Corowa Development:
Offshore Project Proposal

Revision: 3

COR-000-EN-RP-001
27 February 2020

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Executive Summary

ES1. Introduction

The Corowa Development will be centred on the Corowa field, located within Commonwealth waters on the North West Shelf (NWS) ~60 km offshore Western Australia (WA) (Figure ES-1-1). The field lies in ~85–90 m of water within retention lease WA-41-R in the Carnarvon Basin, and contains light crude oil.

KATO Energy Pty Ltd (KATO) plans to develop the Corowa field using a relocatable system known as the 'honeybee production system'. The honeybee production system has been used successfully in many locations around the world, including offshore WA. Advantages of the system include:

- it uses a self-installing jack-up platform, with no requirement for mobilising a crane barge from overseas (which introduces additional risk and cost)
- all infrastructure will be removed before demobilising from the field, and most elements will be re-used on the next project, allowing for ease of decommissioning and minimising number of mobilisations required
- environmental impact is minimised by having no fixed platform
- no offshore piling or trenching is required, further minimising environmental impact.

The Corowa field has previously been appraised by Santos, with three wells drilled between 2001 and 2002. The Corowa field is classified as a small field with a short life span and proven contingent resource of 7 MMstb.

The key components covered in this Offshore Project Proposal (OPP) for the Corowa Development are:

- site survey of the proposed location of subsea infrastructure
- drilling of up to four wells
- installation, hook-up and commissioning of a mobile offshore processing unit (MOPU), catenary anchor leg mooring (CALM) buoy and mooring arrangements, flowline and riser, and a floating storage and offloading (FSO) facility
- operation of the facilities
- decommissioning and removal of subsea and surface infrastructure, and plug and abandonment (P&A) of the wells.

Following decommissioning and abandonment, the MOPU will demobilise and relocate to the next field, which will be covered by a separate OPP.

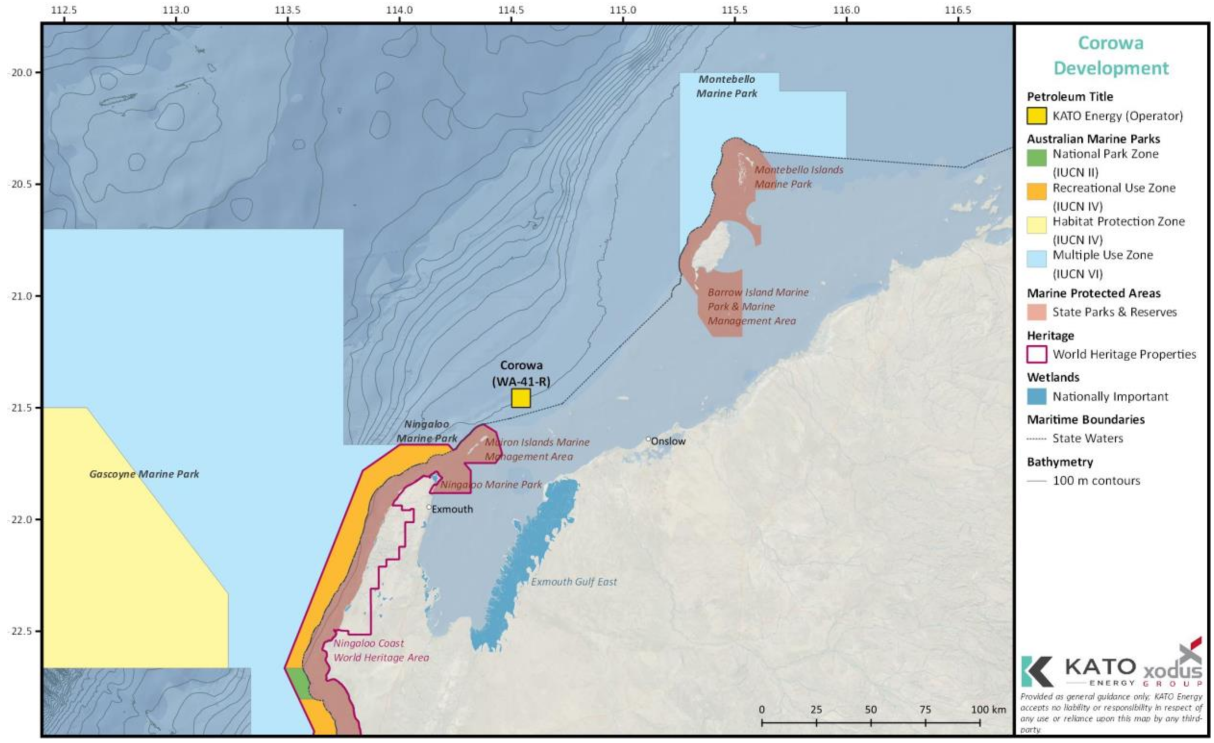


Figure ES-1-1 Location of Corowa Development

Titleholder Details

KATO Energy Pty Ltd (KATO) is the proponent for the Corowa Development.

KATO is an Australian company that was formed to combine 100% ownership of the Corowa and Amulet oil discoveries, and other fields, via wholly owned subsidiaries. The shareholders of KATO are Tamarind Australia Pty Ltd, Aviemore Capital Pty Ltd, and Wisdom Frontier Limited.

In accordance with the Commonwealth *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009* [OPGGS(E)R]; Table ES-1-1 provides the details of titleholders within which the petroleum activity will take place.

Table ES-1-1 Licence and Titleholder Details

Title	Name	Operator	Titleholder Details
WA-41-R	Corowa	KATO Energy	Tamarind Australia (Corowa) Pty Ltd Hydra Energy (WA) Pty Ltd

Document Purpose and Scope

This OPP has been prepared in accordance with the OPGGS(E)R and associated guidelines, which require an OPP to be submitted for all offshore projects to the National Offshore Petroleum Safety and Environment Management Authority (NOPSEMA) for approval. An OPP is an initial and global assessment of a project and must be accepted by NOPSEMA before the titleholder can submit Environment Plans (EPs) for activities that make up the project.

The OPP process involves NOPSEMA's assessment of all potential environmental impacts and risks of petroleum activities conducted over the life of an offshore project, and involves a public consultation period.

ES2. Environmental Legislation and Other Environmental Management Requirements

The Corowa Development is located entirely in Commonwealth waters and therefore falls under Commonwealth jurisdiction, triggering this key legislation, as summarised in Table ES-1-2:

- *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGSS Act)
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

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

Table ES-1-2 Overview of Key Commonwealth Legislation

<table>
<tr><th>Legislation</th><th>Scope</th></tr>
<tr><td>OPGGS Act</td><td>Provides the regulatory framework for all offshore petroleum exploration and production activities in Commonwealth waters, beyond the three nautical mile limit, to ensure that these activities are undertaken:
• consistent with the principles of ecologically sustainable development as defined in section 3A of the EPBC Act
• to reduce environmental impacts and risks of the activity to as low as reasonably practicable (ALARP)
• to ensure 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 royalty. These regulations 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 2009 OPGGS(E)R.
Part 1A of the OPGGS(E)R specifies that before commencing an offshore project, a person must submit an offshore project proposal for the project to the regulator.</td></tr>
<tr><td>EPBC Act</td><td>This is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places — defined in the EPBC Act as Matters of National Environmental Significance (NES).
The aims of the EPBC Act are to:
• protect matters of NES
• provide for Commonwealth environmental assessment and approval processes
• provide for an integrated system for biodiversity conservation and management of protected areas.
Matters of NES identified as relevant to the Corowa Development are:
• Migratory species under international agreements
• Commonwealth marine environment
• World heritage properties
• National heritage places
• Listed threatened species and communities
• RAMSAR wetlands.</td></tr>
</table>

ES3. Description of the Project

Project Overview

KATO plans to develop the Corowa field using a relocatable production system known as the 'honeybee production system', which comprises the key elements shown in Figure ES-1-2:

1. Jack-up mobile offshore production unit (MOPU)
2. Production unit on the MOPU, which will separate and process oil, gas and water
3. Wells workover module on the MOPU, which will have the capability to plug and abandon wells, and potentially to drill; however, a separate mobile offshore drilling unit (MODU) may be used
4. Short flowline and riser to transport oil
5. Catenary anchor leg mooring (CALM) buoy
6. Floating marine hose to transport oil
7. Moored floating storage and offloading (FSO) facility, where oil is stored; or direct to shuttle tankers (depending on export option selected)
8. Floating export hose to offload oil from the FSO to export tankers.

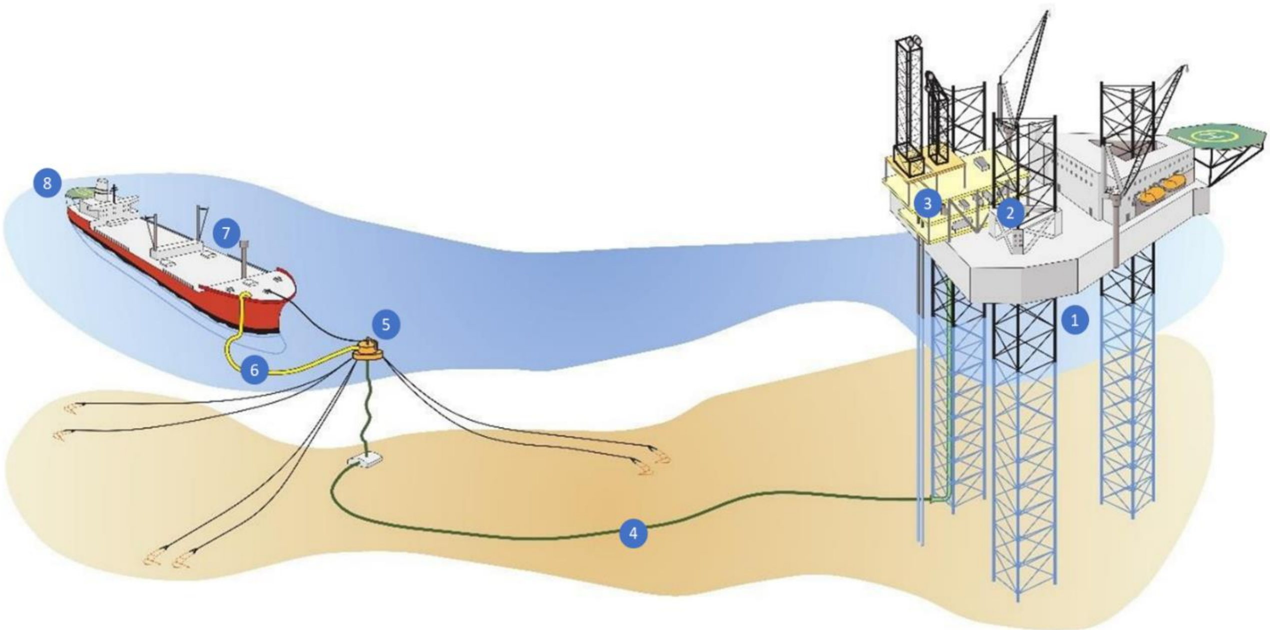


Figure ES-1-2 Corowa Development Infrastructure

Location

The Corowa Development is within Commonwealth waters in offshore petroleum permit WA-41-R, located ~60 km from Onslow in the north-west of Australia, in water depths of ~90 m (Figure 3-2). No petroleum activities are proposed in State waters or onshore.

Under Regulation 5A(5) of the OPGGS(E)R, this OPP is only required to assess petroleum activities within the project area and also covers the area where project vessels will be undertaking petroleum activities.

For the purpose of this OPP, the Project Area has been defined to include the extent of all planned activities described in this proposal with sufficient buffer, which has been conservatively designated as a 5 km radius around the expected position of the MOPU. The final MOPU position will be included in the relevant EP/s.

Vessels transiting to and from the Project Area are not considered a petroleum activity—they fall under the other maritime legislation, including the Commonwealth *Navigation Act 2012*, and therefore are excluded from the scope of this OPP. In addition, helicopter activities outside a petroleum safety zone are not defined as petroleum activities.

Project Schedule

The target schedule for the Corowa Development is detailed in Table ES-1-3.

KATO will become the titleholder for a number of fields. The intent is that as each field is depleted, it is decommissioned, and the honeybee production system is then relocated to the next field. The order of the fields is not yet decided, and the timing shown in Table ES-3 assumes that the Corowa field will be the first development. If the fields are produced in a different order, the timing of Corowa may be later than shown.

Based on statistical modelling of the production profile, the best estimate of production life is two years (also known as P50), and the high estimate is 4.5 years (also known as P10; RPS 2014), meaning the duration of the Operations phase is between two and 4.5 years.

A contingent infill drilling program is included in the preliminary project schedule for a possible second MODU mobilisation for an infill, well repair and/or sidetrack program, dependent on reservoir performance in the initial 6–12 months of production.

The conservative project life for the Corowa Development (from mobilisation to decommissioning) is approximately five years.

Table ES-1-3 Preliminary Project Schedule

Phase	Timing	Indicative Duration
Survey	Q3 2021	1 month
Drilling	Initial campaign – Q4 2021 / Q1 2022 Second campaign (if required) – 1 to 2 years after start-up	Initial campaign – 5 months Second campaign (if required) – additional 4 months
Installation, Hook-up and Commissioning	Q4 2021 / Q1 2022	3 months
Operations	Q2 2022	Between 2 and 4.5 years, at best and high estimates of production, respectively
Decommissioning	Between 2023 and 2026 (depending on duration of operations)	3 months

Project Stages

Key phases of the Corowa Development and associated activities are:

Survey	geophysical survey; geotechnical survey
Drilling	MODU positioning; top-hole drilling; blowout preventer (BOP) installation and testing; bottom-hole drilling; completions; well clean-up and flowback; drill cuttings and fluids
Installation, Hook-up and Commissioning	MOPU; CALM buoy and mooring arrangements; flowlines; FSO
Operations	hydrocarbon extraction; hydrocarbon processing, storage and offloading; inspections; maintenance and repair; well intervention
Decommissioning	inspection and cleaning; well plug and abandonment; removal of subsea infrastructure; disconnection of FSO and MOPU; as-left survey
Support Activities (all phases)	MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations; ROV operations

ES4. Analysis of Alternatives

The OPGGS(E)R requires that:

> *'Part 1A, 5A (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; and*
>
> *(ii) an explanation, in adequate detail, of why the alternative was not preferred.'*

This section addresses this requirement by undertaking an analysis of the feasible alternatives to the:

- development concept
- design and activity options for the selected concept.

The assessment was carried out in two steps: firstly, undertaking a comparative assessment of the options against environmental drivers to identify the options with the least environmental impact; and secondly, further assessing the options against the rest of the criteria (economic, technical feasibility and safety, and social drivers) to justify the final selected option. A qualitative ranking scale was developed based on the KATO Environmental Risk Matrix, to allow differentiation between the alternatives.

Analysis of Concept Alternatives

KATO considered six alternative development concepts for Corowa.

The comparative environmental assessment showed that the most favourable concept environmentally is Concept 5 – Subsea tie-back to existing FSPO/Onshore, with Concept 1 – Honeybee production system ranked second.

The qualitative ranking for economic, technical feasibility and safety, and social drivers showed that Concept 5 – Subsea tie-back to existing FPSO/Onshore facility had the second-worst score, and Concept 1 – Honeybee production system was ranked the best.

An evaluation of all criteria (including environmental) clearly shows Concept 1 – Honeybee production system is the preferred concept, for all criteria. This concept can be used for short periods and relocated, allowing for capital costs to be minimised at each field and prompt removal of all permanent infrastructure, thereby allowing stranded, sub-economic or previously considered immaterial oil assets to be developed.

Table ES-1-4 summarises the comparative assessment outcomes.

Table ES-1-4 Summary of Comparative Assessment of Concept Alternatives

Concept		Summary of comparative assessment evaluation	
1	**Honeybee production system** *Selected Concept*	• Short production lifespan reduces ongoing environmental impacts. • Redeployable nature reduces environmental impact by removing all infrastructure promptly upon cessation of production, increases economic viability, and aligns with KATO strategy. • Production trees located at surface reduce construction, operations and decommissioning complexity and cost. • Economic field development concept, lower capital cost than other concepts except Concept 5. • Keeps open the option for a single production and drilling unit, further reducing complexity of installation and decommissioning. • Aligns with industry analogues for small short-lived shallow-water offshore oil fields. • Associated gas management strategy challenging.	✓
2	**Subsea to Shore**	• High cost and not economic. Field size and field life do not support the cost of subsea development and an onshore process facility. • High safety risk of long-distance road transport of product. • Large development footprint associated with pipeline and onshore facilities.	*X*
3	**FPSO**	• While redeployable, the Corowa field size and field life are not deemed sufficient to support the costs associated with installation and recovery of a mooring system and subsea flowline and riser architecture for a FPSO. • Removal for cyclone events further reduces economic viability over anticipated short field life. • Subsea construction activity and footprint result in greater environmental impact.	*X*
4	**Fixed Platform to FSO, Subsea storage or Export pipeline**	• Field size and field life are not sufficient to support the cost of a fixed platform and/or pipeline to existing facility. • Inability to relocate the facility does not allow the development of other isolated oil fields. • Lower section of fixed platform (and subsea storage tank or pipelines if used) potential to remain in place if lower environmental impact than removal.	*X*
5	**Subsea Tie-back to Existing Facility**	• Distance to existing facility means this option would be technically challenging, requiring the deployment of emerging technology. • Near-term ullage not available. Volume versus risk not aligned with existing facility owners due to perceived risk of allowing third-party entry to owner-operated facilities. • High schedule risk for commercial tolling agreements between existing facility owner and resource owner.	*X*
6	**No Development**	• Titleholder must undertake certain petroleum exploration and production related activities towards commercialising the resource.	*X*

Analysis of Design / Activity Alternatives

Once the concept has been selected (i.e. Concept 1 – Honeybee production system), there are alternatives to consider for more granular activities, designs and construction methods. With the exception of the gas strategy, these options are assessed only against environment criteria, as they are mostly 'lower level' design and methodology decisions. This is because the reservoir is expected to produce associated gas with the oil, with a total gas production anticipated of ~4.9–9.3 Bcf[1] (for best and high estimate respectively). This gas must be used, exported or disposed of to allow for production of the oil.

The gas strategy presents one of the key potential sources of environmental impact and risk for the Corowa Development. Therefore, KATO has undertaken a comparative assessment of the options against all project drivers and criteria, not only against the environmental criteria.

Table ES-1-5 provides a summary of the gas strategy alternatives, showing which options have been taken through into the Front-End Engineering and Design Phase (FEED).

Table ES-1-5 Summary of Comparative Assessment of Gas Strategy Alternatives

Option	Option Justification	
Fuel gas *Selected*	• No additional impacts. • Gas generated from oil production will exceed 0.5 MMscf/d fuel gas demand; therefore, an alternative disposal method is required for this additional gas.	✓
Export via pipeline to existing gas treatment facility	• ~15 km of seabed disturbance associated with export pipeline resulting in moderate localised impact to benthic habitat. • Moderate physical footprint offshore and onshore for ~2–4.5 years of gas production. • Additional resources for pipeline manufacture and installation. • Positive impact of reduced atmospheric emissions from natural gas offsets other fuel use in power generation. • Not economic due to short project life, relatively small volumes of gas; cost of installing and decommissioning pipeline will not be recovered from gas sales. • Addition of large gas treatment, compression and export equipment on MOPU increases congestion, introduces high-pressure gas hazard on topsides resulting in an increase to fire and explosion risk. Tie-in to pipeline requires high-risk diving activity.	*X*
Reinject gas to reservoir	• Introduces the risk of loss of well containment while drilling an additional gas injection well, leading to additional potential widespread impact. • Not economic due to short project life, cost of additional well and small volumes of gas. • Reservoir not suitable for reinjection. Very high risk of gas breakthrough to production wells significantly reducing oil recovery from reservoir.	*X*
Flare *Selected*	• Moderate level of CO_2-e emissions from burning associated reservoir gas during operations phase. Increase in atmospheric emissions by up to 1.1 Mt CO_2-e. Gas is not used. • Moderate level of atmospheric emissions associated with gas flaring. • Flaring of associated gas. Natural resources not used as efficiently as possible. Integrational equity value of flared gas not valued.	✓

[1]Anticipated Gas Oil Ratio (GOR) of 700 scf/stb

Option	Option Justification	
Gas to wire	• ~50 km of seabed disturbance and shore crossing associated with power export cable resulting in moderate localised impact to benthic habitat. • Not economic due to short project life, cost of export cable and small volumes of gas. • There is only one potential market within range (<100 km), as Barrow Island and Onslow have excess electricity generation; however a deep underwater canyon precludes a transmission line to Exmouth.	X
New technologies (Compressed Natural Gas [CNG] / Mini-LNG)	• Not economic due to short project life, cost of additional CNG/mini-LNG infrastructure. The best or low estimate for production profile would have to be assumed, as a worst-case scenario. • Emerging concept. No industry analogues to date. Technically challenging. Facility sizing and gas utilisation trade off. • Export cable route to market (Exmouth) challenged by seabed features.	X

Therefore, the flare design is a key factor in environmental impact – specifically for light and atmospheric emissions. Table ES-1-6 summarises the comparative assessment of the identified flare design options, showing which will be taken through into FEED.

Table ES-1-6 Summary of Comparative Assessment of Flare Design Alternatives

Option	Option Justification	
Open pipe flare	• Simple design which results in very low back-pressure and is typically used for burning light hydrocarbons such as Corowa associated gas. • Applicable for low pressure drop waste gas streams.	✓
Enclosed flare or Ground flare	• Insulated enclosure walls shield light and noise emissions. • The physical footprint of the burner arrangements and enclosure requires a large area, which is not available on the MOPU. • Burner tips require a large pressure drop to create turbulent mixing and efficient combustion.	X
Pit flare	• Open pipe flare is enclosed with earthen or concrete bunds to shield light emissions. • Requires earthen area to excavate and large footprint, which are not feasible offshore.	X
Multi-tip flare	• Multiple tips split gas flow into separate sources and allows for more turbulent mixing with air for increased combustion efficiency. • Typically used for high gas pressure, but low-pressure options suitable for Corowa may be feasible.	✓
Sonic flare	• Uses a high-pressure nozzle on the flare tip which creates high speed gas flow to create turbulence, which can eliminate smoke, lower flame radiation and shorten the flame length. • Only suitable where there is a significant pressure drop available from the waste gas stream, which is not feasible for Corowa.	X
Air assist	• Uses an air blower system to increase turbulence, which results in a quicker burn. • Applicable for low pressure drop waste gas such as Corowa. May result in a difference in flare combustion characteristic including flare luminosity.	✓

Option	Option Justification	
Steam assist	• Injects steam around the flare tip into the combustion zone to induce turbulence. • Requires a high pressure drop. Is not considered feasible as there is no high-quality feed water available, the process does not produce steam, and a large footprint is required for a boiler package and equipment to treat, store and supply boiler feed water.	*X*

Table ES-1-7 summarises the other key options identified, and those selected for use in FEED.

Table ES-1-7 Summary of Comparative Analysis of Design / Activity Options

Design/ Activity Option	Justification for Selected Option
Produced formation water (PFW) treatment and disposal	**Option 1 – Reinjection into reservoir:** *Not Selected* • Requires additional well to be drilled into reservoir and additional topside treatment facilities therefore making the facility larger. • Risk of reservoir souring, scaling and formation damage, additional well interventions, early cessation of production. • Poses additional risks to reservoir integrity, oil production and the potential need for remedial actions, and potential increased safety risks, increased chemical usage and reduced production.
	Option 2 – Discharge to marine environment: *Selected* • Does not require additional subsea equipment or wells, significantly lower capital cost to reinjection • Localised temporary change to water quality.
Drilling facility	**Option 1 – MOPU with Drilling capability:** *Selected* **Option 2 – MOPU and separate MODU:** *Selected* • No significant environmental differentiator. Both options selected to carry through FEED.
Drilling fluid selection	**Option 1 – Water-based mud (WBM):** *Selected* **Option 2 – Synthetic-based mud (SBM):** *Selected* • No significant environmental differentiator. Both options selected to carry through FEED.
Export strategy	**Option 1 – FSO and export tankers:** *Selected* **Option 2 –Shuttle tankers:** *Selected* • No significant environmental differentiator. Both options selected to carry through FEED
Mooring of CALM buoy	**Option 1 – Drilled and grouted anchor piles:** *Selected* **Option 2 – Gravity anchors:** *Selected* • No significant environmental differentiator. Both options selected to carry through FEED.

ES5. Description of Environment

Environment that may be Affected

Under the OPGGS(E)R, the OPP must describe the environment that may be affected (EMBA), including details of the particular values and sensitivities (if any) within that environment.

The environment that may be affected by the Corowa Development has been defined as an area where a change to ambient environmental conditions may potentially occur as a result of planned or unplanned activities. Note: A change does not always imply that an adverse impact will occur; for example, a change may be required over a particular exposure value or over a consistent time period for a subsequent impact to occur.

For the purpose of this OPP, the EMBA associated with the Corowa Development was demarcated into three sub-areas that are used to support the impact and risk assessments, described in Table ES-1-8.

Table ES-1-8 Description of Corowa Development EMBA Sub-Areas

Corowa Development EMBA and Sub-Areas	Description
EMBA	The extent of the EMBA for the Corowa Development is based on the results of stochastic oil spill modelling of a Loss of Well Control (LOWC) scenario as this represented the largest spatial extent of potential changes to ambient environment conditions from an aspect. The EMBA is based on the cumulative extent of 150 model simulations using 'low' exposure values for each modelled oil component (1 g/m^2 floating, 10 ppb dissolved and entrained, 10 g/m^2 shoreline) (Section 7.2.6.2.4) and includes all probabilities of exposure. Note: The outer extent of the modelling has been simplified for the purposes of final EMBA definition and display.
Planned Activities	
Project Area	This area has been defined to include the extent of all planned activities (Section 3.4), and is the area relevant to the impact and risk assessments for all planned and unplanned aspects (Section 7), with the exception of light emissions and accidental hydrocarbon releases. The Project Area has been defined as a 5 km area extending around the expected MOPU position [2].
Light Area	This area has been defined to include the worst-case extent of predicted measurable light based on planned activities (Section 3.4), and is the area relevant to the impact assessment for planned light emissions (Section 7.1.3). This Light Area extends for 30 km around the expected MOPU position[3], and is evaluated as the Potential Impact Area in Section 7.1.3.
Unplanned Activities	

[2] As the position of the MOPU is indicative only at this stage, the identification of values and sensitivities (including an EPBC protected matters search) has been completed using a 7 km buffer around the expected position of the MOPU (Appendix A).

[3] The identification of values and sensitivities (including an EPBC protected matters search) has been completed using a 30 km buffer around the expected position of the MOPU (Appendix A).

Corowa Development EMBA and Sub-Areas	Description
Hydrocarbon Area	This area has been defined to include the worst-case extent of predicted hydrocarbon above ecological and/or visual impact values based on planned activities (Section 3.4), and is the area relevant to the risk assessment for unplanned accidental releases of oil (Corowa Light Crude and Marine Gas Oil) (Sections 7.2.5 and 7.2.7). This Hydrocarbon Area was defined based on the outcomes of stochastic modelling (i.e. it is the cumulative extent of 300 model simulations) using exposure values for each modelled oil component (1 g/m^2 floating, 50 ppb dissolved, 100 ppb entrained, 10 g/m^2 shoreline) and includes all probabilities of exposure[4].

Physical Environment

Table ES-1-9 summarises the physical environment relevant to the Corowa Development.

Table ES-1-9 Summary of Physical Environment Relevant to the Corowa Development

Physical Receptor	Overview
Water quality	Expected to be representative of the typically pristine and high-water quality found in offshore Western Australian waters. Variations to this state (e.g. increased turbidity) may occur in more coastal regions that are subject to large tidal ranges, terrestrial run-off or anthropocentric factors (e.g. ports, industrial discharges).
Sediment quality	Seabed sediments of the continental slope in the North West Shelf Province (NWSP) are generally dominated by carbonate silts and muds, with sand and gravel fractions increasing closer to the shelf break. It is expected that sediment quality will be high, with low background concentrations of trace metals and organic chemicals.
Air quality	The Corowa Project Area is expected to be of typically high air quality due to its offshore location.
Climate	The climate within the region is dry tropical, with a hot summer season from October to April and a milder winter season between May and September. Cyclonic events are characteristic of the summer period.
Ambient noise	Ambient noise within the offshore Pilbara region is expected to be dominated by natural physical (e.g. wind, waves, rain) and biological (e.g. echolocation and communication noises generated by cetaceans and fish) sources. Some vessel traffic, including commercial shipping and fishing, is likely to occur within the Corowa Project Area; however, no main shipping pathways occur in the area. Anthropogenic noise sources likely to be experienced in the area include low-frequency noise from mid to large vessels such as tankers.

Ecological Environment

Table ES-1-10 summarises the ecological environment for the Corowa Development.

Seabirds and shorebirds, fish, marine reptiles and marine mammals may be categorised as Matters of National Environmental Significance (matters of NES) under the EPBC Act.

[4] The identification of values and sensitivities (including an EPBC protected matters search) has been completed using the outer extent of modelled exposures at the above (Appendix A).

Table ES-1-10 Summary of the Ecological Environment Relevant to the Corowa Development

Ecological Receptor	Overview
Plankton	Offshore phytoplankton communities in the region are characterised by smaller taxa (e.g. cyanobacteria), while shelf waters are dominated by larger taxa such as diatoms. No aggregations of larger zooplankton (such as krill) were recorded in offshore waters of the Woodside Ngujima-Yin FPSO (~50 km west of the Project Area) during a dedicated field study conducted by the Australian Institute of Marine Science (AIMS).
Benthic habitats and communities	Benthic community assessment has been carried out for the nearby lease area WA-28-L and included remotely operated vehicle (ROV) surveys of the Vincent field (~50 km west of the project area) by AIMS. Video and still recordings revealed four main invertebrate groups of deepwater benthos including crustaceans, sponges, echinoderms and cnidarians (octocorals). The results also showed that species diversity decreased with depth across the area (Woodside 2005). At the depth of the Project Area (~90 m), the consequent reduced light levels of this deepwater environment, and the general lack of hard substrate that many benthic species depend on for attachment, the benthic communities associated with the unconsolidated sediment habitats are of relatively low environmental sensitivity.
Coastal habitats and communities	Coastal communities are biological communities that live within the coastal zone; these communities include wetlands and other intertidal flora/vegetation such as saltmarsh or mangroves. Coastal habitats are the landforms that coastal communities grow on or in; these are typically considered in terms of shoreline type and can vary from sandy beaches to coastal cliffs. No internationally important (i.e. Ramsar) wetlands occur within the Project Area. Two nationally important marine/coastal wetlands occur within the Hydrocarbon Area: • Exmouth Gulf East • Learmonth Air Weapons Range – Saline Coastal Flats.
Seabirds and Shorebirds	The Protected Matters Search Tool (PMST; EPBC Act) identified the following number of species that may occur within the Corowa Development Areas: • 12 within the Project Area • 120 within the EMBA. Biologically important areas (BIAs) that overlap the sub-areas for planned activities were identified as: • Project Area: Wedge-tailed Shearwater (breeding) • Light Area: Wedge-tailed Shearwater (breeding), Bridled Tern (breeding), Fairy Tern (breeding), Lesser Crested Tern (breeding), Common Noddy (foraging), Lesser Frigatebird (foraging).
Fish	The PMST identified the number of species that may occur within the Corowa Development Areas: • 39 within the Project Area • 74 within the EMBA. BIAs that overlap the sub-areas for planned activities were identified as: • Project Area and Light Area: Whale Shark (foraging).
Marine mammals	The PMST identified the number of species that may occur within the Corowa Development Areas: • 24 within the Project Area

Ecological Receptor	Overview
	• 48 within the EMBA. BIAs that overlap the sub-areas for planned activities were identified as: • Project Area and Light Area: Blue Whale/Pygmy Blue Whale (distribution), Humpback Whale (migration).
Marine reptiles	The PMST identified the number of species that may occur within the Corowa Development Areas: • 18 within the Project Area • 28 within the EMBA Protected and migratory turtle species (e.g. Flatback, Green, and Hawksbill Turtles) are known to nest on the Pilbara inshore islands. BIAs that overlap the sub-areas for planned activities were identified as: • Project Area: Loggerhead Turtle (internesting), Green Turtle (internesting), Flatback Turtle (internesting) • Light Area: Loggerhead Turtle (internesting, nesting), Green Turtle (internesting, nesting), Hawksbill Turtle (internesting), Flatback Turtle (internesting, nesting).

Social, Economic and Cultural Environment

Table ES-1-11 summarises the social, economic and cultural environment for the Corowa Development.

The Commonwealth marine environment is a MNES under the EPBC Act.

Table ES-1-11 Summary of the Social, Economic and Cultural Environment Relevant to the Corowa Development

Social, Economic and Cultural Receptor	Overview
Australian Marine Parks (AMPs)	The Project Area and Light Area do not intersect any AMPs. The closest AMPs to the Corowa Development are Ningaloo, Gascoyne and Montebello Marine Parks, ~40 km, 60 km and 100 km from the expected position of the MOPU respectively. Within the EMBA, 14 AMPs are present—ten within the North-west Marine Region, and four within the South-west Marine Region.
Key Ecological Features	Key Ecological Features (KEFs) 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. The closest KEFs to the Corowa Development are the 'ancient coastline at 125 m depth contour' and the 'canyons linking the Cuvier Abyssal Plan and the Cape Range Peninsula' (~5 km and 7 km away respectively). Within the EMBA, 17 KEFs are present— ten within the North-west Marine Region, and seven within the South-west Marine Region.
Commercial Fisheries	The commercial fisheries that intersect the sub-areas for planned activities were identified as: • Project Area: 3 Commonwealth-managed fisheries (of which none are active); 7 State-managed fisheries (of which one is active – Pilbara Line Fishery). • Light Area: 4 Commonwealth-managed fisheries (of which none are active); 12 State-managed fisheries (of which two are active – Pilbara Line Fishery and Pearling / Aquaculture Leases).

Social, Economic and Cultural Receptor	Overview
Marine Tourism and Recreation	Charter fishing, marine fauna watching, and cruising are the main commercial tourism activities, with fishing, diving, snorkelling and other nature-based activities the main recreational activities that may occur within the EMBA. Most recreational fishing typically occurs in nearshore coastal waters (shore or inshore vessels), and within bays and estuaries. Offshore fishing (>5 km from the coast) only accounts for ~4% of recreational fishing activity in Australia, and the Project Area is 60 km from Onslow.
State Protected Areas – Marine	The Project Area does not intersect any State Protected Areas – Marine. The Light Area intersects the Muiron Islands Marine Management Area. The next closest State marine protected area is Ningaloo Marine Park, 40 km away. There are ten State marine protected areas within the EMBA.
State Protected Areas – Terrestrial	The Project Area does not intersect any State Protected Areas – Terrestrial. The Light Area intersects the Muiron Islands Marine Management Area and Pilbara Inshore Islands Nature Reserves. There are eight State terrestrial protected areas within the EMBA.
Marine and Coastal Industries	The Carnarvon Basin supports >95% of WA's oil and gas production. Oil and gas facilities within the vicinity of the Corowa Development include BHP's Pyrenees FPSO (~46 km), Santos' Ningaloo Vision FPSO (~49 km), Woodside's Ngujima-Yin FPSO (~51 km), and Chevron's Wheatstone LNG plant, onshore near Onslow (52 km). The largest ports within the EMBA are the Ports of Dampier and Port Hedland. Commercial shipping traffic is high within the NWS, with vessel activities including commercial fisheries, tourism, international shipping and oil and gas operations The Project Area is within the Department of Defence's (DoD) North West Exercise Area (NWXA). DoD advised that unexploded ordnance (UXO) may be present on and in the sea floor within the NWXA. There are two submarine telecommunications cables of national significance currently in service within the EMBA (although >400 km from the MOPU).
Heritage and Cultural Features	The EPBC Act provides for listings under World Heritage Areas (WHA), National Heritage (including indigenous or historic) and Commonwealth heritage. The Project Area does not intersect any identified heritage and cultural features. The Light Area intersects the Ningaloo Coast, recognised as a WHA and included on both the National and Commonwealth Heritage lists (~20km from the MOPU), and some historic shipwrecks. There are two World and six National heritage places within the EMBA. The boundary of the Karajarri Indigenous Protected Areas partially occurs within the extent of the EMBA.

ES6. Impact and Risk Methodology

The risk assessment for this OPP was undertaken in accordance with KATO's Risk and Change Management Procedure (KAT-000-GN-PP-002) (KATO 2020a) using the KATO Environmental Risk Matrix.

This approach is consistent with the processes outlined in ISO 31000:2009 Risk Management – Principles and Guidelines (Standards Australia/Standards New Zealand 2009) and Handbook 203:2012 Managing Environment-related Risk (Standards Australia/Standards New Zealand 2012).

The overarching steps in the methodology are:

- Establish the context:
  - Description of the petroleum activity (‘activity’)
  - Identification of particular environmental values (‘receptors’)
  - Identification of relevant environmental aspects
- Risk Assessment:
  - Risk identification – systematic scoping of relationships between Aspects, Impacts and Risks, and Receptors
  - Risk analysis of likelihood and consequence
- Risk Treatment:
  - Identification of control measures
- Acceptability:
  - Assessment against KATO acceptability criteria.

Environmental performance outcomes (EPOs) were developed based on the required levels of performance set either in legislation (such as the OPGGS Act), regulator guidance notes such as the Matters of National Environmental Significance– Significant Impact Guidelines (DoE 2013) or may be the result of specific agreements or expectations with other relevant stakeholders (e.g. fishers or other marine users). KATO have identified 18 EPOs for physical, ecological and social, cultural and heritage receptors.

ES7. Evaluation of Environmental Impacts and Risks

The OPP has identified potential environmental impacts and risks associated with the Corowa Development. The impacts and risks associated with each aspect of the Corowa Development were determined to be acceptable following implementation of the adopted control measures (Table ES-1-12 and Table ES-1-13).

Table ES-1-12 Summary of Environmental Impacts and Risks Associated with the Corowa Development – Planned Aspects

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
Physical Presence- Interaction with Other Users	*Installation, Hook-up and Commissioning* MOPU; CALM buoy and mooring arrangements; flowlines; FSO *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations	**Commercial Fisheries**	Changes to the functions, interests or activities of other users	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.	**CM01**: Vessels to adhere to the navigation safety requirements including the Commonwealth *Navigation Act 2012* and any subsequent Marine Orders. **CM02**: Notify Australian Hydrographic Office (AHO) of activities and movements prior to activity commencing. **CM03**: Pre-start notifications will be provided to relevant stakeholders at appropriate timing, including presence of exclusion and cautionary zones.	Minor
		Industry				Minor
Physical Presence – Seabed Disturbance	*Survey* geotechnical survey *Drilling* MODU positioning; top-hole drilling *Installation, Hook-up and commissioning* MOPU; CALM buoy and mooring arrangements; flowlines	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM04**: Mooring analysis will be undertaken, which will include an environmental sensitivity and seabed topography analysis. **CM05**: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below seabed and removed.	Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
	Operations maintenance and repair; well intervention *Decommissioning* well P&A; removal of subsea infrastructure; disconnection of FSO and MOPU *Support Activities (all phases)* vessel operations	**Benthic habitat and communities**	Change in habitat	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor
		Fish	Injury / mortality to fauna			Minor
Emissions – Light	*Drilling* well clean-up and flowback *Operations* hydrocarbon processing, storage and offloading (flaring)	**Ambient light**	Change in ambient light	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM06**: Lighting will be sufficient for navigational, safety and emergency requirements (e.g. requirements contained in AMSA Marine Order Part 30 and Facility Safety Cases). **CM07**: Best practice design of the flare will be investigated in FEED to reduce flare height.	Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
	Support Activities (all phases) MODU operations; MOPU operations; FSO operations; vessel operations	**Seabirds and shorebirds**	Change in fauna behaviour	**EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	**CM08:** An Artificial Light Management Plan will be developed in alignment with the Draft National Light Pollution Guidelines (DoEE 2019).	Moderate
		Fish				Minor
		Marine reptiles				Moderate
		State Protected Areas	Change in ambient light Change in fauna behaviour Changes to the functions, interests or	**EPO14:** To not result in a change that may have an adverse effect on the protection and conservation of biodiversity, ecological processes and other natural, cultural and heritage values of marine parks and protected areas. **EPO15:** To not result in a change that may cause one or more of the World Heritage values or National Heritage values of a declared World Heritage property or National Heritage place to be lost, degraded or damaged, or notably altered, modified, obscured or diminished.		Moderate
		Heritage features				Moderate

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
			activities of other users Change in aesthetic value			
Emissions – Atmospheric	*Drilling* well clean-up and flowback *Installation, Hook-up and Commissioning* MOPU *Operations* hydrocarbon processing, storage and offloading *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Ambient air quality**	Change in air quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO18**: To not significantly contribute to Australia's annual greenhouse gas emissions.	**CM09**: Compliance with AMSA Marine Order 97 (Marine pollution prevention — air pollution). **CM10**: Restrictions on import and use of Ozone Depleting Substances (ODS) for refrigeration and air conditioning systems as per the Commonwealth *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*. **CM11**: Use of associated gas as fuel gas during operations is optimised to enable the safe and economically efficient operation of the facility. **CM12**: Reporting of GHG emissions are required as per the National Greenhouse and Energy Reporting (NGER) Scheme. **CM13**: Operations designed to be optimised to enable the safe and economically efficient operation of the facility.	Minor
		Climate	Climate change			Minor
Emissions – Underwater Noise	*Survey* geophysical survey (sonar) *Drilling* top-hole drilling; bottom-hole drilling; completions *Operations* well intervention	**Ambient noise**	Change in ambient noise	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM14**: Vessels will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the project area. **CM15**: Vertical seismic profiling (VSP) operations will adhere to the EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines. **CM16**: Equipment will be maintained in accordance with the manufacturers' specifications, facility	Minor
		Fish	Injury / mortality to fauna	**EPO1:** Noise emissions are managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging BIA.		Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
	Decommissioning Well P&A *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations		Change in fauna behaviour	**EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	planned maintenance system and regulatory requirements.	Minor
		Marine mammals	Injury / mortality to fauna			Moderate
			Change in fauna behaviour			Moderate
		Marine reptiles	Change in fauna behaviour			Moderate
Planned Discharge – Drilling cuttings and Fluids	*Drilling* top-hole drilling; bottom-hole drilling; completions; well clean-up and flowback	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM18**: Solid removal and treatment equipment will be used to reduce and minimise the amount of	Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
	Installation, Hook-up and Commissioning CALM buoy and mooring installation *Operations* well intervention *Decommissioning* well P&A	**Ambient sediment quality**	Change in sediment quality		residual fluid contained in drilled cuttings prior to discharge to the marine environment. **CM19**: Drilling and cementing procedures to standard industry practices will be developed that will describe specific well locations, design and fluid volumes.	Minor
Planned Discharge – Cement	*Drilling* top-hole drilling; bottom-hole drilling *Installation, Hook-up and Commissioning* CALM buoy and mooring installation *Operations* well intervention *Decommissioning* well P&A	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM19**: Drilling and cementing procedures to standard industry practices will be developed that will describe specific well locations, design and fluid volumes.	Minor
		Ambient sediment quality	Change in sediment quality			Minor
		Benthic habitats and communities	Injury / mortality to fauna	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor
Planned Discharge –	*Installation, Hook-up and commissioning* flowlines; FSO; MOPU	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts,	Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
Commissioning Fluids	*Decommissioning* disconnection of FSO and MOPU	**Ambient sediment quality**	Change in sediment quality	biodiversity, ecological integrity, social amenity, human health or other marine users.	concentrations and risks to provide technical effectiveness.	Minor
Planned Discharge – Produced Formation Water	*Operations* hydrocarbon processing, storage and offloading	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM20**: A management framework for produced formation water discharges will be developed.	Moderate
		Ambient sediment quality	Change in sediment quality			Minor
		Plankton	Injury / mortality to fauna	**EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Moderate
Planned Discharge – Cooling Water and Brine	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM16**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness.	Minor
		Plankton	Injury / mortality to fauna	**EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor
Planned Discharge – Deck drainage and Bilge	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM16**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness.	Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
					CM21: Compliance with AMSA Marine Order Part 91 (Marine Pollution Prevention – Oil) (MARPOL Annex I. MARPOL International Convention for the Prevention of Pollution from Ships) to prevent accidental pollution and pollution from routine operations.	
Planned Discharge – Sewage, greywater and food waste	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM16**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM22:** Compliance with Marine Order 96 (Marine pollution prevention – Sewage) 2013. **CM23:** Compliance with Marine Order 95 (Marine pollution prevention – Garbage) 2013.	Minor

Table ES-1-13 Summary of Environmental Impacts and Risks Associated with the Corowa Development – Unplanned Aspects

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
Unplanned Introduction of IMS	*Drilling* MODU positioning *Installation, Hook-up and Commissioning* MOPU; FSO; CALM buoy and mooring arrangements *Decommissioning* inspection and cleaning *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Benthic habitats and communities**	Change in ecosystem dynamics	**EPO7:** To not result in an introduced marine species becoming established in the marine environment. **EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution.	**CM24**: Requirements of the Australian Ballast Water Management Requirements Version 7 to be met. **CM25**: Requirements of the National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry to be met. **CM26**: Inspection and in-water cleaning of marine growth as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015) on relocatable subsea infrastructure and MOPU and FSO wetsides before demobilisation from Project Area, including methods to ensure minimal release of biological material into the water. **CM27**: A Biofouling Management Plan will be developed as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015).	Serious	Unlikely	Medium
		Coastal habitats and communities				Serious	Very unlikely	Medium
		Commercial Fisheries	Changes to the functions, interests or activities of other users	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Moderate	Very unlikely	Low
		Industry				Moderate	Very unlikely	Low
Physical Presence – Interaction with Marine Fauna	*Survey* geophysical survey; geotechnical survey *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations;	**Fish**	Injury / mortality to fauna	**EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population.	**CM14**: Vessels will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the Project Area.	Minor	Unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
	vessel operations; helicopter operations	**Marine mammals**		**EPO3:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		Minor	Unlikely	Low
		Marine reptiles				Minor	Unlikely	Low
Physical Presence – Unplanned Seabed Disturbance	*Installation, Hook-up and commissioning* MOPU; CALM buoy and mooring arrangements; flowlines *Decommissioning* Inspection and cleaning; well P&A; Removal of subsea infrastructure; disconnection of MOPU/FSO *Support Activities (all phases)* MODO operations; MOPU operations; FSO operations; vessel operations; ROV operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM04**: Mooring analysis will be undertaken, which will include an environmental sensitivity and seabed topography analysis. **CM05**: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below the mudline and removed. **CM26**: Inspection and in-water cleaning of marine growth will be undertaken as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015) on relocatable subsea infrastructure and MOPU and FSO wetsides before demobilisation from Project Area, including methods to ensure minimal release of biological material into the water.	Minor	Unlikely	Low
		Benthic habitats and communities	Change in habitat Injury / mortality to fauna	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor	Unlikely	Low
Unplanned Discharge – Solid Waste	*Support Activities (all phases)*	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity,	**CM23**: Compliance with Marine Order 95 (Marine Pollution Prevention – Garbage).	Minor	Very Unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
	MODU operations; MOPU operations; FSO operations; vessel operations			ecological integrity, social amenity, human health or other marine users.	**CM28**: Compliance with API Recommended Practice 14G: Recommended Practice for Fire Prevention and Control on Open Type Offshore Production Platforms.			
		Seabirds and Shorebirds	Injury / mortality to fauna	**EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor	Very Unlikely	Low
		Fish				Minor	Very Unlikely	Low
		Marine mammals				Minor	Very Unlikely	Low
		Marine reptiles				Minor	Very Unlikely	Low
Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons)	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; ROV operations; helicopter operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO13**: To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM28**: Compliance with API Recommended Practice 14G: Recommended Practice for Fire Prevention and Control on Open Type Offshore Production Platform. **CM29**: Emergency response activities will be implemented in accordance with a vessel's valid and appropriate	Minor	Very unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
				integrity, social amenity or human health may be adversely affected.	Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class). **CM30**: Spill response equipment will be present and maintained. **CM31**: Bunkering procedures will be implemented to prevent minor loss of containment.			
Accidental Release – Corowa Light Crude Oil	*Drilling* top-hole drilling; bottom-hole drilling; completions; well clean-up and flowback *Operations* hydrocarbon extraction; hydrocarbon processing, storage and offloading; inspections; maintenance and repair; well intervention *Decommissioning* well P&A; removal of subsea infrastructure *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO13**: To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	**CM03**: Pre-start notifications will be provided to relevant stakeholders at appropriate timing. **CM29**: Emergency response activities will be implemented in accordance with a vessel's valid and appropriate Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class). **CM32:** NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place. **CM33:** Emergency response capability will be maintained in accordance with accepted EPs and OPEPs. **CM34:** NOPSEMA-accepted Well Operations Management Plan in place for all wells, in accordance with the OPGGS Act requirements. **CM35**: Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken.	Minor	Unlikely	Low
		Ambient sediment quality	Change in sediment quality			Minor	Unlikely	Low
		Plankton	Injury / mortality to fauna	**EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a		Minor	Very unlikely	Low
		Benthic habitat and communities	Change in habitat Injury / mortality to fauna			Moderate	Very unlikely	Low

<table>
<tr><th>Aspect</th><th>Phase and activity (source of aspect)</th><th>Receptor</th><th>Impact</th><th>EPOs</th><th>Adopted Control Measures</th><th>C</th><th>L</th><th>RL</th></tr>
<tr><td rowspan="7"></td><td rowspan="7"></td><td></td><td>Change in fauna behaviour</td><td rowspan="7">population or interfere with the recovery of a listed threatened species.
EPO6: To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline.
EPO8: To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species.
EPO9: To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.
EPO11: To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results.
EPO12: To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution.
EPO14: To not result in a change that may have an adverse effect on the protection and conservation of biodiversity, ecological processes and other natural, cultural and heritage values of marine parks and protected areas.</td><td rowspan="7">CM36: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, and vessel speed.
CM37: If an infill drilling campaign is required, a simultaneous production and drilling (SIMOPS) workshop will be completed, and a procedure developed to manage and mitigate any additional risks due to concurrent activities. At a minimum, this will include shut-in of production and isolation of the reservoir during:
• MODU approach and disconnection
• handling of the BOP over existing wells
• any drilling clash potential due to new wellbore proximity to an existing production wellbore.</td><td></td><td></td><td></td></tr>
<tr><td>Coastal habitats and communities</td><td>Change in habitat
Injury / mortality to fauna
Change in fauna behaviour
Change in aesthetic value</td><td>Moderate</td><td>Very unlikely</td><td>Low</td></tr>
<tr><td>Seabirds and shorebirds</td><td rowspan="4">Injury / mortality to fauna
Change in fauna behaviour</td><td>Moderate</td><td>Very unlikely</td><td>Low</td></tr>
<tr><td>Fish</td><td>Moderate</td><td>Very unlikely</td><td>Low</td></tr>
<tr><td>Marine reptiles</td><td>Moderate</td><td>Very unlikely</td><td>Low</td></tr>
<tr><td>Marine mammals</td><td>Moderate</td><td>Very unlikely</td><td>Low</td></tr>
<tr><td>Australia Marine Parks</td><td>Change in water quality
Change in sediment quality
Change in habitat</td><td>Moderate</td><td>Very unlikely</td><td>Low</td></tr>
</table>

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
		State protected areas – marine	Injury / mortality to fauna Change in fauna behaviour Changes to the functions, interests or activities of other users Change in aesthetic value	**EPO15:** To not result in a change that may cause one or more of the World Heritage values or National Heritage values of a declared World Heritage property or National Heritage place to be lost, degraded or damaged, or notably altered, modified, obscured or diminished. **EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted. **EPO117**: To not result in an impact to heritage values or social surroundings, including damage or destruction of a historic shipwreck.		Moderate	Very unlikely	Low
		Heritage and cultural features				Moderate	Very unlikely	Low
		Key ecological features	Change in water quality			Minor	Very unlikely	Low
			Change in sediment quality Change in habitat Injury / mortality to fauna Change in fauna behaviour			Minor	Very unlikely	Low
		Industry	Changes to the functions, interests or activities of other users			Minor	Very unlikely	Low
		Commercial Fisheries	Changes to the functions,			Minor	Very unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
			interests or activities of other users					Low
		Tourism and recreation	Changes to the functions, interests or activities of other users Change in aesthetic value			Minor	Very unlikely	Low
Accidental Release – Marine Diesel/Gas Oil	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO13**: To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	**CM03**: Pre-start notifications will be provided to relevant stakeholders at appropriate timing. **CM29**: Emergency response activities will be implemented in accordance with a vessel's valid and appropriate Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class). **CM32:** NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place. **CM33:** Emergency response capability will be maintained in accordance with accepted EPs and OPEPs. **CM34:** NOPSEMA-accepted Well Operations Management Plan in place for all wells, in accordance with the OPGGS Act requirements. **CM35**: Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken.	Minor	Very unlikely	Low
		Plankton	Injury / mortality to fauna	. **EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO2**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species.		Minor	Very unlikely	Low
		Coastal habitats and communities	Change in habitat Injury / mortality to fauna Change in fauna behaviour			Minor	Very unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
			Change in aesthetic value	**EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution. **EPO14:** To not result in a change that may have an adverse effect on the protection and conservation of biodiversity, ecological processes and	**CM36**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area notifications, separation distance, and vessel speed.			
		Seabirds and shorebirds	Injury / mortality to fauna Change in fauna behaviour			Moderate	Very unlikely	Low
		Fish				Moderate	Very unlikely	Low
		Marine reptiles				Moderate	Very unlikely	Low
		Marine mammals				Moderate	Very unlikely	Low
		Australian Marine Parks	Change in water quality Change in habitat Injury / mortality to fauna Change in fauna behaviour Changes to the functions, interests or activities of other users Change in aesthetic value			Moderate	Very unlikely	Low
		State Protected Areas – marine				Moderate	Very unlikely	Low
		Heritage features				Moderate	Very unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
		Key ecological features	Change in water quality Change in sediment quality Change in habitat Injury / mortality to fauna Change in fauna behaviour	other natural, cultural and heritage values of marine parks and protected areas. **EPO15:** To not result in a change that may cause one or more of the World Heritage values or National Heritage values of a declared World Heritage property or National Heritage place to be lost, degraded or damaged, or notably altered, modified, obscured or diminished. **EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted. **EPO17**: To not result in an impact to heritage values or social surroundings, including damage or destruction of a historic shipwreck.		Minor	Very unlikely	Low
		Industry	Changes to the functions, interests or activities of other users			Minor	Very unlikely	Low
		Commercial Fisheries	Changes to the functions, interests or activities of other users			Minor	Very unlikely	Low
		Tourism and Recreation	Changes to the functions, interests or activities of other users Change in aesthetic value			Minor	Very unlikely	Low

C=Consequence, L=Likelihood, RL=Risk Level

ES8. Cumulative Impacts and Risks

The cumulative impact assessment determines whether the incremental impacts will have a cumulated effect along with other impacts of the activity. It should also determine if the impact of a project, in combination with the other impacts, may cause a significant change to a receptor now or in the future, after applying mitigation for the project.

This OPP identifies and evaluates impacts related to planned activities associated with the Corowa Development. Given the low likelihood of unplanned events (e.g. accidental releases) occurring during the Corowa Development, impacts from unplanned events were not considered when assessing cumulative impacts.

To establish the context of the cumulative assessment, the following has been determined:

- spatial and temporal boundary of the assessment
- existing industries / projects—past, present or future
- existing environment within these boundaries
- identification of environmental aspects common to the Corowa Development and other actions / projects.

Spatial and Temporal Boundary of the Assessment

The largest exposure area for any planned aspect is for light emissions (30 km radius around the expected MODU location) and is the distance that artificial lighting from the Corowa Development is expected to be visible. An analysis of light intensity showed that beyond 30 km there was no measurable change to the ambient light intensity levels. All other spatial exposure extents from planned aspects are within the Project Area (5 km radius around MOPU location). Therefore, a conservative spatial extent of 30 km was used for the cumulative impact assessment for the Corowa Development.

The temporal boundary for the assessment has been conservatively set as one year after decommissioning of the Corowa Development. Allowing for a total project life of approximately five years, this gives a conservative temporal extent of six years.

Existing Industries / Projects

Existing industries or projects within the temporal and spatial boundaries of the assessment with similar aspects as the Corowa Development were identified. These may result in cumulative impacts and include:

- State- and Commonwealth-managed fisheries
- tourism and recreation
- marine and coastal industries (existing oil and gas developments, defence training areas and commercial shipping).

Existing Environment within these Boundaries

The existing environment within the EMBA was described in detail. Based on the spatial and temporal boundaries established, this description is sufficient to support the assessment of cumulative impacts.

Identification of Aspect Interactions

Impacts resulting from planned aspects are restricted to the Project Area, which comprises a 5 km buffer around the expected MOPU location, except for the light intensity area, which was modelled as a 30 km radius. The only existing industries / projects within 5 km (i.e. spatial boundary for cumulative assessment for these aspects) are:

- fisheries
- industries (shipping and DoD training areas).

Cumulative Impact Assessment

This OPP identifies potential cumulative impacts and risks associated with the Corowa Development. The impacts and risks associated with each aspect of the Corowa Development (identified as requiring further assessment) were determined to be acceptable; they are summarised in Table ES-14. Consideration of additional control measures is not required—the EPOs previously defined are considered appropriate to ensure that the acceptable level of performance for direct and indirect impacts is achieved.

Table ES-1-14 Summary of Cumulative Impacts Evaluation and Risks Associated with the Corowa Project

Environment	*Phase* and Activity (source of aspect)	Receptor	Impact	Consequence
Physical Environment	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations *Operations* hydrocarbon processing, storage and offloading	**Ambient light**	Change in ambient light	Minor
Ecological Environment	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations *Operations* hydrocarbon processing, storage and offloading	**Plankton**	Change in water quality	Minor
		Fish	Injury / mortality to fauna Change in fauna behaviour	Minor
		Marine reptiles	Change in fauna behaviour	Moderate

ES9. Implementation Strategy

The Corowa Development will be undertaken in accordance with this OPP and subsequent activity-specific EP/s. This section describes the implementation strategies (the systems, practices, and procedures) used to manage risks and impacts of the Development. These will help achieve the EPOs as per the requirements under Section 5A of the OPGGS(E)R.

KATO has an Integrated Management System, referred to as the KATO IMS, detailed in the KATO Integrated Management System Description (KAT-000-GN-PP-001) (KATO 2020c). The KATO IMS is a common framework that uses the principles of risk management to ensure that the hazards associated with all KATO activities are identified and that the associated risks to people, the environment and company assets are assessed and effectively managed.

Table ES-1-15 summarises the key elements of the KATO IMS relevant to this OPP.

Table ES-1-15 Summary of KATO IMS Elements

KATO IMS Element	Description
EMS	Consistent with the Australian/New Zealand Standard AS/NZS ISO14001 Environmental Management Systems – Requirements
Training and awareness	The IMS will ensure that all Corowa Development employees, contractors and visitors have the appropriate training, qualifications, experience and competency.
Emergency Management	The Emergency Management Procedure (KAT-000-HS-PP-002) (KATO 2020d) provides organisational structures, management processes, and the tools necessary to respond to emergencies and to prevent or mitigate emergency and crisis situations, and to respond to incidents in a safe, rapid, and effective manner. It defines specific procedural guidance for emergency and unplanned events including hydrocarbon spills, plus detailed reporting relationships for command, control and communications.
Risk and Change Management	The Risk and Change Management Procedure (KAT-000-GN-PP-002) (KATO 2020a) manages changes to facilities, operations, products, and the organisation so as to prevent incidents, support reliable and efficient operations, and keep unacceptable risks from being introduced.
Incident Management	The Incident Management Procedure (KAT-000-GN-PP-003) (KATO 2020e) governs incident notification, incident investigation, reporting and documentation, incident investigation competency model and communicating lessons learned.
Compliance Assurance	The KATO IMS Description (KAT-000-GN-PP-001) (KATO 2020) ensures a process is in place to enable compliance with applicable legal and company requirements, verify necessary safeguards are in place and functioning, and non-compliances are reported and tracked to closure.
Monitoring and Reporting	Monitoring will be undertaken to demonstrate that KATO complies with regulatory requirements as specified in this OPP and future EP/s, including routine and incident reporting.
Review of EP/s	For the EP stage, as per the OPGGS(E)R, KATO will submit a proposed revision of the accepted EP/s to the Minister: • before the commencement of a new activity, or any significant modification, change or a new stage of an existing activity • before, or as soon as practicable after, the occurrence of any significant new environmental impact or risk, or significant increase in an existing environmental impact or risk that occurred or is to occur.

ES10. Stakeholder Consultation

The principal objectives of KATO's consultation strategy is to:

- identify stakeholders
- initiate and maintain open communications between stakeholders and KATO relevant to their interests
- proactively work with stakeholders on recommended strategies to minimise impacts.

Consultation will be planned, outcomes tracked, and ongoing actions recorded in the KATO Stakeholder Communications Register (KAT-000-GN-RE-001) (KATO 2020f).

Consultation with stakeholders began before submission of this OPP, and will continue throughout the life of the Corowa Development.

The OPP process includes a period of public consultation for a minimum of four weeks. The OPP will be made publicly available, and the public has the opportunity to provide comment to NOPSEMA. Following the public comment period, KATO must demonstrate it has assessed the merits of the comments and how they have been addressed.

1 Introduction

1.1 Activity Location and Overview

The Corowa Development will be centred on the Corowa field, located within Commonwealth waters on the North West Shelf (NWS) ~60 km offshore Western Australia (WA) (Figure 1-1). The field lies in ~85–90 m of water within retention lease WA-41-R in the Carnarvon Basin, and contains light crude oil.

KATO plans to develop the Corowa field using a relocatable system known as the honeybee production system. This system has been used successfully in many locations around the world, including offshore WA. Advantages of the system include:

- it uses a self-installing jack-up platform, with no requirement for mobilising a crane barge from overseas (which introduces additional risk and cost)
- all infrastructure will be removed before demobilising from the field, and some elements will be re-used on the next project, allowing for ease of decommissioning and minimising number of mobilisations required
- environmental impact is minimised by having no fixed platform
- no offshore piling or trenching is required, further minimising environmental impact.

The Corowa field has previously been appraised by Santos, with three wells drilled between 2001 and 2002. The Corowa field is classified as a small field with a short life span and proven contingent resource of 7 MMstb.

The key components covered in this Offshore Project Proposal (OPP) for the Corowa Development are:

- site survey of the proposed location of subsea infrastructure
- drilling of up to four wells
- installation, hook-up and commissioning of a mobile offshore processing unit (MOPU), catenary anchor leg mooring (CALM) Buoy and mooring arrangements, flowline and riser, and a floating storage and offloading (FSO) facility
- operation of the facilities
- decommissioning and removal of subsea and surface infrastructure and plug and abandonment (P&A) of the wells.

