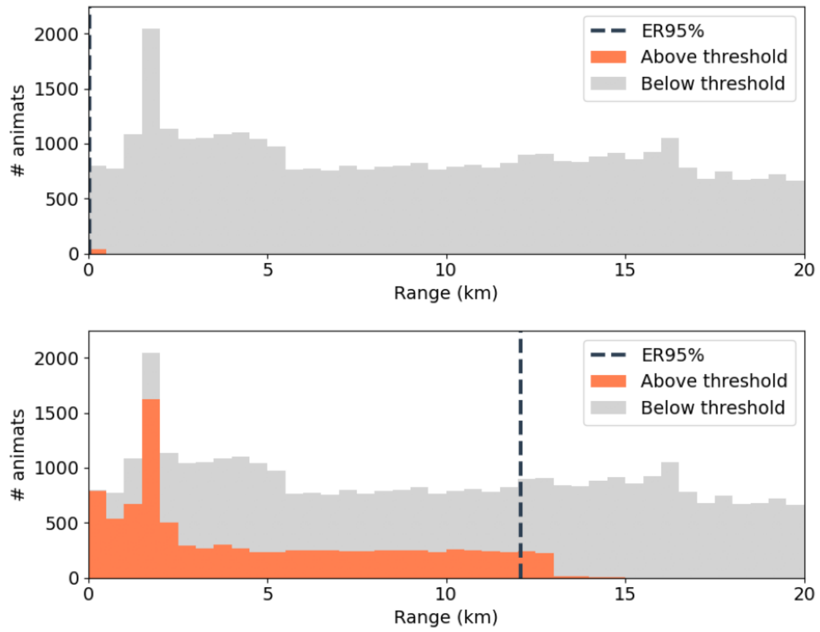

Figure 111. *Scenario 38, pygmy blue whale, north-bound migrating animats, restricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold. Please refer to Section 5.3.1 for further details.

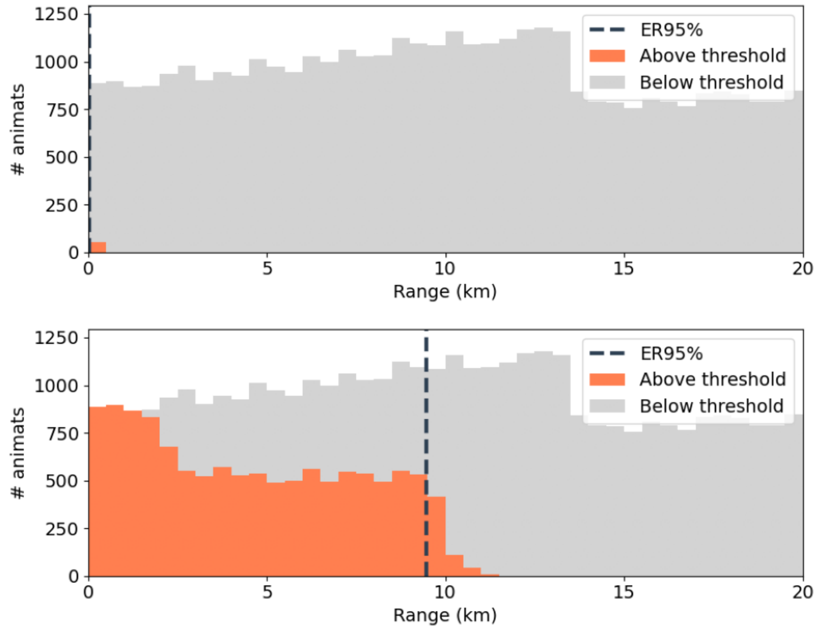

Figure 112. *Scenario 39, pygmy blue whale, north-bound migrating animats, unrestricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

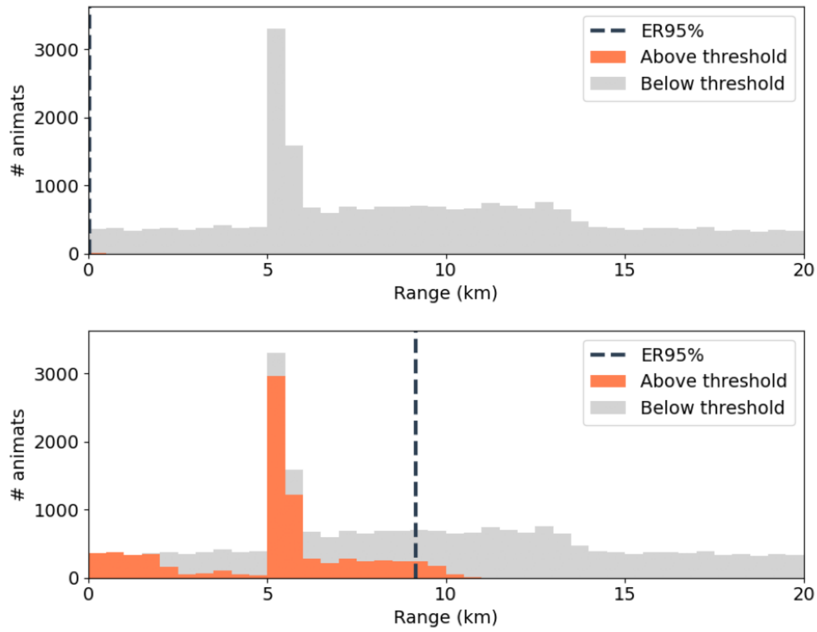

Figure 113. *Scenario 39, pygmy blue whale, north-bound migrating animats, restricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold. Please refer to Section 5.3.1 for further details.

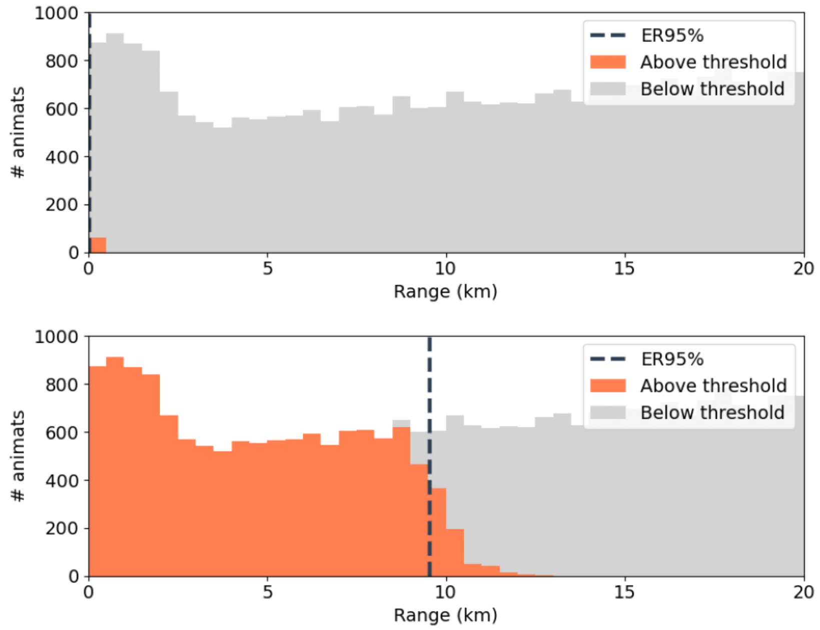

Figure 114. *Scenario 40, pygmy blue whale, north-bound migrating animats, unrestricted seeding:* CPA range histogram for animats, SEL_{24h} TTS threshold (top panel) and SPL behavioural threshold (bottom panel). Bar colours indicate whether the animats exceeded the threshold.

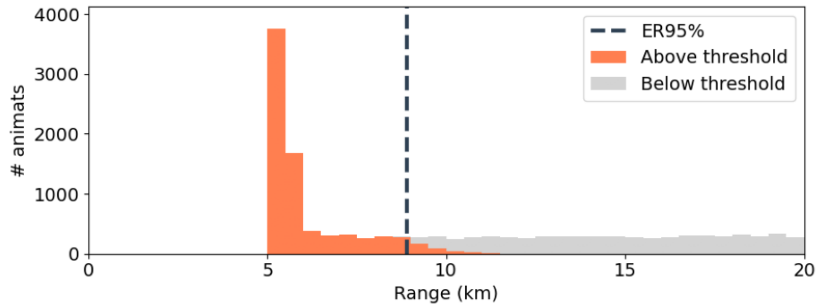

Figure 115. *Scenario 40, pygmy blue whale, north-bound migrating animats, restricted seeding:* CPA range histogram for animats, SPL behavioural threshold. Bar colours indicate whether the animats exceeded the threshold. Please refer to Section 5.3.1 for further details.

5. Discussion and Conclusion

This modelling study predicted underwater sound levels associated with the construction of the Chevron Gorgon Gas Development: Backfill Fields. The modelled sound-emitting activities were vessel activities and vertical seismic profiling (VSP). The modelling study considered 36 individual vessel activity scenarios (Scenarios 1–36) across five Areas, four combined scenarios incorporating multiple individual vessel scenarios (Scenarios 37–40), and three VSP scenarios (Scenarios A, B, and C). Maximum, 95th percentile ranges (R_{max} and $R_{95\%}$) and ensonified area were computed to PTS, TTS, and behavioural response thresholds. The animal movement and exposure analysis combined species-typical movements for migrating pygmy blue whales with modelled sound fields to estimate both exposure range ($ER_{95\%}$) along with the probability of exposure within the calculated exposure ranges for five vessel activity scenarios.

5.1. Acoustic Modelling – Vessel Scenarios

Table 47 summarises the maximum horizontal distances to behavioural (unweighted SPL) and physiological effects (LF cetacean weighted TTS and PTS) thresholds across all 36 modelled individual vessel activity scenarios. LF cetaceans are summarised due to the proximity of the pygmy blue whale BIA; maximum horizontal distances to physiological effects thresholds for other hearing groups (HF and VHF cetaceans and turtles) are included in Section 4.1.

Table 47. Summary of maximum (R_{max}) horizontal distances (in km) from all scenarios considered to the marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) and frequency-weighted LF-cetacean SEL_{24h} TTS and PTS thresholds (179 and 199 dB re 1 µPa²·s, respectively) based on Southall et al. (2019).

Scenario Number	Description	Marine Mammal Behavioural Response [a]	LF-cetacean TTS [b]	LF-cetacean PTS [c]
		R_{max} (km)	R_{max} (km)	R_{max} (km)
1	Area 1, Drillship	5.62	0.78	0.08
2	Area 1, Drillship with OSV	5.87	0.83	0.10
3	Area 1, Pipelay vessel	6.30	0.84	0.05
4	Area 1, Pipelay vessel with resupply OSV	6.56	0.99	0.10
5	Area 1, Pipelay vessel with resupply and support OSVs	6.72	1.07	0.12
6	Area 1, IMR vessel	1.99	0.36	0.04
7	Area 1, OCV	15.5	1.71	0.18
8	Area 1, OCV with 3 support vessels	15.7	1.82	0.21
9	Area 2, Drillship	5.60	0.78	0.07
10	Area 2, Drillship with OSV	5.85	0.84	0.11
11	Area 2, Pipelay vessel	6.42	0.85	0.06
12	Area 2, Pipelay vessel with resupply OSV	6.70	0.99	0.09
13	Area 2, Pipelay vessel with resupply and support OSVs	6.88	1.08	0.12
14	Area 2, IMR vessel	1.74	0.36	0.04
15	Area 2, OCV	15.1	1.70	0.19
16	Area 2, OCV with 3 support vessels	15.4	1.81	0.21
17	Area 3, Drillship	5.30	0.78	0.08
18	Area 3, Drillship with OSV	12.1	0.84	0.11
19	Area 3, Pipelay vessel	5.78	0.84	0.05
20	Area 3, Pipelay vessel with resupply OSV	12.8	0.99	0.09
21	Area 3, Pipelay vessel with resupply and support OSVs	13.0	1.08	0.12
22	Area 3, IMR vessel	2.64	0.36	0.04
23	Area 3, OCV	14.0	1.96	0.19
24	Area 3, OCV with 3 support vessels	14.0	2.10	0.21
25	Area 4, Pipelay vessel	7.87	0.88	0.05
26	Area 4, Pipelay vessel with resupply OSV	9.72	1.20	0.10
27	Area 4, Pipelay vessel with resupply and support OSVs	18.3	1.47	0.12
28	Area 4, IMR vessel	2.24	0.37	0.04
29	Area 5, Drillship	10.0	1.56	0.08
30	Area 5, Drillship with OSV	10.4	1.66	0.11
31	Area 5, Pipelay vessel	12.2	1.69	0.06
32	Area 5, Pipelay vessel with resupply OSV	12.8	1.99	0.10
33	Area 5, Pipelay vessel with resupply and support OSVs	12.9	2.18	0.12
34	Area 5, IMR vessel	3.76	0.63	0.04
35	Area 5, OCV	17.0	4.39	0.19
36	Area 5, OCV with 3 support vessels	17.3	4.58	0.21

Noise exposure criteria: [a] NOAA (2019) and [b] Southall et al. (2019).
A dash indicates the level was not reached within the limits of the modelled resolution (20 m)

The smallest horizontal distances to effect thresholds were associated with scenarios that modelled a single IMR vessel; the largest behavioural response zone for the IMR vessel was 3.76 km and the largest low-frequency (LF) cetacean TTS zone was 0.63 km (both in Area 5) (Table 47).

For the results tables presented in Section 4.1, where a dash is used in place of a horizontal distance, these thresholds may or may not be reached. Due to the discretely sampled 20 m calculation grids of the modelled sound fields, distances to these levels could not be estimated for practicable computational purposes. It is likely that SPL isopleths could be reached at distances between the source and the modelled horizontal resolution (20 m); however, distances to injurious accumulated SEL thresholds may not be reached at any range due the species-specific frequency weighing functions. Additionally, if close-to-source radii are comparable to the dimensions of the modelled vessel then they may only be reached within close proximity to a vessel, if at all.

The modelled individual vessel activity scenarios aimed to demonstrate the iterative effect of adding additional support vessels to each vessel activity (i.e. drilling, pipelaying and construction). In every modelled Area, and for each activity, additional support vessels generated larger distances to effect thresholds (Table 47).

In Areas 1, 2, 3 and 5, the OCV with construction support vessels resulted in the longest distances to effect thresholds (Table 1). The 120 dB SPL marine mammal behavioural effect zone from construction activities with support vessels featured a radius of 15.7 km in Area 1, 15.4 km in Area 2, 14 km in Area 3, and 17.3km in Area 5. Construction activities were not modelled in Area 4, and in this Area the pipelay vessel with two support vessels resulted in the longest distances to effect thresholds (120 dB marine mammal behavioural effect radii of 18.3 km).

It should be noted that in Scenarios 18, 20, 21 and 27 (drilling and pipelay in Areas 3 and 4), successive reflections between the seabed and the sea-surface result in convergence zones, which when combined with a high vessel source level, is evident as ‘sound islands’ for low level isopleths like the marine mammal behavioural threshold of 120 dB re 1 µPa (SPL) for non-impulsive sound sources. These are apparent in Figures 36, 38, 39, and 45. Modelled sites that resulted in sound ‘islands’ can be distinguished in Tables 19 and 20 by comparing the R_{max} effect distance with the $R_{95\%}$ effect distance, with the latter being notably smaller.

Furthermore, the successive reflections resulting from the underwater propagation environment caused some SEL_{24h} thresholds to be exceeded more than once. The very-high frequency (VHF) cetacean TTS threshold (153 dB, weighted) was exceeded more than once in Scenarios 1, 2, 9, 10, 17, 18, 20, 27, 29 and 30 (Figures 59, 60, 67, 68, 75, 76, 78, 85, 87, and 88), and the LF cetacean TTS threshold was exceeded more than once in Scenarios 31 and 32 (Figures 89 and 90). The reported effect radii for these scenarios relate to the longest exceedance distance.

Offshore activities over deep water in Areas 1 and 2 generally featured smaller effect zones than equivalent activities in Areas 3, 4 and 5 where the continental shelf environment was more conducive to effective sound propagation. For sources located above the continental slope, significant amounts of energy can be reflected from the seabed in such a way that this energy can propagate downslope and be trapped in the deep sound channel where it can propagate for larger distances (for example, see Figure 98). Effect zones in Areas 3 and 4 clearly demonstrated more favourable propagation conditions in an offshore direction, with less acoustic energy propagating onto the continental shelf (refer to Figures 39 and 45).

In addition to the 36 individual modelled scenarios, four combined scenarios were also modelled, which incorporated concurrent combinations of individual vessel activity scenarios across the five Areas. Table 48 summarises the percentage change in area ensonified above threshold levels between the corresponding individual vessel activity scenarios and the combined scenarios where the individual vessel activities occur concurrently.

Table 48. Summary of percentage change in ensonified area between corresponding individual scenarios and combined scenarios based on the marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) and frequency-weighted LF-cetacean SEL_{24h} TTS thresholds based on Southall et al. (2019).

Scenario number	Description	Marine Mammal behavioural response [a]	LF-cetacean TTS [b]	LF-cetacean PTS [c]
		Percentage change in ensonified area (km²) from individual to combined scenarios (%)	Percentage change in ensonified area (km²) from individual to combined scenarios (%)	Percentage change in ensonified area from individual scenarios to combined (%)
37	Area 1, pipelay vessel with 2 OSVs + Area 3, drillship with OSV	+0.37	-0.18	*
38	Area 1, OCV with 3 support vessels + Area 2, IMR vessel + Area 3, drillship with OSV	+3.21	0	*
39	Area 3, drillship with OSV + Area 5, pipelay vessel with 2 OSVs	+4.04	0	*
40	Area 5, drillship with OSV + Area 5, pipelay vessel with 2 OSVs	+12.9	+2.80	*

Noise exposure criteria: [a] NOAA (2019) and [b] Southall et al. (2019).
* Percentage change associated with area difference less than the modelled resolution (0.0013 km²)

Only Scenario 40 resulted in overlapping ensonified areas such that the two behavioural effect zones of the drilling and pipelay activities combined into one larger area (with 12.9% greater ensonified area compared to the two individual scenarios. The SEL_{24h} areas for Scenario 40, and all areas for Scenarios 37, 38 and 39, did not result in merged effect zones and the percentage change in ensonified areas therefore remained low (<5%) (Figures 55, 56, and 57). The lack of change in ensonified area for Scenarios 37, 38 and 39 was primarily due to the distances between concurrent activities being larger than the sum of the effect radii of the individual activities.

The pipelaying activities modelled here were located in the centre of flowlines in order to provide a nominal location along the track. At either end of the flowlines, the pipelay vessel and its support vessels will be closer to activities being conducted at specific infrastructure, such as construction or drilling. While the modelled sound fields presented here are specific to the modelled site locations, the effect radii summarised in Section 4.1 provide some guidance to the spacing between individual scenarios that will result in overlapping, or merged, effect zones.

The sound speed profile (Appendix B.1.2) was derived from data from the U.S. Naval Oceanographic Office's Generalized Digital Environmental Model V 3.0 (GDEM; Teague et al. 1990, Carnes 2009). The profile was defined by considering the Development location and was generally consistent with an open ocean deep water profile and it was applied to all modelled sites. This type of sound speed profile is characterised by decreasing sound speed due to decreases in temperature below the sea surface, however at some water depths, sound speeds increase as density increases due to hydrostatic overburden (Jensen et al. 2011). The profile had a minimum sound speed at approximately 800–1000 m water depth, which defines the sound channel axis and is the approximate centre of the deep sound channel. For energy trapped within the deep sound channel or duct, upward travelling energy would be refracted downward and downward travelling energy would be refracted upwards. When acoustic energy becomes trapped in the deep sound channel, it propagates very large distances with little loss within the ocean interior.

5.2. Acoustic Modelling - VSP Scenarios

The VSP produces generally symmetric sound fields across all three sites, as observed in Figures 100–105. Tables 32–42 show that modelling at Site A generally resulted in the largest ranges to considered effect criteria. Site A is the shallowest site and is located above a more reflective seabed than the other considered sites, fine sand sediments compared to silty sediments. These two factors likely contributed to the larger radii at Site A compared to Sites B and C. Sites B and C have very similar distances to thresholds despite the differing seabed characteristics. Whilst the water depths at these sites do differ by about 230 m, they are both located in water approximately 1000 m deep and the radii to effects criteria are therefore likely characterised by similar propagation mechanisms.

Marine mammals:

Marine mammal injury criteria, from Southall et al. (2019), requires two metrics (PK and SEL_{24h}) to be considered for impulsive noise when assessing marine mammal PTS and TTS with the longest distance associated with either metric required to be applied. In this study, the longest horizontal distances to the low-frequency cetacean PTS and TTS thresholds were associated with the SEL_{24h} metric (0.48 km and 3.20 km, respectively), while the longest horizontal distances to the very-high-frequency cetacean PTS and TTS thresholds were associated with the PK metric (0.06 km and 0.13 km, respectively).

The maximum distance to the NOAA (2019) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) was 2.37 km, which was associated with Site A. The corresponding distances at Sites B and C were 1.33 km and 1.35 km, respectively.

Sea turtles:

For sea turtles, the maximum distance to the SEL_{24h} metrics of 204 dB re 1 µPa^{2}s for PTS and 189 dB re 1 µPa^{2}s for TTS was 0.03 km for PTS onset and 0.24 km for TTS onset for the 750 in^3 seismic source (Finneran et al. 2017). As is the case with marine mammals, a reported radius for SEL_{24h} criteria does not mean that sea turtles travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with either PTS or TTS if it remained in that location for 24 hours.

The PK sea turtle injury criteria of 232 dB re 1 µPa for PTS and 226 dB re 1 µPa for TTS from Finneran et al. (2017) was not exceeded at a distance longer than 20 m from the acoustic centre of the source.

The maximum distances to the behavioural response criteria for sea turtles of 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) threshold for behavioural disturbance were 1.03 km and 0.27 km, respectively for the 750 in^3 seismic source (McCauley et al. 2000).

Fish, fish eggs, and fish larvae:

The effects of sound exposure on fish were considered in relation to both PK and SEL_{24h} metrics associated with mortality, potential mortal injury and impairment, based on quantitative criteria from Popper et al. (2014) for the following groups:

- Fish without a swim bladder (also appropriate for sharks in the absence of other information),
- Fish with a swim bladder that do not use it for hearing,
- Fish that use their swim bladders for hearing, and
- Fish eggs and fish larvae.

Table 49 summarises the maximum distances to effect criteria for fish, fish eggs, and fish larvae along with the relevant metric across all three modelled locations. The mortality and recoverable injury distances were comparable across the three sites, but the distance to the TTS threshold was longest at Site A.

Table 49. Summary of maximum fish, fish eggs, and larvae injury and temporary threshold shift (TTS) onset distances for any modelled site, for single impulse and 24 h sound exposure level (SEL_{24h}) modelled scenarios.

Relevant hearing group	Effect criteria	Water column	
		Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Recoverable injury	–	–
	TTS	SEL_{24h}	0.57
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Recoverable injury	SEL_{24h}	0.05
	TTS	SEL_{24h}	0.57
Fish eggs, and larvae	Injury	SEL_{24h}	0.05

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Benthic invertebrates:

The maximum radius of ensonified areas where sound levels exceeded 202 dB re 1 µPa PK-PK (Payne et al. 2008) was 60.8 m from Site A; in this area crustaceans may be negatively affected by sound. This threshold was not exceeded at Sites B or C. Sound levels of 209 to 213 dB re 1 µPa PK-PK (Day et al. (2016a); Day et al (2016b)), which are related to crustacean impairment, were also considered in this study; these levels were not reached for any VSP modelling site at a depth of 5 cm above the seafloor.

5.3. Animal Movement Modelling

The estimated sound fields produced by source and propagation models for the planned construction of the Chevron Gorgon Gas Development were incorporated into an animat sound exposure model for migrating pygmy blue whales to estimate the radial distance within which 95% of the exposure exceedances occur ($ER_{95\%}$), along with the probability that an animat with the closest point of approach within that distance would be exposed above the relevant threshold (P_{exp}).

For the exposure analysis, a subset of acoustic modelling scenarios (see Table 7) were run with BIA-restricted and unrestricted animat seeding. Scenarios 8 and Scenarios 30, 33 and 40 are located approximately 1.6 and 5.5 km outside of the migratory BIA for pygmy blue whales, respectively, whereas Scenarios 14, 18 and 21 fully, and Scenarios 38 and 39 partially overlap with the BIA (Figure 8).

Sections 5.3.1 and 5.3.2 summarise the PTS, TTS and behavioural exposure range results, with Table 50 summarising the maximum exposure range results for pygmy blue whales not restricted to their corresponding BIAs.

Table 50. Summary of animat simulation results for PTS, TTS, and SPL behavioural response criteria for pygmy blue whales with unrestricted seeding Exposure ranges show $ER_{95\%}$ (km) first and probability of exposure of animats travelling within the $ER_{95\%}$ (P_{exp} (%)) in parentheses. A dash (-) indicates that no animat was exposed above the threshold.

Scenario Number	Species	Behavioural response (SPL)[4]	TTS (SEL_{24h})[3]	PTS (SEL_{24h})[3]
		120[2]	179[1]	199[1]
8	Pygmy blue whale	12.4 (99%)	0.04 (67%)	–
14		0.73 (88%)	0.02 (87%)	–
18		2.76 (77%)	0.02 (76%)	–
21		5.03 (73%)	0.02 (91%)	–
30		8.03 (>99%)	0.02 (80%)	–
33		9.56 (>99%)	0.02 (77%)	–
38		12.3 (50%)	0.03 (61%)	–
39		9.47 (63%)	0.02 (77%)	–
40		9.55 (98%)	0.02 (79%)	–

[1] LF-weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)
[2] SPL (L_p; dB re 1 µPa)
[3] Southall et al. (2019) criteria for marine fauna.
[4] NOAA (2019) recommended unweighted behavioural threshold for marine mammals.

5.3.1. Behavioural Effects

Exposure ranges for single exposure metrics, such as the SPL behavioural response criteria, are typically comparable to the predicted acoustic ranges. Acoustic ranges are conservatively calculated using the maximum-over-depth sound fields while exposure ranges account for animats sampling the sound field vertically based on species-specific diving parameters, so exposure ranges are often slightly lower than acoustic ranges.

For all considered scenarios with unrestricted animat seeding, the $ER_{95\%}$ to behavioural threshold ranged from 0.73–12.4 km for pygmy blue whales, with P_{exp} varying between 50 and >99%. Overall, ranges were longest for Scenarios 8 and 38.

The different site locations within the scenarios and their impact on exposure ranges are also visible in the histograms showing the CPA ranges to the behavioural response threshold for BIA-restricted pygmy blue whale animats (see Section 4.5.1).

Scenario 21 is located within the migratory BIA for pygmy blue whales and therefore, shows no significant difference between the BIA-restricted and the unrestricted animat seeding simulations (see Figures 108 and 109).
Scenario 39 includes Sites 21 and 22, which are both located within the migratory BIA for pygmy blue whales, and Sites 37 to 39, which are located approximately 5.5 km outside of the BIA. Figure 111 shows CPA ranges to the behavioural response threshold with a high frequency of exposure ranges within the 5 – 6 km bins, which is the closest any animats can come to Sites 37 to 39 of Scenario 39. Any exposure ranges below that are associated with exposures to Sites 21 and 22 as these ones are located within the BIA.
A similar argument can be applied to the CPA ranges for BIA-restricted animats for Scenario 38 (Figure 111).Furthermore, the closest distance between the modelled sites from Scenario 8, Sites 7 to 10, and the BIA is approximately 1.6 km, which explains why minimum CPA ranges for BIA-restricted animats are within the 1.5 to 2 km bin (see Figure 107). A similar argument applies to the CPA ranges for BIA-restricted animats for Scenario 40 (see Figure 115), where the BIA is located approximately 5.5 km from the associated modelled sites.

Due to the main lobe of acoustic energy extending to larger ranges as depth increases, the animat determined exposure ranges were slightly lower than the static acoustic ranges for all considered scenarios, as expected based on the vertical distribution of the sound field. Migrating pygmy blue whales are expected to spend most of their time in a behavioural mode where most dives reach less than 60 m in depth. Figure 116 shows a vertical slice beginning at the source location and extending towards deeper water at an azimuth of 315°. This plot shows how migrating pygmy blue whales sample the upper portion of the water column, which is quieter, and results in exposure ranges that are shorter than acoustic ranges at this location.

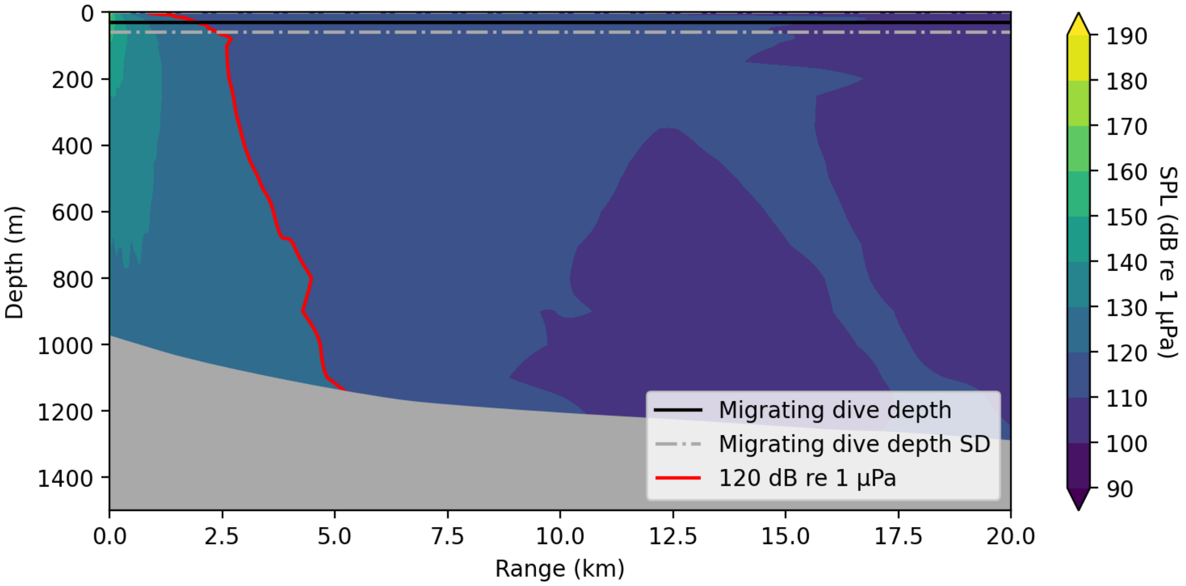

Figure 116. *Scenario 21, Site 23:* Example SPL vertical from the pipelay vessel at an azimuth of 315°. The 120 dB behavioural response threshold is highlighted in red, and the migrating pygmy blue whale dive depth (mean and one standard deviation) is indicated by horizontal lines.