Following decommissioning and abandonment, the MOPU will demobilise and relocate to the next field, which will be covered by a separate OPP.

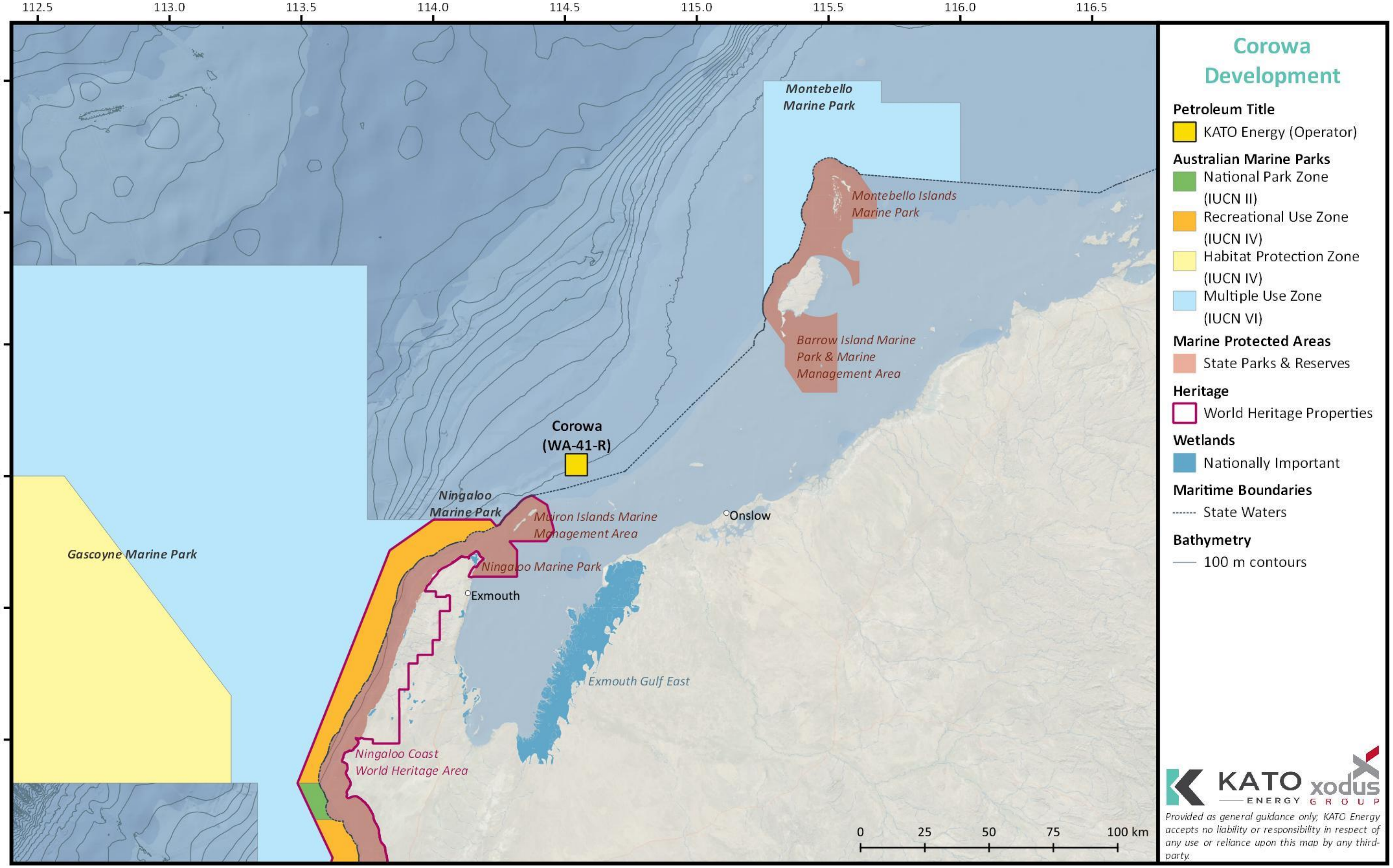


Figure 1-1 Location of Corowa Development

1.2 Titleholder Details

KATO Energy Pty Ltd (KATO) is the proponent for the Corowa Development.

KATO is an Australian company that was formed to combine ownership of the Corowa and Amulet oil discoveries, and other fields, via wholly owned subsidiaries. The shareholders of KATO are Tamarind Australia Pty Ltd (Tamarind Resources group), Aviemore Capital Pty Ltd (Burton group) and Wisdom Frontier Limited (former owner of Hydra group), who own one-third each. KATO owns the titleholders Tamarind Australia (Corowa) Pty Ltd and Hydra Energy (WA) Pty Ltd.

In accordance with the Commonwealth *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009* [OPGGS(E)R]; Table 1-1 provides the details of titleholders within which the petroleum activity will take place.

Table 1-1 Licence and Titleholder Details

Title	Name	Operator	Titleholder Details
WA-41-R	Corowa	KATO Energy	Tamarind Australia (Corowa) Pty Ltd Hydra Energy (WA) Pty Ltd

The titleholder contact details are:

KATO Energy Pty Ltd

102 Forrest Street

Cottesloe, Western Australia 6000

Phone: +61 8 9320 4700

Email: info@katoenergy.com.au

Website: https://katoenergy.com.au

1.3 Document Purpose and Scope

This OPP has been prepared by KATO as licence holder and operator of the Corowa Development in accordance with the Environment Regulations and associated guidelines. Under the OPGGS(E)R, an OPP is required to be submitted for all offshore projects to the National Offshore Petroleum Safety and Environment Management Authority (NOPSEMA) for approval. An OPP is an initial and global assessment of a project and must be accepted by NOPSEMA before the proponent can submit Environment Plans (EPs) for activities that make up the project.

The OPP process involves NOPSEMA's assessment of all potential environmental impacts and risks of petroleum activities conducted over the life of an offshore project. The process includes a public comment period prior to approval and requires a proponent to ensure that all environmental impacts and risks will be managed to acceptable levels.

1.4 Structure of the OPP

The OPP has been prepared to align with NOPSEMA's current OPP content requirements (N-04790-GN-1663, Rev 4, November 2019) and NOPSEMA OPP assessment policy (N-04790-PL-1650, Rev 1, September 2018). The structure of the OPP is summarised in Table 1-2.

Table 1-2 OPP Structure

Section		Content
1	Introduction	Project overview, location, proponent details.
2	Requirements	Legislation, other regulatory requirements, relevant standards and guidelines.
3	Description of the Project	A description of all activities including installation, commissioning, drilling, hydrocarbon offloading and decommissioning.
4	Alternatives Analysis	An analysis of alternative operations and procedures and decision-making processes.
5	Description of the Environment	A description of the existing environment highlighting significant physical, ecological and socioeconomic values.
6	Environmental Impact and Risk Assessment Methodology	The methodology for identifying and evaluating environmental impacts and risks.
7	Environmental Impact and Risk Assessment	Results and justification of environmental impacts and risk assessments.
8	Cumulative Impact Assessment	Provides an assessment of cumulative impacts for the Corowa Development.
9	Implementation Strategy	Details how environmental performance outcomes stated within this OPP will be implemented.
10	Stakeholder Consultation	A summary of KATO's stakeholder consultation methods which includes the process of stakeholder identification and consultation history and future consultation requirements.
11	Terminology and Acronyms	
12	References	

2 Requirements

The Corowa Development is located entirely in Commonwealth waters and therefore falls under Commonwealth jurisdiction, triggering these key Commonwealth acts: *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGSS Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

2.1 Offshore Petroleum and Greenhouse Gas Storage (OPGGS) Act 2006

The OPGGS Act provides the regulatory framework for all offshore petroleum exploration and production activities in Commonwealth waters, beyond the three nautical mile limit, to ensure that these activities are undertaken:

- consistent with the principles of ecologically sustainable development as defined in section 3A of the EPBC Act
- to reduce environmental impacts and risks of the activity to as low as reasonably practicable (ALARP)
- to ensure 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 royalty. These regulations 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 2009 [OPGGS(E)].

Part 1A of the OPGGS(E)R specifies that before commencing an offshore project, a person must submit an offshore project proposal for the project to the regulator.

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

Table 2-1 Concordance Table for the OPP Requirements of the OPGGS(E)R

Regulation	Description	Document section
5A (5)(a)	The proposal must: (a) include the proponent's name and contact details;	Section 1.2
5A (5)(b)	(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 3
5A (5)(c)	(c) describe the existing environment that may be affected by the project;	Section 5
5A (5)(d)	(d) include details of the particular relevant values and sensitivities (if any) of that environment;	Section 5
5A (5)(e)	(e) set out the environmental performance outcomes for the project;	Section 7
5A (5)(f)	(f) describe any feasible alternative to the project, or an activity that is part of the project, including:	Section 4

Regulation	Description	Document section
	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.	
5A (6)	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 5
5A (7)	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
5A (8)	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 7

2.1.1 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 activity. The EP must be appropriate for the nature and scale of the activity, and describe the activity, the existing environment, the impact and risk assessment, and control measures proposed for the activity.

EPs are supported by an Oil Pollution Emergency Plan (OPEP) and Operational and Scientific Monitoring Plan (OSMP), which are required as part of an EP's implementation strategy.

EPs related to activities associated with the Corowa Development will be submitted after the OPP has been submitted to NOPSEMA and cannot be accepted until the OPP has been accepted.

The EPs will be submitted and accepted by NOPSEMA before activities under them can commence.

2.2 Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)

Where there is the potential for a matter of National Environmental Significance (NES) to be impacted by offshore petroleum activities, an assessment of impacts is required to be presented in the OPP. The aims of the EPBC Act are to:

- protect matters of NES
- provide for Commonwealth environmental assessment and approval processes

- provide for an integrated system for biodiversity conservation and management of protected areas.

Matters of NES identified as relevant to the Corowa Development are:

- Listed threatened species and ecological communities
- Listed migratory species (protected under international agreements)
- Commonwealth marine environment
- World heritage properties
- National heritage places
- Ramsar wetlands.

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

2.2.1 EPBC Management Plans

2.2.1.1 Listed Threatened Species Management / Recovery Plans and Conservation Advice

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

The requirements of species recovery plans and conservation advice were considered when developing this OPP to identify the appropriate management of the proposed activities. Table 2-2 outlines the management, recovery plans and conservation advice relevant to the Corowa Development, and the key threats and conservation actions relevant to the project. These were considered when assessing impacts and risks, assessing acceptability, and developing environmental performance outcomes (EPOs).

Table 2-2 Summary of EPBC Management / Recovery Plans and Conservation Advice Relevant to the Corowa Development

Species / Sensitivity	Plan	Protection under EPBC Act	Key threats identified	Relevant Conservation Actions
Vertebrates				
All Vertebrate Fauna	Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (DoEE 2018a)	N/A	Marine debris	No explicit 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).
Marine mammals				
Sei Whale	Conservation advice *Balaenoptera borealis* Sei Whale (TSSC 2015a)	Vulnerable	Noise interference	Assess and manage acoustic disturbance.
			Vessel disturbance	Assess and manage physical disturbance and development activities.
			Climate and oceanographic	Continue to meet Australia's international commitments to reduce greenhouse gas emissions.

Species / Sensitivity	Plan	Protection under EPBC Act	Key threats identified	Relevant Conservation Actions
			variability and change	
			Pollution (persistent toxic pollutants)	No explicit relevant management actions; pollution identified as a threat.
Blue Whale (including Pygmy Blue Whale subspecies)	Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 2015–2025 [(CoA) 2015a]	Endangered	Noise interference	Assess and address anthropogenic noise.
			Vessel disturbance	Minimise vessel collision.
			Climate variability and change	Understanding impacts of climate variability and change.
Fin Whale	Conservation advice *Balaenoptera physalus* Fin Whale (TSSC 2015b)	Vulnerable	Noise interference	Once the spatial and temporal distribution (including biologically important areas) of Fin Whales is further defined, assess the impacts of increasing anthropogenic noise (including seismic surveys, port expansion, and coastal development).
			Vessel disturbance	Develop a national vessel strike strategy that investigates the risk of vessel strikes on Fin Whales and identifies potential mitigation measures.
				Ensure all vessel strike incidents are reported in the National Vessel Strike Database.
			Climate and oceanographic variability and change	Continue to meet Australia's international commitments to reduce greenhouse gas emissions.
			Pollution (persistent toxic pollutants)	No explicit relevant management actions; pollution identified as a threat.
Humpback Whale	Approved Conservation Advice for *Megaptera novaeangliae* (Humpback Whale) (TSSC 2015c)	Vulnerable	Noise interference	For actions involving acoustic impacts (example pile driving, explosives) on Humpback Whale calving, resting, feeding areas, or confined migratory pathways, undertake site-specific acoustic modelling (including cumulative noise impacts).

Species / Sensitivity	Plan	Protection under EPBC Act	Key threats identified	Relevant Conservation Actions
			Vessel disturbance	Ensure the risk of vessel strike on Humpback Whales is considered when assessing actions that increase vessel traffic in areas where Humpback Whales occur and, if required appropriate mitigation measures are implemented to reduce the risk of vessel strike.
			Climate and Oceanographic Variability and Change	Continue to meet Australia's international commitments to reduce greenhouse gas emissions.
Southern Right Whale	Conservation Management Plan for the Southern Right Whale (DSEWPaC 2011)	Endangered	Noise interference	Assess and address anthropogenic noise.
			Vessel disturbance	Address vessel collisions.
			Climate Variability and Change	Assess impacts of climate variability and change. Continue to meet Australia's international commitments to reduce greenhouse gas emissions.
Marine Reptiles				
Loggerhead Turtle, Hawksbill Turtle, Green Turtle, Olive Ridley Turtle, Flatback Turtle and Leatherback Turtle	Recovery plan for Marine Turtles in Australia (CoA 2017)	Endangered – Loggerhead, Leatherback, Olive Ridley Turtles Vulnerable – Green, Hawksbill, Flatback Turtles	Vessel disturbance	Vessel interactions identified as a threat; no specific management actions in relation to vessels prescribed in the plan.
			Light pollution	Minimise light pollution.
				Identify the cumulative impact on turtles from multiple sources of onshore and offshore light pollution.
			Acute chemical discharge (oil pollution)	Minimise chemical and terrestrial discharge. Ensure spill risk strategies and response programs include management for turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs.
			Climate change and variability	No specific management actions in relation to climate prescribed in the plan relevant to industry.
			Marine debris	Reduce the impacts from marine debris.

Species / Sensitivity	Plan	Protection under EPBC Act	Key threats identified	Relevant Conservation Actions
Leatherback Turtle	Approved conservation advice for *Dermochelys coriacea* (Leatherback Turtle) (TSSC 2009a)	Endangered	Vessel disturbance	No explicit relevant management actions; vessel strikes identified as a threat.
			Marine debris	No explicit relevant management actions; marine debris identified as a threat.
Short-nosed Seasnake	Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Seasnake) (TSSC 2011b)	Critically Endangered	Habitat loss, disturbance and modification	Monitor known populations to identify key threats. Ensure there is no anthropogenic disturbance in areas where the species occurs, excluding necessary actions to manage the conservation of the species.
Fish				
Great White Shark	Recovery plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013a)	Vulnerable	Climate change	No explicit relevant management actions; threat identified as ‘climate change ecosystem effects as a result of habitat modification and climate change (including changes in sea temperature, ocean currents and acidification).’
Dwarf Sawfish, Queensland Sawfish	Approved conservation advice for *Pristis clavata* (Dwarf Sawfish) (TSSC 2009b)	Vulnerable	Habitat degradation/ modification	No explicit relevant management actions; habitat loss, disturbance and modification identified as threats.
	Sawfish and river shark multispecies recovery plan (CoA 2015b)			Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.
Green Sawfish, Dindagubba, Narrowsnout Sawfish	Approved conservation advice for Green Sawfish (TSSC 2008a)	Vulnerable	Habitat degradation/ modification	No explicit relevant management actions; habitat loss, disturbance and modification identified as threats.
	Sawfish and river shark multispecies recovery plan (2015b)			Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish	Approved Conservation Advice for *Pristis pristis* (Largetooth Sawfish) (DoE 2014a).	Vulnerable	Habitat degradation/ modification	Implement measures to reduce adverse impacts of habitat degradation and/or modification.

Species / Sensitivity	Plan	Protection under EPBC Act	Key threats identified	Relevant Conservation Actions
Whale Shark	Conservation advice *Rhincodon typus* (Whale Shark) (TSSC 2015d)	Vulnerable	Vessel disturbance	Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with Whale Shark aggregations and along the northward migration route that follows the northern Western Australian coastline along the 200 m isobath.
			Climate change	No explicit relevant management actions; climate change identified as less important threats.
	Whale Shark (*Rhincodon typus*) recovery plan 2005–2010 (DEH 2005a)		Habitat degradation/ modification	No explicit relevant management actions; seasonal aggregations of Ningaloo recognised as important habitat.
Grey Nurse Shark (west coast population)	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (DoE 2014b)	Vulnerable	Marine debris	No explicit relevant management actions; marine debris identified as a threat.
Seabirds and shorebirds				
Migratory shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (DoEE 2015)	N/A	Habitat loss / modification	No explicit relevant management actions; identified as a threat.
			Anthropogenic disturbance	An improved understanding of the cumulative impacts of development on migratory shorebird habitat can be demonstrated by 2020. All assessments of future developments are undertaken in accordance with the EPBC Act and the associated guidelines and policy documents and take account of information included in the wildlife conservation plan for migratory shorebirds and other sources of information.
			Climate change	No explicit relevant management actions; identified as a threat.
Red Knot	Conservation advice *Calidris canutus* (Red Knot) (TSSC 2016a)	Endangered	Habitat degradation/ modification	No explicit relevant management actions; oil pollution recognised as a threat.
			Climate change	No explicit relevant management actions; climate change recognised as a threat.

Species / Sensitivity	Plan	Protection under EPBC Act	Key threats identified	Relevant Conservation Actions
Curlew Sandpiper	Conservation advice *Calidris ferruginea* (Curlew Sandpiper) (DoE 2015a)	Critically Endangered	Habitat degradation/ modification (oil pollution)	No explicit relevant management actions; oil pollution recognised as a threat.
Bar-tailed Godwit (Western Alaskan)	Conservation advice *Limosa lapponica baueri* [Bar-tailed Godwit (Western Alaskan)] (TSSC 2016b)	Vulnerable	Habitat degradation/ modification	No explicit relevant management actions; oil pollutions recognised as a threat.
Bar-tailed Godwit (Northern Siberian)	Conservation advice *Limosa lapponica menzbieri* (Bar-tailed Godwit (Northern Siberian)) (TSSC 2016c)	Critically Endangered	Habitat degradation/ modification	No explicit relevant management actions; oil spills recognised as a threat.
Southern Giant Petrel	National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011)	Endangered	Marine Pollution	Quantify and reduce the threats to the foraging habitat of albatrosses and giant petrels within areas under Australian jurisdiction.
			Climate change	No explicit relevant management actions; climate change recognised as a threat.
Australian Fairy Tern	Conservation advice for *Sterna nereis nereis* (Fairy Tern) (TSSC 2011b)	Vulnerable	Habitat degradation/ modification (oil pollution)	Ensure appropriate oil spill contingency plans are in place for the subspecies' breeding sites that are vulnerable to oil spills.
Eastern Curlew, Far Eastern Curlew	Conservation Advice for *Numenius madagascariensis* (Eastern Curlew) (DoE 2015c)	Critically Endangered	Habitat loss, disturbance and modification	Manage disturbance at important sites when the species is present.

2.2.1.2 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. AMPs that occur within the EMBA are summarised in Table 2-3.

Table 2-3 AMPs that Occur within the Corowa Areas

Australian Marine Park	Distance from Project Area	IUCN Protected Area Category
Carnarvon Canyon*	~385 km	Habitat Protection Zone (IUCN IV)
Gascoyne^	~60 km	National Park Zone (IUCN II) Habitat Protection Zone (IUCN IV) Multiple Use Zone (IUCN VI)
Montebello*	~105 km	Multiple Use Zone (IUCN VI)

Australian Marine Park	Distance from Project Area	IUCN Protected Area Category
Ningaloo*	~40 km	National Park Zone (IUCN II) Recreational Use Zone (IUCN IV)
Dampier*	~270 km	National Park Zone (IUCN II) Habitat Protection Zone (IUCN IV) Multiple Use Zone (IUCN VI)
Shark Bay*	~345 km	Multiple Use Zone (IUCN VI)
Eighty Mile Beach*	~495 km	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace*	~455 km	Multiple Use Zone (IUCN VI) National Park Zone (IUCN II) Special Purpose Zone (Trawl) (IUCN VI)
Mermaid Reef*	~705 km	National Park Zone (IUCN II)
Abrolhos^	~530 km	Recreational Use Zone (IUCN IV) Habitat Protection Zone (IUCN IV) National Park Zone (IUCN II) Special Purpose Zone (IUCN VI)
Jurien^	~965 km	Special Purpose Zone (IUCN VI)
Two Rocks^	~1,115 km	Recreational Use Zone (IUCN IV)

**within North-west Network (Director of National Parks 2018a)*

^ within South-west Network (Director of National Parks 2018b)

AMPs listed in Table 2-3 are described in detail in Section 5.

Australian IUCN Reserve Management Principles for each category are set out in the EPBC Regulations and are summarised in Table 2-4 (Environment Australia 2002). In addition to these management principles, all activities undertaken within an AMP must be consistent with the objectives of the zone, and the values of the marine park (Director of National Parks 2018):

- National Park Zone (II) – to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.
- Habitat Protection Zone (IV) – to provide for the conservation of ecosystems, habitats and native species in as natural a state as possible, while allowing activities that do not harm or cause destruction to seafloor habitats.
- Multiple Use Zone (VI) – to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.

Table 2-4 Australian IUCN Reserve Management Principles

Category II: National Park:	Category IV: Habitat/Species Management Area	Category VI: Managed Resource Protected Areas
3.01 The reserve or zone should be protected and managed to preserve its natural condition according to the following principles.	5.01 The reserve or zone should be managed primarily, including (if necessary) through active intervention, to ensure the maintenance of habitats or to meet the requirements of collections or specific species based on the following principles.	7.01 The reserve or zone should be managed mainly for the sustainable use of natural ecosystems based on the following principles.
3.02 Natural and scenic areas of national and international significance should be protected for spiritual, scientific, educational, recreational or tourist purposes.	5.02 Habitat conditions necessary to protect significant species, groups or collections of species, biotic communities or physical features of the environment should be secured and maintained, if necessary, through specific human manipulation.	7.02 The biological diversity and other natural values of the reserve or zone should be protected and maintained in the long term.
3.03 Representative examples of physiographic regions, biotic communities, genetic resources, and native species should be perpetuated in as natural a state as possible to provide ecological stability and diversity.	5.03 Scientific research and environmental monitoring that contribute to reserve management should be facilitated as primary activities associated with sustainable resource management.	7.03 Management practices should be applied to ensure ecologically sustainable use of the reserve or zone.
3.04 Visitor use should be managed for inspirational, educational, cultural and recreational purposes at a level that will maintain the reserve or zone in a natural or near natural state.	5.04 The reserve or zone may be developed for public education and appreciation of the characteristics of habitats, species or collections and of the work of wildlife management.	7.04 Management of the reserve or zone should contribute to regional and national development to the extent that this is consistent with these principles.
3.05 Management should seek to ensure that exploitation or occupation inconsistent with these principles does not occur.	5.05 Management should seek to ensure that exploitation or occupation inconsistent with these principles does not occur.	
3.06 Respect should be maintained for the ecological, geomorphologic, sacred and aesthetic attributes for which the reserve or zone was assigned to this category.	5.06 People with rights or interests in the reserve or zone should be entitled to benefits derived from activities in the reserve or zone that are consistent with these principles.	
3.07 The needs of indigenous people should be taken into	5.07 If the reserve or zone is declared for the purpose of	

Category II: National Park:	Category IV: Habitat/Species Management Area	Category VI: Managed Resource Protected Areas
account, including subsistence resource use, to the extent that they do not conflict with these principles.	a botanic garden, it should also be managed for the increase of knowledge, appreciation and enjoyment of Australia's plant heritage by establishing, as an integrated resource, a collection of living and herbarium specimens of Australian and related plants for study, interpretation, conservation and display.	
3.08 The aspirations of traditional owners of land within the reserve or zone, their continuing land management practices, the protection and maintenance of cultural heritage and the benefit the traditional owners derive from enterprises, established in the reserve or zone, consistent with these principles should be recognised and taken into account.		

Source: Environment Australia 2002

2.3 Relevant Commonwealth Legislation

Table 2-5 summarises Commonwealth legislation that is relevant to the environmental management of the Corowa Development, in addition to the OPGGS Act and EPBC Act.

Table 2-5 Relevant Commonwealth Legislation

Legislation	Scope	Application to Activities under the OPGGS(E)R
Air Navigation Act 1920	This Act is responsible for managing navigation within the avian environment.	Helicopter and other aircraft activities occurring throughout all phases of the project are required to abide to the requirements under this Act.
Australian Heritage Council Act 2003	This Act was formed to establish the Australian Heritage Council and associated functions. The Act also classifies areas that have heritage value, including those identified on the Commonwealth Heritage list, Wold Heritage List and National heritage List.	This Act applies to any activities that may occur within areas that may have associated heritage values.

Legislation	Scope	Application to Activities under the OPGGS(E)R

Australian Maritime Safety Authority Act 1990	The 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 AMSA.
		The Act applies to offshore petroleum activities that have the potential to affect maritime safety and/or result in environmental damage including pollution associated with the operation of vessels. This is also relevant to oil spills from vessels during petroleum activities.

Australian Radiation Protection and Nuclear Safety Act 1998	This Act aims at protecting the health and safety of people and the environment from radiation effects.	The use of radioactive material during formation evaluation must comply with the Act.
Biosecurity Act 2015	In June 2016, the Biosecurity Act 2016 replaced the Quarantine Act 1908. This Act provides a definition of ‘quarantine’ and establishes the Australian Quarantine Inspection Service (AQIS). All information concerning the voyage of the vessel and the ballast water is declared correctly to the quarantine officers.	With regard to the petroleum industry, the Act regulates the condition of vessels and drilling rigs entering Australian waters with regard to ballast water and hull fouling.
Environment Protection (Sea Dumping) Act 1981	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.	Regulates the disposal of hazardous waste from installations and operational vessels relating to the project. Sea Dumping Permits will be in place where required. 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*	Provides regulations for operating aircraft and vessels in the vicinity of cetaceans	All aircraft and vessels to operate at required distances from cetaceans. The requirements are detailed in the Australian National Guidelines for Whale and Dolphin Watching (DEWHA 2005)
Hazardous Waste (Regulation of Exports and Imports) Act 1989	The main purpose of this Act is regulating the import, export and transport of hazardous waste. It aims at ensuring adequate disposal of hazardous waste to minimise impacts to humans and the environment within and outside Australia.	The handling and export of hazardous waste during the project must be done in accordance with the Act.

Legislation	Scope	Application to Activities under the OPGGS(E)R
Industrial Chemicals (Notification and Assessment Act) 1989	This Act enforces restrictions on using particular chemicals that may have detrimental and harmful effects on health and the environment and creates a national register of chemicals used in industry.	Chemicals used throughout the project will be considered under the requirements of this Act prior to use.
National Environment Protection Measures (Implementation) Act 1998	This Act aims to implement National Environment Protection Matters (NEPM's) to enhance, restore and protect the Australian environment. This Act also ensures adequate and relevant information on pollution is provided to the community.	Activities associated with the project will result in the generation of pollution. Requirements of the Act must be adhered to including energy and greenhouse gas reporting.
National Greenhouse and Energy Reporting Act 2007 (NGER Act)	Introduced a single national framework for reporting and disseminating company information about greenhouse gas emissions, energy production and energy consumption. It is administered by the Clean Energy Regulator.	Activities associated with the project will result in the generation of atmospheric emissions and greenhouse gases. Requirements of the Act must be adhered to including energy and greenhouse gas reporting.
Navigation (Consequential Amendments) 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 • Passengers • Personnel qualifications and welfare • Vessel construction standards • Handling of cargoes • Marine pollution prevention • Monitoring and enforcement activities.	All ships associated with petroleum activities within Australian waters must abide to the requirements under the Navigation Act. Marine orders that relate to petroleum activities include: • Marine Order Part 21: Safety of navigation and emergency procedures • Marine Order Part 30: Prevention of collisions • Marine Order Part 59: Offshore industry vessel operations
Offshore Petroleum and Greenhouse Gas Storage (Regulatory Levies) Act 2003 Offshore Petroleum and Greenhouse Gas Storage (Regulatory Levies) Regulations 2004	An Act to impose levies relating to the regulation of offshore petroleum activities and greenhouse gas storage activities.	This Act will apply to KATO as a licence holder and operator.

Legislation	Scope	Application to Activities under the OPGGS(E)R
Ozone Protection and Synthetic Greenhouse Gas Management Act 1989	This Act aims at controlling and reducing the manufacturing, import and export of substances that deplete the ozone layer and synthetic greenhouse gases.	This Act will apply to KATO if the company manufactures, imports or exports these kinds of substances.
Protection of the Sea (Harmful Antifouling Systems) Act 2006	This Act aims at protecting the marine environment from the effects of harmful anti-fouling 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 must hold 'antifouling certificates', providing they meet specific criteria.	Ships involved with offshore petroleum activities within Australian waters are required to abide to the requirements under this Act.
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	This Act 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 greater than 400 gross tonnes to have in place pollution emergency plans, and also provides for emergency discharges from ships.	Ships involved with petroleum activities within Australian waters are required to abide to the requirements under this Act. Numerous Marine Orders are enacted under this Act concerning to offshore petroleum activities, including: • MO Part 91: Marine Pollution Prevention – Oil • MO Part 93: Marine Pollution Prevention – Noxious Liquid Substances • MO Part 94: Marine Pollution Prevention – Harmful Substances in Packaged Forms • MO Part 95: Marine Pollution Prevention – Garbage • MO Part 96: Marine Pollution Prevention – Sewage • MO Part 97: Marine Pollution Prevention – Air Pollution • MO Part 98: Marine Pollution Prevention – Anti-fouling Systems.
Underwater Cultural Heritage Act 2019	Protects the heritage values of shipwrecks, sunken aircraft and relics (older than 75 years) in Australian Territorial 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 / conduct prohibited within each zone will be specified.	In the event of removal, damage or interference to shipwrecks, sunken aircraft or relics declared to be historic under the legislation, activity is proposed with declared protection zones, or there is the discovery of shipwrecks or relics.

2.4 Relevant Policies and Guidelines

Table 2-6 summarises Commonwealth policies and international conventions that are relevant to the Corowa Development.

Table 2-6 Relevant Commonwealth Policies and Guidelines

Policy / Guideline / Convention	Purpose	Relevance to the Corowa Development
EPBC Policy Statement 2.1 Interaction with Marine Wildlife	Provide 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.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000	Aims to achieve the sustainable use of water resources by protecting and enhancing their quality while maintaining economic and social development.	Provide guideline values on ambient water quality and monitoring assessment.
Australian Ballast Water Management Requirements 2017	Provides guidance on how vessel operators should manage ballast water when operating within Australian seas in order to comply with the *Biosecurity Act 2015*. They also align to the International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (the Ballast Water Management Convention).	All vessels and installations are required to manage their ballast water and sediments in accordance with the Convention and *Biosecurity Act 2015*.
Australian Offshore Petroleum Development Policy	Encourages ongoing investment in, and development of, Australia's offshore petroleum (oil and gas) resources.	KATO has an obligation to explore and develop petroleum reserves within the held title.
International Maritime Organisation (IMO) Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (Biofouling Guidelines) 2011	Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species	Specific requirements are that vessels have a biofouling management plan and biofouling record book.
National Biofouling Management Guidance for the Petroleum Production and Exploration Industry 2009	Voluntary biofouling management guidance documents for risk of marine pest translocation and introduction via biofouling.	All vessels and installations to implement effective biofouling controls as best practice.

Policy / Guideline / Convention	Purpose	Relevance to the Corowa Development
The Marine Bioregional Plans	Designed to improve decisions made under the EPBC Act, particularly in relation to the protection of marine biodiversity and the sustainable use of our oceans and their resources by our marine-based industries.	The plans provide information on the Australian Government's marine environment protection and biodiversity conservation responsibilities, objectives and priorities in the four marine regions.

2.5 International Agreements

The principal international agreement governing petroleum operations in Commonwealth waters is the United Nations Convention on the Law of the Sea, 1982 (UNCLOS). Australia is also a signatory to several international conventions of potential relevance to the proposed Corowa Development, including:

- International Convention for the Prevention of Pollution from Ships, London, 1973/1978 (commonly known as MARPOL 73/78)
- International Convention on Civil Liability for Oil Pollution Damage, 1969 and 1992 (CLC 69; CLC 92)
- Convention on the International Regulations for Preventing Collisions at Sea 1972 (COLREGS)
- Convention on the International Maritime Organisation 1948
- London Protocol / Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1996
- International Convention on Harmful Anti Fouling Systems 2001 (AFS Convention)
- International Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal 1989 (Basel Convention)
- Kyoto Protocol 1997
- Paris Agreement 2016 under the United Nations Framework Convention on Climate Change
- United Nations Framework Convention on Climate Change 1992
- Montreal Protocol on Substances that Deplete the Ozone Layer 1987
- Rotterdam Convention a multilateral treaty to promote shared responsibilities in relation to importation of hazardous chemicals
- International Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
- International Convention on the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention)
- Agreement on the Conservation of Albatrosses and Petrels (ACAP)
- China Australia Migratory Birds Agreement (CAMBA)
- Japan Australia Migratory Birds Agreement (JAMBA)
- The Republic of Korea Migratory Birds Agreement (ROKAMBA).

3 Description of the Project

3.1 Project Overview

KATO plans to develop the Corowa field using a relocatable production system known as the honeybee production system, which comprises the key elements shown in Figure 3-1:

1. Jack-up mobile offshore production unit (MOPU)
2. Production unit on the MOPU, which will separate and process oil, gas and water
3. Wells workover module on the MOPU, which will have the capability to plug and abandon wells, and potentially to drill; however, a separate mobile offshore drilling unit (MODU) may be used
4. Short flowline and riser to transport oil
5. Catenary anchor leg mooring (CALM) buoy
6. Floating marine hose to transport oil
7. Moored floating storage and offloading (FSO) facility, where oil is stored; or direct to shuttle tankers (depending on export option selected)
8. Floating export hose to offload oil from the FSO to export tankers.

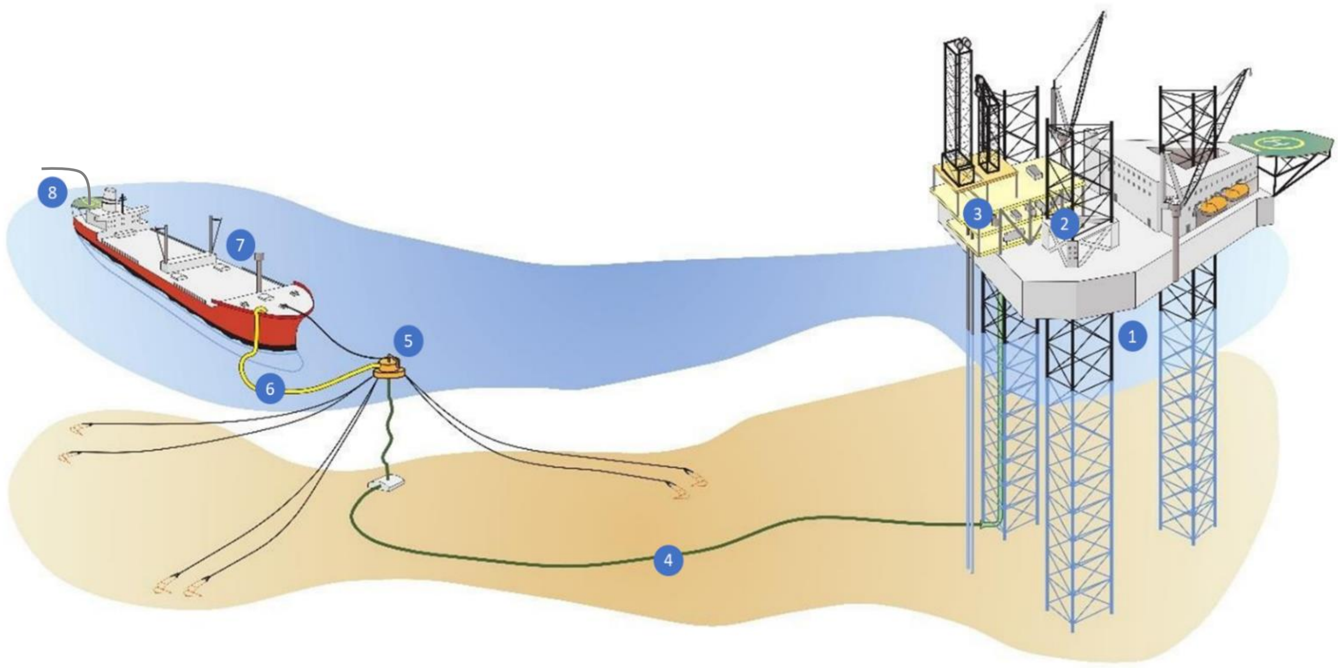


Figure 3-1 Corowa Development Infrastructure

3.1.1 Location

The Corowa Development is within Commonwealth waters in offshore petroleum permit WA-41-R, located ~60 km from Onslow in the north-west of Australia in water depths of 85–90 m (Figure 3-2). No petroleum activities are proposed in State waters, or onshore.

Under Regulation 5A(5) of the OPGGS(E)R this OPP is only required to assess petroleum activities within the project area and also covers the area where project vessels will be undertaking petroleum activities.

For the purpose of this OPP, the Project Area has been defined to include the extent of all planned activities described in this proposal with sufficient buffer, which has been conservatively designated as a 5 km radius around the expected position of the MOPU. The final MOPU position will be included in the relevant EP/s.

Vessels transiting to and from the Project Area are not considered a petroleum activity, they fall under the other maritime legislation, including the Commonwealth *Navigation Act 2012,* and therefore are excluded from the scope of this OPP.

Figure 3-2 shows the Project Area boundary and key infrastructure coordinates.

The expected location of the MOPU is shown in Table 3-1.

Table 3-1 Expected MOPU Coordinates

Facility	Latitude	Longitude
MOPU	21° 28’ 59.4” South	114° 33’ 26.2” East

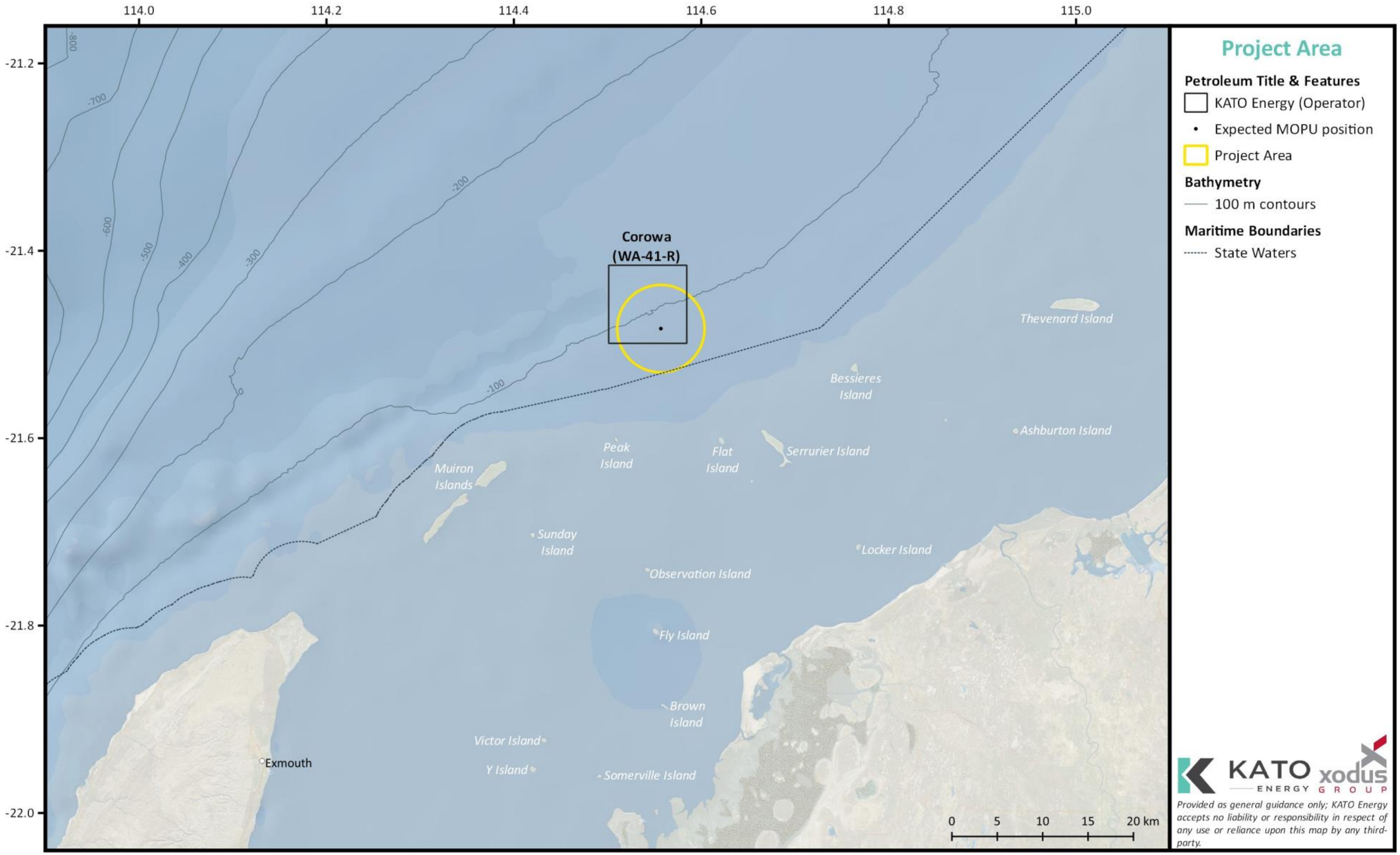


Figure 3-2 Corowa Development Project Area

3.1.2 Project Schedule

The target schedule for the Corowa Development is detailed in Table 3-2. KATO will become the titleholder for a number of fields, and the intent is that as each field is depleted, it is decommissioned, and the honeybee production system is then relocated to the next field. The order of the fields is not yet decided, and the timing shown in Table 3-2 assumes that the Corowa field will be the first development. If the fields are produced in a different order, the timing of Corowa may be later than shown.

Based on statistical modelling of the production profile, the best estimate of production life is two years (also known as P50), and the high estimate is 4.5 years (also known as P10; RPS 2014), meaning the duration of the Operations phase is between two and 4.5 years. A contingent infill drilling program is included in the preliminary project schedule for a possible second MODU mobilisation for an infill, well repair and/or sidetrack program, dependent on reservoir performance in the initial 6–12 months of production.

The conservative project life for the Corowa Development (from mobilisation to decommissioning) is approximately five years. Durations for each phase in Table 3-2 are conservative estimates, and are used for purposes of impact assessment.

Table 3-2 Preliminary Project Schedule

Phase	Estimated Timing	Indicative Duration
Survey	Q3 2021	1 month
Drilling	Initial campaign – Q4 2021 / Q1 2022 Second campaign (if required) – 1–2 years after start-up	Initial campaign – 5 months Second campaign (if required) – additional 4 months
Installation, Hook-up and Commissioning	Q4 2021 / Q1 2022	3 months
Operations	Q2 2022	Between 2 and 4.5 years, at best and high estimates of production respectively
Decommissioning	Between 2023 and 2026 (depending on duration of operations)	3 months

3.1.3 Options to be Selected in FEED

As OPPs are developed early in the concept select stage of a major capital project, some activity and design options will not be determined until later in the Front-End Engineering Design (FEED) phase.

For the Corowa Development, the four key options that will be selected in FEED are summarised in Table 3-3. Therefore, all options are included in the OPP, and their environmental impacts and risks assessed in Section 7.

Table 3-3 Design and Activity Options Carried into FEED

Activity or Design Option	Option description	Implications
Flare design	Open pipe flare	There is no significant environmental differentiator between the alternatives. All three feasible options are carried into FEED, when further investigation will be undertaken when topsides design is more advanced and key process
	Multi-tip flare	
	Air-assist flare	

Activity or Design Option	Option description	Implications
		inputs are known (e.g. separator pressure, flare compositional data). As the base case, the open pipe flare option has been used for impact assessment in the OPP.
Drilling facility	Drilling will be undertaken by the MOPU, if the selected rig has drilling capability.	The base case of a separate MODU conducting the drilling presents the greater potential environmental impact, due to the presence of two facilities in the field during drilling. The key additional environmental impacts are: • planned discharges • seabed disturbance. Therefore, the option of a separate MODU has been assessed and used as the basis for the impact assessment in the OPP.
	Drilling will be undertaken by a separate MODU, which is positioned alongside the MOPU.	
Export methodology	Oil is exported to the FSO, which is permanently connected to the CALM buoy. Export tankers will offload alongside the FSO.	The export strategy has implications for the manning strategy. If the base case of an FSO is selected, it is more likely to be the normally manned facility (but not necessarily). If an FSO is not selected, the MOPU must have additional storage capacity for crude (600 m^3), though this is much lower than the storage capacity of the FSO (~111,291 m^3). The key additional environmental impacts from the FSO option are: • planned discharges from the FSO in-field for project life • accidental releases – greater volume of crude storage. For these reasons, the base case of the FSO and export tankers has been used as the basis for the impact assessment in the OPP.
	Oil is exported directly to shuttle tankers, which will connect directly to the CALM buoy (i.e. FSO not required).	
Mooring of CALM buoy	Drilled and grouted anchor piles	There is no significant environmental differentiator between the two alternatives. Gravity anchors have a larger area of seabed disturbance, but drilled and grouted anchor piles have additional planned discharge of drilling cuttings and cement. Therefore, the worst-case seabed disturbance footprint (for gravity anchors), and the worst-case discharge (drill and grout) has been used for impact assessment.
	Gravity anchors	
Manning methodology	FSO normally manned, and MOPU not normally manned.	The manning strategy will be determined in the FEED phase, with either the FSO or MOPU housing the majority of personnel. The key additional environmental impacts are: • planned discharges. For the purposes of this OPP, it has been assumed that both facilities could normally be manned.
	FSO/shuttle tanker normally manned, and MOPU normally manned.	

3.2 Reservoir Characteristics and History

Three wells have previously been drilled within the WA-41-R offshore petroleum permit area.

The field was initially discovered in 2001 by Santos, who drilled the Corowa-1 exploration well to a total depth of 1651 m. The well flowed at ~839 m^3/day, and was then plugged and abandoned.

In 2002 the Corowa Flank-1 well was drilled, 1.7 km northwest of Corowa-1, but did not identify any hydrocarbon bearing sandstones, and was plugged and abandoned. In 2005 the Corowa East-1 well was drilled 1.2 km east of Corowa-1, and oil was confirmed (Geoscience Australia 2019a).

The Corowa field has a likely resource of 7.0 MMstb. The field has an oil gravity of 50°API with a gas-oil-ratio (GOR) is 700 scf/stb. No significant CO_2 or H_2S has been recorded.

The reservoir fluid and gas composition for the Corowa Field is detailed in Table 3-4.

Table 3-4 Fluid and Gas Composition for the Corowa Field

Component	Composition range (mol%)
Carbon dioxide	0.57
Nitrogen	0.82
Methane	33.11
Ethane	6.52
Propane	6.83
Hydrogen Sulphide (H_2S)	0

3.3 Description of Infrastructure

The key infrastructure components proposed for the Corowa Development are described in the subsections below.

3.3.1 Wells

Up to four production wells may be drilled, potentially over two drilling campaigns (depending on initial drilling outcomes). Either a separate MODU will be used, or the MOPU selected for use may have drilling capability itself (Section 4.3.4). If a separate MODU is used, it will be a jack-up rig, which will set-up adjacent to the MOPU, and drill the wells through the MOPU conductor deck. The well design is such that each conductor casing extends from the seabed to the conductor deck on the MOPU (~24 m above sea level), and the production tree and the drilling BOP for each well will be above the conductor deck level.

Each well will have a separate entry point (approximately <1 m diameter hole). The seabed entry points for all the wells (up to four) will be within an approximate 10 m by 10 m footprint (i.e. within a total footprint of <100 m^2). Once below the seabed, the wells will be directionally drilled to target different areas of the reservoir.

Well design considers the well barrier envelope during well construction, operations and production to provide two independent verifiable barriers.

Figure 3-3 shows an indicative section view of a potential three-well P10 development option.

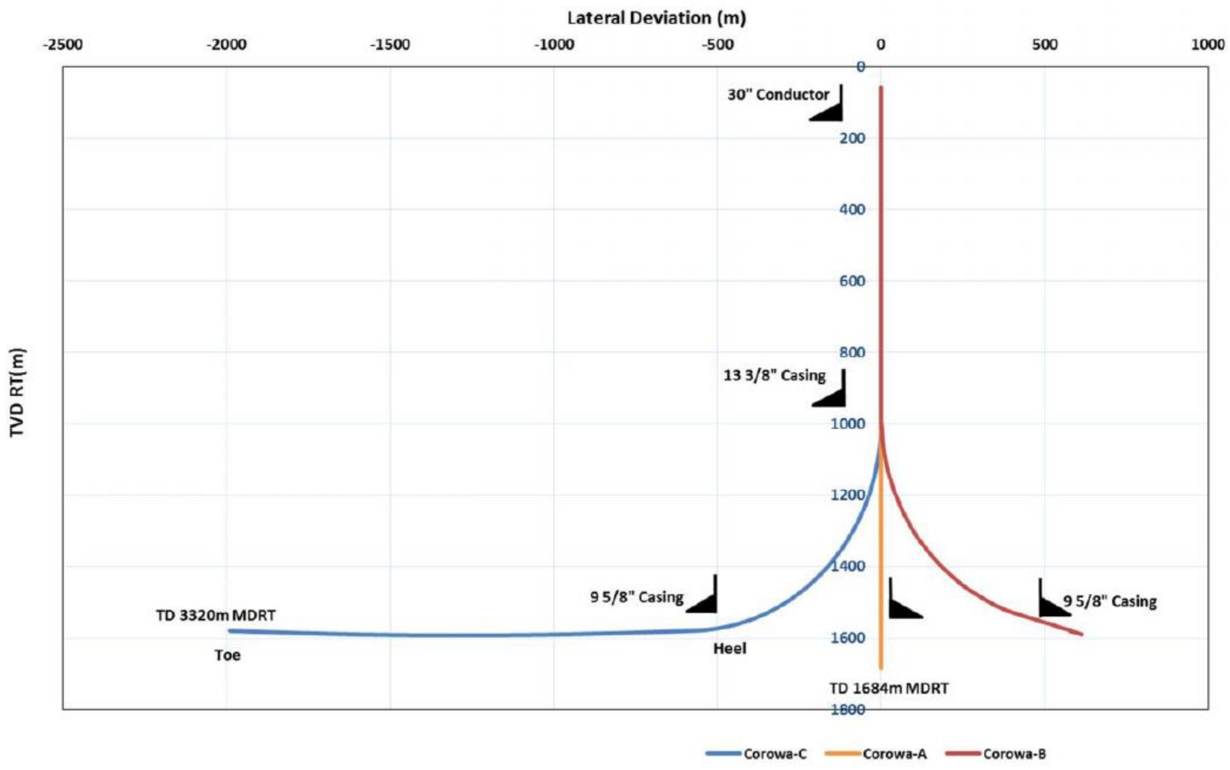


Figure 3-3 Indicative Section View of a Three-well P10 Development Option

During the later period of the production phase, the wells may not flow to surface naturally and require artificial lift. Gas-lift or electric submersible pumps (ESPs) may be used for artificial lift of the wells at this time. This selected method will be confirmed during FEED.

Table 3-5 summarises the key well design characteristics.

Table 3-5 Key Characteristics of the Wells

Characteristic	Description
Well location (expected MOPU location)	Latitude: 21° 28’ 59.4” South Longitude: 114 ° 33’ 26.2” East
Well depth	TVD 1,500 m to 1,600 m
Total area direct seabed disturbance	100 m^2 Including 50% contingency – **150 m^2**

3.3.2 MOPU

The MOPU will be a jack-up rig that has been modified to include a production unit, and storage for small quantities of processed oil, or it may be a custom-built facility. It will also have a wells workover module with ability to undertake well workovers and plug and abandonment of the wells on departure from the field.

A jack-up rig is a type of mobile platform that comprises a buoyant hull fitted with a number of movable legs. It will be towed to location with its legs extended in the ‘up’ position (i.e. above the hull) and the hull floating on the water. Once on location at the Project Area, the legs are extended down onto the seafloor, and the hull then elevated to sit at a pre-determined height above the sea surface.

The base case for the Corowa Development is that a separate MODU will drill the wells adjacent to the MOPU; however, there is an option that the MOPU itself may have drilling capability. In this case, a separate MODU would not be required (refer to Section 4.3.4).

If a separate MODU is required, it will set-up adjacent to the MOPU, and drill the wells through the MOPU conductor deck via a cantilever derrick.

As this base case (that is separate MOPU and MODU) also presents the greater potential environmental impact due to having two facilities in the field during drilling, it has been used as the basis for the impact assessment in the OPP.

If an FSO is selected, the MOPU would likely be not normally manned, except for commissioning, decommissioning and maintenance/workover campaigns, and would house a maximum of 30 persons on board (POB) during these periods.

If shuttle tankers are selected, the MOPU will normally be manned by 12–15 POB, and would require ~1,000 m^3 of crude storage capacity, that would only be used during shuttle tanker changeover.

Table 3-6 summarises the key MOPU characteristics.

Table 3-6 Key Characteristics of the MOPU

Characteristic	Description
MOPU type	Jack-up rig or custom-built facility
Deck Dimensions (L x W x H)	Hull length: ~80–90 m Hull width: ~90 m Hull depth: ~10 m
Rig feet	Rig feet are attached to the bottom of each leg, and each foot sits into the ocean floor supporting the rig, adding stability to the rig during operations. • three rig feet, one for each leg • rig feet diameter: ~17–20 m • rig footing area: ~250–315 m^2 each
Nominal POB	If not normally-manned, zero POB. For commissioning and decommissioning, and maintenance/workover campaigns, may be manned by an additional 30 POB. If normally manned, <15 POB during production, and <45–50 POB during commissioning and decommissioning, and maintenance/workover campaigns. If the MOPU itself has drilling capability, the normally manned POB during drilling would be up to 150.
Maximum crude storage	1,000 m^3 (depending on export method – if shuttle tanker option is selected)
Maximum diesel storage	800 m^3
Power consumption	Installed power: 6 MW Diesel generation (normal operations): 6 MW (jacking on diesel) for 12 hours, 2 MW (80% gas) Emergency diesel generation: 1 MW (diesel) Firewater pump/s diesel driven: 300 kW

Characteristic	Description
Process capacity	Total throughput (oil) max design capacity 4,000 m^3/day (25,000 bopd) Total throughput (gas) max design capacity 700,000 sm^3/day (25 MMscfd) Maximum PFW discharge rate 178 m^3/hour (4,275 m^3/day)
Total footprint	~1,500 m^2 (for all three rig footings)

3.3.3 Flowlines and Marine Hoses

There will be a short subsea static flowline extending ~1.5 km from the riser on the MOPU to the Flowline End Termination (FLET) and a dynamic section (riser) up to the CALM buoy. The likely diameter of the subsea flowline is 6", with an assumed corridor of 5 m. Stabilisation may require concrete mattress and/or grout bags. The flowline may have communication and power cables bundled with it or laid alongside.

The subsea flowline and cables will remain on location during a cyclonic event and be designed to withstand the 100 year return cyclonic storm conditions.

The FSO or shuttle tanker will connect to the CALM buoy via a short floating marine hose (~300 m long, 6" diameter). It is fitted with breakaway couplings and will be capable of being recovered and stored on the FSO or alternative (for shuttle tanker option).

Export tankers will connect to the FSO via a short floating export hose (~300 m long, 12" diameter), which will be stored on reels on the FSO when not in use.

Table 3-7 summarises the key flowlines characteristics. The flowlines and CALM buoy arrangement are shown in Figure 3-4.

Table 3-7 Key Characteristics of the Flowlines

Characteristic	Description
Subsea flowline dimensions	~1.5 km long Likely diameter of 6" (inventory of ~30 m^3). May be bundled with a power and communications cable.
Subsea flowline footprint	1.5 km long, assuming 5 m wide disturbance corridor. Note if power and communication cables or mattresses/ grout bags are used, these will be within the 5 m corridor. Total of ~7,530 m^2
Flowline end terminations (FLET) structure footprint	~7 m x 4 m Total area of 30 m^2
Floating marine hose dimensions (CALM buoy to FSO or shuttle tanker)	~300 m long Likely diameter of 6" (inventory of ~5.5 m^3)
Floating export hose dimensions (FSO to export tanker)	~300 m long Likely diameter of 12" (inventory of ~24 m^3)
Total Footprint	7,560 m^2 Including 50% contingency – **11,340 m^2**

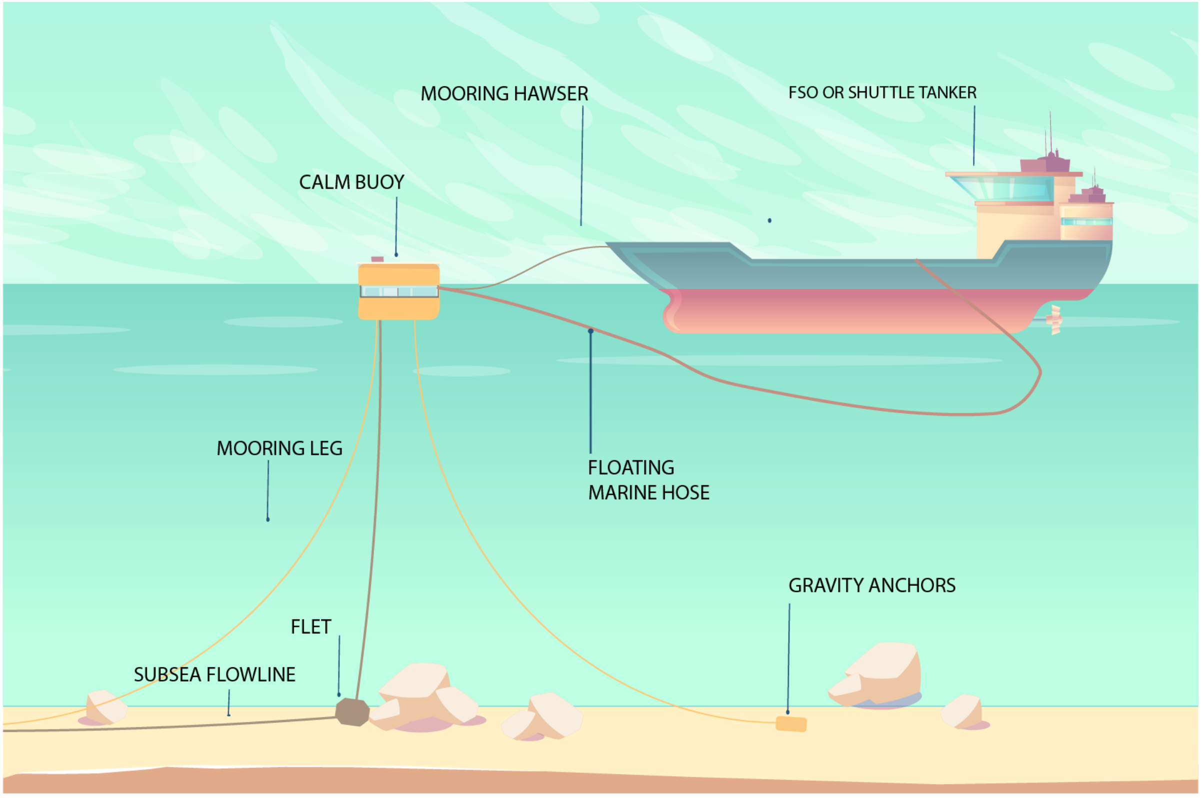


Figure 3-4 FSO, CALM Buoy and Mooring Arrangement

3.3.4 CALM Buoy and Mooring Arrangements

The CALM buoy is a floating hull with a rotating head to which vessels can moor, typically with a turntable positioned above the stationary hull mounted on a bearing. It will include a single fluid swivel suitable for transfer of stabilised crude oil from the dynamic flexible riser to the floating export hose. It may include an electric swivel to enable transfer of power or communications between MOPU and FSO.

The FSO (or shuttle tanker) will be connected to the CALM buoy by a single mooring hawser (i.e. chain and nylon rope) ~70 m long, and allowed to weathervane (Figure 3-4). The floating marine hose will connect from the rotating section of the CALM buoy to the FSO or shuttle tanker, prior to transferring crude. The turntable swivel allows fluid to transfer between the stationary section of the CALM buoy while the moored vessel weathervanes. The vast majority of marine terminals installed since the mid-1990s have been CALM buoys.

The mooring system will likely have three mooring legs, with two chains each, equally spaced 120 degrees. During installation these are lowered to the seabed, then individually lifted and tensioned onto the CALM buoy.

There are two options for the mooring of the CALM buoy—gravity anchors or drilled and grouted anchor piles (refer to Section 4.3.7 for option analysis).

The gravity anchors would be gravity structures (steel or concrete) with a skirt for lateral stability. These will be lowered to the seabed from a support vessel (ISV or AHT). Ballast may then be lowered into the structures, which would potentially be anchor chain or weights. These will be suitably sized for the system to withstand extreme weather events, and are relocatable.

If drilled and grouted anchor piles are selected, a <1.5 m hole ~25 m deep is drilled, and casing inserted, which is then pumped with grout and a mooring line connected. At decommissioning, the mooring system will be cut, and the below-mudline section of the casing left in situ.

The CALM buoy and moorings are relocatable.

Up to three dead man's anchors (DMAs) will be installed within the Project Area, for support vessels to use. These will consist of concrete clump weights. Support vessels will select which DMA to use depending on prevailing conditions, to ensure they are clear of the MOPU, weathervaning FSO and export/shuttle tankers.

Table 3-8 summarises the key characteristics of the CALM buoy and mooring arrangements.

Table 3-8 Key Characteristics of the CALM Buoy and Mooring Arrangements

Characteristic	Description
Mooring radius / method	Mooring leg length approximately <600m 6 chains in a 3x2 leg combination.
Mooring leg footprint	For each leg (comprising two chains), assumes a 600 m long by 5 m wide disturbance area, including the laydown of the leg on the seabed during installation. Three legs of 3,000 m^2 footprint per leg, giving a total of 9,000 m^2.
Gravity anchor option – footprint	Three gravity anchors of 240 m^2 each gives a total of 720 m^2.
Drilled and grouted anchor piles option	Three holes drilled ~25 m deep with seawater. ~45 m^3 cuttings discharge per hole, giving a total of 140 m^3. Footprint ~20 m^2 each hole, giving a total of 60 m^2.
Dead Man's Anchor for support vessels	<25 m^2 for each of the potential three DMAs, giving a total 75 m^2.
Total area seabed disturbance	9,795 m^2 Including 50% contingency – **14,963 m^2**

3.3.5 FSO

Should an FSO be selected as the export strategy, it will likely be an Aframax tanker size (80,000 to 120,000 DWT). It will house the control room and accommodate all permanent offshore personnel, except during hook-up and commissioning, workovers, decommissioning, and plugging and abandoning when personnel will be housed on the MOPU for these activities.

The FSO mooring connect/disconnect system to the CALM buoy has a hawser line and the floating export marine hose. The mooring systems connecting the FSO to the rotating section of the CALM buoy will comprise a ~70 m long hawser (chain and nylon rope), connected to the FSO via chain stopper, with a quick release mechanism, and recovery winch on the FSO.

The FSO will connect to the CALM buoy via a short floating marine hose. Export tankers will connect via a floating export hose from the FSO. Export tankers will be secured by hawser line to the FSO, and potentially to a tug / support vessel for the duration of offload.

Offload is expected to take ~48 to 72 hours.

In the event of a cyclone, the production will be shut-in, the MOPU made safe, and the FSO will disconnect and sail to a safe location.

Table 3-9 summarises the key characteristics of the FSO.

Table 3-9 Key Characteristics of the FSO

Characteristic	Description
Vessel type	Aframax tanker 80,000–120,000 DWT
Hull	Monohull, double skin
Deck Dimensions (L x W x H)	Approximate 250 m x 45 m x 20 m
Mooring	Will be connected to the CALM buoy via a 70 m mooring hawser, and will have 360º movement around the buoy. No proposed anchoring of FSO.
Nominal POB	17- 30 POB (depending on manning strategy)
Maximum crude storage	Storage 95,392–111,291 m^3 (600,000–700,000 bbl) in segregated cargo tanks. The cargo offloading system will be designed to offload a 63,594 m^3 (400,000 bbl) parcel within 24 hours.
Maximum diesel storage	~4,000 m^2 Including 50% contingency – **6,000 m^2**

3.3.6 Shuttle / Export Tankers

If shuttle tankers are selected as the export strategy, they will likely be Panamax (60,000 to 80,000 DWT) or Aframax. These may be owned by KATO or third parties.

Shuttle tankers will connect directly to the CALM buoy using similar system as FSO; i.e. mooring hawser and short floating export hose (~300 m long) (Figure 3-4). Changeover may take 6–8 hours, between shuttle tankers connecting to the CALM buoy and oil export recommencing.

If an FSO and export tankers are selected as the export strategy, export tankers are likely to be Aframax (80,000 to 120,000 DWT), but may be up to Suezmax (120,000 DWT to 200,000 DWT).

Tankers are considered part of the petroleum activity while within the Project Area (5 km radius of the MOPU); otherwise they fall under the Commonwealth *Navigation Act 2012*.

3.4 Description of Activities

The following subsections outline activities associated with each phase of the development.

Support Activities (Section 3.4.6) may be used throughout all phases of the Corowa Development, and covers those activities on the vessels/facilities that are common and not process related; for example, sewage and greywater discharge, refuelling, bulk transfer, lighting, reverse osmosis brine discharge. As an example, sewage discharge from the MOPU is described under Support Operations (Section 3.4.6.2), not under Hydrocarbon Processing (Section 3.4.4.2).

3.4.1 Site Survey

3.4.1.1 Geophysical Survey

A geophysical survey of the well location and mooring spread may be required before the MODU is mobilised to the project area to ensure suitable seabed conditions exist for anchoring and jacking. This survey may consist of these scopes:

- high-resolution sub-bottom profiler – determine shallow and surface geology
- magnetometer – to detect buried submerged objects

- multibeam bathymetric – mapping water depths
- side-scan sonar
- high-resolution multibeam echo sounder – delineating seabed features and identifying any seabed hazards.

3.4.1.2 Geotechnical Survey

A geotechnical survey of the well location and mooring spread may be undertaken before the MODU is mobilised to the project area. This may include the following sampling methods to determine the shallow and surface geology/sediments at the project location plus verify any side-scan sonar data obtain (if required):

- borehole sampling
- coring
- Piezocone Penetration Test (PCPT)
- seabed grab sampling
- vibro-coring.

A single survey is proposed within the footprint. In the unlikely event the target location is found to have obstruction or unsuitable soil conditions, alternative locations within the Project Area may be investigated.

A seabed site investigation frame is typically 3 m x 3 m (i.e. <10 m^2). Conservatively assuming multiple sample and locations may be required, the total seabed disturbance footprint for the geotechnical survey is expected to be <100 m^2.

3.4.2 Drilling

The base case is for a separate MODU, to set-up adjacent to the MOPU, and drill the wells through the MOPU's conductor deck (shown in Figure 3-5; refer to Section 4.3.4).

However, there is potential that the selected MOPU could have drilling capability – in this case, a separate MODU would not be required.

Up to four production wells may be drilled, potentially over two drilling campaigns (depending on initial drilling outcomes). Drilling activities will require the use of a jack-up MODU due to shallow-water depths, and is expected to take approximately five months for the initial campaign, and an additional four months if an infill drilling campaign is required.

For the base case of a separate MODU, the activity sequence will likely be:

- MOPU will be towed into Project Area by two to three support vessels [likely anchor handling tugs (AHTs)].
- once positioned at the correct location, the MOPU will commence jacking operations to be self-standing on location.
- conductor deck will be lowered into position using MOPU lifting equipment.
- MODU will then be towed into the Project Area by two to three support vessels.
- once positioned at the correct location, opposite the MOPU and within cantilever reach of the MOPU conductor deck, the MODU will commence jacking operations to be self-standing on location.
- MODU cantilever will be extended to proposed well conductor location and the drilling operations will commence on the wells.

Removal of the MODU from the Project Area will be the reverse, after completing the drilling activities.

If the contingent second drilling campaign is undertaken, a MODU of similar specifications will be remobilised to the Project Area and positioned adjacent to the MOPU. The activity sequence will be similar to the first campaign described above. As the field will be in production, a simultaneous production and drilling (SIMOPS) workshop will be completed, and a procedure developed to manage and mitigate any additional risks due to concurrent activities. As a minimum, production will be shut-in and the reservoir isolated for MODU approach and disconnection, BOP handling above live tress and any drilling class potential due to new wellbore proximity to existing production wells.

Secondary wellbores known as 'sidetracks' may be drilled from an already drilled well to access other areas of the reservoir (via the same wellhead). The bottom-hole section of the existing well section is P&A'd, and the new bottom-hole section is drilled and completed as per Sections 3.4.2.4 and 3.4.2.5.

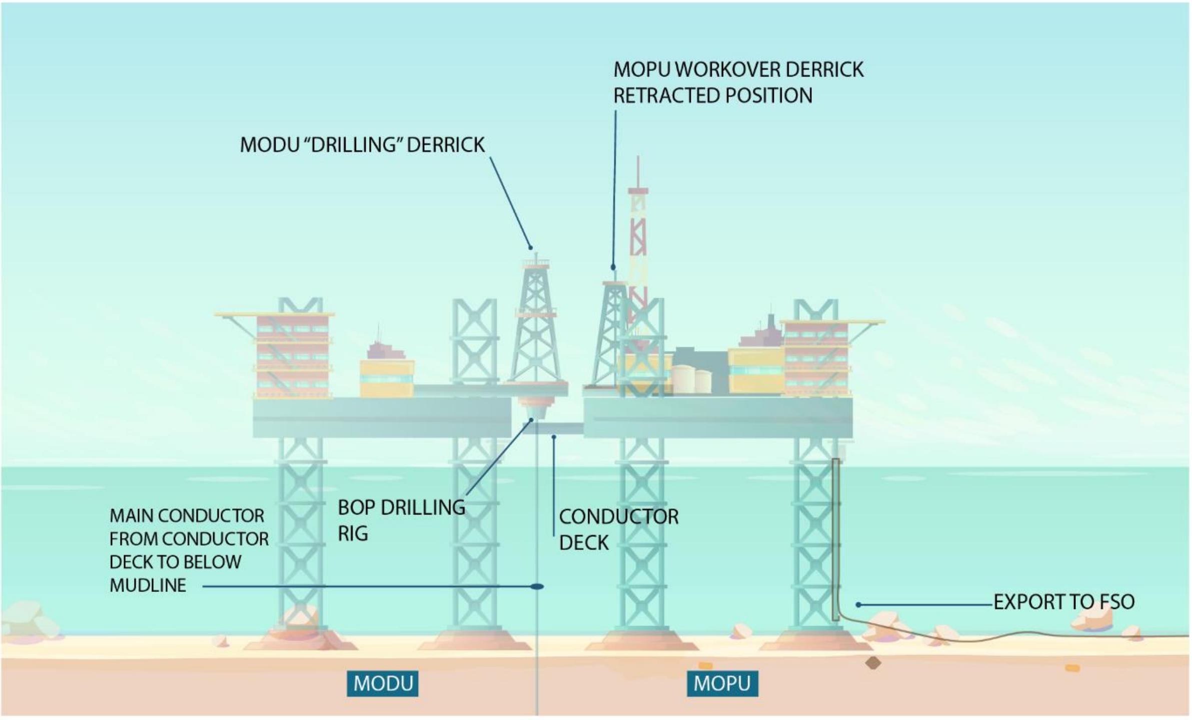


Figure 3-5 MODU and MOPU Set-up during Drilling

Up to four production wells will be drilled, to a vertical depth of ~1,500–1,600 m. The top-hole locations of each well will be within a 10 m x 10 m area, and will then run directionally to target different areas of the reservoir. This will depend on several factors including final position of hydrocarbon targets and substrate composition within the project area and therefore is subject to change. Well design is described in Section 3.3.1. A more detailed description of expected activities involved in drilling is given below.

Note the final well design is subject to FEED. The *Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011* requires that detailed well design and management is approved by NOPSEMA before drilling can commence, approved via the Well Operations Management Plan (WOMP).

3.4.2.1 MODU Positioning

The base case is for a separate MODU, to set-up adjacent to the MOPU, and drill the wells through the MOPU's conductor deck. In this case, the separate MODU will mobilise into and then exit the project area, likely towed by two to three support vessels (e.g. AHTs). However, if the MOPU can drill, the MODU will not be required (see Section 4.3.4).

The MODU selected to complete the activities will be a jack-up rig. It is expected to have three rig feet with a footprint of ~315 m^2 each, giving a conservative total footprint of 1,500 m^2.

In the event a second drilling campaign is required, a MODU will be remobilised to the Project Area and positioned adjacent to the MOPU. Whilst preferred, the rig feet may not be located in exactly the same footprint as for the first campaign. Therefore, for the purposes of impact assessment, the total area of seabed disturbance allowance has been doubled, giving a total 3,000 m^2.

Transponders may be used to accurately position the MODU. Transponders are attached to temporary clump weights and then lowered onto the seabed, which are recovered once the MODU is installed.

A 500 m petroleum safety zone (PSZ) will be established, as assessed by NOPSEMA under the OPGGS Act.

The MODU will be of cantilever derrick type with cantilever skidding capability. During sailing, the cantilever will be in the fully retracted position within the perimeter of the MODU hull. Once the MOPU is on location and self-supporting, the cantilever will be extended to reach over the conductor deck of the MOPU, to be in position to commence drilling operations (typical arrangement shown in Figure 3-4).

Once drilling is completed, the drilling cantilever derrick will be retracted from over the MOPU conductor deck. The MODU would be jacked down and floated, the rig feet lifted off the seabed, legs fully retracted into the ‘up’ position, and the MODU towed away.

There are no additional anchors required for a jackup MODU.

3.4.2.2 Conductor and Top-Hole Drilling

Once the derrick is positioned over the well location (through the conductor deck), drilling will commence with the top-hole section. This would likely follow this sequence (subject to FEED):

- commence drilling the hole for the conductor to a depth of ~200 m (gel chemical mud system, cuttings discharged at seabed)
- install the conductor tensioning equipment on the MODU conduction deck
- run the large bore conductor, through the tensioning equipment and into the drilled hole
- run cement through the conductor, up the outside of the conductor to mudline
- set tension and test the conductor
- drill through the conductor a hole for the surface casing to a depth of ~950 m below mudline (cuttings discharged to sea after treatment on MODU)
- run a smaller surface casing inside the main conductor
- run cement through the narrow surface casing, up the outside of the casing for ~500 m.

Casing of the drilled hole for the well ensures it does not collapse and protects the well from outside contaminants like sand or water, and provides pressure containment within. It can also provide an extra level of containment for the reservoirs/strata encountered in the hole. The casing is steel pipe joined together to make a continuous hollow tube that is run into the hole. There are different sizes of casing for each section of the well. For the Corowa Development, conductor casing (a carbon steel pipe) is used from the MOPU conductor deck to the seabed. Inside this is various diameters of casing extending down into the reservoir, where the lower completion will be installed to allow the entry of hydrocarbons.

During drilling of the conductor and surface casing, sweeps of pre-hydrated bentonite clay (known as 'gel') or guar may be used, which would be discharged to the marine environment.

Approximately 8 m^3 per 15 m drilled would be used (giving a total for top-hole drilling of ~650 m^3 per well).

For each casing installed in the drilled hole, a cement slurry is pumped into the well, displacing drilling fluids and filling and sealing the space between the casing and the formation. Comprising a special mixture of additives and cement, the slurry is left to harden, sealing the well from contaminants and permanently positioning the casing into place. Minor volumes of cement will be released at the seabed during installation of the main conductor at the seabed (estimated 30 m^3 maximum overspill). Once the main conductor has been installed, all further displaced fluids are returned to the MODU.

Upon completion of each cementing activity during drilling, the cementing head and blending tanks are cleaned, which results in a release of cement contaminated water to the marine environment of <0.8 m^3 per well. Also, in the unlikely event that cement products become contaminated by drilling fluids, the entire volume may need to be recovered to surface and discharged to sea (estimated maximum volume of 15 m^3).

3.4.2.3 BOP Installation and Testing

A blowout preventor (BOP) is a large mechanical device installed at the top of a well that is designed to close if control of the formation fluids is lost, to provide a means for sealing, controlling and monitoring the well. In the unlikely event of a loss of well control (LOWC), this device can be closed to regain control of the well and provides multiple barriers to mitigate the loss of hydrocarbons.

The BOP will be installed on the conductor deck on the MODU. All drilling activity into the hydrocarbon reservoir will be through the BOP.

Since BOPs are critically important to the integrity and safety of the MODU and the well, BOPs are inspected, tested and refurbished at regular intervals determined by a combination of equipment manufacturer recommendations, risk assessment, local practice, well type and legal requirements. Pressure testing will take place before being put into operational service on the wellhead, after the disconnection of any pressure containment seal in the BOP, at ~21 day intervals with an additional function test after installation.

Often BOPs are subsea and release small volumes of control fluid to the marine environment during function or pressure tests. However, because Corowa uses a 'dry' BOP, it uses a closed-circuit hydraulic system, and does not require any discharge of fluid to the marine environment during testing.

3.4.2.4 Bottom-Hole Drilling

Once the BOP is installed, drilling the intermediate sections and bottom-hole sections will commence. These sections are where the operations will enter hydrocarbon bearing zones. This would likely follow this sequence (subject to FEED):

- drill through the BOP to a depth of ~1,450 m, immediately before entering the reservoir (hydrocarbon zone)
- run the intermediate casing inside
- run cement through the intermediate casing, up the outside of the casing for ~500 m
- drill into the reservoir to the desired. Likely to be inclined or horizontal.

Water- or synthetic-based drilling fluid (also known as drilling mud) may be used. No fluid would be discharged to the environment, and cuttings would be discharged in accordance with regulatory requirements.

3.4.2.4.1 Sidetracks

Occasionally the initial bottom-hole section of a well may require re-drilling within the reservoir. This may be managed by drilling a new bottom-hole section, via a sidetrack from an existing well.

In order to drill sidetracks, the bottom-hole section of the existing well section is P&A'd, and the new bottom-hole section is drilled and completed as per Sections 3.4.2.4 and 3.4.2.5.

The cuttings are processed to remove coarse and fine material as per Section 3.4.2.7, with the fluids recirculated back for further use. Processed cuttings are discharged at the surface below the water line.

Conservative cuttings volumes discharged during sidetrack drilling are ~170 m^3 per sidetrack well.

3.4.2.5 Completions

Running the well completion is the process of transforming a drilled well into a producing one. These steps include casing, cementing, perforating, installing screens, gravel packing and installing a production tree (which is the term for an assembly of valves, spools, and fittings used to regulate hydrocarbon flow within a well).

The lower completion will be a liner or screen in the reservoir (hydrocarbon zone). The upper completion will be hung from the wellhead at surface and consist primarily of narrow production tubing.

Once the drilled hole into the reservoir has been completed, the completions will be run. This would likely follow this sequence (subject to FEED):

- install lower completion, which will be a liner or screen assembly into the 8½" hole into the reservoir (no discharge to the environment)
- wellbore clean-up run (casing scrapers, circulate well to clean fluid)
- run the production tubing, including the wellhead (at surface)
- the tubing will include safety and production related devices; specifically, a downhole subsurface safety valve placed up to 500 m below the seabed. Wells will always have a minimum of two barriers during field life. Downhole and surface safety valves fail closed if a downstream low pressure is detected, simulating a loss of containment downstream.

Bottom-hole completions will be determined at FEED; options are to:

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

Additional production and integrity components could include gas-lift mandrels and chemical injection valves (specified in FEED).

Finally, a production tree will be installed. For the Corowa Development, the tree will be located above the sea surface, on the MOPU conductor deck (known as a 'dry' tree).

This would likely follow this sequence (subject to FEED):

- install isolation plug (in a nipple profile in the completion tubing or in the tubing hanger)
- remove BOP
- install production tree on the conductor
- rig up slickline pressure control equipment and recover isolation plug
- rig down slickline pressure control equipment.

The well 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.

Vertical seismic profiling (VSP) may also be used as an evaluation technique, which refers to measurements made in a vertical wellbore using geophones inside the wellbore, and a surface seismic source, commonly a small air gun array. During VSP operations, the airgun array is discharged approximately for a few seconds at intervals, which generates sound pulses that reflect through the seabed and are recorded by the receivers to generate a profile along that section of the wellbore. This process is repeated as required for different stations in the wellbore and it may take up to 24 hours to complete, depending on the wellbore's depth and number of stations being profiled.

3.4.2.6 Well Clean-up and Flowback

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 from previous stages) from the wellbore.

During the clean-up process, fluids are circulated back to the MODU or MOPU, and, if required, 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 overboard.

Prior to production, the well will be cleaned up to remove any remaining debris and solids coming out of the formation and perforations, plus the drilling and completion fluids (~53 m^3 per well).

If flaring is required during flowback, this can be undertaken either from the MODU or MOPU, but most likely the MOPU. The flowback and well clean-up process may take up to 24 hours for each production well.

The flare arrangement is described in Section 3.4.4.2.

3.4.2.7 Drilling cuttings and Fluids

Drilling fluids (also known as drilling muds) are used in drilling operations to carry rock cuttings to the surface and to lubricate and cool the drill bit. The drilling fluid, by hydrostatic pressure, also helps prevent the collapse of unstable strata into the borehole and the intrusion of water from water-bearing strata that may be encountered. During drilling operations, two types of drilling fluids will be used, water-based muds (WBM) and synthetic-based muds (SBM). Refer to Section 4.3.5 for analysis of alternative options.

The general constituents of drilling fluids may include:

- WBM – water or saltwater is the major liquid phase as well as the wetting (external) phase. May also contain bentonite clay, barite and gellents (e.g. guar gum or xanthan gum).
- SBM – synthetic-based fluid, which may contain a hydrocarbon, ether, ester, or acetal. SBM may also contain organophilic clays, barite, lime, aqueous chloride, rheology modifiers fluid loss control agents and emulsifiers. SBM are particularly useful for deep water and deviated hole drilling.

The specific type and mix of drilling fluid will depend on the final proposed design and drilling requirements encountered on site.

During drilling of the main conductor hole section of the well, cuttings (and drilling fluids) will be released directly to the seabed in the vicinity of the well site (at the seabed) as drilling is undertaken.

WBM will be used to drill the conductor section. The estimated volume of cuttings discharged directly subsea for drilling of the conductor are expected to be ~75 m^3 per well. The conductor will also be cemented in place, and excess cement discharged subsea is estimated to be up to 30 m^3 per well.

Top-hole drilling will use WBM or seawater, and gel sweeps, giving an estimated discharge volume of ~50 m^3 per well for the top-hole section.

Following the completion of the installation of the main conductor (riser) of the well, the remainder of the top-hole and bottom-hole well sections will be drilled through the main conductor, allowing the drilling cuttings and fluids to be routed back to the MODU or MOPU, forming a closed-circuit system.

Cuttings are then processed within the solids control equipment (SCE), with drilling fluids separated from the cuttings and recirculated back for further use. The cuttings are processed further through shale shakers and centrifuges to remove coarse and fine material. Processed cuttings are discharged at the surface below the water line.

Volumes of cuttings discharged during the remaining top-hole and the bottom-hole section are estimated to be ~350 m^3 per well, with variations expected depending on the depth of the well.

The remaining top-hole and bottom-hole drilling may use SBM or WBM depending on technical feasibility and safety, and drilling technical requirements (refer to Section 4.3.5). If SBM is used, there is no planned discharge of SBM to the marine environment during drilling. If WBM is used, a maximum of 159 m^3 of WBM per well could be discharged to the marine environment at the end of the drilling operations. This fluid is recycled where possible to use for subsequent wells.

3.4.3 Installation, Hook-up and Commissioning

Activities associated with the installation, hook-up and commissioning phase include:

- installation, hook-up and commissioning of the MOPU (which should arrive pre-commissioned)
- installation of CALM buoy and mooring arrangements
- installation and commissioning of the flowlines (subsea flowline and dynamic riser, floating marine hose and floating export hose), including stabilisation and commissioning
- hook-up of FSO.

3.4.3.1 MOPU

The MOPU will be a jack-up rig that has been modified to include a production unit, and storage for small quantities of processed oil, or may be a custom-built facility. The intent is for the MOPU to be fully pre-commissioned in the fabrication yard before the MOPU is towed to site, including pre-commissioning and full function testing of all non-hydrocarbon systems; i.e. most of the utility systems (e.g. power generation, cooling water, utility/instrument air and heat medium circulation).

However, minor pre-commissioning activities may be completed onsite, if any pre-commissioning was unable to be completed in the fabrication yard; for example, in the event of late delivery of components, or for technical reasons (e.g. instrumentation on a process vessel).

The MOPU will be towed to site by two to three support vessels (e.g. AHTs) and installed in ~90 m of water (see Section 3.3.2 for description). During installation, the MOPU will undertake a pre-load test in situ to ensure it will be stable during operations, including cyclonic conditions.

As a minimum, the following hook-up scope will be undertaken on location at Corowa:

- lowering of the conductor deck and associated access stair into position (likely to be hinged and retracted for the tow)
- installation of the spools between the production tree on the well and the production manifold and leak testing

- lowering into place the flare boom (likely hinged off the side of the MOPU for towing)
- any breakout spools removed for the tow.

To ensure systems have not been loosened during the tow of the MOPU, the hydrocarbon pressure retaining systems will also be re-leak tested with nitrogen on location (expected volume of multiple nitrogen quads – ~2,000 sm^3). If any hydrotesting is required once the MOPU is in position, the hydrotest fluid will be sent to the bilge system, and treated and discharged as per bilge water.

Transponders may be used to accurately position the MOPU. Transponders are attached to temporary clump weights and then lowered onto the seabed, which are recovered once the MOPU is installed.

The positioning and installation of the MOPU is expected to take up to 6 days to complete depending on the weather conditions.

Once the MOPU arrives at the Corowa Development location, in-field commissioning activities are expected to include:

- sequential pressurisation of topsides systems and final leak checks
- cold venting to clear nitrogen from the equipment and piping systems
- opening the production well and introducing hydrocarbons at a controlled rate
- commissioning hydrocarbon systems
- commissioning water treatment systems
- fuel gas system commissioning to run the main power generation/heat medium system
- when export specifications have been met, slowly increasing oil production rates to system capacity.

With the exception of the nitrogen venting, emissions and discharges during commissioning are the same as during the operation of the MOPU (refer Sections 3.4.4 and 3.4.6.2).

3.4.3.2 CALM Buoy and Mooring Arrangements

Support vessel/s will be mobilised to the field, which is likely an installation vessel (ISV).

There are two options for mooring the CALM buoy—gravity anchors and drilled and grouted anchor piles (refer Section 4.3.7 for option analysis).

If the gravity anchor option is selected, the gravity structures (steel or concrete) will be lowered and positioned on the seabed. The two mooring chains attached to each basket will be lowered to the seafloor, then ballast (anchor chain and/or weights) will be lowered into the gravity structures until the design weight is reached.

If drilled and grouted anchor piles are selected, a shallow hole will be drilled off the ISV, which the casing is lowered into. Grout is then pumped inside and around each casing to attach it to the substrate.

During the mooring installation, the CALM buoy will be floated into position, and appropriately secured to a support vessel. Transponders may be used to accurately position the CALM buoy and mooring system. Transponders are attached to temporary clump weights and then lowered onto the seabed, which are recovered once the CALM buoy and mooring system is installed.

Once the mooring system is in place, the two mooring chains from each gravity anchor or casing will be retrieved from the seafloor and the gravity anchor capacity tested using a ‘pull test’ from a support vessel (likely an AHT). After testing, the mooring chains are connected to the floating CALM buoy.

At completion of connection to the CALM buoy, each mooring chain will be tensioned at the CALM buoy to the design requirements.

Diving may be required during installation / decommissioning of the flowline and CALM buoy system.

In addition to the CALM buoy, up to three dead man's anchors (DMAs) will be installed in the Project Area, for support vessels to moor to. These will be clump weights, installed by support vessels. They will be retrieved at decommissioning.

3.4.3.3 Flowlines and Marine Hoses

The static flowline (~1.5 km) and dynamic riser will be stored and transported to the Project Area by support vessels (ISVs and/or barges) on a reel assembly. The flowline will be pre-commissioned, and pressure tested prior to arrival on site.

The flowline and FLET will be installed after both the MOPU and the CALM buoy and mooring system have been fully installed.

The flowline will be laid directly on the seabed. It may be installed in one or two sections. One end of the static section will be 'pulled' up a J-tube on the MOPU and connected to the production export system. The other end will be laid and secured on the Flowline End Termination (FLET), which is a gravity based/skirted structure providing a secure point. The dynamic section, also called the riser section (which may or may not be fully integrated with the static section), will route from the secured point on the FLET to the underside of the stationary section of the CALM buoy.

A communications and power cable may be bundled with the flowline or laid in similar manner alongside the flowline, within the flowline corridor.

If flowline stabilisation is required, this would likely be concrete mattresses and/or grout bags, and would be installed after the flowline is laid.

The high-level installation methodology is as below, to be confirmed during FEED:

- static flowline will be pulled up off the reel on the ISV up the J-tube within the MOPU leg to the production deck of the MOPU
- remaining static flowline laid on the seabed
- flowline stabilisation installed as required (concrete mattress and/or grout bags)
- final end connection installed into FLET, which is lowered into position below the CALM buoy
- dynamic riser is connected to the FLET, and bend restrictors and floatation to be added (as required)
- final end to be pulled into the CALM buoy for final connection.

After installation, the subsea flowline, riser and floating marine hose will be leak tested to assess structural integrity, using treated seawater with a fluorescent dye, and potentially corrosion inhibiter and oxygen scavenger. This fluid will remain in the flowline to provide corrosion protection prior to the introduction of hydrocarbons. The base case is for commissioning fluid to be displaced to the FSO or the first shuttle tanker on commencement of production, but it may be discharged to the marine environment. The volume of commissioning fluid is expected to be ~70 m^3, allowing for double the total inventory.

In the event a cyclone shutdown is required, the full flowline volume will be displaced to the FSO with either treated seawater or produced formation water (PFW), and the flowline sealed. The FSO would then disconnect and sail to a safe location. After the FSO remobilises to the Project Area, the flowlines will be reconnected to the FSO, and the flowline contents (commissioning fluid or PFW) would be displaced to the FSO for treatment within the FSO system (i.e. not discharged directly to the marine environment).

The intent is to re-use the flowlines on subsequent fields. However, the current philosophy is to hold a spare static and dynamic flowline, which will be used for installation at the next field, and to refurbish the recovered flowline and riser to store ready for use as a spare.

The floating marine hose and floating export hose are stored on reels on the FSO or shuttle tanker. The FSO will have a small tender vessel to assist with pick-up of the hose to enable connection.

3.4.3.4 FSO

As the base case, the FSO will be moored via hawser to the CALM buoy and operate as the storage and offtake vessel during the Corowa Development. Note that if the shuttle tanker option is selected, an FSO is not required, however the shuttle tankers will connect to the CALM buoy in a similar manner. In this case, no installation or commissioning is required.

The FSO will undergo any required refurbishments at a regional fabrication yard and pre-commissioned before it travels to the Project Area.

In the event of a cyclone, the intent is for the marine hose to be disconnected from the CALM buoy and reeled onto the FSO, before the FSO sails away to a safe location.

The disconnection process (after displacement of the oil in the flowline, but prior to arrival of cyclone) will typically be (subject to FEED):

- oil in flowline is displaced to the FSO, and flowline is filled with inhibited seawater or PFW
- support vessel attends the CALM buoy
- disconnect (at dry-break) at CALM and recover the 6” floating marine hose to FSO
- FSO will recover full hose length on board (recovery reel)
- FSO will move forward to slacken hawser line
- disconnect hawser at CALM and recover the hawser via the hawser winch line to the FSO.

Reconnection will be reverse of the disconnection process, and the flowline contents (inhibited seawater or PFW) would be displaced to the FSO for treatment in the bilge system, then discharged.

Export tankers will connect via a 12” floating export hose to the FSO. Export tankers will be secured by hawser line to the FSO, and potentially to a tug / support vessel for the duration of offload. A small tender vessel will likely assist the pick-up of the mooring hawser and export hose and enable connection. Under no circumstances will export to export tankers be undertaken when there is a risk of a cyclone.

Emissions and discharges during commissioning are the same as during the operation of the FSO (refer Section 3.4.6.3).

3.4.4 Operations

Activities associated with the operations phase include:

- hydrocarbon extraction
- hydrocarbon processing, storage and offloading
- inspection, maintenance and repair
- well intervention /workovers.

3.4.4.1 Hydrocarbon Extraction

Once production begins, hydrocarbons from the reservoir will flow up the wellbore to the MOPU production facilities. The well stream will be separated into oil, water and gas, and each stream treated on the MOPU, and then discharged within application specifications. Control of all the systems, including the downhole systems, will be via a control and safeguarding system on the MOPU.

As the dry tree is on the MOPU conductor deck, there will be no routine discharges to the marine environment as part of normal operation. The downhole safety valve will likely be closed circuit, but even if not, it will discharge to the annulus of the well and not the marine environment.

3.4.4.2 Hydrocarbon Processing, Storage and Offloading

The primary control and monitoring of the process will be undertaken from a dedicated Central Control Room (CCR) on either the MOPU or the FSO (in the case of the MOPU being not normally manned). The secondary production module control and safeguarding systems interface will also be located on the MOPU.

The production module on the MOPU comprises the key process systems summarised in Table 3-10.

Non-process related utilities and activities on the MOPU (e.g. accommodation, sewage treatment, refuelling) are described in Section 3.4.6.2.

Table 3-10 Key Process System Overview

Process System	Description
Production and Injection Manifold	The production and injection manifold provide connections for all associated flowlines from the wells.
Production Separator	The main 3 phase production separator, which separates: • oil to the Crude Processing Stream • water to the PFW Treatment System • gas to Gas Treatment.
Crude Oil Processing	This system removes water and gas from the crude oil. Likely comprising: • crude heater • second stage separator • crude oil rundown cooler • oil export pumps for export to the FSO via the export flowline. The export crude to FSO is monitored for crude oil quality via a crude oil sample collection point for laboratory testing.
PFW Treatment System	This system removes entrained oil from the produced water to achieve the design specification. Likely comprising: • free water knock out (KO) drum • produced water pumps • de-oiling hydrocyclone • degasser vessel/tank • discharge pipe
Cooling Water System	• Seawater cooling system for refrigeration and cooling systems. • Hypochlorite system will inject chlorine to protect the seawater cooling system from biofouling. Residual chlorine will be discharged overboard as part of the cooling-water discharge stream. • Residual chlorine levels will be monitored and routinely maintained not to exceed 2,000 ppb at the point of discharge. • Higher concentrations of up to 5,000 ppb may occur at times, if shock dosing is required.
Fuel Gas System	Separated gas from the Production Separator provides the facilities fuel gas requirement (option selected for use as described in Section 4.3.1). Fuel gas uses include: • gas engine generator set [for power generation]

Process System	Description

	• purge gas for:
	  ○ flare gas header
	  ○ PFW treatment package
	• pilot gas for flare gas ignition
	• fuel gas for Heat Medium System heater
	• sparge gas for produced water treatment package (if required).

Heat Medium System	Provides process heating duty, which may be required for: • crude oil stabilisation • fuel gas pre-heating, and/or • to improve crude oil separation. The heater can operate on dual fuel, primarily produced gas with a diesel/crude option.
Flare System and Flare Boom	The flare disposal system includes the flare ignition panel and flare tip. The flare boom will be cantilever type (nominally 30–40 m), with a hinged base connection to facilitate stowage of the boom during extreme weather event, or prior to MOPU movements. Flare tower will be set at an angle between 45° to 60° to the horizontal, with expected flare tip height ~75 m above sea level. Pilot will have an auto-ignition system. Refer to Section 4.3.1 for the gas management strategy, which has identified continuous flaring as the selected option for excess gas (after fuel gas usage). Flaring is expected to peak at 15–17 MMscfd (P50-P10) at the commencement of production for 7–12 months (P50-P10), then decline as the reservoir depletes to end of field life. System capacity rates are described in Table 3-11.
Chemical Injection System	A chemical injection package can inject these typical chemicals: • demulsifier • corrosion inhibitor • scale inhibitor • antifoulant • defoamer • oxygen scavenger • biocide • MEG • methanol (likely commissioning only).

The oil will be exported via the flowlines and floating export hose to the FSO for storage, and ultimately offloading to an export tanker (or direct to shuttle tankers).

Table 3-11 provides the maximum expected production rates and specifications of oil, gas and water. Refer to Section 4.3.1 for the comparative analysis of different gas strategies, and Section 4.3.2 for PFW options.

Table 3-11 Maximum Production System Capacity (Oil, Gas and Water)

Description	System Capacity	Specification
Produced Oil	25,000 BOPD	Target specification 0.5 vol% water
Produced Gas	25 MMscfd	Excess gas to be flared
Produced Formation Water	30,000 BWPD	Oil-in-Water of less than 29 mg/L

3.4.4.3 Inspections

Inspections are required to prevent the deterioration of equipment and infrastructure, which could lead to a significant failure. Inspections will also maintain reliability and performance plus ensure the safe and reliable operation of the facility. Inspections will be undertaken at regular intervals as determined by the maintenance management plan.

Subsea components (including flowlines, moorings, anchors, MOPU legs, FSO hull) will be subject to inspections, which will likely be completed by support vessels and ROVs.

Subsea monitoring may include but is not limited to:

- cathodic protection surveys
- fluid leaks
- general visual inspections for damage and missing items
- marine growth and fouling
- seabed scouring
- wall thickness measurements.

Top side inspections may include:

- corrosion protection (including painting and anode replacement)
- cycling of valves
- pressure and leak testing
- rotating equipment
- ultrasonic wall thickness testing.

3.4.4.4 Maintenance and Repair

Maintenance activities will be required to ensure the continued safe and efficient operation of the MOPU, CALM buoy, mooring arrangements and FSO. Maintenance and repairs will be both part of a regular inspection campaign and will also be an outcome of inspection results as discussed in Section 3.4.4.3

Typical maintenance and repairs undertaken which may also have an environmental impact include:

- anode replacement
- cathodic protection system maintenance
- flowline repairs
- flowline stabilisation
- general subsea infrastructure servicing (includes leak testing)
- general topside servicing (includes welding, cutting, blasting, spray painting, deck cleaning, valve change-out, fabric maintenance)
- marine growth removal

- removal of fishing nets or other marine debris
- re-commissioning (similar to Section 3.4.3).

In the case of disconnection for a cyclone, the floating marine hose is recovered onto the FSO, and the subsea flowline is shut-in and remains in place on the seabed.

In the event of flowline failure, the flowline may need to be repaired, which involves similar activities to decommissioning, and re-commissioning (refer to Sections 3.4.5 and 3.4.3).

If modifications or repairs are required to the equipment on the MOPU or the FSO facilities during the life of the Corowa Development, then this would a follow a similar process to installation, hook-up and commissioning.

Diving operations may be required for subsea inspections or maintenance.

Prior to cessation of production, the marine systems of the MOPU will require reactivation, in preparation for relocation to the next field, including preparing the jack-up legs. This will be a specific program of works akin to non-routine maintenance.

3.4.4.5 Well Intervention

Well intervention is the ability to safely enter a well for purposes other than drilling, usually to:

- evaluate a well's condition or performance
- remove obstructions
- stimulate the well
- repair well casing
- replace electric submersible pumps if selected.

Well intervention generally occurs within the wellbore and involves specific types of tools that can be delivered down the inside the well. It includes activities such as:

- slickline / wireline / coil-tubing operations
- well testing and flowback
- well workovers (mechanical or hydraulic).

The frequency of well intervention activities depends on well performance. No well interventions are planned; however, for the purposes of this OPP it is assumed that one or two may occur over project life. The activities are similar to those described under Drilling (Section 3.4.2). The worst case would be an unplanned intervention where use of kill fluid may be required, which may be discharged during well clean-up and flowback, at an estimated maximum 127–160 m^3. However, the completions will be designed with appropriate nipple profiles for isolation plugs, such that intervention can occur without pumping kill fluid into the well.

3.4.5 Decommissioning

Activities associated with decommissioning include:

- plug and abandon development wells
- removal of subsea infrastructure
- disconnection of MOPU and FSO
- conduct as-left survey.

During operations, KATO will monitor the field production rates to determine an appropriate end-of-field life 'window'. Once a decommissioning window has been determined, planning would be finalised to execute the move from Corowa to the next field. An inspection and clean-up will be undertaken of subsea infrastructure before production is shut-in, anticipated as three to six months before production ceases. Production will only be shut-in once all the appropriate processes, contracts and so on are lined up to execute P&A, decommissioning and the relocation.

The base case for decommissioning is complete removal of all above-mudline infrastructure from the Project Area. The facilities (i.e. MOPU, FSO) and some infrastructure will be re-used at the next field (i.e. CALM buoy and mooring system).

However, there is an option to potentially leave some small inert seabed fixtures in situ, such as grout bags, concrete mattress and clump weights.

3.4.5.1 Inspection and Cleaning

About three to six months before decommissioning, an inspection will be undertaken of subsea infrastructure and the 'wetsides' of the MOPU and FSO, specifically on the relocatable systems, including:

- legs of the MOPU
- hull of the FSO
- CALM buoy
- mooring arrangement (CALM buoy, mooring legs, gravity anchors).

The flowline will be inspected and treated onshore, as the spare will be used at the next field. Note, there will be regular inspection of the marine and export hoses during the operations phase. These may be changed out during the operations phase and/or between fields.

Depending on the results of the inspection, removal of marine growth on subsea infrastructure and wetsides may be undertaken in situ at Corowa, prior to demobilisation and redeployment at the next field. Diving and ROV operations may be required.

As the biofouling on the honeybee production system would be acquired over the project life at the same location as the cleaning is undertaken (i.e. at the Corowa Project Area), it is considered 'regional' biofouling. The Anti-fouling and in-water Cleaning Guidelines (Commonwealth of Australia 2015) provides guidance on cleaning methodologies appropriate for different types of biofouling and types of anti-foul coatings.

Cleaning may include these methods:

- brushing
- soft tools (clothes, squeegees, wiping tools)
- water jet and air jet (blast) systems
- technologies that kill, rather than remove biofouling – e.g. heat (steam or heated water), or suffocation (wrapping in plastic or canvas).

Infrastructure such as the marine hoses and mooring chains may be retrieved and cleaned on the deck of the FSO or a support vessel. If so, the material will be collected and disposed of appropriately onshore.

3.4.5.2 Well Plug and Abandonment

The honeybee production system means that all infrastructure can be recovered, and wells plugged and abandoned before the MOPU relocates to the next field.

The MOPU will have plug and abandon (P&A) capabilities and will P&A the wells prior to demobilisation.

Well P&A procedures are designed to isolate the well and prevent the release of wellbore fluids into the marine environment. During abandonment cement and/or mechanical plugs may be set within the wellbore to install a permanent reservoir and surface barrier. Other activities may include:

- install a temporary isolation plug in wellbore
- remove dry tree
- installation of BOP
- isolate all reservoir and production zones with cement plugs
- recover upper completion (production tubing)
- set permanent cement plug just below the mudline
- remove the BOP stack
- cut conductor at mudline and recover section to MOPU.

It is estimated that P&A would take up to two weeks per well.

3.4.5.3 Removal of Subsea Infrastructure

The flowlines and riser are flushed with inhibited seawater or PFW and recovered to the FSO and stored. As the flowline and any power and communication cables are reeled up, this water is discharged from the flowlines to the marine environment, comprising a total of ~59 m^3 for the subsea flowline, marine hose and export hose. They are recovered onto a storage reel on a support vessel, ready for redeployment at the next field or onshore storage.

The CALM buoy, gravity anchors and chains and DMAs will be retrieved, in a reverse of the installation methodology (Sections 3.4.3.2 and 3.4.3.3), using installation support vessels and an ROV.

If drilled and grouted anchor piles were used, the mooring lines will be cut off below the mudline. The grouted pile is left in situ below the seabed.

The OPGGS Act (Section 572(3)) states that a titleholder:

> *'must remove from the title area all structures that are, and all equipment and other property that is, neither used nor to be used in connection with the operations.'*

However, this obligation is subject to other provisions of the Act and allows titleholders to identify and seek approval for alternative arrangements.

The base case for decommissioning is complete removal of all above-mudline infrastructure from the Project Area. However, there is potentially a need to leave some smaller inert seabed fixtures in situ, such as grout bags, concrete mattress and clump weights (subject to other provisions of the OPGGS Act). These smaller objects can be difficult to retrieve. In this case, approval under the Commonwealth *Environment Protection (Sea Dumping) Act 1981* would be sought prior to decommissioning.

In general, this may include:

- displacement of hydrocarbons in the static flowline and dynamic riser with either treated seawater or treated PFW to the FSO, followed by depressurisation
- disconnect all flowlines and riser
- removal and recovery of the static flowline and riser from the seabed onto a support vessel
- recovery of floating marine hose
- retrieval of any flowline stabilisation
- recovery of the CALM buoy and mooring system, and gravity-based anchors
- if drilled and grouted anchor piles are used, cut off mooring lines below mudline.

Anchor and seabed infrastructure removal will require activities being undertaken at or near the seabed, and removal of marine growth in situ will result in material falling to the seabed. Therefore, there is the potential for localised seabed disturbance. During anchor decommissioning, chains may require cutting, resulting in metal shavings and other minor waste.

It is estimated that flushing of the production system to the FSO would take approximately two weeks, and recovery of the subsea infrastructure approximately three weeks.

3.4.5.4 Disconnection of FSO and MOPU

The FSO and MOPU will disconnect in a reverse of the installation methodology (Sections 3.4.3.1 and 3.4.3.4), using support vessels and an ROV.

Following the disconnection of the export hose and mooring hawser, these will be reeled onto the FSO for stowage and re-use at the next field, and the FSO will sail away.

Following P&A of the wells, and disconnection of the flowlines, the MOPU will disconnect by:

- stowage of the conductor deck and flare boom (into sailing position)
- jack down MOPU, float and recover legs
- tow MOPU away from field using 2–3 AHTs.

The MOPU's marine systems will need to be reactivated prior to decommissioning and relocation, including preparing the jack-up legs and propulsion systems, and potentially other maintenance. This will be undertaken in situ at the Project Area, before demobilisation.

Jacking down and demobilisation of the MOPU from the Project Area is expected to take ~3 days.

3.4.5.5 As-left Survey

A seabed survey of the Project Area will be undertaken following retrieval of subsea infrastructure and following demobilisation of the MOPU and FSO.

3.4.6 Support Activities

Support activities associated with the projects are likely to include facilities, vessels, helicopters, ROVs and diving, with varying requirements depending on project phase (Table 3-12).

The manning strategy will be determined in the FEED phase, with either the FSO or MOPU housing the majority of personnel.

For the purposes of this OPP, the total potential manning has been assumed (e.g. for calculation of wastewater discharge volumes). Manning will peak during drilling, installation and commissioning activities, and decommissioning, and will be the lowest during normal operations (i.e. production phase).

Table 3-12 Support Activities for each Project Phase

Support Activity type		Site Survey	Drilling	Installation, hook-up, commissioning	Operations	Decommissioning
MODU			✓			
MOPU			✓ if required	✓	✓	✓
FSO				✓	✓	
Support vessels	Survey vessel	✓				
	Supply vessel		✓	✓	✓	✓

Support Activity type		Site Survey	Drilling	Installation, hook-up, commissioning	Operations	Decommissioning
	Standby vessel				✓ if required^	
	AHT		✓	✓		✓
	ISV			✓		✓
Tankers					✓	
Helicopters			✓	✓	✓	✓
ROVs and Diving		✓	✓	✓	✓	✓
Total POB of facilities during phase*		30	160	60	30	60
Approximate Duration		1 month	5 months 4 months#	3 months	2–4.5 years	3 months

**doesn't include supply vessels not permanently in Project Area.*

^If FSO is selected, it will have a fast rescue tender, and standby vessel won't be required.

#Contingent infill drilling campaign ~4 months duration (if required).

3.4.6.1 MODU Operations

A separate jack-up rig may be used for drilling, and restricted to the drilling phase, unless the selected MOPU has drilling capability.

A jack-up MODU would be required, due to shallow-water depths. During drilling the nominal POB would be ~100. The MODU would be alongside the MOPU for approximately five months during drilling the initial campaign, and four months for the contingent infill campaign (if required).

Non-drilling activities occurring on the MODU include:

- bunkering / bulk transfer of fuel, chemicals, and supplies
- transfer of waste to supply vessels
- discharge of:
  - sewage, greywater and food waste
  - cooling water and reverse osmosis (RO) brine
  - deck drainage and bilge
- helicopter operations (~5–8 round trips per week from mainland to facilities).

3.4.6.2 MOPU Operations

The MOPU jack-up platform will be used throughout all phases of the development (assumed ~5 years). The base case is for a separate MODU to conduct drilling operations through the MOPU conductor deck; however, the MOPU itself may have the capability to drill. The MOPU has P&A capabilities, and the infrastructure is described in Section 3.3.2.

Depending on the manning strategy selected, the MOPU will have between 30–60 POB (peaking during hook-up, installation and commissioning). If the MOPU itself has drilling capability, the normally manned POB during drilling would be up to 150.

Non-processing activities occurring on the MOPU include:

- bunkering / bulk transfer of fuel, chemicals, and supplies (anticipated 2–3 times per month)

- transfer of waste to supply vessels
- discharge of:
  - sewage, greywater and food waste
  - cooling water and RO brine
  - deck drainage and bilge
  - produced formation water
- inspection, maintenance and repair activities
- helicopter operations (~5–8 round trips per week from mainland to facilities)
- crew transfer by vessel.

3.4.6.3 FSO Operations

The FSO will enable in-field hydrocarbon processing, storage and export. It is expected that offload via a visiting export tanker will occur every 15–20 days, and is expected to take ~48–72 hours.

Depending on the manning strategy selected, the FSO will have between 17 and 30 POB (peaking during commissioning and decommissioning).

The FSO will adjust ballast to keep within stability range as the storage fills up and then add ballast during offload to export tanker.

Non-processing activities occurring on the FSO include:

- bunkering / bulk transfer of fuel, chemicals, and supplies (anticipated 2–3 times per month)
- transfer of waste to supply vessels
- discharge of:
  - sewage, greywater and food waste
  - cooling water and RO brine
  - deck drainage and bilge
- maintenance operations
- vessel positioning (low speed thrusters) – to maintain direction, as position is maintained by mooring to the CALM buoy
- helicopter operations (~5–8 round trips per week from mainland to facilities)
- crew transfer by vessel.

Note if the shuttle tanker option is selected, an FSO is not required.

3.4.6.4 Vessel Operations

Vessels will be used throughout all phases of the Corowa Development. The expected vessel types, numbers and specifications is provided in Table 3-13. An estimated frequency of transit from the Project Area to port is provided.

Supply vessels are expected to operate from local regional ports (e.g. Exmouth, Onslow, Dampier) to transport fuel, stores, waste and specialist supplies such as cement and drilling fluids.

Activities occurring on the vessels while on site include:

- bunkering / bulk transfer of fuel, chemicals, and supplies to facilities
- transfer of waste from facilities
- discharge of:
  - sewage, greywater and food waste
  - cooling water and RO brine

- deck drainage and bilge

- vessel positioning
- anchoring.

Vessels may anchor within the Project Area, if they are onsite for a few days, to save on fuel usage.

Vessels may also be used to undertake various inspection, maintenance and repair activities, within the Project Area.

Vessel transiting to and from the Project Area are managed under the Commonwealth *Navigation Act 2012* and therefore this activity is excluded from the scope of the OPP.

Table 3-13 Summary of Support Vessel Requirements

Vessel Type	Purpose	Expected Duration for Relevant Phase	Expected Transit Frequency	Nominal POB
Survey vessel	One vessel expected for geophysical / geotechnical surveys.	Site survey 1 month.	1 x round trip during Project life	Typically 30 POB
Supply vessel/s	It is expected that there will be one support vessel during production operations. There would be additional supply vessel/s during installation and/or drilling phases.	Project life ~5 years.	Drilling, Hook-up, Installation and Commissioning phase: • 3 x round trips per week Operations and Decommissioning: • 1 round trip per week	Typically 12 POB per vessel
Standby vessel	Only required for shuttle tanker option (i.e. not required for FSO).	If required, duration ~2–4.5 years during operations.	1 x round trip during Project life	Typically 5 POB
Tug	A tug may be used to tether export tankers while they are connected to the CALM buoy or FSO, though this role may be undertaken by the primary supply vessel.	If required, duration ~2–4.5 years during operations. On an intermittent basis (expected ~16 times over field life)	1 x round trip during Project life	Typically 12 POB
AHT	2–3 AHTs are expected to be used to tow the MOPU and MODU into position during hook-up, and again for decommissioning and demobilisation. i.e. potentially 6 AHTs altogether.	Duration during Drilling (over 5-month period, and additional 4 months if second campaign is required), and Installation (over 3-month period), Decommissioning (over 3-month period).	Drilling: • 4 x round trips (mobilisation and demobilisation of the MODU, assuming two drilling campaigns) Hook-up, Installation and Commissioning and Decommissioning phase: • 4 x round trips each phase (mooring system)	Typically 12 POB per vessel

Vessel Type	Purpose	Expected Duration for Relevant Phase	Expected Transit Frequency	Nominal POB
ISV	One ISV for commissioning and decommissioning of CALM buoy, gravity anchors and flowline.	Duration ~3 months for installation, and 3 months for decommissioning.	Hook-up, Installation and Commissioning and Decommissioning phase: • 2 x round trips (mooring system and flowline)	Typically 60–80 POB

3.4.6.5 Helicopter Operations

Helicopters are the primary form of transport for personnel to be carried to and from the MOPU or FSO. It will also be the quickest and preferred method to evacuate personnel in an emergency.

During hook-up and commissioning it is expected that there will be one to two round trips per day from the mainland to the facilities. For steady state operations, there may be five to eight round trips per week, but this may be subject to operational requirements.

Refuelling of helicopters offshore is not planned to take place offshore. Helicopter flights will likely operate from a regional airport in the north-west of WA.

3.4.6.6 ROV Operations

ROV operations may be conducted throughout all phases of the Corowa Development such as site surveys, installation, hook-up and commissioning, operations (inspections, maintenance and repair), and decommissioning. ROVs may also be used in an unplanned event such as a loss of well control.

ROVs are not required to park or moor on the seabed.

3.4.6.7 Diving Operations

Diving operations may be conducted throughout all phases of the Corowa Development such as site surveys, installation, hook-up and commissioning, operations (inspections, maintenance and repair), and decommissioning. Diving may also be used in an unplanned event such as a loss of containment from a flowline.

4 Alternatives Analysis

The OPGGS(E)R requires that:

> *'Part 1A, 5A (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; and*
>
> *(ii) an explanation, in adequate detail, of why the alternative was not preferred.'*

This section addresses this requirement by undertaking an analysis of the feasible alternatives to the:

- project concept (Section 4.2)
- design and activities of the selected concept (Section 4.3).

4.1 Background

4.1.1 History

KATO acquired the Corowa title (WA-41-R) in 2018. The previous titleholder (Hydra) intended to develop the field via a honeybee production system and had undertaken comprehensive Concept Select and Front-End Engineering Design (FEED) work, as well as drafting a preliminary OPP in 2015. However, market conditions curtailed Hydra's development activity.

Since acquisition, KATO have reviewed Hydra's development studies in all disciplines and concurred with Hydra's conclusion that the honeybee production system concept represents the best project development solution (Section 3). KATO intends to mature the design initiated by Hydra to deliver a fit-for-purpose production system, which can be used for short periods and relocated allowing for capital costs to be minimised at each field and prompt removal of all permanent infrastructure, thereby allowing stranded, sub-economic or previously considered immaterial oil assets to be developed.

KATO considered these alternative development concepts for Corowa:

- Honeybee production system, including MOPU *(selected)*
- Subsea to shore *(not selected)*[5]*
- Subsea tie-back to an existing facility *(not selected)**
- Fixed Production, Utilities and Quarters (PUQ) Platform and FSO *(not selected)*
- Fixed Wellhead Platform (WHP) and FPSO *(not selected)*
- FPSO and Subsea Well *(not selected)*
- Do not undertake the development *(not selected).*

KATO has expanded its assessment to include the subsea tie-back to an existing facility, and tie-back to an existing shore-based facility options as they are represented by regional field development analogues and therefore worthy of consideration.

KATO has used Hydra's study work as well as in-house evaluation to inform the assessment of these alternatives, presented in Section 4.2.

KATO did not evaluate the WHP and FPSO option. Whilst technically feasible and possessing some merits in terms of well intervention, it represented a significant increase in infrastructure above an FPSO and subsea wells, for what was considered only marginal gain, due to the small reservoir size and small field life of Corowa. Furthermore, the environmental implications of installing and

[5] Alternatives denoted with '*' were not identified by Hydra.

subsequently removing fixed steel structures at the Corowa location were deemed adequately addressed via the comparative evaluation of the PUQ Platform option.

4.1.2 Comparative Assessment Process

4.1.2.1 Overview of Decision-making Process

KATO's focused, Australia-based team has been able to rapidly progress the development planning work since acquisition in 2018. This team is fully accountable for the key development decisions captured in this section. KATO's intent is for the Development Management Team to transition into an Asset Management Team, thereby ensuring continuity of ownership of these development decisions through the life-of-field for Corowa, and to develop subsequent fields using the Honeybee production system concept.

To support the development team's efforts, KATO have leveraged off the processes and procedures of their joint venture partner Tamarind Resources (Tamarind).

Therefore, Tamarind's Field Development Gate Process (Figure 4-1) has been used in the decision-making process.

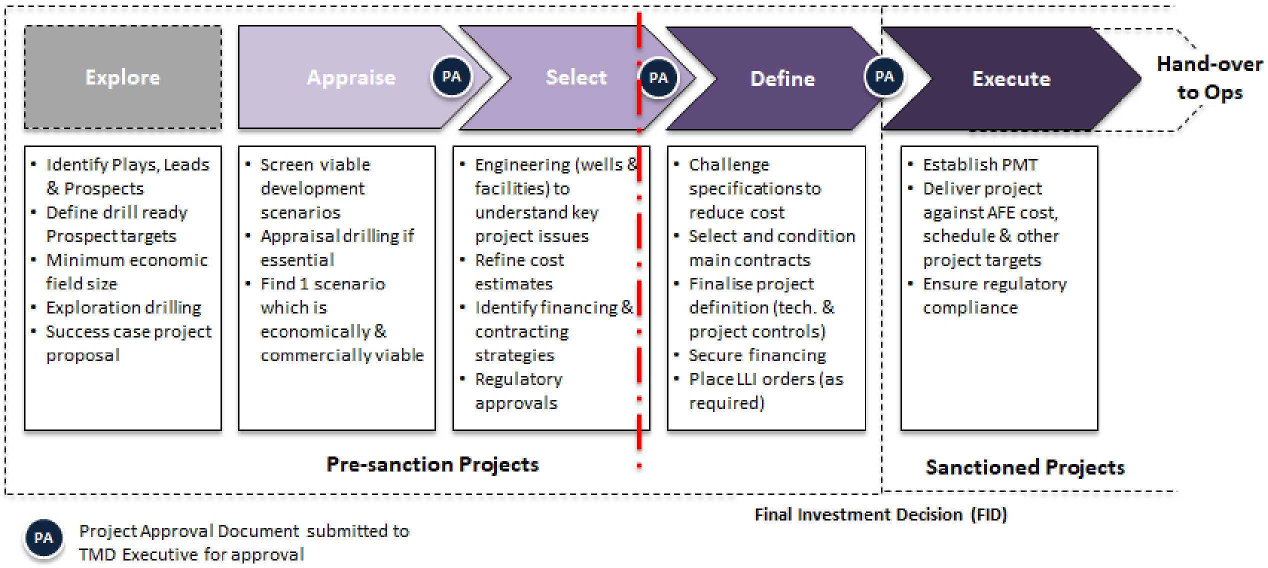


Figure 4-1 KATO JV Partner Tamarind's Development Process

KATO has consciously placed the project in re-cycle mode, since it is strongly believed improvements can be made on the both the Concept Select and Define (i.e. FEED) phase work undertaken by Hydra, as well as wishing to substantially progress regulatory consents prior to entering a revised Define (i.e. FEED) phase. Therefore KATO considers the Corowa Development to be in the latter stages of Select, represented by the red line in Figure 4-1.

Throughout recent development planning, a series of workshops were held to challenge the concept and key components. The outcome of these sessions is incorporated into Sections 4.2 and 4.3. Where key decisions were made, either as a result of peer review during workshops or the development work carried out in-house, these were captured in Decision Notes to ensure a concise and transparent record, both as good practice and in support of any external review the Development may be subjected to.

4.1.2.2 Assessment Criteria

To conduct a comparative assessment of the alternatives, KATO has identified key drivers for consideration:

- environmental
- economic
- technical feasibility and safety
- social.

Table 4-1 provides the specific criteria identified for each driver, which were considered by KATO as part of the decision-making process to identify the optimal concept for developing the project.

The assessment is carried out in two steps:

1. Undertake a comparative assessment of the alternatives against environmental criteria to identify the options with the least environmental impact.
2. Further assess alternatives against the other criteria (economic, technical feasibility and safety, and social drivers) to justify the final selected option.

Table 4-1 Key Assessment Criteria used in the Assessment of Alternatives (as relevant)

Driver	Criteria
Environmental	
Physical presence	• Seabed disturbance • Interaction with marine fauna (vessel movements)
Emissions	• Underwater sound emissions • Atmospheric emissions • Light emissions
Introduction of IMS	• IMS
Discharges	• Planned liquid and solid discharges and waste • Unplanned discharges and accidental releases
Lifecycle environmental impacts	• Holistic consideration of relative life-of-field impact spanning both infrastructure construction, in-place footprint, production operations and any abandonment legacy*
Economic	
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
Technical Feasibility and Safety	
Safety Risk	• In line with industry standards and good practice
Operability and Feasibility Risk	• Technically feasible and ability to operate and maintain
Technical Readiness	• Project considers an acceptable technology readiness level (TRL). TRL is a method of estimating technology maturity of Critical Technology Elements (CTE)
Constructability, Re-usability	• Ability to construct • Ability to relocate and redeploy

Driver	Criteria
Decommissioning Feasibility	• Ability to deploy as generic design at future multiple locations: plant, process, personnel • Simplicity of returning the site to natural conditions
Social	
Socioeconomic Impacts	• Avoidance/minimisation of impacts to other industry • Avoidance/minimisation of impacts to fishery resources
Reputation	• Reputation and community expectation

** E.g. Subsea tie-back to existing facility concept compared to using a MOPU; cumulative impact of total project is greater than just the MOPU – in this case due to increased seabed disturbance.*

Table 4-2 shows the qualitative ranking scale used in the comparative assessment and is aligned with the KATO Environmental Risk Matrix (Section 6). In order to allow more differentiation between the alternatives, the risk levels of the KATO Environmental Risk Matrix have been further broken down as shown in Figure 4-2.

Table 4-2 Qualitative Ranking Scale for Assessment of the Options

Qualitative Rank	Qualitative Risk/ Impact	Description
1	Very low impact/ risk	Environment/Financial/Business/Health and Safety Very low impact/risk. **Environment:** Limited less than minor impact localised or temporary on non-threatened species, habitat or environment.
2	Low impact/ risk	Environment/Financial/Business/Health and Safety Very low impact/risk. **Environment:** Limited minor impact localised or temporary on non-threatened species, habitat or environment.
3	Moderate impact/ risk	Environment/Financial/Business/Health and Safety Low to Medium impact/risk. **Environment:** Minor to moderate impact localised or short term on species, habitat or environment.
4	High impact/ risk/ barrier to development	Environment/Financial/Business/Health and Safety Medium to High impact/risk. **Environment:** Serious impact localised and long term or widespread and short term on species, habitat or environment.

Likelihood ➡			Extremely unlikely	Very unlikely	Unlikely	Likely	Very likely	Almost certain
		Guidance	Rare or unheard of	Reasonable to expect not to occur	Exceptional conditions may allow to occur	Conditions may allow to occur	Conditions may reasonably allow to occur	Expected to occur
Consequence ⬇	Guidance	Level	A	B	C	D	E	F
Catastrophic	Permanent environmental landscape-scale impact over extensive area. Permanent loss of ecosystem or extinction of species.	6	High	High	Very High	Very High	Extreme	Extreme
Severe	Severe or extensive impact; widespread and persistent on ecosystem or threatened species.	5	Medium	High	High	Very High	Very High	Extreme
Major	Major impact; widespread and long-term on ecosystem or threatened species.	4	Medium	Medium	High	High	Very High	Very High
Serious	Serious impact; localised and long-term; or widespread and short-term on ecosystem or threatened species.	3	Low	Medium	Medium	High	High	Very High
Moderate	Moderate impact; localised and short-term on ecosystem or threatened species.	2	Low	Low	Medium	Medium	High	High
Minor	Limited/minor impact; localised and temporary on non-threatened species or their habitat.	1	Low	Low	Low	Medium	Medium	High
			Very Low	Very Low	Very Low	Very Low	Low	Low

Qualitative Rank	Qualitative Risk/ Impact	Description
1	Very low impact/ risk	Environment/Financial/Business/Health and Safety Very low impact/risk. **Environment:** Limited less than minor impact localised or temporary on non-threatened species, habitat or environment.
2	Low impact/ risk	Environment/Financial/Business/Health and Safety Very low impact/risk. **Environment:** Limited minor impact localised or temporary on non-threatened species, habitat or environment.
3	Moderate impact/ risk	Environment/Financial/Business/Health and Safety Low to Medium impact/risk. **Environment:** Minor to moderate impact localised or short term on species, habitat or environment.
4	High impact/ risk/ barrier to development	Environment/Financial/Business/Health and Safety Medium to High impact/risk. **Environment:** Serious impact localised and long term or widespread and short term on species, habitat or environment.