5.3.2. PTS and TTS

Exposure ranges from animal movement modelling for PTS and TTS criteria are typically shorter than those predicted using acoustic propagation modelling because of the generally shorter time ('dwell time') to accumulate sound energy of the moving animats. In this analysis, there were no PTS exposures predicted for any of the pygmy blue whale simulations. Unrestricted seeding of animats resulted in a maximum $ER_{95\%}$ for TTS of 0.04 km with a corresponding exposure probability for animats travelling within that range of 67%.

Exposure ranges are, in general, slightly longer for TTS and PTS for unrestricted vs BIA-restricted scenarios because unrestricted animats have more opportunities to be exposed to sound fields closer to the source and for a longer time, which effectively lengthens their dwell time. This is the case for this study. Restricting animats to the migratory BIA for pygmy blue whales resulted in no exposures above TTS for Scenarios 8, 30, 33 and 40. The maximum $ER_{95\%}$ for TTS was 0.02 km with a corresponding exposure probability for animats travelling within the range of 87%.

5.4. Conclusion

This modelling study considered underwater sound levels associated with vessel activities and VSP for the construction of the Chevron Gorgon Gas Development: Backfill Fields. The modelling study considered 30 individual vessel activity scenarios across five representative Areas of the Development, four combined vessel scenarios, and scenarios at three VSP sites. The modelling study predicted the distances from operations at which underwater sound levels reached noise effect thresholds and criteria for marine mammals, sea turtles and fish.

The greatest horizontal distances were associated with the OCV with construction support vessels in Areas 1, 2, 3 and 5, which resulted in a 120 dB SPL marine mammal behavioural effect radius of up to 17.3 km. In Area 4, where construction was not modelled, the pipelay vessel with two support vessels resulted in the longest distances to effect thresholds (120 dB SPL marine mammal behavioural effect radii 18.3 km in Area 4). The smallest horizontal distances to effect thresholds were associated with scenarios that modelled a single IMR vessel.

In the combined vessel scenarios, the lack of change in ensonified area for Scenarios 37, 38 and 39 was primarily due to the distances between concurrent activities being larger than the sum of the effect radii of the individual activities. Only Scenario 40 resulted in overlapping ensonified areas such that the two behavioural effect zones of the drilling and pipelay activities in Area 5 combined into one larger area (with 12.9% greater ensonified area compared to the two individual scenarios). While the modelled sound fields presented here are specific to the modelled site locations, the effect radii summarised in Section 4.1 provide some guidance to the spacing between individual scenarios that will result in overlapping, or merged, effect zones.

The VSP results demonstrated that the greatest distances to noise-effect thresholds were generally associated with Site A, the shallowest site, rather than Sites B and C. It is likely that the shallow water depth at Site A resulted in sound reflecting from the seabed. The longest horizontal distances to the low-frequency cetacean PTS and TTS thresholds were 0.48 km and 3.20 km, respectively. The maximum distance to the 160 dB re 1 µPa (SPL) marine mammal behavioural response criterion was 2.37 km, which was associated with Site A. The corresponding distances at Sites B and C were 1.33 km and 1.35 km, respectively. For sea turtles, behavioural disturbance could occur up to 1.03 km from the VSP acoustic centre, with PTS and TTS maximum distances of 0.03 km and 0.24 km, respectively. All effect zones for fish were less than 0.6 km. Crustaceans may be affected within 60.8 m of Site A, but levels were not predicted to exceed effect thresholds at Sites B or C.

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to predict sound exposure for migrating pygmy blue whales in their migration BIA. The exposure ranges predicted using animat modelling are significantly more realistic than the acoustic modelling outlined above, due to the incorporation of species-specific realistic movements. In this study, there were no exposures above PTS threshold for any of the pygmy blue whale scenarios. The maximum $ER_{95\%}$ to TTS threshold was 0.04 km. 67% of pygmy blue whale animats that travelled within this distance were exposed above the TTS threshold. All scenarios resulted in the exposure of pygmy blue whale animats above the SPL behavioural response threshold NOAA (2019). Of these, the maximum $ER_{95\%}$ to the threshold was 12.4 km pygmy blue whales (Scenario 8 – OCV under DP with three support vessels). The probability of exposure for animats that travelled within this range was 99%.

Glossary

1/3-octave

One third of an octave. *Note*: A 1/3-octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec).

absorption

The conversion of sound energy to heat energy. Specifically, the reduction of sound pressure amplitude due to particle motion energy converting to heat in the propagation medium.

acoustic noise

Sound that interferes with an acoustic process.

acoustic self-noise

Sound at a receiver caused by the deployment, operation, or recovery of a specified receiver, and its associated platform (ISO 18405:2017).

agent-based modelling

A computer simulation of autonomous agents (sometimes called animats) acting in an environment, used to assess the agents' experience of the environment and/or their effect on the environment. See also animal movement modelling.

ambient sound

Sound that would be present in the absence of a specified activity (ISO 18405:2017). It is usually a composite of sound from many sources near and far, e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.

animal movement modelling

Simulation of animal movement based on behavioural rules for the purpose of predicting an animal's experience of an environment. A type of agent-based modelling.

attenuation

The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium. Attenuation depends on frequency—higher frequency sounds are attenuated faster than lower frequency sounds.

audiogram

A graph or table of hearing threshold as a function of frequency that describes the hearing sensitivity of an animal over its hearing range.

auditory frequency weighting

The process of applying an auditory frequency-weighting function. An example for marine mammals are the auditory frequency-weighting functions published by Southall et al. (2007).

auditory frequency-weighting function

Frequency-weighting function describing a compensatory approach accounting for a species' (or functional hearing group's) frequency-specific hearing sensitivity.

background noise

Combination of ambient sound, acoustic self-noise, and, where applicable, sonar reverberation (ISO 18405:2017) that is detected, measured, or recorded with a signal.

bandwidth

A range within a continuous band of frequencies. Unit: hertz (Hz).

broadband level

The total level measured over a specified frequency range. If the frequency range is unspecified, the term refers to the entire measured frequency range.

cavitation

A rapid formation and collapse of vapor cavities (i.e., bubbles or voids) in water, most often caused by a rapid change in pressure. Fast-spinning vessel propellers typically cause cavitation, which creates a lot of noise.

cetacean

Member of the order Cetacea. Cetaceans are aquatic mammals and include whales, dolphins, and porpoises.

compressional wave

A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called a longitudinal wave. In seismology/geophysics, it's called a primary wave or P-wave. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

conductivity-temperature-depth (CTD)

Measurement data of the ocean's conductivity, temperature, and depth; used to compute sound speed profiles and salinity.

continuous sound

A sound whose sound pressure level remains above the background noise during the observation period and may gradually vary in intensity with time, e.g., sound from a marine vessel.

critical band

The auditory bandwidth within which background noise strongly contributes to masking of a single tone. Unit: hertz (Hz).

critical ratio level

The difference between the sound pressure level of a masked tone, which is barely audible, and the spectral density level of the background noise at similar frequencies, referenced to 1 Hz. Unit: decibel (dB).

decade

Logarithmic frequency interval whose upper bound is ten times larger than its lower bound (ISO 80000-3:2006). For example, one decade up from 1000 Hz is 10,000 Hz, and one decade down is 100 Hz.

decibel (dB)

Unit of level used to express the ratio of one value of a power quantity to another on a logarithmic scale. Especially suited to quantify variables with a large dynamic range.

decidecade

One tenth of a decade. Approximately equal to one third of an octave (1 ddec ≈ 0.3322 oct), and for this reason sometimes referred to as a 1/3-octave.

decidecade band

Frequency band whose bandwidth is one decidecade. *Note*: The bandwidth of a decidecade band increases with increasing centre frequency.

delphinid

Member of the family of oceanic dolphins (Delphinidae), composed of approximately 35 extant species, including dolphins, porpoises, and killer whales.

energy source level

A property of a sound source equal to the sound exposure level measured in the far field plus the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 $\mu Pa^2\, m^2\, s$.

ensonified

Exposed to sound.

equal-loudness-level contour

Curve that shows, as a function of frequency, the sound pressure level required to produce a given loudness for a listener having normal hearing, listening to a specified kind of sound in a specified manner (ANSI S1.1-2013).

far field

The zone where, to an observer, sound originating from an array of sources (or a spatially distributed source) appears to radiate from a single point.

frequency

The rate of oscillation of a periodic function measured in cycles per unit time. The reciprocal of the period. Unit: hertz (Hz). Symbol: f. 1 Hz is equal to 1 cycle per second.

frequency weighting

The process of applying a frequency-weighting function.

frequency-weighting function

The squared magnitude of the sound pressure transfer function (ISO 18405:2017). For sound of a given frequency, the frequency-weighting function is the ratio of output power to input power of a specified filter, sometimes expressed in decibels. Examples include the following:

- *Auditory frequency-weighting function*: compensatory frequency-weighting function accounting for a species' (or functional hearing group's) frequency-specific hearing sensitivity.
- *System frequency-weighting function*: frequency-weighting function describing the sensitivity of an acoustic recording system, which typically consists of a hydrophone, one or more amplifiers, and an analog-to-digital converter.

functional hearing group

Category of animal species when classified according to their hearing sensitivity, hearing anatomy, and susceptibility to sound. For marine mammals, initial groupings were proposed by Southall et al. (2007), and revised groupings are developed as new research/data becomes available. Revised groupings proposed by Southall et al. (2019) include low-frequency cetaceans, high-frequency cetaceans, very high-frequency cetaceans, phocid carnivores in water, other carnivores in water, and sirenians. See auditory frequency-weighting functions, which are often applied to these groups. Example hearing groups for fish include species for which the swim bladder is involved in hearing, species for which the swim bladder is not involved in hearing, and species without a swim bladder (Popper et al. 2014).

geoacoustic

Relating to the acoustic properties of the seabed.

harmonic

A sinusoidal sound component that has a frequency that is an integer multiple of the frequency of a sound to which it is related. For a sound with a fundamental frequency of f, the harmonics have frequencies of $2f$, $3f$, $4f$, etc.

hearing threshold

For a given species or functional hearing group, the sound level for a given signal that is barely audible (i.e., that would be barely audible for a given individual in the presence of specified background noise during a specific percentage of experimental trials).

hertz (Hz)

Unit of frequency defined as one cycle per second. Often expressed in multiples such as kilohertz (1 kHz = 1000 Hz).

high-frequency (HF) cetaceans

See functional hearing group. *Note*: The mid- and high-frequency cetaceans groups proposed by Southall et al. (2007) were renamed high- and very-high-frequency cetaceans, respectively, by Southall et al. (2019).

hydrophone

An underwater sound pressure transducer. A passive electronic device for recording or listening to underwater sound.

hydrostatic pressure

The pressure at any given depth in a static liquid that is the result of the weight of the liquid acting on a unit area at that depth, plus any pressure acting on the surface of the liquid. Unit: pascal (Pa).

impulsive sound

Qualitative term meaning sounds that are typically transient, brief (less than 1 s), broadband, with rapid rise time and rapid decay. They can occur in repetition or as a single event. Sources of impulsive sound include, among others, explosives, seismic airguns, and impact pile drivers.

isopleth

A line drawn on a map through all points having the same value of some specified quantity (e.g., sound pressure level isopleth).

knot (kn)

Unit of vessel speed equal to 1 nautical mile per hour.

level

A measure of a quantity expressed as the logarithm of the ratio of the quantity to a specified reference value of that quantity. For example, a value of sound pressure level with reference to 1 μPa^2 can be written in the form *x* dB re 1 μPa^2.

low-frequency (LF) cetaceans

See functional hearing group.

masking

Obscuring of sounds of interest by other sounds at similar frequencies.

median

The 50th percentile of a statistical distribution.

mid-frequency (MF) cetaceans

See functional hearing group. *Note*: The mid-frequency cetaceans group proposed by Southall et al. (2007) was renamed high-frequency cetaceans by Southall et al. (2019).

monopole source level (MSL)

A source level that has been calculated using an acoustic model that accounts for the effect of the sea-surface and seabed on sound propagation, assuming a point source (monopole). Often used to quantify source levels of vessels or industrial operations from measurements. See also radiated noise level.

Monte Carlo simulation

A method of investigating the distribution of a non-linear multi-variate function by random sampling of its input variable distributions.

multiple linear regression

A statistical method that seeks to explain the response of a dependent variable using multiple explanatory variables.

M-weighting

A set of auditory frequency-weighting functions proposed by Southall et al. (2007).

mysticete

Member of the Mysticeti, a suborder of cetaceans. Also known as baleen whales, mysticetes have baleen plates (rather than teeth) that they use to filter food from water (or from sediment as for grey whales). This group includes rorquals (Balaenopteridae, such as blue, fin, humpback, and minke whales), right and bowhead whales (Balaenidae), and grey whales (*Eschrichtius robustus*).

N percent exceedance level

The sound level exceeded *N* % of the time during a specified time interval. See also percentile level.

non-impulsive sound

Sound that is not an impulsive sound. Not necessarily a continuous sound.

octave

The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete

Member of Odontoceti, a suborder of cetaceans. These whales, dolphins, and porpoises have teeth (rather than baleen plates). Their skulls are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

otariid

Member of the family Otariidae, one of the three groupings of pinnipeds (along with phocids and walrus). These eared seals, commonly called fur seals and sea lions, are adapted to semi-aquatic life; they use their large fore flippers for propulsion underwater and can walk on all four limbs on land.

otariid pinnipeds underwater (OW)

See functional hearing group.

other marine carnivores in water (OCW)

See functional hearing group.

parabolic equation method

A computationally efficient solution to the acoustic wave equation that is used to model propagation loss. The parabolic equation approximation omits effects of backscattered sound (which are negligible for most ocean-acoustic propagation problems), simplifying the computation of propagation loss.

particle acceleration, particle displacement, particle motion, particle velocity

See sound particle acceleration, sound particle displacement, sound particle motion, sound particle velocity.

peak sound pressure level (PK), zero-to-peak sound pressure level

The level (L_{pk}) of the squared maximum magnitude of the sound pressure (p_{pk}^2) in a stated frequency band and time window. Defined as $L_{\mathrm{pk}} = 10\log_{10}(p_{\mathrm{pk}}^2/p_0^2) = 20\log_{10}(p_{pk}/p_0)$. Unit: decibel (dB). Reference value (p_0^2) for sound in water: 1 µPa^2.

peak-to-peak sound pressure

The difference between the maximum and minimum sound pressure over a specified frequency band and time window. Unit: pascal (Pa).

percentile level

The sound level not exceeded *N* % of the time during a specified time interval. The *N*th percentile level is equal to the (100−*N*) % exceedance level. See also N percent exceedance level.

permanent threshold shift (PTS)

An irreversible loss of hearing sensitivity caused by excessive noise exposure. Considered auditory injury. Compare with temporary threshold shift.

phocid

Member of the family Phocidae, one of the three groupings of pinnipeds (along with otariids and walrus). These true/earless seals are more adapted to in-water life than are otariids, which have more terrestrial adaptations. Phocids use their hind flippers to propel themselves underwater.

phocid pinnipeds underwater (PW), phocid carnivores in water (PCW)

See functional hearing group.

pinniped

Member of the superfamily Pinnipedia, which is composed of phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source

A source that radiates sound as if from a single point.

propagation loss (PL)

Difference between a source level (SL) and the level at a specified location, $\mathrm{PL}(x) = \mathrm{SL} - L(x)$. Unit: decibel (dB). See also transmission loss.

radiated noise level (RNL)

A source level that has been calculated assuming sound pressure decays geometrically with distance from the source, with no influence of the sea-surface or seabed. Often used to quantify source levels of vessels or industrial operations from measurements. See also monopole source level.

received level

The level of a given field variable measured (or that would be measured) at a given location.

reference value

Standard value of a quantity used for calculating underwater sound level. The reference value depends on the quantity for which the level is being calculated:

Quantity	Reference value
Sound pressure	p_0^2 = 1 μPa^2 or p_0 = 1 μPa
Sound exposure	E_0 = 1 μPa^2 s
Sound particle displacement	δ_0^2 = 1 pm^2
Sound particle velocity	u_0^2 = 1 nm^2/s^2
Sound particle acceleration	a_0^2 = 1 μm^2/s^4

sensation level

Difference between the sound pressure level and hearing threshold at a specified frequency. Unit: decibel (dB).

shear wave

A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called a secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

sirenians (SI)

Members of the order Sirenia, which includes several manatee species and the dugong. See also functional hearing group.

sound

A time-varying disturbance in the pressure, stress, or material displacement of a medium propagated by local compression and expansion of the medium. In common meaning, a form of energy that propagates through media (e.g., water, air, ground) as pressure waves.

sound exposure

Time integral of squared sound pressure over a stated time interval in a stated frequency band. The time interval can be a specified time duration (e.g., 24 h) or from start to end of a specified event (e.g., a pile strike, an airgun pulse, a construction operation). Unit: pascal squared second (Pa^2 s). Symbol: E.

sound exposure level (SEL)

The level (L_E) of the sound exposure (E) in a stated frequency band and time window: $L_E = 10\log_{10}(E/E_0)$ (ISO 18405:2017). Unit: decibel (dB). Reference value (E_0) for sound in water: 1 μPa^2 s.

sound exposure spectral density

Distribution as a function of frequency of the time-integrated squared sound pressure per unit bandwidth of a sound having a continuous spectrum (ISO 18405:2017). Unit: pascal squared second per hertz (Pa^2 s/Hz).

sound field

Region containing sound waves.

sound intensity

Product of the sound pressure and the sound particle velocity (ISO 18405:2017). The magnitude of the sound intensity is the sound energy flowing through a unit area perpendicular to the direction of propagation per unit time. Unit: watt per metre squared (W/m^2). Symbol: I.

sound particle acceleration

The rate of change of sound particle velocity. Unit: metre per second squared (m/s^2). Symbol: a.

sound particle motion

Movement caused by the action of sound of the smallest volume of a medium that represents its mean physical properties. Important for determining effects of underwater noise on fishes and invertebrates because their hearing organs sense particle motion rather than sound pressure.

sound particle displacement

Displacement of a material element caused by the action of sound, where a material element is the smallest element of the medium that represents the medium's mean density (ISO 18405:2017). Unit: metre (m). Symbol: δ.

sound particle velocity

The velocity of a particle in a material moving back and forth in the direction of the pressure wave. Unit: metre per second (m/s). Symbol: u.

sound pressure

The contribution to total pressure caused by the action of sound (ISO 18405:2017). Unit: pascal (Pa). Symbol: p.

sound pressure level (SPL), rms sound pressure level

The level (L_p) of the time-mean-square sound pressure (p^2_{rms}) in a stated frequency band and time window: $L_p = 10\log_{10}(p^2_{\text{rms}}/p^2_0) = 20\log_{10}(p_{rms}/p_0)$, where rms is the abbreviation for root-mean-square. Unit: decibel (dB). Reference value (p^2_0) for sound in water: 1 μPa^2. SPL can also be expressed in terms of the root-mean-square (rms) with a reference value of p_0 = 1 μPa. The two definitions are equivalent.

sound speed profile

The speed of sound in the water column as a function of depth below the water surface.

soundscape

The characterization of the ambient sound in terms of its spatial, temporal, and frequency attributes, and the types of sources contributing to the sound field (ISO 18405:2017).

source level (SL)

A property of a sound source equal to the sound pressure level measured in the far field plus the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 μPa^2 m^2.

spectrogram

A visual representation of acoustic amplitude over time and frequency. A spectrogram's resolution in the time and frequency domains should generally be stated as it determines the information content of the representation.

spectrum

Distribution of acoustic signal content over frequency, where the signal's content is represented by its power, energy, mean-square sound pressure, or sound exposure.

surface duct

The upper portion of a water column within which the gradient of the sound speed profile causes sound to refract upward and therefore reflect repeatedly off the surface resulting in relatively long-range sound propagation with little loss.

temporary threshold shift (TTS)

Reversible loss of hearing sensitivity caused by noise exposure. Compare with permanent threshold shift.

thermocline

A depth interval near the ocean surface that experiences larger temperature gradients than the layers above and below it due to warming or cooling by heat conduction from the atmosphere and by warming from the sun.

transmission loss (TL)

The difference between a specified level at one location and that at a different location: $\text{TL}(x_1,x_2) = L(x_1) - L(x_2)$ (ISO 18405:2017). Unit: decibel (dB). See also propagation loss.

unweighted

Term indicating that no frequency-weighting function is applied.

very high-frequency (VHF) cetaceans

See functional hearing group.

wavelength

Distance over which a wave completes one cycle of oscillation. Unit: metre (m). Symbol: λ.

Literature Cited

[ANSI] American National Standards Institute and [ASA] Acoustical Society of America. S1.1-2013. *American National Standard: Acoustical Terminology*. NY, USA. https://webstore.ansi.org/Standards/ASA/ANSIASAS12013.

[DEWHA] Department of the Environment, Water, Heritage, and the Arts (Australia). 2008. *EPBC Act Policy Statement 2.1 - Interaction Between Offshore Seismic Exploration and Whales*. 14 p. http://www.environment.gov.au/resource/epbc-act-policy-statement-21-interaction-between-offshore-seismic-exploration-and-whales.

[HESS] High Energy Seismic Survey. 1999. *High Energy Seismic Survey Review Process and Interim Operational Guidelines for Marine Surveys Offshore Southern California*. Prepared for the California State Lands Commission and the United States Minerals Management Service Pacific Outer Continental Shelf Region by the High Energy Seismic Survey Team, Camarillo, CA, USA. 98 p. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB2001100103.xhtml.

[ISO] International Organization for Standardization. 2006. *ISO 80000-3:2006 Quantities and units – Part 3: Space and time*. https://www.iso.org/standard/31888.html.

[ISO] International Organization for Standardization. 2016. *ISO 17208-1:2016. Underwater acoustics – Quantities and procedures for description and measurement of underwater sound from ships – Part 1: Requirements for precision measurements in deep water used for comparison purposes*. https://www.iso.org/standard/62408.html.

[ISO] International Organization for Standardization. 2017. *ISO 18405:2017. Underwater acoustics – Terminology*. Geneva. https://www.iso.org/standard/62406.html.

[NMFS] National Marine Fisheries Service (US). 1998. *Acoustic Criteria Workshop*. Dr. Roger Gentry and Dr. Jeanette Thomas Co-Chairs.

[NMFS] National Marine Fisheries Service (US). 2016. *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts*. US Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-55. 178 p.

[NMFS] National Marine Fisheries Service (US). 2018. *2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts*. US Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59. 167 p. https://media.fisheries.noaa.gov/dam-migration/tech_memo_acoustic_guidance_(20)_(pdf)_508.pdf.

[NOAA] National Oceanic and Atmospheric Administration (US). 2013. *Draft guidance for assessing the effects of anthropogenic sound on marine mammals: Acoustic threshold levels for onset of permanent and temporary threshold shifts*. National Oceanic and Atmospheric Administration, US Department of Commerce, and NMFS Office of Protected Resources, Silver Spring, MD, USA. 76 p.

[NOAA] National Oceanic and Atmospheric Administration (US). 2015. *Draft guidance for assessing the effects of anthropogenic sound on marine mammal hearing: Underwater acoustic threshold levels for onset of permanent and temporary threshold shifts*. NMFS Office of Protected Resources, Silver Spring, MD, USA. 180 p.

[NOAA] National Oceanic and Atmospheric Administration (US). 2016. *Document Containing Proposed Changes to the NOAA Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Threshold Levels for Onset of Permanent and Temporary Threshold Shifts*. National Oceanic and Atmospheric Administration and US Department of Commerce. 24 p.

[NOAA] National Oceanic and Atmospheric Administration (US). 2018. Takes of Marine Mammals Incidental to Specified Activities; Taking Marine Mammals Incidental to Marine Site Characterization Surveys off of Delaware. *Federal Register* 83(65): 14417-14443. https://www.federalregister.gov/d/2018-12225.

[NOAA] National Oceanic and Atmospheric Administration (US). 2019. *ESA Section 7 Consultation Tools for Marine Mammals on the West Coast* (web page), 27 Sep 2019. https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/esa-section-7-consultation-tools-marine-mammals-west.

[ONR] Office of Naval Research. 1998. *ONR Workshop on the Effect of Anthropogenic Noise in the Marine Environment*. Dr. R. Gisiner, Chair.

Aerts, L.A.M., M. Blees, S.B. Blackwell, C.R. Greene, Jr., K.H. Kim, D.E. Hannay, and M.E. Austin. 2008. *Marine mammal monitoring and mitigation during BP Liberty OBC seismic survey in Foggy Island Bay, Beaufort Sea, July-August 2008: 90-day report*. Document P1011-1. Report by LGL Alaska Research Associates Inc., LGL Ltd., Greeneridge Sciences Inc., and JASCO Applied Sciences for BP Exploration Alaska. 199 p. ftp://ftp.library.noaa.gov/noaa_documents.lib/NMFS/Auke%20Bay/AukeBayScans/Removable%20Disk/P1011-1.pdf.

AIMS unpublished data. 2021.

Amoser, S. and F. Ladich. 2003. Diversity in noise-induced temporary hearing loss in otophysine fishes. *Journal of the Acoustical Society of America* 113(4): 2170-2179. https://doi.org/10.1121/1.1557212.

Austin, M.E. and G.A. Warner. 2012. *Sound Source Acoustic Measurements for Apache's 2012 Cook Inlet Seismic Survey*. Version 2.0. Technical report by JASCO Applied Sciences for Fairweather LLC and Apache Corporation.

Austin, M.E. and L. Bailey. 2013. *Sound Source Verification: TGS Chukchi Sea Seismic Survey Program 2013*. Document 00706, Version 1.0. Technical report by JASCO Applied Sciences for TGS-NOPEC Geophysical Company.

Austin, M.E., A. McCrodan, C. O'Neill, Z. Li, and A.O. MacGillivray. 2013. *Marine mammal monitoring and mitigation during exploratory drilling by Shell in the Alaskan Chukchi and Beaufort Seas, July–November 2012: 90-Day Report*. *In*: Funk, D.W., C.M. Reiser, and W.R. Koski (eds.). Underwater Sound Measurements. LGL Rep. P1272D–1. Report from LGL Alaska Research Associates Inc. and JASCO Applied Sciences, for Shell Offshore Inc., National Marine Fisheries Service (US), and US Fish and Wildlife Service. 266 pp plus appendices.

Austin, M.E. 2014. Underwater noise emissions from drillships in the Arctic. *In*: Papadakis, J.S. and L. Bjørnø (eds.). *UA2014 - 2nd International Conference and Exhibition on Underwater Acoustics*. 22-27 Jun 2014, Rhodes, Greece. pp. 257-263.

Austin, M.E., H. Yurk, and R. Mills. 2015. *Acoustic Measurements and Animal Exclusion Zone Distance Verification for Furie's 2015 Kitchen Light Pile Driving Operations in Cook Inlet*. Version 2.0. Technical report by JASCO Applied Sciences for Jacobs LLC and Furie Alaska.

Austin, M.E. and Z. Li. 2016. *Marine Mammal Monitoring and Mitigation During Exploratory Drilling by Shell in the Alaskan Chukchi Sea, July–October 2015: Draft 90-day report*. *In*: Ireland, D.S. and L.N. Bisson (eds.). Underwater Sound Measurements. LGL Rep. P1363D. Report from LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Applied Sciences Ltd. For Shell Gulf of Mexico Inc, National Marine Fisheries Service, and US Fish and Wildlife Service. 188 pp + appendices.

Bartol, S.M. and D.R. Ketten. 2006. *Turtle and tuna hearing*. *In*: Swimmer, Y. and R. Brill (eds.). Sea turtle and pelagic fish sensory biology: Developing techniques to reduce sea turtle bycatch in longline fisheries. Volume December 2006. NOAA Technical Memorandum NMFS-PIFSC-7. 98-103 p. http://www.sefsc.noaa.gov/turtles/TM_NMFS_PIFSC_7_Swimmer_Brill.pdf#page=108.

Buckingham, M.J. 2005. Compressional and shear wave properties of marine sediments: Comparisons between theory and data. *Journal of the Acoustical Society of America* 117: 137-152. https://doi.org/10.1121/1.1810231.

Carnes, M.R. 2009. *Description and Evaluation of GDEM-V 3.0*. US Naval Research Laboratory, Stennis Space Center, MS. NRL Memorandum Report 7330-09-9165. 21 p. https://apps.dtic.mil/dtic/tr/fulltext/u2/a494306.pdf.

Collins, M.D. 1993. A split-step Padé solution for the parabolic equation method. *Journal of the Acoustical Society of America* 93(4): 1736-1742. https://doi.org/10.1121/1.406739.

Collins, M.D., R.J. Cederberg, D.B. King, and S. Chin-Bing. 1996. Comparison of algorithms for solving parabolic wave equations. *Journal of the Acoustical Society of America* 100(1): 178-182. https://doi.org/10.1121/1.415921.

Coppens, A.B. 1981. Simple equations for the speed of sound in Neptunian waters. *Journal of the Acoustical Society of America* 69(3): 862-863. https://doi.org/10.1121/1.382038.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, J.M. Semmens, and Institute for Marine and Antarctic Studies. 2016a. *Assessing the Impact of Marine Seismic Surveys on Southeast Australian Scallop and Lobster Fisheries*. Impacts of Marine Seismic Surveys on Scallop and Lobster Fisheries. Fisheries Ressearch & Development Corporation. FRDC Project No 2012/008, University of Tasmania, Hobart. 159 p.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, and J.M. Semmens. 2016b. Seismic air gun exposure during early-stage embryonic development does not negatively affect spiny lobster *Jasus edwardsii larvae* (Decapoda:Palinuridae). *Scientific Reports* 6: 1-9. https://doi.org/10.1038/srep22723.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, and J.M. Semmens. 2017. Exposure to seismic air gun signals causes physiological harm and alters behavior in the scallop *Pecten fumatus*. *Proceedings of the National Academy of Sciences of the United States of America* 114(40): E8537-E8546. https://doi.org/10.1073/pnas.1700564114.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, and J.M. Semmens. 2019. Seismic air guns damage rock lobster mechanosensory organs and impair righting reflex. *Proceedings of the Royal Society B* 286(1907). https://doi.org/10.1098/rspb.2019.1424.

Department of the Environment and Energy, NSW Government, and Queensland Government. 2017. *Recovery Plan for Marine Turtles in Australia*. https://www.environment.gov.au/marine/publications/recovery-plan-marine-turtles-australia-2017.