Qualitative Ranking Scale

Figure 4-2 Qualitative Ranking Scale Alignment with KATO Environmental Risk Matrix

4.2 Analysis of Concept Alternatives

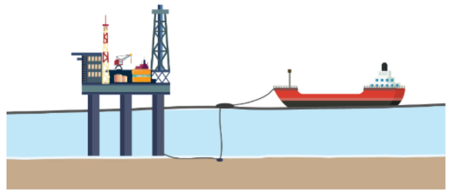
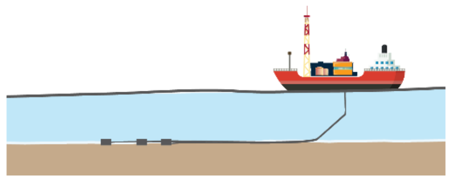
KATO has further considered development options and undertaken a comparative assessment (including a ‘no development’ option) to identify the benefits, risks and impacts of each. gives a schematic and brief overview of each concept.

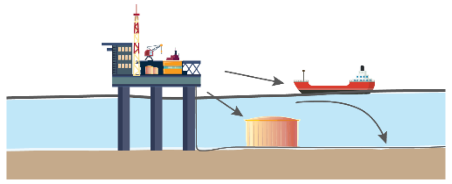
The supporting comparative assessment of the concepts against key criteria is detailed in Table 4-1.

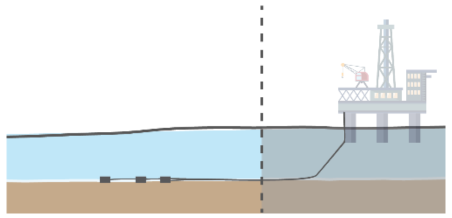
Concept 6 – No development has not been evaluated further. The Australian Government’s mandate is to develop offshore oil and gas resources; specifically, to increase investment in petroleum development in Commonwealth offshore areas. The Government recognises that investment in this area provides benefits to the Australian community through taxation revenues, employment, regional development and enhanced energy security.

In order to satisfy offshore permit retention lease requirements, KATO have an obligation to develop any commercially viable hydrocarbon reserves. In this context, the ‘no development’ alternative is not consistent with the legal obligations and commercial objectives of KATO, and was not considered further.

Table 4-3 Concept Alternatives Overview

Concept	Overview	Key Activities
Concept 1 – Honeybee production system		
	• Selected concept – described in detail in Section 3. • Uses a self-installing jackup MOPU and MODU to drill and support up to four production wells. • Oil production, water treatment, well control, flaring and oil export facilities are located on MOPU topsides. • Export of treated crude oil is via a flowline to a CALM buoy, and offtake via an FSO or direct to a shuttle tanker.	• Mobilisation and installation of the jack-up MOPU and potentially a separate MODU (Section 4.3.4), interconnecting flowline, CALM buoy, FSO / shuttle tanker (Section 4.3.6). • Production, workovers and P&A will take place from the MOPU. • Production export via subsea flowline to CALM buoy for export. • Gas flaring (Section 4.3.1). • P&A of the wells by MOPU. • The facilities (MOPU, flowline, CALM and FSO) will be re-floated, recovered and redeployed at the next field.
Concept 2 – Subsea tie-back to shore		
	• Uses a MODU and support vessels to drill and install subsea production wells, control system and gathering system. • Well fluids exported via a pipeline to shore. • Gas may be separated subsea and transported via a separate pipeline or comingled in a single multiphase pipeline. • Pipeline and umbilical crosses the shore to a production facility where the well fluids are separated, gas dehydrated, stabilised, stored and exported. • Export of treated crude is via road tankers.	• Mobilisation of semi-sub or jackup MODU for installation, workover and decommissioning of subsea wells. • Any subsequent workover and P&A requires additional mobilisations of a rig. • Installation of subsea trees, ~40 km of subsea flowlines and umbilicals, and a shore crossing. • Construction and operation of an onshore processing, storage and export facility. • Onshore utilities include water treatment, well control systems, emergency flares, power generation, oil loading facilities for export. • Installation of onshore gas pipeline to DBNGP or Macedon gas facility. • Long-distance truck tanker transport of oil product.
Concept 3 – Floating, Production, Storage and Offloading (FPSO)		
	• Uses a MODU and support vessels to drill and install subsea production wells, control system and gathering system. • Well fluids are exported via a flowline and riser system to an FPSO facility where the well fluids are separated, stabilised and stored. • FPSO utilities are water treatment, well control systems, flare, power generation, oil offloading facilities. • Export via shuttle or export tanker.	• Mobilisation of semi-sub or jackup MODU for drilling of the subsea wells. • Any subsequent workover and P&A requires additional mobilisation of a rig. • Installation of subsea trees, subsea flowlines and control systems with support vessels. • Mobilisation and installation of the FPSO. • Installation of mooring piles and mooring system using support vessels. • Gas flaring (Section 4.3.1). • Flowline/s, umbilical/s and FPSO mooring system removed by vessel.
Concept 4 – Fixed Platform and FSO, Subsea Storage or Export Pipeline		

	• A MODU is used to drill and install dry tree production wells.
	• Uses a PUQ platform including topsides and jacket.
	• Oil production, dehydration, water treatment, well control, flaring and oil export facilities located on the fixed platform topsides.
	• Export of treated crude oil is via either:
	  ○ an FSO moored on a CALM buoy and offtake system
	  ○ subsea storage system to shuttle tanker
	  ○ tie-in to existing oil pipeline system.
		• Mobilisation of jackup MODU for drilling of the platform wells.
		• Any subsequent workover and P&A requires additional mobilisation of a rig.
		• Construction and installation of a PUQ platform jacket using HLV /support vessels.
		• Depending on export options selected:
		  ○ installation of CALM buoy, FSO and offtake system
		  ○ installation of subsea storage system
		  ○ installation of pipeline to tie into existing pipeline.
		• Gas flaring (Section 4.3.1)
		• Platform and flowlines are removed using HLV / support vessels, with limited re-use potential.

Concept 5 – Subsea tie-back to existing facility		
	This option is identical to either Concept 2 or Concept 3, with the exception that the production facilities are already constructed and owned by a third party.	As per Concept 2 and 3.

Concept	Overview	Key Activities
Concept 6 – No Development		
	Titleholder is required to undertake certain petroleum exploration and production related activities towards commercialising the resource.	No activities.

4.2.1 Comparative Assessment of Concepts

The common activities associated with all the concepts were identified and grouped, as shown in Table 4-4.

These activities were systematically mapped against the environmental driver and key criteria identified in Section 4.1.2, and the relevant concepts identified.

Note: Some activities depend on sub-options of each concept.

Table 4-5 provides the comparative assessment of environmental criteria for each concept.

Table 4-4: Environmental Criteria Related to Activities Associated with each Concept

Activity	Related Concept	Physical Presence		IMS Risk	Emissions and Discharges				
		Seabed disturbance	Interaction with marine fauna	IMS	Underwater sound emissions	Atmospheric emissions	Light emissions	Planned Discharges	Unplanned Discharges / Accidental Releases
Site surveys									
Geophysical survey	1, 2, 3, 4, 5		✓	✓	✓	✓		✓	✓
Geotechnical survey	1, 2, 3, 4, 5	✓	✓	✓	✓	✓		✓	✓
Drilling									
Mobilisation / 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									
Installation and commissioning of flowlines	2, 3, 4, 5	✓	✓	✓	✓			✓	✓
Installation of piles and anchors	1, 2, 3, 4, 5	✓			✓				
Installation and commissioning of production facilities	1, 2, 3, 4	✓	✓	✓	✓	✓		✓	✓
Installation of mooring and offloading system	1, 4	✓	✓	✓	✓			✓	✓
Operations									
Production flaring	1, 3, 4, 5*					✓	✓		
Produced water treatment and disposal	1, 2, 3, 4, 5*	✓				✓		✓	✓

Activity	Related Concept	Physical Presence		IMS Risk	Emissions and Discharges				
		Seabed disturbance	Interaction with marine fauna	IMS	Underwater sound emissions	Atmospheric emissions	Light emissions	Planned Discharges	Unplanned Discharges / Accidental Releases
Offloading of oil (offshore)	1, 3 4 5*		✓	✓	✓				✓
Offloading of oil (onshore)	2, 5*								✓
Decommissioning									
Plug and abandon wells	1, 2, 3, 4, 5	✓	✓	✓	✓			✓	✓
Removal of infrastructure	1, 2, 3, 4, 5	✓	✓	✓	✓			✓	✓
Support Operations									
Facility operations – offshore	1, 2, 3, 4	✓	✓	✓	✓	✓	✓	✓	✓
Facility operations – onshore	2, 5*	✓				✓	✓	✓	✓
Vessel operations	1, 2, 3, 4, 5	✓	✓	✓	✓	✓	✓	✓	✓

**indicates activity dependant on a sub-option (i.e. FPSO or onshore)*

Table 4-5 Comparative Assessment of Environmental Criteria for each Alternative Concept

Criteria		Evaluated Concepts – Qualitative Ranking and Justification									
		Concept 1 – Honeybee production system		*Concept 2 – Subsea tie-back to shore*		*Concept 3 – FPSO*		*Concept 4 – Fixed Platform*		*Concept 5 – Subsea tie-back to existing facility*	
Physical presence	**Seabed disturbance**	1	Minimal development footprint	4	Subsea and onshore pipelines increase footprint. Shoreline crossing required. Onshore water supply required.	2	Localised development footprint.	3	Localised development footprint, decommissioning required for lower portion.	3	Offshore pipeline and potential shore crossing increases footprint.
Physical presence	**Interaction with marine fauna (vessel movement)**	2	FSO, OSV and tanker movements required	1	MODU, OSV, pipelay and subsea construction vessels required	2	MODU, FPSO, OSV, subsea construction and tanker movements	3	MODU, international heavy lift vessels and barges required. FSO, OSV and tanker movements	2	MODU, pipelay and subsea construction vessels required. Additional tanker movements required
Emissions	**Underwater sound emissions**	1	Minimal underwater noise sources	2	Subsea pumps required to run continuously during operation.	2	Subsea piling required for mooring system (drill and grout)	3	Major construction activity over sustained period Pilling required (drill and grout)	2	Subsea pumps required to run continuously during operation.
Emissions	**Atmospheric emissions**	3	Flaring of associated gas likely to be required due to reservoir and topside facilities constraints.	1	Associated gas may be exported to DBNGP. Onshore emissions from power generation. Additional power requirements to pump oil to shore.	3	Flaring of associated gas likely to be required. Space and weight not a constraint for gas compression equipment.	3	Flaring of associated gas likely to be required due to reservoir constraints.	1	Gas disposal dependant on existing facility. Disposal to existing reservoir or export to DBNGP.
Emissions	**Light emissions**	2	Minor offshore impacts associated with physical presence of facility and flare incremental to existing oil developments	2	Minor onshore impacts associated with physical presence of facility and flare	2	Minor offshore impacts associated with physical presence of facility and flare incremental to existing oil developments	2	Minor offshore impacts associated with physical presence of facility and flare incremental to existing oil developments	1	No additional impacts associated with operation of existing facility, may require incremental flaring if gas export route not in place
IMS risk	**IMS**	2	Use of local / Australian waters construction vessels. Mobilisation of MODU/MOPU IMS risk. IMS risk associated with tanker movements if not local.	3	Construction and decommissioning risk using international vessels. Mobilisation of MODU risk. Minor operations risk from subsea inspection and maintenance only.	3	Mobilisation of FPSDO and MODU IMS risk. IMS risk associated with tanker movements.	4	Construction and decommissioning risk using large international vessels. Mobilisation of MODU IMS risk. IMS risk associated with tanker movements.	3	Construction and decommissioning risk using international vessels. Mobilisation of MODU IMS risk. Incremental IMS risk with tanker movements at existing facility.
Discharges	**Planned liquid and solid discharges and wastes**	2	Minor local offshore impacts associated with produced water, process wastewater and cooling-water discharge.	2	Minor local nearshore / onshore impacts associated with produced water, process wastewater and cooling-water discharge.	2	Minor local offshore impacts associated with produced water, process wastewater and cooling-water discharge.	2	Minor local offshore impacts associated with produced water, process wastewater and cooling-water discharge.	1	Minimal incremental additional impact associated with existing facility
Discharges	**Unplanned discharges and Accidental Releases**	4	Moderate risk of MOPU, FSO and oil export loss of containment. High risk associated with drilling loss of containment.	4	Low risk of subsea wells loss of containment / constrained inventory. Onshore oil storage. Long-distance trucking of oil increases risk of loss of containment from an accidental spill. High risk associated with drilling loss of containment.	4	Moderate risk of subsea wells loss of containment, FPSO and oil export loss of containment. High risk associated with drilling loss of containment.	4	Moderate risk of platform, FSO and oil export loss of containment, higher if subsea tank. High risk associated with drilling loss of containment.	4	Low risk of subsea wells and pipeline loss of containment / constrained inventory. Incremental additional risk associated with existing facility. High risk associated with drilling loss of containment.
Lifecycle Environmental Impact	**Lifecycle Environmental Impact**	2	Small physical project footprint. Facilities redeployed at end of field life. Significant atmospheric emissions.	3	Large physical project footprint onshore and offshore. Facilities not redeployed at end of field life. Significant resources consumed for pipeline construction.	2	Small physical project footprint. Facilities redeployed at end of field life. Significant atmospheric emissions.	2	Moderate physical project footprint. Facilities not redeployed at end of field life. Significant atmospheric emissions.	1	Moderate physical project footprint. Utilises existing facilities.

Figure 4-3 shows the qualitative ranking score for environmental criteria, for each concept, as assessed in Table 4-5, with the lowest score giving the best outcome.

The comparative environmental assessment shows that the most favourable concept environmentally is Concept 5 Subsea tie-back to existing FSPO/Onshore, with the Concept 1 Honeybee production system ranked second. Concept 1, 2 and 3 are ranked quite closely.

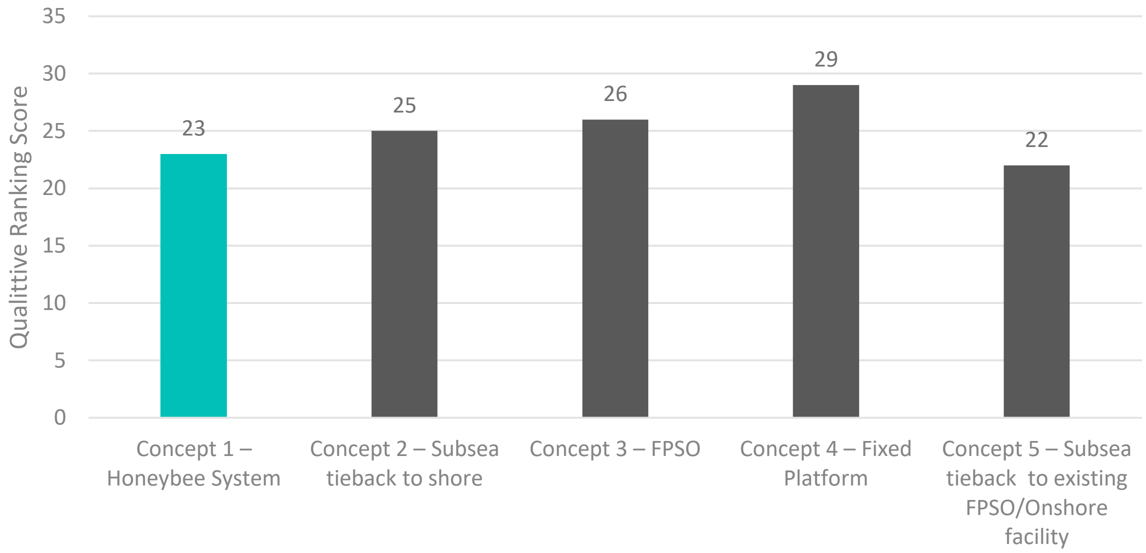


Figure 4-3 Qualitative Ranking of Environmental Criteria for Concept Alternatives

The next step of the comparative assessment is to assess the other project drivers and key criteria (economic, technical feasibility and safety and social).

This allows a comparison of Concept 5 and Concept 1 (as the selected concept). Table 4-5 provides the comparative assessment of other projects drivers for each alternative.

Table 4-6 Comparative Assessment of Economic, Technical Feasibility and Safety, and Social Criteria for each Alternative Concept

Criteria		Evaluated Concepts – Qualitative Ranking and Justification									
		Concept - Honeybee production system		*Concept 2 – Subsea tie-back to shore*		*Concept 3 – FPSO*		*Concept 4 – Fixed Platform*		*Concept 5 – Subsea tie-back to existing facility*	
Economic											
Schedule Risk	Ability to meet the development timeline	2	Less time to convert rig than build platform. Provides option to drill and produce from same platform offers further compressed schedule.	3	Onshore approvals and construction likely to add 12–24 months to schedule.	2	Similar or fewer conversion requirements to Concept 1.	3	Construction of offshore platform likely to add 12–18 months to schedule.	4	Volume vs Risk not appealing to existing facility owners. Commercial tolling agreements between existing facility owner and resource owner unlikely to be agreed in timely manner.
Cost Risk	Economic viability	1	Economic development concept. Lower CAPEX option with ability to redeploy to the next field allows for developing small reserves volume.	4	Uneconomic development concept due to small reservoir volumes	3	Uneconomic development concept due to small reservoir volumes vs cost of additional subsea mooring infrastructure (including installation and recovery) and FPSO lease term	4	Uneconomic development concept due to small reservoir volumes and not re-deployable infrastructure.	3	Third-party tolling rate likely to reduce likelihood of economic viability
Future Flexibility Risk	Ability to accommodate future development including ties-ins of other fields	1	MOPU may be remobilised to future development or sold at end of field life.	4	Tie in of other isolated fields not likely to be feasible without installation of further offshore processing/equipment	1	FPSO may be remobilised to future development or lease relinquished at end of field life.	4	Tie in of other isolated fields not likely to be feasible without installation of further offshore processing/equipment	4	Tie in of other isolated fields not likely to be feasible without installation of further offshore processing/ equipment
Technical Feasibility and Safety											
Safety Risk	In line with industry standards and good practice	3	Offshore personnel required to operate production facilities.	4	Lowest safety risk offshore, no offshore manned facilities. Prolonged pipeline installation campaign. High safety risk associated with road tanker export	3	Offshore personnel required to operate production facilities. Additional subsea construction	4	Offshore personnel required to operate production facilities. Major on and offshore construction	1	Low safety risk, no additional offshore manned facilities. Incremental increase in risk at existing facilities.
Operability & Feasibility Risk	Technically feasible	2	No major feasibility issues. Some topsides weight and space constraints	4	High flow assurance operability risk of long subsea tie-back – may not be technically feasible	1	Common development concept. No major feasibility issues	2	Common development concept. No major feasibility issues. Some topsides weight and space constraints. Subsea storage historically problematic	4	High flow assurance operability risk of very long subsea tie-back – may not be technically feasible
Technical Readiness	Technology readiness levels (TRL) (Note TRL are a method of estimating technology maturity of Critical Technology Elements (CTE) of a program.	1	Minimal novelty.	4	Potentially >40km subsea oil pipeline to existing facility is a technical step change and would require significant CAPEX for flow assurance mitigation and subsea pumping	2	Minimal novelty. Shallow-water mooring system required for FPSO feasible, but challenging.	1	Minimal novelty.	4	Potentially >40km subsea oil pipeline to existing facility is a technical step change and would require significant CAPEX for flow assurance mitigation and subsea pumping

Criteria		Evaluated Concepts – Qualitative Ranking and Justification									
		Concept - Honeybee production system		***Concept 2 – Subsea tie-back to shore***		***Concept 3 – FPSO***		***Concept 4 – Fixed Platform***		***Concept 5 – Subsea tie-back to existing facility***	
Constructability, Re-useability & Decommissioning	Ability to: construct, and redeploy as a generic design.	3	Ability to use MOPU for well abandonment. 100% of facility relocatable.	4	Additional drilling rig mobilisations required for installation and abandonment of wells. Pipeline likely to be left in situ. Some onshore facilities may be able to be removed and recycled. Not relocatable	2	Additional drilling rig mobilisations required for installation and abandonment of wells. FPSO relocatable Mooring piles left in situ	4	Additional drilling rig required for installation and abandonment of wells. Heavy lift vessel remobilised to remove topsides. Substructure likely to be left in situ. Topside re-use may be possible, but limited opportunities Not relocatable	3	Additional drilling rig mobilisations required for installation and abandonment of wells. Pipeline likely to be left in situ. Minimal new facilities to decommission.
Social											
Socioeconomic Impacts	Avoidance/ minimisation of impacts to other oil and gas activities Avoidance/ minimisation of impacts to fishery resources	1	Minor development footprint with minimal integration with oil and gas and fisheries activities	2	Pipeline footprint with some integration with fisheries activities	1	Minor development footprint with minimal integration with oil and gas and fisheries activities	1	Minor development footprint with minimal integration with oil and gas and fisheries activities	2	SIMOPS risk to existing oil and gas facility during construction/tie in may impact facility operations.
Reputation	Reputation and community expectation	3	Flaring of associated gas.	1	Associated gas fully used	3	Flaring of associated gas	2	Sub options involve either flaring of associated gas or tie-in to existing facility	2	Sub options involve either flaring of associated gas or tie-in to existing facility

Figure 4-4 shows the qualitative ranking score for technical feasibly and safety, economic and social drivers, for each concept, as assessed in Table 4-6 with the lowest score giving the best outcome.

The comparative environmental assessment shows that the most favourable concept environmentally is Concept 1 – Honeybee production system ranked first, followed by Concept 3 – FSPO.

The qualitative ranking for all the other criteria shows that Concept 5 – Subsea tie-back to existing FPSO/Onshore facility has the second-worst score, mainly due to:

- technical feasibly of a very long subsea tie-back
- volume vs risk is unlikely to be appealing to existing facility owners, given the small reservoir size and field life
- means that redeployment to the next field (e.g. Amulet) is not feasible without installing further offshore infrastructure.

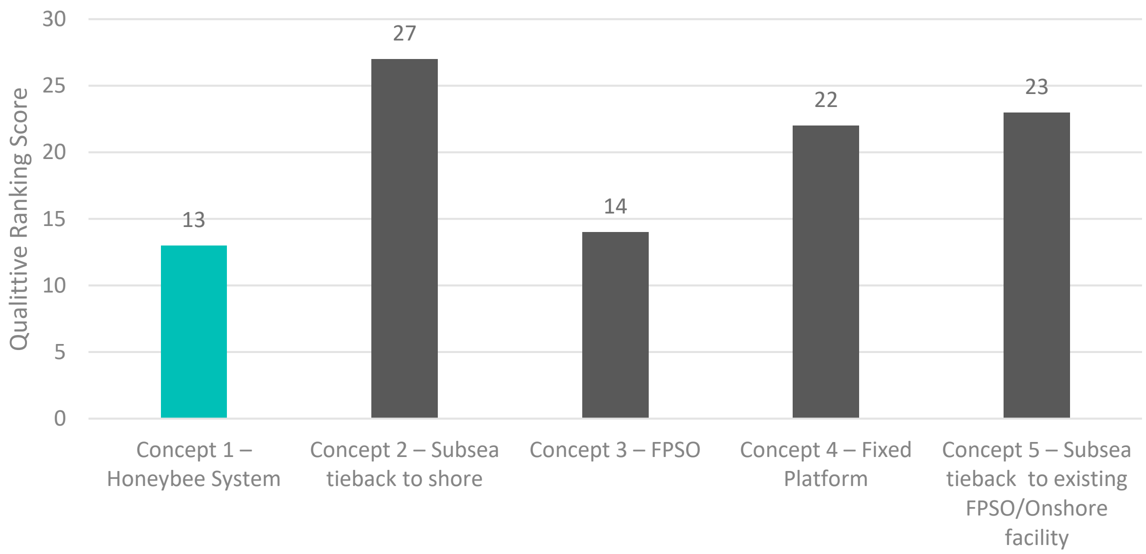


Figure 4-4 Qualitative Ranking of Economic, Technical Feasibility and Safety and Social Criteria for Concept Alternatives

Figure 4-5 shows the total qualitative ranking score for each concept against the all assessment drivers and criteria (including environmental criteria). This clearly shows that Concept 1 – Honeybee production system is the preferred option for all criteria.

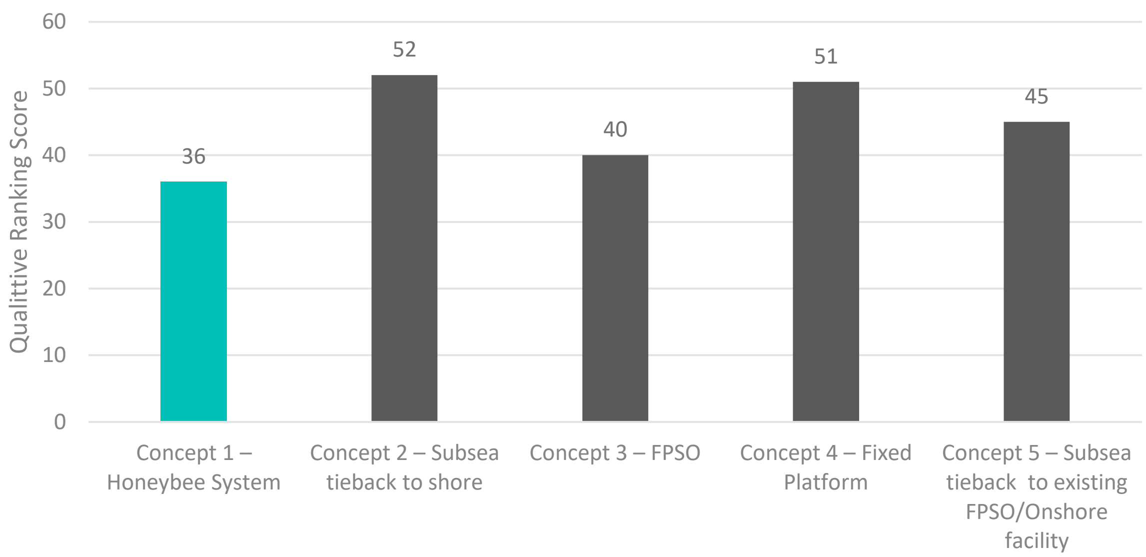


Figure 4-5 Qualitative Ranking of All Criteria for Concept Alternatives

In summary, the alternatives concepts were not selected for these primary reasons:

- Concept 2 – Subsea tie-back to shore was not selected due to the technical step change of the very long tie-back and its significant onshore and offshore footprint. This option is not re-deployable and is not economically viable.
- Concept 3 – Subsea wells with FPSO was not selected due to a lack of materiality of the size of the reservoir and the cost of installation and decommissioning of the FPSO mooring system and subsea wells and production system.
- Concept 4 – Fixed platform was not selected due to not been able to be redeployed and having a significant cost to install and decommission and therefore economically unviable.
- Concept 5 – Subsea tie-back to existing FSPO/Onshore facility was not selected due to due to the technical step change of the very long tie-back and commercial / technical concerns in accessing third-party infrastructure. Concept deemed unlikely to be economically viable as brownfield tie-in scope to third-party facility likely to be uncompetitive compared to standalone solution. Cumulative environmental impact is comparable to subsea to shore (Concept 2).

A summary of the evaluation outcome is presented in Table 4-7.

Table 4-7 Summary of Assessment of Alternative Concepts for the Corowa Development

Concept		Summary of comparative assessment evaluation	
1	**Honeybee production system** *Analogue – Stag and Legendre self-installing platform (Australia)*	• Short production lifespan reduces ongoing environmental impacts. • Re-deployable nature reduces environmental impact by removing all infrastructure promptly upon cessation of production, increases economic viability and aligns with KATO strategy. • Production trees located at surface reduce construction, operations and decommissioning complexity and cost. • Economic field development concept, lower capital cost than other concepts except Concept 5. • Retains opportunity for a single production and drilling unit further reducing complexity of installation and decommissioning.	✓

	Concept	Summary of comparative assessment evaluation	
		• Aligns with industry analogues for small short-lived shallow-water offshore oil fields. • Associated gas management strategy challenging.	
2	**Subsea to Shore** *Analogue – Macedon (Australia)*	• High cost and not economic. Field size and field life do not support the cost of subsea development and an onshore process facility. • High safety risk of long-distance road transport of product. • Large development footprint associated with pipeline and onshore facilities.	*X*
3	**FPSO** *Analogue – Pyrenees, Van Gogh (Australia)*	• While re-deployable, the Corowa field size and field life are not deemed sufficient to support the costs associated with installation and recovery of a mooring system and subsea flowline and riser architecture for a FPSO. • Removal for cyclone events further reduces economic viability over anticipated short field life. • Subsea construction activity and footprint result in greater environmental impact.	*X*
4	**Fixed Platform to FSO, Subsea storage or Export pipeline** *Analogues –* *With FSO: West Patricia (Malaysia); Manora (Thailand)* *With pipeline: North Rankin (Australia)* *With subsea tank: Premier Solan (UK)*	• Field size and field life are not sufficient to support the cost of a fixed platform and/or pipeline to existing facility. • Inability to relocate the facility does not allow the development of other isolated oil fields. • Lower section of fixed platform (and subsea storage tank or pipelines if used) potential to remain in place if lower environmental impact than removal.	*X*
5	**Subsea Tie-back to Existing Facility** *Analogue – Greater Enfield*	• Distance to existing facility means this option would be technically challenging, requiring the deployment of emerging technology. • Near term ullage not available. Volume versus risk not aligned with existing facility owners due to perceived risk of allowing third party entry to owner operated facilities. • High schedule risk for commercial tolling agreements between existing facility owner and resource owner.	*X*
6	**No Development**	• Titleholder is required to undertake certain petroleum exploration and production related activities towards commercialising the resource.	*X*

4.3 Analysis of Design / Activity Alternatives

Once the concept has been selected (i.e. Concept 1 – Honeybee production system), there are alternatives to consider for more granular activities, designs and construction methods.

This section describes the key alternative options for design and activities, for the selected concept.

The key design and activity elements of the Corowa Development that may have potential impacts and risks on the environment include:

- gas strategy
- produced formation water treatment and disposal
- drilling facility
- export strategy
- drilling fluid selection
- mooring of CALM buoy.

The following subsections set out the alternatives for these key elements where they are evident at the current phase of engineering maturity, with each alternative assessed as per the process described in Section 4.1.2. With the exception of the gas strategy, these options are assessed only against environment criteria, as they are mostly 'lower level' design and methodology decisions.

A description of the alternative and the comparative assessment is shown for each of these key design / activity elements.

4.3.1 Gas Strategy

Corowa is an oil field with Standard Tank Oil In Place (STOIIP) of 12.8 MMstb and Contingent Resource of 7.0 MMstb[6]. Production is planned to occur for a relatively short period, between two and 4.5 years (for best and high production estimate respectively). While the reservoir has no gas cap, it will produce associated gas with the oil, this gas must be used, exported or disposed of to allow for production of the oil (Figure 4-6). The total gas production anticipated is ~4.9–9.3 Bcf[7] (for best and high estimate respectively).

As with all oil and gas developments there remains a degree of uncertainty in reservoir behaviour until the full production system is put into operation. Table 4-8 summarises KATO's view of the potential range of gas production at the Corowa field, at low, high, and best estimates.

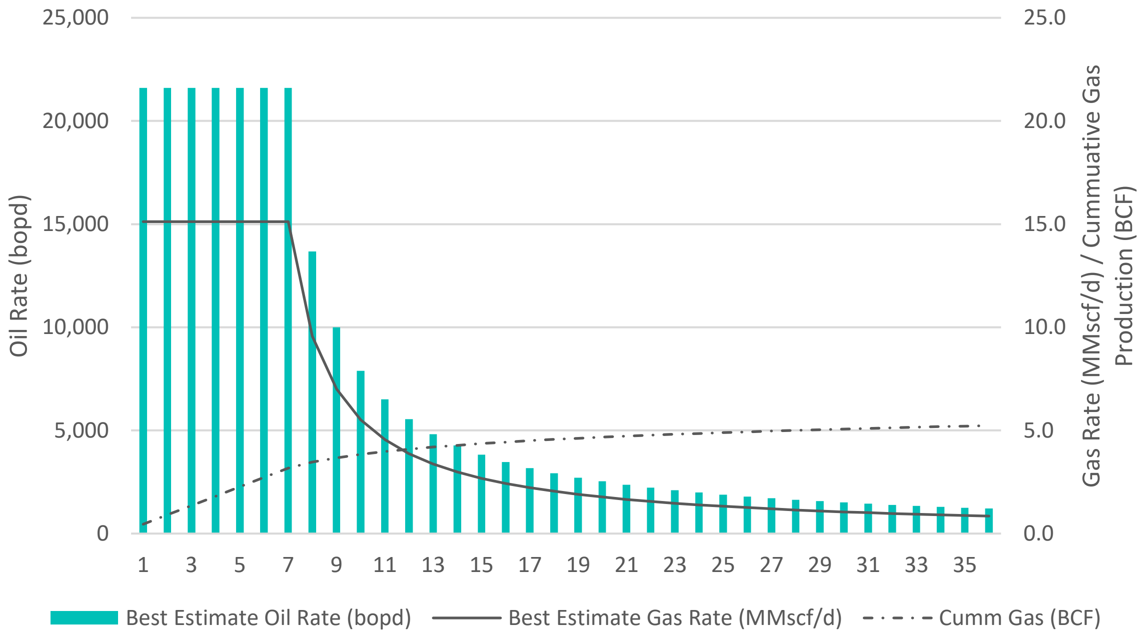


Figure 4-6 Corowa Hydrocarbon Monthly Production Forecast (at the wellhead) – Best Estimate (P50)

[6] Economically recoverable volume, Independent Certified by RPS Energy Services Pty Ltd (2014), based on 2,000 bbl/d nominal economic production threshold and contemporary economics, 2C reserves.

[7] Anticipated Gas Oil Ratio (GOR) of 700 scf/stb.

Table 4-8 Range of Potential Gas Production

Parameter	Low Estimate (P90)	Best Estimate (P50)	High Estimate (P10)
Plateau oil production rate (bbl/d)^	21,600	21,600	24,250
Gas-Oil-Ratio or GOR (scf/bbl)^	700	700	700
Peak Gas Production (MMscf/d)	15.1	15.1	17.0
Duration of plateau production (months)	5	7	13
Total Gas Production (Bcf)*	**2.9**	**4.9**	**9.3**
Assumptions: ** based on duration of plateau production and Best Estimate GOR* *^ numbers from certified reserves report*			

Table 4-9 summarises the design / activity options identified for the produced gas.

Given the very short production period, the economically viable alternatives for associated gas strategy are limited. For this reason, greenfield development alternatives with high capital cost including onshore gas treatment and export facilities to the Dampier to Bunbury Natural Gas Pipeline and processing as Liquified Natural Gas are not discussed further.

Table 4-9 Summary of Gas Strategy Options

Option		Description
1	**Fuel gas**	• A portion of the produced gas could be used as a fuel gas to reduce the amount of fuel oil used on the facility for power generation and process heating. • Includes the installation of fuel gas treatment facilities on the MOPU and installation of either dual fuel or dedicated gas fired equipment for power generation (internal combustion engines or turbines) and process heating (boilers or fired heaters).
2	**Export via pipeline to existing gas treatment facility**	• Gas could be exported to an existing facility. This option includes: ○ installing additional power generation, gas treatment, compression and export facilities on the MOPU, and installing and decommissioning a pipeline from Corowa to the existing onshore gas treatment facilities near Onslow (~50 km of offshore pipeline and ~15 km of onshore pipeline) ○ or tie-back to an existing trunkline (~8 km to the Macedon pipeline).
3	**Reinject gas to reservoir**	• Gas could be reinjected to the producing oil and gas reservoir formation. • Includes the installation of additional facilities on the MOPU (power generation, gas treatment, compression, injection facilities) and construction of a gas injection well. This option also requires a substantial upgrade to the planned MOPU topside facilities to cope with additional recycled gas production.
4	**Flare**	• Associated gas is burned via the existing MOPU flare system. • $CO_{2\text{-}e}$ emissions calculations for this option are based on the production profile presented in Figure 4-6 extending beyond likely economic production cut off for a total duration of 48 months.
5	**Gas to wire**	• Gas could be used as a fuel gas to produce electricity, which is exported via a subsea cable to shore. Onshore it is tied into the electricity network. • Includes the installation of fuel gas treatment facilities on the MOPU and installation of either dual fuel or dedicated gas fired power generation (internal combustion engines or turbines).

Option		Description
		• The power export requires installing a subsea cable to shore. Onshore switchgear is required to tie into the electricity network.
6	**New technologies (Compressed Natural Gas – CNG / Mini Liquified natural gas (LNG)**	• KATO has considered the International Finance Corporation (IFC) zero routine flaring by 2030 initiative. In line with the IFC publications *Comparison of Mini-Micro LNG and CNG for commercialization of small volumes of associated gas* KATO screened mini-LNG and CNG. • Mini-LNG requires the installation of a small gas treatment and liquefaction, storage and export facility on a barge, platform or ship. • CNG requires the offshore treatment, compression and export of compressed gas to a dedicated CNG ship, construction of a receiving terminal and tie-in to an existing natural gas pipeline.

Option 6 – New technologies (CNG/mini-LNG) is not considered further for these reasons:

- Not economic due to short project life, cost of additional CNG/mini-LNG infrastructure. The best or low estimate for production profile would have to be assumed, as a worst-case scenario.
- FLNG has a high capital cost, which requires extended periods of operation to break even. Wood Mackenzie (2019a) note that FLNG is likely to be an uneconomic development option for gas discoveries of less than 0.5 tcf in resource size. Recent screening studies indicate mini-FLNG is not economic at gas rates of <30 MMscf/d, and that such rates would have to be sustained for longer periods (>5 years) than anticipated field life.
- Industry analogues for small-scale FLNG developments are targeting between 0.5 and 2 tcf gas resources (Offshore Energy 2017; Wood Mackenzie 2019). The smallest operating offshore FLNG facility is producing from a resource of 0.8 tcf, breakeven for this FLNG project is forecast to occur after five years of plateau production (Wood Mackenzie 2019b). Given Corowa gas reserve is two orders of magnitude below this size and production of gas will occur for one to three years FLNG is not a feasible development option.
- While the cost of delivered CNG depends on project-specific conditions such as gas volume and composition, the World Bank (2015) concluded in general that marine CNG is not yet commercially proven. Currently no marine CNG analogues are in operation, thus it is concluded that CNG is not feasible for the development of Corowa gas.

Due to this potential gas production, the design and activity options for the gas strategy present one of the key potential sources of impact and risk for the Corowa Development. Therefore, KATO has undertaken a comparative assessment of the options against <u>all</u> project drivers and criteria (Table 4-1), not only against the environmental criteria.

Table 4-10 provides the comparative assessment of environmental criteria for each option.

Table 4-10 Comparative Assessment of Environmental Criteria for each Gas Strategy Option

Criteria	Evaluated Concepts – Qualitative Ranking and Justification									
	Option 1 – Fuel Gas		*Option 2 – Export via pipeline to existing facility*		*Option 3 – Reinject gas*		*Option 4 – Flare*		*Option 5 – Gas to wire*	
Seabed disturbance	1	No additional seabed disturbance	3	~15 km of seabed disturbance associated with export pipeline resulting in moderate localised impact to benthic habitat	2	Additional gas injection well and associated cuttings resulting in limited minor localised impact to benthic habitat	1	No additional seabed disturbance	3	~50 km of seabed disturbance and shore crossing associated with power export cable resulting in moderate localised impact to benthic habitat
Interaction with marine fauna (vessel movement)	1	No additional vessel movements	1	Minor short-term localised impact to marine mammals associated with additional construction, inspection and maintenance vessel movements	1	No additional vessel movements	1	No additional vessel movements	1	Minor short-term localised impact to marine mammals associated with additional construction, inspection and maintenance vessel movements
Underwater sound emissions	1	No additional underwater noise	1	Minor localised temporary noise emissions associated with export compressor discharge piping	1	Minor localised temporary noise emissions associated with export compressor discharge piping	1	No additional underwater noise	1	No additional underwater noise
Atmospheric emissions	1	Positive impact: Reduction in atmospheric emissions associated with using gas as a fuel reducing the volume of fuel oil required. Fuel gas results in ~30% less CO_2-e than diesel. Reduces volume of gas flared by ~0.5 MMscfd.	1	Very low level of incremental CO_2-e emissions from additional power generation associated with gas compression. Gas used via pipeline network. ~7.5 kt CO_2-e embodied emissions in pipeline.	2	Low-level incremental CO_2-e emissions from additional power generation associated with gas compression. Gas is not used.	3	Moderate level of CO_2-e emissions from burning associated reservoir gas during operations. Increase in atmospheric emissions by up to 1.1 Mt CO_2-e. Gas is not used.	2	Some additional power generation associated with gas compression. Gas used via pipeline network.
Light emissions	1	No additional light emissions	1	No additional light emissions	1	No additional light emissions	2	Light emissions associated with continuous flaring. Near-field incremental light increase not measurable outside 12.6 km. Flare visible as a light low on the horizon up to 36 km away including Muiron Islands. (refer Section 7.1.3)	1	No additional light emissions
IMS	1	No additional IMS risk	2	Incremental IMS risk associated with additional pipeline construction vessels	1	No additional IMS risk	1	No additional IMS risk	1	No additional IMS risk
Planned liquid and solid discharges and wastes	1	No additional emissions or discharges	1	No additional emissions or discharges	2	25% additional cuttings with SBM or WBM associated with gas injection well resulting in limited minor localised impact to benthic habitat and water quality.	1	No additional emissions or discharges	2	Increased cooling-water discharges associated with energy generation
Unplanned discharges and Accidental Releases	1	No significant additional risk of unplanned discharges or accidental release	2	Introduces the risk of pipeline rupture, resulting in loss of containment of hydrocarbon gas resulting in an additional impact.	4	Introduces the risk of loss of well containment while drilling an additional gas injection well, leading to additional potential widespread impact.	1	No significant additional risk of unplanned discharges or accidental release	1	No significant additional risk of unplanned discharges or accidental release.

Criteria	Evaluated Concepts – Qualitative Ranking and Justification									
	Option 1 – Fuel Gas		*Option 2 – Export via pipeline to existing facility*		*Option 3 – Reinject gas*		*Option 4 – Flare*		*Option 5 – Gas to wire*	
Lifecycle environmental impacts	1	Positive impact reduced atmospheric emissions from natural gas offsets liquid fuel use in power generation. Fuel gas results in ~30% less CO_2-e than diesel.	3	Moderate physical footprint offshore and onshore for ~2–4.5 years of gas production. Additional resources for pipeline manufacture and installation. Positive impact reduced atmospheric emissions from natural gas offsets other fuel use in power generation.	1	Incremental atmospheric emissions associated with gas compression. Minor localised benthic disturbance and water quality impacts	3	Moderate level of atmospheric emissions associated with gas flaring.	2	Moderate physical footprint offshore and onshore. Additional resources for cable manufacture. Positive impact reduced atmospheric emissions from natural gas offsets other fuel use in power generation.

Figure 4-7 shows the qualitative ranking score for environmental criteria, for each option, as assessed in Table 4-10 with the lowest score giving the best outcome.

The comparative environmental assessment shows that the most favourable option environmentally is Option 1 – Fuel gas, followed by Option 5 – Gas to Wire. Options 2, 3 and 4 are ranked the same. The key differentiators were seabed disturbance, and atmospheric and light emissions.

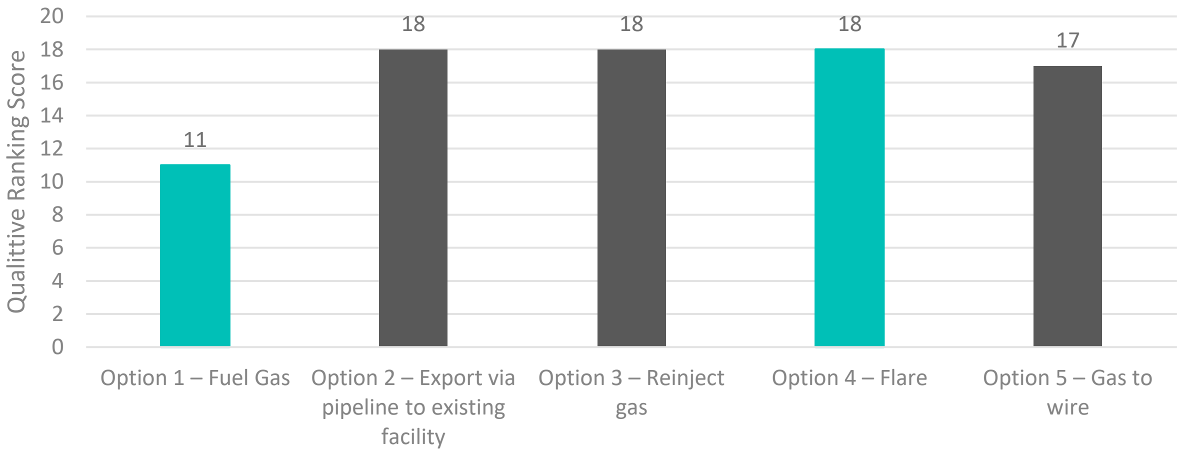


Figure 4-7 Qualitative Ranking of Environmental Criteria for Gas Strategy Alternatives

The next step of the comparative assessment is to assess the other project drivers and key criteria (economic, technical feasibility and safety and social). This allows a further comparison of the options.

Table 4-11 provides the comparative assessment of other projects drivers for each alternative.

Table 4-11 Comparative Assessment of Economic, Technical Feasibility and Safety and Social Criteria for each Gas Strategy Option

Criteria	Evaluated Concepts – Qualitative Ranking and Justification									
	Option 1 – Fuel Gas		*Option 2 – Export via pipeline to existing facility*		*Option 3 – Reinject gas*		*Option 4 – Flare*		*Option 5 – Gas to wire*	
Economic										
Schedule risk	1	Planned as base case schedule	4	Risk of disruption to existing facility owners' current operations of tying in the small volume of Corowa oil is grossly disproportionate to the potential financial reward of processing the oil. KATO has undertaken preliminary engagements with other facility operator. Initial feedback is a strong aversion to allowing a hot-tap into existing facilities given limited commercial upside when considered against the small gas volumes and high risks of tie-in.	2	Some additional equipment or modifications required. Additional well required. Schedule delay ~6months	1	Planned as base case schedule	4	Onshore approvals and construction likely to add 12–24 months to schedule
Economic viability	2	This option will require additional capital cost for installation of gas treatment systems and gas fired utilities. Use of associated gas will reduce operational costs associated with supply of fuel.	4	Tie-back to shore or existing trunkline is not economic due to short project life, and relatively small volumes of gas; cost of installing and decommissioning pipeline will not be recovered from gas sales.	4	Not economic due to short project life, cost of additional well and small volumes of gas.	1	Low capital cost as this option utilises the existing flare.	4	Not economic due to short project life, cost of export cable and small volumes of gas. There is only one potential market within range (<100 km), as Barrow Island and Onslow have excess electricity generation; however, a deep underwater canyon precludes a transmission line to Exmouth.
Future flexibility risk	1	Allows for redeployment of MOPU	4	Tie in of other isolated fields not likely to be feasible without installation of further offshore processing/ equipment	3	Tie in of other isolated fields may require another gas injection well to be drilled (depending on amount of associated gas). Not likely to be feasible without installation of further offshore equipment	1	Allows for redeployment of MOPU	3	Tie in of other isolated fields not likely to be feasible without installation of further offshore equipment
Technical Feasibility and Safety										
Safety risk	2	Addition of small gas treatment and fuel gas compression equipment on MOPU increases congestion, introduces high-pressure gas hazard on topsides resulting in an increase to fire and explosion risk.	4	Addition of large gas treatment, compression and export equipment on MOPU increases congestion, introduces high-pressure gas hazard on topsides resulting in an increase to fire and explosion risk. Tie-in to pipeline requires high risk diving activity.	3	Addition of large gas treatment, compression and export equipment on MOPU increases congestion, introduces high-pressure gas on topsides resulting in an increase to fire and explosion risk.	1	No additional risk	2	Addition of medium gas treatment and fuel gas compression equipment on MOPU increases congestion, introduces high-pressure gas hazard on topsides resulting in an increase to fire and explosion risk.

Criteria	Evaluated Concepts – Qualitative Ranking and Justification									
	Option 1 – Fuel Gas		*Option 2 – Export via pipeline to existing facility*		*Option 3 – Reinject gas*		*Option 4 – Flare*		*Option 5 – Gas to wire*	
Operability and feasibility risk	1	Using associated gas for power generation and process heating is feasible and common practice in offshore oil production facilities.	3	Gas export is a feasible technology. Additional equipment will introduce space and weight demands on MOPU concept, requiring the unit to be larger.	4	Reservoir not suitable for reinjection[8]. Very high risk of gas breakthrough to production wells significantly reducing oil recovery from reservoir.	1	Flaring of associated gas is feasible. The flare system is designed for maximum process upset gas rate in all cases. No additional process systems required, no increase in safety risk.	3	Emerging concept. No industry analogues to date. Technically challenging. Facility sizing and gas utilisation trade off. Export cable route to market (Exmouth) challenged by seabed features.
Technical readiness	1	No significant novelty	1	No significant novelty	1	No significant novelty	1	No significant novelty	2	Some novel components for power export and long-distance subsea power cable
Constructability, Re-useability Decommissioning Feasibility	1	Re-deployable with MOPU.	4	Not re-deployable. Site-specific. More difficult to decommission.	3	Some components re-deployable with MOPU. Additional well required at each site. More difficult to decommission – requires P&A of an additional well.	1	Re-deployable with MOPU.	3	Some components re-deployable with MOPU. Additional export cable required at each site. More difficult to decommission.
Social										
Avoidance/ minimisation of impacts to other oil and gas activities / fisheries	1	Using gas for fuel has a positive socioeconomic impact.	2	Restrictions to other marine user activities along pipeline route while in construction and operation.	1	No additional impact	1	No additional impact	2	Restrictions to other marine user activities along cable route while in construction and operation. Using gas for fuel has a positive socioeconomic impact.
Reputation and community expectation	1	Associated gas fully used	1	Associated gas fully used	2	Associated gas partially used and available as a resource for future generations.	3	Flaring of associated gas. Natural resources not used as efficiently as possible. Integrational equity value of flared gas not valued.	1	Associated gas fully used

[8] Technical Note – Corowa Gas Reinjection Review (2019)

Figure 4-8 shows the qualitative ranking score for technical feasibly and safety, economic and social drivers, for each option, as assessed in Table 4-11, with the lowest score giving the best outcome.

The comparative environmental assessment shows that the most favourable option environmentally is Option 1 – Fuel Gas ranked first, followed by Option 5 – Gas to Wire.

However, the qualitative ranking against all other criteria shows that Option 5 – Gas to Wire has the second-worst score, mainly due to:

- not economic due to short project life and relatively small volumes of gas
- onshore approvals and construction likely to add 12–24 months to schedule
- additional lifecycle impact and footprint onshore and shore crossing
- means that redeployment to the next field (e.g. Amulet) is not feasible without installing further infrastructure.

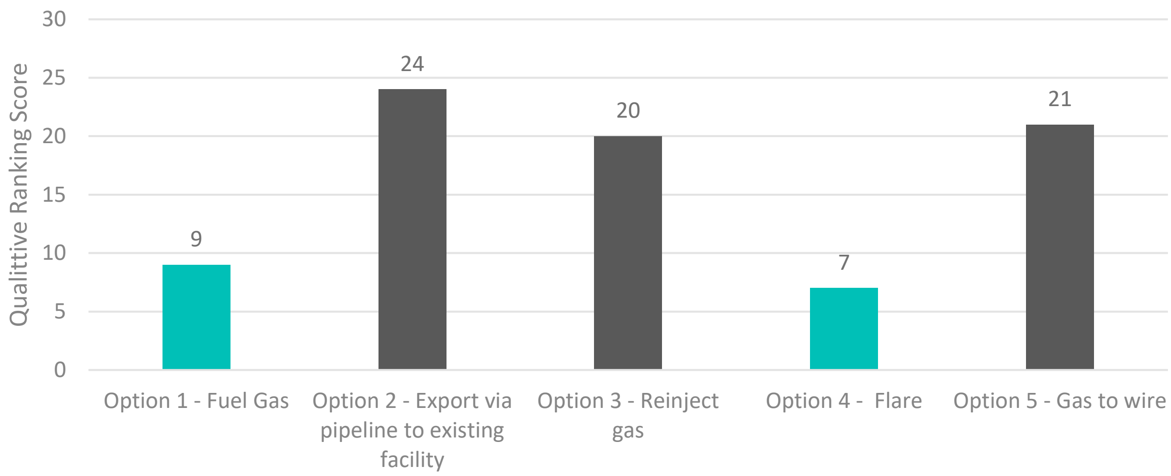


Figure 4-8 Qualitative Ranking of Economic, Technical Feasibility and Safety and Social Criteria for Option Alternatives

Figure 4-9 shows the total qualitative ranking score for each option against the all assessment drivers and criteria (including environmental criteria). This clearly shows that Option 1 – Fuel Gas and Option 4 – Flare are the preferred option against all criteria.

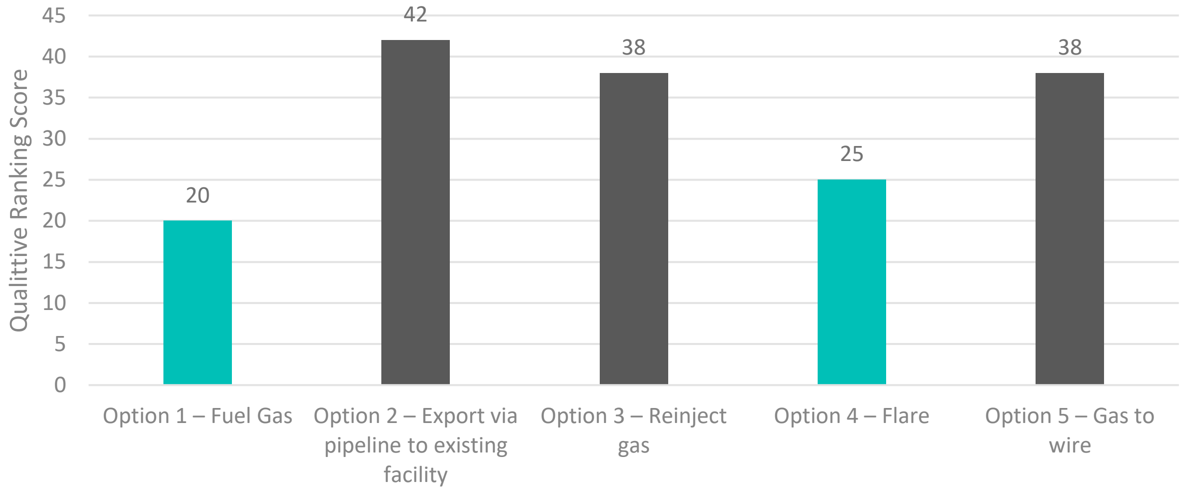


Figure 4-9 Qualitative Ranking of All Criteria for Gas Strategy Options

In summary, the alternatives options were not selected for these primary reasons:

- Option 2 – Export to existing facility was deemed unfeasible due to economic factors. Installation of new offshore pipeline and hot tap introduces new risks of pipeline rupture and greater seabed disturbance, and construction of a pipeline to shore, shore crossing, and onshore pipeline means significantly greater area of seabed disturbance. Construction of a new pipeline is not economic for such a short duration of gas production (between two and 4.5 years) and relatively small volumes of gas. The risk of disrupting existing facility owners' current operations from tying in the small volume of Corowa oil is grossly disproportionate to the potential financial reward of processing the oil, and is not likely to appeal to existing facility owners, nor the new risks of conducting a hot tap into an existing pipeline.
- Option 3 – Reinject gas was deemed not technically feasible due to unsuitable reservoir and increased risk of gas breakthrough and increased safety hazards. It is also uneconomic due to short project life, cost of additional well and small volumes of gas.
- Option 5 – Gas to Wire was deemed unfeasible due to economic factors i.e. short project life, cost of export cable and small volumes of gas, and the additional of environmental risks from a shore crossing and onshore works (and consequent schedule risk). The only market for electricity within range (Exmouth) is precluded by a deep canyon obstructing the pipeline route.

In all cases the small produced volumes of gas expected make other alternatives particularly challenging.

In consideration of the comparative assessment against multiple drivers and criteria in Table 4-10, Option 1 – Fuel Gas has been selected as KATO's preferred gas strategy options. This option is anticipated to use ~0.5 MMscf/d of produced gas as fuel.

However, gas generated from oil production will exceed 0.5 MMscf/d fuel gas demand; therefore, an alternative disposal method is required for this additional gas.

Therefore, Option 4 – Flare is selected to dispose of the remainder of associated gas. Use of associated gas as fuel gas is a viable option with positive environmental outcomes when compared to using fuel oil for MOPU power and heat requirements.

This alternatives assessment aligns with the previous operator Hydra, who concluded that there were no technically and commercially feasible options for commercialisation of the associated gas.

The potential environmental impact from the selected options is evaluated in Section 7, of which the key potential aspects are atmospheric emission, and light emissions.

Flaring of associated gas during operations will contribute emissions of ~1.1 Mt CO_2-e over the life of the field (refer to Section 7.1.4). This is equivalent to the CO_2-e emissions from burning 360 ML of diesel, which is equivalent to 20 days of diesel use emissions from Western Australia (DoEE 2018f).

Flaring may be visible at night on the horizon as direct light source up to 36 km from the MOPU, and is predicted to have no measurable change to the background light density levels beyond 12.6 km from the MOPU.

4.3.2 Flare Design

The Corowa Development will produce associated gas at a rate of between 17 MMscf/d and 1 MMscf/d over the life of the field (declining over time as the field is depleted). Produced gas will be used for fuel gas and excess associated gas is flared to safely dispose of the gas. The flare gas stream characteristics include a waste gas molecular weight of ~27 g/mol and a production separator pressure of approximately 10 bar.

In flares, combustion occurs by means of a diffusion flame. A diffusion flame is one in which air diffuses across the boundary of the fuel/combustion product stream toward the centre of the fuel flow, forming the envelope of a combustible gas mixture around a core of fuel gas. On ignition, this mixture establishes a stable flame zone around the gas core above the burner tip. This inner gas core is heated by diffusion of hot combustion products from the flame zone. Cracking can occur with the formation of small hot particles of carbon that give the flame its characteristic luminosity. Different mixing results in different flame characteristics including luminosity.

Table 4-12 summarises the various flare design options identified for the excess gas. They differ primarily in their accomplishment of mixing (US EPA 2002). Table 4-13 provides the comparative assessment of environmental criteria for each option.

Table 4-12 Summary of Flare Design Options

Option			Description
1	**Open Pipe**		• The simplest industrial process flare design. Consisting of an open pipe, they result in very low backpressure and are typically used for burning light hydrocarbons such as Corowa associated gas. • Steam injection may be used on open pipe flare to encourage smokeless burning of waste gas streams and is discussed as a separate alternative below (Option 7 – Steam assist). • Open pipe flares are feasible for Corowa and this alternative is carried through to FEED. • This option is used as the base case for impact assessment in Section 7.1.3.
2	**Enclosed or Ground flare**	 *Source: Honeywell 2019*	• In an enclosed flare, the burner heads are inside a shell that is internally insulated. This shell reduces noise, luminosity, and heat radiation and provides wind protection. Enclosed flares generally require a large pressure drop to provide adequate mixing and have less capacity than open flares (US EPA 2002; Cheremisinoff 2016). • High wind loads in cyclonic conditions require significant structural support and/or reliable removal systems on the MOPU. • This option is only feasible in locations with a large footprint available or for a low flow rate such as landfill applications. ○ The MOPU has a very small footprint available that is inadequate for the flare flow rate, therefore this option is not considered further.
3	**Pit flare**	 *Source: TCD-Italia 2020*	• Similar to Option 1 – Open pipe flare but enclosed with earthen or concrete bunds to shield light emissions. • Is applicable for low pressure drop waste gas systems such as Corowa. • Requires an earthen area to excavate and construct bund walls, and a large physical ○ This option is only feasible in a land-based location and is not considered further.

Option			Description
4	**Multi-tip flare**	 *Source: Jahagirdar 2013*	• Similar to Option 1 – Open pipe flare however it uses multiple tips to split gas flow into separate sources and allows for more turbulent mixing with air for increased combustion efficiency. • Typically used where high gas pressure is available. While this is not the case for the Corowa Development, the option of low-pressure multi-tip flare design may be investigated further with flare suppliers during FEED to reduce flame height. • This alternative is carried through to FEED.
5	**Sonic flare**	 *Source: Aereon 2020*	• Sonic flares use a high-pressure nozzle on the flare tip which creates high speed gas flow to create turbulence and burn more efficiently. This can eliminate smoke, lower flame radiation and shorten the flame length. • This alternative is only employed where there is a significant pressure drop available from the waste gas stream. The high velocity results in increased noise emissions. ○ Due to the requirement for a high pressure drop for this design, this option is not feasible for the Corowa Development and is not considered further.
6	**Air assist**	 *Source: Zeeco 2020*	• Comprises two risers and an air blower system providing supplemental combustion air. This air assist causes turbulence in the waste gas stream at low flow rates which improves mixing. This enhances combustion efficiency, promotes turbulent mixing and results in a quicker burn. • Air assist results in additional noise associated with the high velocity air injected into the flare. Air assist is useful when flaring at lower than the design flare rates (up to 20%) (Cheremisinoff 2016). This may result in a difference in flare combustion characteristic, including flare luminosity. • This option will be carried into FEED to consider light emissions at lower flare flow rates.
7	**Steam assist**	 *Source: John Zink Hamworthy Combustion 2020*	• Similar to Option 1 – Open pipe flare or Option 4 – Multi-tip flare, this option injects steam around the perimeter of the flare tip into the combustion zone to induce turbulence. • Steam assist flares introduce an issue with noise from the high-pressure steam injection. • This alternative is not considered practical in an offshore location on the MOPU as a steam boiler system requires a high-quality feed water that isn't readily available on the MOPU, and steam is not produced by the hydrocarbon processing. A large footprint would be required for a boiler package, reverse osmosis equipment, storage and additional power generation to supply water and boiler feedwater treatment.

Option			Description
			○ Due to the requirement for a high pressure drop for this design, and additional facilities required, this option is not considered feasible for the Corowa Development and is not considered further.

Table 4-13 Comparative Assessment of Environment Criteria for each Flare Design Option

Criteria	Evaluated Options – Qualitative Ranking and Justification					
	Option 1 – Open Pipe		***Option 4 – Multi-Tip***		***Option 6 – Air assist***	
Seabed disturbance	1	No additional seabed disturbance. Flare is mounted on the MOPU deck.	1	No additional seabed disturbance. Flare is mounted on the MOPU deck.	1	Minor additional amount of equipment required, air blower. No additional seabed disturbance. Flare is mounted on the MOPU deck.
Interaction with marine fauna	1	No change to marine fauna interactions.	1	No change to marine fauna interactions.	1	No change to marine fauna interactions.
Noise emissions	1	No increase in noise emissions identified for this alternative.	1	No increase in noise emissions identified for this alternative.	1	Incremental increase in atmospheric noise emissions from low flow rate scenarios when air assist is operational. No sensitive environmental receptors identified for atmospheric noise emissions.
Atmospheric emissions	3	CO_2-e emissions are consistent across all flare designs. Moderate level of CO_2-e emissions from burning excess associated reservoir gas during operations. Gas is not used.	3	CO_2-e emissions are consistent across all flare designs. Moderate level of CO_2-e emissions from burning excess associated reservoir gas during operations. Gas is not used.	3	CO_2-e emissions are consistent across all flare designs. Moderate level of CO_2-e emissions from burning excess associated reservoir gas during operations. Gas is not used.

Criteria	Evaluated Options – Qualitative Ranking and Justification					
	Option 1 – Open Pipe		***Option 4 – Multi-Tip***		***Option 6 – Air assist***	
Light emissions	2	Light emissions associated with continuous flaring. Near-field incremental light increase not measurable outside 12.6 km. Flare visible as a light low on the horizon up to 36 km away including Muiron Islands.	2	Light emissions associated with continuous flaring. Near-field incremental light increase not measurable outside 12.6 km. Flare visible as a light low on the horizon up to 36 km away including Muiron Islands. Potential incremental reduction in luminosity when compared to open pipe flare.	2	Light emissions associated with continuous flaring. Near-field incremental light increase not measurable outside 12.6 km. Flare visible as a light low on the horizon up to 36 km away including Muiron Islands. Potential incremental reduction in luminosity at low flow rates (circa 20% of design rate) when compared to open pipe flare.
IMS	1	No additional IMS risk	1	No additional IMS risk	1	No additional IMS risk
Planned liquid and solid discharges and wastes	1	No additional risk	1	No additional risk	1	No additional risk
Unplanned discharges and Accidental Releases	1	No additional risk	1	No additional risk	1	No additional risk
Lifecycle environmental impacts	3	Moderate level of atmospheric emissions associated with gas flaring.	3	Moderate level of atmospheric emissions associated with gas flaring.	3	Moderate level of atmospheric emissions associated with gas flaring.

Options 2, 3, 5 and 7 were not considered further for the following reasons:

- Option 2: This alternative is only feasible in locations with a large footprint available or for a low flow rate such as landfill applications. The MOPU has a very small footprint availability, inadequate for an enclosed flare/ ground flare flow rate. The Corowa Development is also in a cyclonic region, requiring significant structural reinforcement. Therefore Option 2 is not considered further.
- Option 3: This alternative is only feasible in a land-based location and is not considered further.
- Option 5: Due to the requirement for a high pressure drop for this alternative this option is not feasible for Corowa and is not considered further.
- Option 7: This alternative is not considered feasible in an offshore location on the MOPU as steam is not available from the process and a large footprint is required for a boiler package and equipment to produce, treat, store and supply boiler feed water to supply steam to the flare.

Figure 4-10 shows the qualitative ranking score for environmental criteria, for each alternative, as assessed in Table 4-13, with the lowest score giving the best outcome.

The comparative environmental assessment shows that all alternatives are equal in terms of environmental impact with qualitative scores of 14. No key differentiators were identified in the alternatives analysis.

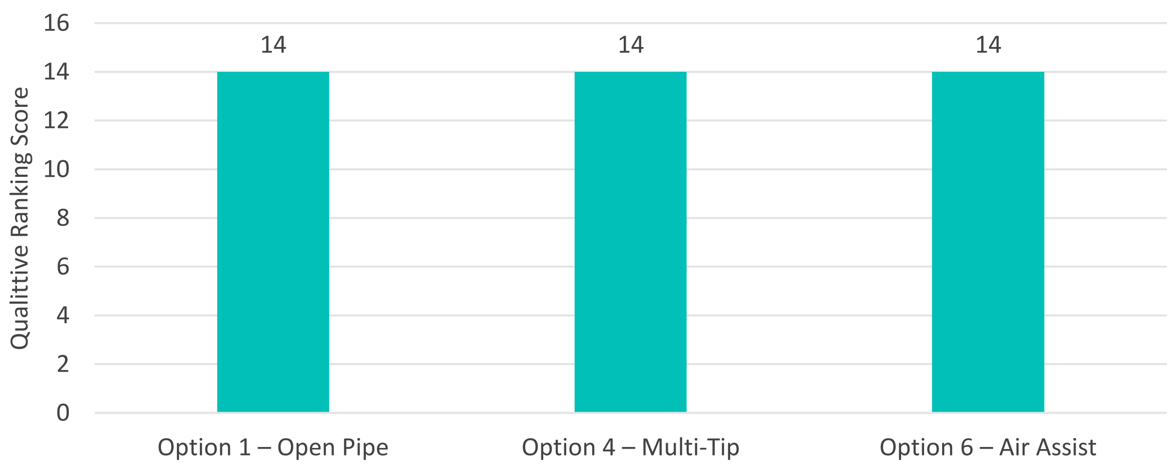


Figure 4-10 Qualitative Ranking of Environmental Criteria for Flare Design Alternatives

The next step of the comparative assessment is to assess the other project drivers and key criteria (economic, technical feasibility and safety and social). This allows a further comparison of the options.

Table 4-14 provides the comparative assessment of other projects drivers for each alternative.

Table 4-14 Comparative Assessment of Economic, Technical Feasibility and Safety and Social Criteria for each Flare Design Option

Criteria	Evaluated Concepts – Qualitative Ranking and Justification					
	Option 1 – Open Pipe		*Option 4 – Multi-Tip*		*Option 6 – Air assist*	
Schedule risk	1	No additional schedule risk identified	1	No additional schedule risk identified	1	No additional schedule risk identified
Economic viability	1	Lowest cost alternative	2	Additional cost of flare headers, tips and flare structure	2	Additional cost of flare headers, tips, flare structure and blower package
Future flexibility risk	1	No risk to future flexibility. Flare will be sized for associated gas rate of each field	1	No risk to future flexibility. Flare will be sized for associated gas rate of each field	1	No risk to future flexibility. Flare will be sized for associated gas rate of each field
Safety risk	1	No additional safety risk identified	2	Minor increased complexity of flare tip may result in additional minor maintenance activities. No significant change in safety risk identified.	2	Minor increased complexity of flare tip and blower may result in additional minor maintenance activities. No significant change in safety risk identified
Operability and feasibility risk	1	No additional risk identified. Simplest flare system available	2	Minor increased complexity of flare tip may result in additional minor maintenance activities.	2	Minor increased complexity of flare tip and blower may result in additional minor maintenance activities.
Technical readiness	1	Standard practice and readily deployed design in industry	1	Standard practice and readily deployed design in industry	1	Standard practice and readily deployed design in industry

Criteria	Evaluated Concepts – Qualitative Ranking and Justification					
	Option 1 – Open Pipe		***Option 4 – Multi-Tip***		***Option 6 – Air assist***	
Constructability, Re-useability, Decommissioning Feasibility	1	No issues identified	1	No issues identified	1	No issues identified
Avoidance/ minimisation of impacts to other oil and gas activities / fisheries	1	No issues identified	1	No issues identified	1	No issues identified
Reputation and community expectation	3	Flaring of associated gas. Not utilising natural resources as efficiently as possible. Intergenerational equity value of flared gas not valued.	3	Flaring of associated gas. Not utilising natural resources as efficiently as possible. Intergenerational equity value of flared gas not valued.	3	Flaring of associated gas. Not utilising natural resources as efficiently as possible. Intergenerational equity value of flared gas not valued.

Figure 4-11 shows the qualitative ranking score for technical feasibly and safety, economic and social drivers, for each option, as assessed in Table 4-14, with the lowest score giving the best outcome.

The comparative assessment (excluding environment) shows that the most favourable concept environmentally is Option 1.

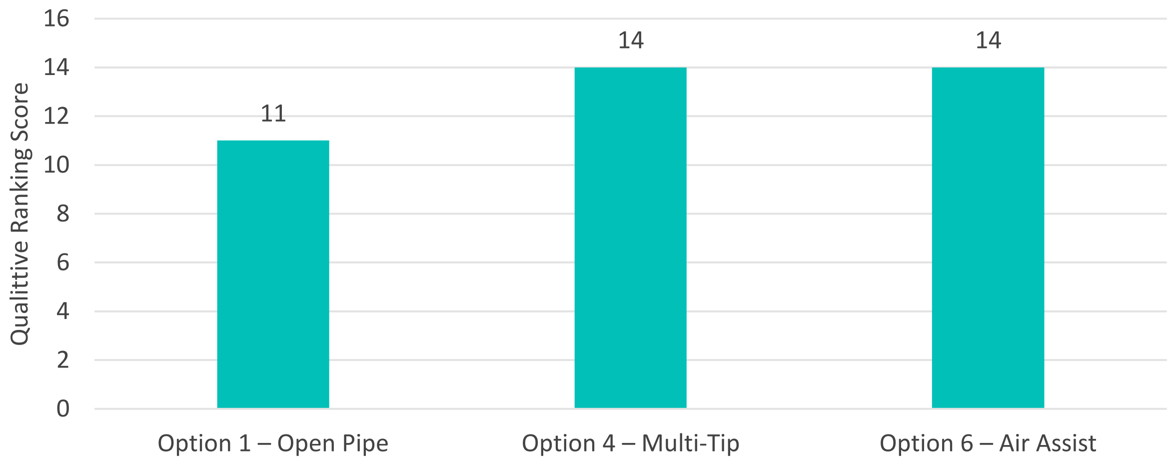


Figure 4-11 Qualitative Ranking of Economic, Technical Feasibility and Safety and Social Criteria for Flare Design

Figure 4-12 shows the total qualitative ranking score for each concept against the all assessment drivers and criteria (including environmental criteria). This shows that there is limited differentiation between all alternatives when considering all criteria.

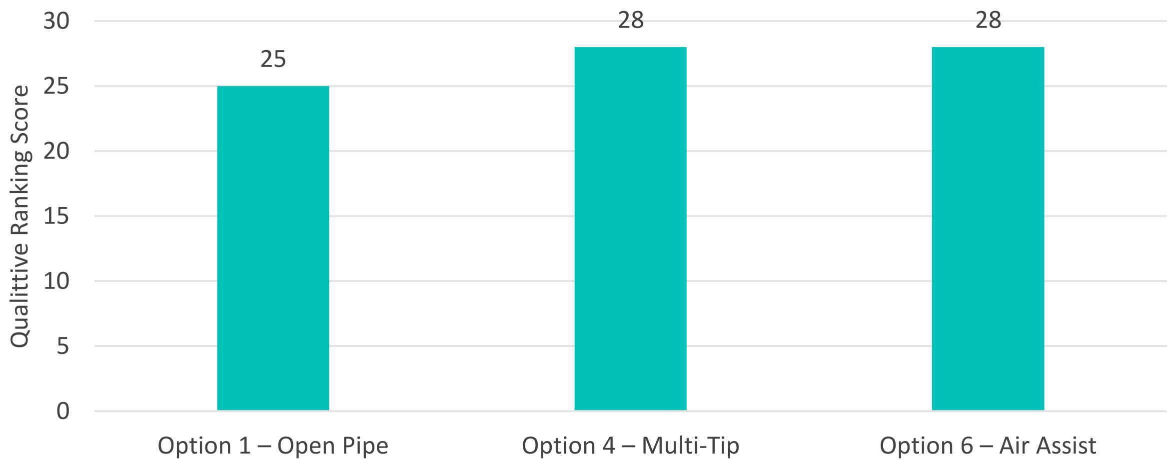


Figure 4-12 Qualitative Ranking of All Criteria for Flare Design Options

In summary, all alternatives were selected to be carried through to FEED as for there is limited differentiation between each. There is no significant environmental differentiator between Options 1, 4 and 6 (Open pipe, Multi-tip and Air assist) alternatives.

Further design and engineering work are required to understand the benefits of each alternative and make an ALARP decision on the selection of the flare design, which will be undertaken when topsides design is more advanced, and the process design is completed. Key inputs include separator operating pressure envelope, stream discharge compositions and manufacturer design details.

Therefore, the three feasible alternatives will be carried through to FEED to allow for detailed study to determine if incremental changes in combustion conditions associated with each flare type will result in an ALARP flare design for light emissions. This analysis will be described in future EPs.

4.3.3 Produced Formation Water (PFW) Treatment and Disposal

Produced Formation Water (PFW) is produced as a by-product along with the oil and gas. PFW contains some of the chemical characteristics of the formation from which it was produced and from the associated hydrocarbons.

Two options were considered for PFW treatment and disposal.

- **Option 1 – Reinjection:** Eliminates discharge of PFW to the marine environment. This alternative requires installation of water treatment and injection skid, additional power generation on the MOPU and construction of a water injection well to a suitable injection zone. As no well exists a new water injection well is required. Water is separated from the oil with primary treatment to remove oil and solids and is then pumped into a water disposal well.
- **Option 2 – Discharge to ocean**: Separation of oil and water and treatment of water to 29 mg/L prior to discharge to the ocean. This alternative requires the installation of water treatment equipment such as oil-water separator, degasser, coalescer, hydrocyclone or centrifuge units to remove oil-in-water. Following treatment produced water is discharged to the ocean either at the surface or subsea.

Both options are considered feasible, therefore both alternatives were carried through into the comparative assessment.

The relevant environmental criteria for the comparative assessment were selected from Table 4-1, and were identified as:

- Physical Presence (Seabed Disturbance)
- Atmospheric Emissions
- Planned Discharges
- Unplanned Discharges / Accidental Releases.

Environmental criteria were assessed using the process and criteria described in Section 4.1.2. Table 4-15 provides the comparative assessment of environmental criteria for each option. Environmental drivers and criteria refer to relevant environmental aspects triggered by activities undertaken for each option. Where an environmental aspect was not triggered, low or no risk is determined.

Table 4-15 Assessment Against Environmental Criteria for PFW Disposal Options

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – Reinjection		*Option 2 – Discharge to Ocean*	
Physical Presence: Seabed Disturbance	1	Minor impact associated with drilling cuttings for additional well.	1	No impact: No subsea infrastructure

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – Reinjection		*Option 2 – Discharge to Ocean*	
Atmospheric Emissions	2	Produced water reinjection requires significant additional power generation and associated air emissions.	1	Minimal additional power requirements
Planned Discharges	1	Minor emissions from drilling of a disposal well. No produced water discharges.	3	Moderate impact: Localised temporary impact associated with discharge of produced water to the marine environment.
Unplanned Discharges / Accidental Releases	4	Additional well required. Incremental risk of well loss of containment during construction and operation.	2	Potential for process upset leading to unplanned discharge of out of specification produced water and localised temporary impact to marine water quality.

PFW reinjection eliminates discharge into the marine environment. The drilling of a water disposal well results in liquid and solid waste and an increase in physical footprint associated with drilling cuttings and drilling fluids. The construction of the injection well introduces an incremental well control risk by entering the reservoir with a second penetration. Reinjection of PFW into the production reservoir poses additional risks to reservoir integrity, oil production and the potential need for remedial actions:

- increased water cut / production – additional topside treatment facilities therefore making the facility larger
- reservoir souring, scaling and formation damage – additional well interventions, early cessation of production.

These may result in increased safety risks, increased chemical usage and reduced production. Reservoir injection is not feasible in all reservoirs, as such this alternative does not align with the design philosophy of the MODU. The cost of a drilling a dedicated water disposal well and associated surface high-pressure pumping equipment is not cost commensurate compared to the overall development cost. Given the above this alternative is not selected.

Therefore, Option 1 – Reinjection was not selected, and Option 2 – Discharge to Ocean has been selected as KATO's preferred strategy for PFW disposal.

Treatment and disposal of PFW will result in localised temporary impacts to water quality, which has been assessed for potential environment impact in Section 7.1.9. This alternative does not require additional subsea equipment or wells, has a significantly lower capital cost to reinjection and is in line with the design philosophy of Concept 1 – Honeybee production system, allowing for redeployment at the next field.

Other oil and gas operators in the Carnarvon Basin and North West Shelf successfully meet environmental performance criteria with this PFW treatment and disposal strategy.

KATO will finalise the produced water treatment strategy including selection of produced water treatment technology during FEED.

4.3.4 Drilling Facility – MOPU and Separate MODU or MOPU with Drilling Capability

Two options for the drilling facilities were considered:

- **Option 1 – MOPU (Mobile offshore drilling and production unit) with Drilling capability**: This alternative is a mobile self-elevating jack-up platform with both drilling, production and export facilities installed. This unit is able to drill, plug and abandon oil wells as well as produce, process and export oil via a separate catenary anchor leg mooring (CALM) buoy oil export system.
- **Option 2 – MOPU and separate MODU (Mobile offshore drilling unit)**: This alternative utilises two separate mobile self-elevating jack-up platforms. The MOPU has facilities to plug and abandon wells but does not have the capability to drill wells. A MOPU is first positioned on site with oil processing and treatment and export facilities preinstalled. The export facilities are connected to a separate catenary anchor leg mooring (CALM) buoy oil export system. Once installed a MODU is set-up adjacent to the MOPU, and drills wells through the MOPU's conductor deck. Once the wells are drilled the MODU demobilises. The MODU would be in position alongside the MOPU for approximately six months during the drilling phase only.

The key environmental criteria for the comparative assessment were selected from Table 4-1, and were identified as:

- IMS
- Physical Presence: Seabed Disturbance
- Planned Discharges
- Unplanned Discharges / Accidental Releases.

Environmental criteria were assessed using the process and criteria described in Section 4.1.2. Table 4-16 provides the comparative assessment of environmental criteria for each option. Environmental drivers and criteria refer to relevant environmental aspects triggered by activities undertaken for each option. Where an environmental aspect was not triggered, low or no risk is determined.

Table 4-16 Assessment Against Environmental Criteria for Drilling Facility Options

Criteria	Evaluated Option – Qualitative Ranking and Justification			
	Option 1 – MOPU with Drilling capability		*Option 2 – MOPU and separate MODU*	
Invasive Marine Species	2	Moderate risk of IMS with mobilisation of MOPU.	2	Moderate risk of IMS with mobilisation of MOPU and incremental increase in risk with mobilisation of additional MODU, although if a MODU already in Australian waters was available, this would be preferred for cost and regulatory reasons.
Physical Presence: Seabed Disturbance	1	Slight impact associated with physical footprint of jack-up legs (~1,500 m^2)	2	Slightly greater physical footprint of jack-up legs for two facilities – assume double that of MOPU alone (~3,500 m^2).
Planned Discharges	1	Planned discharges from drilling activities and vessel systems (cooling water, sewage)	1	Planned discharges from drilling activities and vessel systems (cooling water, sewage) for two facilities, though the MODU is only at Corowa for ~5 months, possibly an additional 4 months if infill drilling is required.

Criteria	Evaluated Option – Qualitative Ranking and Justification			
	Option 1 – MOPU with Drilling capability		*Option 2 – MOPU and separate MODU*	
Unplanned Discharges / Accidental Releases	4	High risk associated with drilling loss of containment.	4	High risk associated with drilling loss of containment.

There is no significant environmental differentiator between the two alternatives. Therefore, the decision for selection of mooring methodology will be based on technical feasibility, safety and cost.

Both options are selected to carry through to FEED. As Option 2 – MOPU and separate MODU presents the slightly greater environmental risk, this has been used as the basis for impact assessment in Section 7. It is also the base case.

4.3.5 Drilling Cuttings Handling and Drilling Fluids Type

Drilling fluids (drilling muds) are used in drilling operations to carry rock cuttings to the surface and to lubricate and cool the drill bit. The drilling fluids, by hydrostatic pressure, also helps prevent the collapse of unstable strata into the borehole and the intrusion of water from water-bearing strata that may be encountered. The drilling fluid is weighted to provide a barrier to reservoir fluids and prevent fluids from migrating to the surface during drilling operations.

The specific type and mix of drilling fluid will depend on the final proposed design and drilling requirements encountered on site. WBM will be used in preference to SBM due to their better environmental performance. The requirement to use SBM is typically associated with technical drilling needs and drilling safety when encountering challenging drilling.

There are two types of drilling fluids—water-based muds (WBM) and synthetic-based muds (SBM).

The options that were considered are:

- **Option 1 – Water-based mud (WBM)** – WBM is a water or saltwater based fluid. WBM combines other additives such as bentonite clay, barite and gellents (e.g. guar gum or xanthan gum) to make the drilling mud more effective.
- **Option 2 – Synthetic-based mud (SBM)** – SBM is a nonaqueous based fluid such as hydrocarbon, ether, ester, or acetal rather than water or oil. SBM combines other additives to make the drilling mud more effective such as organophilic clays, barite, lime, aqueous chloride, rheology modifiers fluid loss control agents and emulsifiers. SBM are particularly useful for drilling in hard substrate conditions as may be found at Corowa and ensuring hole stability when deviated hole drilling.

The relevant environmental criteria for the comparative assessment were selected from Table 4-1, and were identified as:

- Physical Presence: Seabed Disturbance
- Planned Discharges.

Environmental criteria were assessed using the process and criteria described in Section 4.1.2. Table 4-17 provides the comparative assessment of environmental criteria for each option. Environmental drivers and criteria refer to relevant environmental aspects triggered by activities undertaken for each option. Where an environmental aspect was not triggered, low or no risk is determined.

Table 4-17 Assessment Against Environmental Criteria for Drilling Fluid Options

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – WBM		*Option 2 – SBM*	
Planned Discharges	2	Some components of WBMs likely to be of low to moderate toxicity and persistent in the marine environment.	3	Some components of SBMs likely to be of moderate toxicity and persistent in the marine environment.
Physical Presence: Seabed Disturbance	1	Cuttings likely to accumulate in piles with local disturbance. Some components of WBMs may have a long half-life in the environment.	2	Cuttings likely to accumulate in piles with local disturbance. Some components of SBMs are known to have a long half-life in the environment.

There is no significant environmental differentiator between the two alternatives, though WBM have a slightly better ranking. Therefore, the decision for selection of drilling fluids will be based on technical feasibility and safety, and drilling technical requirements. Drilling of top-hole sections will likely use seawater and/or WBM, but bottom-hole sections and into the reservoir will likely use SBM. Both options are selected to carry through to FEED, and a combination of both may be used.

4.3.6 Oil Export Strategy

Oil is exported from the MOPU via a subsea pipeline connected to a CALM buoy. A vessel is connected to the CALM buoy, where oil is stored prior to transport to an oil refinery. Two alternatives were considered for the oil export strategy:

- **Option 1 – FSO and export tankers**: A single FSO moored to the CALM buoy for the duration of the project with trading tankers periodically receiving cargo from the FSO via a flexible offloading hose.
- **Option 2 – Shuttle tankers**: A shuttle tanker attaching to the CALM buoy receiving oil from the MOPU until its cargo tanks are full. Once the tanker is full the MOPU diverts oil to onboard buffer holding tank. The shuttle tanker disconnects form the CALM buoy and sails to a refinery. A second shuttle tanker connects to the CALM buoy and oil production is then diverted from the MOPU buffer holding tank to the second shuttle tanker until its cargo tanks are full and the above process is repeated.

As both oil export strategy alternatives are technically feasible a comparative assessment has been undertaken. The relevant environmental criteria for the comparative assessment were selected from Table 4-1, and were identified as:

- IMS
- Interaction with marine fauna (vessel movement)
- Planned Discharges
- Unplanned Discharges / Accidental Releases.

Environmental criteria were assessed using the process and criteria described in Section 4.1.2. Table 4-18 shows the comparative environmental assessment of the alternatives. Environmental drivers and criteria refer to relevant environmental aspects triggered by activities undertaken for each concept. Where an environmental aspect was not triggered, low or no risk is determined.

Table 4-18 Assessment Against Environmental Criteria for Oil Export Strategy Options

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – FSO and Export tankers		*Option 2 – Shuttle Tankers*	
Invasive marine species	1	One vessel movement per cargo.	1	One vessel movement per cargo
Physical Presence: Interaction with marine fauna	1	One vessel movement per cargo	1	One vessel movement per cargo
Planned Discharges	2	The FSO is permanently on location at Corowa, therefore the usual vessel discharges would occur for the production life of 2–4.5 years. POB is only ~17–30, so is not significant.	1	Shuttle tanker may take 6–8 hours to offtake, therefore would only discharge during this period.
Unplanned Discharges / Accidental Releases	2	Loss of containment risk from FSO and export tanker and export hose. FSO has greater size of largest storage tanks.	2	Increased oil inventory on MOPU due to requirement for buffer storage tank. Loss of containment risk from MOPU storage, export hose and shuttle tankers.

There is no significant environmental differentiator between the two alternatives, as such the decision for selection of oil export strategy will be based on technical feasibility, safety and cost.

Both options are selected to carry through to FEED. As Option 1 – FSO and export tankers presents the slightly greater environmental risk, this has been used as the basis for impact assessment in Section 7. It is also the base case.

4.3.7 Mooring of CALM Buoy

Whichever oil storage method is ultimately selected, the catenary anchor leg mooring (CALM) buoy is a key focus area. KATO has undertaken a range of studies into various technical options for mooring anchors, which is summarised below (Hydra 2015):

- **Option 1 – Anchoring** (drag anchors): Utilises the vessels' anchor and chain.
  - This option is not considered further due to technical feasibility: not feasible due to insufficient holding capacity and hard substrate conditions limiting anchor embedment.
- **Option 2 – Suction anchor piles**: This alternative involves a tube (e.g. casing) sealed at one end being lowered onto the seabed, water is then pumped out of the space between the seabed and the top of the sealed tube to embed it in the seabed. A mooring is then attached to the top of the tube.
  - This option is not considered further due to technical feasibility: The Corowa location is not suitable for suction piling due to the occurrence of hard layers in the substrate.
- **Option 3 – Drilled and grouted anchor piles**: Installation of piles by using an installation support vessel (ISV). This vessel drills a hole that the pile (e.g. drill casing) is lowered into. Grout is then pumped around the base of the pile to attach it to the substrate. A mooring is then installed on each pile. Piles are not relocatable; the mooring line would be cut off below the mudline at decommissioning.
- **Option 4 – Gravity anchor** (dead man's anchor): This alternative requires large gravity structures (concrete or steel) with a mooring attached being lowered to the sea floor, then filling with ballast (anchor chain or weights). Gravitational forces ensure the anchor does not move. Gravity anchors are recoverable and reusable at the end of field life.

The relevant environmental criteria for the comparative assessment were selected from Table 4-1, and were identified as:

- Physical Presence: Seabed Disturbance
- Underwater Noise Emissions
- Planned Discharges
- Lifecycle environmental impacts.

As both drilled and grouted anchor piles and gravity anchors are technically feasible, a comparative assessment has been undertaken.

Environmental criteria were assessed using the process and criteria described in Section 4.1.2. Table 4-19 provides the comparative assessment of environmental criteria for each option. Environmental drivers and criteria refer to relevant environmental aspects triggered by activities undertaken for each option. Where an environmental aspect was not triggered, low or no risk is determined.

Table 4-19 Assessment Against Environmental Criteria for CALM Buoy Mooring Options

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 3 – Drilled and Grouted Anchor Piles		***Option 4 – Gravity Anchors***	
Physical Presence: Seabed Disturbance	2	There will be some direct seabed disturbance at the Project Area where the piles are installed due to cuttings discharge (total of 60 m^2), however as area does not intersect environmentally sensitive habitats, this impact is low. .	2	There will be a total of 720 m^2 seabed disturbance at the Project Area for the three gravity anchors, however as area does not intersect environmentally sensitive habitats, this impact is low.
Underwater Noise Emissions	1	Installation noise emissions from installation vessel and drilling. Drilling would be of short duration as is shallow (~25 m).	1	Noise emissions are from the installation vessel.
Planned Discharges	2	Some minor localised discharges associated with drilling cuttings and grouting, ~45 m^3 cuttings per hole. Seawater would be used to drill.	1	No planned discharges associated with mooring installation.
Lifecycle environmental impact	1	Casings are not relocatable, but the mooring chain would be cut off below the mudline.	1	Can easily be retrieved when decommissioning.

There is no significant environmental differentiator between the two alternatives, although gravity anchors have a slightly better ranking. Therefore, the decision for selection of mooring of the CALM buoy will be based on technical feasibility and safety, and mooring technical requirements. Both options are selected to carry through to FEED.

5 Description of the Environment

5.1 Overview

The Corowa Development occurs in Commonwealth waters ~60 km offshore from the mainland Pilbara coast, and within the IMCRA Northwest Shelf Province bioregion (Figure 5-1). The Northwest Shelf Province is located primarily on the shelf between North West Cape and Cape Bougainville and covers much of the area commonly known as the North West Shelf (NWS) (Section 5.2.1.1).

5.1.1 Environment that may be Affected

The environment that may be affected (EMBA) by the Corowa Development has been defined as an area where a change to ambient environmental conditions may potentially occur as a result of planned or unplanned activities.

Note: A change does not always imply that an adverse impact will occur; for example, a change may be required over a particular exposure value and/or over a consistent time period for a subsequent impact to occur. The EMBA for the Corowa Development extends between Perth and Lagrange Bay (south of Broome), and offshore into and beyond the Commonwealth waters boundary (Figure 5-2).

For the purposes of the OPP, the EMBA associated with the Corowa Development has been demarcated into three sub-areas that are used to support impact and risk assessments (Table 5-1, Figure 5-2).

Table 5-1 Description of Corowa Development EMBA and Sub-Areas

Corowa Development EMBA and Sub-Areas	Description
EMBA	This area has been defined as an area where a change to ambient environmental conditions may potentially occur as a result of planned or unplanned activities. The spatial extent of the EMBA for the Corowa Development is based on the results of stochastic oil spill modelling of a Loss of Well Control (LOWC) scenario as this represented the largest spatial extent of potential changes to ambient environment conditions from an aspect. That is, the EMBA is based on the cumulative extent of 150 model simulations using 'low' exposure values for each modelled oil component (1 g/m^2 floating, 10 ppb dissolved and entrained, 10 g/m^2 shoreline) (Section 7.2.6.2.4) and includes all probabilities of exposure. The spatial area was then smoothed and simplified to define a northern, southern and offshore outer boundary for the EMBA (Figure 5-2).
Planned Activities	
Project Area	This area has been defined to include the extent of all planned activities (Section 3.4), and is the area relevant to the impact and risk assessments for all planned and unplanned aspects (Section 7), with the exception of light emissions and accidental hydrocarbon releases. The Project Area has been defined as a 5 km area extending around the expected MOPU position [9].

[9] As the position of the MOPU is indicative only at this stage, the identification of values and sensitivities (including an EPBC protected matters search) was completed using a 7 km buffer around the expected position of the MOPU (Appendix A).

Corowa Development EMBA and Sub-Areas	Description
Light Area	This area has been defined to include the worst-case extent of predicted measurable light based on planned activities (Section 3.4), and is the area relevant to the impact assessment for planned light emissions (refer to 'potential impact area' in Section 7.1.3). This Light Area has been defined as a 30 km area extending around the expected MOPU position [10], and is evaluated as the Potential Impact Area in Section 7.1.3
Unplanned Activities	
Hydrocarbon Area	This area has been defined to include the worst-case extent of predicted oil concentrations above ecological and/or visual impact values based on planned activities (Section 3.4), and is the area relevant to the risk assessment for unplanned accidental releases of oil (Corowa Light Crude and Marine Gas Oil; Sections 7.2.6 and 7.2.7 respectively). This Hydrocarbon Area has been defined based on the outcomes of stochastic modelling (i.e. it is the cumulative extent of 150/300[11] model simulations) using exposure values for each modelled oil component (1 g/m^2 floating, 50 ppb dissolved, 100 ppb entrained, 10 g/m^2 shoreline) and includes all probabilities of exposure[12].

Under the OPGGS(E)R, the OPP must describe the EMBA (Regulation 5A(5c)), including details of the particular values and sensitivities (if any) within that environment (Regulation 5A(5d)). Identified values and sensitivities must include, but are not necessarily limited to, the matters protected under Part 3 of the EPBC Act (Regulation 5A(6)).

Descriptions of the physical, ecological, social, economic and cultural environments, their associated values and sensitivities, and their presence in each of the above sub-areas, are described in the following subsections.

[10] The identification of values and sensitivities (including an EPBC protected matters search) was completed using a 30 km buffer around the expected position of the MOPU (Appendix A).

[11] 150 model simulations were run for the subsea release of Corowa Light Crude, and 300 simulations were completed for the surface release of MGO (refer to Sections 7.2.6 and 7.2.7 for further discussion on modelling).

[12] The identification of values and sensitivities (including an EPBC protected matters search) was completed using the outer extent of modelled exposures at the above (Appendix A).

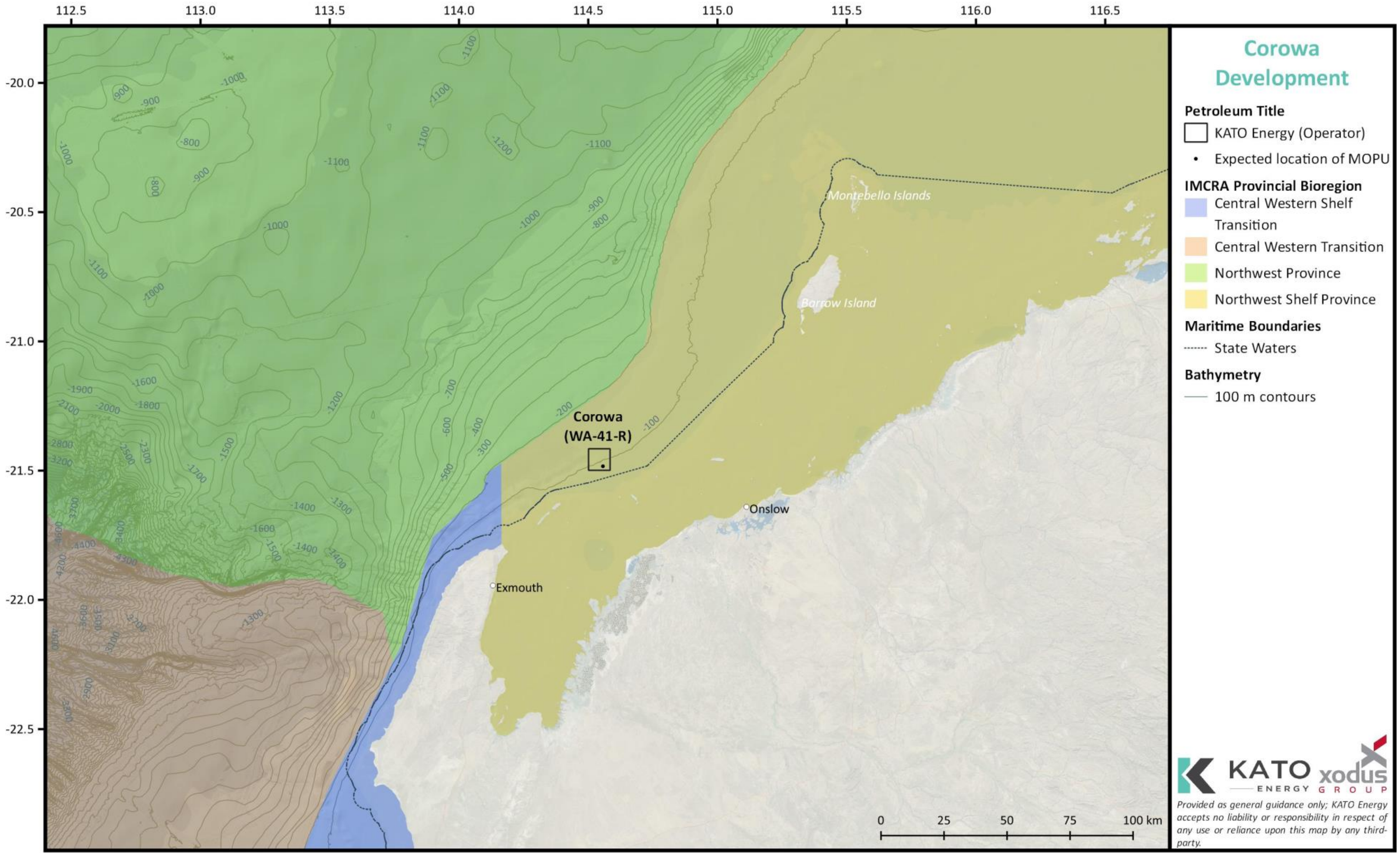


Figure 5-1 Location of Corowa Development with IMCRA Provincial Bioregions

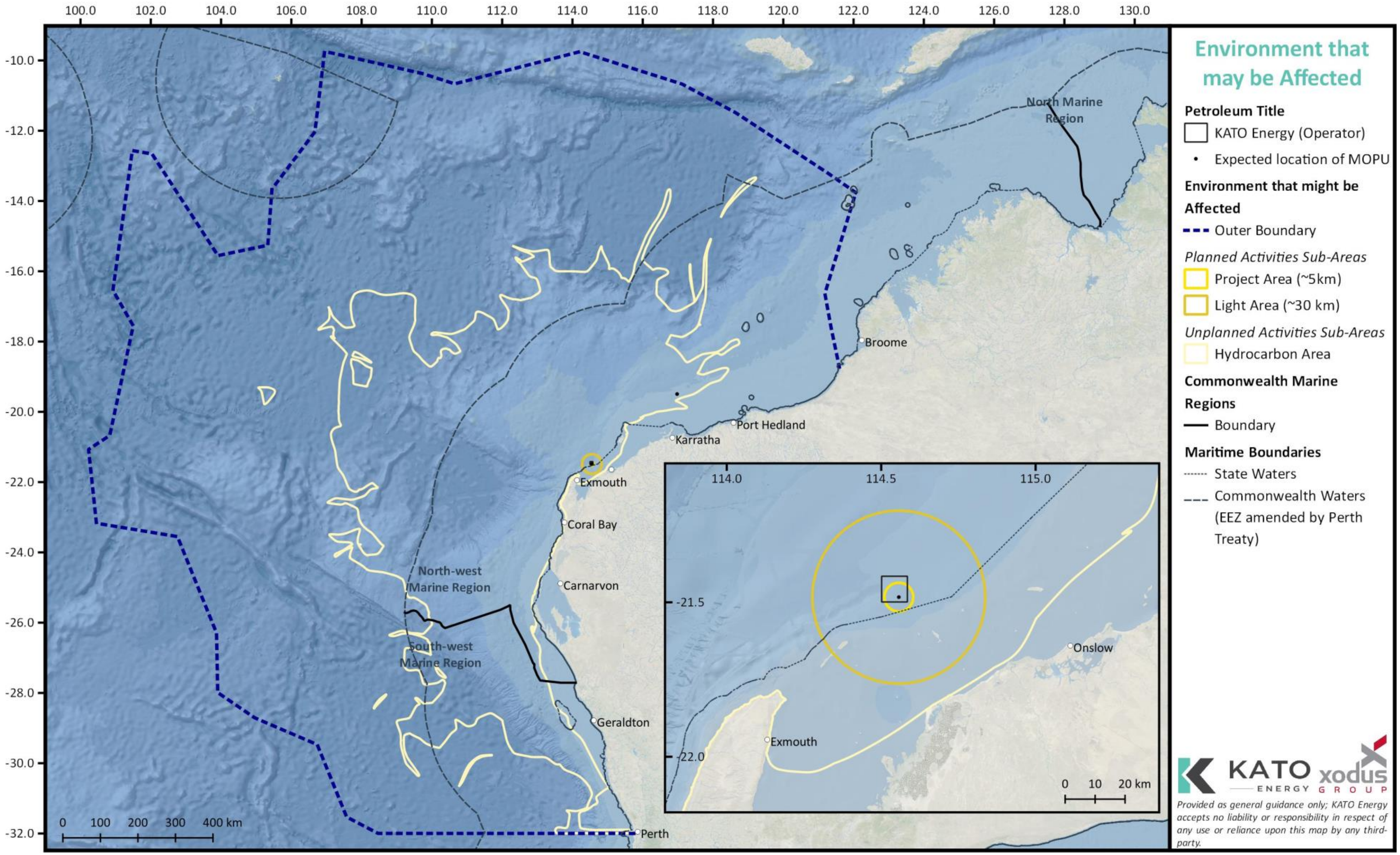


Figure 5-2 Environment that may be Affected (with sub-areas) for the Corowa Development

5.2 Regional Context

5.2.1 North-west Marine Region

The North-west Marine Region (NWMR)comprises Commonwealth waters from the Western Australian – Northern Territory border to Kalbarri (Figure 5-2), covering ~1.07 million km^2 of tropical and subtropical waters (DEWHA 2008).

Those parts of the NWMR adjacent to the Kimberley and Pilbara include thousands of square kilometres of shallow continental shelf (accounting for ~30% of the total NWMR). The NWMR also includes Australia's narrowest shelf margin, located at Ningaloo Reef. Over 60% of the seafloor in the NWMR is continental slope, of which extensive terraces and plateaux make up a large proportion. Those parts of the Argo and Cuvier abyssal plains that are within the NWMR comprise ~10% of the total area.

Overall, the NWMR is relatively shallow with more than 50% having water depths of <500 m. The deepest parts are associated with the Argo and Cuvier abyssal plains, reaching water depths of ~6,000 m.

The NWMR is characterised by shallow-water tropical marine ecosystems. While in general endemism is not particularly high by Australian standards, the NWMR is home to globally significant populations of internationally threatened species (DEWHA 2008).

5.2.1.1 North-west Shelf Province

The North-west Shelf Province covers an area of 238,759 km^2 and is located primarily on the continental shelf between North West Cape and Cape Bougainville. The bioregion varies in width from ~50 km at Exmouth Gulf to greater >250 km off Cape Leveque and covers water depths of 0–200 m (>45% of which are within the shallower 50–100 m range) (DEWHA 2008).

The bioregion is a dynamic oceanographic environment, influenced by strong tides, cyclonic storms, long-period swells and internal tides. The oceanography is dominated by the movement of surface currents derived from the Indonesian Throughflow (which are warm and oligotrophic) and circulate throughout the bioregion via branches of the South Equatorial and Eastern Gyral Currents. The Holloway Current also moves southwards along the NWS, bringing waters from the Banda and Arafura seas and the Gulf of Carpentaria at the conclusion of the Australian monsoon season (DEWHA 2008; Pattiaratchi et al. 2014).

The surface water layers of this bioregion are highly stratified during summer months, with the thermocline occurring at water depths of 30–60 m, whereas during winter the surface waters are well mixed, with the thermocline occurring at ~120 m depth (DEWHA 2008).

The sandy substrates on the continental shelf are thought to support low-density benthic communities of bryozoans, molluscs and echinoids (DEWHA 2008). Sponge communities are also sparsely distributed on the shelf but are found only in areas of hard substrate (DEWHA 2008).

Fish communities are diverse, with both benthic and pelagic fish communities represented. The benthic and pelagic fish communities of the Northwest Shelf Province are strongly depth-related, indicative of a close association between fish communities and benthic habitats (Brewer et al. 2007; DEWHA 2008). Humpback Whales migrate through the bioregion and Exmouth Gulf is an important resting area, particularly for mothers and calves on their southern migration (DEWHA 2008). Numerous nesting sites for Green, Hawksbill, Flatback and Loggerhead Turtles occur along the coast and on offshore islands in and adjacent to the NWMR.

The bioregion supports significant breeding populations of several seabird species including Wedge-tailed Shearwaters, Crested, Bridled and Sooty Terns, Brown Boobies and Lesser Frigatebirds (DEWHA 2008). A number of important seabird breeding sites are located in areas adjacent to the

NWMR including the Lacepede Islands, Eighty Mile Beach, Roebuck Bay, Serrurier Island and Montebello, Lowendal and Barrow islands (DEWHA 2008).

5.2.2 South-west Marine Region

The South-west Marine Region (SWMR) comprises Commonwealth waters from the eastern end of Kangaroo Island in South Australia to Kalbarri in Western Australia. The region spans ~1.3 million km^2 of temperate and subtropical waters (DEWHA 2008e).

The main physical features of the SWMR include a narrow continental shelf on the west coast from the subtropics to temperate waters off south-west Western Australia, with a wide continental shelf dominated by sandy carbonate sediments of marine origin (i.e. crushed shells from snails and other small animals and calcareous algae) in the Great Australian Bight. There is high wave energy on the continental shelf around the whole region.

Depths vary throughout the SWMR, with islands and reefs in both subtropical (e.g. Houtman Abrolhos Islands) and temperate waters (e.g. Recherche Archipelago), and a steep, muddy continental slope, which include many canyons (the most significant being the Perth Canyon, the Albany canyon group and the canyons near Kangaroo Island). Deeper waters also occur, including large tracts of abyssal plains in water depths >4,000 m, the Diamantina Fracture Zone (a rugged area of steep mountains and troughs off south-west Australia at depths up to 5,900 m) and the Naturaliste Plateau (an extension of Australia's continental mass that provides deep water habitat at depths of 2,000–5,000 m).

By global standards, the marine environment of the SWMR has high biodiversity and large numbers of species native to the region (DEWHA 2008e). Particular hotspots for biodiversity are the Houtman Abrolhos Islands, he Recherche Archipelago and the soft sediment ecosystems in the Great Australian Bight.

The biological productivity of the SWMR is relatively low, mainly because of the interactions of the Leeuwin Current with other currents, which result in the absence of large seasonal upwellings of nutrient-rich water from the deeper parts of the SWMR. However, small seasonal upwellings (e.g. Spencer Gulf, Cape Mentelle, Perth Canyon) do occur and this enhanced productivity increases local biodiversity and aggregation.

5.2.3 Christmas Island Territory

Christmas Island an external territory located in the Indian Ocean, part of the Indian Ocean Territories (IOT). The island has an area of 137.4 km^2 and includes the Christmas Island National Park (135 km^2).

Christmas Island is the summit of a submarine mountain, which rises steeply from sea level to a central plateau (of up to 361 m) and consists mainly of limestone and layers of volcanic rock (Geoscience Australia 2019c). Its coast is an almost continuous sea cliff reaching heights of up to 20 m and is surrounded by a narrow tropical reef. There is virtually no shelf region, with water depths increasing to ~500 m within ~200 m of the edge of the reef (Geoscience Australia 2019c).

Christmas Island's proximity to South-East Asia and the equator has resulted in a diverse range of flora and fauna. The land crabs and seabirds are the most noticeable fauna on the island: to date, 20 terrestrial and intertidal crabs have been described, and eight species or subspecies of seabirds are known to nest on the island (DITCRD 2019).

5.2.4 Outside Australia's Exclusive Economic Zone

Australia's Exclusive Economic Zone (EEZ) extends to 200 nm from the territorial sea limit along the mainland and Australia's Indian Ocean Territories. Australia's EEZ shares boundaries with:

- international waters to the west and south of the WA

- Indonesia to the north west (this boundary is defined in accordance with the Perth Treaty negotiated with the Republic of Indonesia)
- the Joint Petroleum Development Area (JPDA) in the Timor Sea along the northern edge of the EEZ.

International waters are managed under the United Nations Law of the Sea Convention (UNCLOS), administered by the International Maritime Organisation (IMO). The JPDA is regulated by the National Petroleum Authority (Autoridade Nacional do Petróleo) of Timor-Leste on behalf of the Government of Australia and the Government of Timor-Leste.

The EMBA does not extend into nearshore or coastal areas of Indonesia.

5.3 Physical Environment

5.3.1 Water Quality

Marine water quality within the Pilbara region is expected to be representative of the typically pristine and high-water quality found in offshore Western Australian waters. Variations to this state (e.g. increased turbidity) may occur in more coastal regions that are subject to large tidal ranges, terrestrial run-off or anthropocentric factors (i.e. ports, industrial discharges, etc.).

Water quality sampling data available within Pilbara coastal waters show:

- no detectable hydrocarbons, with BTEX, PAH and TPH below the laboratory LOR (Wenziker et al. 2006)
- concentrations of metals were typically below the ANZECC and ARMCANZ (2000) 99% species protection guidelines (Wenziker et al. 2006)
- slightly elevated levels (although still above the 95% species protection levels) of copper and zinc were recorded within the inner harbour at Port Hedland (Wenziker et al. 2006).

It is expected that water quality within the vicinity of the Corowa Development and wider EMBA will be typical of the offshore marine environment on the NWS, which is characterised by high water quality with low background concentrations of trace metals and organic chemicals.

5.3.2 Sediment Quality

Marine sediment quality within the Pilbara region is expected to be representative of the typically pristine offshore Western Australian waters. Variations to this state (e.g. increased metal concentrations) may occur in more coastal regions that are subject to large tidal ranges, terrestrial run-off or anthropocentric factors (i.e. ports, industrial discharges, etc.).

Sediment quality sampling data available within Pilbara coastal waters (DEC 2006a) shows:

- no detectable hydrocarbons, with BTEX and PAH below the laboratory LOR
- metal concentrations were variable over the Pilbara coast with no specific trend apparent
- concentrations of metals were typically below the ANZECC and ARMCANZ (2000) ISQG-low guidelines, with the exception of arsenic
- TOC concentrations ranged from 0.13% in Port Hedland to 1.3% at Ashburton River mouth.

It is expected that sediment quality in within the vicinity of the Corowa Development and wider EMBA will be typical of the offshore marine environment on the NWS, which is characterised by high sediment quality with low background concentrations of trace metals and organic chemicals, and little anthropocentric influence.

5.3.3 Air Quality

The majority of the offshore Pilbara region is relatively remote and therefore air quality is expected to be high.

Anthropogenic sources (e.g. vessels, industry developments) would contribute to local variation in air quality. However, results of previous monitoring within the region suggest that the concentration of air quality parameters remains low. For example, measured levels of nitrogen dioxide and ozone during a Pilbara air quality study were below the NEPM standards (DoE 2004).

The Corowa Development and wider EMBA is expected to be of typically high air quality due to its offshore location.

5.3.4 Climate

The Pilbara is characterised by very hot summers, mild winters and low and variable rainfall (Sudmeyer 2016). The Pilbara experiences two main seasons: summer/wet and winter/dry (CSIRO 2011). Rainfall is typically greatest during the summer period due to tropical lows and tropical cyclone activity (CSIRO 2011, Sudmeyer 2016). The Pilbara is the most tropical cyclone prone coast in Australia, averaging two cyclones crossing the coast each year. The tropical cyclones experienced within the Pilbara region are also, on average, more severe than elsewhere in Australia (CSIRO 2011).

5.3.5 Ambient Light

Ambient light within the offshore Pilbara region is expected to predominantly be from solar/lunar luminance. However, artificial light sources associated with anthropogenic activities also exist, including both permanent (e.g. onshore/offshore developments) and temporary (e.g. vessels) light sources.

The Corowa Development is located near other permit areas with existing developments, which may influence the ambient light levels of the area by increased anthropogenic activities with artificial light.

5.3.6 Ambient Noise

Ambient noise within the offshore Pilbara region is expected to be dominated by natural physical (e.g. wind, waves, rain) and biological (e.g. echolocation and communication noises generated by cetaceans and fish) sources. Anthropogenic noise sources that are also likely to be experienced in the area include low-frequency noise from vessels.

Background noise levels within the Corowa field are expected to represent the typical range for calm to windy conditions, though heavy rain can result in higher noise levels in the area.

Some vessel traffic, including commercial shipping and fishing, is likely to occur within the vicinity of the Corowa Development; however, main shipping pathways do not occur. Therefore, ambient noise is likely to include some occasional anthropogenic sound sources, typical of those generated by mid to large vessels such as tankers.

5.4 Ecological Environment

5.4.1 Plankton

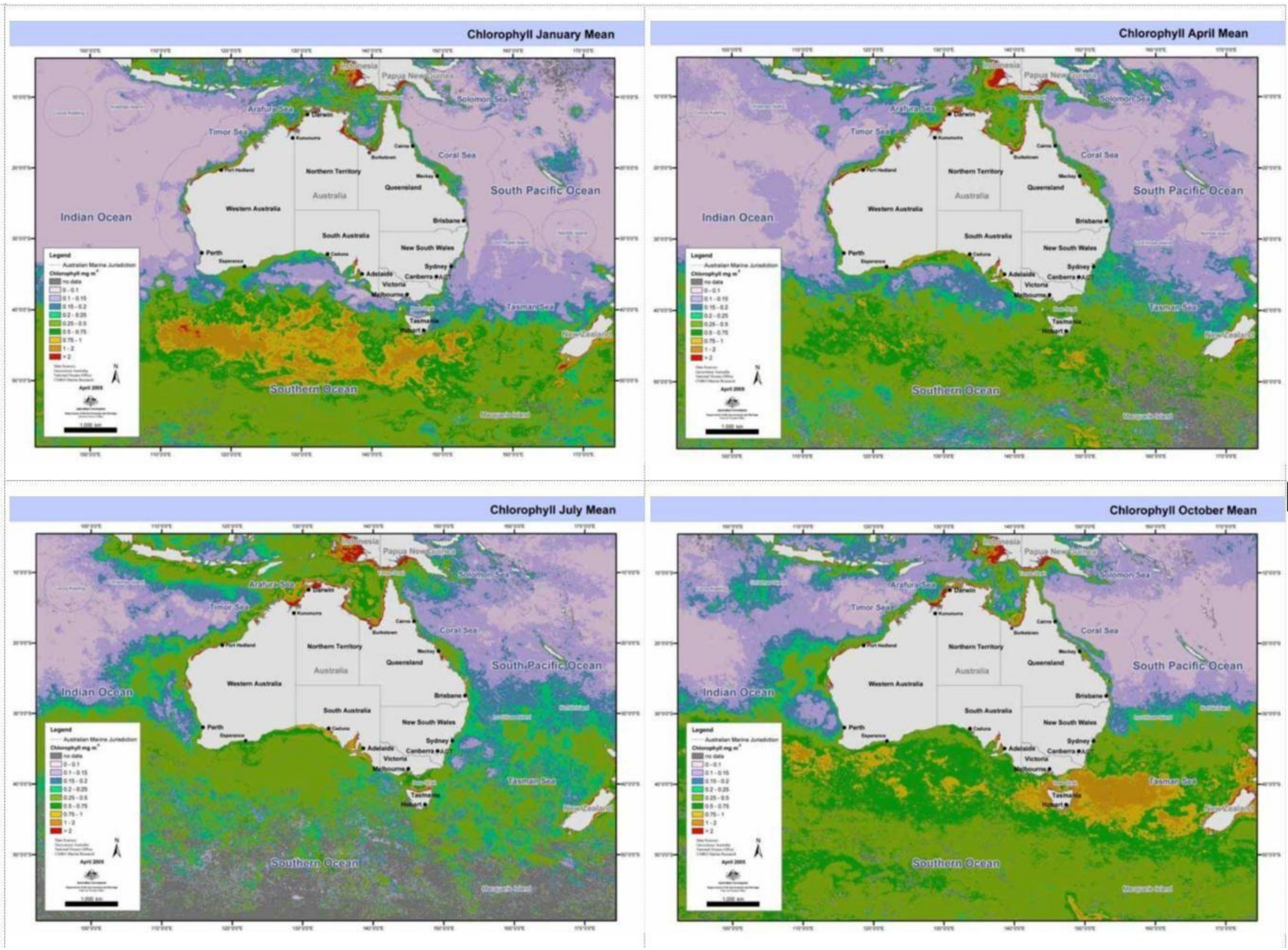
Plankton are microscopic organisms drifting or floating in the sea, consisting chiefly of diatoms, protozoans, small crustaceans, and the eggs and larval stages of larger animals.

Phytoplankton are autotrophic planktonic organisms living within the photic zone, and are the start of the food chain in the ocean (McClatchie et al. 2006). Phytoplankton communities are largely comprised of protists, including green algae, diatoms, and dinoflagellates (McClatchie et al. 2006). Diatoms and dinoflagellates are the most abundant of the micro and nanoplankton size classes and are generally responsible for the majority of oceanic primary production (McClatchie et al. 2006). Phytoplankton are dependent on oceanographic processes (e.g. currents and vertical mixing), that supply nutrients needed for photosynthesis. Thus, phytoplankton biomass is typically variable (spatially and temporally), but greatest in areas of upwelling, or in shallow waters where nutrient levels are high. Seasonal variation in phytoplankton (via chlorophyll-a concentrations) has been demonstrated in Australian waters from the analysis for MODIS-Aqua sensor imagery (Figure 5-3). Offshore phytoplankton communities in the region are characterised by smaller taxa (e.g. cyanobacteria), while shelf waters are dominated by larger taxa such as diatoms (Hanson et al. 2007).

Primary productivity of the North-west Marine Region is generally low and appears to be largely driven by offshore influences (Brewer et al. 2007), with periodic upwelling events and cyclonic influences driving coastal productivity with nutrient recycling and advection. Within the region, peak primary productivity along the shelf edge occurs in late summer/early autumn. Variation in productivity can also be linked to higher biologically productive period in the area (e.g. mass coral spawning events).

Phytoplankton species rapidly multiply in response to bursts in nutrient availability and are subsequently consumed by zooplankton, that are in turn consumed by small pelagic fish. Higher-order tertiary consumers, including squid, mackerel and seabirds, feed on small pelagic fish. Scavengers such as crabs, shrimps and demersal sharks, and fish species such as queenfish, mackerel, King Salmon and Barramundi may also be common (Brewer et al. 2007).

Zooplankton is the faunal component of plankton, comprised of small protozoa, crustaceans (e.g. krill) and the eggs and larvae from larger animals. Zooplankton includes species that drift with the currents and also those that are motile. No aggregations of larger zooplankton (such as krill) were recorded in offshore waters of the Woodside Ngujima-Yin FPSO (~50 km west of the Corowa Development) during a dedicated field (Woodside 2005). The inshore ichthyoplankton assemblages are characterised by shallow reef fishes such as blennies (family Blenniidae), damselfish (family Pomacentridae) and north-west snappers (family Lethrinidae), while offshore assemblages are dominated by deepwater and pelagic taxa such as tuna (family Scombridae) and lanternfish (family Myctophidae) (Beckley, Muhling, and Gaughan 2009). Some of these taxa are commercially and recreationally important species in the region.



Source: McClatchie et al. 2006

Figure 5-3 Seasonal Phytoplankton Growth from MODIS Ocean Colour Composites

5.4.2 Benthic Habitats and Communities

Benthic communities are biological communities that live in or on the seabed. These communities typically contain light-dependent taxa such as algae, seagrass and corals, which obtain energy primarily from photosynthesis, and/or animals such as molluscs, sponges and worms, that obtain their energy by consuming other organisms or organic matter. Benthic habitats are the seabed substrates that benthic communities grow on or in; these can range from unconsolidated sand to hard substrates (e.g. limestone) and occur either singly or in combination.

5.4.2.1 Substrate

The majority of the Northwest Shelf Province is located on continental shelf, with a small area off Cape Leveque that extends onto the containing continental slope (DEWHA 2008). The Corowa Development is situated in ~85–90 m water depth, within the continental shelf, and is characterised by a mixture of calcareous gravel, sands and silts (Figure 5-4). The sediment composition becomes finer (muds and calcareous ooze) in deeper and offshore waters. The shelf gradually slopes from the coast to the shelf break but displays several distinct seafloor features (e.g. banks/shoals, canyons). Key topographic features offshore from the Corowa Development include the Exmouth Plateau, Montebello Trough and Cape Range Canyon.

5.4.2.2 Benthic Communities

The sandy substrates on the continental shelf within the Northwest Shelf Province are thought to support low-density benthic communities of bryozoans, molluscs and echinoids (DEWHA 2008). Sponge communities are also sparsely distributed on the shelf, and typically only occur in areas of hard substrate (DEWHA 2008). Other benthic and demersal species in this bioregion include sea cucumbers, urchins, prawns and squid (DEWHA 2008).

Benthic community assessment has been carried out for the nearby lease area WA-28-L and included ROV surveys of the Vincent field (~50 km west of the Corowa Development). Video and still recordings revealed four main invertebrate groups of deepwater benthos including crustaceans, sponges, echinoderms and cnidarians (octocorals). The results also showed that species diversity decreased with depth across the area (Woodside 2005). Considering the water depth of the Corowa Development, the consequent reduced benthic light levels, and the general lack of hard substrate that many benthic species depend on for attachment, the benthic communities associated with the unconsolidated sediment habitats within the Project Area are of likely to be of relatively low environmental sensitivity.

5.4.2.3 Coral

Corals are generally divided into two broad groups: the zooxanthellate (‘reef-building’, ‘hermatypic’ or ‘hard’) corals, which contain symbiotic microalgae (zooxanthellae) that enhance growth and allow the coral to secrete large amounts of calcium carbonate, and the azooxanthellate (‘ahermatypic’ or ‘soft’) corals, which are generally smaller and often solitary (Tzioumis and Keable 2007). Hard corals are generally found in shallower (<50 m) waters while the soft corals are found at most depths, particularly those below 50 m (Tzioumis and Keable 2007).

The shallower waters within the continental shelf contain an extensive array of small barrier and fringing reefs, including important sites such as Ningaloo Reef and Dampier Archipelago. Corals are also known to occur in shallow areas around some of the Pilbara inshore islands (Figure 5-5).

The Ningaloo Reef is the largest fringing coral reef in Australia and is over 300 km long, forming a discontinuous barrier enclosing a lagoon (CALM 2005). The Ningaloo Reef is a complex ecosystem with high species diversity (CALM 2005). Within Ningaloo Reef there is a high diversity of hard corals with at least 217 species representing 54 genera of hermatypic (reef-building) corals recorded (CALM 2005). Corals are the most important reef-building organisms, and provide food, settlement substrate and shelter for a wide variety of other marine flora and fauna. Coral communities are also important for protection of coastlines through accumulation and cementation of sediments and dissipation of wave energy.

5.4.2.4 Macrophytes

Macrophyte are aquatic plants that grows in or near water and are either emergent, submergent, or floating; they include seagrass and macroalgae.