Double, M.C., V. Andrews-Goff, K.C.S. Jenner, M.-N. Jenner, S.M. Laverick, T.A. Branch, and N.J. Gales. 2014. Migratory Movements of Pygmy Blue Whales (*Balaenoptera musculus brevicauda*) between Australia and Indonesia as Revealed by Satellite Telemetry. *PLOS ONE* 9(4). https://doi.org/10.1371/journal.pone.0093578.

Dow Piniak, W.E., S.A. Eckert, C.A. Harms, and E.M. Stringer. 2012. *Underwater hearing sensitivity of the leatherback sea turtle (Dermochelys coriacea): Assessing the potential effect of anthropogenic noise*. US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2012-00156. 35 p.

Dragoset, W.H. 1984. A comprehensive method for evaluating the design of airguns and airgun arrays. *16th Annual Offshore Technology Conference* Volume 3, 7–9 May 1984. OTC 4747, Houston, TX, USA. pp. 75–84. https://doi.org/10.4043/4783-MS.

Duncan, A. and C. Erbe. 2019. *Acoustic Propagation Loss Modelling for the proposed Jansz-Io Subsea Compression Facility. Report 2019-15. Report by Centre for Marine Science and Technology (CMST) for Chevron Energy Technology Pty Ltd.*

Duncan, A.J., A.N. Gavrilov, N. Alexander, R.D. McCauley, I.M. Parnum, and J.M. Collis. 2013. Characteristics of sound propagation in shallow water over an elastic seabed with a thin cap-rock layer. *Journal of the Acoustical Society of America* 134(1): 207-215. https://doi.org/10.1121/1.4809723.

Dunlop, R.A., M.J. Noad, R.D. McCauley, L. Scott-Hayward, E. Kniest, R. Slade, D. Paton, and D.H. Cato. 2017. Determining the behavioural dose–response relationship of marine mammals to air gun noise and source proximity. *Journal of Experimental Biology* 220(16): 2878-2886. https://doi.org/10.1242/jeb.160192.

Dunlop, R.A., M.J. Noad, R.D. McCauley, E. Kniest, R. Slade, D. Paton, and D.H. Cato. 2018. A behavioural dose-response model for migrating humpback whales and seismic air gun noise. *Marine Pollution Bulletin* 133: 506-516. https://doi.org/10.1016/j.marpolbul.2018.06.009.

Ellison, W.T., C.W. Clark, and G.C. Bishop. 1987. *Potential use of surface reverberation by bowhead whales, Balaena mysticetus, in under-ice navigation: Preliminary considerations*. Report of the International Whaling Commission. Volume 37. 329-332 p.

Ellison, W.T. and P.J. Stein. 1999. *SURTASS LFA High Frequency Marine Mammal Monitoring (HF/M3) Sonar: Sustem Description and Test & Evaluation*. Under US Navy Contract N66604-98-D-5725. http://www.surtass-lfa-eis.com/wp-content/uploads/2018/02/HF-M3-Ellison-Report-2-4a.pdf.

Ellison, W.T. and A.S. Frankel. 2012. A common sense approach to source metrics. *In* Popper, A.N. and A.D. Hawkins (eds.). *The Effects of Noise on Aquatic Life*. Volume 730. Springer, New York. pp. 433-438. https://doi.org/10.1007/978-1-4419-7311-5_98.

Esso Australia Resources Pty Ltd and ExxonMobil. 2021. *JUR Drilling Environment Plan*. https://docs.nopsema.gov.au/A821197.

Finneran, J.J. and A.K. Jenkins. 2012. *Criteria and thresholds for U.S. Navy acoustic and explosive effects analysis*. SPAWAR Systems Center Pacific, San Diego, CA, USA. 64 p.

Finneran, J.J. 2015. *Auditory weighting functions and TTS/PTS exposure functions for cetaceans and marine carnivores*. Technical report by SSC Pacific, San Diego, CA, USA.

Finneran, J.J. 2016. *Auditory weighting functions and TTS/PTS exposure functions for marine mammals exposed to underwater noise*. Technical Report for Space and Naval Warfare Systems Center Pacific, San Diego, CA, USA. 49 p. https://apps.dtic.mil/dtic/tr/fulltext/u2/1026445.pdf.

Finneran, J.J., E.E. Henderson, D.S. Houser, K. Jenkins, S. Kotecki, and J. Mulsow. 2017. *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III)*. Technical report by Space and Naval Warfare Systems Center Pacific (SSC Pacific). 183 p. https://nwtteis.com/portals/nwtteis/files/technical_reports/Criteria_and_Thresholds_for_U.S._Navy_Acoustic_and_Explosive_Effects_Analysis_June2017.pdf.

Frankel, A.S., W.T. Ellison, and J. Buchanan. 2002. Application of the acoustic integration model (AIM) to predict and minimize environmental impacts. *OCEANS 2002*. 29-31 Oct 2002. IEEE, Biloxi, MI, USA. pp. 1438-1443. https://doi.org/10.1109/OCEANS.2002.1191849.

Funk, D.W., D.E. Hannay, D.S. Ireland, R. Rodrigues, and W.R. Koski. 2008. *Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–November 2007: 90-day report*. LGL Report P969-1. Prepared by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Research Ltd. for Shell Offshore Inc., National Marine Fisheries Service (US), and US Fish and Wildlife Service. 218 p. http://www-static.shell.com/static/usa/downloads/alaska/shell2007_90-d_final.pdf.

Gallagher, S.J., C.S. Fulthorpe, K. Bogus, and the Expedition 356 Scientists. 2017. *Indonesian Throughflow*. Proceedings of the International Ocean Discovery Program, Expedition 356 of the riserless drilling platform, Fremantle, Australia, to Darwin, Australia; Sites U1458-U1464, 31 July-30 September 2015, Volume 356, College Station, TX, USA. http://publications.iodp.org/proceedings/356/356title.html.

Hannay, D.E., A.O. MacGillivray, M. Laurinolli, and R. Racca. 2004. *Sakhalin Energy: Source Level Measurements from 2004 Acoustics Program*. Version 1.5. Technical report for Sakhalin Energy by JASCO Applied Sciences.

Hannay, D.E. and R.G. Racca. 2005. *Acoustic Model Validation*. Document 0000-S-90-04-T-7006-00-E, Revision 02. Technical report by JASCO Research Ltd. for Sakhalin Energy Investment Company Ltd. 34 p.

Houser, D.S. and M.J. Cross. 1999. *Marine Mammal Movement and Behavior (3MB): A Component of the Effects of Sound on the Marine Environment (ESME) Distributed Model*. Version 8.08, by BIOMIMETICA.

Houser, D.S. 2006. A method for modeling marine mammal movement and behavior for environmental impact assessment. *IEEE Journal of Oceanic Engineering* 31(1): 76-81. https://doi.org/10.1109/JOE.2006.872204.

Ireland, D.S., R. Rodrigues, D.W. Funk, W.R. Koski, and D.E. Hannay. 2009. *Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–October 2008: 90-Day Report*. Document P1049-1. 277 p.

Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. 2011. *Computational Ocean Acoustics*. 2nd edition. AIP Series in Modern Acourics and Signal Processing. AIP Press - Springer, New York. 794 p.

Landrø, M. 1992. Modeling of GI gun signatures. *Geophysical Prospecting* 40(7): 721–747. https://doi.org/10.1111/j.1365-2478.1992.tb00549.x.

Laws, R.M., L. Hatton, and M. Haartsen. 1990. Computer modelling of clustered airguns. *First Break* 8(9): 331–338. https://doi.org/10.3997/1365-2397.1990017.

Lurton, X. 2002. *An Introduction to Underwater Acoustics: Principles and Applications*. Springer, Chichester, UK. 347 p.

MacDonnell, J.T. 2017. *Shelburne Basin Venture Exploration Drilling Project: Sound Source Characterization, 2016 Field Measurements of the Stena IceMAX*. Document 01296, Version 3.0. Technical report by JASCO Applied Sciences for Shell Canada Limited. https://www.cnsopb.ns.ca/sites/default/files/pdfs/shelburne_ceaa_3.12.3_sound_source_characterization_final_april202017.pdf.

MacGillivray, A.O. 2018. Underwater noise from pile driving of conductor casing at a deep-water oil platform. *Journal of the Acoustical Society of America* 143(1): 450-459. https://doi.org/10.1121/1.5021554.

Malme, C.I., P.R. Miles, C.W. Clark, P.L. Tyack, and J.E. Bird. 1983. *Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior*. Report 5366. http://www.boem.gov/BOEM-Newsroom/Library/Publications/1983/rpt5366.aspx.

Malme, C.I., P.R. Miles, C.W. Clark, P.L. Tyack, and J.E. Bird. 1984. *Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior. Phase II: January 1984 Migration*. Report 5586. Report by Bolt Beranek and Newman Inc. for the US Department of the Interior, Minerals Management Service, Cambridge, MA, USA. https://www.boem.gov/sites/default/files/boem-newsroom/Library/Publications/1983/rpt5586.pdf.

Malme, C.I., B. Würsig, J.E. Bird, and P.L. Tyack. 1986. *Behavioral responses of gray whales to industrial noise: Feeding observations and predictive modeling*. Document 56. NOAA Outer Continental Shelf Environmental Assessment Program. Final Reports of Principal Investigators. 393-600 p.

Martin, S.B., K. Bröker, M.-N.R. Matthews, J.T. MacDonnell, and L. Bailey. 2015. Comparison of measured and modeled air-gun array sound levels in Baffin Bay, West Greenland. *OceanNoise 2015*. 11-15 May 2015, Barcelona, Spain.

Martin, S.B. and A.N. Popper. 2016. Short- and long-term monitoring of underwater sound levels in the Hudson River (New York, USA). *Journal of the Acoustical Society of America* 139(4): 1886-1897. https://doi.org/10.1121/1.4944876.

Martin, S.B., J.T. MacDonnell, and K. Bröker. 2017a. Cumulative sound exposure levels—Insights from seismic survey measurements. *Journal of the Acoustical Society of America* 141(5): 3603-3603. https://doi.org/10.1121/1.4987709.

Martin, S.B., M.-N.R. Matthews, J.T. MacDonnell, and K. Bröker. 2017b. Characteristics of seismic survey pulses and the ambient soundscape in Baffin Bay and Melville Bay, West Greenland. *Journal of the Acoustical Society of America* 142(6): 3331-3346. https://doi.org/10.1121/1.5014049.

Matthews, M.-N.R. and A.O. MacGillivray. 2013. Comparing modeled and measured sound levels from a seismic survey in the Canadian Beaufort Sea. *Proceedings of Meetings on Acoustics* 19(1): 1-8. https://doi.org/10.1121/1.4800553.

Mattsson, A. and M. Jenkerson. 2008. Single Airgun and Cluster Measurement Project. *Joint Industry Programme (JIP) on Exploration and Production Sound and Marine Life Proramme Review*. 28-30 Oct 2008. International Association of Oil and Gas Producers, Houston, TX, USA.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, et al. 2000. *Marine seismic surveys: Analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid*. Report R99-15. Prepared for Australian Petroleum Production Exploration Association by Centre for Maine Science and Technology, Western Australia. 198 p. https://cmst.curtin.edu.au/wp-content/uploads/sites/4/2016/05/McCauley-et-al-Seismic-effects-2000.pdf.

McCrodan, A., C.R. McPherson, and D.E. Hannay. 2011. *Sound Source Characterization (SSC) Measurements for Apache's 2011 Cook Inlet 2D Technology Test*. Version 3.0. Technical report by JASCO Applied Sciences for Fairweather LLC and Apache Corporation. 51 p.

McPherson, C.R. and G.A. Warner. 2012. *Sound Sources Characterization for the 2012 Simpson Lagoon OBC Seismic Survey 90-Day Report*. Document 00443, Version 2.0. Technical report by JASCO Applied Sciences for BP Exploration (Alaska) Inc.

McPherson, C.R., K. Lucke, B.J. Gaudet, S.B. Martin, and C.J. Whitt. 2018. *Pelican 3-D Seismic Survey Sound Source Characterisation*. Document 001583. Version 1.0. Technical report by JASCO Applied Sciences for RPS Energy Services Pty Ltd.

McPherson, C.R. and S.B. Martin. 2018. *Characterisation of Polarcus 2380 in^3 Airgun Array*. Document 001599, Version 1.0. Technical report by JASCO Applied Sciences for Polarcus Asia Pacific Pte Ltd.

McPherson, C.R., Z. Li, C.C. Wilson, K.A. Kowarski, and M.W. Koessler. 2021. Appendix 8. Beach Otway Development Acoustic Monitoring. *In* Beach (ed.). *Environment Plan Appendices Geographe Subsea Installation & Commissioning (VIC/L23)*. https://docs.nopsema.gov.au/A802937.

McPherson, C.R. 2022. *Jansz-Io Compression Project: Additional Modelling and Animat Work*. Version 1.0. Technical memorandum by JASCO Applied Sciences for Chevron.

Nedwell, J.R. and A.W. Turnpenny. 1998. The use of a generic frequency weighting scale in estimating environmental effect. *Workshop on Seismics and Marine Mammals*. 23–25 Jun 1998, London, UK.

Nedwell, J.R., A.W. Turnpenny, J. Lovell, S.J. Parvin, R. Workman, J.A.L. Spinks, and D. Howell. 2007. *A validation of the dB$_{ht}$ as a measure of the behavioural and auditory effects of underwater noise*. Document 534R1231 Report by Subacoustech Ltd. for Chevron Ltd, TotalFinaElf Exploration UK PLC, Department of Business, Enterprise and Regulatory Reform, Shell UK Exploration and Production Ltd, The Industry Technology Facilitator, Joint Nature Conservation Committee, and The UK Ministry of Defence. 74 p. https://tethys.pnnl.gov/sites/default/files/publications/Nedwell-et-al-2007.pdf.

O'Neill, C., D. Leary, and A. McCrodan. 2010. Sound Source Verification. (Chapter 3) *In* Blees, M.K., K.G. Hartin, D.S. Ireland, and D.E. Hannay (eds.). *Marine mammal monitoring and mitigation during open water seismic exploration by Statoil USA E&P Inc. in the Chukchi Sea, August-October 2010: 90-day report*. LGL Report P1119. Prepared by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Applied Sciences Ltd. for Statoil USA E&P Inc., National Marine Fisheries Service (US), and US Fish and Wildlife Service. pp. 1-34.

Owen, K., C.S. Jenner, M.-N.M. Jenner, and R.D. Andrews. 2016. A week in the life of a pygmy blue whale: Migratory dive depth overlaps with large vessel drafts. *Animal Biotelemetry* 4: 17. https://doi.org/10.1186/s40317-016-0109-4.

Payne, J.F., C. Andrews, L. Fancey, D. White, and J. Christian. 2008. *Potential Effects of Seismic Energy on Fish and Shellfish: An Update since 2003*. Report 2008/060. Canadian Science Advisory Secretariat. 22 p. https://waves-vagues.dfo-mpo.gc.ca/Library/335123.pdf.

Payne, R. and D. Webb. 1971. Orientation by means of long range acoustic signaling in baleen whales. *Annals of the New York Academy of Sciences* 188: 110-141. https://doi.org/10.1111/j.1749-6632.1971.tb13093.x.

Popper, A.N., A.D. Hawkins, R.R. Fay, D.A. Mann, S. Bartol, T.J. Carlson, S. Coombs, W.T. Ellison, R.L. Gentry, et al. 2014. *Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*. ASA S3/SC1.4 TR-2014. SpringerBriefs in Oceanography. ASA Press and Springer. https://doi.org/10.1007/978-3-319-06659-2.

Porter, M.B. and Y.C. Liu. 1994. Finite-element ray tracing. *In*: Lee, D. and M.H. Schultz (eds.). *International Conference on Theoretical and Computational Acoustics*. Volume 2. World Scientific Publishing Co. pp. 947-956.

Quijano, J.E. and C.R. McPherson. 2021. *Acoustic Characterisation of the Technip Deep Orient: Measuring Operational Sound Levels*. Document 02527, Version 2.0. Technical report by JASCO Applied Sciences for Woodside Energy Limited.

Racca, R., A.N. Rutenko, K. Bröker, and M.E. Austin. 2012a. A line in the water - design and enactment of a closed loop, model based sound level boundary estimation strategy for mitigation of behavioural impacts from a seismic survey. *11th European Conference on Underwater Acoustics*. Volume 34(3), Edinburgh, UK.

Racca, R., A.N. Rutenko, K. Bröker, and G. Gailey. 2012b. Model based sound level estimation and in-field adjustment for real-time mitigation of behavioural impacts from a seismic survey and post-event evaluation of sound exposure for individual whales. *In*: McMinn, T. (ed.). *Acoustics 2012*. Fremantle, Australia. http://www.acoustics.asn.au/conference_proceedings/AAS2012/papers/p92.pdf.

Racca, R., M.E. Austin, A.N. Rutenko, and K. Bröker. 2015. Monitoring the gray whale sound exposure mitigation zone and estimating acoustic transmission during a 4-D seismic survey, Sakhalin Island, Russia. *Endangered Species Research* 29(2): 131-146. https://doi.org/10.3354/esr00703.

Scholik, A.R. and H.Y. Yan. 2002. Effects of boat engine noise on the auditory sensitivity of the fathead minnow, *Pimephales promelas*. *Environmental Biology of Fishes* 63(2): 203-209. https://doi.org/10.1023/A:1014266531390.

Smith, M.E., A.B. Coffin, D.L. Miller, and A.N. Popper. 2006. Anatomical and functional recovery of the goldfish (*Carassius auratus*) ear following noise exposure. *Journal of Experimental Biology* 209(21): 4193-4202. https://doi.org/10.1242/jeb.02490.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, et al. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals* 33(4): 411-521. https://doi.org/10.1578/AM.33.4.2007.411.

Southall, B.L., D.P. Nowaceck, P.J.O. Miller, and P.L. Tyack. 2016. Experimental field studies to measure behavioral responses of cetaceans to sonar. *Endangered Species Research* 31: 293-315. https://doi.org/10.3354/esr00764.

Southall, B.L., J.J. Finneran, C.J. Reichmuth, P.E. Nachtigall, D.R. Ketten, A.E. Bowles, W.T. Ellison, D.P. Nowacek, and P.L. Tyack. 2019. Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals* 45(2): 125-232. https://doi.org/10.1578/AM.45.2.2019.125.

Southall, B.L., D.P. Nowacek, A.E. Bowles, V. Senigaglia, L. Bejder, and P.L. Tyack. 2021. Marine Mammal Noise Exposure Criteria: Assessing the Severity of Marine Mammal Behavioral Responses to Human Noise. *Aquatic Mammals* 47(5): 421-464.

Spence, J.H., R. Fischer, M.A. Bahtiarian, L. Boroditsky, N. Jones, and R. Dempsey. 2007. *Review of Existing and Future Potential Treatments for Reducing Underwater Sound from Oil and Gas Industry Activities*. Report NCE 07-001. Report by Noise Control Engineering, Inc. for the Joint Industry Programme on E&P Sound and Marine Life. 185 p.

Teague, W.J., M.J. Carron, and P.J. Hogan. 1990. A comparison between the Generalized Digital Environmental Model and Levitus climatologies. *Journal of Geophysical Research* 95(C5): 7167-7183. https://doi.org/10.1029/JC095iC05p07167.

Thums, M. and L.C. Ferreira. 2021. *Informing spatial management for pygmy blue whale management: fine scale analysis of movement.* 19 p.

Tougaard, J. and E.T. Griffiths. 2020. *Harbour porpoises and the construction of Nord Stream 2 gas pipeline. Scientific Report from DCE – Danish Centre for Environment and Energy No. 398. 29 p. http://dce2.au.dk/pub/SR398.pdf.*

Warner, G.A., C. Erbe, and D.E. Hannay. 2010. Underwater Sound Measurements. (Chapter 3) *In* Reiser, C.M., D. Funk, R. Rodrigues, and D.E. Hannay (eds.). *Marine Mammal Monitoring and Mitigation during Open Water Shallow Hazards and Site Clearance Surveys by Shell Offshore Inc. in the Alaskan Chukchi Sea, July-October 2009: 90-Day Report*. LGL Report P1112-1. Report by LGL Alaska Research Associates Inc. and JASCO Applied Sciences for Shell Offshore Inc., National Marine Fisheries Service (US), and Fish and Wildlife Service (US). pp. 1-54.

Warner, G.A., M.E. Austin, and A.O. MacGillivray. 2017. Hydroacoustic measurements and modeling of pile driving operations in Ketchikan, Alaska [Abstract]. *Journal of the Acoustical Society of America* 141(5): 3992. https://doi.org/10.1121/1.4989141.

Whiteway, T. 2009. *Australian Bathymetry and Topography Grid, June 2009*. GeoScience Australia, Canberra. http://pid.geoscience.gov.au/dataset/ga/67703.

Zhang, Z.Y. and C.T. Tindle. 1995. Improved equivalent fluid approximations for a low shear speed ocean bottom. *Journal of the Acoustical Society of America* 98(6): 3391-3396. https://doi.org/10.1121/1.413789.

Ziolkowski, A.M. 1970. A method for calculating the output pressure waveform from an air gun. *Geophysical Journal International* 21(2): 137-161. https://doi.org/10.1111/j.1365-246X.1970.tb01773.x.

Zykov, M.M. and J.T. MacDonnell. 2013. *Sound Source Characterizations for the Collaborative Baseline Survey Offshore Massachusetts Final Report: Side Scan Sonar, Sub-Bottom Profiler, and the R/V Small Research Vessel experimental*. Document 00413, Version 2.0. Technical report by JASCO Applied Sciences for Fugro GeoServices, Inc. and the (US) Bureau of Ocean Energy Management.

Appendix A. Acoustic Metrics

This section describes in detail the acoustic metrics, impact criteria, and frequency weighting relevant to the modelling study.

A.1. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 μPa. Because the perceived loudness of sound, especially pulsed sound such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate sound and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow International Organization for Standardization definitions and symbols for sound metrics (e.g., ISO 2017, ANSI S1.1-2013).

The sound pressure level (SPL or L_p; dB re 1 μPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T; s). It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt \Big/ p_0^2\right)\,\mathrm{dB} \tag{A-1}$$

where $g(t)$ is an optional time weighting function. In many cases, the start time of the integration is marched forward in small time steps to produce a time-varying SPL function.

The sound exposure level (SEL or L_E; dB re 1 μPa^2·s) is the time-integral of the squared acoustic pressure over a duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)\,dt \Big/ T_0 p_0^2\right)\,\mathrm{dB} \tag{A-2}$$

where T_0 is a reference time interval of 1 s. SEL continues to increase with time when non-zero pressure signals are present. It is a dose-type measurement, so the integration time applied must be carefully considered for its relevance to impact to the exposed recipients.

SEL can be calculated over a fixed duration, such as the time of a single event or a period with multiple acoustic events. When applied to pulsed sounds, SEL can be calculated by summing the SEL of the N individual pulses. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{E,N} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right)\,\mathrm{dB}\,. \tag{A-3}$$

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,LFC,24h}$; Appendix A.4). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should also be specified.

A.2. Decidecade Band Analysis

The distribution of a sound's power with frequency is described by the sound's spectrum. The sound spectrum can be split into a series of adjacent frequency bands. Splitting a spectrum into 1 Hz wide bands, called passbands, yields the power spectral density of the sound. This splitting of the spectrum into passbands of a constant width of 1 Hz, however, does not represent how animals perceive sound.

Because animals perceive exponential increases in frequency rather than linear increases, analysing a sound spectrum with passbands that increase exponentially in size better approximates real-world scenarios. In underwater acoustics, a spectrum is commonly split into decidecade bands, which are one tenth of a decade wide. A decidecade is sometimes referred to as a "1/3 octave" because one tenth of a decade is approximately equal to one third of an octave. Each decade represents a factor 10 in sound frequency. Each octave represents a factor 2 in sound frequency. The centre frequency of the ith band, $f_c(i)$, is defined as:

$$f_c(i) = 10^{\frac{i}{10}} \text{ kHz} \tag{A-4}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith decade band are defined as:

$$f_{lo,i} = 10^{\frac{-1}{20}} f_c(i) \quad \text{and} \quad f_{hi,i} = 10^{\frac{1}{20}} f_c(i) \tag{A-5}$$

The decidecade bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure A-1). The acoustic modelling spans from band 10 ($f_c(10)$ = 10 Hz) to band 44 ($f_c(44)$ = 25 kHz).

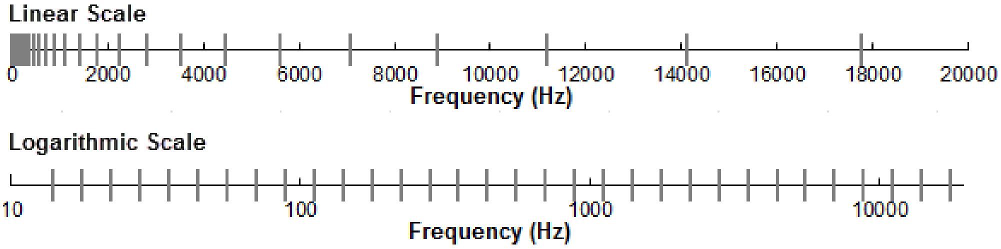

Figure A-1. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

The sound pressure level in the ith band ($L_{p,i}$) is computed from the spectrum $S(f)$ between $f_{lo,i}$ and $f_{hi,i}$:

$$L_{p,i} = 10\, log_{10} \int_{f_{lo,i}}^{f_{hi,i}} S(f)\, df \;\; \text{dB} \tag{A-6}$$

Summing the sound pressure level of all the bands yields the broadband sound pressure level:

$$\text{Broadband SPL} = 10 \log_{10} \sum_i 10^{\frac{L_{p,i}}{10}} \text{ dB} \tag{A-7}$$

Figure A-2 shows an example of how the decidecade band sound pressure levels compare to the sound pressure spectral density levels of an ambient sound signal. Because the decidecade bands are wider than 1 Hz, the decidecade band SPL is higher than the spectral levels at higher frequencies. Acoustic modelling of decidecade bands requires less computation time than 1 Hz bands and still resolves the frequency-dependence of the sound source and the propagation environment.

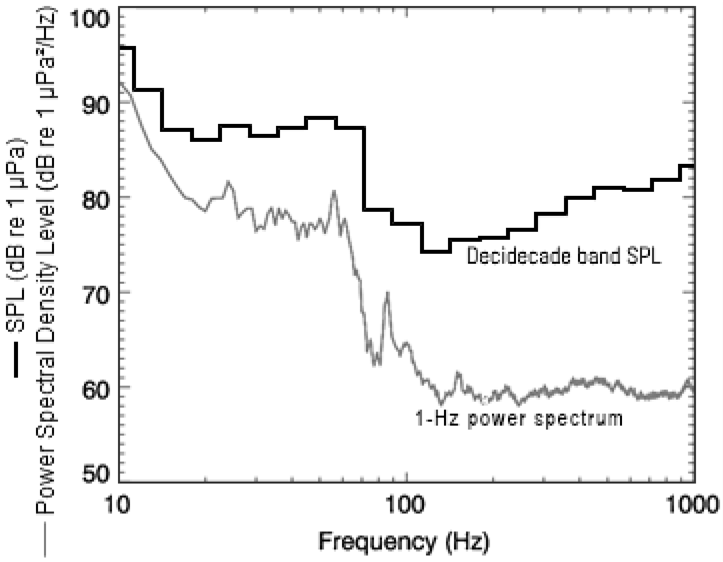

Figure A-2. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient noise shown on a logarithmic frequency scale.Because the decidecade bands are wider with increasing frequency, the decidecade band SPL is higher than the power spectrum.

A.3. Marine Mammal Noise Effect Criteria

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggest that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources—primarily airguns used in seismic surveys—could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for auditory injury, impairment, and disturbance. The following sections summarise the recent development of thresholds; however, this field remains an active research topic.

A.3.1. Injury and Hearing Sensitivity Changes

In recognition of shortcomings of the SPL-only based auditory injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual auditory injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted 24h refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for humans; see Appendix A.4). The SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it implies a 3 dB exchange rate).

As of present, a definitive approach is still not apparent. There is consensus in the research community that an SEL-based method is preferable, either separately or in addition to an SPL-based approach to assess the potential for injuries. In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA 2013, 2015, 2016), NMFS finalised technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2016). The guidance describes auditory injury criteria with new thresholds and frequency weighting functions for the five hearing groups described by Finneran and Jenkins (2012). The latest revision to this work was published in 2018 (NMFS 2018). Southall et al. (2019) revisited the interim criteria published in 2007. All noise exposure criteria in NMFS (2018) and Southall et al. (2019) are identical (for impulsive and non-impulsive sounds); however, the mid-frequency cetaceans from NMFS (2018) are classified as high-frequency cetaceans in Southall et al. (2019), and high-frequency cetaceans from NMFS (2018) are classified as very-high-frequency cetaceans in Southall et al. (2019).

A.3.2. Behavioural Response

Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioural reactions. However, it is recognised that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison and Frankel 2012, Southall et al. 2016, Southall et al. 2021).

A.3.2.1. Non-Impulsive Noise

NMFS currently uses step function (all-or-none) threshold of 120 dB re 1 µPa SPL (unweighted) for non-impulsive sounds to assess and regulate noise-induced behavioural impacts on marine mammals (NOAA 2019). The 120 dB re 1 µPa threshold is associated with continuous sources and was derived based on studies examining behavioural responses to drilling and dredging, referring to Malme et al. (1983), Malme et al. (1984), and Malme et al. (1986), which were considered in Southall et al. (2007). Malme et al. (1986) found that playback of drillship noise did not produce clear evidence of disturbance or avoidance for levels below 110 dB re 1 µPa (SPL), possible avoidance occurred for exposure levels approaching 119 dB re 1 µPa. Malme et al. (1984) determined that measurable reactions usually consisted of rather subtle short-term changes in speed and/or heading of the whale(s) under observation. It has been shown that both received level and proximity of the sound source is a contributing factor in eliciting behavioural reactions in humpback whales (Dunlop et al. 2017, Dunlop et al. 2018).