Seagrasses are marine flowering plants, with about 30 species found in Australian waters (Huisman 2000). Seagrass generally grows in soft sediments within intertidal and shallow subtidal waters where there is sufficient light and are common in sheltered coastal areas such as bays, lees of islands and fringing coastal reefs (McClatchie et al. 2006; McLeay et al. 2003). Seagrass meadows are important in stabilising seabed sediments, and providing nursery grounds for fish and crustaceans, and a protective habitat for the juvenile fish and invertebrates species (Huisman 2000; Kirkman 1997). Seagrasses also provide important habitat for fish and Dugongs within the Northwest Shelf Province (DEWHA 2008).

Known key areas of seagrass habitat within the vicinity of the Corowa Development include within the Ningaloo reef area and within Exmouth Gulf. Ten seagrass species are known to have a geographic distribution encompassing the North West Cape and Exmouth Gulf region (McMahon et al. 2017, Oceanwise 2019). Despite a relatively diverse composition of seagrasses, previous studies have reported relatively low abundance of seagrass habitat within Exmouth Gulf (McCook et al. 1995). However, it is still recognised that large numbers of Dugongs that reside in or visit the Gulf to feed on seagrass beds (DEWHA 2008).

Macroalgae communities are generally found on intertidal and shallow subtidal rocky substrates. Macroalgal systems are an important source of food and shelter for many ocean species, including in their unattached drift or wrack forms (McClatchie et al. 2006). Brown algae are typically the most visually dominant and form canopy layers (McClatchie et al. 2006). The principal physical factors affecting the presence and growth of macroalgae include temperature, nutrients, water motion, light, salinity, substratum, sedimentation and pollution (Sanderson 1997). Macroalgae habitat is known to occur within the nearshore areas surrounding some of the Pilbara inshore islands, including the Muiron Island (Figure 5-5).

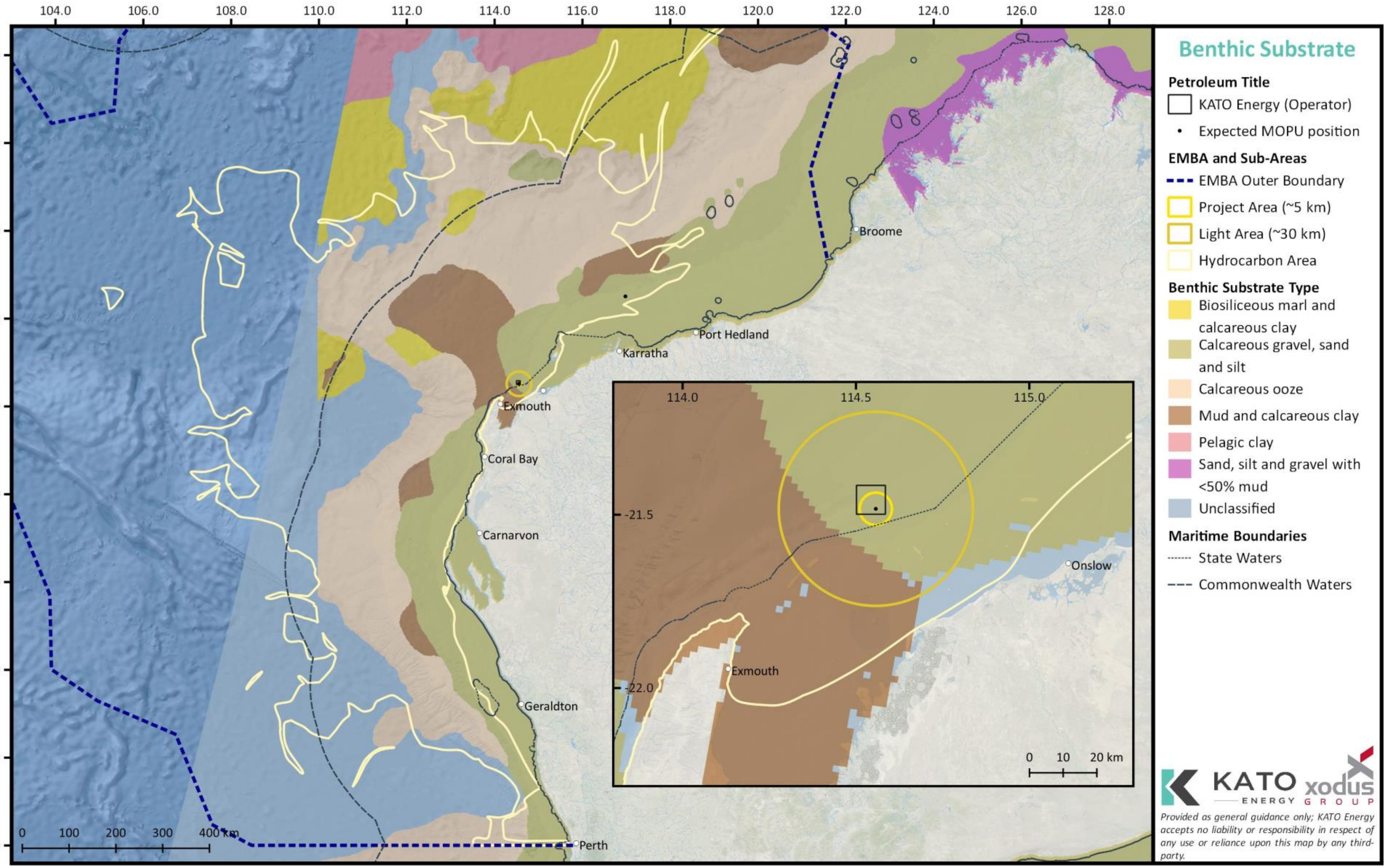


Figure 5-4 Benthic Substrates

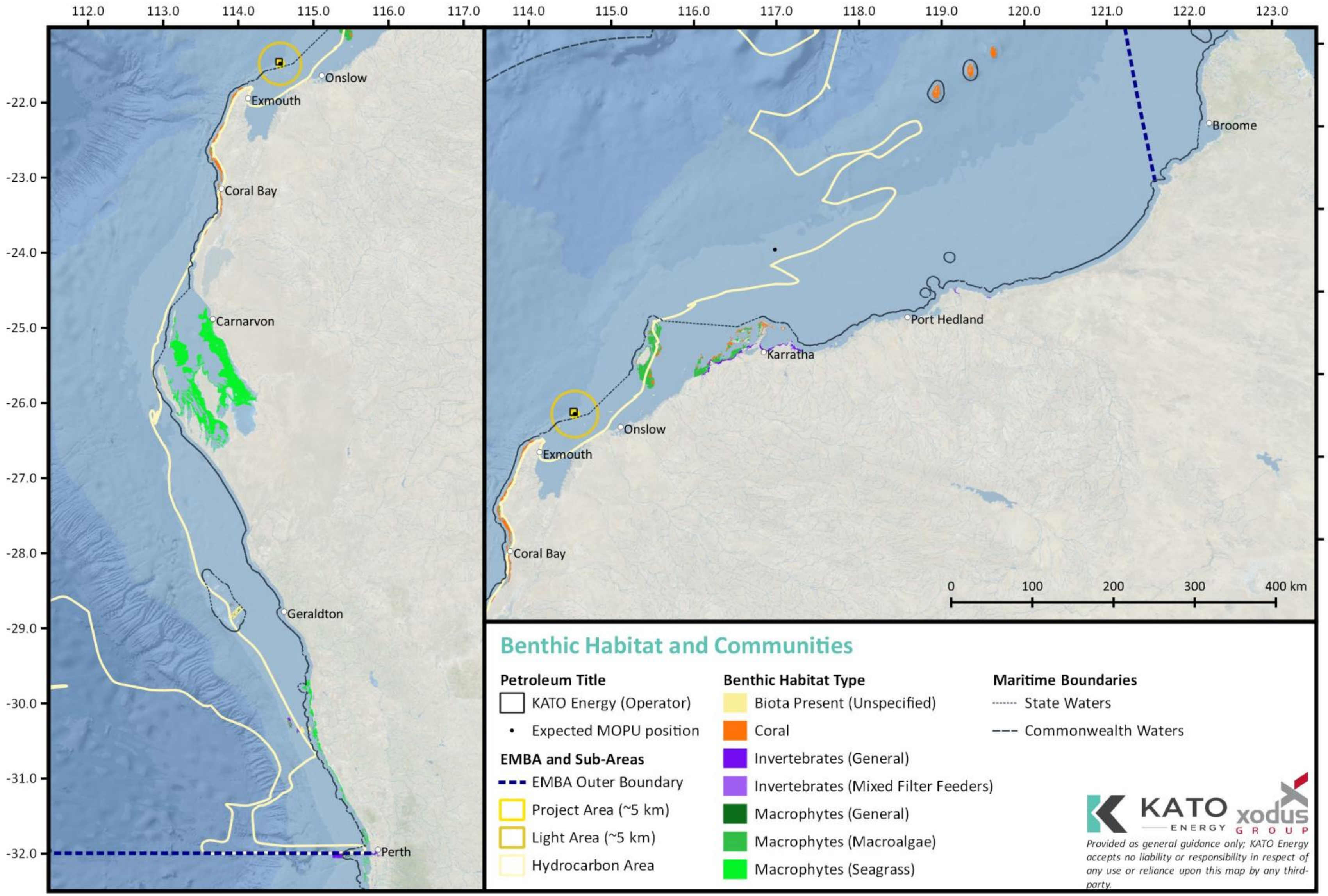


Figure 5-5 Benthic Habitats and Communities

5.4.3 Coastal Habitats and Communities

Coastal communities are biological communities that live within the coastal zone; these communities include wetlands and other intertidal flora/vegetation such as saltmarsh or mangroves. A variety of fauna (e.g. birds) also form a part of these coastal communities. Coastal habitats are the landforms that coastal communities grow on or in; these are typically considered in terms of shoreline type and can vary from sandy beaches to coastal cliffs.

5.4.3.1 Shoreline Type

Shoreline types within the EMBA are dominated by sandy beaches and tidal flats, with areas of rocky coast present (Table 5-2, Figure 5-6). Rocky coasts and sandy beaches are present on parts of the Pilbara inshore islands, while sandy beaches and tidal flats are the dominant shorelines of North West Cape and Exmouth Gulf region. Each of these shoreline types has the potential to support different flora and fauna assemblage due to the different physical factors (e.g. waves, tides, light etc.) influencing the habitat.

Table 5-2 Shoreline Types within the Corowa Development EMBA

Shoreline Type	Description	EMBA	Project Area	Light Area	Hydrocarbon Area
Cliff	Hard and soft rock features, over five metres high.	✓	X	X	X
Rocky	Hard and soft rocky shores, including bedrock outcrops, platforms, low cliffs (less than five metres), and scarps. Depending on exposure, rocky shores can be host to a diverse range of flora and fauna, including barnacles, mussels, sea anemones, sponges, sea snails, starfish and algae.	✓	X	✓	✓
Sandy	Beaches dominated by sand-sized (0.063–2 mm) particles; also includes mixed sandy beaches (i.e. sediments may include muds or gravel, but sand is the dominant particle size). Sandy beaches are dynamic environments, naturally fluctuating in response to external forcing factors (e.g. waves, currents etc.). Sandy beaches can support a variety of infauna, and provide nesting habitat to birds and turtles. Sand particles vary in size, structure and mineral content; this in turn affects the shape, colour and inhabitants, of the beach.	✓	X	✓	✓
Tidal Flats	This shoreline type can often be associated with mangrove or saltmarsh environments. These typically sheltered habitats can provide a nursery ground for many species of fish and crustacean, and provide shelter or nesting areas for birds.	✓	X	X	✓
Artificial	Artificial structures along the coast, including breakwaters, piers, jetties. This is a common feature in urban areas, although does not typically extend for long stretches of coast.	✓	X	X	X

5.4.3.2 Mangroves and Saltmarsh

Mangroves grow in intertidal mud and sand, with specially adapted aerial roots (pneumatophores) that provide for gas exchange during low tide (McClatchie et al. 2006). Mangrove forests can help stabilise coastal sediments, provide a nursery ground for many species of fish and crustacean, and provide shelter or nesting areas for seabirds (McClatchie et al. 2006). The mangrove along the Pilbara coast are known to provide important nursery habitat for many marine fish species and support prawn and crab (e.g. Coral, Blue and Swimmer Crab) fisheries (DEWHA 2008). Coastal mangrove (and associated algal mat habitat) are sites of nitrogen fixation and nutrient recycling, providing nutrients in shallower waters that are transported across the shelf via currents and tides (DEWHA 2008).

Saltmarshes are terrestrial halophytic (salt-adapted) ecosystems that mostly occur in the upper-intertidal zone. They are typically dominated by dense stands of halophytic plants such as herbs, grasses and low shrubs. The diversity of saltmarsh plant species increases with increasing latitude (in contrast to mangroves). The vegetation in these environments is essential to the stability of the saltmarsh, as they trap and bind sediments. The sediments are generally sandy silts and clays, and can often have high organic material content. Saltmarshes provide a habitat for a wide range of both marine and terrestrial fauna, including infauna and epifaunal invertebrates, fish and birds.

These two types of habitat are common within tidal flats or wetland habitats along the Pilbara coast (Figure 5-7). The mangroves of the southwest Exmouth Gulf (e.g. Heron Point, Bay of Rest) are considered regionally significant with a very high conservation value (EPA 2001, Oceanwise 2019). The larger expanse of mangroves and saltmarsh habitat on the eastern side of Exmouth Gulf coincides with the Exmouth Gulf East wetland (Section 5.4.3.3). Along the western coast of North West Cape, these habitats are less common; the largest area is Mangrove Bay. The Mangrove Bay area is also known to support a high diversity of bird species, including eight species at their southern limit in WA (CALM 2005).

5.4.3.2.1 Subtropical and Temperate Coastal Saltmarsh

The EPBC Act provides for the listing of threatened ecological communities (TECs), and these are considered as MNES under the EPBC Act.

The Subtropical and Temperate Coastal Saltmarsh ecological community occurs within a relatively narrow margin of the Australian coastline, within the subtropical and temperate climatic zones south of the South-east Queensland IBRA bioregion boundary at 23° 37' latitude along the east coast and south of (and including) Shark Bay at 26° on the west coast (DSEWPaC 2013).

The physical environment for the ecological community is coastal areas under regular or intermittent tidal influence. In southern latitudes saltmarsh is often the main vegetation-type in the intertidal zone and commonly occurs in association with estuaries (Adam 2002; Fairweather 2011). It is typically restricted to the upper-intertidal environment, occurring in areas within the astronomical tidal limit, often between the elevation of the mean high tide and the mean spring tide (Saintilan et al. 2009).

The Coastal Saltmarsh ecological community consists mainly of salt-tolerant vegetation (halophytes) including grasses, herbs, sedges, rushes and shrubs. Succulent herbs, shrubs and grasses generally dominate, and vegetation is generally of less than 0.5 m height (with the exception of some reeds and sedges) (Adam 1990). Many species of non-vascular plants are also found in saltmarsh, including epiphytic algae, diatoms and cyanobacterial mats (Adam 2002; Fotheringham and Coleman 2008; Green et al. 2012; Millar 2012).

The ecological community is inhabited by a wide range of infaunal and epifaunal invertebrates, and low-tide and high-tide visitors such as prawns, fish and birds (Adam 2002; Saintilan and Rogers 2013). It often constitutes important nursery habitat for fish and prawn species. The dominant marine residents are benthic invertebrates, including molluscs and crabs that rely on the sediments, vascular plants, and algae, as providers of food and habitat across the intertidal landscape (Ross et al. 2009).

Small isolated patches of the subtropical and temperate coastal saltmarsh habitat have been mapped along the WA coast (Figure 5-8).

5.4.3.3 Wetlands

Under the Ramsar Convention, wetland types have been defined to identify the main wetland habitats. The classification system uses three categories (with several wetland types within each): marine/coastal, inland, and human-made. The classification of a marine/coastal wetland is extensive and includes those wetlands that while predominantly based inland have some form of connection with the coast and/or marine waters. A similar classification system is used for the wetlands recognised as being nationally important.

One marine/coastal Wetlands of International Importance (Ramsar Wetland) has been identified within the EMBA: Eighty-mile Beach (Table 5-3, Figure 5-9, Appendix A). Ten wetlands of national importance have been identified within the EMBA; the closest to the Corowa Development is Exmouth Gulf East (Table 5-3, Figure 5-9). None of the marine/coastal wetlands occur within any of the sub-areas (Project, Light or Hydrocarbon) identified within the EMBA (Table 5-3).

The Exmouth Gulf East wetland comprises wetlands in the eastern part of Exmouth Gulf, from Giralia Bay to Urala Creek Locker Point. This area includes marine waters <6 m deep at low tide, the tidal mudflats and saline coastal flats. The Exmouth Gulf East wetland is considered significant as an example of a tidal wetland systems of low coast of northwest Australia, with well- developed tidal creeks, extensive mangrove swamps and broad saline coastal flats (DoEE 2019a). The seagrass and mangroves provide nursery and feeding areas for marine fish and crustaceans, and the area supports a population (estimated at >1,000) of Dugongs (DoEE 2019a).

Table 5-3 Presence of Wetland Habitats within the Corowa Development EMBA

Wetland	EMBA	Project Area	Light Area	Hydrocarbon Area
International Importance*				
Eighty-mile Beach	✓	X	X	X
National Importance				
De Grey River	✓	X	X	X
Eighty Mile Beach System	✓	X	X	X
Exmouth Gulf East	✓	X	X	X
Hamelin Pool	✓	X	X	X
Learmonth Air Weapons Range – Saline Coastal Flats	✓	X	X	X
Leslie Saltfields System	✓	X	X	X
Mermaid Reef	✓	X	X	X
Murchison River	✓	X	X	X
Shark Bay East	✓	X	X	X
Swan-Canning Estuary	✓	X	X	X

*✓ = Present within area; X = not present within area; *= Matter of National Environmental Significance*

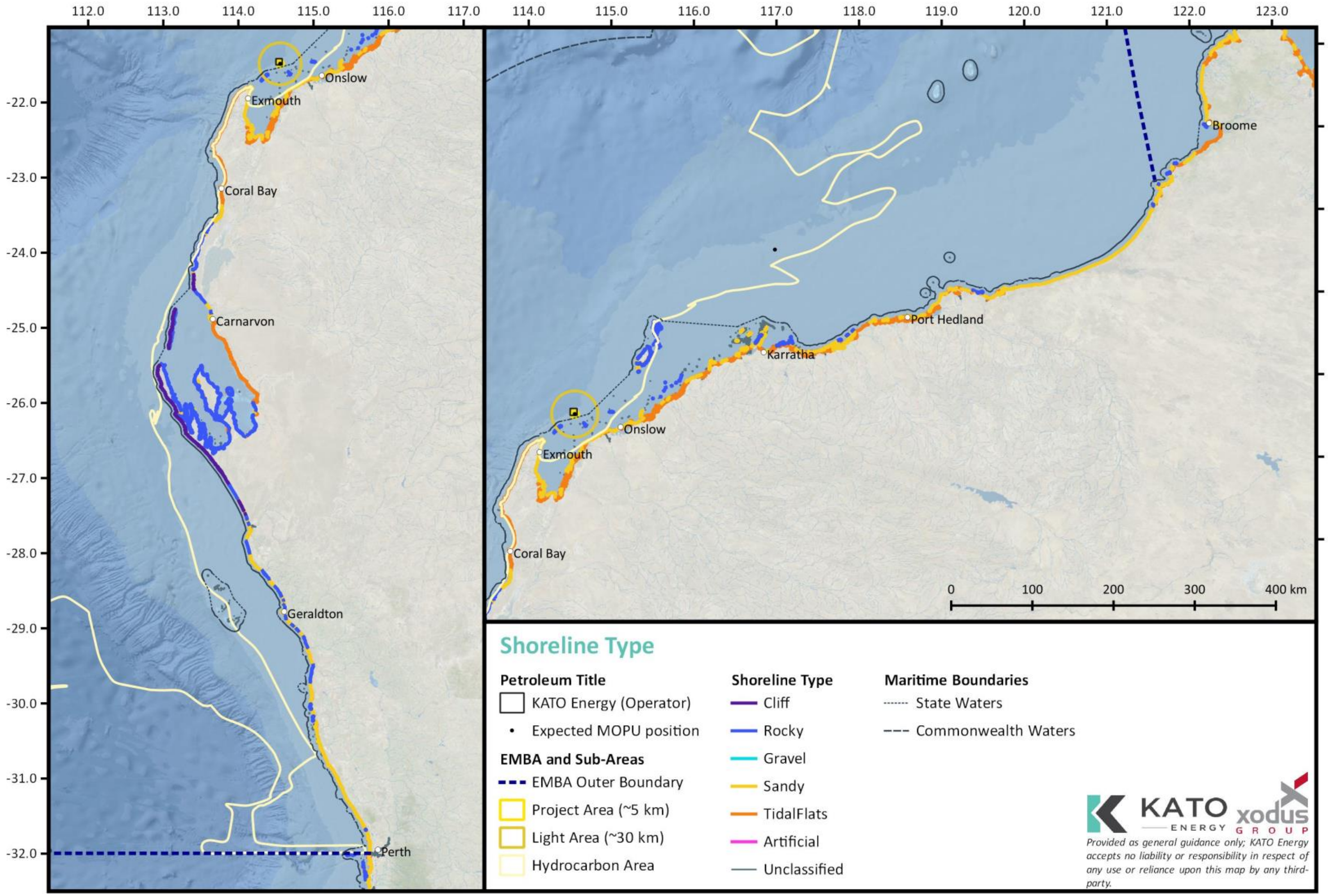


Figure 5-6 Shoreline Types

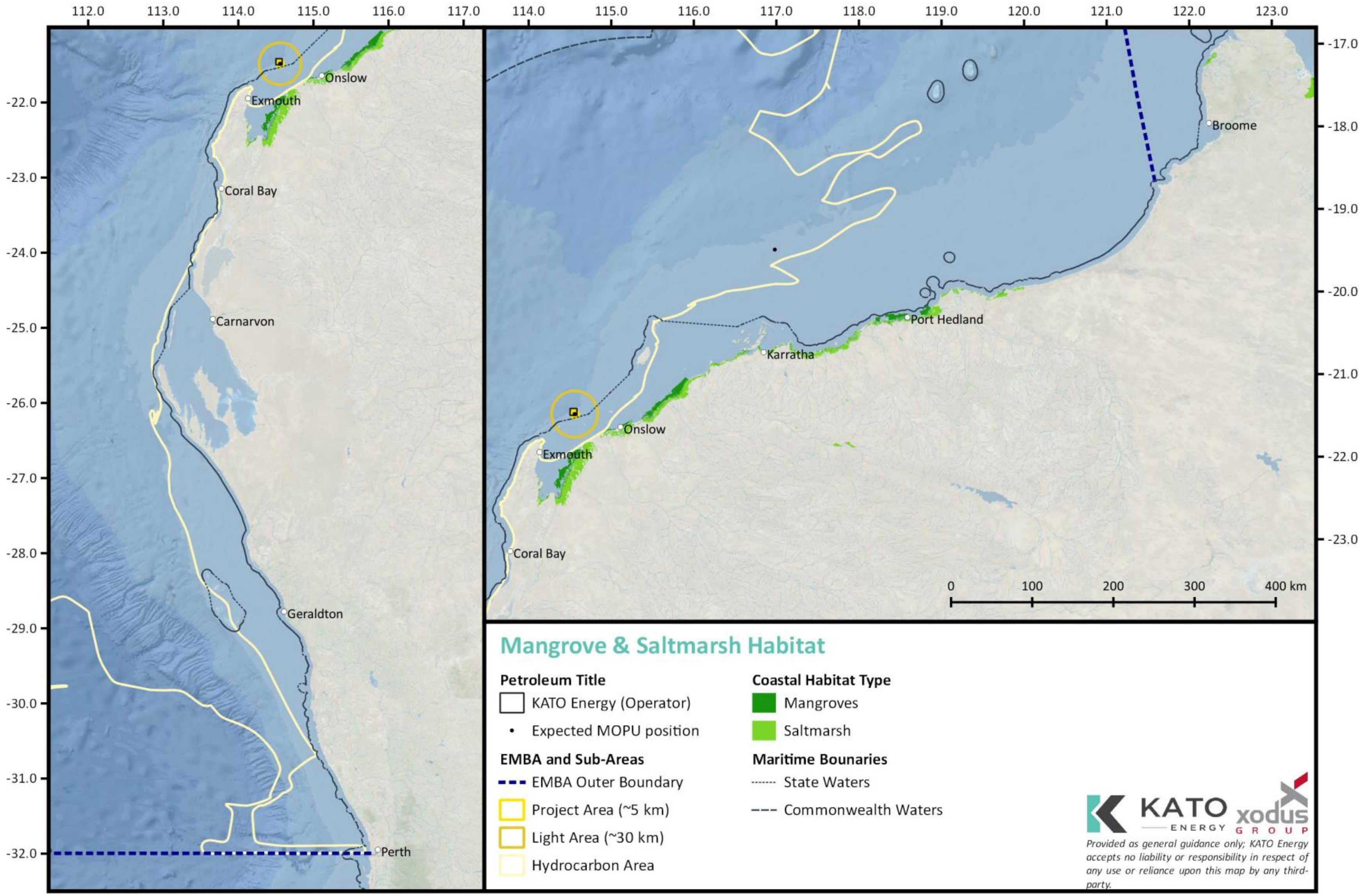


Figure 5-7 Coastal Habitats

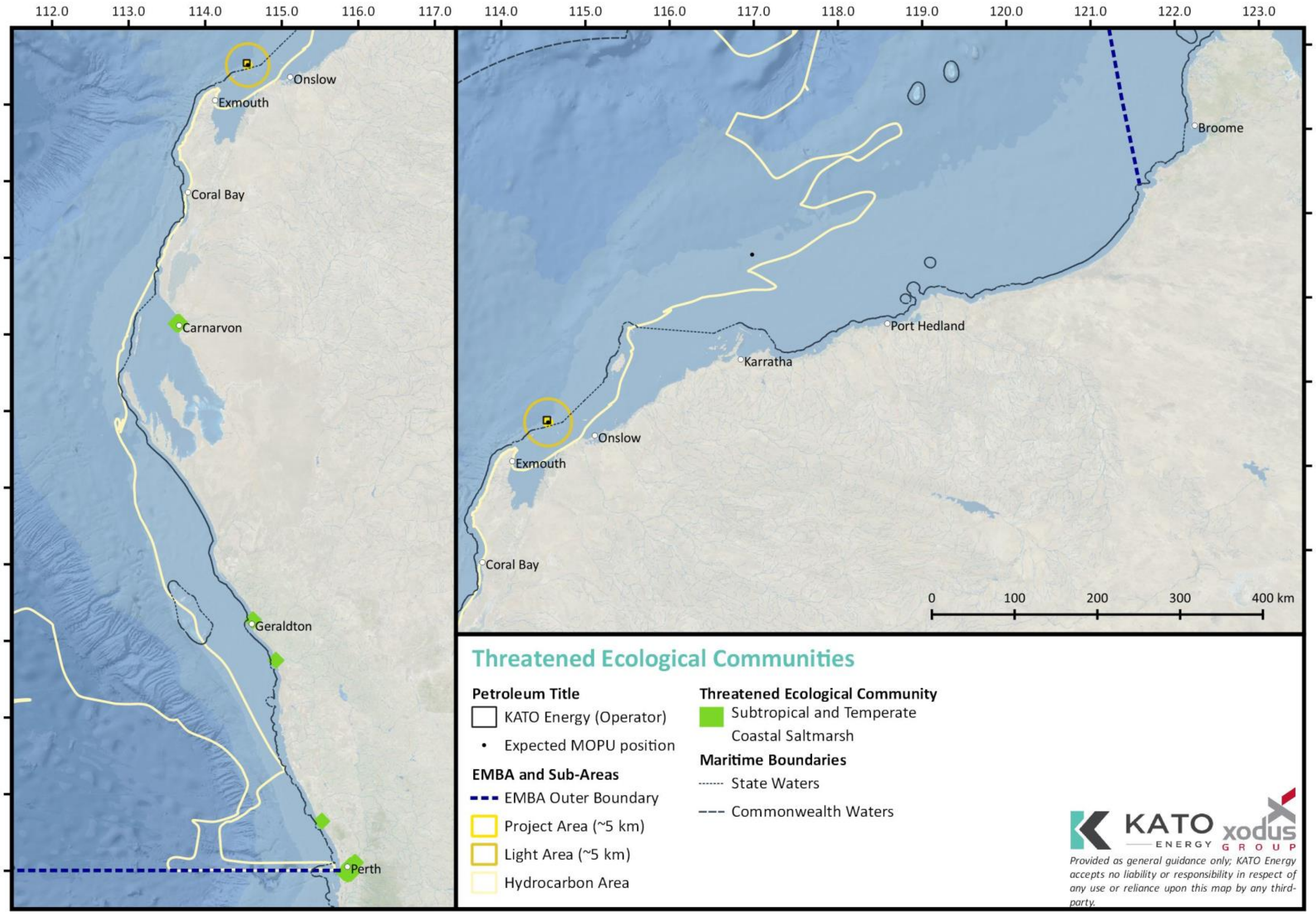


Figure 5-8 Subtropical and Temperate Coastal Saltmarsh TEC

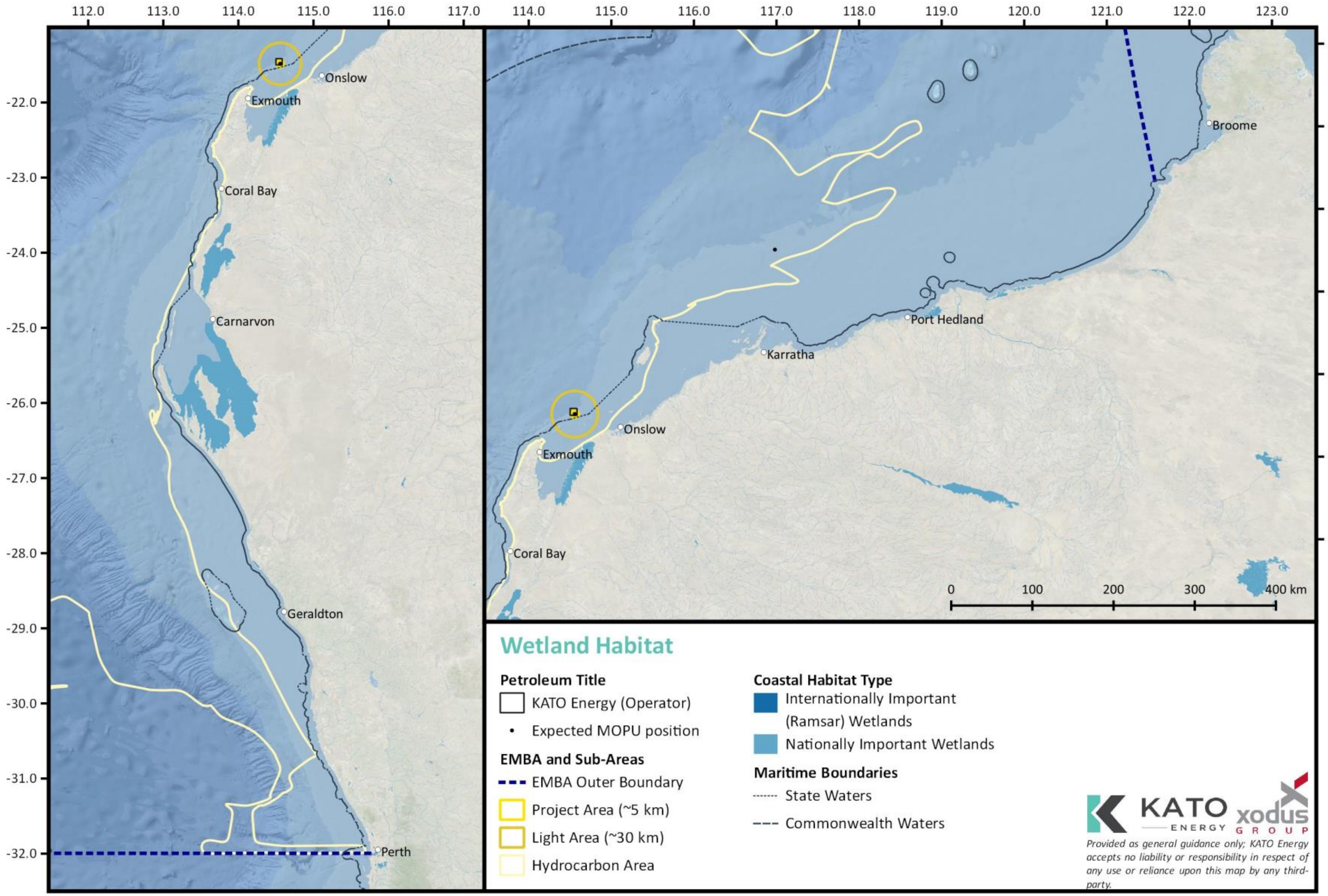


Figure 5-9 Internationally and Nationally Important Wetlands

5.4.4 Seabirds and Shorebirds

Multiple species (or species habitat) of seabirds and shorebirds may occur within the EMBA (Table 5-4, Appendix A). The presence of most species, particularly within the Project Area, are expected to be of a transitory nature only. However, the type of presence for some species within the EMBA were identified as having important behaviours (e.g. breeding, roosting, foraging) (Table 5-4, Appendix A).

The Pilbara coast and islands provide important refuge for several seabird and shorebird species. For migratory shorebirds, the rocky shores, sandy beaches, saltmarshes, intertidal flats and mangroves are important feeding and resting habitat during spring and summer (DBCA 2017). Migratory seabirds, including terns and shearwaters, use the islands for nesting (DBCA 2017). Island habitats are important for seabirds as they provide relatively undisturbed roosting and nesting habitats close to oceanic foraging grounds. Oystercatchers, Red-capped Plovers and Beach Stone-curlews are among the species that are resident populations on the Pilbara coast; these shorebirds are present throughout the year and nest along the coast and on offshore islands (DBCA 2017).

Biologically important areas[13] (BIAs) have also been identified for some bird species (Table 5-5) within the EMBA. Those closest to the Corowa Development are the breeding BIAs for the Wedge-tailed Shearwater (Figure 5-10), Fairy Tern, Lesser Crested Tern and Roseate Tern (Figure 5-11, Figure 5-12). Of these, the only one that intersects with the Project Area is the Wedge-tailed Shearwater. The breeding BIAs for this species are buffers around islands (such as Muiron and Serrurier islands) that this species is known to nest on (Table 5-5). Bird species may forage in the waters surrounding the islands during nesting seasons.

Wedge-tailed Shearwaters are a pelagic, migratory visitor to WA; estimates indicate more than one million shearwaters migrate to the Pilbara islands each year (DBCA 2017). 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 in early April to early May and travel north to the Indian Ocean (Marchant and Higgins 1990; Cannell et al. 2019). Known breeding locations in the North-west Marine Region include Forestier Island (Sable Island), Bedout Island, Dampier Archipelago, Passage Island, Lowendal Island, islands off Barrow Island (Mushroom, Double and Boodie islands), islands in the Onslow area (including Airlie, Bessieres, Serrurier, North and South Muiron and Locker islands), islands in Freycinet Estuary, and south Shark Bay (Slope, Friday, Lefebre, Charlie, Freycinet, Double and Baudin islands) (DEWHA 2008a). Breeding populations on some of the Pilbara inshore islands (e.g. Serrurier, Locker, Airlie and Flat islands) have been estimated as ~1,000–10,000 (Conservation Commission 2009).

North and South Muiron Island are significant nesting sites for the Wedge-tailed Shearwater, with 292,844 breeding pairs observed between March 2013 and January 2014 (Surman and Nicholson 2015). A study on foraging behaviour of the 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 (Cannell et al. 2019). 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; and a consistent pattern of foraging near seamounts was observed (Cannell et al. 2019). It is noted that this same area is part of the extent used by the Wedge-tailed Shearwaters from both Pelsaert and Houtman Abrolhos islands) (Surman et al. 2018; Cannell et al. 2019). The use of a bimodal foraging strategy suggests that prey availability close to the colony (i.e. areas that would be utilised on short trips) are inadequate for the large numbers of breeding shearwaters (Cannell et al. 2019).The Fairy, Lesser Crested and Roseate Terns may have

[13] Biologically important areas are spatially defined areas where aggregations of individuals of a species are known to display biologically important behaviour such as breeding, foraging, resting or migration.

both a resident sub-population and a migratory population present in the Pilbara (DBCA 2017). The Fairy Tern has breeding grounds on offshore islands in Gascoyne and Pilbara, with breeding typically late July to September (Table 5-5). The Lesser Crested Terns breeding will also breed on offshore islands in Pilbara and Gascoyne, with their season typically March to June (Table 5-5). Both the tern species are known to nest within the region of the Ningaloo Marine Park, Muiron and Sunday islands (CALM 2005). These tern species breed in dense colonies on islands and nest in open areas, typically sand scrapes/depressions on the sandy beaches of offshore islands. The Montebello Islands support the largest breeding population of Roseate Terns in WA (DEWHA 2008).

Caspian Terns, Little Terns, and ospreys have also been known to breed on Serrurier Island and neighbouring inshore islands (DEWHA 2008). Bedout Island (offshore from Port Hedland) supports one of the largest colonies of Brown Boobies in WA (Figure 5-13); Masked Boobies, Lesser Frigatebirds, Roseate Terns and Common Noddies also breed in the area (DEWHA 2008).

Table 5-4 Seabird and Shorebird Species or Species Habitat that may Occur within the Corowa Development EMBA

Scientific Name	Common Name	EPBC Status				Type of Presence			
		Recovery Plan / Conservation Advice	Threatened Species*	Migratory Species*	Listed Marine Species	EMBA	Project Area	Light Area	Hydrocarbon Area
Actitis hypoleucos	Common Sandpiper			✓(W)	✓	KO	MO	MO	KO
Anous stolidus	Common Noddy			✓(M)	✓	LO	MO	MO	LO
Anous tenuirostris melanops	Australian Lesser Noddy		V		✓	BKO			BKO
Apus pacificus	Fork-tailed Swift			✓(M)	✓	LO		LO	LO
Ardea alba	Great Egret				✓	BKO		LO	BKO
Ardea ibis	Cattle Egret				✓	MO			MO
Ardenna carneipes	Flesh-footed Shearwater			✓(M)	✓	FLO			FLO
Ardenna pacifica	Wedge-tailed Shearwater			✓(M)	✓	BKO		BKO	BKO
Arenaria interpres	Ruddy Turnstone			✓(W)	✓	RKO			RKO
Botaurus poiciloptilus	Australasian Bittern		E			KO			KO
Calidris acuminata	Sharp-tailed Sandpiper			✓(W)	✓	RKO	MO	MO	RKO
Calidris alba	Sanderling			✓(W)	✓	RKO			RKO
Calidris canutus	Red Knot	Y	E	✓(W)	✓	KO	MO	MO	KO
Calidris ferruginea	Curlew Sandpiper	Y	CE	✓(W)	✓	KO	MO	MO	KO
Calidris melanotos	Pectoral Sandpiper			✓(W)	✓	KO	MO	MO	KO
Calidris ruficollis	Red-necked Stint			✓(W)	✓	RKO			RKO
Calidris subminuta	Long-toed Stint			✓(W)	✓	KO			

Scientific Name	Common Name	EPBC Status: Recovery Plan / Conservation Advice	EPBC Status: Threatened Species*	EPBC Status: Migratory Species*	EPBC Status: Listed Marine Species	Type of Presence: EMBA	Type of Presence: Project Area	Type of Presence: Light Area	Type of Presence: Hydrocarbon Area
Calidris tenuirostris	Great Knot		CE	✓(W)	✓	RKO			KO
Calonectris leucomelas	Streaked Shearwater			✓(M)	✓	KO	LO	LO	LO
Calyptorhynchus banksii naso	Forest Red-tailed Black-Cockatoo		V			KO			
Calyptorhynchus latirostris	Carnaby's Cockatoo		E			KO			
Catharacta skua	Great Skua				✓	MO			MO
Cecropis daurica	Red-rumped Swallow			✓(T)		MO			
Charadrius bicinctus	Double-banded Plover			✓(W)	✓	RKO			RKO
Charadrius dubius	Little Ringed Plover			✓(W)	✓	KO			
Charadrius leschenaultii	Greater Sand Plover		V	✓(W)	✓	RKO			RKO
Charadrius mongolus	Lesser Sand Plover		E	✓(W)	✓	RKO			RKO
Charadrius ruficapillus	Red-capped Plover				✓	RKO			RKO
Charadrius veredus	Oriental Plover			✓(W)	✓	RKO			MO
Chrysococcyx osculans	Black-eared Cuckoo				✓	RKO			KO
Cuculus optatus	Oriental Cuckoo			✓(T)		MO			
Diomedea amsterdamensis	Amsterdam Albatross		E	✓(M)	✓	MO			LO
Diomedea dabbenena	Tristan Albatross		E	✓(M)	✓	MO			
Diomedea epomophora	Southern Royal Albatross		V	✓(M)	✓	FLO			FLO
Diomedea exulans	Wandering Albatross		V	✓(M)	✓	FLO			FLO
Diomedea sanfordi	Northern Royal Albatross		E	✓(M)	✓	FLO			FLO
Eudyptula minor	Little Penguin				✓	BKO			
Fregata ariel	Lesser Frigatebird			✓(M)	✓	BKO	LO	LO	KO
Fregata andrewsi	Christmas Island Frigatebird		E	✓(M)	✓	FLO			
Fregata minor	Great Frigatebird			✓(M)	✓	MO			MO
Gallinago megala	Swinhoe's Snipe			✓(W)	✓	RLO			RLO

Scientific Name	Common Name	EPBC Status				Type of Presence			
		Recovery Plan / Conservation Advice	Threatened Species*	Migratory Species*	Listed Marine Species	EMBA	Project Area	Light Area	Hydrocarbon Area
Gallinago stenura	Pin-tailed Snipe			✓(W)	✓	RLO			RLO
Glareola maldivarum	Oriental Pratincole			✓(W)	✓	RLO			MO
Haliaeetus leucogaster	White-bellied Sea-Eagle				✓	BKO		MO	KO
Halobaena caerulea	Blue Petrel		V		✓	MO			MO
Heteroscelus brevipes	Grey-tailed Tattler				✓	RKO			RKO
Himantopus himantopus	Pied Stilt				✓	RKO			RKO
Hirundo daurica	Red-rumped Swallow				✓	MO			
Hirundo rustica	Barn Swallow			✓(T)	✓	KO		MO	KO
Hydroprogne caspia	Caspian Tern			✓(M)	✓	BKO			BKO
Larus novaehollandiae	Silver Gull				✓	BNO		BKO	BKO
Larus pacificus	Pacific Gull				✓	BKO			BKO
Leipoa ocellata	Malleefowl		V			MO			
Limicola falcinellus	Broad-billed Sandpiper			✓(W)	✓	RKO			
Limnodromus semipalmatus	Asian Dowitcher			✓(W)	✓	RKO			
Limosa lapponica	Bar-tailed Godwit			✓(W)	✓	KO			KO
Limosa lapponica baueri	Bar-tailed Godwit (baueri)	Y	V			MO			LO
Limosa lapponica menzbieri	Northern Siberian Bar-tailed Godwit	Y	CE			MO			MO
Limosa limosa	Black-tailed Godwit			✓(W)	✓	RKO			RKO
Macronectes giganteus	Southern Giant Petrel	Y	E	✓(M)	✓	MO	MO	MO	MO
Macronectes halli	Northern Giant Petrel		V	✓(M)	✓	MO			MO
Malurus leucopterus edouardi	White-winged Fairy-wren (Barrow Island)		V			LO			LO
Malurus leucopterus leucopterus	White-winged Fairy-wren (Dirk Hartog Island)					LO			
Merops ornatus	Rainbow Bee-eater				✓	MO			MO

Scientific Name	Common Name	EPBC Status				Type of Presence			
		Recovery Plan / Conservation Advice	Threatened Species*	Migratory Species*	Listed Marine Species	EMBA	Project Area	Light Area	Hydrocarbon Area
Motacilla cinerea	Grey Wagtail			✓(T)	✓	MO		MO	MO
Motacilla flava	Yellow Wagtail			✓(T)	✓	KO		MO	MO
Numenius madagascariensis	Eastern Curlew	Y	CE	✓(W)	✓	KO	MO	MO	KO
Numenius minutus	Little Curlew			✓(W)	✓	RKO			RLO
Numenius phaeopus	Whimbrel			✓(W)	✓	RKO			RKO
Onychoprion anaethetus	Bridled Tern			✓(M)	✓	BKO		BKO	BKO
Pachyptila turtur subantarctica	Fairy Prion		V		✓	KO			KO
Pandion haliaetus	Osprey			✓(W)	✓	BKO	MO	BKO	BKO
Papasula abbotti	Abbott's Booby		E		✓	LO			MO
Pelagodroma marina	White-faced Storm-Petrel				✓	BKO			MO
Pezoporus occidentalis	Night Parrot		E			MO			MO
Phaethon lepturus	White-tailed Tropicbird			✓(M)	✓	BLO			
Phaethon lepturus fulvus	Christmas Island White-tailed Tropicbird		E		✓	MO			
Phaethon rubricauda	Red-tailed Tropicbird			✓(M)	✓	BKO			BKO
Phalacrocorax fuscescens	Black-faced Cormorant				✓	BLO			BLO
Phalaropus lobatus	Red-necked Phalarope			✓(W)	✓	RKO			RKO
Philomachus pugnax	Ruff			✓(W)	✓	RKO			
Phoebetria fusca	Sooty Albatross		V	✓(M)	✓	MO			MO
Pluvialis fulva	Pacific Golden Plover			✓(W)	✓	RKO			RKO
Pluvialis squatarola	Grey Plover			✓(W)	✓	RKO			RKO
Pterodroma macroptera	Great-winged Petrel				✓	FKO			FKO
Pterodroma mollis	Soft-plumaged Petrel		V		✓	FKO			FKO
Puffinus assimilis	Little Shearwater				✓	BKO			BKO

Scientific Name	Common Name	EPBC Status				Type of Presence			
		Recovery Plan / Conservation Advice	Threatened Species*	Migratory Species*	Listed Marine Species	EMBA	Project Area	Light Area	Hydrocarbon Area
Puffinus huttoni	Hutton's Shearwater				✓	FKO			FKO
Recurvirostra novaehollandiae	Red-necked Avocet				✓	RKO			RKO
Rostratula australis	Australian Painted Snipe		E			LO			
Rostratula benghalensis (sensulato)	Painted Snipe		E		✓	LO		MO	
Sterna albifrons	Little Tern				✓	BKO			
Sterna anaethetus	Bridled Tern				✓	BKO		BKO	BKO
Sterna bengalensis	Lesser Crested Tern					BKO		BKO	BKO
Sterna bergii	Crested Tern				✓	BKO		BKO	BKO
Sterna caspia	Caspian Tern				✓	BKO			BKO
Sterna dougallii	Roseate Tern			✓(M)	✓	BKO			BKO
Sterna fuscata	Sooty Tern				✓	BKO		BKO	BKO
Sterna nereis	Fairy Tern				✓	BKO		BKO	BKO
Sternula albifrons	Little Tern			✓(M)		BKO			
Sternula nereis nereis	Australian Fairy Tern	Y	V			BKO	FLO	BKO	BKO
Stiltia isabella	Australian Pratincole				✓	RKO			
Sula dactylatra	Masked Booby			✓(M)	✓	BKO			
Sula leucogaster	Brown Booby			✓(M)	✓	BKO			
Thalasseus bergii	Crested Tern			✓(W)	✓	BKO		BKO	BKO
Thalassarche carteri	Indian Yellow-nosed Albatross		V	✓(M)	✓	FMO			FMO
Thalassarche cauta cauta	Shy Albatross		V	✓(M)	✓	FLO			FLO
Thalassarche cauta steadi	White-capped Albatross		V			FLO			
Thalassarche impavida	Campbell Albatross		V	✓(M)	✓	MO			MO
Thalassarche melanophris	Black-browed Albatross		V	✓(M)	✓	MO			MO
Thalassarche steadi	White-capped Albatross			✓(M)	✓	FLO			FLO
Thinornis rubricollis	Hooded Plover				✓	FLO			KO

Scientific Name	Common Name	EPBC Status: Recovery Plan / Conservation Advice	EPBC Status: Threatened Species*	EPBC Status: Migratory Species*	EPBC Status: Listed Marine Species	Type of Presence: EMBA	Type of Presence: Project Area	Type of Presence: Light Area	Type of Presence: Hydrocarbon Area
Tringa brevipes	Grey-tailed Tattler			✓(W)		RKO			BKO
Tringa glareola	Wood Sandpiper			✓(W)	✓	KO			
Tringa nebularia	Common Greenshank			✓(W)	✓	KO			KO
Tringa stagnatilis	Marsh Sandpiper			✓(W)	✓	RKO			RKO
Tringa totanus	Common Redshank			✓(W)	✓	RKO			RKO
Turnix varius scintillans	Painted Button-quail		V			LO			
Xenus cinereus	Terek Sandpiper			✓(W)	✓	RKO			RKO

Threatened Species:

V *Vulnerable*
E *Endangered*
CE *Critically Endangered*

Migratory Species:

M *Marine*
W *Wetland*
T *Terrestrial*

Type of Presence:

MO *Species of 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*
FMO *Foraging, feeding or related behaviour may occur within area*
FLO *Foraging, feeding or related behaviour likely to occur within area*
FKO *Foraging, feeding or related behaviour known to occur within area*
BLO *Breeding likely to occur within area*
BKO *Breeding known to occur within area*
RLO *Roosting likely to occur within area*
RKO *Roosting known to occur within area*

**=* Matter of National Environmental Significance*

Table 5-5 Biologically Important Areas for Seabird and Shorebird Species within the Corowa Development EMBA

Scientific Name	Common Name	BIA Presence: EMBA	BIA Presence: Project Area	BIA Presence: Light Area	BIA Presence: Hydrocarbon Area	Summary Description of BIA
Anous stolidus	Common Noddy	f			f	Foraging grounds around islands used for breeding (e.g. Abrolhos). Presence likely around Abrolhos mid-August to late-April.
Anous tenuirostris melanops	Australian Lesser Noddy	f			f	Foraging grounds around islands used for breeding (e.g. Abrolhos).

Scientific Name	Common Name	BIA Presence				Summary Description of BIA
		EMBA	Project Area	Light Area	Hydrocarbon Area	
						Presence may occur throughout the year.
Ardenna carneipes	Flesh-footed Shearwater	a				Aggregation area used pre-migration. Presence may occur late-April to late-June, and late-August to early-November.
Ardenna pacifica	Wedge-tailed Shearwater	b,f	b	b	b	Breeding grounds and buffer area around offshore islands (including Muiron and Serrurier islands). Breeding presence may occur between mid-August to April (Pilbara) or to mid-May (Shark Bay).
Eudyptula minor	Little Penguin	f				Foraging grounds (generally inshore waters) from Perth to Bunbury. Adults may be present near breeding grounds throughout the all year.
Fregata ariel	Lesser Frigatebird	b				Breeding grounds and buffer area around offshore islands in Pilbara and Kimberley. Breeding season March to September.
Larus pacificus	Pacific Gull	f			f	Foraging grounds (generally inshore waters) along west coast and around Abrolhos Islands.
Phaethon lepturus	White-tailed Tropicbird	b				Breeding grounds and buffer area around offshore islands in Pilbara and Kimberley. Breeding recorded between May and October.
Pterodroma mollis	Soft-plumaged Petrel	f			f	Oceanic foraging grounds on continental shelf waters (not observed inshore). Presence may occur March to late-September.
Puffinus assimilis	Little Shearwater	f			f	Oceanic foraging grounds (4–200 km off coast) between Kalbarri and Eucla, with high usage around Abrolhos Islands. Presence mainly occurs April to November.
Sterna anaethetus	Bridled Tern	f			f	Oceanic foraging grounds. Presences is generally driven by breeding season, late September to late February/early May.
Sterna caspia	Caspian Tern	f			f	Oceanic foraging grounds.
Sterna dougallii	Roseate Tern	b,f,r			b,f	Breeding grounds and buffer area around offshore islands in Gascoyne,

Scientific Name	Common Name	BIA Presence EMBA	Project Area	Light Area	Hydrocarbon Area	Summary Description of BIA
						Pilbara and Kimberley. Breeding presence may occur mid-March to July. Oceanic foraging grounds on west coast and round Abrolhos Islands. Resting area located northern end of Eighty Mile Beach.
Sterna fuscata	Sooty Tern	f			f	Oceanic foraging grounds; common in Abrolhos area but in small numbers. Presence associated with breeding season from late August to early May.
Sterna nereis	Fairy Tern	b,f		b	b,f	Breeding grounds and buffer area around offshore islands in Gascoyne and Pilbara. Breeding may occur late July to September. Oceanic foraging grounds on west coast and round Abrolhos Islands.
Sternula albifrons	Little Tern	b,r				Breeding grounds and buffer area and resting areas, around offshore islands in Pilbara and Kimberley. Breeding has been recorded June to October.
Sula leucogaster	Brown Booby	b				Breeding grounds and buffer area around offshore islands in Pilbara and Kimberley. Breeding presence may occur February to October.
Thalasseus bengalensis	Lesser Crested Tern	b		b	b	Breeding grounds and buffer area around offshore islands in Gascoyne and Pilbara. Breeding may occur March to June.
Biologically Important Area *a: Aggregation; b: Breeding; f: Foraging; r: Resting*						

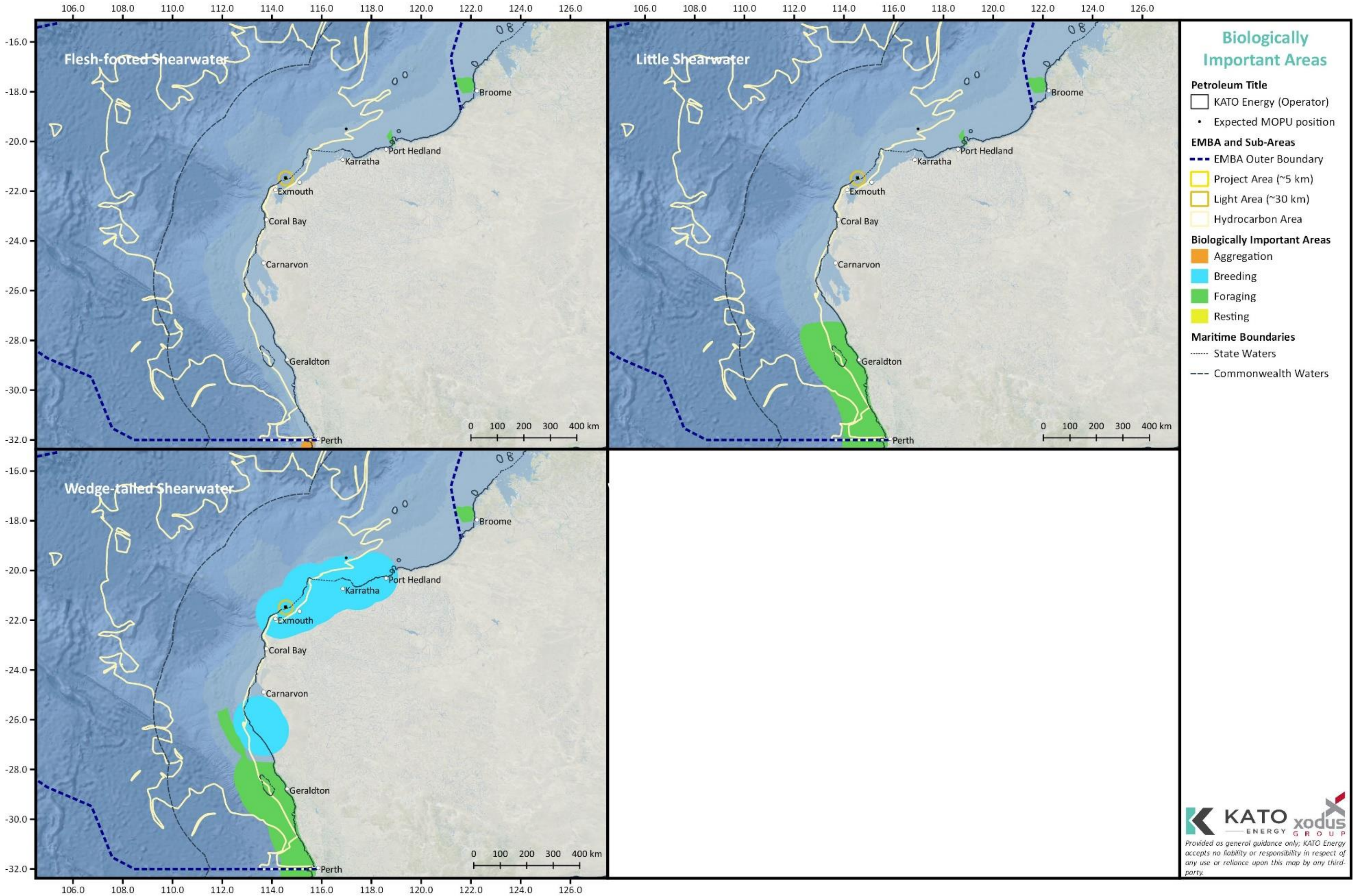


Figure 5-10 Biologically Important Areas for Flesh-footed, Little and Wedge-tailed Shearwater Species

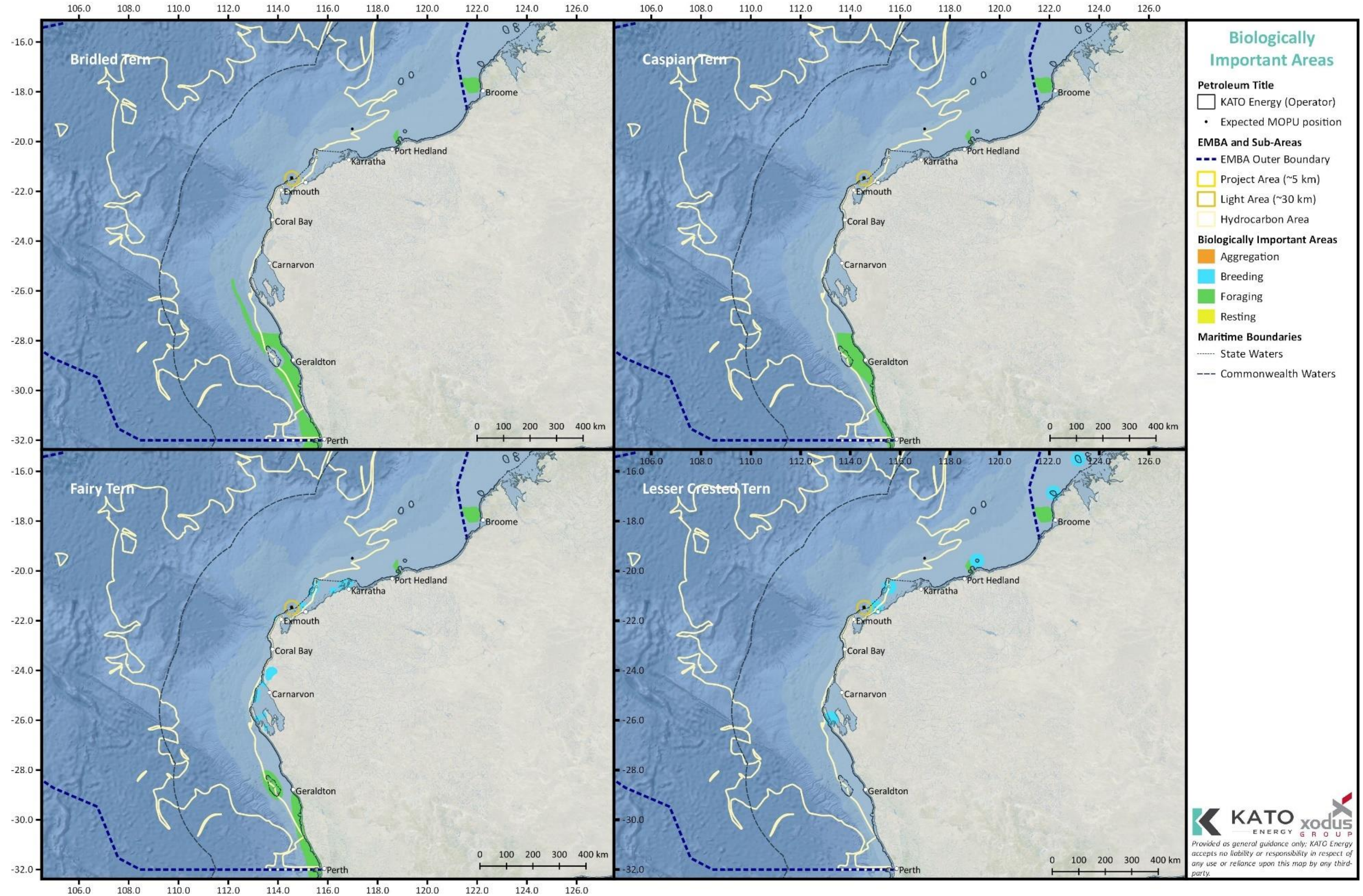


Figure 5-11 Biologically Important Areas for Bridled, Caspian, Fairy and Lesser Crested Tern Species

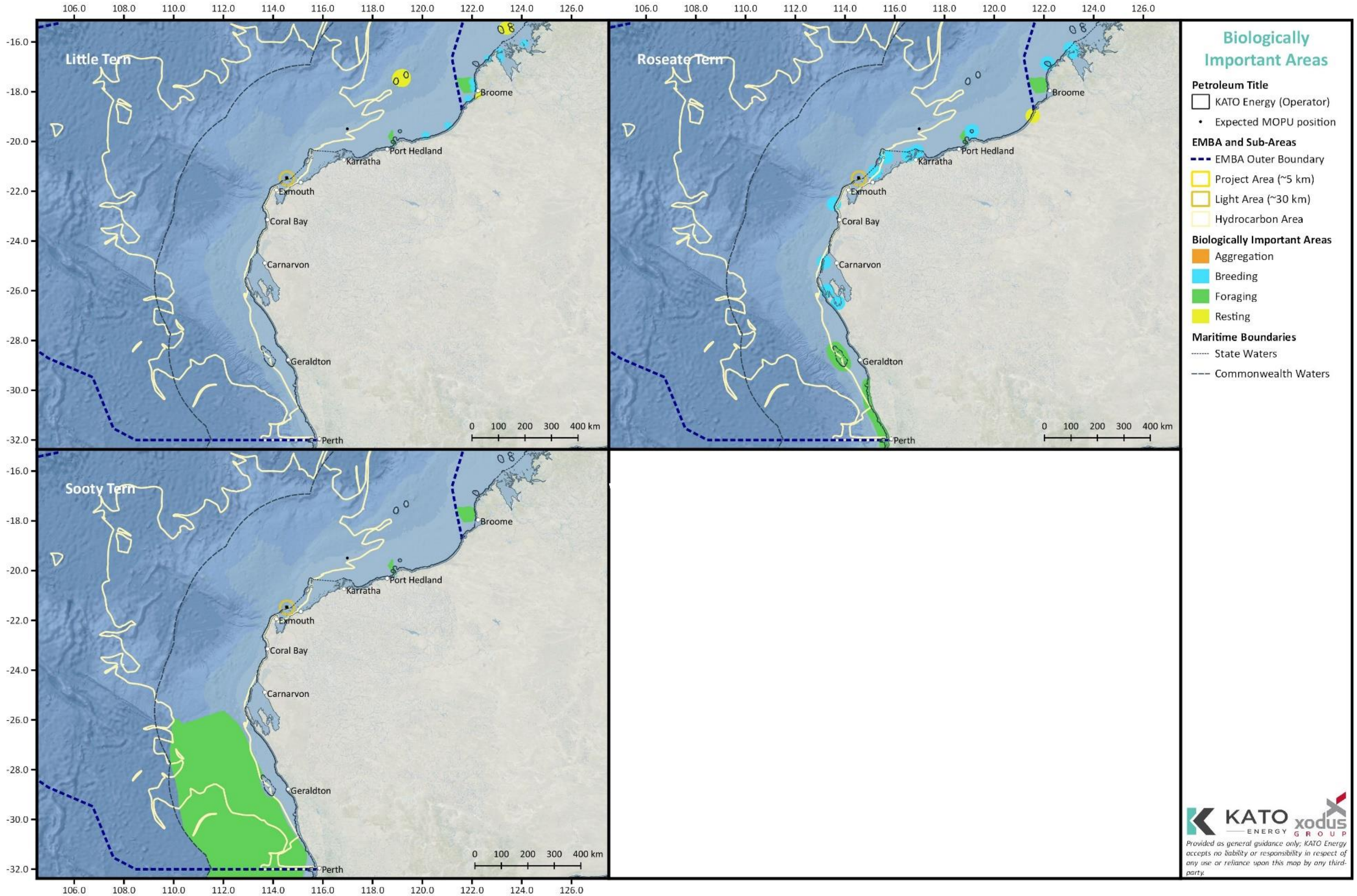


Figure 5-12 Biologically Important Areas for Little, Roseate and Sooty Tern species