A.3.2.2. Impulsive Noise

For impulsive noise, NMFS currently uses step function thresholds of 160 dB re 1 µPa SPL (unweighted) to assess and regulate noise-induced behavioural impacts for marine mammals (NOAA 2018, NOAA 2019). The threshold for impulsive sound is derived from the High-Energy Seismic Survey (HESS) panel (HESS 1999) report that, in turn, is based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1984)For impulsive noise, NMFS currently uses step function thresholds of 160 dB re 1 µPa SPL (unweighted) to assess and regulate noise-induced behavioural impacts for marine mammals (NOAA 2018, NOAA 2019). The threshold for impulsive sound is derived from the High-Energy Seismic Survey (HESS) panel (HESS 1999) report that, in turn, is based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1984). The HESS team recognised that behavioural responses to sound may occur at lower levels, but significant responses were only likely to occur above a SPL of 140 dB re 1 µPa. Southall et al. (2007) found varying responses for most marine mammals between a SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but lack of convergence in the data prevented them from suggesting explicit step functions.

A.4. Marine Mammal Frequency Weighting

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

A.4.1. Marine Mammal Frequency Weighting Functions

In 2015, a US Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is expressed as:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \quad \text{(A-8)}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively), phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA's technical guidance that assesses acoustic impacts on marine mammals (NMFS 2018), and in the latest guidance by Southall (2019). The updates did not affect the content related to either the definitions of frequency-weighting functions or the threshold values. Table A-1 lists the frequency-weighting parameters for each hearing group relevant to this assessment, and Figure A-3 shows the resulting frequency-weighting curves.

Table A-1. Parameters for the auditory weighting functions used in this project as recommended by Southall et al. (2019).

Hearing group	a	b	flo (Hz)	fhi (kHz)	*K* (dB)
Low-frequency cetaceans (baleen whales)	1.0	2	200	19,000	0.13
High-frequency cetaceans (most dolphins, plus sperm, beaked, and bottlenose whales)	1.6	2	8,800	110,000	1.20
Very-high-frequency cetaceans (true porpoises, *Kogia*, river dolphins, *Cephalorhynchus* spp., *Lagenorhynchus cruciger* and *L. australis*)	1.8	2	12,000	140,000	1.36

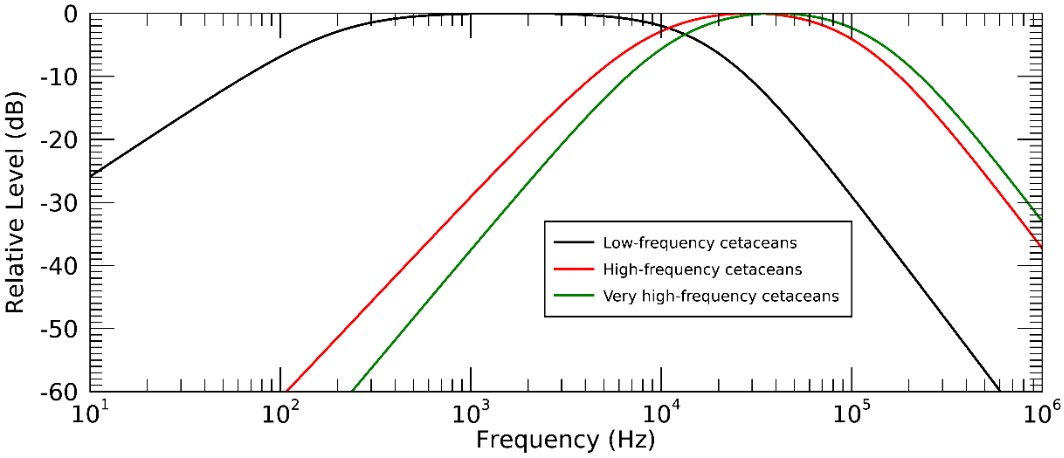

Figure A-3. Auditory weighting functions for functional marine mammal hearing groups used in this project as recommended by Southall et al. (2019).

Appendix B. Methods and Parameters

B.1. Environmental Parameters

B.1.1. Bathymetry

Bathymetry throughout the modelled area was extracted from the Australian Bathymetry and Topography Grid, a 9 arc-second grid rendered for Australian waters (Whiteway 2009). Bathymetry data were re-gridded and combined onto a Map Grid of Australia (MGA) coordinate projection (Zone 50) with a regular grid spacing of 200 × 200 m (Figure B-1).

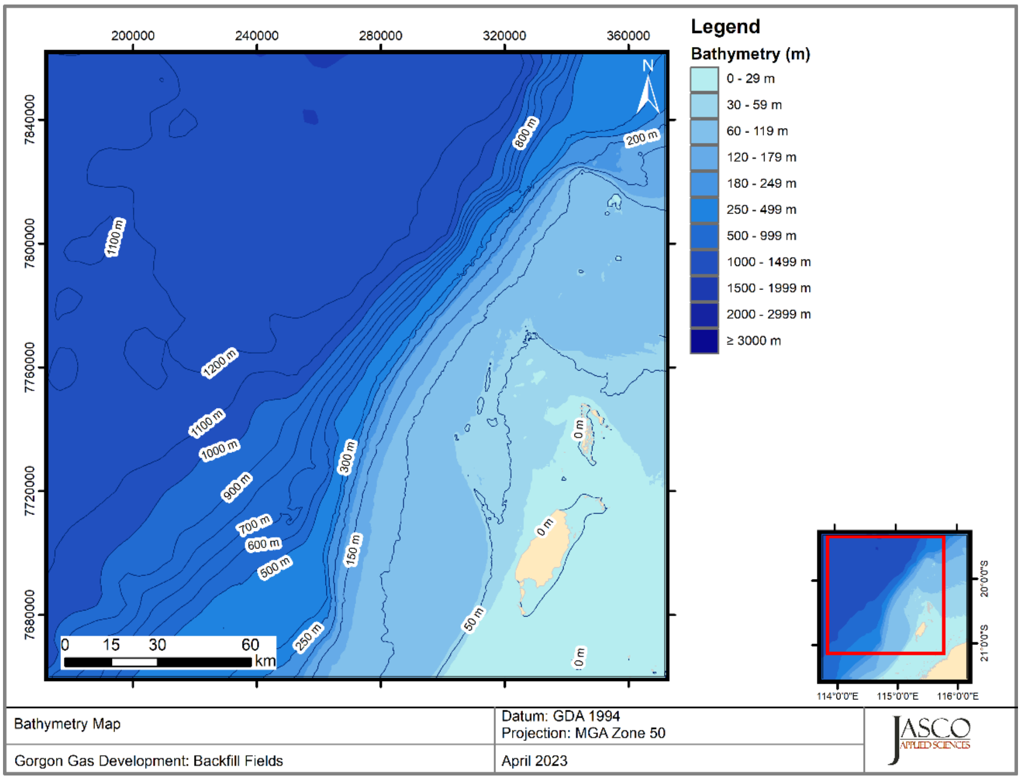

Figure B-1. Bathymetry in the modelled area.

B.1.2. Sound Speed Profile

The sound speed profile in the area was derived from temperature and salinity profiles from the US Naval Oceanographic Office's Generalized Digital Environmental Model V 3.0 (GDEM; Teague et al. 1990, Carnes 2009). GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the US Navy's Master Oceanographic Observational Data Set (MOODS). The climatology profiles include 78 fixed depth points to a maximum depth of 6800 m (where the ocean is that deep). The GDEM temperature-salinity profiles were converted to sound speed profiles according to Coppens (1981).

Mean monthly sound speed profiles were derived from the GDEM profiles at distances less than 100 km around a representative modelled site. To allow for operational flexibility, the sound speed profiles considered for modelling of operations were selected through a sensitivity analysis considering all months, as shown in Figure B-2. The month of August was found to be the most favourable for sound propagation and this profile was considered in the modelling.

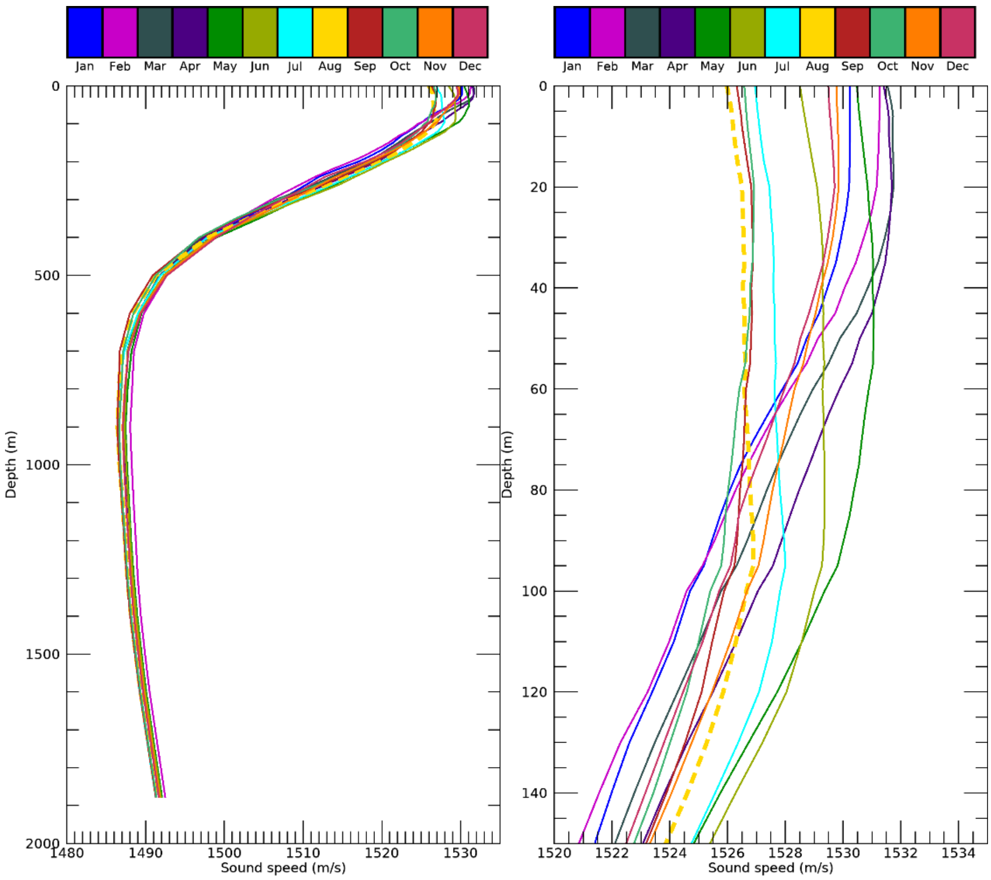

Figure B-2. Sound speed profiles per month for the modelled area: (Left) full profile and (right) top 150 m. The dashed profile indicates the profile considered in the modelling (August).

B.1.3. Geoacoustics

The propagation model used in this study considers five geoacoustic areas, which determine how sound is reflected from the seabed, as well as how it is transmitted, reflected, and absorbed into the sediment layers.

For Areas 1 to 4, information on seabed geology was provided by the client in the form of a geohazards assessment report (Duncan and Erbe 2019). Based on the information provided in that report, the seabed in the study area was divided into four geoacoustic regions.

1. Kangaroo Syncline – The region in water depths greater than 1200 m, close enough to the continental shelf to have potentially been affected by debris flows, as described by Duncan and Erbe (2019).
2. Exmouth Plateau and surrounding area – The Exmouth plateau and the region in water depths greater than 1200 m, considered unlikely to be impacted by debris flow events.
3. Continental Slope – The top of the continental slops was taken as the 200 m bathymetry contour. The bottom of the slope was taken as the 1200 m bathymetry contour, except in the vicinity of the saddle leading to the Exmouth plateau where the 1000 m contour was used.
4. Continental Shelf – Water depths less than 200 m.
5. For the purposes of this modelling study, Area 1 was situated in the Exmouth Plateau, Areas 2 and 3 were situated in the Kangaroo Syncline Area, and Area 4 was situated in the Continental Slope region. The composition of the seabed in each of these regions is summarised in Tables B-1 to B-3.

Table B-1. Geoacoustic profile for the Exmouth Plateau sites (Area 1). Each parameter varies linearly within the stated range. The compressional wave is the primary wave and the shear wave is the secondary wave.

Depth below seafloor (m)	Material	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–5	Carbonate silt	1.70	1561-1566	1.0	130	2.5
5-205	Sedimentary transition layer	1.96	1580-1766	1.0		
>205	Sedimentary rock halfspace	2.40	3400	0.1		

Table B-2. Geoacoustic profile for the Kangaroo Syncline sites (Areas 2 and 3). Each parameter varies linearly within the stated range. The compressional wave is the primary wave and the shear wave is the secondary wave.

Depth below seafloor (m)	Material	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–5	Carbonate silt	1.70	1561-1566	1.0	270	2.5
5-15	45 ky bp debris flow	1.90	1636-1645	1.0		
15-20	Post MTC1 transitional	1.92	1650-1700	1.0		
20-120	Mass transport complex	1.95	1710-1803	0.8		
120-320	Sedimentary transition layer	1.96	1790-1980	1.0		
>320	Sedimentary rock halfspace	2.40	3400	0.1		

Table B-3. Geoacoustic profile for the Continental Slope sites (Area 4). Each parameter varies linearly within the stated range. The compressional wave is the primary wave and the shear wave is the secondary wave.

Depth below seafloor (m)	Material	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–50	Carbonate silt	1.70	1565-1611	1.0	259	2.5
50-200	Sedimentary transition layer	1.96	1620-1759	1.0		
>200	Sedimentary rock halfspace	2.40	3400	0.1		

Area 5, on the Continental Shelf, was located in close proximity to a coring location sampled during IODP Cruise 356 Gallagher et al. (2017). The core information was used to estimate the thickness of the un-lithified sediment and the average sediment lithology. The geoacoustic properties were then calculated using the grain-shearing sediment model of Buckingham (2005) based on the information from Gallagher et al. (2017). The core information indicated a loose sediment layer approximately 450 m thick overlaying the bedrock estimated as cemented calcarenite (Table B-4) (the parameters for calcarenite were taken from Duncan et al. (2013)).

Table B-4. Geoacoustic profile for Continental Shelf sites (Area 5). Each parameter varies linearly within the stated range. The compressional wave is the primary wave and the shear wave is the secondary wave.

Depth below seafloor (m)	Predicted lithology	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0-3	Silty Sand	1.66-1.67	1539-1650	0.24-0.68	200.0	3.65
3-10		1.67-1.69	1650-1740	0.68-0.96		
10-50	Increasingly consolidated sand-silt-clay	1.75-1.78	1704-1872	0.80-1.26		
50-100		1.78	1872-1979	1.26-1.51		
100-450		1.78-1.96	1979-2382	1.51-2.04		
>450	Well-cemented sand/calcarenite	2.20	2600	0.12		

B.2. Sound Propagation Models

B.2.1. Propagation Loss

The propagation of sound through the environment was modelled by predicting the acoustic propagation loss—a measure, in decibels, of the decrease in sound level between a source and a receiver some distance away. Geometric spreading of acoustic waves is the predominant way by which propagation loss occurs. Propagation loss also happens when the sound is absorbed and scattered by the seawater, and absorbed scattered, and reflected at the water surface and within the seabed. Propagation loss depends on the acoustic properties of the ocean and seabed; its value changes with frequency.

If the acoustic energy source level (ESL), expressed in dB re 1 μPa²·s m², and propagation loss (PL), in units of dB, at a given frequency are known, then the received level (RL) at a receiver location can be calculated in dB re 1 μPa²·s by:

$$\mathrm{RL} = \mathrm{SL} - \mathrm{PL}. \qquad \text{(B-1)}$$

B.2.2. MONM-BELLHOP

Long-range sound fields were computed using JASCO's Marine Operations Noise Model (MONM). While other models may be more accurate for steep-angle propagation in high-shear environment, MONM is well suited for effective longer-range estimation. This model computes sound propagation at frequencies of 10 Hz to 1 kHz via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). MONM computes sound propagation at frequencies > 1 kHz via the BELLHOP Gaussian beam acoustic ray-trace model (Porter and Liu 1994).

The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modelled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

MONM computes acoustic fields in three dimensions by modelling propagation loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ number of planes (Figure B-3).

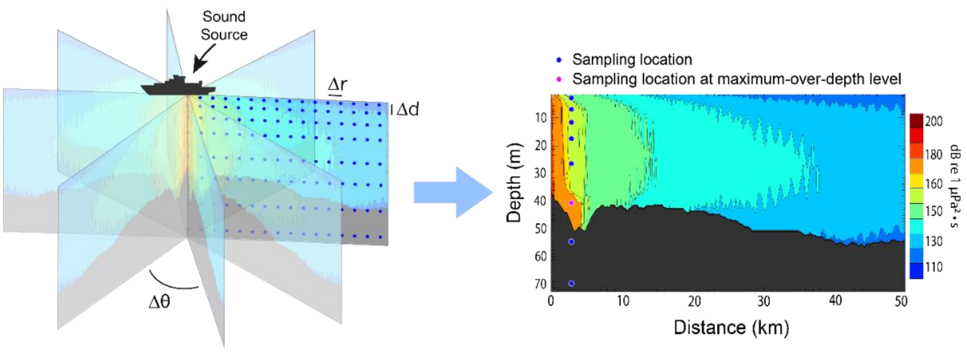

Figure B-3. The N×2-D and maximum-over-depth modelling approach used by MONM.

MONM treats frequency dependence by computing acoustic propagation loss at the centre frequencies of decidecade bands. Sufficiently many decidecade frequency-bands, starting at 10 Hz, are modelled to include most of the acoustic energy emitted by the source. At each centre frequency, the propagation loss is modelled within each of the N vertical planes as a function of depth and range from the source. The decidecade received per-second SEL are computed by subtracting the band propagation loss values from the directional source level in that frequency band. Composite broadband received per-second SEL are then computed by summing the received decidecade levels.

The received 1-s SEL sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. For areas with deep water, sampling is not performed at depths beyond those reachable by marine mammals. The received per-second SEL at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received per-second SEL. These maximum-over-depth per-second SEL are presented as colour contours around the source.

B.3. Estimating Range to Thresholds Levels

Sound level contours were calculated based on the underwater sound fields predicted by the propagation models, sampled by taking the maximum value over all modelled depths above the sea floor for each location in the modelled region. The predicted distances to specific levels were computed from these contours. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure B-4).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure B-4(a). In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases such as shown in Figure B-4(b), on the other hand, $R_{95\%}$ neglects to account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features affecting propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.

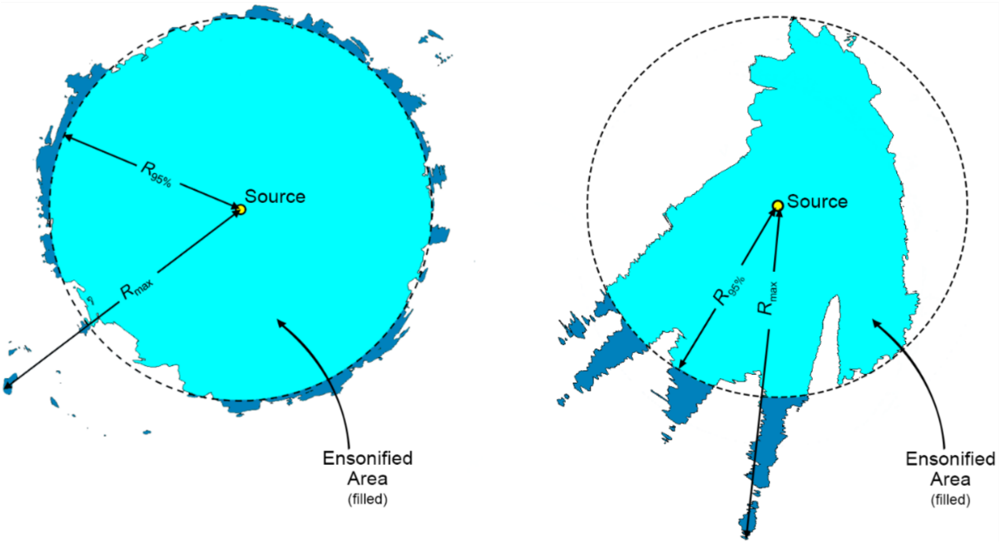

Figure B-4. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

B.4. Estimating Sound Field from Moving Vessels

During vessel transit, new sound energy is constantly being introduced to the environment. The noise footprint for the transiting vessels considered in this report were estimated by modelling the 1-s SEL for the vessel at one location, and by translating and summing these footprints along the vessel transit routes. The vessel locations along the tracks were spaced uniformly, with an approximate step of $\Delta s \approx 100$ m for all scenarios with a track.

The SEL sound field at any given point along the path is dependent upon the duration of exposure, which with a fixed footprint spacing depends upon the speed of the vessel during each segment of the transit. The 1-s SEL footprint at each vessel location (i) were therefore scales based on the speed of the vessel following:

$$\mathrm{SEL}_i = \mathrm{SEL}_{1s} + 10\log_{10}\left(\frac{\Delta s}{v}\right). \tag{B-2}$$

where v represents the vessel speed in m/s.

The present method acceptably reflects large-scale sound propagation features, primarily dependent on water depth, which dominate the cumulative field and is thus considered to provide a meaningful estimate of the SEL_{24h} field.

B.5. Model Validation Information

Predictions from JASCO's propagation models (MONM, FWRAM, and VSTACK) have been validated against experimental data from a number of underwater acoustic measurement programs conducted by JASCO globally, including the United States and Canadian Artic, Canadian and southern United States waters, Greenland, Russia and Australia (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Matthews and MacGillivray 2013, Martin et al. 2015, Racca et al. 2015, Martin et al. 2017a, Martin et al. 2017b, Warner et al. 2017, MacGillivray 2018, McPherson et al. 2018, McPherson and Martin 2018).

In addition, JASCO has conducted measurement programs associated with a significant number of anthropogenic activities that have included internal validation of the modelling (including McCrodan et al. 2011, Austin and Warner 2012, McPherson and Warner 2012, Austin and Bailey 2013, Austin et al. 2013, Zykov and MacDonnell 2013, Austin 2014, Austin et al. 2015, Austin and Li 2016, Martin and Popper 2016).

Appendix C. VSP Source

C.1. Airgun Array Source Model

The source levels and directivity of the seismic source were predicted with JASCO's Airgun Array Source Model (AASM). AASM includes low- and high-frequency modules for predicting different components of the seismic source spectrum. The low-frequency module is based on the physics of oscillation and radiation of airgun bubbles, as originally described by Ziolkowski (1970), that solves the set of parallel differential equations that govern bubble oscillations. Physical effects accounted for in the simulation include pressure interactions between airguns, port throttling, bubble damping, and generator-injector (GI) gun behaviour discussed by Dragoset (1984), Laws et al. (1990), and Landrø (1992). A global optimisation algorithm tunes free parameters in the model to a large library of airgun source signatures.

While airgun signatures are highly repeatable at the low frequencies, which are used for seismic imaging, their sound emissions have a large random component at higher frequencies that cannot be predicted using a deterministic model. Therefore, AASM uses a stochastic simulation to predict the high-frequency (800−25,000 Hz) sound emissions of individual airguns, using a data-driven multiple-regression model. The multiple-regression model is based on a statistical analysis of a large collection of high quality seismic source signature data recently obtained from the Joint Industry Program (JIP) on Sound and Marine Life (Mattsson and Jenkerson 2008). The stochastic model uses a Monte-Carlo simulation to simulate the random component of the high-frequency spectrum of each airgun in an array. The mean high-frequency spectra from the stochastic model augment the low-frequency signatures from the physical model, allowing AASM to predict airgun source levels at frequencies up to 25,000 Hz.

AASM produces a set of "notional" signatures for each array element based on:

- Array layout
- Volume, operating depth, and firing pressure of each airgun
- Interactions between different airguns in the array

These notional signatures are the pressure waveforms of the individual airguns at a standard reference distance of 1 m; they account for the interactions with the other airguns in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in all directions. This far-field array signature is filtered into decidecade bands to compute the source levels of the array as a function of frequency band and azimuthal angle in the horizontal plane (at the source depth), after which it is considered a directional point source in the far field.

A seismic array consists of many sources and the point source assumption is invalid in the near field where the array elements add incoherently. The maximum extent of the near field of an array (R_{nf}) is:

$$R_{nf} < \frac{l^2}{4\lambda} \tag{C-1}$$

where λ is the sound wavelength and l is the longest dimension of the array (Lurton 2002, §5.2.4). For example, a seismic source length of l = 21 m yields a near-field range of 147 m at 2 kHz and 7 m at 100 Hz. Beyond this R_{nf} range, the array is assumed to radiate like a directional point source and is treated as such for propagation modelling.

The interactions between individual elements of the array create directionality in the overall acoustic emission. Generally, this directionality is prominent mainly at frequencies in the mid-range between tens of hertz to several hundred hertz. At lower frequencies, with acoustic wavelengths much larger than the inter-airgun separation distances, the directionality is small. At higher frequencies, the pattern of lobes is too finely spaced to be resolved and the effective directivity is less.

C.2. VSP Source Parameters

The layout of the seismic source is provided in Figure C-1. Details of the airgun parameters are provided in Table C-1. In the context of this source geometry the broadside direction is perpendicular to the sagittal plane of the array and the endfire direction is parallel to the sagittal plane of the array.

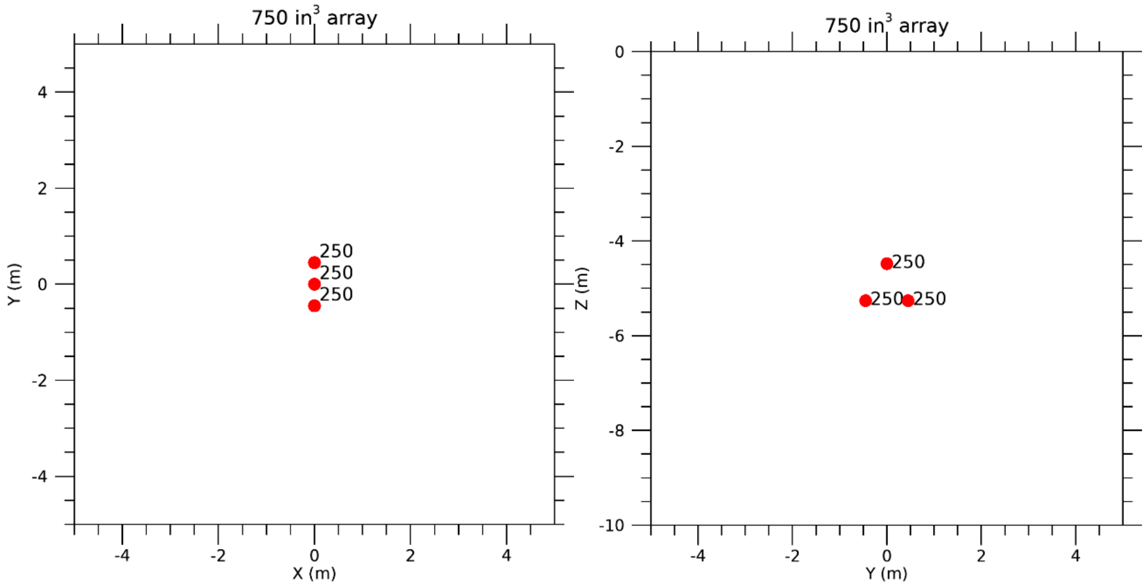

Figure C-1. (Left) Plan and (right) side layouts of the modelled 750 in^3 seismic source array Operational depth is 5 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table C-1.

Table C-1. Layout of the modelled 750 in^3 seismic source array. Operational depth is 5 m. Firing pressure for all guns is 2000 psi. Also see Figure C-1.

Gun	x (m)	y (m)	z (m)	Volume (in^3)
1	0.0	0.0	4.48	250
2	0.0	0.45	5.26	250
3	0.0	−0.45	5.26	250

C.3. Array Source Levels and Directivity

Figure C-2 shows the broadside (perpendicular to the sagittal plane), endfire (parallel to the sagittal plane), and vertical overpressure signature and corresponding power spectrum levels for the 750 in^3 array (see Appendix C.2). Horizontal decidecade band source levels shown as a function of band centre frequency and azimuth (Figure C-3) indicate that this array is mainly isotropic.

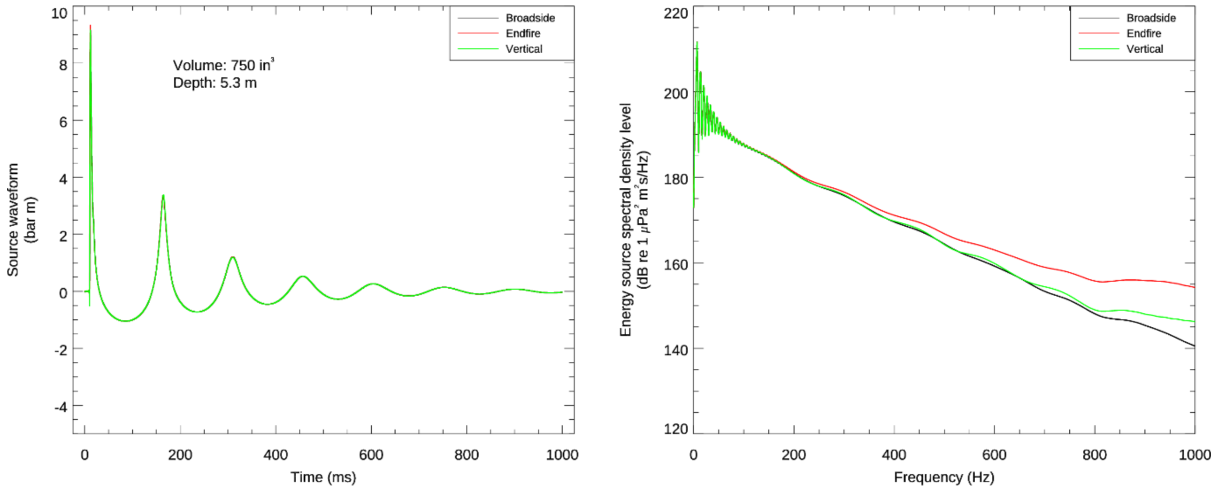

Figure C-2. Predicted source level details for the 750 in^3 array at a 5 m operational depth. (Left) the overpressure signature and (right) the power spectrum for horizontal (broadside and endfire) and vertical directions.

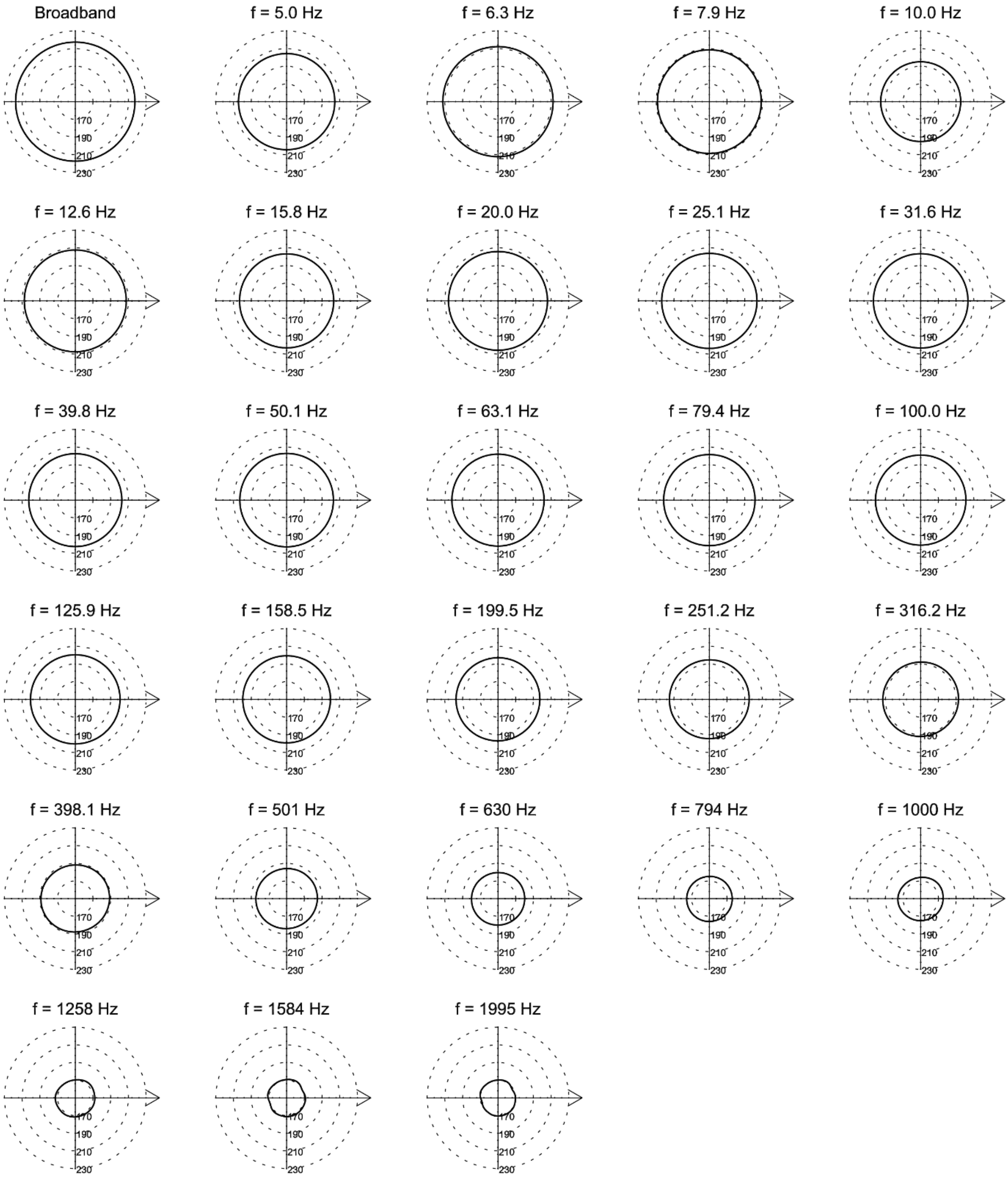

Figure C-3. Directionality of the predicted horizontal source levels for the 750 in^3 seismic source array, 10 Hz to 2 kHz. Source levels (in dB re 1 μPa^2·s m^2) are shown as a function of azimuth for the centre frequencies of the decidecade bands modelled, shown above the plots. The endfire axis (i.e., axis parallel to the sagittal plane) is to the right. Operational depth is 5 m.

Appendix D. Animal Movement and Exposure Modelling

Animal movement and exposure modelling considers the movement of both sound sources and animals over time. Acoustic source and propagation modelling are used to generate 3-D sound fields that vary as a function of distance to source, depth, and azimuth. Sound sources are modelled at representative sites and the resulting sound fields are assigned to source locations using the minimum Euclidean distance. The sound received by an animal at any given time depends on its location relative to the source. Because the true locations of the animals within the sound fields are unknown, realistic animal movements are simulated using repeated random sampling of various behavioural parameters. The Monte Carlo method of simulating many animals within the operations area is used to estimate the sound exposure history of the population of simulated animals (animats).

Monte Carlo methods provide a heuristic approach for determining the probability distribution function (PDF) of complex situations, such as animals moving in a sound field. The probability of an event's occurrence is determined by the frequency with which it occurs in the simulation. The greater the number of random samples, in this case the more simulated animats, the better the approximation of the PDF. Animats are randomly placed, or seeded, within the simulation boundary at a specified density (animats/km^2). Higher densities provide a finer PDF estimate resolution but require more computational resources. To ensure good representation of the PDF, the animat density is set as high as practical allowing for computation time. Typically, the animat density is much higher than the real-world density to ensure good representation of the PDF. The resulting PDF can be scaled using the real-world density if it is available.

Several models for marine mammal movement have been developed (Ellison et al. 1987, Frankel et al. 2002, Houser 2006). These models use an underlying Markov chain to transition from one state to another based on probabilities determined from measured swimming behaviour. The parameters may represent simple states, such as the speed or heading of the animal, or complex states, such as likelihood of participating in foraging, play, rest, or travel. Attractions and aversions to variables like anthropogenic sounds and different depth ranges can be included in the models.

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was based on the open-source marine mammal movement and behaviour model (3MB, Houser 2006) and used to predict the exposure of animats to sound arising from the anthropogenic activities. Animats are programmed to behave like the species likely to be present in the survey area. The parameters used for forecasting realistic behaviours (e.g., diving, foraging, aversion, surface times, etc.) are determined and interpreted from marine species studies (e.g., tagging studies) where available, or reasonably extrapolated from related species. An individual animat's modelled sound exposure levels are summed over the total simulation duration to determine its total received energy, and then compared to the assumed threshold criteria.

JASMINE uses the same animal movement algorithms as 3MB (Houser, 2006), but has been extended to be directly compatible with JASCO's Marine Operations Noise Model (MONM) and Full Waveform Range-dependent Acoustic Model acoustic field predictions, for inclusion of source tracks, and importantly for animats to change behavioural states based on time and space dependent modelled variables such as received levels for aversion behaviour, although aversion was not considered in this study.

D.1. Animal Movement Parameters

JASMINE uses previously measured behaviour to forecast behaviour in new situations and locations. The parameters used for forecasting realistic behaviour are determined (and interpreted) from marine species studies (e.g., tagging studies). Each parameter in the model is described as a probability distribution. When limited or no information is available for a species parameter, a Gaussian or uniform distribution may be chosen for that parameter. For the Gaussian distribution, the user determines the mean and standard deviation of the distribution from which parameter values are drawn. For the uniform distribution, the user determines the maximum and minimum distribution from which parameter values are drawn. When detailed information about the movement and behaviour of a species are available, a user-created distribution vector, including cumulative transition probabilities, may be used (referred to here as a vector model; Houser 2006). Different sets of parameters can be defined for different behaviour states. The probability of an animat starting out in or transitioning into a given behaviour state can in turn be defined in terms of the animat's current behavioural state, depth, and the time of day. In addition, each travel parameter and behavioural state has a termination function that governs how long the parameter value or overall behavioural state persists in simulation.

The parameters used in JASMINE describe animal movement in both the vertical and horizontal planes. The parameters relating to travel in these two planes are briefly described below.

Travel sub-models

- **Direction**– determines an animat's choice of direction in the horizontal plane. Sub-models are available for determining the heading of animats, allowing for movement to range from strongly biased to undirected. A random walk model can be used for behaviours with no directional preference, such as feeding and playing. In a random walk, all bearings are equally likely at each parameter transition time step. A correlated random walk can be used to smooth the changes in bearing by using the current heading as the mean of the distribution from which to draw the next heading. An additional variant of the correlated random walk is available that includes a directional bias for use in situations where animals have a preferred absolute direction, such as migration. A user-defined vector of directional probabilities can also be input to control animat heading. For more detailed discussion of these parameters, see Houser (2006) and Houser and Cross (1999).
- **Travel rate**–defines an animat's rate of travel in the horizontal plane. When combined with vertical speed and dive depth, the dive profile of the animat is produced.

Dive sub-models

- **Ascent rate**–defines an animat's rate of travel in the vertical plane during the ascent portion of a dive.
- **Descent rate**–defines an animat's rate of travel in the vertical plane during the descent portion of a dive.
- **Depth**–defines an animat's maximum dive depth.
- **Reversals**–determines whether multiple vertical excursions occur once an animat reaches the maximum dive depth. This behaviour is used to emulate the foraging behaviour of some marine mammal species at depth. Reversal-specific ascent and descent rates may be specified.
- **Surface interval**–determines the duration an animat spends at, or near, the surface before diving again.

D.2. Exposure Integration Time

The interval over which acoustic exposure (L_E) should be integrated and maximal exposure (L_p) determined is not well defined. Both Southall et al. (2007) and the NMFS (2018) recommend a 24 h baseline accumulation period, but state that there may be situations where this is not appropriate (e.g., a high-level source and confined population). Resetting the integration after 24 h can lead to overestimating the number of individual animals exposed because individuals can be counted multiple times during an operation. The type of animal movement engine used in this study simulates realistic movement using swimming behaviour collected over relatively short periods (hours to days) and does not include large-scale movement such as migratory circulation patterns. For this study, a representative 24-hour period was simulated.

Ideally, a simulation area is large enough to encompass the entire range of a population so that any animal that could approach the source during an operation is included. However, there are limits to the simulation area, and computational overhead increases with area. For practical reasons, the simulation area is limited. In the simulation, every animat that reaches a border is replaced by another animat entering at the opposing border—e.g., an animat crossing the northern border of the simulation is replaced by one entering the southern border at the same longitude. When this action places the animat in an inappropriate water depth, the animat is randomly placed on the map at a depth suited to its species definition. The exposures of all animats (including those leaving the simulation and those entering) are kept for analysis. This approach maintains a consistent animat density and allows for longer integration periods with finite simulation areas.

D.3. Seeding Density and Scaling

Seeding density refers to the spatial sample rate, in units of animats/km^2, used in the simulation. It is not related to the real-world animal density, but rather is a model parameter that controls the how samples are drawn from the model space. The minimum required seeding density for any given project depends on several factors such as bathymetry, source characteristics, and the behavioural profile of the animats, with the main constraint being computation time and resources. Seeding density is adjusted as needed based on model conditions specific to a project or project area.

In the present study, the exposure criteria for continuous sounds were used to determine the number of animats exceeding exposure thresholds. To generate statistically reliable probability density functions, all simulations were seeded with an animat density of 4 animat/km^2 over the entire simulation area. Due to insufficient density data availability, the modelling results are not related to real-world density estimates for pygmy blue whales within the BIA.

Appendix E Emissions Inventory Technical Report

Chevron Australia

Greenhouse Gas Emissions Inventory Technical Report

Gorgon Gas Development: Backfill Fields

ASSIGNMENT P100264-S03
DOCUMENT P-100264-S03-A-REPT-002

XODUS

Perth

Level 1
1 William Street . Perth
WA 6000 . Australia

T +61 (0)86555 5600
E Matthew.Holding@xodusgroup.com

www.xodusgroup.com

REVISIONS & APPROVALS

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REV	DATE	DESCRIPTION	ISSUED	CHECKED	APPROVED	CLIENT
0	11/12/2023	Issued for Information	FC	MH	MH	Chevron
E	22/11/2023	Issued for review	FC	MH	MH	Chevron
D	19/05/2023	Issued for review	FC	MH	MH	Chevron
C	08/05/2023	Issued for review	FC	MH	MH	Chevron
B	31/03/2023	Issued for review	FC	GL, KS	MH	Chevron
A	16/02/2023	Issued for review	FC	GL, KS	GL	Chevron

CONTENTS

1 INTRODUCTION

1.1 Project Overview

The Gorgon Gas Development: Backfill Fields (the Development) is the construction, operation and decommissioning of seven gas fields in the Greater Gorgon Area to maintain gas supply to the Gorgon Foundation Project (GFP). All seven fields are located in Commonwealth waters off the north-west coast of Western Australia (WA); and comprise Chandon, Chrysaor, Dionysus, Eurytion, Geryon, Semele and West Tryal Rocks. The development of these fields was outlined in the original Gorgon Gas Development Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) (Chevron Australia, 2005), which stated that the other fields of the Greater Gorgon Area would be developed once production from the Gorgon and Jansz-Io fields began their natural decline.

The GFP included the construction and operation of the Gorgon Gas Treatment Plant (GTP) and domestic gas plant on Barrow Island, and the development of the Gorgon and Jansz-Io fields. A full definition of the GFP is provided in Section 1.3. To maintain gas supply for operation of the three-train GTP, Chevron Australia plans to supplement the existing subsea gathering network by bringing the next seven fields online. This involves surveys, drilling campaigns, installation of additional subsea infrastructure and infield flowlines to tie into the existing GFP subsea infrastructure.

1.2 Aim and Objectives

This technical report presents the estimated greenhouse gas (GHG) emissions inventory for the Development for the purpose of environmental impact assessment in the Offshore Project Proposal (OPP) required under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* and Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 [OPGGS(E)R]. This includes direct and indirect emissions associated with the Development. NB: the terms Scope 1, 2, and 3 have been used where relevant, as these terms are used in Ministerial Statement No.: 1198 (MS 1198) and *National Greenhouse and Energy Reporting* (NGER) *Act 2007* (Cth).

An outline of the estimation methodology has been included. The GHG emissions inventory has been built by:

- Defining the boundary of assessment
- Reviewing existing data
- Estimating GHG emissions.

1.3 Definitions

Table 1-1 outlines the definitions of the acronyms/abbreviations applied in this document.

Table 1-1: Definitions table

ACRONYM	DETAILS
API	American Petroleum Institute
AUV	Autonomous Underwater Vehicle
CEO	The Chief Executive Officer of the Department of the Public Service of the State responsible for the administration of section 48 of the Environmental Protection Act 1986 (WA), or their delegate.
Certified Improvement	As defined in MS 1198, an improvement to technology and/or processes approved in writing by the CEO as an improvement that was or would be unlikely to occur in the ordinary implementation of the proposal (disregarding the effect of these conditions), and which is the subject of a report that: (a) describes the improvement; (b) demonstrates that the improvement was or would be unlikely to occur in the ordinary implementation of the proposal (disregarding the effect of these conditions); and (c) has been reviewed by a suitably qualified peer reviewer, who has been approved by the CEO, and who confirms that he or she agrees with the conclusions set out in the report.
DomGas	Domestic Gas
EIS	Environmental Impact Statement
GFP	Refers to the 'Gorgon Foundation Project', also described in the fourth train PER/EIS as the 'Gorgon Gas Development Foundation Project', as amended from time to time, which comprises: • the 'initial Gorgon Gas Development', the development proposed in the Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) (Chevron Australia 2005) and subsequently approved under EPBC Reference: 2003/1294 and Ministerial Implementation Statement No. 748 (MS 748). • the 'Revised and Expanded Gorgon Gas Development', the development proposed in the Public Environmental Review (PER) (Chevron Australia 2008) and subsequently approved under EPBC Reference: 2008/4178 and Ministerial Implementation Statements No. 800 and 865. • the 'Jansz–Io Development Project and Jansz Feed Gas Pipeline', the development assessed via EPBC Referral assessment processes and Environmental Impact Statement/Assessment on Referral Information (ARI) (Mobil Australia 2005; Mobil Exploration 2006) and subsequently approved under EPBC Reference: 2005/2184 and Ministerial Implementation Statement No. 769. • the 'Gorgon Gas Development Additional Construction Laydown and Operations Support Area' (Additional Support Area), use of additional uncleared land for the Gorgon Gas Development as approved under Ministerial Implementation Statement No. 965 and regulated through variations to EPBC References: 2003/1294 and 2008/4178. • the 'Fourth Train Expansion Proposal' (Fourth Train Proposal), development proposed in the Public Environmental Review/Environmental Impact Statement (PER/EIS) (Chevron Australia 2014), and subsequently approved under Ministerial Implementation Statement No. 1002 (MS 1002) and regulated through a variation EPBC References: 2011/5942. • as amended by Section 46 of the Environmental Protection Act 1986, and subsequently approved under Ministerial Implementation Statement No. 1136 and Ministerial Implementation Statement No. 1198 (MS 1198).
GFP Emissions	Refers to Gorgon Foundation Project Emissions, which are 'Proposal GHG Emissions' under MS 1198. 'Proposal GHG Emissions' is defined in MS 1198 as Scope 1 GHG Emissions released to the atmosphere as a direct result of an activity or series of activities that comprise/s or form/s part of the proposal, calculated in accordance with: (a) the National Greenhouse Gas Energy and Reporting (NGER) Act 2007 (Cth) and its subsidiary legislation; or (b) if that Act or the relevant subsidiary legislation is amended or repealed such that it does not provide a mechanism for calculating the Proposal Emissions, any other Act, regulation or instrument concerning greenhouse gases as specified by the CEO.

ACRONYM	DETAILS
	For purposes of the Development, GFP Emissions are considered indirect emissions associated with gas processing.
GHGMP	Gorgon GTP Greenhouse Gas Management Plan
GTP	Gorgon Gas Treatment Plant - As defined in GHGMP, GTP includes natural gas trains that produce liquefied natural gas (LNG), condensate and domestic gas (DomGas), Carbon Dioxide Injection System and associated terrestrial facilities such as the accommodation facility, utilities area and waste transfer station.
GHG	Greenhouse Gas
GWP	Global Warming Potential
IMO	International Maritime Organization
IMR	Inspection, Maintenance, and Repair
IPCC AR5	Intergovernmental Panel on Climate Change Fifth Assessment Report
IPIECA	International Petroleum Industry Environmental Conservation Association
LNG	Liquefied Natural Gas
MODU	Mobile Offshore Drilling Unit
NGER	National Greenhouse and Energy Reporting
Non-Reservoir GHG Emissions	As defined in MS 1198, GFP Emissions other than Reservoir Carbon Dioxide which have not been injected underground.
Reservoir Carbon Dioxide	As defined in MS 1198, GHG Emissions that are separated (from natural gas or the products produced from extracted hydrocarbons) in the acid gas removal units and expected to be subsequently injected underground, and where GHG Emissions are defined in MS 1198 as Greenhouse gas emissions expressed in tonnes of carbon dioxide equivalent (CO_2-e) as calculated in accordance with the definition of 'carbon dioxide equivalence' in section 7 of the National Greenhouse and Energy Reporting Act 2007 (Cth), or, if that definition is amended or repealed, the meaning set out in an Act, regulation or instrument concerning greenhouse gases as specified by the Minister. Also referred to in this text as 'Reservoir Carbon Dioxide Emissions' for clarity (i.e. represents the portion emitted to atmosphere rather than injected).
ROV	Remotely Operated Vehicles
The Development	The Development will develop and operate 7 gas fields and associated flowlines and tie-ins, which will feed into the Gorgon GTP on Barrow Island, as outlined in Section 4.1 of the OPP.

Abbreviation	details
CO_2-e	A metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential, by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.
MMTJ	Million terajoules
MMscf	Million standard cubic feet
$MtCO_2$-e	Million tonnes carbon dioxide equivalents
Mtpa	Million tonnes carbon dioxide equivalents per annum
tCO_2-e	Tonnes carbon dioxide equivalent
tCO_2-e/TJ	Tonnes carbon dioxide equivalents per terajoule of product combusted

2 GREENHOUSE GAS ASSESSMENT

In accordance with the requirements of the Environmental Protection Authority's (EPA) Environmental Factor Guideline (EFG) on Greenhouse Gas Emissions (EPA WA, 2020) and MS 1198, Chevron Australia has prepared the Gorgon Greenhouse Gas Management Plan (GHGMP) outlining its plan for managing the GHG emissions for Gorgon Gas Development and the GTP's planned contribution to the Western Australia's (WA) current aspiration of achieving net zero emissions by 2050 (Chevron Australia, 2023). The GHGMP estimates all Scope 1 GHG emissions from GTP outlined in MS 800 within Western Australian jurisdiction and outlines the measures to meet MS 1198 (EPA WA, 2022). The Scope 1 GHG emissions estimated in the GHGMP are defined as Proposal GHG Emissions in MS 1198. For clarity in this document, these Proposal GHG Emissions are referred to as GFP Emissions.

As illustrated by the boundary of assessment in Figure 1-1, this technical report addresses and categorises emissions into the following groups:

- Direct emissions are created as a direct result of the Development activities, including Survey, Drilling, Installation and Commissioning, Operations, and Decommissioning. These emissions originate from the use of mobile offshore drilling unit (MODU) and vessels within Commonwealth jurisdiction, including flaring. Direct emissions from the Development Operations phase includes emissions from vessel use within Commonwealth jurisdiction during the inspection, maintenance, and repair (IMR) activities.
- Indirect emissions from activities associated with processing of gas at the GTP have been included in the GFP Emissions. Key sources of emissions include:
    - Liquefaction gas turbines
    - Power generation gas turbines
    - Acid gas removal (Reservoir CO_2) venting
    - Flaring
    - Fired heaters
    - Other emissions; including fugitive emissions and diesel used for transport and machinery, tugs, pilots and other marine vessels, and back-up power generation at the accommodation facility.

  The production of the Greater Gorgon Gas Fields, including the Development, and its processing at the GTP was described within EPBC Reference: 2003/1294 and MS 748.
- Downstream indirect emissions associated with those contemplated backfill fields were similarly outlined within EPBC Reference: 2003/1294 and MS 748. While development of backfill fields was articulated under previous primary approvals documentation, the OPP constitutes the primary approval document for these fields. The Gorgon Gas Development supplies both the Australian domestic market and the international market, so these third-party indirect emissions may occur across multiple global regions. A large percentage of LNG produced by the Gorgon Gas Development is supplied internationally under long-term contracts. This long-term export market is primarily Japan, with some exports to other countries including South Korea. These indirect emissions would be direct emissions for the end consumers and would also have to operate under other regulatory regimes, Australian, Japanese, and South Korean, to manage their emissions and any associated impacts.

There are no indirect emissions attributed to the purchase of an energy commodity (i.e., Scope 2) associated with the Development as Chevron Australia generates its own power requirements directly.

The GHG emissions inventory excludes the following emission sources:

- Flights and helicopters for personnel travel
- Embodied carbon from construction materials.

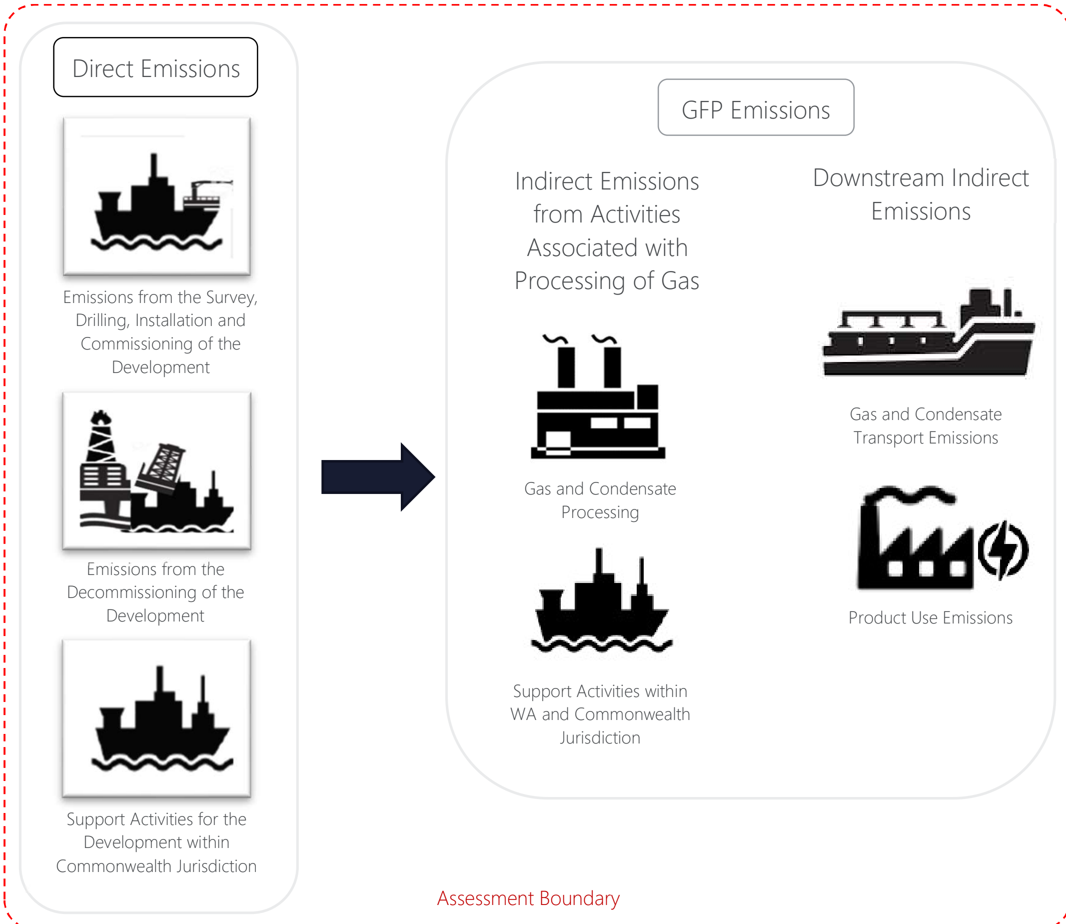


Figure 2-1: Boundary of assessment

The indicative duration for each phase of the Development is as documented in the OPP (Xodus, 2022). The first stage of the Development is likely to be ready for construction in 2025. The GTP is anticipated to operate for 8,160 hours per year (or 340 days per year) (Chevron Australia, 2005).

The life of the Development is within the 60-year life of the GFP (Chevron Australia, 2005). The operations phase is forecast to end in approximately 2066 and decommissioning phase by approximately 2070.

3 METHODS

3.1 Direct GHG Emissions

For direct emissions estimation, the calculations are based on the methodologies consistent with the NGER Act and its supporting regulations, determinations, and technical guidelines (Clean Energy Regulator, 2022). Estimates for fuel usage of vessels and MODU have been extracted from Xodus' database. Note that where options are included, the worst-case option related to GHG emissions has been assessed.

The following information/assumptions have been used for estimating the direct emissions.

- Well drilling:
  - A total of 40 wells have been considered for the Development.
  - The approximate emissions from flaring of natural gas during well testing and completions have been taken as 60 MMscf/day. Flaring is a contingency activity and if required, it will be undertaken from one well at a time, with an estimated duration of approximately one day per well. Unforeseen circumstances such as weather events, may cause an additional flaring. As flaring is not planned to be undertaken at all wells, the emissions estimate for flaring remains based on approximately one day per well as this should not impact the overall emissions envelope.
  - Emissions from venting have been taken as 0.1 MMscf/well.
- Operations:
  - The IMR activities will be undertaken every two years and each IMR event will take 20 working days on average.
  - The approximate emissions from flaring of natural gas during well interventions have been taken as 60 MMscf/day. Flaring is a contingency activity and if required, it will be undertaken from one well at a time, with an estimated duration of approximately one day per well. Unforeseen circumstances such as weather events, may cause an additional flaring. As flaring is not planned to be undertaken at all wells, the emissions estimate for flaring remains based on approximately one day per well as this should not impact the overall emissions envelope.
- Decommissioning:
  - Emissions from decommissioning activities have been assumed to be 60% of the emissions from well drilling (verified with Xodus' database).
- Support activities:
  - Anticipated vessel use is shown in Table 3-1.
  - Vessel standby days have been taken as 20% of the vessel working days.

Table 3-1: Input for estimating the direct emissions

PHASE	SURVEY	DRILLING	INSTALLATION AND COMMISSIONING	OPERATIONS	DECOMMISSIONING
Duration (cumulative days)	105	3,652	1,176	29,920	2,088
Flaring of gas (MMscf/well)	-	60	-	60 (during IMR)	36
Venting (MMscf/well)	-	0.1	-	-	0.06
Vessel requirement:	• Survey • ROV/ AUV	• MODU • Support • Supply	• Pipelay • Heavy construction • Light construction • Support • ROV/ AUV	• Light construction • Support	• MODU • Survey • Support • Supply

3.2 Indirect GHG Emissions

3.2.1 Indirect GHG Emissions Associated with Gas Processing

For indirect emissions estimation from activities associated with processing of gas at the GTP, the GFP Emissions data was supplied by Chevron Australia. The emissions data supplied include historical actual and forecast indirect emissions, based on the methodologies consistent with the NGER Act and its supporting regulations, determinations, and technical guidelines (Clean Energy Regulator, 2022).

3.2.2 Downstream Indirect GHG Emissions

Downstream indirect GHG emissions estimates from product transport and use were supplied by Chevron Australia. These were calculated by adopting the following methodologies as outlined in the GHGMP (Chevron Australia, 2023):

- Emissions factors sourced from IMO Resolution MEPC.245(66) (International Maritime Organization, 2018), and IPCC AR5 100-year GWP.
- Emissions from third party use of products are calculated in alignment with methods in Category 11 of IPIECA, Estimating Petroleum Industry Value Chain (Scope 3) Greenhouse Gas Emissions (IPIECA, 2016).
- Evaluation based upon LNG, Condensate and Domgas production ratios from a representative year (FY19 as per the GHGMP and Operations EP) and a contemporary LNG forecast applying American Petroleum Institute (API) compendium methodologies and factors (American Petroleum Institute, 2021, 2009) and IPCC AR5 100-year global warming potential.
- Transport emissions estimated from shipping fuel consumption, scaled for production.

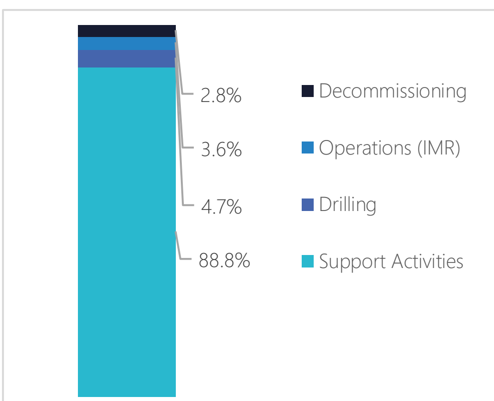
4 RESULTS

4.1 Direct GHG Emissions

The total direct GHG emissions are estimated to be approximately 3.7 MtCO_2-e throughout the life of the Development.