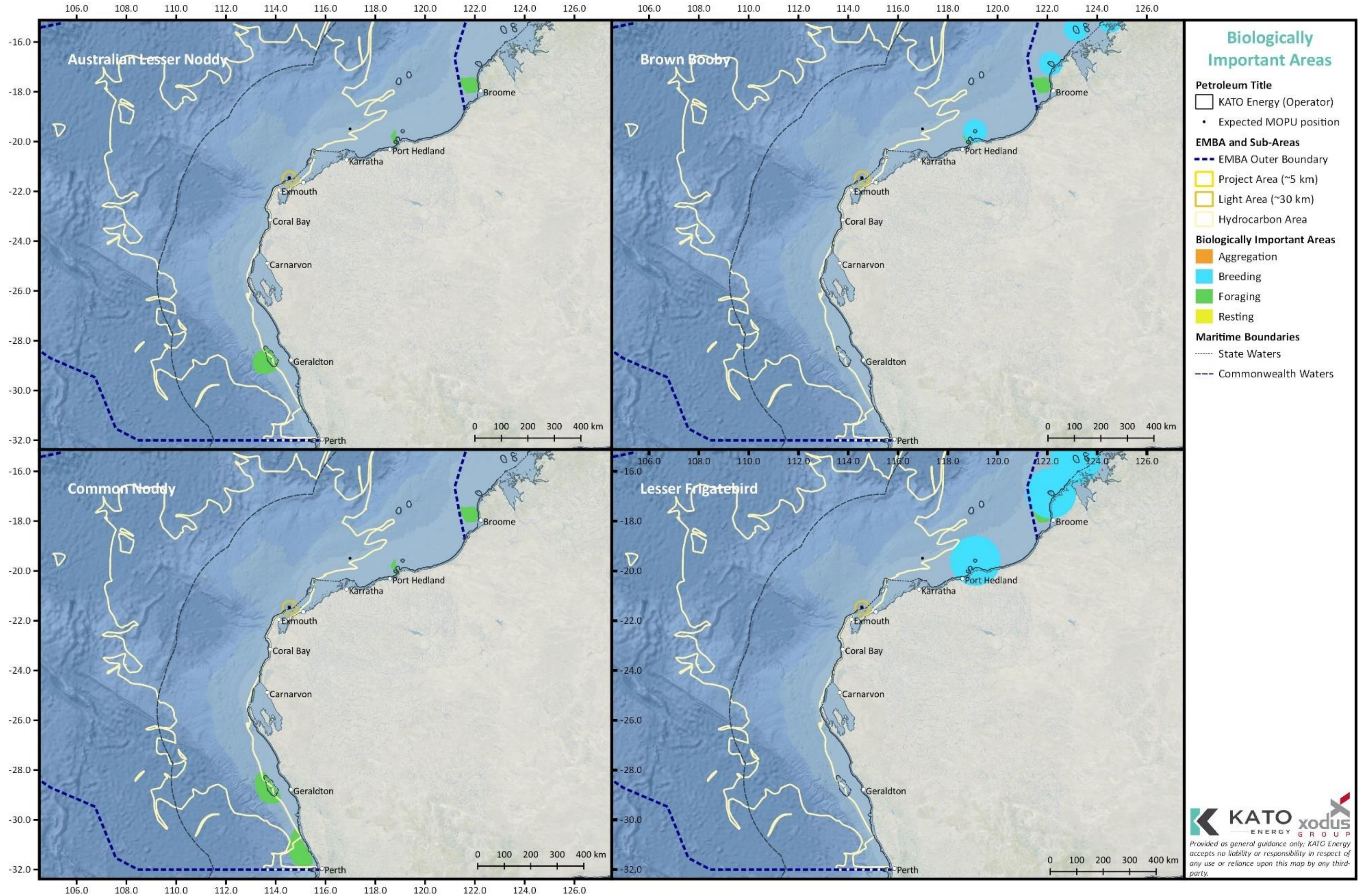


Figure 5-13 Biologically Important Areas for the Australian Lesser Noddy, Brown Booby, Common Noddy and Lesser Frigatebird

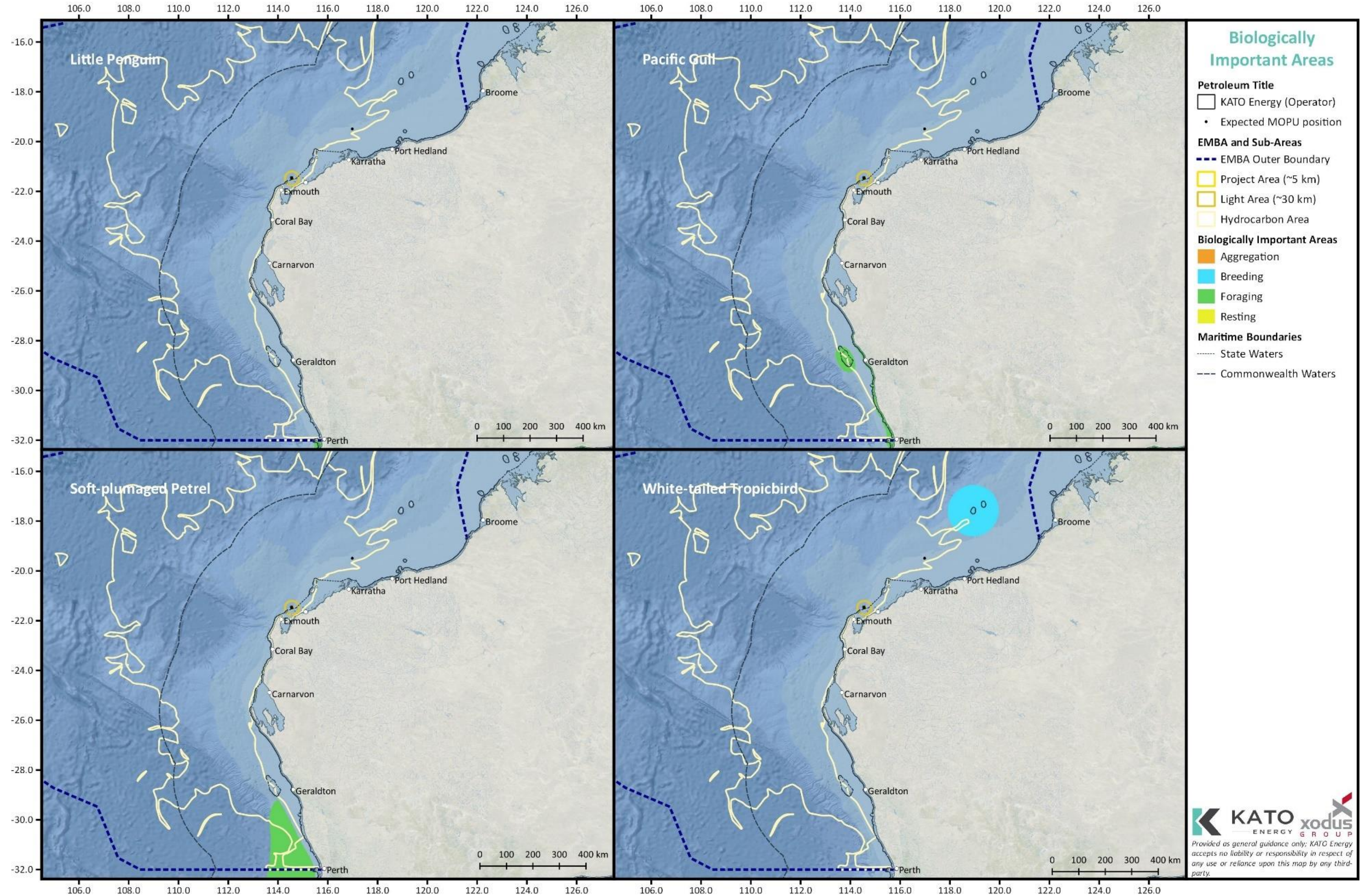


Figure 5-14 Biologically Important Areas for the Little Penguin, Pacific Gull, Soft-plumaged Petrel and White-tailed Tropicbird

5.4.5 Fish

Multiple species (or species habitat) of fish may occur within the EMBA (Table 5-6, Appendix A). The presence of most species, within the Project Area and wider EMBA, are expected to be of a transitory nature only, with only a small number of species having an important behaviours (e.g. foraging) identified (Table 5-6, Appendix A).

BIAs have also been identified for some fish species (Table 5-7) within the EMBA. The closest BIA to the Corowa Development is the foraging BIA for the Whale Shark (Figure 5-15). The foraging BIA for the Whale Shark does intersect with the Project Area (Table 5-7, Figure 5-15). The other species with BIAs (White Shark and the Dwarf, Freshwater and Green Sawfish) occur within the EMBA, but not within any of the sub-areas (Project, Light or Hydrocarbon) identified within the EMBA (Table 5-7, Figure 5-15, Figure 5-16). The Whale Shark is widely distributed in Australian waters, but are known to travel along the 200 m depth contour, with Ningaloo Reef being their main known aggregation area for intensive foraging (DEWHA 2008b). It is estimated that 300 to 500 Whale Sharks aggregate within the Ningaloo Reef region during April and May each year, with the majority of individuals being juvenile males. When they depart Ningaloo, satellite tracking has shown that they will generally migrate toward the north-east into Indonesian waters (Meekan et al. 2008).

The Whale Shark is a suction filter feeder, with a diet of planktonic and nektonic prey, and feeds at or close to the water's surface by swimming forward with mouth agape, sucking in prey (DoEE 2017b). While the species is generally encountered close to or at the surface, it will regularly dive and move through the water column.

The benthic and pelagic fish communities of the Northwest Shelf Province are strongly depth-related (Brewer et al. 2007, DEWHA 2008). The fish communities are also diverse. Fish species commonly found on the inner shelf include lizardfish, goatfish, trevally, angelfish and tuskfish; fish species commonly found in slightly deeper (100–200 m) shelf water include deep goatfish, deep lizardfish, ponyfish, Deep Threadfin Bream, adult trevally, billfish and tuna (DEWHA 2008). Spanish Mackerel spawn in this bioregion between August and November. A small aggregation of the vulnerable Grey Nurse Sharks has been identified off Exmouth during a five-year (2007–2012) study (Hosche and Whisson 2016). Aggregation sites are important in the life cycle of the Grey Nurse Shark for mating and pupping (Hosche and Whisson 2016).

Much of the seabed in the immediate vicinity of the Project Area is expected to be flat and unvegetated soft sediment. Consequently, the demersal fish fauna abundance and diversity is likely to be lower as compared to nearshore vegetated areas or offshore areas with complex topography.

Regional Pilbara waters are also habitat for several important commercial fish species, such as Red Emperor, Spanish Mackerel and Pink Snapper (Section 5.5.2). Limited commercial fishing stocks or activity are expected within the Project Area for the Corowa Development.

Table 5-6 Fish Species or Species Habitat that may Occur within the Corowa Development EMBA

Scientific Name	Common Name	EPBC Status: Recovery Plan / Conservation Advice	EPBC Status: Threatened Species*	EPBC Status: Migratory Species*	EPBC Status: Listed Marine Species	Type of Presence: EMBA	Type of Presence: Project Area	Type of Presence: Light Area	Type of Presence: Hydrocarbon Area
Sharks and Rays									
Anoxypristis cuspidata	Narrow Sawfish			✓		KO	MO	LO	KO
Carcharias taurus	Grey Nurse Shark	Y	V			KO	MO	KO	KO
Carcharodon carcharias	White Shark	Y	V	✓		FKO	MO	KO	FKO
Glyphis garricki	Northern River Shark		E			MO			
Isurus oxyrinchus	Shortfin Mako			✓		BKO		LO	LO
Isurus paucus	Longfin Mako			✓		LO		LO	LO
Lamna nasus	Porbeagle, Mackerel Shark			✓		MO			MO
Manta alfredi	Reef Manta Ray			✓		KO	KO	KO	KO
Manta birostris	Giant Manta Ray			✓		KO	KO	KO	KO
Pristis clavata	Dwarf Sawfish	Y	V	✓		BKO	KO	KO	KO
Pristis pristis	Freshwater Sawfish	Y	V	✓		KO			
Pristis zijsron	Green Sawfish	Y	V	✓		BKO	KO	KO	KO
Rhincodon typus	Whale Shark	Y	V	✓		FKO	FKO	FKO	FLO
Pipefish, Seahorse and Seadragons									
Acentronura australe	Southern Pygmy Pipehorse				✓	MO			MO
Acentronura larsonae	Helen's Pygmy Pipehorse				✓	MO	MO	MO	MO
Bhanotia fasciolata	Corrugated Pipefish				✓	MO			
Bulbonaricus brauni	Braun's Pughead Pipefish				✓	MO	MO	MO	MO
Campichthys galei	Gale's Pipefish				✓	MO			MO
Campichthys tricarinatus	Three-keel Pipefish				✓	MO	MO	MO	MO
Choeroichthys brachysoma	Pacific Short-bodied Pipefish				✓	MO	MO	MO	MO
Choeroichthys latispinosus	Muiron Island Pipefish				✓	MO	MO	MO	MO
Choeroichthys suillus	Pig-snouted Pipefish				✓	MO	MO	MO	MO
Corythoichthys amplexus	Fijian Banded Pipefish				✓	MO			
Corythoichthys flavofasciatus	Reticulate Pipefish				✓	MO			MO

Scientific Name	Common Name	EPBC Status				Type of Presence			
		Recovery Plan / Conservation Advice	Threatened Species*	Migratory Species*	Listed Marine Species	EMBA	Project Area	Light Area	Hydrocarbon Area
Corythoichthys intestinalis	Australian Messmate Pipefish				✓	MO			
Corythoichthys schultzi	Schultz's Pipefish				✓	MO			
Cosmocampus banneri	Roughridge Pipefish				✓	MO			MO
Doryrhamphus dactyliophorus	Banded Pipefish				✓	MO	MO	MO	MO
Doryrhamphus excisus	Bluestripe Pipefish				✓	MO			MO
Doryrhamphus janssi	Cleaner Pipefish				✓	MO	MO	MO	MO
Doryrhamphus multiannulatus	Many-banded Pipefish				✓	MO	MO	MO	MO
Doryrhamphus negrosensis	Flagtail Pipefish				✓	MO	MO	MO	MO
Festucalex scalaris	Ladder Pipefish				✓	MO	MO	MO	MO
Filicampus tigris	Tiger Pipefish				✓	MO	MO	MO	MO
Halicampus brocki	Brock's Pipefish				✓	MO	MO	MO	MO
Halicampus dunckeri	Red-hair Pipefish				✓	MO			MO
Halicampus grayi	Mud Pipefish				✓	MO	MO	MO	MO
Halicampus nitidus	Glittering Pipefish				✓	MO	MO	MO	MO
Halicampus spinirostris	Spiny-snout Pipefish				✓	MO	MO	MO	MO
Haliichthys taeniophorus	Ribboned Pipehorse				✓	MO	MO	MO	MO
Heraldia nocturna	Upside-down Pipefish				✓	MO			MO
Hippichthys penicillus	Beady Pipefish				✓	MO	MO	MO	MO
Hippocampus angustus	Western Spiny Seahorse				✓	MO	MO	MO	MO
Hippocampus breviceps	Short-head Seahorse				✓	MO			MO
Hippocampus histrix	Spiny Seahorse				✓	MO	MO	MO	MO
Hippocampus kuda	Spotted Seahorse				✓	MO	MO	MO	MO
Hippocampus planifrons	Flat-face Seahorse				✓	MO	MO	MO	MO
Hippocampus spinosissimus	Hedgehog Seahorse				✓	MO			MO

Scientific Name	Common Name	EPBC Status				Type of Presence			
		Recovery Plan / Conservation Advice	Threatened Species*	Migratory Species*	Listed Marine Species	EMBA	Project Area	Light Area	Hydrocarbon Area
Hippocampus subelongatus	West Australian Seahorse				✓	MO			MO
Hippocampus trimaculatus	Three-spot Seahorse				✓	MO	MO	MO	MO
Histiogamphelus cristatus	Rhino Pipefish				✓	MO			MO
Lissocampus caudalis	Australian Smooth Pipefish				✓	MO			MO
Lissocampus fatiloquus	Prophet's Pipefish				✓	MO			MO
Lissocampus runa	Javelin Pipefish				✓	MO			MO
Maroubra perserrata	Sawtooth Pipefish				✓	MO			MO
Micrognathus micronotopterus	Tidepool Pipefish				✓	MO	MO	MO	MO
Mitotichthys meraculus	Western Crested Pipefish				✓	MO			MO
Nannocampus subosseus	Bonyhead Pipefish				✓	MO			MO
Phoxocampus belcheri	Black Rock Pipefish				✓	MO	MO	MO	MO
Phycodurus eques	Leafy Seadragon				✓	MO			MO
Phyllopteryx taeniolatus	Common Seadragon				✓	MO			MO
Pugnaso curtirostris	Pugnose Pipefish				✓	MO			MO
Solegnathus hardwickii	Pallid Pipehorse				✓	MO	MO	MO	MO
Solegnathus lettiensis	Gunther's Pipehorse				✓	MO	MO	MO	MO
Solenostomus cyanopterus	Robust Ghostpipefish				✓	MO	MO	MO	MO
Stigmatopora argus	Spotted Pipefish,				✓	MO			MO
Stigmatopora nigra	Widebody Pipefish,				✓	MO			MO
Syngnathoides biaculeatus	Double-end Pipehorse				✓	MO	MO	MO	MO
Trachyrhamphus bicoarctatus	Bentstick Pipefish				✓	MO	MO	MO	MO
Trachyrhamphus longirostris	Straightstick Pipefish				✓	MO	MO	MO	MO
Urocampus carinirostris	Hairy Pipefish				✓	MO			MO

Scientific Name	Common Name	EPBC Status: Recovery Plan / Conservation Advice	EPBC Status: Threatened Species*	EPBC Status: Migratory Species*	EPBC Status: Listed Marine Species	Type of Presence: EMBA	Type of Presence: Project Area	Type of Presence: Light Area	Type of Presence: Hydrocarbon Area
Vanacampus margaritifer	Mother-of-pearl Pipefish				✓	MO			MO
Vanacampus phillipi	Port Phillip Pipefish				✓	MO			MO
Vanacampus poecilolaemus	Longsnout Pipefish				✓	MO			MO

Threatened Species:

V Vulnerable

E Endangered

Type of 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

FKO Foraging, feeding or related behaviour known to occur within area

BKO Breeding known to occur within area

**= Matter of National Environmental Significance*

Table 5-7 Biologically Important Areas for Fish Species within the Corowa Development EMBA

Scientific Name	Common Name	BIA Presence				Summary Description of BIA
		EMBA	Project Area	Light Area	Hydrocarbon Area	
Carcharodon carcharias	White Shark	f			f	Foraging grounds along west coast and Abrolhos Islands; foraging is associated with sea lion colonies in the area providing a food source.
Rhincodon typus	Whale Shark	f	f	f	f	Oceanica foraging grounds; Whale Sharks known to travel along the 200 m depth contour. Presence may occur during spring.
Pristis clavata	Dwarf Sawfish	f,n				Inshore foraging, pupping and nursery area along Eighty Mile Beach.
Pristis pristis	Freshwater Sawfish	f,n				Inshore foraging and pupping area along Eighty Mile Beach. Pupping occurs from January to May.
Pristis zijsron	Green Sawfish	f,n				Inshore foraging, pupping and nursery area along Eighty Mile Beach.

Biologically Important Area

f: Foraging; n: Nursing, pupping and/or juvenile

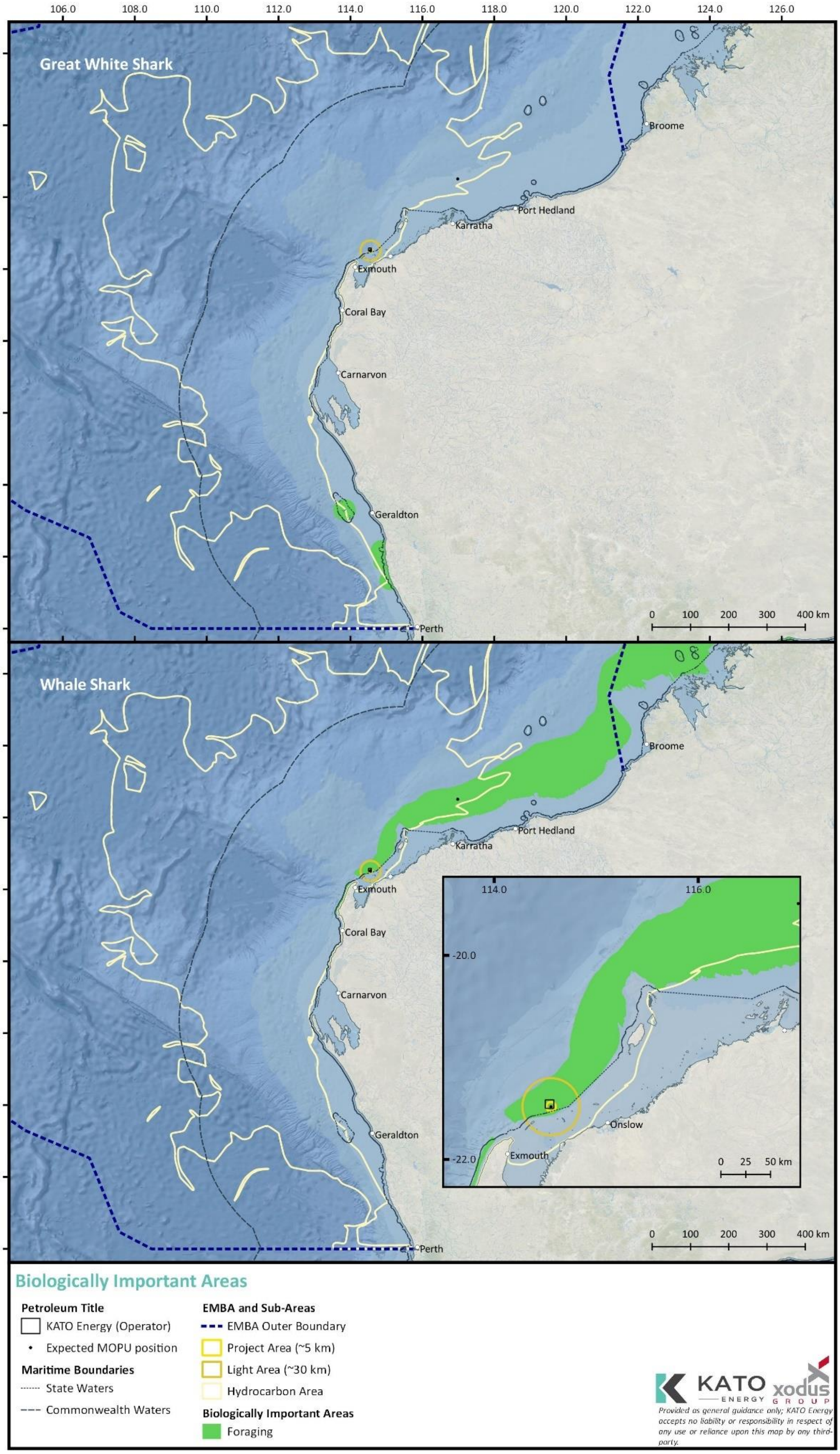


Figure 5-15 Biologically Important Areas for Shark Species (Great White and Whale Shark)

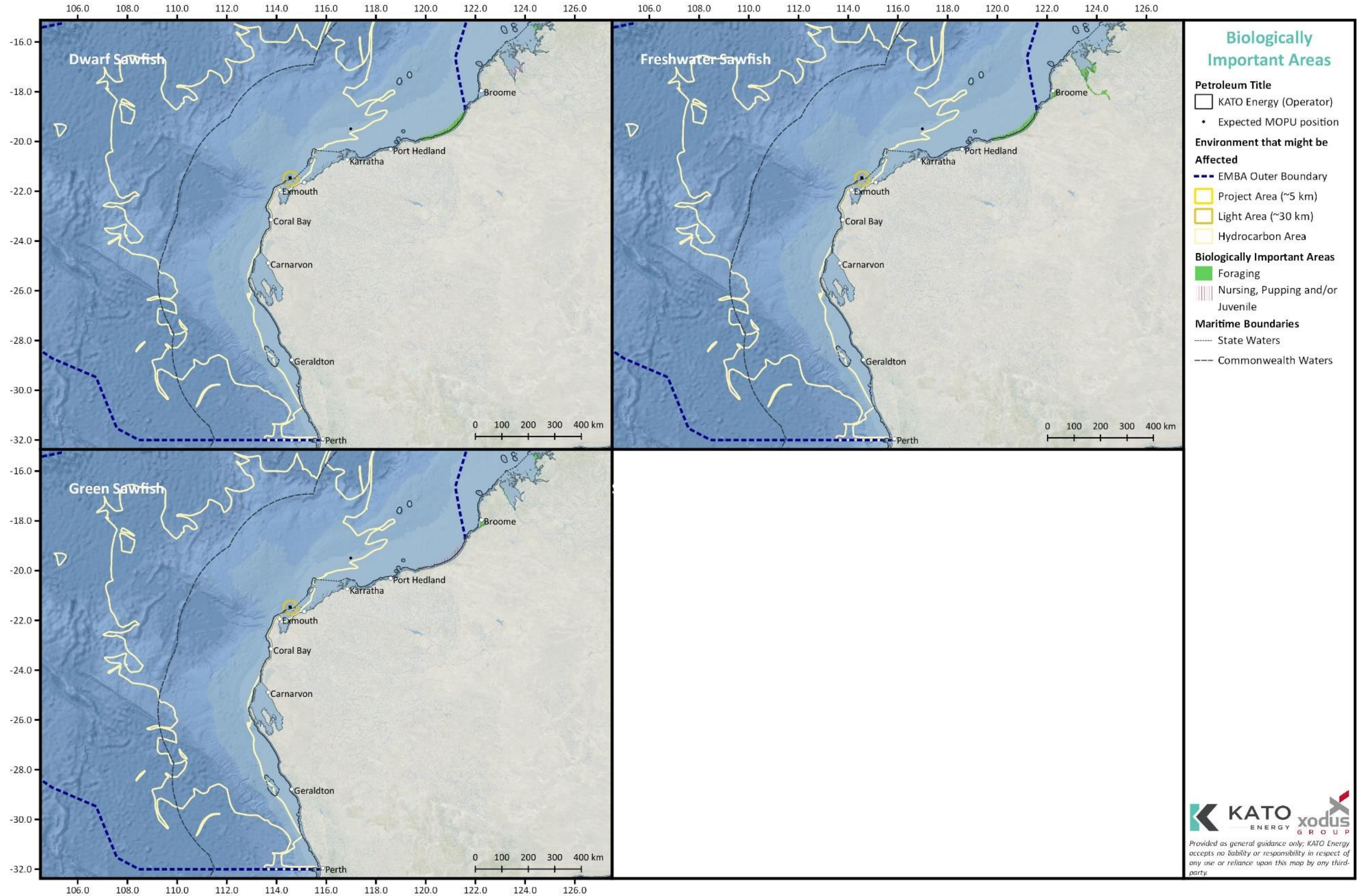


Figure 5-16 Biologically Important Areas for Sawfish Species (Dwarf, Freshwater and Green Sawfish)

5.4.6 Marine Mammals

Multiple species (or species habitat) of marine mammal may occur within the EMBA (Table 5-8, Appendix A). The presence of most species, within the Project Area and wider EMBA, are expected to be of a transitory nature only, with only a small number of species having an important behaviours (e.g. foraging, breeding) identified (Table 5-8, Appendix A).

BIAs have also been identified for some mammal species (Table 5-9) within the EMBA. The closest BIA to the Corowa Development is the migration BIAs for the Pygmy Blue and Humpback Whales, and the foraging, breeding and calving/nursing BIAs for the Dugong (Table 5-9, Figure 5-17, Figure 5-18). Of these, the only one that intersects with the Project Area is the migration BIA for the Humpback Whale, and a distribution BIA of the Pygmy Blue Whale (Table 5-9, Figure 5-17). Humpback Whales migrate north from their Antarctic feeding grounds around May each year, and reach the waters of the North-west Marine Region in early June (DEWHA 2008c); however, the exact timing of the migration period can vary from year to year. From the 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 (Jenner et al. 2001).

Breeding and calving grounds are estimated to extend south from Camden Sound to at least North West Cape (Irvine et al. 2018), with breeding and calving occurring between August and September (DEWHA 2008c). This also coincides with the start of the southern migration. The southward migration path is typically closer to the coast, with some corridors located only ~50–100 km offshore. Exmouth Gulf and Shark Bay are both important resting areas for migrating Humpbacks, particularly for cows and calves on the southern migration (Figure 5-17) (DEWHA 2008). The southerly migration, from around the Lacepede Islands (north of Broome) extends parallel to the coast on approx. the 20–30 m depth contour (Jenner et al. 2001, DEWHA 2008). Southbound migration is more diffuse and irregular, lacking an obvious peak. An increase in southerly migrating individuals may be observed between the North West Cape and the Montebello Islands around November (Jenner et al. 2001). The Project Area does not overlap with any known resting, breeding or feeding areas; however, it is within their known migration route and therefore it is possible that Humpback Whales may have a transitory presence within this area.

Two subspecies of Blue Whales are found in the southern hemisphere and are known to occur in Australian waters—the Antarctic Blue Whale and the Pygmy Blue Whale. Antarctic Blue Whales are not expected to occur within the EMBA. Pygmy Blue Whales are expected to occur and seasonally important areas within WA include the Perth Canyon. The migratory pathway of Pygmy Blue Whales along the WA coast is reasonably well understood (McCauley and Jenner 2010; DEWHA 2008c). During the northern migration the whales are around the Perth Canyon area from January to May, and then travel past North West Cape between April to August; the southern migration typically occurs from October to late December (DEWHA 2008c).

Much of the Australian continental shelf and coastal waters have no particular significance to the Blue Whales as it is only used for migration and opportunistic feeding. No known foraging, resting or migratory route for the Pygmy Blue Whale exists within the Project Area, and as such any presence would be transitory only.

Areas supporting Dugong populations in WA include Shark Bay and the Ningaloo region. A significant proportion of the world’s Dugong population occurs in coastal waters from Shark Bay (WA) to Moreton Bay (QLD) (DEWHA 2008d).

Shark Bay supports a significant population of Dugongs, with an estimated 10,000 individuals (DEWHA 2008d). Dugongs are highly migratory species as a result of their search for suitable seagrass beds or warmer waters (Marsh, Penrose, Eros and Hugue 2002). In Shark Bay, Dugongs have been tracked to move over 100 km north-westward to the warmer part of that bay during the winter and return to the eastern part of the bay during summer. The maximum recorded movement is of more than 400 km in around 40 days.

Dugongs are also known to feed and migrate through the Northwest Shelf Province, including Exmouth Gulf, around North West Cape and offshore on the NWS. The Exmouth Gulf Dugong population is considered stable and the only one not in decline (Oceanwise 2019). Exmouth Gulf is considered important to this species, as it has been recorded as providing significant breeding and feeding habitat (Figure 5-18) (Jenner and Jenner 2005, Oceanwise 2019). Seagrass is the preferred food of Dugongs, but they are also known to eat algae and macroinvertebrates.

No known foraging, resting or migratory route for the Dugongs exist within the Project Area, and as such any presence would be transitory only.

Table 5-8 Marine Mammal Species or Species Habitat that may Occur within the Corowa Development EMBA

		EPBC Status				Type of Presence			
Scientific Name	Common Name	Recovery Plan / Conservation Advice	Threatened Species*	Migratory Species*	Listed Marine Species	EMBA	Project Area	Light Area	Hydrocarbon Area
Whales									
Balaenoptera acutorostrata	Minke Whale				✓	MO	MO	MO	MO
Balaenoptera bonaerensis	Antarctic Minke Whale			✓	✓	LO			LO
Balaenoptera borealis	Sei Whale	Y	V	✓	✓	FLO	LO	LO	FLO
Balaenoptera edeni	Bryde's Whale			✓	✓	LO	MO	LO	LO
Balaenoptera musculus	Blue Whale	Y	E	✓	✓	FKO	LO	LO	FNO
Balaenoptera physalus	Fin Whale	Y	V	✓	✓	FLO	LO	LO	FLO
Caperea marginata	Pygmy Right Whale				✓	FMO			FMO
Eubalaena australis	Southern Right Whale	Y	E	✓	✓	BKO	MO	LO	BKO
Globicephala macrorhynchus	Short-finned Pilot Whale				✓	MO	MO	MO	MO
Globicephala melas	Long-finned Pilot Whale				✓	MO			MO
Hyperoodon planifrons	Southern Bottlenose Whale				✓	MO			MO
Kogia breviceps	Pygmy Sperm Whale				✓	MO	MO	MO	MO
Kogia simus	Dwarf Sperm Whale				✓	MO	MO	MO	MO
Indopacetus pacificus	Longman's Beaked Whale				✓	MO			MO
Megaptera novaeangliae	Humpback Whale	Y	V	✓	✓	BKO	KO	CKO	CKO

Scientific Name	Common Name	EPBC Status				Type of Presence			
		Recovery Plan / Conservation Advice	Threatened Species*	Migratory Species*	Listed Marine Species	EMBA	Project Area	Light Area	Hydrocarbon Area
Mesoplodon bowdoini	Andrew's Beaked Whale				✓	MO			MO
Mesoplodon densirostris	Blainville's Beaked Whale				✓	MO			MO
Mesoplodon ginkgodens	Gingko-toothed Beaked Whale				✓	MO			MO
Mesoplodon grayi	Gray's Beaked Whale				✓	MO			MO
Mesoplodon layardii	Strap-toothed Beaked Whale				✓	MO			MO
Mesoplodon mirus	True's Beaked Whale				✓	MO			MO
Peponocephala electra	Melon-headed Whale				✓	MO	MO	MO	MO
Physeter macrocephalus	Sperm Whale			✓	✓	FKO	MO	MO	FKO
Ziphius cavirostris	Cuvier's Beaked Whale				✓	MO	MO	MO	MO
Sirenians									
Dugong dugon	Dugong			✓	✓	BKO		BKO	BKO
Dolphins									
Delphinus delphis	Common Dolphin				✓	MO	MO	MO	MO
Feresa attenuata	Pygmy Killer Whale				✓	MO	MO	MO	MO
Grampus griseus	Risso's Dolphin				✓	MO	MO	MO	MO
Lagenodelphis hosei	Fraser's Dolphin				✓	MO			MO
Lagenorhynchus obscurus	Dusky Dolphin			✓	✓	LO			
Lissodelphis peronii	Southern Right Whale Dolphin			✓	✓	MO			MO
Orcaella brevirostris	Irrawaddy Dolphin				✓	MO			
Orcaella heinsohni	Australian Snubfin Dolphin			✓		MO			
Orcinus orca	Killer Whale			✓	✓	MO	MO	MO	MO
Peponocephala electra	Melon-headed Whale				✓	MO			
Pseudorca crassidens	False Killer Whale				✓	LO		LO	MO
Sousa chinensis	Indo-Pacific Humpback Dolphin			✓	✓	KO		LO	KO
Stenella attenuata	Spotted Dolphin				✓	MO	MO	MO	MO
Stenella coeruleoalba	Striped Dolphin				✓	MO	MO	MO	MO

Scientific Name	Common Name	EPBC Status: Recovery Plan / Conservation Advice	EPBC Status: Threatened Species*	EPBC Status: Migratory Species*	EPBC Status: Listed Marine Species	Type of Presence: EMBA	Type of Presence: Project Area	Type of Presence: Light Area	Type of Presence: Hydrocarbon Area
Stenella longirostris	Long-snouted Spinner Dolphin				✓	MO	MO	MO	MO
Steno bredanensis	Rough-toothed Dolphin				✓	MO	MO	MO	MO
Tursiops aduncus	Spotted Bottlenose Dolphin			✓	✓	LO	KO	KO	LO
Tursiops aduncus (Arafura/Timor Sea populations)	Indian Ocean Bottlenose Dolphin				✓	KO	KO	KO	KO
Tursiops truncatus s. str.	Bottlenose Dolphin				✓	MO	MO	MO	
Pinnipeds									
Arctocephalus forsteri	Long-nosed Fur-seal, New Zealand Fur-seal				✓	MO			MO
Neophoca cinerea	Australian Sea Lion		V		✓	BKO			BKO

Threatened Species:

V Vulnerable

E Endangered

Type of 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

FMO Foraging, feeding or related behaviour may occur within area

FLO Foraging, feeding or related behaviour likely to occur within area

FKO Foraging, feeding or related behaviour known to occur within area

BKO Breeding known to occur within area

CKO Congregation known to occur within area

**= Matter of National Environmental Significance*

Table 5-9 Biologically Important Areas for Marine Mammal Species within the Corowa Development EMBA

Scientific Name	Common Name	BIA Presence				Summary Description of BIA
		EMBA	Project Area	Light Area	Hydrocarbon Area	
Balaenoptera musculus	Blue Whale, Pygmy Blue Whale	d,f,m	d	d	d,f,m	Offshore migration corridor, typically along the shelf edge at depths 500–1,000 m; this occurs close to the coast around Exmouth. Presence during northern migration past Exmouth area may occur April to August (whereas January to May past Perth Canyon area). Southern migration presence may occur October to late December.
Eubalaena australis	Southern Right Whale	c				Seasonal calving habitat and buffer along south-western and southern coast. Presence may occur late-autumn, winter and spring.
Megaptera novaeangliae	Humpback Whale	m,r	m	m	m	Migration corridor extends out to ~50–100 km from the coast. Presence during the northern migration may occur late July to September. Winter resting areas identified within Exmouth Gulf and Shark Bay.
Physeter macrocephalus	Sperm Whale	f				Oceanic foraging grounds at western end of Perth Canyon. Presence may occur during summer.
Dugong dugon	Dugong	b,c,f				Breeding, calving, nursing and foraging grounds within the Exmouth Gulf and North West Cape regions. May be present throughout the year. Presence in Shark Bay BIAs may be more seasonal, between April and November.
Neophoca cinerea	Australian Sea Lion	f				Oceanic foraging grounds along west coast and around Abrolhos Islands for resident populations. Presence may occur throughout the year.

Biologically Important Area

b: Breeding; c: Calving and/or nursing; d: Distribution; f: Foraging: m: Migration

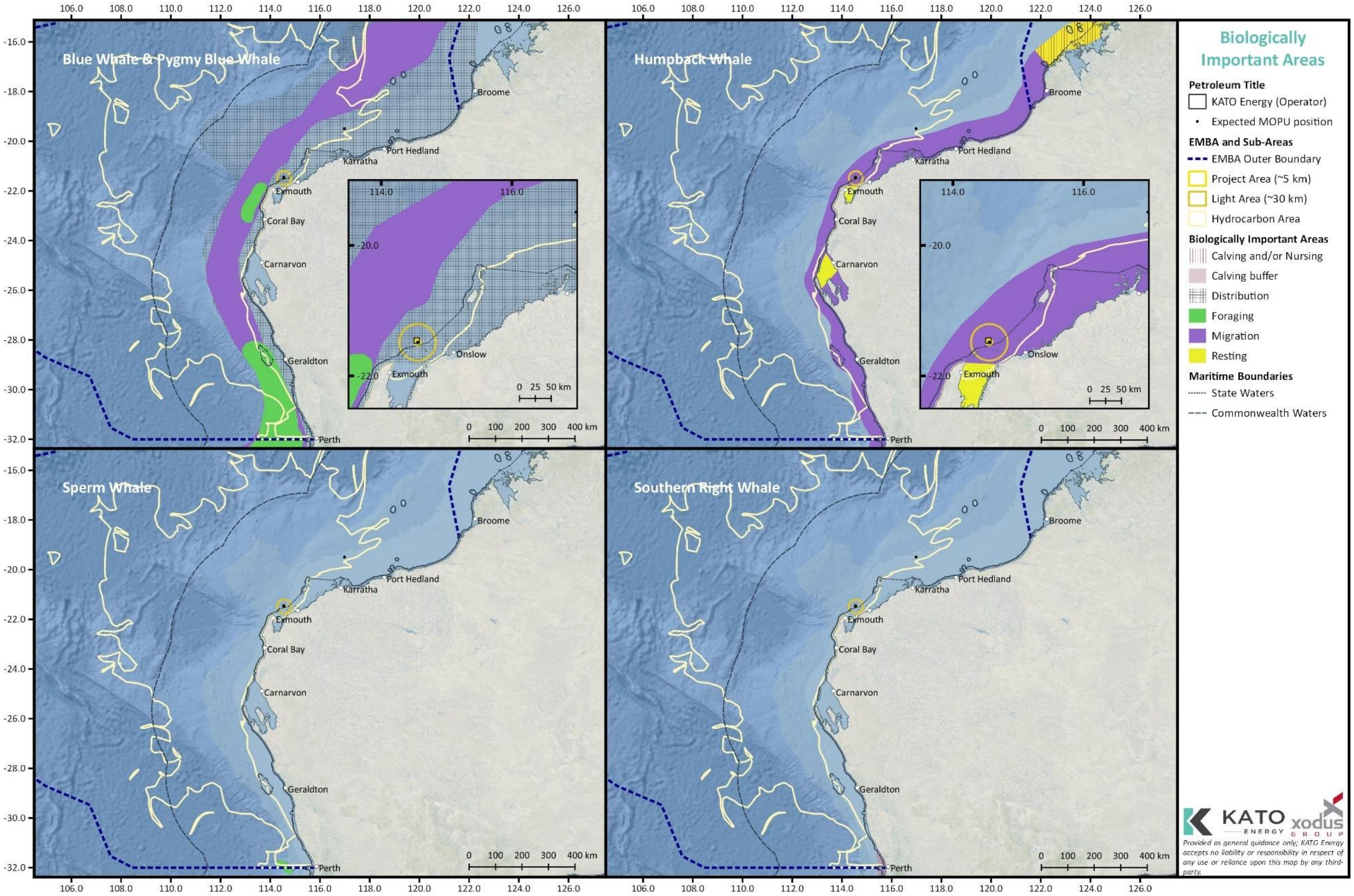


Figure 5-17 Biologically Important Areas for Whale Species (Blue, Pygmy Blue, Humpback, Sperm and Southern Right Whale)

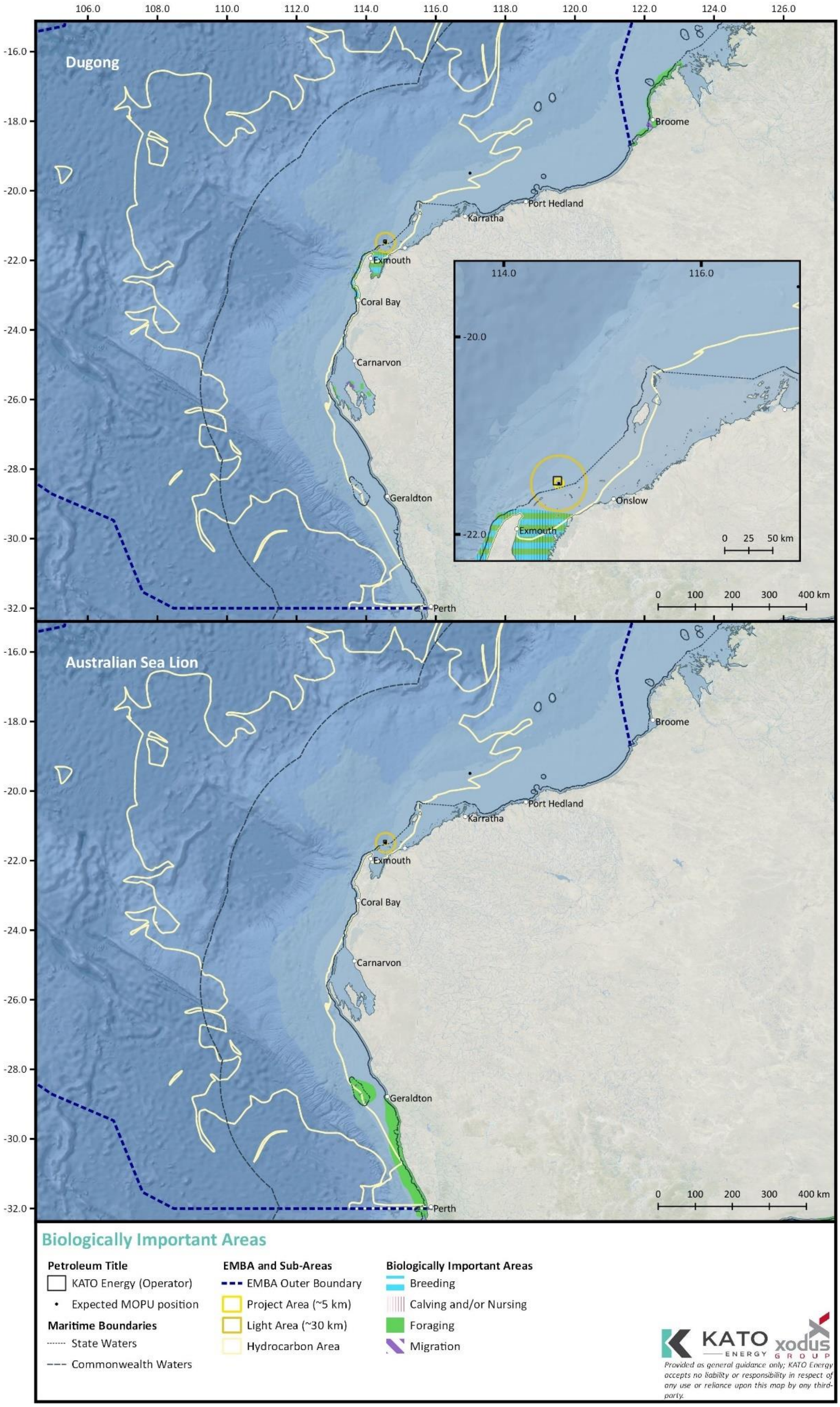


Figure 5-18 Biologically Important Areas for the Dugong and Australian Sea Lion

5.4.7 Marine Reptiles

Multiple species (or species habitat) of marine reptile may occur within the EMBA (Table 5-11, Appendix A). The presence of most species, within the Project Area, are expected to be of a transitory nature only. However, the type of presence for some species within the EMBA were identified as having important behaviours (e.g. breeding, foraging) (Table 5-11, Appendix A).

BIAs and critical habitat have also been identified for some turtle species (Table 5-12) within the EMBA. Those closest to the Corowa Development are the nesting and internesting BIAs for the Flatback, Green, Hawksbill and Loggerhead Turtle (Figure 5-19). These internesting BIAs do intersect with the Corowa Development Project Area, however presence is only expected to be of a transient and intermittent nature. Use of internesting areas by turtles is typically for resting or foraging between nesting attempts. No significant benthic habitat or complex substrate structure exists within the Project Area that would provide foraging habitat for the turtles and therefore no aggregation within the area would be expected to occur.

Marine turtles have a highly migratory life history and rely on both marine and terrestrial habitats. The Pilbara region, including the offshore islands are known nesting and internesting habitat for turtle species. Nesting and internesting habitat critical to the survival of a species has been identified for genetic stocks present in WA (CoA 2017). These important nesting locations include areas inshore of the Corowa Development at Muiron and Serrurier islands, the North West Cape and Ningaloo coast (Table 5-10, Figure 5-19). Estimates of turtle populations within the entire NWS vary, but are typically largest for the Green and Flatback Turtles. The proportion of this nesting occurring within the southern Pilbara inshore islands is lower than some other areas (e.g. Barrow and Montebello Islands or Dampier Archipelago) but these areas are still considered important habitats for the species.

Nesting season for all four species occurs over summer:

- Flatback, begins in late November/December, peaks in January, and end in February/March
- Green, begins in November, peak in January/February, and end in April
- Hawksbill, can occur year-round, but with a peak between October and January
- Loggerhead, between November and March.

The DBCA undertakes monitoring on Muiron Island and the North West Cape; studies have shown that ~150–350 females breed at Muiron Island per year (Baldwin et al. 2003), and that Muiron Island is considered important habitat for all four turtle species (Prince 1998).

A longitudinal study found sighting rates of turtles between 1989 and 2007 were increasing in Shark Bay and the Ningaloo Reef region, but not in Exmouth Gulf (Hodgson 2007, Oceanwise 2019). In the Exmouth Gulf sub-adults are known to use mangrove habitat area as foraging grounds. Boat-based sightings indicate that the most common species within the Gulf from August to November are Green and Hawksbill Turtles (Jenner and Jenner 2005; Oceanwise 2019).

Table 5-10 Habitats Critical to the Survival of Marine Turtle Species

Species (Genetic Stock)	Nesting locations	Internesting buffer	Nesting season
Flatback Turtle (Pilbara)	Montebello Islands, Mundabullangana Beach, Barrow Island, Cemetery Beach, Dampier Archipelago (including Delambre Island and Hauy Island), coastal islands from Cape Preston to Locker Island	60 km	October to March

Species (Genetic Stock)	Nesting locations	Internesting buffer	Nesting season
Green Turtle (NWS)	Adele Island, Maret Island, Cassini Island, Lacepede Islands, Barrow Island, Montebello Islands (all with sandy beaches), Serrurier Island, Dampier Archipelago, Thevenard Island, North West Cape, Ningaloo coast	20 km	November to March
Hawksbill Turtle (WA)	Dampier Archipelago (including Rosemary Island and Delambre Island), Montebello Islands (including Ah Chong Island, South East Island and Trimouille Island), Lowendal Islands (including Varanus Island, Beacon Island and Bridled Island), Sholl Island	20 km	October to February
Loggerhead Turtle (WA)	Dirk Hartog Island, Muiron Islands, Gnaraloo Bay, Ningaloo coast	20 km	October to March

Table 5-11 Marine Reptile Species or Species Habitat that may Occur within the Corowa Development EMBA

		EPBC Status				Type of Presence			
Scientific Name	Common Name	Recovery Plans / Conservation Advice	Threatened Species*	Migratory Species*	Listed Marine Species	EMBA	Project Area	Light Area	Hydrocarbon Area
Turtles									
Caretta caretta	Loggerhead Turtle	Y	E	✓	✓	BKO	KO	FKO	BKO
Chelonia mydas	Green Turtle	Y	V	✓	✓	BKO	KO	BKO	BKO
Dermochelys coriacea	Leatherback Turtle	Y	E	✓	✓	FKO	KO	KO	FKO
Eretmochelys imbricate	Hawksbill Turtle	Y	V	✓	✓	BKO	KO	BKO	BKO
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle	Y	E	✓	✓	FLO			
Natator depressus	Flatback Turtle	Y	V	✓	✓	BKO	C/A	BKO	BKO
Seasnakes									
Acalyptophis peronii	Horned Seasnake				✓	MO	MO	MO	MO
Aipysurus apraefrontalis	Short-nosed Seasnake	Y	CE		✓	KO	MO	LO	KO
Aipysurus duboisii	Dubois' Seasnake				✓	MO	MO	MO	MO
Aipysurus eydouxii	Spine-tailed Seasnake				✓	MO	MO	MO	MO
Aipysurus fuscus	Dusky Seasnake				✓	KO			
Aipysurus laevis	Olive Seasnake				✓	MO	MO	MO	MO
Aipysurus pooleorum	Shark Bay Seasnake				✓	MO			MO
Aipysurus tenuis	Brown-lined Seasnake				✓	MO			MO
Astrotia stokesii	Stokes' Seasnake				✓	MO	MO	MO	MO
Disteira kingii	Spectacled Seasnake				✓	MO	MO	MO	MO

Scientific Name	Common Name	EPBC Status				Type of Presence			
		Recovery Plans / Conservation Advice	Threatened Species*	Migratory Species*	Listed Marine Species	EMBA	Project Area	Light Area	Hydrocarbon Area
Disteira major	Olive-headed Seasnake				✓	MO	MO	MO	MO
Emydocephalus annulatus	Turtle-headed Seasnake				✓	MO	MO	MO	MO
Ephalophis greyi	North-western Mangrove Seasnake				✓	MO	MO	MO	MO
Hydrelaps darwiniensis	Black-ringed Seasnake				✓	MO			MO
Hydrophis coggeri	Slender-necked Seasnake				✓	MO			
Hydrophis czeblukovi	Fine-spined Seasnake				✓	MO			MO
Hydrophis elegans	Elegant Seasnake				✓	MO	MO	MO	MO
Hydrophis mcdowelli	null				✓	MO			MO
Hydrophis ornatus	Spotted Seasnake				✓	MO	MO	MO	MO
Lapemis hardwickii	Spine-bellied Seasnake				✓	MO			
Pelamis platurus	Yellow-bellied Seasnake				✓	MO	MO	MO	MO
Other Reptiles									
Crocodylus porosus	Salt-water Crocodile			✓	✓	LO			

Threatened Species:		*Type of Presence:*	
V	*Vulnerable*	*MO*	*Species or species habitat may occur within area*
E	*Endangered*	*LO*	*Species or species habitat likely to occur within area*
CE	*Critically Endangered*	*KO*	*Species or species habitat known to occur within area*
		FKO	*Foraging, feeding or related behaviour known to occur within area*
		BKO	*Breeding known to occur within area*
		C/A	*Congregation / aggregation known to occur within area*

**= Matter of National Environmental Significance*

Table 5-12 Biologically Important Areas for Marine Reptile Species within the Corowa Development EMBA

Scientific Name	Common Name	BIA Presence				Summary Description of BIA
		EMBA	Project Area	Light Area	Hydrocarbon Area	
Caretta caretta	Loggerhead Turtle	f,i,n	i	i,n	f,i,n	Nesting and internesting areas around rookeries, including Ningaloo Coast, Muiron, Lowendal and Montebello Islands and Dampier Archipelago. Presence may occur during spring and early summer. Oceanic foraging area between De Grey River and Bedout Island may be used throughout the year by multiple turtle species.
Chelonia mydas	Green Turtle	a,b,f, i,n,m	i	i,n	a,b,f, i,n	Nesting and internesting areas around rookeries, including North West Cape, Barrow and Montebello Islands and Dampier Archipelago. Presence may occur during summer. Oceanic foraging area around the inshore islands between Cape Preston and Onslow; Barrow and Montebello Islands; and De Grey River and Bedout Island.
Eretmochelys imbricate	Hawksbill Turtle	f,i,n, m		i	f,i,n	Nesting and internesting areas around rookeries, including Ningaloo Coast, Thevenard, Barrow, Montebello and Lowendal Islands and Dampier Archipelago. Oceanic foraging area around the inshore islands between Cape Preston and Onslow; Barrow and Montebello Islands; and De Grey River and Bedout Island.
Natator depressus	Flatback Turtle	a,f,i, n,m	i	i,n	a,f, i,n	Nesting and internesting areas around rookeries, including Thevenard (and other Pilbara inshore islands), Barrow and Montebello Islands and Dampier Archipelago. Presence may occur during summer. Oceanic foraging area around the inshore islands between Cape Preston and Onslow; Barrow and Montebello Islands; and De Grey River and Bedout Island.
Biologically Important Area *a: Aggregation; b: Basking; f: Foraging; i: Internesting; n: Nesting; m: Migration*						

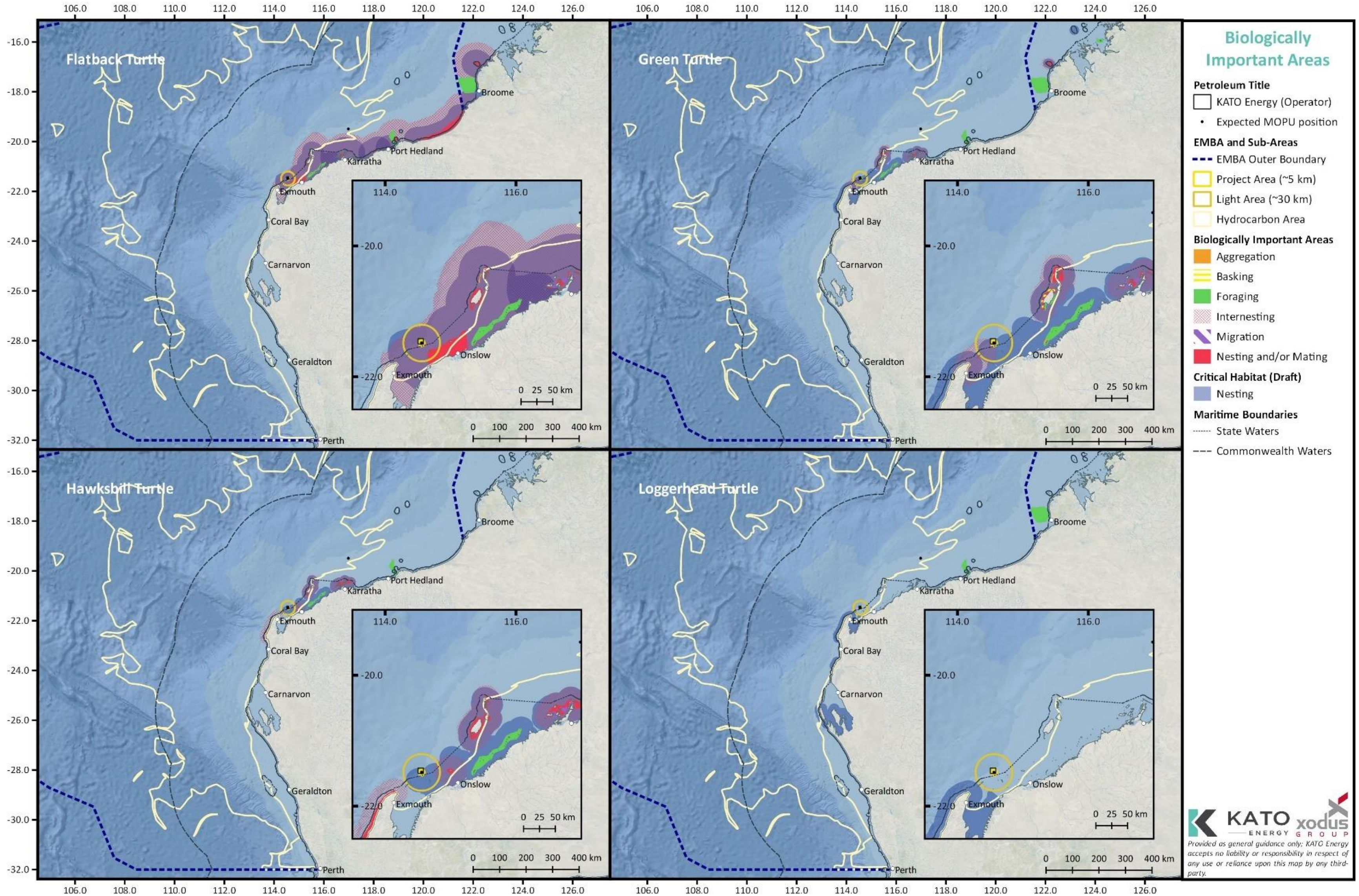


Figure 5-19 Biologically Important Areas and Critical Habitat for Turtle Species (Flatback, Green, Hawksbill and Loggerhead Turtle)

5.5 Social, Economic and Cultural Environment

5.5.1 Commonwealth Marine Area

The Commonwealth marine environment is a matter of national environment significance (MNES) under the EPBC Act. The EMBA for the Corowa Development occurs within waters off Western Australia that are part of two bioregions:

- North-west Marine Region, which comprises the Commonwealth waters and seabed from the Western Australia / Northern Territory border south to Kalbarri.
- South-west Marine Region, which comprises the Commonwealth waters and seabed from Kalbarri to eastern end of Kangaroo Island (South Australia).

The North-west Marine Region is distinguished by its predominantly wide continental shelf, very high tidal regimes (especially in the north), very high cyclone incidence, unique current systems and warm, low-nutrient surface waters (DEWHA 2012a). The region supports high species richness of tropical Indo-west Pacific biota, but low levels of endemism (DSEWPaC 2012a).

The South-west Marine Region is generally characterised by low levels of nutrients and high species biodiversity, including a large number of endemic species (DSEWPaC 2012b). The flora and fauna of the region are a blend of tropical, subtropical and temperate species; the temperate species dominate the southern and eastern parts of the region, while tropical species become progressively more common towards the north of the region (DSEWPaC 2012b).

Conservation values of the Commonwealth marine area include:

- protected species and/or their habitat (Section 5.4)
- protected places including Australian Marine Parks (Section 5.5.1.1) and heritage places (Section 5.5.5)
- key ecological features (Section 5.5.1.2).

5.5.1.1 Australian Marine Parks

Australian Marine Parks (AMPs) occur within Commonwealth waters and were proclaimed as Commonwealth reserves under the EPBC Act in 2007 and 2013. Within the EMBA, 14 AMPs are present—ten within the North-west Marine Region, and four within the South-west Marine Region (Table 5-13, Figure 5-20). The closest AMPs to the Corowa Development are Ningaloo, Gascoyne and Montebello Marine Parks, ~40 km, 60 km and 100 km from the expected position of the MOPU respectively (Figure 5-20).