As presented in Figure 4-1, when broken down by emissions activity, approximately 3.3 MtCO_2-e or around 89% of the direct emissions are attributed to the use of Support Activities (vessels and MODU), and approximately 0.4 MtCO_2-e or around 11% attributable to flaring and venting during Drilling, Operations (IMR) and Decommissioning. Apart from the Support Activities, there are no direct emissions from the Operations.

When considering the timing of the Support Activities across the different stages of the Development, the Installation and Commissioning phase of the Development presents the largest phase of direct GHG emissions, with approximately 2.1 MtCO_2-e (58%), followed by the Drilling phase estimated to emit approximately 0.8 MtCO_2-e (22%), and the Decommissioning phase with estimated emissions around 0.5 MtCO_2-e (13%).



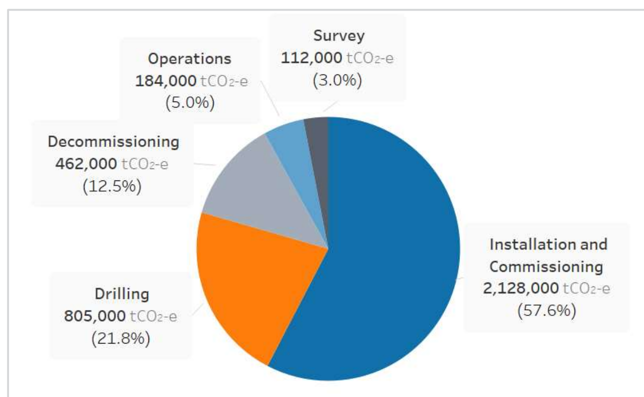


Figure 4-1: Direct GHG emissions overview

4.2 Indirect GHG Emissions Associated with Gas Processing

4.2.1 Indirect Emissions Associated with Gas Processing Historical Profile

Figure 4-2 shows the historical GHG profile of the GFP Emissions as per the GHGMP (Chevron Australia, 2023), however also incorporating GFP vessel-based activities occurring in Commonwealth waters. Commissioning activities were undertaken in FY16 and FY17 and this resulted in elevated flaring emissions. Reservoir CO_2 emissions increased in FY18/19 due to technical issues which were then resolved with the start-up and operation of the Carbon Dioxide Injection System in FY20. The primary source of emissions in FY20 and FY21 was combustion of fuel gas in the Liquefaction Gas Turbines that drive refrigerant compressors used for LNG liquefaction. Reservoir CO_2 emissions were elevated in FY22 due to injection rate limitations associated with reservoir pressure management.

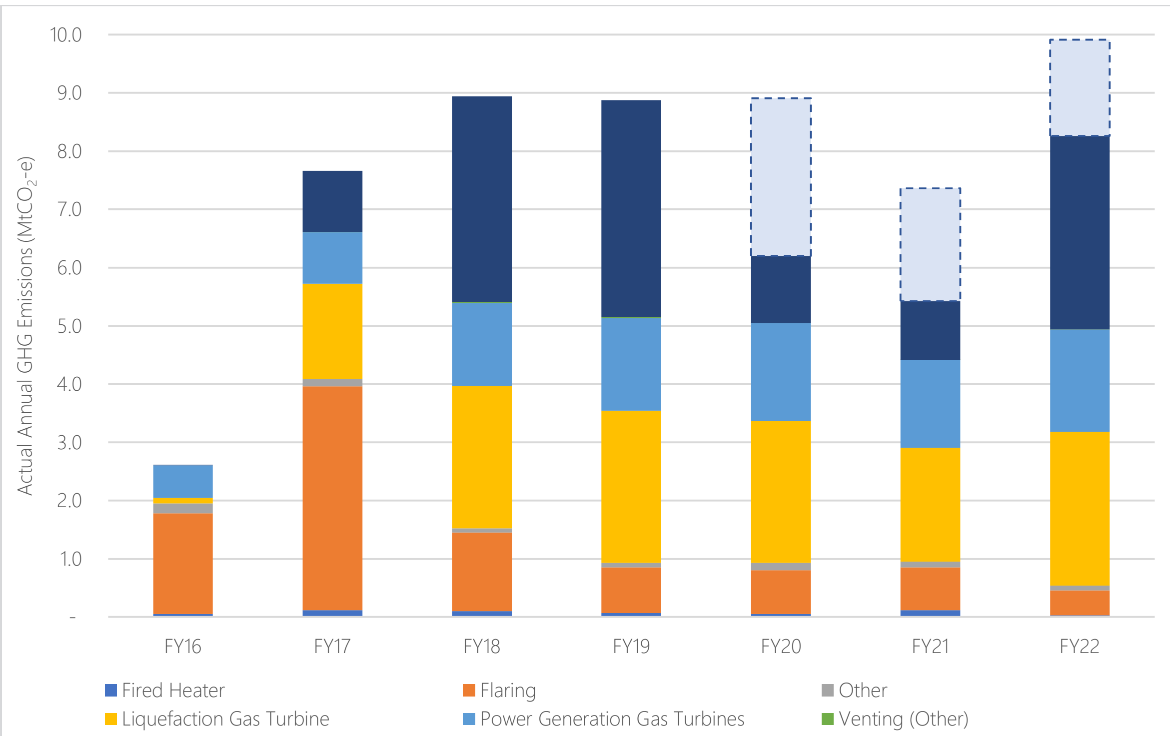


Figure 4-2: Historical annual breakdown of the GFP Emissions

4.2.2 Indirect Emissions Associated with Gas Processing Forecast

As summarised in Table 4-1, the total estimated indirect emissions associated with gas processing (also referred to as GFP Emissions), are 211 $MtCO_2$-e for the remainder of the life of the GFP (FY23+). The estimated GFP GHG Emissions Intensity, calculated based on a total of 34 MMTJ of production from the GTP, has been estimated to be 6.2 tCO_2-e/TJ.

As shown in Figure 4-3, the key emission sources for the remainder of the life of the GFP (FY23+) are the Liquefaction Gas Turbines and Power Generation Gas Turbines, consisting of 42% and 37% of the total emissions respectively.

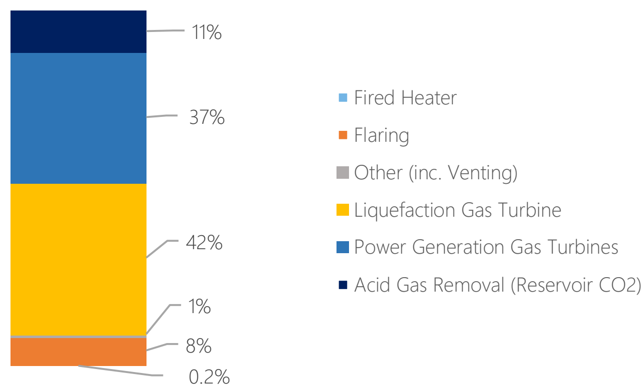


Figure 4-3: Indirect emissions breakdown (GFP Emissions over the remainder of the life of the GFP)

Table 4-1: Scope 1 (Indirect) emissions overview

ESTIMATED EMISSIONS DATA FOR THE REMAINDER OF THE LIFE OF THE GFP (FY23+)	UNIT	VALUE
Estimated Emissions	**Mtpa**	**9.5**
GFP Emissions	**$MtCO_2$-e**	**211**
Reservoir Carbon Dioxide Emissions[1]	$MtCO_2$-e	24
Non-Reservoir GHG Emissions	$MtCO_2$-e	187
GFP GHG Emissions Intensity	**tCO_2-e/TJ**	**6.2**
Reservoir GHG Emissions Intensity	tCO_2-e/TJ	0.7
Non-Reservoir GHG Emissions Intensity	tCO_2-e/TJ	5.5
Estimated Net Emissions per MS 1198		
Net GFP GHG Emissions	**$MtCO_2$-e**	**92**
Net GFP GHG Emissions Intensity[2]	**tCO_2-e/TJ**	**2.7**

[1] Reservoir Carbon Dioxide Emissions estimates range from ~24 – 47 $MtCO_2e$, while GFP Emissions range from ~211 – 234 $MtCO_2$-e.

[2] The Net GHG Emissions Intensity applies after the MS 1198 limits have been met, factoring in the combined effects of emissions reductions, technical abatement and/or offsetting.

The production of the Greater Gorgon Gas Fields via processing at the GTP was approved under EPBC Reference: 2003/1294 and MS 748. Therefore the indirect emissions from activities associated with processing of gas at the GTP as a result of the Development have been assessed and approved under EPBC Reference: 2003/1294 and MS 748. The Fourth Train Expansion Proposal PER/Draft EIS, outlined an annual estimated emission rate of 9.5 Mtpa CO_2-e for three LNG trains, which was subsequently approved under EPBC Reference: 2011/5942 and MS 1002. The implementation of the Development is within the approved emissions of 9.5 Mtpa established in the Fourth Train Expansion Proposal.

4.2.3 Ministerial Statement 1198

Condition 27.1 of MS 1198 applies net GHG emissions limits (Scope 1) to the Gorgon Gas Development to ensure that the net GHG emissions (Scope 1) do not exceed:

- 5,220,000 tCO_2-e/year for the period until 30 June 2030
- 4,250,000 tCO_2-e/year for the period between 1 July 2030 and 30 June 2035
- 3,220,000 tCO_2-e/year for the period between 1 July 2035 and 30 June 2040
- 2,120,000 tCO_2-e/year for the period between 1 July 2040 and 30 June 2045
- 1,090,000 tCO_2-e/year for the period between 1 July 2045 and 30 June 2050
- zero tCO_2-e/year for every five-year period from 1 July 2050 onwards.

Under MS 1198 Condition 27.1, the Net GHG Emissions estimate is 92 MtCO_2-e for the remainder of the life of the GFP, and the corresponding Net GHG Emissions Intensity is 2.7 tCO_2-e/TJ. The Net GHG Emissions Intensity represents the emissions intensity after the MS 1198 conditions have been met, factoring in the combined effects of emissions reductions, abatement and/or offsetting.

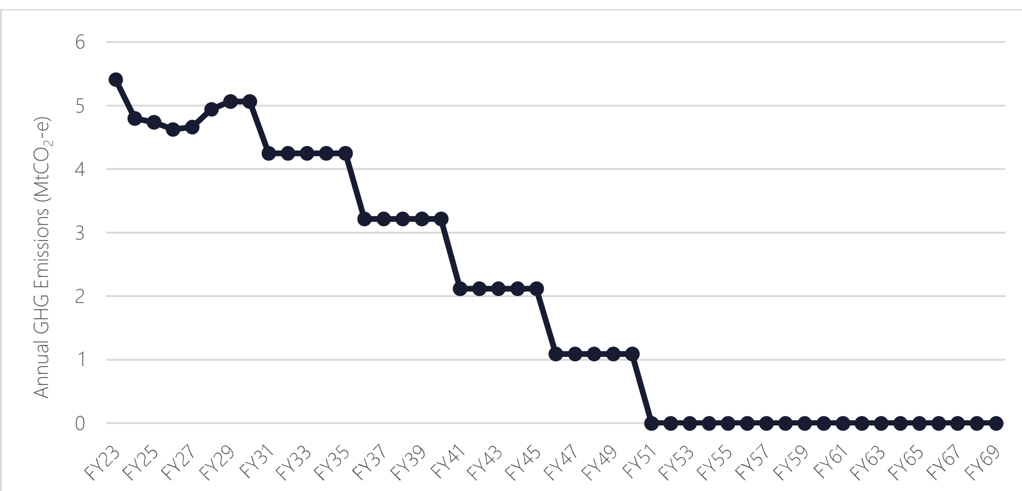


Figure 4-4: Annual Net GHG Emissions under MS 1198 condition

4.3 Downstream Indirect GHG Emissions

4.3.1 Downstream Indirect Emissions Historical Profile

Figure 4-5 shows the historical GHG profile of the downstream indirect emissions from GFP associated with transport and third-party end of use of products, estimated using the methodology in Section 3 and applying historical production data. This results in a total of 253 MtCO_2-e to FY22.

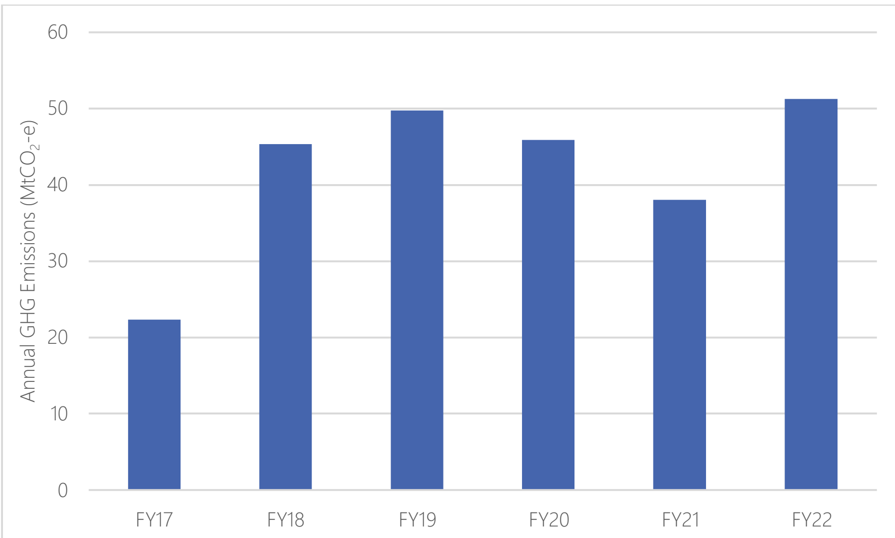


Figure 4-5: Historical annual downstream indirect emissions profiles

4.3.2 Downstream Indirect Emissions Forecast

For the Gorgon Gas Development as a whole including the Development, using the methodology in Section 3 and applying the forecast production profile, the estimate of downstream indirect GHG emissions associated with transport and third-party end of use of products is an annual average of approximately 38 Mtpa, or approximately 49 Mtpa for a representative production year of Three-Train operation (based on a total of 34 MMTJ of gas to be produced at the GTP). The associated downstream indirect emissions intensity is estimated to be 50 tCO_2-e/TJ. This figure corresponds to total potential downstream indirect emissions and does not take into account any emissions mitigations and reductions associated with shipping or undertaken by the end user. The downstream indirect emissions are outside of Chevron Australia's operational control.

5 CONCLUSIONS

This technical report presents the GHG emissions inventory for the Development separately and as part of the Gorgon Gas Development.

An assessment has been conducted to derive the direct, indirect and downstream indirect emissions with the following key points:

- Direct emissions are estimated to be approximately 3.7 $MtCO_2$-e throughout the life of the Development. These consist of:
  - 89% emissions from vessels and MODU
  - 11% emissions from flaring and venting.
- Indirect emissions from the Gorgon Gas Development in Australia (GFP Emissions) are estimated to be approximately 211 $MtCO_2$-e for the remainder of the life of the GFP (FY23+), with the GFP GHG Emissions Intensity of 6.2 tCO_2-e/TJ. These consist of:
  - 42% emissions from Liquefaction Gas Turbines
  - 37% emissions from Power Generation Gas Turbines
  - 11% emissions from Acid Gas Removal (Reservoir CO_2)
  - 8% emissions from Flaring
  - 0.2% emissions from Fired Heater
  - 1% emissions from others.
- The production of the Greater Gorgon Gas Fields via processing at the GTP was approved under EPBC Reference: 2003/1294 and MS 748. Therefore the indirect emissions from activities associated with processing of gas at the GTP as a result of the Development have been assessed and approved under EPBC Reference: 2003/1294 and MS 748. The Fourth Train Expansion Proposal PER/Draft EIS, outlined an annual estimated emission rate of 9.5 Mtpa CO_2-e for three LNG trains, which was subsequently approved under EPBC Reference: 2011/5942 and MS 1002. The implementation of the Development does not increase emissions above the approved emissions of 9.5 Mtpa established in the Fourth Train Expansion Proposal.
- MS 1198 requires that Net GHG Emissions are limited to 92 $MtCO_2$-e for the remainder of the life of the GFP (FY23+). The emissions intensity that will be required is estimated at 2.7 tCO_2-e/TJ produced.
- Downstream indirect GHG emissions are estimated to be an annual average of approximately 38 Mtpa, or approximately 49 Mtpa for a representative production year of Three-Train operation (based on a total of 34 MMTJ of gas to be produced at the GTP), with an emissions intensity of 50 tCO2-e/TJ produced.
- The production of the Greater Gorgon Gas Fields via processing at the GTP was approved under EPBC Reference: 2003/1294 and MS 748. Therefore the downstream indirect emissions as a result of the Development have been assessed and approved under EPBC Reference: 2003/1294 and MS 748.

6 REFERENCES

Author	Title
American Petroleum Institute, 2021	Compendium of Greenhouse Gas Emissions - Methodologies for the Natural Gas and Oil Industry.
American Petroleum Institute, 2009	Compendium of Greenhouse Gas Emissions Methodologies for the Natural gas and Oil Industry.
Chevron Australia, 2023	Gorgon Gas Treatment Plant Greenhouse Gas Management Plan (GOR-COP-03025).
Chevron Australia, 2005	Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Gorgon Development.
Clean Energy Regulator, 2022	Measurement Determination [WWW Document]. URL https://www.cleanenergyregulator.gov.au/NGER/Legislation/Measurement-Determination (accessed 12.5.22).
EPA WA, 2020	Statement to amend the implementation conditions applying to a proposal (No. Statement No. 1198), Section 46 of the Environmental Protection Act 1986) (accessed 12.5.22).
EPA WA, 2022	Environmental Factor Guideline - Greenhouse Gas Emissions (accessed 12.5.22).
International Maritime Organization, 2018	2018 Guidelines on the Method of Calculation of the Attained Energy Efficiency Design Index (EEDI) for new ships (No. MEPC.308(73)).
IPIECA, 2016	Estimating petroleum industry value chain (Scope 3) greenhouse gas emissions, Overview of methodologies.
Xodus, 2022	Draft Offshore Project Proposals for Gorgon Gas Development: Backfill Fields.

Appendix F Aboriginal Cultural Heritage Inquiry System Report

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

Search Criteria

123 Aboriginal Cultural Heritage (ACH) Directory in Shapefile - BFF Hydrocarbon Social EMBA

Disclaimer

The *Aboriginal Cultural Heritage Act 2021 (Act)* recognises, protects, conserves, and preserves Aboriginal cultural heritage (ACH), and recognises the fundamental importance of ACH to Aboriginal people and its role in Aboriginal communities past, present and future. The Act recognises the value of ACH to Aboriginal people as well as to the wider Western Australian community.

Aboriginal cultural heritage in Western Australia is protected, whether or not the ACH has been reported to the ACH Council or exists on the Directory.

The information provided is made available in good faith and is predominately based on the information provided to the Department of Planning, Lands and Heritage by third parties. The information is provided solely on the basis that readers will be responsible for making their own assessment as to the accuracy of the information. If you find any errors or omissions in our records, including our maps, it would be appreciated if you email the details to the Department at AboriginalHeritage@dplh.wa.gov.au and we will make every effort to rectify it as soon as possible.

Terminology

ID: Reported ACH is assigned a unique ID by the Department of Planning, Lands and Heritage using the format: ACH-00000001. For ACH places on the former Register the ID numbers remain unchanged and use the new format. For example the ACH ID of the place Swan River was previously '3536' and is now 'ACH-00003536'.

Access and Restrictions:

- **Boundary Reliable (Yes/No):** Indicates whether the location and extent of the ACH boundary is considered reliable.
- **Boundary Restricted = No:** ACH location is shown as accurately as the information submitted allows.
- **Boundary Restricted = Yes:** To preserve confidentiality the exact location and extent of the place is not displayed on the map. However, the shaded region (generally with an area of at least 4km²) provides a general indication of where the ACH is located. If you are a landowner and wish to find out more about the exact location of the place, please contact the Department of Planning, Lands and Heritage.
- **Culturally Sensitive = No:** Availability of information that the Department of Planning, Lands and Heritage holds in relation to the ACH is not restricted in any way.
- **Culturally Sensitive = Yes:** Some of the information that the Department of Planning, Lands and Heritage holds in relation to the ACH is restricted if it is considered culturally sensitive information. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the people who provided the information. To request access please contact AboriginalHeritage@dplh.wa.gov.au.
- **Culturally Sensitive Nature:**
  - **No Gender / Initiation Restrictions:** *Anyone* can view the information.
  - **Men only:** Only *males* can view restricted information.
  - **Women only:** Only *females* can view restricted information.

Status:

- **ACH Directory**: Aboriginal cultural heritage place or cultural landscape.
- **Pending**: Aboriginal cultural heritage place or cultural landscape with information in a verification stage.
- **Historic**: Aboriginal heritage places determined to not meet the criteria of Section 5 of the Aboriginal Heritage Act 1972. Includes places that no longer exist as a result of land use activities with existing approvals.

ACH Type:

- **Cultural Landscape:** a group of areas interconnected through the tangible elements of Aboriginal culture heritage present.
- **Place**: an area in which tangible elements of Aboriginal cultural heritage are present.

Place Type: The type of Aboriginal cultural heritage place. For example an artefact scatter place or engravings place.

Legacy Place Status: A status determined under the previous *Aboriginal Heritage Act 1972*:

- **Registered Site:** the place was assessed as meeting Section 5 of the *Aboriginal Heritage Act 1972.*
- **Lodged:** Information was received in relation to the place, but an assessment was not completed to determine if it met section 5 of the *Aboriginal Heritage Act 1972.*
- **Stored Data/Not a Site:** The place was assessed as not meeting Section 5 of the *Aboriginal Heritage Act 1972.*

Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place.

Coordinates

Map coordinates are based on the GDA 94 Datum.

Basemap Copyright

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Topographic basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community.

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
508	POINT MURAT 03	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P07503
563	POINT MURAT 01	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P07501
564	POINT MURAT 02	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P07502
628	CAMP THIRTEEN BURIAL	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Burial	*Registered Knowledge Holder names available from DPLH	Registered Site	P07434
873	MONTEBELLO IS: NOALA CAVE.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden; Rock Shelter	*Registered Knowledge Holder names available from DPLH	Registered Site	P07287
883	BARROW ISLAND 01	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07291
884	BARROW ISLAND 02	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07292
885	BARROW ISLAND 03	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07293
886	BARROW ISLAND 04	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07294
887	BARROW ISLAND 05	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07295
888	BARROW ISLAND 06 A-F	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07296
889	BARROW ISLAND 07	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07297

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
890	BARROW ISLAND 08	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07298
891	BARROW ISLAND 09	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07299
892	BARROW ISLAND 10	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07300
893	BARROW ISLAND 11	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07301
894	BARROW ISLAND 12	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07302
926	MONTEBELLO IS: HAYNES CAVE.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Sub surface cultural material; Artefacts / Scatter; Midden; Rock Shelter	*Registered Knowledge Holder names available from DPLH	Registered Site	P07286
973	ROSEMARY IS.18: DEEP WATER	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P07226
974	ROSEMARY IS.19: CHITON	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P07227
975	ROSEMARY IS.20: HALFWAY CK	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P07228
6311	POINT MURAT.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Burial; Artefacts / Scatter; Camp; Midden; Other	*Registered Knowledge Holder names available from DPLH	Registered Site	P06628
6346	MT SALT	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Burial	*Registered Knowledge Holder names available from DPLH	Lodged	P06610
6575	JINTA 1 MIDDEN	Yes	No	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06370

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
6617	BURUBARLADJI	Yes	Yes	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Creation / Dreaming Narrative	*Registered Knowledge Holder names available from DPLH	Registered Site	P06362
6618	DEW TALU.	Yes	Yes	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Ritual / Ceremonial; Water Source	*Registered Knowledge Holder names available from DPLH	Registered Site	P06363
6754	OSPREY BAY 6	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06165
6755	OSPREY BAY INTERDUNAL 1	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06166
6756	OSPREY BAY INTERDUNAL 2	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06167
6757	BLOODWOOD CREEK MIDDEN 1	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06168
6758	BLOODWOOD CREEK MIDDEN 2	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06169
6759	BLOODWOOD CREEK MIDDEN 3	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06170
6760	BLOODWOOD CREEK SHORELINE	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06171
6761	LOW POINT MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06172
6762	MILYERING MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06173
6763	YARDIE ROCKSHELTERS NORTH.	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden; Rock Shelter	*Registered Knowledge Holder names available from DPLH	Registered Site	P06174

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
6764	CAMP 17 SOUTH MIDDENS	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06175
6765	CAMP 17 NORTH MIDDENS	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06176
6782	28 MILE CREEK NORTH 1	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06140
6783	28 MILE CREEK NORTH 2	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Lodged	P06141
6784	MANDU MANDU CREEK SOUTH	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06142
6785	MANDU MANDU CREEK NORTH	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06143
6786	LAKESIDE COASTAL PLAIN	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Lodged	P06144
6789	TURQUOISE BAY NORTH	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Lodged	P06147
6790	YARDIE CREEK SOUTH 1	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06148
6791	YARDIE CREEK SOUTH 2	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06149
6797	YARDIE WELL ROCKSHELTER.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Sub surface cultural material; Artefacts / Scatter; Midden; Other; Rock Shelter	*Registered Knowledge Holder names available from DPLH	Registered Site	P06155
6798	YARDIE INTERDUNAL SWALE	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06156

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
6799	YARDIE BEACH MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06157
6800	OYSTER STACKS MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06158
6801	NORTH T-BONE BAY	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06159
6802	OSPREY BAY 1	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06160
6803	OSPREY BAY 2	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06161
6804	OSPREY BAY 3	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06162
6805	OSPREY BAY 4	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06163
6806	OSPREY BAY 5	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06164
7126	MESA CAMP	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05792
7203	BAUBOODJOO POINT (Bruboodjoo Midden Site)	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Camp; Hunting Place; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05707
7206	WEALJUGOO MIDDEN.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Camp; Hunting Place; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05710
7208	MILYERING ROCKS.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Hunting Place	*Registered Knowledge Holder names available from DPLH	Lodged	P05712

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
7254	SANDY BAY NORTH	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05652
7265	LAKE SIDE VIEW	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05664
7298	YARDIE CREEK ROCKSHELTERS	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Registered Site	P05644
7299	YARDIE CREEK	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05645
7300	MANDU MANDU CK ROCKSHELTERS	Yes	Yes	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Registered Site	P05646
7303	TULKI WELL MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05649
7304	PILGRAMUNNA BAY MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05650
7305	MANGROVE BAY.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Burial; Artefacts / Scatter; Hunting Place; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05651
8301	NINGALOO STATION	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Registered Site	P04353
10381	VLAMING HEAD	Yes	No	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Ritual / Ceremonial; Creation / Dreaming Narrative	*Registered Knowledge Holder names available from DPLH	Registered Site	P01799
11401	5 Mile Well (Cape Range)	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Sub surface cultural material; Artefacts / Scatter; Engraving; Painting; Quarry	*Registered Knowledge Holder names available from DPLH	Registered Site	P00751
11458	NINGALOO (near)	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Painting	*Registered Knowledge Holder names available from DPLH	Registered Site	P00701

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
11772	ROSEMARY ISLAND 09	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P00369
11775	ROSEMARY ISLAND 06	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Engraving	*Registered Knowledge Holder names available from DPLH	Registered Site	P00372
11801	COASTAL MIDDEN, 5 MILE	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Lodged	P00345
11820	ENDERBY ISLAND 01	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Engraving	*Registered Knowledge Holder names available from DPLH	Registered Site	P00364
17193	Ningaloo Station	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Burial	*Registered Knowledge Holder names available from DPLH	Registered Site	
18822	Cape Preston 19	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Quarry	*Registered Knowledge Holder names available from DPLH	Registered Site	
18823	Cape Preston 20	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Quarry	*Registered Knowledge Holder names available from DPLH	Registered Site	
18824	Cape Preston 21	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	
18825	Cape Preston 22	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Quarry	*Registered Knowledge Holder names available from DPLH	Registered Site	
18826	Cape Preston 23	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Quarry	*Registered Knowledge Holder names available from DPLH	Registered Site	
18827	Cape Preston 24	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Quarry	*Registered Knowledge Holder names available from DPLH	Registered Site	
18838	Cape Preston 35	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
19171	Ceremonial Ground	Yes	Yes	Yes	Men only	ACH Directory	Place	Ritual / Ceremonial; Creation / Dreaming Narrative; Engraving	*Registered Knowledge Holder names available from DPLH	Lodged	
22943	Flacourt Bay 01	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Rock Shelter	*Registered Knowledge Holder names available from DPLH	Lodged	
25076	Norwegian Bay Burial 01/2008	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Burial	*Registered Knowledge Holder names available from DPLH	Lodged	
26005	Site No. 18	Yes	Yes	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Engraving	*Registered Knowledge Holder names available from DPLH	Registered Site	
26006	Site No. 25	Yes	Yes	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Engraving	*Registered Knowledge Holder names available from DPLH	Registered Site	
26017	P08 - 02	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Engraving; Grinding areas / Grooves; Midden; Quarry; Shell	*Registered Knowledge Holder names available from DPLH	Registered Site	
26019	P08 - 08	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	Registered Site	
26020	P08 - 09	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	Registered Site	
26441	P09 - 01	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Shell	*Registered Knowledge Holder names available from DPLH	Registered Site	
26444	P09 - 04	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	Registered Site	
26446	P09 - 06	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	Registered Site	
26736	ACHM - 09-05	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Registered Site	

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
29549	Boodie Soak	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
31762	Site 1	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
31763	Site 2	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
32879	Lower Fortescue River (Mardathuni)	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Camp; Creation / Dreaming Narrative; Hunting Place; Landscape / Seascape Feature; Plant Resource; Water Source	*Registered Knowledge Holder names available from DPLH	Registered Site	
36199	Boodie Cave	No	Yes	No		ACH Directory	Place	Artefacts / Scatter; Rock Shelter	*Registered Knowledge Holder names available from DPLH	Lodged	
36200	John Wayne Country Rockshelter	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Rock Shelter	*Registered Knowledge Holder names available from DPLH	Lodged	
36234	South End structures, Barrow Island.	No	No	No		ACH Directory	Place	Historical; Traditional Structure	*Registered Knowledge Holder names available from DPLH	Lodged	
36261	G-13-S0001	No	Yes	No		ACH Directory	Place	Quarry	*Registered Knowledge Holder names available from DPLH	Lodged	
36262	H-24-S0001	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36263	H-24-S0002	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36264	I-23-S0001	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
36265	I-23-S0002	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36266	I-24-S0003	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36267	J-23-S0001	No	Yes	No		ACH Directory	Place	Grinding areas / Grooves	*Registered Knowledge Holder names available from DPLH	Lodged	
36268	J-23-S0002	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36269	J-23-S0003	No	Yes	No		ACH Directory	Place	Modified Tree	*Registered Knowledge Holder names available from DPLH	Lodged	
36270	M-03-S0001	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36271	N-02-S0001	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36272	O-02-S0002	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36273	O-05-S0003	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36344	N-05-S0002	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36345	N-05-S0001	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36346	O-05-S0001	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
36347	O-05-S0002	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36348	P-04-S0001	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
39191	Warnangura (Cape Range) Cultural Precinct	No	Yes	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Ritual / Ceremonial; Creation / Dreaming Narrative; Engraving; Midden; Rock Shelter; Water Source	*Registered Knowledge Holder names available from DPLH	Lodged	
39730	Tantabiddi Midden 1	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place		*Registered Knowledge Holder names available from DPLH	Lodged	

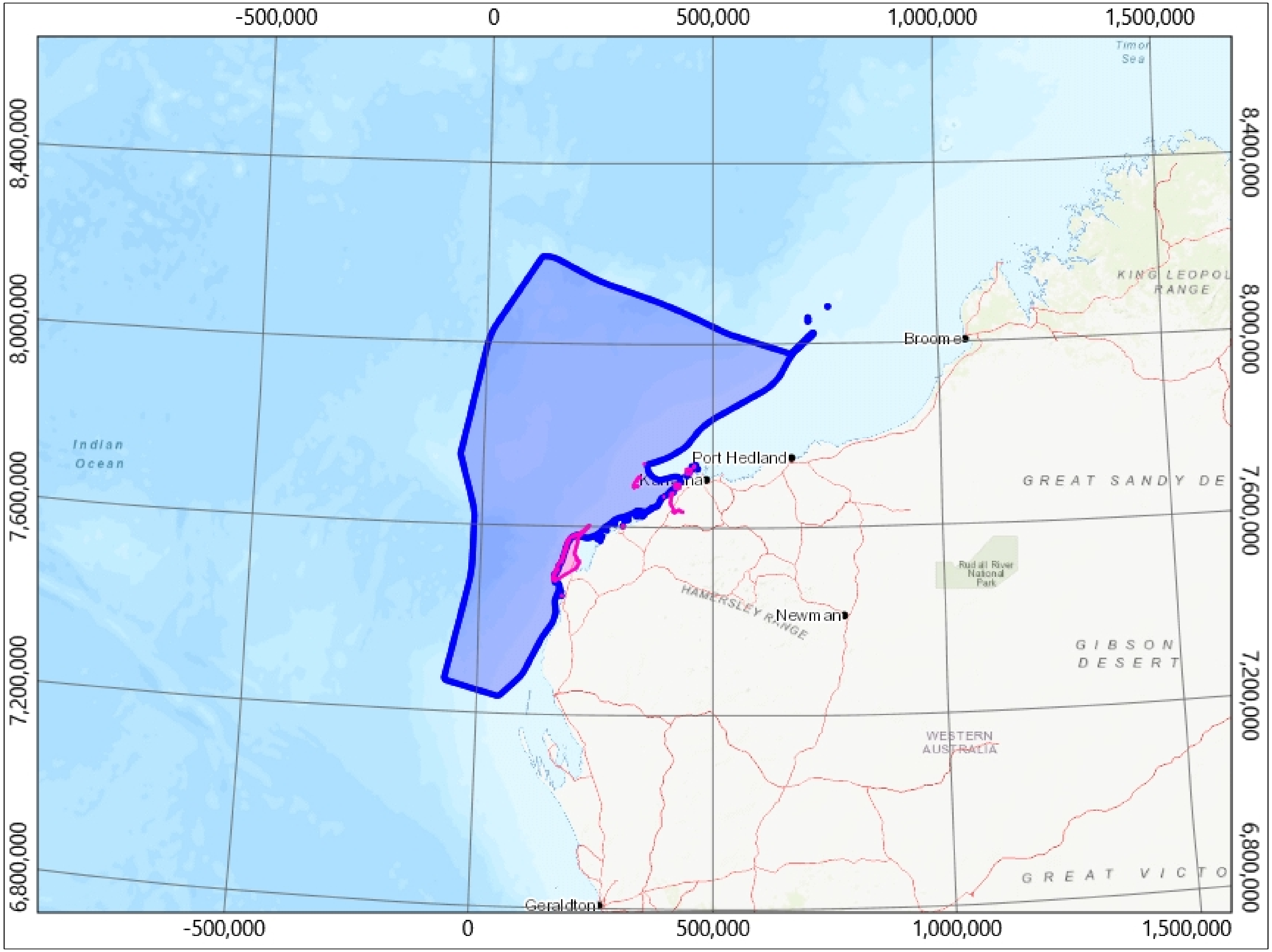
Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Cultural Heritage Inquiry System

Map of Aboriginal Cultural Heritage (ACH) Directory

For further important information on using this information please see the Department of Planning, Lands and Heritage's Disclaimer statement at https://www.wa.gov.au/disclaimer



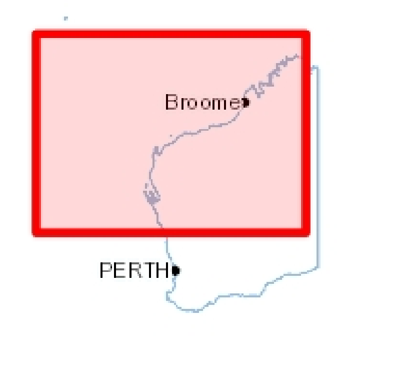
Legend

- Aboriginal Cultural Heritage (ACH) Directory
- Search Area
- Aboriginal Community
  - *Permanent*
  - *Seasonal*
  - *Town Based*
- Town
- Road
- River
- Local Government Authority

444.29 kilometres

Map Scale 1 : 13,460,000

MGA Zone 50 (GDA94)



Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Pending

Search Criteria

No Aboriginal Cultural Heritage (ACH) Pending in Shapefile - BFF Hydrocarbon Social EMBA

Disclaimer

The Aboriginal Cultural Heritage Act 2021 (Act) recognises, protects, conserves, and preserves Aboriginal cultural heritage (ACH), and recognises the fundamental importance of ACH to Aboriginal people and its role in Aboriginal communities past, present and future. The Act recognises the value of ACH to Aboriginal people as well as to the wider Western Australian community.

Aboriginal cultural heritage in Western Australia is protected, whether or not the ACH has been reported to the ACH Council or exists on the Directory.

The information provided is made available in good faith and is predominately based on the information provided to the Department of Planning, Lands and Heritage by third parties. The information is provided solely on the basis that readers will be responsible for making their own assessment as to the accuracy of the information. If you find any errors or omissions in our records, including our maps, it would be appreciated if you email the details to the Department at AboriginalHeritage@dplh.wa.gov.au and we will make every effort to rectify it as soon as possible.

Coordinates

Map coordinates are based on the GDA 94 Datum.

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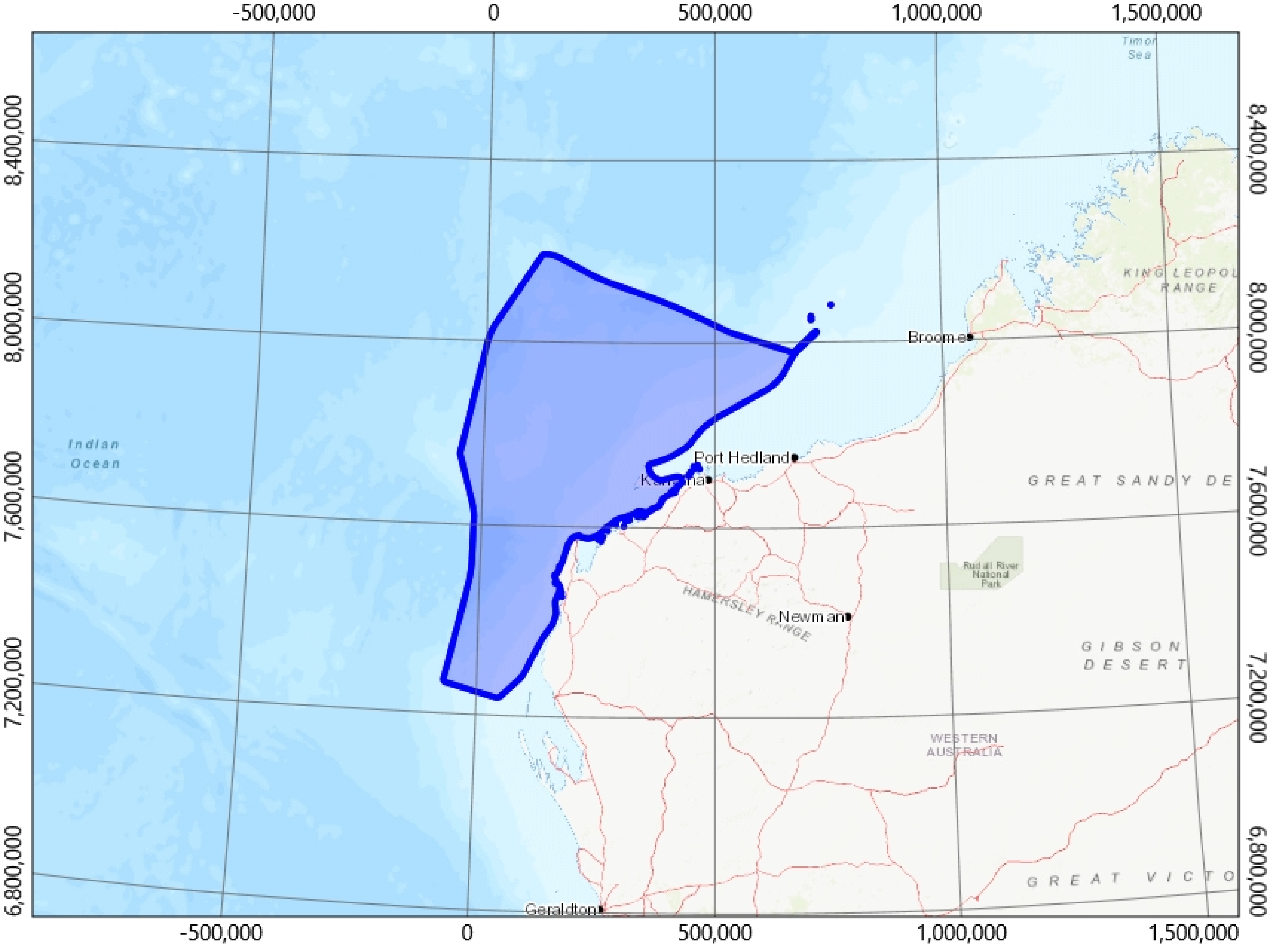
Aboriginal Cultural Heritage Inquiry System

Map of Aboriginal Cultural Heritage (ACH) Pending



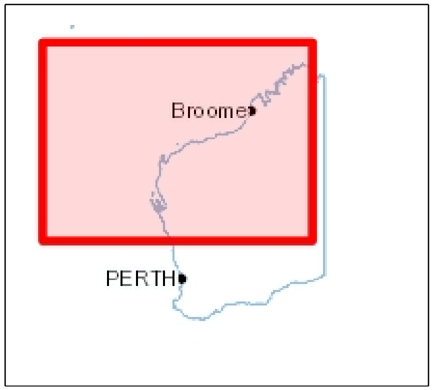
Legend

- Aboriginal Cultural Heritage (ACH) Pending
- Search Area
- Aboriginal Community
  - *Permanent*
  - *Seasonal*
  - *Town Based*
- Town
- Road
- River
- Local Government Authority

444.29 kilometres

Map Scale 1 : 13,460,000

MGA Zone 50 (GDA94)



Search Criteria

16 Aboriginal Cultural Heritage (ACH) Historic in Shapefile - BFF Hydrocarbon Social EMBA

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Terminology

ID: Reported ACH is assigned a unique ID by the Department of Planning, Lands and Heritage using the format: ACH-00000001. For ACH places on the former Register the ID numbers remain unchanged and use the new format. For example the ACH ID of the place Swan River was previously '3536' and is now 'ACH-00003536'.

Access and Restrictions:

- Boundary Reliable (Yes/No): Indicates whether the location and extent of the ACH boundary is considered reliable.
- Boundary Restricted = No: ACH location is shown as accurately as the information submitted allows.
- Boundary Restricted = Yes: To preserve confidentiality the exact location and extent of the place is not displayed on the map. However, the shaded region (generally with an area of at least $4km^2$) provides a general indication of where the ACH is located. If you are a landowner and wish to find out more about the exact location of the place, please contact the Department of Planning, Lands and Heritage.
- Culturally Sensitive = No: Availability of information that the Department of Planning, Lands and Heritage holds in relation to the ACH is not restricted in any way.
- Culturally Sensitive = Yes: Some of the information that the Department of Planning, Lands and Heritage holds in relation to the ACH is restricted if it is considered culturally sensitive information. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the people who provided the information. To request access please contact AboriginalHeritage@dplh.wa.gov.au.
- Culturally Sensitive Nature:
  - No Gender / Initiation Restrictions: Anyone can view the information.
  - Men only: Only males can view restricted information.
  - Women only: Only females can view restricted information.

Status:

- ACH Directory: Aboriginal cultural heritage place or cultural landscape.
- Pending: Aboriginal cultural heritage place or cultural landscape with information in a verification stage.
- Historic: Aboriginal heritage places determined to not meet the criteria of Section 5 of the Aboriginal Heritage Act 1972. Includes places that no longer exist as a result of land use activities with existing approvals.

ACH Type:

- Cultural Landscape: a group of areas interconnected through the tangible elements of Aboriginal culture heritage present.
- Place: an area in which tangible elements of Aboriginal cultural heritage are present.

Place Type: The type of Aboriginal cultural heritage place. For example an artefact scatter place or engravings place.

Legacy Place Status: A status determined under the previous Aboriginal Heritage Act 1972:

- Registered Site: the place was assessed as meeting Section 5 of the Aboriginal Heritage Act 1972.
- Lodged: Information was received in relation to the place, but an assessment was not completed to determine if it met section 5 of the Aboriginal Heritage Act 1972.
- Stored Data/Not a Site: The place was assessed as not meeting Section 5 of the Aboriginal Heritage Act 1972.

Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place.

Coordinates

Map coordinates are based on the GDA 94 Datum.

Basemap Copyright

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
599	NORWEGIAN BAY 2 #Duplicate of ID 7037	No	Yes	No	No Gender / Initiation Restrictions	Historic	Place	Burial; Artefacts / Scatter; Midden; Other	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	P07441
6796	ROAD ALIGNMENT 4	No	Yes	No	No Gender / Initiation Restrictions	Historic	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	P06154
8951	BARROW ISLAND	No	No	No	No Gender / Initiation Restrictions	Historic	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	P03542
11403	THEVENARD ISLAND	No	No	No	No Gender / Initiation Restrictions	Historic	Place	Midden	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	P00753
18837	Cape Preston 34	No	Yes	No	No Gender / Initiation Restrictions	Historic	Place	Midden	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
25987	Site No 5	No	Yes	No	No Gender / Initiation Restrictions	Historic	Place	Grinding areas / Grooves	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
25988	Site No 10	No	Yes	No	No Gender / Initiation Restrictions	Historic	Place	Engraving	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
26001	Site No 24	No	Yes	No	No Gender / Initiation Restrictions	Historic	Place	Engraving	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
26003	Site No. 6	Yes	Yes	Yes	Men only	Historic	Place	Engraving	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
26004	Site No. 7/8/9	Yes	Yes	Yes	Men only	Historic	Place	Engraving; Grinding areas / Grooves; Quarry	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
26445	P09 - 05	No	Yes	No	No Gender / Initiation Restrictions	Historic	Place	Engraving	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
26447	P09 - 07	No	Yes	No	No Gender / Initiation Restrictions	Historic	Place	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Historic

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
26448	P09 - 08	No	Yes	No	No Gender / Initiation Restrictions	Historic	Place	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
26449	P09 - 09	No	Yes	No	No Gender / Initiation Restrictions	Historic	Place	Artefacts / Scatter; Quarry	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
26457	WG14	No	Yes	No	No Gender / Initiation Restrictions	Historic	Place	Engraving; Quarry	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
38763	Wapet Shell Midden	No	Yes	No		Historic	Place	Shell	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	

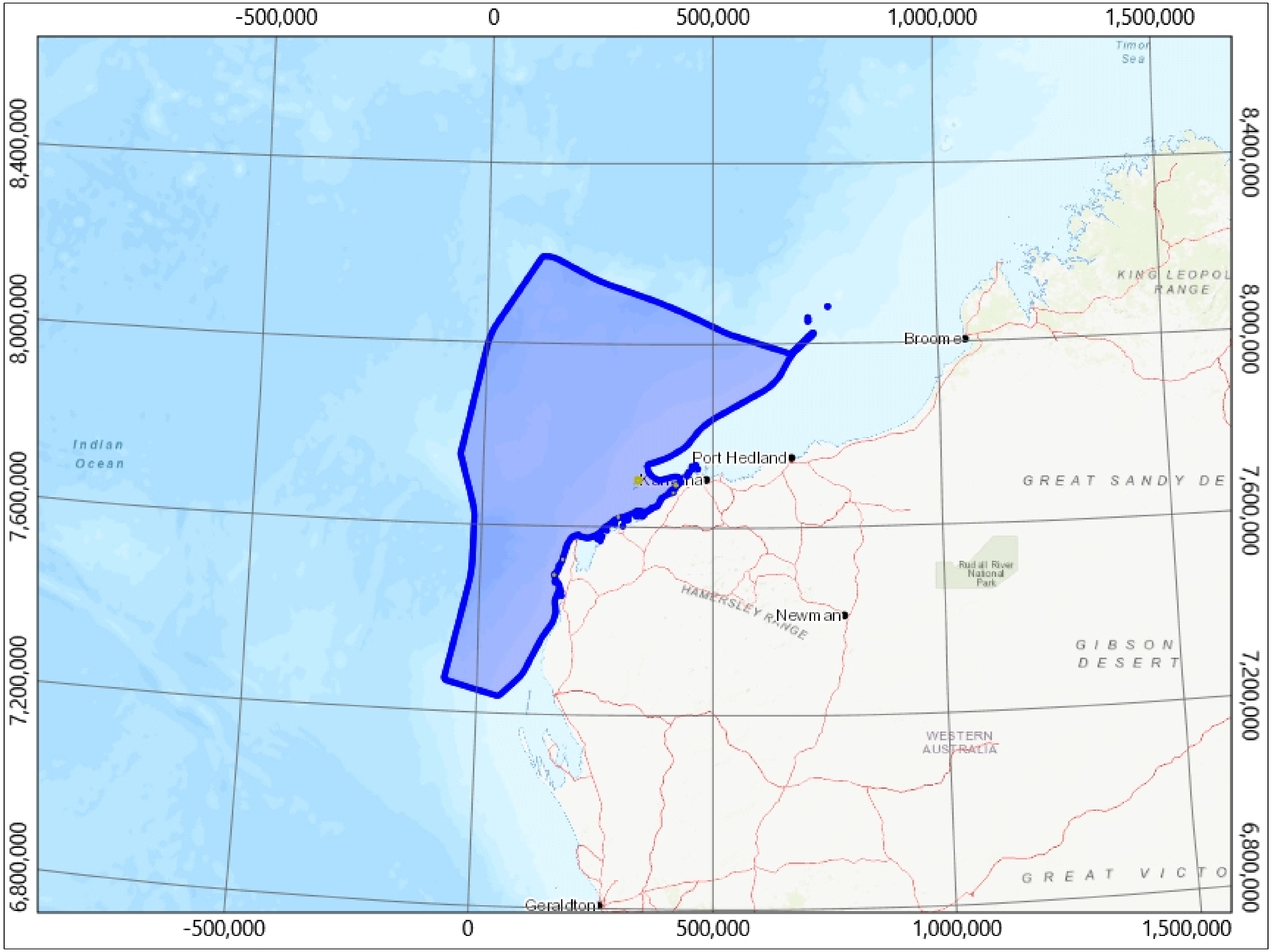
Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Cultural Heritage Inquiry System

Map of Aboriginal Cultural Heritage (ACH) Historic

For further important information on using this information please see the Department of Planning, Lands and Heritage's Disclaimer statement at https://www.wa.gov.au/disclaimer



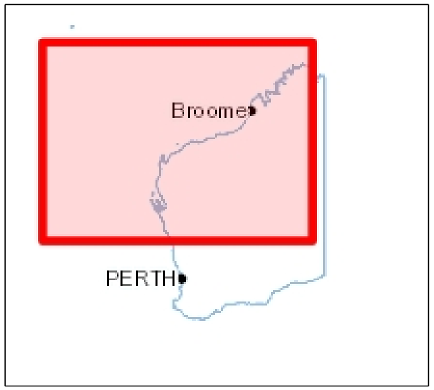
Legend

- Aboriginal Cultural Heritage (ACH) Historic
- Search Area
- Aboriginal Community
  - *Permanent*
  - *Seasonal*
  - *Town Based*
- Town
- Road
- River
- Local Government Authority

444.29 kilometres

Map Scale 1 : 13,460,000

MGA Zone 50 (GDA94)



Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

Search Criteria

89 Aboriginal Cultural Heritage (ACH) Directory in Shapefile - BFF Hydrocarbon Ecological EMBA

Disclaimer

The Aboriginal Cultural Heritage Act 2021 (Act) recognises, protects, conserves, and preserves Aboriginal cultural heritage (ACH), and recognises the fundamental importance of ACH to Aboriginal people and its role in Aboriginal communities past, present and future. The Act recognises the value of ACH to Aboriginal people as well as to the wider Western Australian community.

Aboriginal cultural heritage in Western Australia is protected, whether or not the ACH has been reported to the ACH Council or exists on the Directory.

The information provided is made available in good faith and is predominately based on the information provided to the Department of Planning, Lands and Heritage by third parties. The information is provided solely on the basis that readers will be responsible for making their own assessment as to the accuracy of the information. If you find any errors or omissions in our records, including our maps, it would be appreciated if you email the details to the Department at AboriginalHeritage@dplh.wa.gov.au and we will make every effort to rectify it as soon as possible.

Copyright

Terminology

ID: Reported ACH is assigned a unique ID by the Department of Planning, Lands and Heritage using the format: ACH-00000001. For ACH places on the former Register the ID numbers remain unchanged and use the new format. For example the ACH ID of the place Swan River was previously '3536' and is now 'ACH-00003536'.

Access and Restrictions:

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Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place.

Coordinates

Map coordinates are based on the GDA 94 Datum.

Basemap Copyright

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
508	POINT MURAT 03	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P07503
563	POINT MURAT 01	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P07501
564	POINT MURAT 02	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P07502
628	CAMP THIRTEEN BURIAL	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Burial	*Registered Knowledge Holder names available from DPLH	Registered Site	P07434
873	MONTEBELLO IS: NOALA CAVE.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden; Rock Shelter	*Registered Knowledge Holder names available from DPLH	Registered Site	P07287
883	BARROW ISLAND 01	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07291
884	BARROW ISLAND 02	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07292
885	BARROW ISLAND 03	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07293
886	BARROW ISLAND 04	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07294
887	BARROW ISLAND 05	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07295
888	BARROW ISLAND 06 A-F	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07296
889	BARROW ISLAND 07	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07297

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
890	BARROW ISLAND 08	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07298
891	BARROW ISLAND 09	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07299
892	BARROW ISLAND 10	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07300
893	BARROW ISLAND 11	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07301
894	BARROW ISLAND 12	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	P07302
926	MONTEBELLO IS: HAYNES CAVE.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Sub surface cultural material; Artefacts / Scatter; Midden; Rock Shelter	*Registered Knowledge Holder names available from DPLH	Registered Site	P07286
6311	POINT MURAT.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Burial; Artefacts / Scatter; Camp; Midden; Other	*Registered Knowledge Holder names available from DPLH	Registered Site	P06628
6346	MT SALT	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Burial	*Registered Knowledge Holder names available from DPLH	Lodged	P06610
6754	OSPREY BAY 6	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06165
6755	OSPREY BAY INTERDUNAL 1	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06166
6757	BLOODWOOD CREEK MIDDEN 1	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06168
6758	BLOODWOOD CREEK MIDDEN 2	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06169

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
6759	BLOODWOOD CREEK MIDDEN 3	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06170
6760	BLOODWOOD CREEK SHORELINE	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06171
6761	LOW POINT MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06172
6762	MILYERING MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06173
6764	CAMP 17 SOUTH MIDDENS	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06175
6765	CAMP 17 NORTH MIDDENS	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06176
6782	28 MILE CREEK NORTH 1	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06140
6783	28 MILE CREEK NORTH 2	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Lodged	P06141
6784	MANDU MANDU CREEK SOUTH	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06142
6785	MANDU MANDU CREEK NORTH	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06143
6786	LAKESIDE COASTAL PLAIN	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Lodged	P06144
6789	TURQUOISE BAY NORTH	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Lodged	P06147

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
6790	YARDIE CREEK SOUTH 1	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06148
6799	YARDIE BEACH MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06157
6800	OYSTER STACKS MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06158
6801	NORTH T-BONE BAY	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06159
6802	OSPREY BAY 1	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06160
6803	OSPREY BAY 2	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06161
6804	OSPREY BAY 3	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06162
6805	OSPREY BAY 4	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06163
6806	OSPREY BAY 5	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P06164
7126	MESA CAMP	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05792
7206	WEALJUGOO MIDDEN.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Camp; Hunting Place; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05710
7208	MILYERING ROCKS.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Hunting Place	*Registered Knowledge Holder names available from DPLH	Lodged	P05712

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
7254	SANDY BAY NORTH	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05652
7265	LAKE SIDE VIEW	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05664
7299	YARDIE CREEK	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05645
7300	MANDU MANDU CK ROCKSHELTERS	Yes	Yes	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Registered Site	P05646
7303	TULKI WELL MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05649
7304	PILGRAMUNNA BAY MIDDEN	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05650
7305	MANGROVE BAY.	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Burial; Artefacts / Scatter; Hunting Place; Midden	*Registered Knowledge Holder names available from DPLH	Registered Site	P05651
10381	VLAMING HEAD	Yes	No	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Ritual / Ceremonial; Creation / Dreaming Narrative	*Registered Knowledge Holder names available from DPLH	Registered Site	P01799
11458	NINGALOO (near)	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Painting	*Registered Knowledge Holder names available from DPLH	Registered Site	P00701
11801	COASTAL MIDDEN, 5 MILE	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Midden	*Registered Knowledge Holder names available from DPLH	Lodged	P00345
17193	Ningaloo Station	No	No	No	No Gender / Initiation Restrictions	ACH Directory	Place	Burial	*Registered Knowledge Holder names available from DPLH	Registered Site	
19171	Ceremonial Ground	Yes	Yes	Yes	Men only	ACH Directory	Place	Ritual / Ceremonial; Creation / Dreaming Narrative; Engraving	*Registered Knowledge Holder names available from DPLH	Lodged	

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

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22943	Flacourt Bay 01	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Rock Shelter	*Registered Knowledge Holder names available from DPLH	Lodged	
26005	Site No. 18	Yes	Yes	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Engraving	*Registered Knowledge Holder names available from DPLH	Registered Site	
26006	Site No. 25	Yes	Yes	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Engraving	*Registered Knowledge Holder names available from DPLH	Registered Site	
26736	ACHM - 09-05	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Registered Site	
29549	Boodie Soak	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
31762	Site 1	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
31763	Site 2	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36199	Boodie Cave	No	Yes	No		ACH Directory	Place	Artefacts / Scatter; Rock Shelter	*Registered Knowledge Holder names available from DPLH	Lodged	
36200	John Wayne Country Rockshelter	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Rock Shelter	*Registered Knowledge Holder names available from DPLH	Lodged	
36234	South End structures, Barrow Island.	No	No	No		ACH Directory	Place	Historical; Traditional Structure	*Registered Knowledge Holder names available from DPLH	Lodged	
36261	G-13-S0001	No	Yes	No		ACH Directory	Place	Quarry	*Registered Knowledge Holder names available from DPLH	Lodged	
36262	H-24-S0001	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	

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36263	H-24-S0002	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36264	I-23-S0001	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36265	I-23-S0002	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36266	I-24-S0003	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36267	J-23-S0001	No	Yes	No		ACH Directory	Place	Grinding areas / Grooves	*Registered Knowledge Holder names available from DPLH	Lodged	
36268	J-23-S0002	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36269	J-23-S0003	No	Yes	No		ACH Directory	Place	Modified Tree	*Registered Knowledge Holder names available from DPLH	Lodged	
36270	M-03-S0001	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36271	N-02-S0001	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36272	O-02-S0002	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36273	O-05-S0003	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36344	N-05-S0002	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

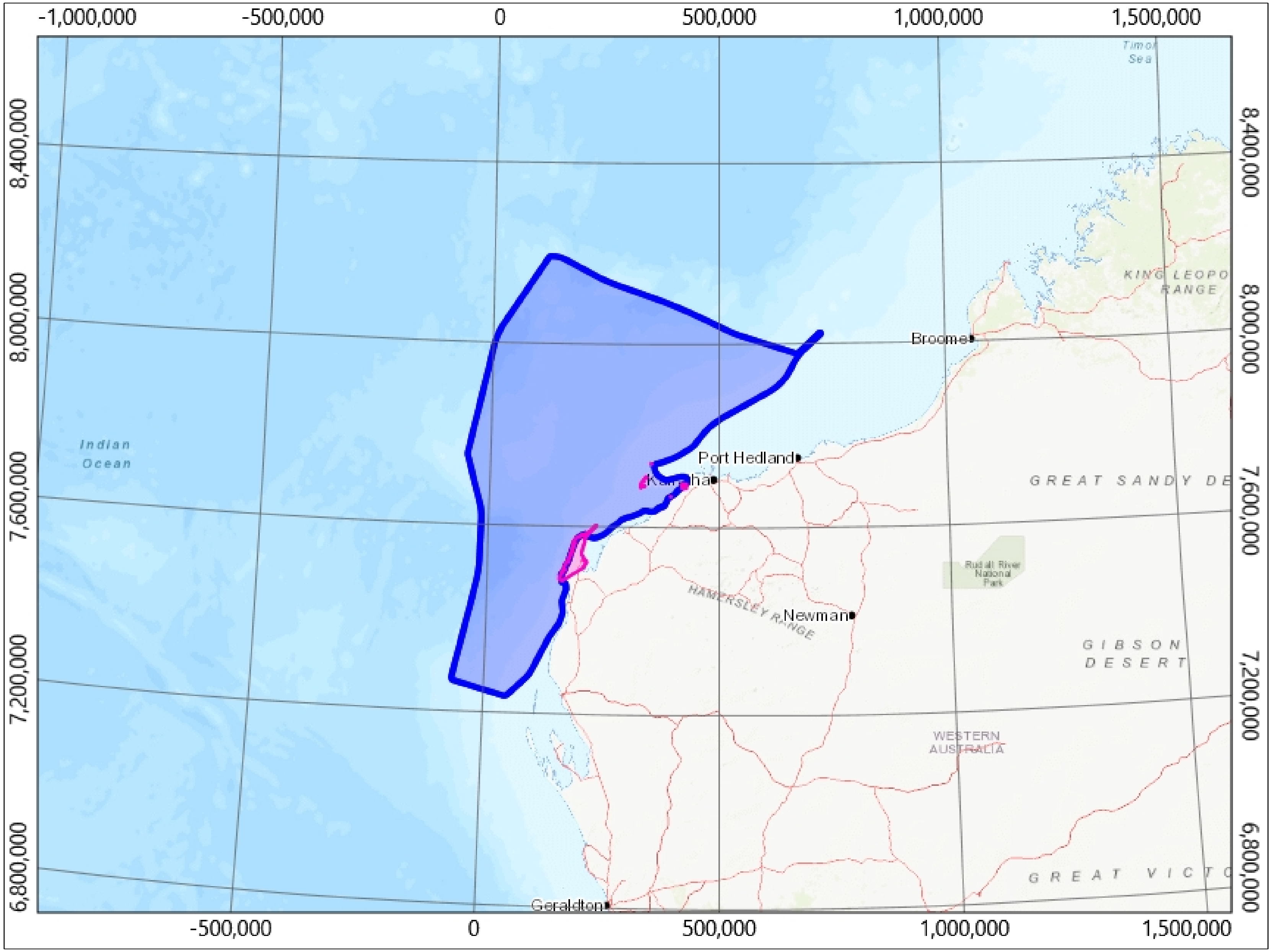
ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
36345	N-05-S0001	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36346	O-05-S0001	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36347	O-05-S0002	No	Yes	No	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
36348	P-04-S0001	No	Yes	No		ACH Directory	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Lodged	
39191	Warnangura (Cape Range) Cultural Precinct	No	Yes	Yes	No Gender / Initiation Restrictions	ACH Directory	Place	Artefacts / Scatter; Ritual / Ceremonial; Creation / Dreaming Narrative; Engraving; Midden; Rock Shelter; Water Source	*Registered Knowledge Holder names available from DPLH	Lodged	

Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Cultural Heritage Inquiry System

Map of Aboriginal Cultural Heritage (ACH) Directory



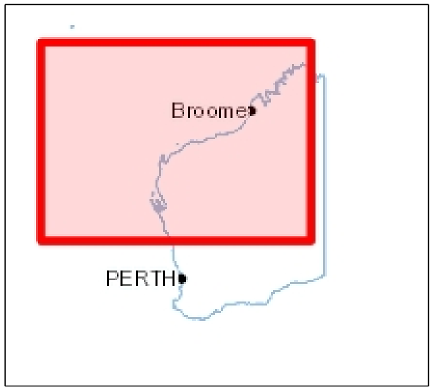
Legend

- Aboriginal Cultural Heritage (ACH) Directory
- Search Area
- Aboriginal Community
  - *Permanent*
  - *Seasonal*
  - *Town Based*
- Town
- Road
- River
- Local Government Authority

444.29 kilometres

Map Scale 1 : 13,460,000

MGA Zone 50 (GDA94)



Map created: 31/10/2023 12:46:02 PM by: GIS_NET_USER

Identifier: 815500

Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Pending

Search Criteria

No Aboriginal Cultural Heritage (ACH) Pending in Shapefile - BFF Hydrocarbon Ecological EMBA

Disclaimer

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Copyright

Coordinates

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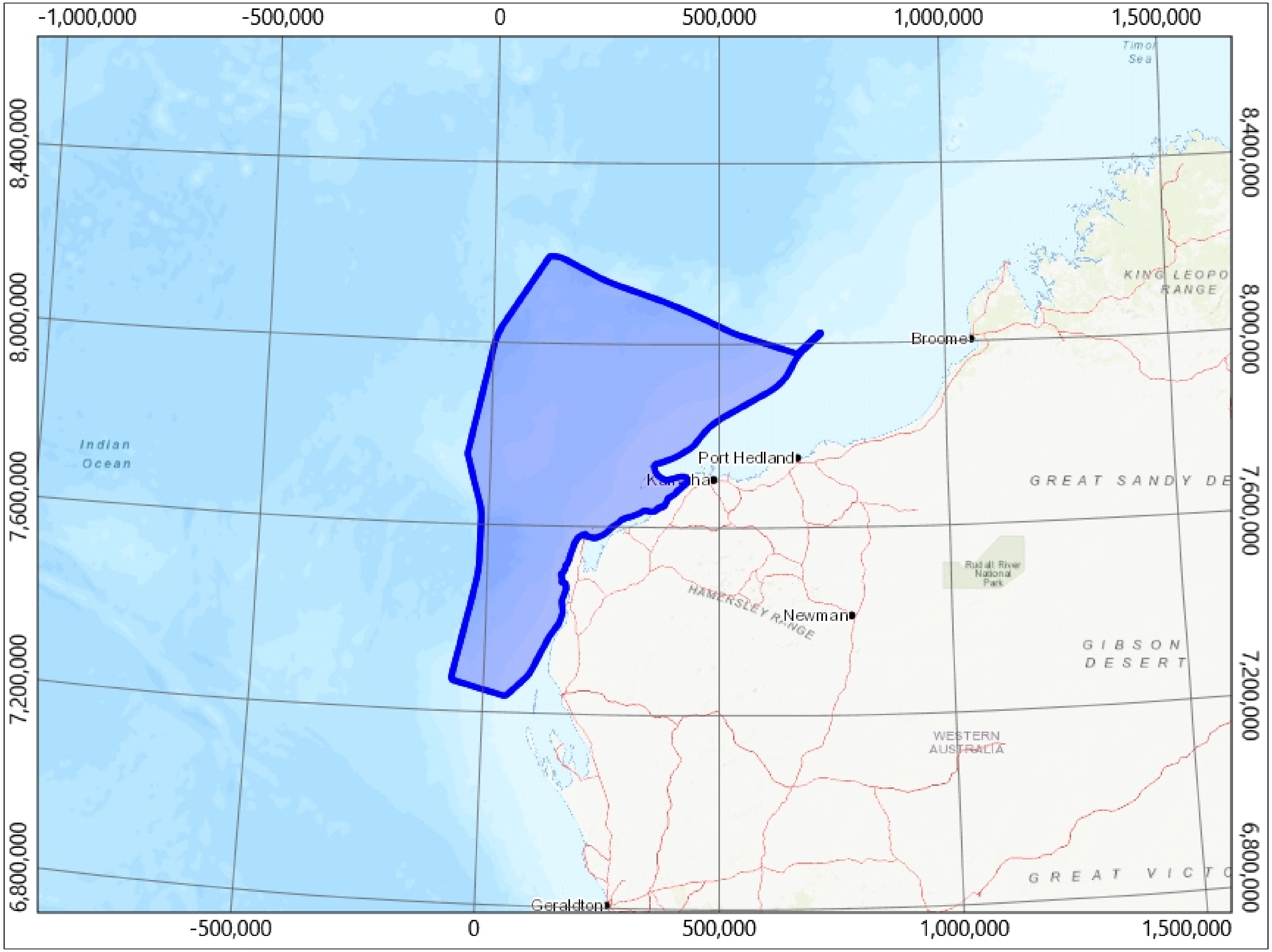
Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Cultural Heritage Inquiry System

Map of Aboriginal Cultural Heritage (ACH) Pending



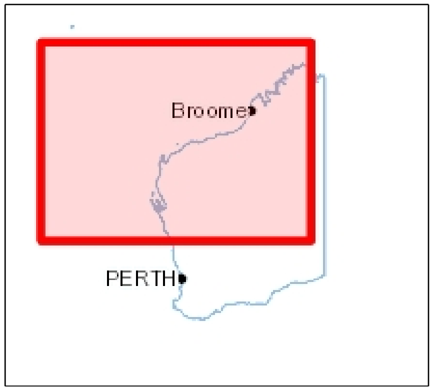
Legend

- Aboriginal Cultural Heritage (ACH) Pending
- Search Area
- Aboriginal Community
  - *Permanent*
  - *Seasonal*
  - *Town Based*
- Town
- Road
- River
- Local Government Authority

444.29 kilometres

Map Scale 1 : 13,460,000

MGA Zone 50 (GDA94)



Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Historic

Search Criteria

5 Aboriginal Cultural Heritage (ACH) Historic in Shapefile - BFF Hydrocarbon Ecological EMBA

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Terminology

ID: Reported ACH is assigned a unique ID by the Department of Planning, Lands and Heritage using the format: ACH-00000001. For ACH places on the former Register the ID numbers remain unchanged and use the new format. For example the ACH ID of the place Swan River was previously '3536' and is now 'ACH-00003536'.

Access and Restrictions:

- Boundary Reliable (Yes/No): Indicates whether the location and extent of the ACH boundary is considered reliable.
- Boundary Restricted = No: ACH location is shown as accurately as the information submitted allows.
- Boundary Restricted = Yes: To preserve confidentiality the exact location and extent of the place is not displayed on the map. However, the shaded region (generally with an area of at least 4km²) provides a general indication of where the ACH is located. If you are a landowner and wish to find out more about the exact location of the place, please contact the Department of Planning, Lands and Heritage.
- Culturally Sensitive = No: Availability of information that the Department of Planning, Lands and Heritage holds in relation to the ACH is not restricted in any way.
- Culturally Sensitive = Yes: Some of the information that the Department of Planning, Lands and Heritage holds in relation to the ACH is restricted if it is considered culturally sensitive information. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the people who provided the information. To request access please contact AboriginalHeritage@dplh.wa.gov.au.
- Culturally Sensitive Nature:
  - No Gender / Initiation Restrictions: Anyone can view the information.
  - Men only: Only males can view restricted information.
  - Women only: Only females can view restricted information.

Status:

- ACH Directory: Aboriginal cultural heritage place or cultural landscape.
- Pending: Aboriginal cultural heritage place or cultural landscape with information in a verification stage.
- Historic: Aboriginal heritage places determined to not meet the criteria of Section 5 of the Aboriginal Heritage Act 1972. Includes places that no longer exist as a result of land use activities with existing approvals.

ACH Type:

- Cultural Landscape: a group of areas interconnected through the tangible elements of Aboriginal culture heritage present.
- Place: an area in which tangible elements of Aboriginal cultural heritage are present.

Place Type: The type of Aboriginal cultural heritage place. For example an artefact scatter place or engravings place.

Legacy Place Status: A status determined under the previous Aboriginal Heritage Act 1972:

- Registered Site: the place was assessed as meeting Section 5 of the Aboriginal Heritage Act 1972.
- Lodged: Information was received in relation to the place, but an assessment was not completed to determine if it met section 5 of the Aboriginal Heritage Act 1972.
- Stored Data/Not a Site: The place was assessed as not meeting Section 5 of the Aboriginal Heritage Act 1972.

Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place.

Coordinates

Map coordinates are based on the GDA 94 Datum.

Basemap Copyright

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Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Historic

ID	Name	Boundary Restricted	Boundary Reliable	Culturally Sensitive	Culturally Sensitive Nature	Status	ACH Type	Place Type	Knowledge Holders	Legacy Place Status	Legacy ID
8951	BARROW ISLAND	No	No	No	No Gender / Initiation Restrictions	Historic	Place	Artefacts / Scatter	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	P03542
11403	THEVENARD ISLAND	No	No	No	No Gender / Initiation Restrictions	Historic	Place	Midden	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	P00753
26003	Site No. 6	Yes	Yes	Yes	Men only	Historic	Place	Engraving	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
26004	Site No. 7/8/9	Yes	Yes	Yes	Men only	Historic	Place	Engraving; Grinding areas / Grooves; Quarry	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	
38763	Wapet Shell Midden	No	Yes	No		Historic	Place	Shell	*Registered Knowledge Holder names available from DPLH	Stored Data / Not a Site	

Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Cultural Heritage Inquiry System

Map of Aboriginal Cultural Heritage (ACH) Historic

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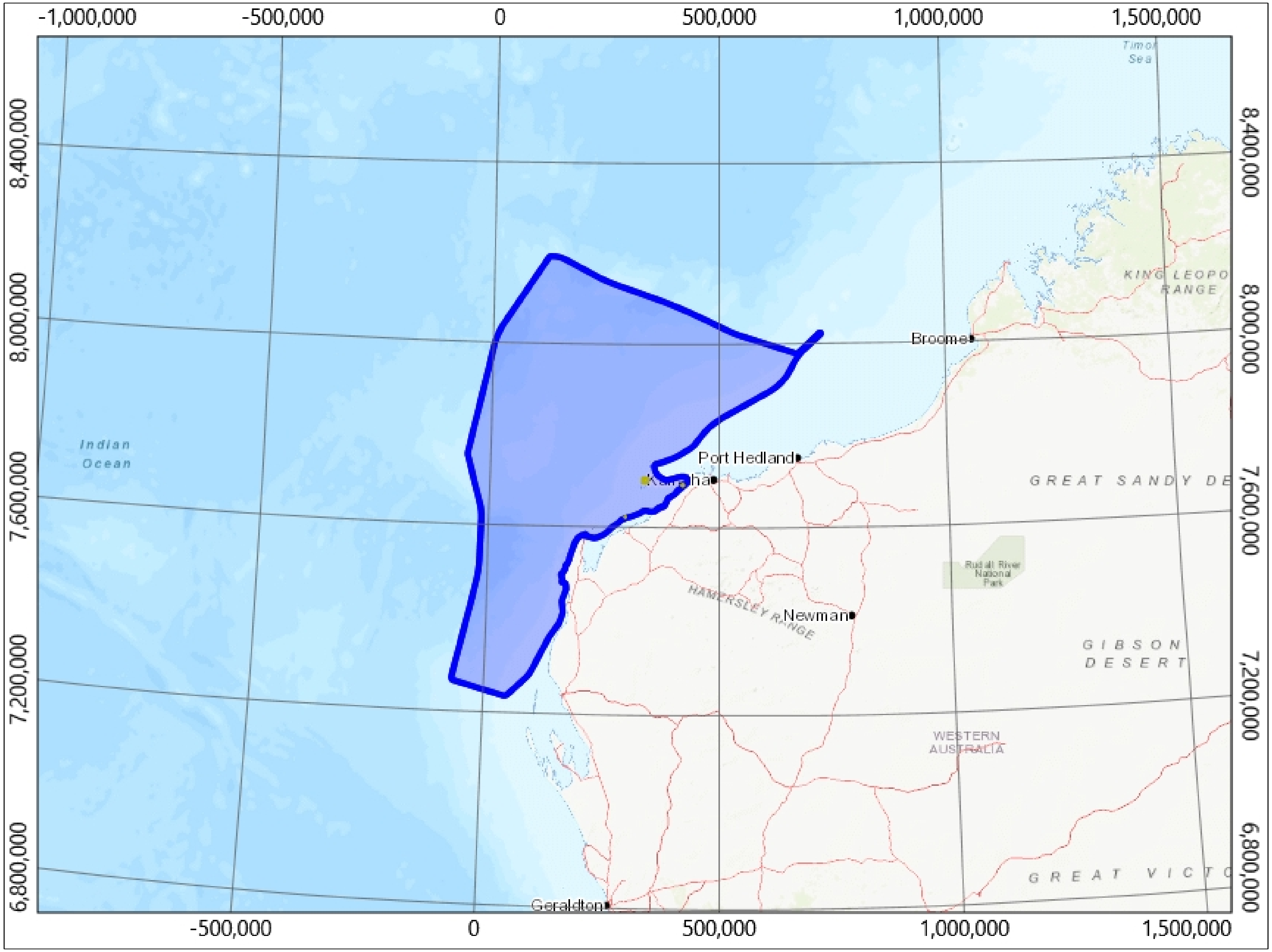


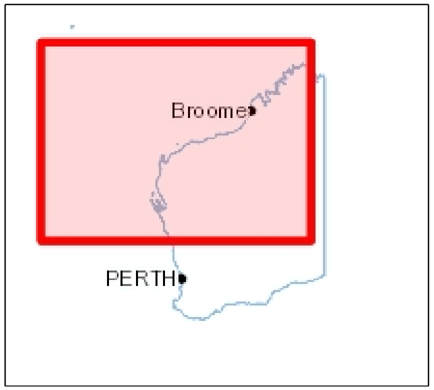
Legend

- Aboriginal Cultural Heritage (ACH) Historic
- Search Area
- Aboriginal Community
  - *Permanent*
  - *Seasonal*
  - *Town Based*
- Town
- Road
- River
- Local Government Authority

444.29 kilometres

Map Scale 1 : 13,460,000

MGA Zone 50 (GDA94)



Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Directory

Search Criteria

No Aboriginal Cultural Heritage (ACH) Directory in Shapefile - BFF OA

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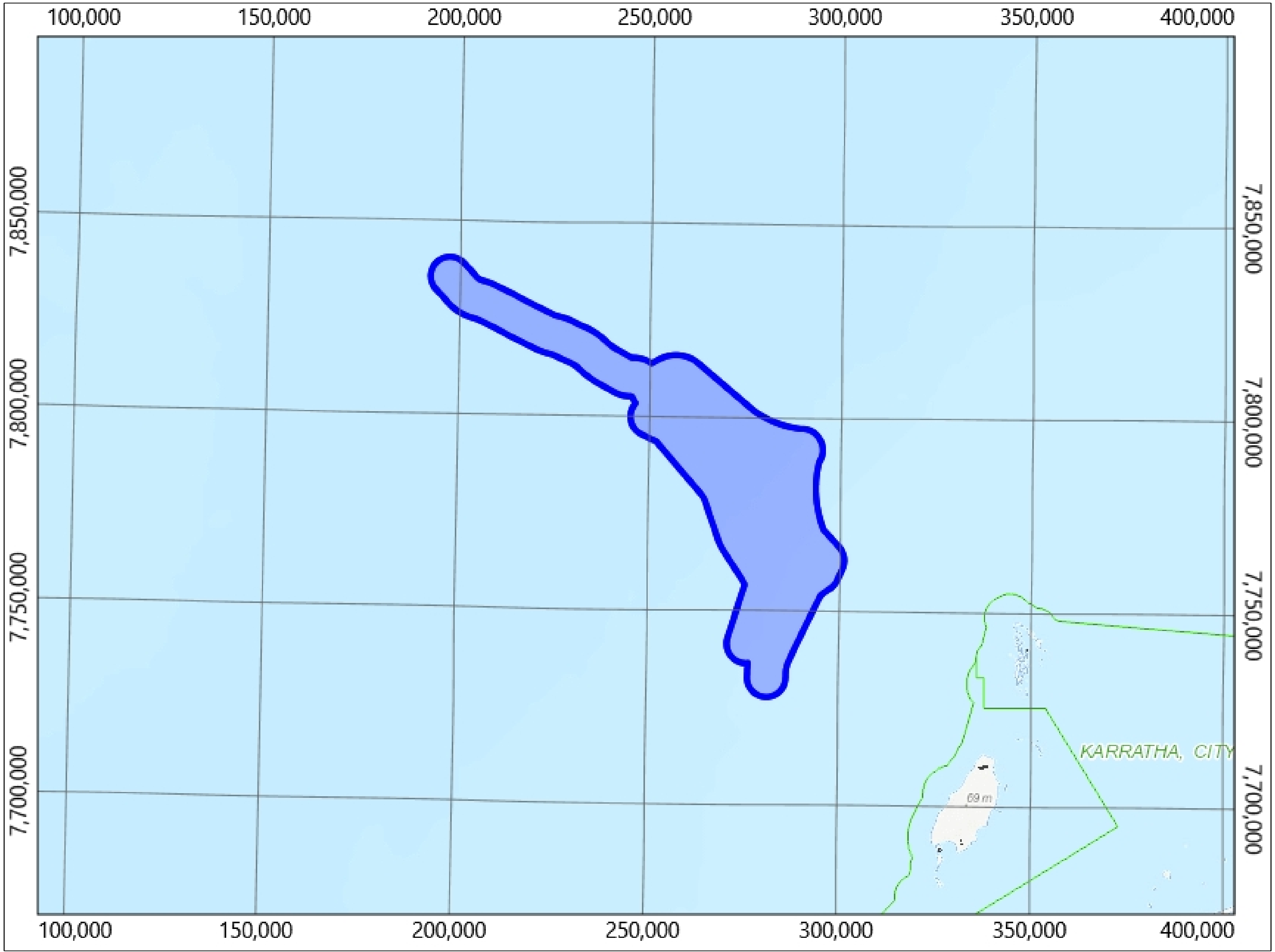
Aboriginal Cultural Heritage Inquiry System

Department of Planning, Lands and Heritage
GOVERNMENT OF WESTERN AUSTRALIA

Map of Aboriginal Cultural Heritage (ACH) Directory



Legend

- Aboriginal Cultural Heritage (ACH) Directory
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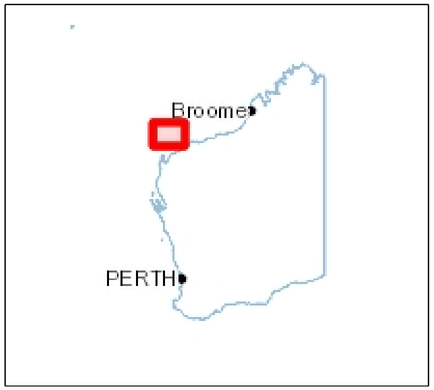
52.92 kilometres

Map Scale 1 : 1,600,000

MGA Zone 50 (GDA94)



Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Pending

Search Criteria

No Aboriginal Cultural Heritage (ACH) Pending in Shapefile - BFF OA

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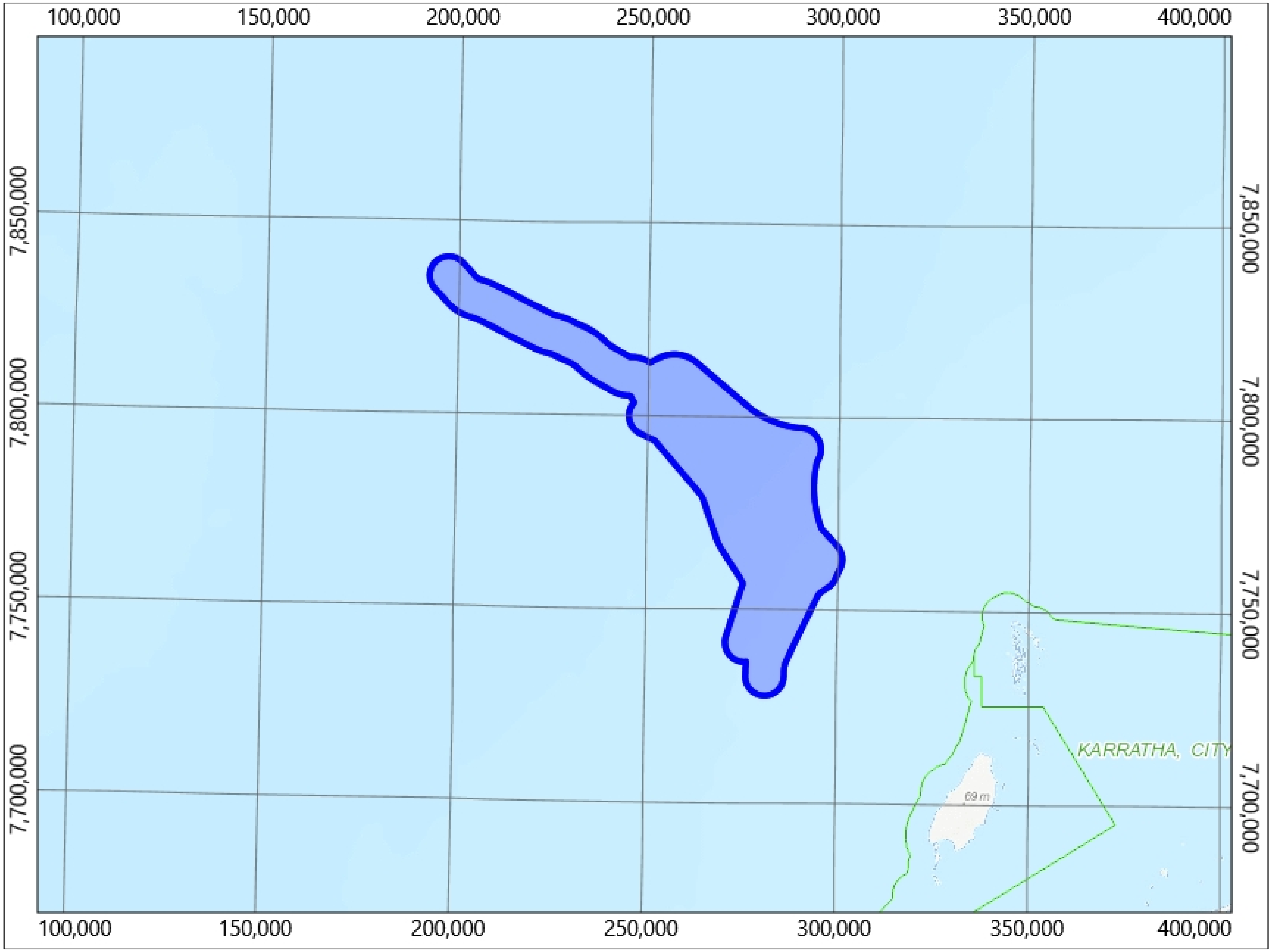
GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Cultural Heritage Inquiry System

Map of Aboriginal Cultural Heritage (ACH) Pending



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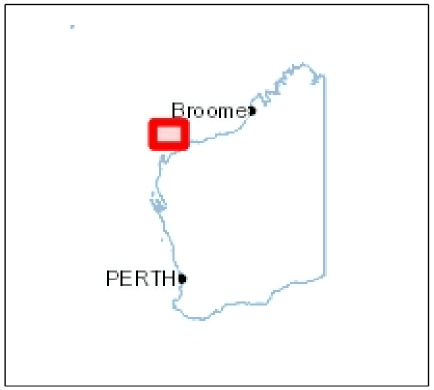
52.92 kilometres

Map Scale 1 : 1,600,000

MGA Zone 50 (GDA94)



Aboriginal Cultural Heritage Inquiry System

List of Aboriginal Cultural Heritage (ACH) Historic

Search Criteria

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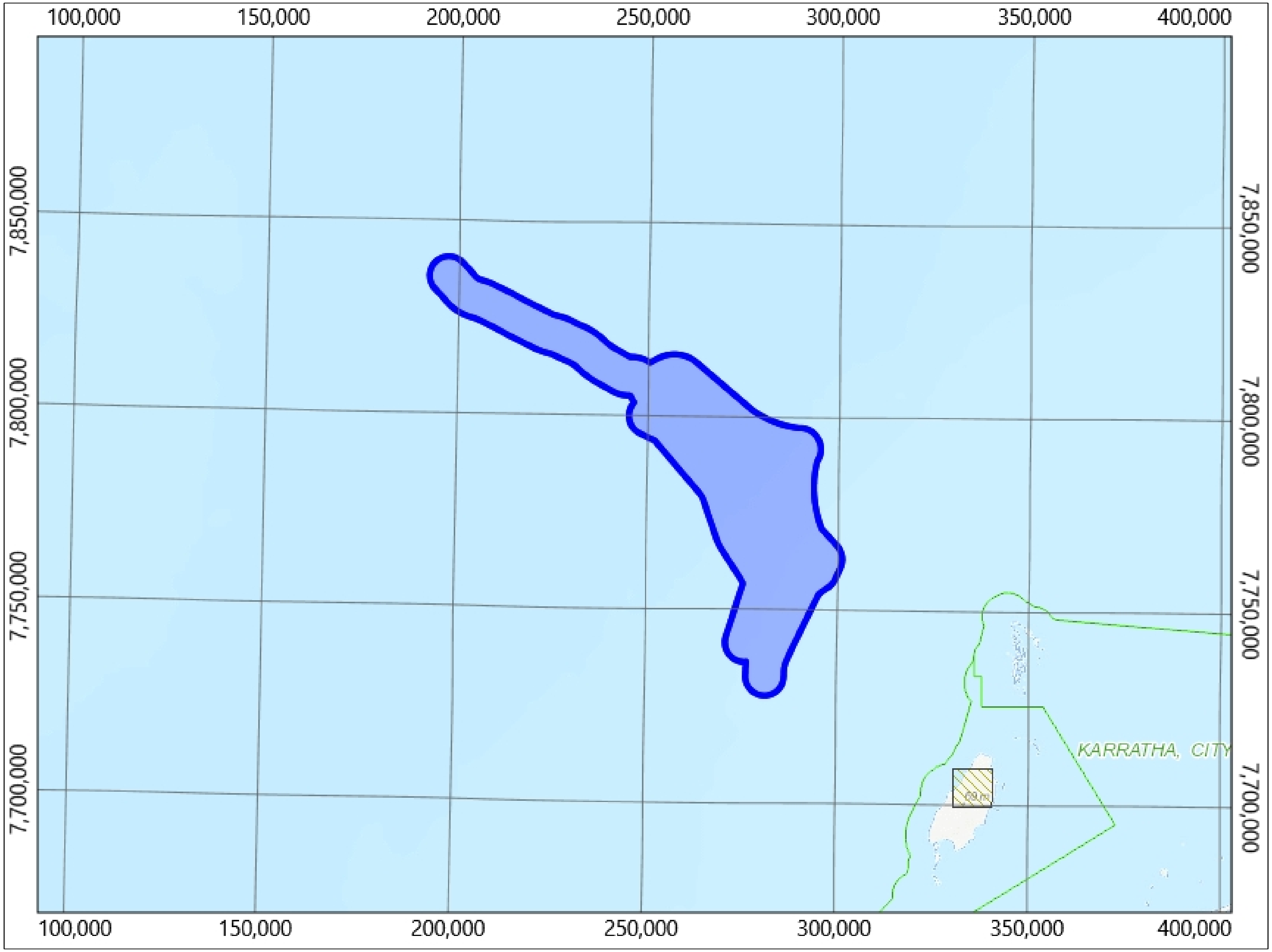
GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Cultural Heritage Inquiry System

Map of Aboriginal Cultural Heritage (ACH) Historic



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- Aboriginal Cultural Heritage (ACH) Historic
- Search Area
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- Road
- River
- Local Government Authority

52.92 kilometres

Map Scale 1 : 1,600,000

MGA Zone 50 (GDA94)