The following types of values have been identified for each marine park within the respective management plans (DNP 2018a; DNP 2018b), and are summarised in Table 5-14:

- natural values, as habitats, species and ecological communities, and the processes that support their connectivity, productivity and function
- cultural values, as living and cultural heritage recognising Indigenous beliefs, practices and obligations for country, places of cultural significance and cultural heritage sites
- heritage values, as non-Indigenous heritage that has aesthetic, historic, scientific or social significance
- socioeconomic values, as the benefits for people, businesses and/or the economy.

Table 5-13 Australian Marine Parks within the Corowa Development EMBA

Australian Marine Park	EMBA	Project Area	Light Area	Hydrocarbon Area
North-west Marine Region				
Kimberley	✓	X	X	X
Argo-Rowley Terrace	✓	X	X	X
Mermaid Reef	✓	X	X	X
Eighty Mile Beach	✓	X	X	X
Dampier	✓	X	X	X
Montebello	✓	X	X	✓
Ningaloo	✓	X	X	✓
Gascoyne	✓	X	X	✓
Carnarvon Canyon	✓	X	X	✓
Shark Bay	✓	X	X	✓
South-west Marine Region				
Abrolhos	✓	X	X	✓
Jurien	✓	X	X	✓
Two Rocks	✓	X	X	X
Perth Canyon	✓	X	X	✓

✓ = Present within area; X = not present within area

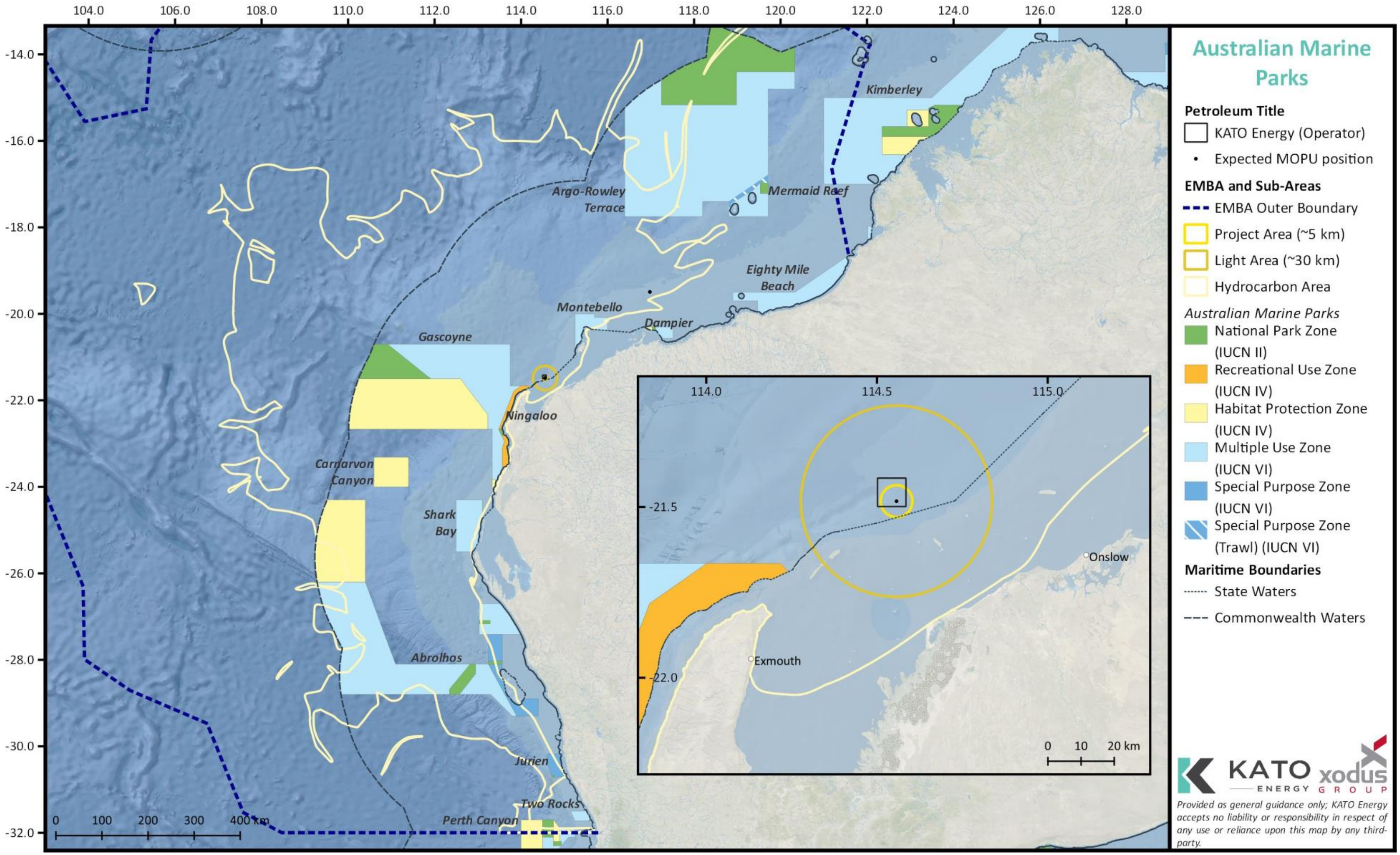


Figure 5-20 Australian Marine Parks

Table 5-14 Significance and Values of Australian Marine Parks

Australian Marine Parks – Significance and Values
North-west Marine Region
Kimberley Marine Park

The Kimberley Marine Park is located ~100 km north of Broome, extending from the Lacepede Islands to the Holothuria Banks offshore from Cape Bougainville. The Marine Park is adjacent to the State Lalang-garram/Camden Sound Marine Park and the North Kimberley Marine Park. The Marine Park covers an area of 74,469 km² and water depths from <15 m to 800 m. Marine Park includes three zones: National Park Zone (II), Habitat Protection Zone (IV) and Multiple Use Zone (VI).
Statement of significance
The Kimberley Marine Park is significant because it includes habitats, species and ecological communities associated with the Northwest Shelf Province, Northwest Shelf Transition and Timor Province, and includes two KEFs. The Marine Park provides connectivity between deeper offshore waters, and the inshore waters of the adjacent State North Kimberley and Lalang-garram/Camden Sound Marine Parks.
Natural values
• Examples of ecosystems representative of the:
  ○ Northwest Shelf Province, an area influenced by strong tides, cyclonic storms, long-period swells and internal tides. The region includes diverse benthic and pelagic fish communities, and an ancient coastline thought to be an important seafloor feature and migratory pathway for Humpback Whales.
  ○ Northwest Shelf Transition, this area straddles the North-west and North Marine Regions and includes shelf break, continental slope, and the majority of the Argo Abyssal Plain and is subject to a high incidence of cyclones. Benthic biological communities in the deeper parts of the region have not been extensively studied, although high levels of species diversity and endemism occur among demersal fish communities on the continental slope.
  ○ Timor Province, an area dominated by warm, nutrient-poor waters. The reefs and islands of the region are regarded as biodiversity hotspots; endemism in demersal fish communities of the continental slope is high and two distinct communities have been identified on the upper and mid slopes.
• Contains two KEFs: ancient coastline at the 125-m depth contour, and the continental slope demersal fish communities (Section 5.5.1.2).
• Supports a range of species, including species listed as threatened, migratory, marine or cetacean under the EPBC Act.
• BIAs within the Marine Park include breeding and foraging habitat for seabirds, internesting and nesting habitat for marine turtles, breeding, calving and foraging habitat for inshore dolphins, calving, migratory pathway and nursing habitat for Humpback Whales, migratory pathway for Pygmy Blue Whales, foraging habitat for Dugong and foraging habitat for Whale Sharks.
Cultural values
• Sea country is valued for Indigenous cultural identity, health and wellbeing. The Wunambal Gaambera, Dambimangari, Mayala, Bardi Jawi and the Nyul Nyul people have responsibilities for sea country in the Marine Park.
• The Wunambal Gaambera people's country includes daagu (deep waters), with ~3,400 km² of their sea country located in the Marine Park.
• The national heritage listing for the West Kimberley also recognises these key cultural heritage values:
  ○ cultural tradition of the Wanjina-Wunggurr people incorporates many sea country cultural sites
  ○ log-raft maritime tradition, which involved using tides and currents to access warruru (reefs) far offshore to fish
  ○ interactions with Makassan traders around sea foods over hundreds of years
  ○ important pearl resources that were used in traditional trade through the wunan (traditional sharing and business trading system) and in contemporary commercial agreements.
Heritage values
• No international, Commonwealth or national heritage listings apply to the Marine Park.

Australian Marine Parks – Significance and Values
• The Marine Park contains over 40 known historic shipwrecks (Section **5.5.5**). **Social and economic values** • Tourism, commercial fishing, mining, recreation, including fishing, and traditional use are important activities in the Marine Park.
Argo-Rowley Terrace Marine Park

The Argo-Rowley Terrace Marine Park is located ~270 km north-west of Broome. The Marine Park is adjacent to the Mermaid Reef Marine Park and the State Rowley Shoals Marine Park. The Marine Park covers an area of 146,003 km^2 and water depths of 220–6,000 m. The Marine Park includes three zones: National Park Zone (II), Multiple Use Zone (VI) and Special Purpose Zone (Trawl) (VI).
Statement of significance
The Argo-Rowley Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Transition and Timor Province, and includes two KEFs. The Marine Park is the largest in the North-west Network. It includes the deeper waters of the region and a range of seafloor features (e.g. canyons on the slope between the Argo Abyssal Plain, Rowley Terrace and Scott Plateau). These are believed to be up to 50 million years old and are associated with small, periodic upwellings that results in localised higher levels of biological productivity.
Natural values
• Examples of ecosystems representative of the:
  ○ Northwest Transition, an area of shelf break, continental slope, and the majority of the Argo Abyssal Plain. Together with Clerke Reef and Imperieuse Reef, Mermaid Reef is a biodiversity hotspot and key topographic feature of the Argo Abyssal Plain.
  ○ 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.
• Contains two KEFs: Canyons linking the Argo Abyssal Plain with the Scott Plateau, and Mermaid Reef and Commonwealth waters surrounding Rowley Shoals (Section 5.5.1.2).
• Supports a range of species, including species listed as threatened, migratory, marine or cetacean under the EPBC Act.
• BIAs within the 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 Indigenous cultural identity, health and wellbeing. However, to date there is limited information about the cultural significance of this Marine Park.
Heritage values
• No international, Commonwealth or national heritage listings apply to the Marine Park.
• The Marine Park contains two known historic shipwreck: *Alfred* (1908) and *Pelsart* (1908) (Section **5.5.5**).
Social and economic values
• Commercial fishing and mining are important activities in the Marine Park.

Mermaid Reef Marine Park
The Mermaid Reef Marine Park is located ~280 km north-west of Broome, adjacent to the Argo-Rowley Terrace Marine Park and ~13 km from the WA Rowley Shoals Marine Park. The Marine Park covers an area of 540 km^2 and covers water depths from <15 m to 500 m. The Marine Park includes one zone: National Park Zone (II). **Statement of significance** The Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Transition and includes one KEF. Mermaid Reef is one of three reefs forming the Rowley Shoals; the others are Clerke Reef and Imperieuse Reef and occur to the south-west of the Marine Park. The Rowley Shoals have been described as the best geological examples of shelf atolls in Australian waters. The reefs of the Rowley Shoals are ecologically significant in that they are considered ecological stepping-stones for reef species originating in Indonesian/Western Pacific waters, are one of a few offshore reef

Australian Marine Parks – Significance and Values
systems on the North West Shelf, and may also provide an upstream source for recruitment to reefs further south. **Natural values** • Examples of ecosystems representative of the Northwest Transition, an area of shelf break, continental slope, and the majority of the Argo Abyssal Plain. Together with Clerke Reef and Imperieuse Reef, Mermaid Reef is a biodiversity hotspot and key topographic feature of the Argo Abyssal Plain. • Contains one KEF: Mermaid Reef and Commonwealth waters surrounding Rowley Shoals (Section 5.5.1.2). • Ecosystems are associated with emergent reef flat, deep reef flat, lagoon, and submerged sand habitats. • Supports a range of species, including species listed as threatened, migratory, marine or cetacean under the EPBC Act. • BIAs within the Marine Park include breeding habitat for seabirds and a migratory pathway for the Pygmy Blue Whale. **Cultural values** • Sea country is valued for Indigenous cultural identity, health and wellbeing. However, to date there is limited information about the cultural significance of this Marine Park. **Heritage values** • No international or national heritage listings apply to the Marine Park. • The Marine Park surrounds the Mermaid Reef – Rowley Shoals Commonwealth Heritage Place (Section **5.5.5**). • The Marine Park contains one known historic shipwreck: *Lively* (1810) (Section 5.5.5). **Social and economic values** • Tourism, recreation, and scientific research are important activities in the Marine Park.
Eighty Mile Beach Marine Park
The Eighty Mile Beach Marine Park is located ~74 km north-east of Port Hedland, adjacent to the State Eighty Mile Beach Marine Park. The Marine Park covers an area of 10,785 km² and covers water depths from <15 m to 70 m. The Marine Park includes one zone: Multiple Use Zone (VI). **Statement of significance** The Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Province; its shallow shelf habitats include terraces, banks and shoals. The Marine Park is adjacent to the Eighty Mile Beach Ramsar site, recognised as one of the most important areas for migratory shorebirds in Australia, and the State Eighty Mile Beach Marine Park, providing connectivity between offshore and inshore coastal waters of Eighty Mile Beach. **Natural values** • 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 region includes diverse benthic and pelagic fish communities, and ancient coastline thought to be an important seafloor feature and migratory pathway for Humpback Whales. • Supports a range of species, including species listed as threatened, migratory, marine or cetacean under the EPBC Act. • BIAs within the Marine Park include breeding, foraging and resting habitat for seabirds, internesting and nesting habitat for marine turtles, foraging, nursing and pupping habitat for sawfish and a migratory pathway for Humpback Whales. **Cultural values** • Sea country is valued for Indigenous cultural identity, health and wellbeing. The Nyangumarta, Karajarri and Ngarla people have responsibilities for sea country in the Marine Park. **Heritage values** • No international, Commonwealth or national heritage listings apply to the Marine Park.

Australian Marine Parks – Significance and Values
• The Marine Park contains three known historic shipwrecks: *Lorna Doone* (1923), *Nellie* (1908) and *Tifera* (1923) (Section 5.5.5). **Social and economic values** • Tourism, commercial fishing, pearling and recreation are important activities in the Marine Park.
Dampier Marine Park
The Dampier Marine Park is located ~10 km north-east of Cape Lambert and 40 km from Dampier extending from the WA state water boundary. The Marine Park covers an area of 1,252 km² and a water depth range from <15 m to 70 m. The Marine Park includes three zones: National Park Zone (II), Habitat Protection Zone (IV) and Multiple Use Zone (VI). **Statement of significance** The Dampier Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Province. The Marine Park provides protection for offshore shelf habitats adjacent to the Dampier Archipelago, and the area between Dampier and Port Hedland, and is a hotspot for sponge biodiversity. The Marine Park includes several submerged coral reefs and shoals including Delambre Reef and Tessa Shoals. **Natural values** • 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 region includes diverse benthic and pelagic fish communities, and ancient coastline thought to be an important seafloor feature and migratory pathway for Humpback Whales. • Supports a range of species, including species listed as threatened, migratory, marine or cetacean under the EPBC Act. • BIAs within the Marine Park include breeding and foraging habitat for seabirds, internesting habitat for marine turtles and a migratory pathway for Humpback Whales. **Cultural values** • Sea country is valued for Indigenous cultural identity, health and wellbeing. The Ngarluma, Yindjibarndi, Yaburara, and Mardudhunera people have responsibilities for sea country in the Marine Park. **Heritage values** • No international, Commonwealth or national heritage listings apply to the Marine Park. **Social and economic values** • Port activities, commercial fishing and recreation, including fishing, are important activities in the Marine Park.
Montebello Marine Park
The Montebello Marine Park is located offshore of Barrow Island and 80 km west of Dampier extending from the WA State water boundary. The Marine Park covers an area of 3,413 km² and water depths from <15 m to 150 m. The Marine Park includes one IUCN zone: Multiple Use Zone (IUCN VI). **Statement of significance** The Montebello Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Province. The Marine Park includes one KEF, the ancient coastline at the 125-m depth contour (see Section 5.5.1.2). The Marine Park provides connectivity between deeper waters of the continental shelf and slope, and the adjacent State Barrow Island and Montebello Islands Marine Parks. A prominent seafloor feature in the Marine Park is Trial Rocks, which has two close coral reefs; these reefs are emergent at low tide. **Natural values** • 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 region includes diverse benthic and pelagic fish communities. • Contains one KEF: the ancient coastline at the 125-m depth contour (Section 5.5.1.2).

Australian Marine Parks – Significance and Values
• Supports a range of species, including species listed as threatened, migratory, marine or cetacean under the EPBC Act. • BIAs within the 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 Indigenous cultural identity, health and wellbeing. However, to date there is limited information about the cultural significance of this Marine Park. **Heritage values** • No international, Commonwealth or national heritage listings apply to the Marine Park. • The Marine Park contains two known historic shipwrecks: *Trial* (1622) and *Tanami* (unknown date) (Section 5.5.5). **Social and economic values** • Tourism, commercial fishing, mining and recreation are important activities in the Marine Park.
Ningaloo Marine Park

The Ningaloo Marine Park stretches ~300 km along the west coast of the Cape Range Peninsula, and is adjacent to the State Ningaloo Marine Park and Commonwealth Gascoyne Marine Park. The Marine Park covers an area of 2,435 km^2 and occurs over a water depth range of 30 m to >500 m. The Marine Park contains zones designated as National Park Zone (IUCN II) and Recreational Use Zone (IUCN IV).
Statement of significance
The Ningaloo Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Shelf Transition, Central Western Transition, Northwest Province, and Northwest Shelf Province, and contains three KEFs.
The Marine Park provides connectivity between deeper offshore waters of the shelf break and shallower coastal waters. It includes some of the most diverse continental slope habitats in Australia, in particular the continental slope area between North West Cape and the Montebello Trough. Canyons in the Marine Park are important for their role in sustaining the nutrient conditions that support the high diversity of Ningaloo Reef. The Marine Park is located in a transition zone between tropical and temperate waters and sustains tropical and temperate flora and fauna, with many species at the limits of their distributions.
Natural values
• Examples of ecosystems representative of the:
  o Central Western Shelf Transition, an area of continental shelf of water depths up to 100 m, and a significant transition zone between tropical and temperate species
  o Central Western Transition, characterised by large areas of continental slope, a range of topographic features (e.g. terraces, rises and canyons), seasonal and sporadic upwelling, and benthic slope communities comprising tropical and temperate species
  o Northwest Province, an area of continental slope comprising diverse and endemic fish communities
  o Northwest Shelf Province, an area influenced by strong tides, cyclonic storms, long-period swells and internal tides; this region includes diverse benthic and pelagic fish communities, and ancient coastline thought to be an important seafloor feature and migratory pathway for Humpback Whales.
• Contains three KEFs: Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula, Commonwealth waters adjacent to Ningaloo Reef, and Continental slope demersal fish communities (Section 5.5.1.2).
• Ecosystems are influenced by the Leeuwin and Ningaloo currents, and the Leeuwin undercurrent.
• Supports a range of species, including species listed as threatened, migratory, marine or cetacean under the EPBC Act.
• BIAs within the 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.

Australian Marine Parks – Significance and Values
Cultural values • Sea country is valued for Indigenous cultural identity, health and wellbeing. The Gnulli people have responsibilities for sea country in the Marine Park. **Heritage values** • The Marine Park is within the Ningaloo Coast World Heritage Property, adjacent to the Ningaloo Coast National Heritage Place, and within the Ningaloo Marine Area (Commonwealth waters) Commonwealth Heritage Place (Section 5.5.5). • The Marine Park contains over 15 known historic shipwrecks (Section **5.5.5**). **Social and economic values** • Tourism and recreation (including fishing) are important activities in the Marine Park
Gascoyne Marine Park

The Gascoyne Marine Park is located ~20 km off the west coast of the Cape Range Peninsula, adjacent to the State and Commonwealth Ningaloo Marine Parks. The Marine Park covers an area of 81,766 km^2 and over water depths between 15–6,000 m. The Marine Park contains zones designated as National Park Zone (IUCN II), Habitat Protection Zone (IUCN IV) and Multiple Use Zone (IUCN VI).
Statement of significance
The Gascoyne Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Shelf Transition, Central Western Transition, and Northwest Province, and includes four KEFs.
The Marine Park includes some of the most diverse continental slope habitats in Australia, in particular the continental slope area between North West Cape and the Montebello Trough. Canyons in the Marine Park link the Cuvier Abyssal Plain to the Cape Range Peninsula and are important for their role in sustaining the nutrient conditions that support the high diversity of Ningaloo Reef.
Natural values
• Examples of ecosystems representative of the:
  ○ Central Western Shelf Transition, an area of continental shelf of water depths up to 100 m, 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 (e.g. 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.
• Contains four KEFs: Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula, Commonwealth waters adjacent to Ningaloo Reef, Continental slope demersal fish communities, and the Exmouth Plateau (Section 5.5.1.2).
• Ecosystems are influenced by the Leeuwin and Ningaloo currents, and the Leeuwin undercurrent.
• Supports a range of species, including species listed as threatened, migratory, marine or cetacean under the EPBC Act.
• BIAs within the 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 Indigenous cultural identity, health and wellbeing. The Gnulli people have responsibilities for sea country in the Marine Park.
Heritage values
• The Marine Park is adjacent to Ningaloo Coast World Heritage Property and National Heritage Place, and the Ningaloo Marine Area (Commonwealth waters) Commonwealth Heritage Place (Section **5.5.5**).
• The Marine Park contains over 5 known historic shipwrecks (Section **5.5.5**).
Social and economic values
• Commercial fishing, mining and recreation are important activities in the Marine Park.

Australian Marine Parks – Significance and Values
Carnarvon Canyon Marine Park
The Carnarvon Canyon Marine Park is located ~300 km north-west of Carnarvon. It covers an area of 6,177 km^2 and occurs over a water depth range of 1,500–6,000 m. The Marine Park includes one IUCN zone: Habitat Protection Zone (IUCN IV). **Statement of significance** The Carnarvon Canyon Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Transition, including deep water ecosystems associated with the Carnarvon Canyon. The Marine Park lies within a transition zone between tropical and temperate species and is an area of high biotic productivity. **Natural values** • Examples of ecosystems representative of the Central Western Transition, which is a bioregion characterised by large areas of continental slope, a range of topographic features (e.g. terraces, rises and canyons), seasonal and sporadic upwelling, and benthic slope communities comprising tropical and temperate species. • The Carnarvon Canyon is a single-channel canyon covering the entire depth range of the Marine Park. • Ecosystems are influenced by tropical and temperate currents, deep water environments and proximity to the continental slope and shelf. • The soft-bottom environment at the base of the Carnarvon Canyon is likely to support species that are typical of the deep seafloor (e.g. holothurians, polychaetes and sea-pens). • Supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act. **Cultural values** • Sea country is valued for Indigenous cultural identity, health and wellbeing. However, to date there is limited information about the cultural significance of this Marine Park. **Heritage values** • No international, Commonwealth or national heritage listings apply to the Marine Park. **Social and economic values** • Commercial fishing is an important activity in the Marine Park.
Shark Bay Marine Park

The Shark Bay Marine Park is located ~60 km offshore of Carnarvon, adjacent to the Shark Bay world heritage property and national heritage place (Section 5.5.5). The Marine Park covers an area of 7,443 km^2, extending from the WA state water boundary, over a water depth range of 15–220 m. The Marine Park includes one IUCN zone: Multiple Use Zone (IUCN VI).
Statement of significance
The Shark Bay Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Shelf Province and Central Western Transition. The Marine Park provides connectivity between deeper Commonwealth waters and the inshore waters of the Shark Bay world heritage property.
Natural values
• Examples of ecosystems representative of the:
  ○ Central Western Shelf, which is a predominantly flat, sandy and low-nutrient area, in water depths of 50–100 m; this region is a transitional zone between tropical and temperate species
  ○ Central Western Transition, which is 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 are influenced by the Leeuwin, Ningaloo and Capes currents.
• Supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act.

Australian Marine Parks – Significance and Values
• BIAs within the 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 Indigenous cultural identity, health and wellbeing. The Gnulli and Malgana people have responsibilities for sea country in the Marine Park. **Heritage values** • No international, Commonwealth or national heritage listings apply to the Marine Park. • The Marine Park contains ~20 known historic shipwrecks (Section 5.5.5). **Social and economic values** • Tourism, commercial fishing, mining and recreation are important activities in the Marine Park.
South-west Marine Region
Abrolhos Marine Park

The Abrolhos Marine Park is located adjacent to the Houtman Abrolhos Islands, and extends from ~27 km south-west of Geraldton north to ~330 km west of Carnarvon. The Marine Park covers an area of 88,060 km² and a water depth range from <15 m to 6,000 m. The Marine Park includes four zones: National Park Zone (II), Habitat Protection Zone (IV), Multiple Use Zone (VI) and Special Purpose Zone (VI).
Statement of significance
The Abrolhos Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Province, Central Western Shelf Province, Central Western Transition and South-west Shelf Transition regions, and includes seven KEFs. The southern shelf component of the Marine Park partially surrounds the State Houtman Abrolhos Islands Nature Reserve. The islands and surrounding reefs are renowned for their high level of biodiversity, due to the southward movement of species by the Leeuwin Current. The Marine Park contains several seafloor features including the Houtman Canyon, the second largest submarine canyon on the west coast.
Natural values
• Examples of ecosystems representative of the:
  o Central Western Province, characterised by a narrow continental slope incised by many submarine canyons and the most extensive area of continental rise in any of Australia's marine regions. A significant feature within the area are several eddies that form off the Leeuwin Current at predictable locations, including west of the Houtman Abrolhos Islands.
  o Central Western Shelf Province, a predominantly flat, sandy and low-nutrient area, in water depths of 50–100 m. Significant seafloor features of this area include a deep hole and associated area of banks and shoals offshore of Kalbarri. The area is a transitional zone between tropical and temperate species.
  o Central Western Transition, a deep ocean area characterised by large areas of continental slope, a range of significant seafloor features including the Wallaby Saddle, seasonal and sporadic upwelling, and benthic slope communities comprising tropical and temperate species.
  o South-west Shelf Transition, an area of narrow continental shelf that is noted for its physical complexity. The Leeuwin Current has a significant influence on the biodiversity of this nearshore area as it pushes subtropical water southward along the area's western edge. The area contains a diversity of tropical and temperate marine life including a large number of endemic fauna species.
• Contains seven KEFs: Commonwealth marine environment surrounding the Houtman Abrolhos Islands, Demersal slope and associated fish communities of the Central Western Province, Mesoscale eddies, Perth Canyon and adjacent shelf break, and other west-coast canyons, Western Rock Lobster, Ancient coastline between 90 m and 120 m depth, and the Wallaby Saddle (Section 5.5.1.2).
• Supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act.
• BIAs within the Marine Park include foraging and breeding habitat for seabirds, foraging habitat for Australian Sea Lions and White Sharks, and a migratory pathway for Humpback and Pygmy Blue Whales.

Australian Marine Parks – Significance and Values
• The Marine Park is adjacent to the northernmost Australian Sea Lion breeding colony in Australia on the Houtman Abrolhos Islands. **Cultural values** • Sea country is valued for Indigenous cultural identity, health and wellbeing. The Nanda and Naaguja people have responsibilities for sea country in the Marine Park. **Heritage values** • No international, Commonwealth or national heritage listings apply to the Marine Park. • The Marine Park contains 11 known historic shipwrecks (Section 5.5.5). **Social and economic values** • Tourism, commercial fishing, mining, recreation including fishing, are important activities in the Marine Park.
Jurien Marine Park

The Jurien Marine Park is located ~148 km north of Perth and 155 km south of Geraldton, adjacent to the State Jurien Bay Marine Park. The Marine Park covers an area of 1,851 km² of continental shelf, and over water depths of 15–220 m. The Marine Park includes two zones: National Park Zone (II) and Special Purpose Zone (VI).
Statement of significance
The Jurien Marine Park is significant because it includes habitats, species and ecological communities associated with the South-west Shelf Transition and Central Western Province, and includes three KEFs. The Marine Park contains a mixture of tropical species carried south by the Leeuwin Current, and temperate species carried north by the Capes Current. The Marine Park's shelf habitats are defined by distinct ridges of limestone reef with extensive beds of macroalgae. Inshore lagoons are inhabited by a diverse range of invertebrates and fish. Seagrass meadows occur in more sheltered areas as well as in the inter-reef lagoons along exposed sections of the coast. The Marine Park includes habitats connecting to and complementing the adjacent State Jurien Bay Marine Park.
Natural values
• Examples of ecosystems representative of the:
  o South-west Shelf Transition, an area of narrow continental shelf that is noted for its physical complexity. The Leeuwin Current has a significant influence on the biodiversity of this nearshore area as it pushes subtropical water southward along the area's western edge. The area contains a diversity of tropical and temperate marine life including a large number of endemic fauna species.
  o Central Western Province, characterised by a narrow continental slope and influenced by the Leeuwin Current.
• Contains three KEFs: Demersal slope and associated fish communities of the Central Western Province, Western Rock Lobster and Ancient coastline between 90 m and 120 m depth (Section 5.5.1.2).
• Supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act.
• BIAs within the Marine Park include foraging habitat for seabirds, Australian Sea Lions and White Sharks, and a migratory pathway for Humpback and Pygmy Blue Whales.
Cultural values
• Sea country is valued for Indigenous cultural identity, health and wellbeing. The Noongar people have responsibilities for sea country in the Marine Park.
Heritage values
• No international, Commonwealth or national heritage listings apply to the Marine Park.
• The Marine Park contains two known historic shipwrecks: *SS Cambewarra* (1914) and *Oleander* (1884) (Section 5.5.5).
Social and economic values
• Tourism, commercial fishing, mining and recreation, including fishing, are important activities in the Marine Park.

Australian Marine Parks – Significance and Values
Two Rocks Marine Park
The Two Rocks Marine Park is located ~25 km north-west of Perth. The Marine Park covers an area of 882 km², over a water depth range from 15–120 m. The Marine Park includes two zones: National Park Zone (II) and Multiple Use Zone (VI). **Statement of significance** The Two Rocks Marine Park is significant because it includes habitats, species and ecological communities associated with the South-west Shelf Transition and includes three KEFs. The Marine Park is shallow and provides connectivity between offshore waters and the west coast inshore lagoons, which are key areas for the recruitment of rock lobster and other commercially and recreationally important fish species. **Natural values** • Examples of ecosystems representative of the South-west Shelf Transition, an area of narrow continental shelf that is noted for its physical complexity. The Leeuwin Current has a significant influence on the biodiversity of this nearshore area as it pushes subtropical water southward along the area's western edge. The area contains a diversity of tropical and temperate marine life including a large number of endemic fauna species. • The inshore lagoons are thought to be important areas for benthic productivity and recruitment for a range of marine species. • Contains three KEFs: Commonwealth marine environment within and adjacent to the west-coast inshore lagoons, Western Rock Lobster and Ancient coastline between 90 m and 120 m depth (Section 5.5.1.2). • Supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act. • BIAs within the Marine Park include foraging habitat for seabirds and Australian Sea Lions, a migratory pathway for Humpback and Pygmy Blue Whales, and a calving buffer area for Southern Right Whales. **Cultural values** • Sea country is valued for Indigenous cultural identity, health and wellbeing. The Swan River traditional owners have responsibilities for sea country in the Marine Park. **Heritage values** • No international, Commonwealth or national heritage listings apply to the Marine Park. **Social and economic values** • Tourism, commercial fishing, recreation, including fishing, and scientific research are important activities in the Marine Park.
Perth Canyon Marine Park
The Perth Canyon Marine Park is located ~52 km west of Perth and ~19 km west of Rottnest Island. The Marine Park covers an area of 7,409 km² and covers water depths of 120–5,000 m. The Marine Park includes three zones: National Park Zone (II), Habitat Protection Zone (IV) and Multiple Use Zone (VI). **Statement of significance** The Marine Park is significant because it includes habitats, species and ecological communities associated with the Central Western Province, South-west Shelf Province, Southwest Transition and South-west Shelf Transition, and also includes four KEFs. The Marine Park includes the majority of the Perth Canyon, Australia's largest submarine canyon, which is home to the largest feeding aggregations of Blue Whales in Australia. This unique feature is also of significance because it cuts into the continental shelf at ~150 m depth west of Rottnest Island, linking the shelf with deeper (up to 5,000 m) ecosystems. The Marine Park represents the southern end of the transition area from tropical to temperate marine environments. **Natural values** • Examples of ecosystems representative of the: ○ Central Western Province, characterised by a narrow continental slope incised by many submarine canyons (including Perth Canyon), and the most extensive area of continental rise in any of Australia's marine regions. A significant feature within the area are several eddies that form off the Leeuwin Current at predictable locations (including the Perth Canyon)

Australian Marine Parks – Significance and Values
○ South-west Shelf Province, an area of diverse marine life, influenced by the warm waters of the Leeuwin Current ○ South-west Transition, characterised by the submarine canyons that incise the northern parts of the slope and the deep water mixing that results from the dynamics of major ocean currents when these meet the seafloor (particularly in the Perth Canyon) ○ South-west Shelf Transition, an area of narrow continental shelf that is noted for its physical complexity. The Leeuwin Current has a significant influence on the biodiversity of this nearshore area as it pushes subtropical water southward along the area's western edge. The area contains a diversity of tropical and temperate marine life including a large number of endemic fauna species. • Contains four KEFs: Perth Canyon and adjacent shelf break, and other west-coast canyons, Demersal slope and associated fish communities of the Central Western Province, Western Rock Lobster and Mesoscale eddies (Section 5.5.1.2). • Supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act. • BIAs within the Marine Park include foraging habitat for seabirds, Antarctic Blue, Pygmy Blue and Sperm Whales, a migratory pathway for Humpback, Antarctic Blue and Pygmy Blue Whales, and a calving buffer area for Southern Right Whales. **Cultural values** • Sea country is valued for Indigenous cultural identity, health and wellbeing. The Swan River traditional owners have responsibilities for sea country in the Marine Park. **Heritage values** • No international, Commonwealth or national heritage listings apply to the Marine Park. **Social and economic values** • Tourism, commercial shipping, commercial fishing, recreation, including fishing, and defence training are important activities in the Marine Park.

5.5.1.2 Key Ecological Features

Key Ecological Features (KEFs) 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. 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.

Within the EMBA, 17 KEFs are present—ten within the North-west Marine Region, and seven within the South-west Marine Region (Table 5-16, Figure 5-21). The closest KEFs to the Corowa Development are the 'ancient coastline at 125 m depth contour' and the 'canyons linking the Cuvier Abyssal Plan and the Cape Range Peninsula', ~5 km and 7 km from the expected position of the MOPU respectively (Figure 5-21).

The importance and values have been identified for each KEF within the SPRAT database (DoEE 2019b), and are summarised in Table 5-16.

Table 5-15 Key Ecological Features within the Corowa Development EMBA

Key Ecological Feature	EMBA	Project Area	Light Area	Hydrocarbon Area
North-west Marine Region				
Ancient coastline at 125 m depth contour	✓	✓*	✓	✓
Canyons linking the Argo Abyssal Plain with the Scott Plateau	✓	X	X	X
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	✓	X	✓	✓

Key Ecological Feature	EMBA	Project Area	Light Area	Hydrocarbon Area
Commonwealth waters adjacent to Ningaloo Reef	✓	X	X	✓
Continental slope demersal fish communities	✓	X	✓	✓
Exmouth Plateau	✓	X	X	✓
Glomar Shoals	✓	X	X	✓
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	✓	X	X	X
Seringapatam Reef and Commonwealth waters in the Scott Reef complex	✓	X	X	X
Wallaby Saddle	✓	X	X	✓
South-west Marine Region				
Ancient coastline at 90–120 m depth	✓	X	X	✓
Commonwealth marine environment surrounding the Houtman Abrolhos Islands	✓	X	X	✓
Commonwealth marine environment within and adjacent to the west coast inshore lagoons	✓	X	X	X
Mesoscale eddies ^	✓	X	X	✓
Perth Canyon and adjacent shelf break, and other west coast canyons	✓	X	X	✓
Western demersal slope and associated fish communities	✓	X	X	✓
Western Rock Lobster	✓	X	X	✓

✓ = Present within area; X = not present within area

^ Mesoscale eddies is not a spatially defined KEF and therefore is not shown on Figure 5-21.

** The Project Area is defined and shown as a 5 km buffer from the expected position of the MOPU (Figure 5-21). However, as the position of the MOPU is indicative only at this stage, the identification of values and sensitivities (including the EPBC protected matters search) has been completed using a 7 km buffer. This extension to a 7 km buffer includes the 'ancient coastline at 125 m depth contour' for the Project Area.*

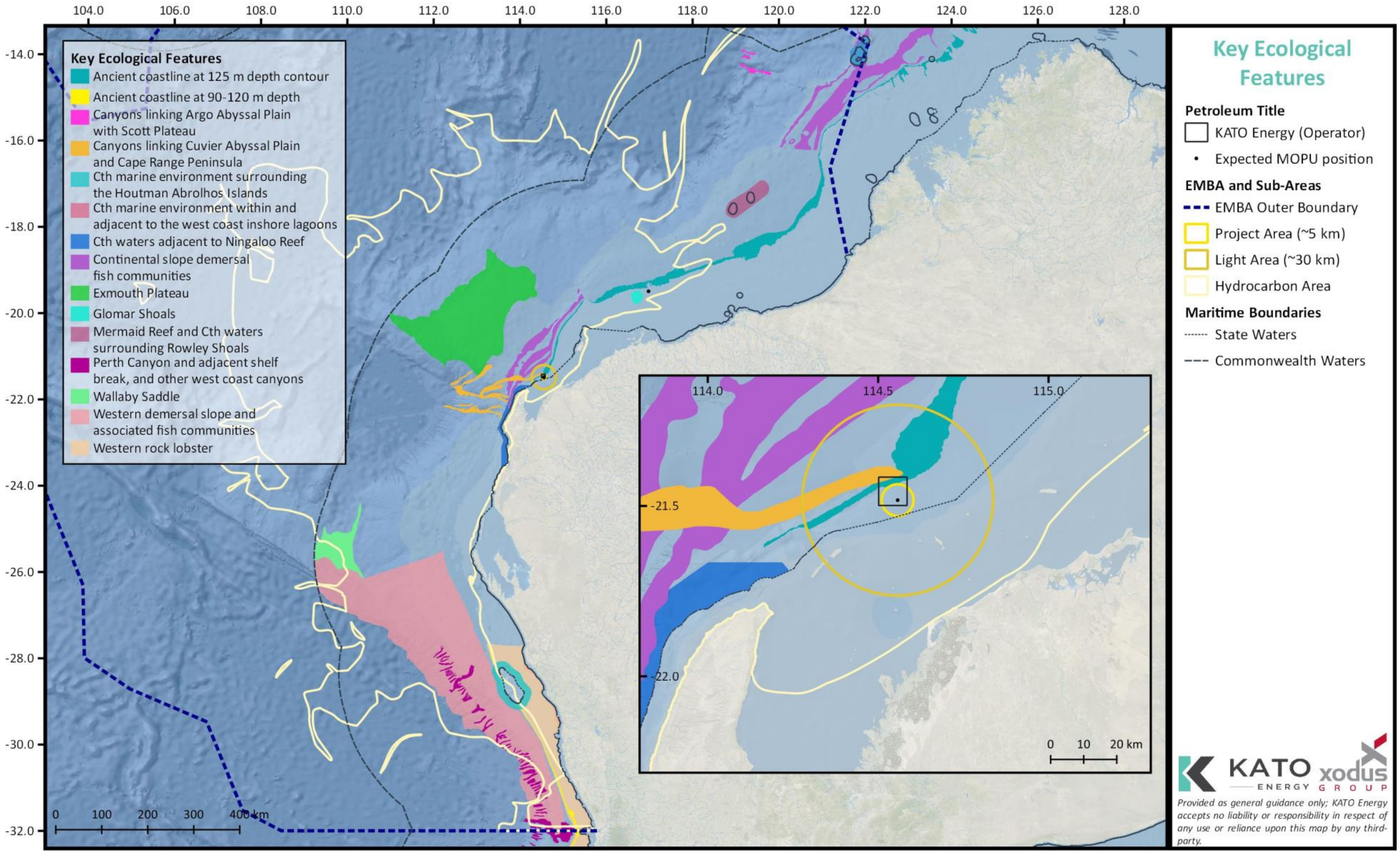


Figure 5-21 Key Ecological Features

Table 5-16 Importance and Values of Key Ecological Features

Key Ecological Features – Importance and Values
North-west Marine Region
Ancient coastline at 125m depth contour
National and/or regional importance The ancient coastline at 125 m depth contour is defined as a key ecological feature as it is a unique seafloor feature with ecological properties of regional significance. **Location** The shelf of the North-west Marine Region contains several terraces and steps, which reflect changes in sea level that occurred over the last 100,000 years. The most prominent of these features occurs as an escarpment along the NWS and Sahul Shelf at a depth of 125 m. The spatial boundary of this KEF is defined by depth range 115–135 m in the Northwest Shelf Province and Northwest Shelf Transition IMCRA provincial bioregions. **Description and values** 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 bioregion. The escarpment may also facilitate increased availability of nutrients off the Pilbara by interacting with internal waves and enhancing vertical mixing of water layers. Enhanced productivity associated with the sessile communities and increased nutrient availability may attract larger marine life such as Whale Sharks and large pelagic fish. Humpback Whales appear to migrate along the ancient coastline, using it as a guide to move through the region.
Canyons linking the Argo Abyssal Plain with the Scott Plateau
National and/or regional importance The Canyons linking the Argo Abyssal Plain with the Scott Plateau are defined as a KEF for their high productivity and aggregations of marine life. These values apply to both the benthic and pelagic habitats within the feature. **Location** The spatial boundary of this KEF includes the three canyons adjacent to the south-west corner of Scott Plateau. The Bowers and Oates canyons are the largest canyons connecting the Scott Plateau with the Argo Abyssal Plain; they are situated in the Timor Province (IMCRA provincial bioregion), west of Scott Reef. **Description and values** The Bowers and Oats canyons are major canyons on the slope between the Argo Abyssal Plain and Scott Plateau. The canyons cut deeply into the south-west margin of the Scott Plateau at a depth of ~2,000–3,000 m, and act as conduits for transport of sediments to depths of more than 5,500 m on the Argo Abyssal Plain. Benthic communities at these depths are likely to be dependent on particulate matter falling from the pelagic zone to the sea floor. The water masses at these depths are deep Indian Ocean water on the Scott Plateau and Antarctic bottom water on the Argo Abyssal Plain; both water masses are cold, dense and nutrient-rich. The ocean above the canyons may be an area of moderately enhanced productivity, attracting aggregations of fish and higher-order consumers such as large predatory fish, sharks, toothed whales and dolphins. The canyons linking the Argo Abyssal Plain and Scott Plateau are likely to be important features due to their historical association with Sperm Whale aggregations. Noting that the reasons for these historical aggregations of marine life remains unclear.

Key Ecological Features – Importance and Values
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula
National and/or regional importance The Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula are defined as a key ecological feature as they are unique seafloor features with ecological properties of regional significance, which apply to both the benthic and pelagic habitats within the feature. **Location** The largest canyons on the slope linking the Cuvier Abyssal Plain and Cape Range Peninsula are the Cape Range Canyon and Cloates Canyon, which are located along the southerly edge of Exmouth Plateau adjacent to Ningaloo Reef. The canyons are unusual because their heads are close to the coast of North West Cape. **Description and values** 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. 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; these waters are cooler and richer in nutrients and strong internal tides may also aid upwelling at the canyon heads. The narrow shelf width (~10 km) near the canyons facilitates nutrient upwelling and this nutrient-rich water interacts with the Leeuwin Current at the canyon heads. Aggregations of Whale Sharks, manta rays, Humpback Whales, seasnakes, sharks, large predatory fish and seabirds are known to occur in this area and are related to productivity. The canyons, Exmouth Plateau and Commonwealth waters adjacent to Ningaloo Reef operate as a system to create the conditions for enhanced productivity seen in this region.
Commonwealth waters adjacent to Ningaloo Reef
National and/or regional importance The Commonwealth waters adjacent to Ningaloo Reef are defined as a KEF for their high productivity and aggregations of marine life, which apply to both the benthic and pelagic habitats. **Location** Ningaloo Reef extends >260 km along Cape Range Peninsula with a landward lagoon 0.2–6 km wide. Seaward of the reef crest, the reef drops gently to depths of 8–10 m; the waters reach 100 m depth, 5–6 km beyond the reef edge. Commonwealth waters over the narrow shelf (10 km at its narrowest) and shelf break are contiguous with Ningaloo Reef and connected via oceanographic and trophic cycling. **Description and values** Ningaloo reef is globally significant as the only extensive coral reef in the world that fringes the west coast of a continent; it is also globally significant as a seasonal aggregation site for Whale Sharks. 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, seasnakes, sharks, large predatory fish and seabirds. Detrital input from phytoplankton production in surface waters and from higher-trophic consumers cycles back to the deeper waters of the shelf and slope. 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 areas of potentially high and unique sponge biodiversity. The outer reef is marked by a well-developed spur and groove system of fingers of coral formations penetrating the ocean with coral sand channels in between. The spurs support coral growth, while the grooves experience strong scouring surges and tidal run-off and have little coral growth.

Key Ecological Features – Importance and Values
Continental slope demersal fish communities
National and/or regional importance This species assemblage is recognised as a key ecological feature because of its biodiversity values, including high levels of endemism. **Location** This KEF is defined as the area of slope found in the Northwest Province and Timor Province provincial bioregions, at the depth ranges of 220–500 m and 750–1,000 m. **Description and values** 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 Australian continental slope. The continental slope between North West Cape and the Montebello Trough has >500 fish species, 76 of which are endemic, which makes it the most diverse slope bioregion in Australia. The slope of the Timor Province and the Northwest Transition also contains >500 species of demersal fish of which 64 are considered endemic. The Timor Province and Northwest Transition bioregions are the second-richest areas for demersal fish across the entire continental slope. The demersal fish species occupy two distinct demersal community types (biomes) associated with the upper slope (water depth of 225–500 m) and the mid-slope (750–1,000 m). Although poorly known, it is suggested that the demersal-slope communities rely on bacteria and detritus-based systems comprised of infauna and epifauna, which in turn become prey for a range of teleost fish, molluscs and crustaceans. Higher-order consumers may include carnivorous fish, deepwater sharks, large squid and toothed whales. Pelagic production is phytoplankton based, with hot spots around oceanic reefs and islands. 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. Loss of benthic habitat along the continental slope at depths known to support demersal fish communities may lead to a decline in species richness, diversity and endemism associated with this feature.
Exmouth Plateau
National and/or regional importance The Exmouth Plateau is defined as KEF as it is a unique seafloor feature with ecological properties of regional significance, which apply to both the benthic and pelagic habitats. **Location** The Exmouth Plateau is located in the Northwest Province and covers an area of 49,310 km² in water depths of 800–4,000 m. **Description and values** Although the seascapes of this plateau are not unique, it is believed that the large size of Exmouth Plateau and its expansive surface may modify deep water flow and be associated with the generation of internal tides; both of these features may contribute to the upwelling of deeper, nutrient-rich waters closer to the surface. The topography of the plateau (with valleys and channels), in addition to potentially constituting 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 depths of around 1,000 m. Sediments on the plateau suggest that biological communities include scavengers, benthic filter feeders and epifauna. The plateau's surface is rough and undulating. The northern margin is steep and intersected by large canyons (e.g. Montebello and Swan canyons), the western margin is moderately steep and smooth, and the southern margin is gently sloping and virtually free of canyons. Satellite observations suggest that productivity is enhanced along the northern and southern boundaries of the plateau and along the shelf edge, which in turn suggests that the plateau is a significant contributor to the productivity of the region. Whaling records from the 19th century suggest that the Exmouth Plateau may have supported large populations of Sperm Whales.

Key Ecological Features – Importance and Values
Glomar Shoals
National and/or regional importance
The Glomar Shoals are defined as a KEF for their high productivity and aggregations of marine life.
Location
The Glomar Shoals are a submerged littoral feature located ~150 km north of Dampier on the Rowley Shelf at depths of 33–77 m.
Description and values
While the biodiversity associated with the Glomar Shoals has not been studied, 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. 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.
The shoals have a high percentage of marine-derived sediments with high carbonate content and gravels of weathered coralline algae and shells. The area's higher concentrations of coarse material in comparison to surrounding areas are indicative of a high-energy environment subject to strong seafloor currents. Cyclones are also frequent in this area and stimulate periodic bursts of productivity as a result of increased vertical mixing.
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals
National and/or regional importance
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals is defined as a KEF for its enhanced productivity and high species richness, that apply to both the benthic and pelagic habitats.
Location
The Rowley Shoals are a collection of three atoll reefs (Clerke, Imperieuse and Mermaid), which are located ~300 km northwest of Broome. The KEF encompasses Mermaid Reef MP as well as waters from 3–6 nm surrounding Clerke and Imperieuse reefs.
Mermaid Reef lies ~29 km north of Clerke and Imperieuse reefs and is totally submerged at high tide. Mermaid Reef falls under Commonwealth jurisdiction, while the Clerke and Imperieuse reefs are within the Rowley Shoals Marine Park and under State jurisdiction.
Description and values
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals are regionally important in supporting high species richness, higher productivity and aggregations of marine life associated with the adjoining reefs. The Rowley Shoals contain 214 coral species, ~530 species of fish, 264 species of molluscs and 82 species of echinoderms; no seasnakes are known to occur.
The reefs provide a distinctive biophysical environment in the region as there are few offshore reefs in the north-west. They have steep and distinct reef slopes and associated fish communities Enhanced productivity is thought to be facilitated by the breaking of internal waves in the waters surrounding the reefs, causing mixing and resuspension of nutrients from water depths of 500–700 m into the photic zone. The steep changes in slope around the reef also attract a range of migratory pelagic species including dolphins, tuna, billfish and sharks.
Rowley Shoals' reefs are different from other reefs in the chain of reefs on the outer shelf of the North-west Marine Region, both in structure and genetic diversity. There is little connectivity between Rowley Shoals and other outer-shelf reefs. Both coral communities and fish assemblages of Rowley Shoals differ from similar habitats in eastern Australia. In evolutionary terms, the reefs may play a role in supplying coral and fish larvae to reefs further south via the southward flowing Indonesian Throughflow.
Seringapatam Reef and Commonwealth waters in the Scott Reef complex
National and/or regional importance
Seringapatam Reef and Commonwealth waters in the Scott Reef complex are defined as a KEF as they support diverse aggregations of marine life, have high primary productivity relative to other parts of the region, are relatively pristine and have high species richness, which apply to both the benthic and pelagic habitats.

Key Ecological Features – Importance and Values
Location
Scott and Seringapatam reefs are part of a series of submerged reef platforms that rise steeply from the sea floor between the 300–700 m depth on the northwest continental slope within the Timor Province. Scott and Seringapatam reefs provide an important biophysical environment in the region as one of few offshore reefs in the northwest.
Scott Reef has two separate reef formations—North Reef and South Reef. The KEF encompasses the waters beyond 3 nm at South Scott Reef and the reefs and surrounding waters at North Scott and Seringapatam reefs. The total area of the KEF is ~2,418 km².
Description and values
Seringapatam Reef and Commonwealth waters in the Scott Reef complex are regionally important in supporting the diverse aggregations of marine life, high primary productivity and high species richness associated with the reefs. As two of the few offshore reefs in the northwest, they provide an important biophysical environment in the region.
The coral communities at Scott and Seringapatam reefs play a key role in maintaining the species richness and subsequent aggregations of marine life. Scott Reef is a particularly biologically diverse system and includes >300 species of reef-building corals, ~400 mollusc species, 118 crustacean species, 117 echinoderm species and ~720 fish species. Corals and fish at Scott Reef have higher species diversity than the Rowley Shoals. Recent studies suggest that the capacity for coral dispersal between Scott Reef and other offshore reefs in the region may be limited
Scott and Seringapatam reefs and the waters surrounding them attract aggregations of marine life including Humpback Whales (on their northerly migration) and numerous other cetacean species, Whale Sharks and several species of seasnake. Two species of marine turtle (Green and Hawksbill) nest during the summer months on Sandy Islet (South Scott Reef); the turtles also internest and forage in the surrounding waters. This KEF also provides foraging areas for seabird species such as the Lesser Frigatebird, Wedge-tailed Shearwater, Brown Booby and Roseate Tern.
Aggregations of marine life, high primary productivity and species richness on the reefs and in the surrounding Commonwealth waters are likely due to the steep rise of the reef from the seabed. This causes nutrient-rich waters from below the thermocline (~100 m) to mix with the warmer, relatively nutrient-poor tropical surface waters via the action of internal waves and from mixing and higher productivity in the lee of emergent reefs.
Wallaby Saddle
National and/or regional importance
Wallaby Saddle is defined as a KEF for its high productivity and aggregations of marine life; these values apply to both the benthic and pelagic habitats.
Location
The Wallaby Saddle covers 7,880 km² of seabed and is an abyssal geomorphic feature that connects the northwest margin of the Wallaby Plateau with the margin of the Carnarvon Terrace on the upper continental slope at a depth of 4,000–4,700 m.
Description and values
The Wallaby Saddle is regionally important in that it represents almost the entire area of this type of geomorphic feature in the North-west Marine Region. The Wallaby Saddle is located within the Indian Ocean water mass and is thus differentiated from systems to the north that are dominated by transitional fronts or the Indonesian Throughflow. Little is known about the Wallaby Saddle; however, the area is considered one of enhanced productivity and low habitat diversity.
Historical Sperm Whale Aggregations in the area of Wallaby Saddle may be attributable to higher productivity and aggregations of baitfish.
South-west Marine Region
Ancient coastline at 90–120 m depth
National and/or regional importance

Key Ecological Features – Importance and Values
The Ancient coastline between 90–120 m depth is defined as a key ecological feature for its potential high productivity and aggregations of marine life, biodiversity and endemism. Both benthic habitats and associated demersal communities are of conservation value. **Location** The continental shelf of the South-west Marine Region contains several terraces and steps. A prominent escarpment occurs close to the middle of the continental shelf at a depth of ~90–120 m. **Description and values** The continental shelf of the South-west Marine Region contains several terraces and steps, which reflect the gradual increase in sea level across the shelf that occurred over the past 12,000 years. Some of these occur as escarpments, although their elevation and distinctness vary throughout the region. Where they are prominent, they create topographic complexity; for example, through exposure of rocky substrates that may facilitate small, localised upwellings, benthic biodiversity and enhanced biological productivity. While the ancient coastline is present throughout the region, it is particularly evident in the Great Australian Bight, where it provides complex habitat for a number of species. Parts of this ancient coastline may support some demersal fish species travelling across the continental shelf to the upper continental slope, thereby supporting ecological connectivity. Benthic biodiversity and productivity occur where the ancient coastline forms a prominent escarpment of exposed hard substrates.
Commonwealth marine environment surrounding the Houtman Abrolhos Islands
National and/or regional importance The Commonwealth marine environment surrounding the Houtman Abrolhos Islands (and adjacent shelf break) is defined as a KEF for its high levels of biodiversity and endemism in benthic and pelagic habitats. **Location** The Houtman Abrolhos Islands are a complex of 122 islands and reefs located at the edge of the continental shelf, ~60 km offshore from the Mid West coast of WA. **Description and values** The Houtman Abrolhos waters and reefs are noted for their high biodiversity and mix of temperate and tropical species, resulting from the southward transport of species by the Leeuwin Current over thousands of years. The area represents the southern limit in WA of many widespread Indo-Pacific tropical fish. The islands are the largest seabird breeding station in the eastern Indian Ocean, supporting more than one million pairs of breeding seabirds, including sedentary and migratory species. Many of the islands' biodiversity features rely on the benthic and pelagic ecosystems in deeper, offshore waters; most notably, seabirds and rock lobster. The Houtman Abrolhos Islands lie in a transitional zone between major marine biogeographic provinces: the warm, tropical water of the Leeuwin Current and colder water more typical of the islands' latitude. The Leeuwin Current allows the Houtman Abrolhos Islands to support the highest-latitude coral reefs in the Indian Ocean. The reefs are composed of 184 known species of coral that support ~400 species of demersal fish, 492 species of molluscs, 110 species of sponges, 172 species of echinoderms and 234 species of benthic algae. In addition, the area provides important habitat for Western Rock Lobsters (*Panulirus cygnus*). The surrounding Commonwealth marine environment is also recognised as an important resting area for migrating Humpback Whales. The islands are the northernmost breeding site of the Australian Sea Lion, although sea lions are not thought to be an important component of this ecosystem because of their low population numbers.

Key Ecological Features – Importance and Values
Commonwealth marine environment within and adjacent to the west coast inshore lagoons
National and/or regional importance
The Commonwealth marine environment within and adjacent to the west-coast inshore lagoons is defined as a KEF for its high productivity and aggregations of marine life. Both benthic and pelagic habitats within the feature are of conservation value.
Location
The spatial boundary of this KEF is based on waters <30 m depth, in Commonwealth waters, from Kalbarri to slightly south of Mandurah.
Description and values
A chain of inshore lagoons extends along the WA coast from south of Mandurah to Kalbarri. The lagoons are formed by distinct ridges of north–south oriented limestone reef with extensive beds of macroalgae (principally *Ecklonia* spp.) and extend to a depth of 30 m. Although macroalgae and seagrass appear to be the primary source of production, it is suggested that groundwater enrichment may supplement the supply of nutrients to the lagoons. Seagrass provides important habitat for many marine species, and epiphytes are the main food source in the lagoonal system. The lagoons are associated with high biodiversity and endemism, containing a mix of tropical, subtropical and temperate flora and fauna. The area includes breeding and nursery aggregations for many temperate and tropical marine species. They are important areas for the recruitment of commercially and recreationally important fishery species; extensive schools of migratory fish visit the area annually, including herring, garfish, tailor and Australian salmon. The mix of sheltered and exposed seabeds form a complex mosaic of habitats. The inshore lagoons are important areas for the recruitment of Western Rock Lobster, Dhufish, Pink Snapper, Breaksea Cod, Baldchin and Blue Gropers, abalone and many other reef species.
Mesoscale eddies
National and/or regional importance
Mesoscale eddies are defined as pelagic KEF for their high productivity and aggregations of marine life.
Location
Eddies and eddy fields form at predictable locations off the western and south-western shelf break: southwest of Shark Bay; offshore of the Houtman Abrolhos Islands; southwest of Jurien Bay; Perth Canyon; southwest of Cape Leeuwin; and south of Albany, Esperance and the Eyre Peninsula.
Description and values
Driven by interactions between currents and bathymetry, persistent mesoscale eddies form regularly (three to nine eddies per year) within the meanders of the Leeuwin Current. These features range between 50–200 km in diameter and typically last more than five months. Mesoscale eddies are important food sources, particularly for mesozooplankton, given the broader region's nutrient-poor conditions, and they become prey hotspots for a complex range of higher trophic-level species. Mesoscale eddies and seasonal upwellings have a significant impact on the regional production patterns. The mesoscale eddies of this region are important transporters of nutrients and plankton communities, taking them far offshore into the Indian Ocean, where they are consumed by oceanic communities. They are likely to attract a range of organisms from the higher trophic levels, such as marine mammals, seabirds, tuna and billfish. The eddies play a critical role in determining species distribution, as they influence the southerly range boundaries of tropical and subtropical species, the transport of coastal phytoplankton communities offshore and recruitment to fisheries.

Key Ecological Features – Importance and Values
Perth Canyon and adjacent shelf break, and other west coast canyons
National and/or regional importance The Perth Canyon forms a major biogeographical boundary and it is defined as a KEF because it is an area of higher productivity that attracts feeding aggregations of deep-diving mammals and large predatory fish. It is also recognised as a unique seafloor feature with ecological properties of regional significance. **Location** The west coast system of canyons spans an extensive area (8,744 km²) of continental slope offshore from Kalbarri to south of Perth. It includes the Geographe, Busselton, Pelsaert, Geraldton, Wallaby, Houtman and Murchison canyons and, most notably, the Perth Canyon (offshore of Rottnest Island), which is Australia's largest ocean canyon. **Description and values** The Perth Canyon is prominent among the west coast canyons because of its magnitude and ecological importance; however, the sheer abundance of canyons spread over a broad latitudinal range makes this feature important. In the Perth Canyon, interactions between the canyon topography and the Leeuwin Current induce clockwise-rotating eddies that transport nutrients upwards in the water column from greater depths. Due to the canyon's depth and the Leeuwin Current's barrier effect, this remains a subsurface upwelling (depths >400 m), which confers ecological complexity that is typically absent from canyon systems in other areas. The Perth Canyon also marks the southern boundary for numerous tropical species groups on the shelf, including sponges, corals, decapods and xanthid crabs. The Perth Canyon marks the southern boundary of the Central Western Province. Deep ocean currents upwelling in the canyon create a nutrient-rich, cold-water habitat that attracts deep-diving mammals and large predatory fish, which feed on small fish, krill and squid. A number of cetaceans, predominantly Pygmy Blue Whales, aggregate in the canyon during summer to feed on the prey aggregations. Arriving from November onwards, their numbers peak in March to May. The topographical complexity of the canyon is also believed to provide more varied habitat that supports higher levels of epibenthic biodiversity than adjacent shelf areas.
Western demersal slope and associated fish communities
National and/or regional importance The demersal slope and associated fish communities are recognised as a KEF for their high levels of biodiversity and endemism. **Location** This KEF extends from the edge of the shelf to the limit of the exclusive economic zone, between Perth and the northern boundary of the South-west Marine Region. **Description and values** The western continental slope provides important habitat for demersal fish communities. In particular, the continental slope of the Central Western provincial bioregion supports demersal fish communities characterised by high diversity compared with other, more intensively sampled, oceanic regions of the world. Its diversity is attributed to the overlap of ancient and extensive Indo-west Pacific and temperate Australasian fauna. Approx. 480 species of demersal fish inhabit the slope of this bioregion, and 31 of these are considered endemic to the bioregion. A diverse assemblage of demersal fish species below a depth of 400 m is dominated by relatively small benthic species such as grenadiers, dogfish and cucumber fish. Unlike other slope fish communities in Australia, many of these species display unique physical adaptations to feed on the seafloor (such as a mouth position adapted to bottom feeding), and many do not appear to migrate vertically in their daily feeding habits.

Key Ecological Features – Importance and Values
Western Rock Lobster
National and/or regional importance
The Western Rock Lobster is defined as a KEF due to its presumed ecological role on the west coast continental shelf.
Location
The spatial boundary of this KEF includes Commonwealth waters in the South-west Marine Region, to a depth of 150 m, north of Cape Leeuwin.
Description and values
Western Rock Lobster (*Panulirus cygnus*) is the dominant large benthic invertebrate in this bioregion, and can be found north of Cape Leeuwin to a depth of 150 m. It is also an important part of the food web on the inner shelf, particularly as a juvenile, when it is preyed upon by octopus, cuttlefish, Baldchin Groper, Blue Groper, Dhufish, Pink Snapper, Wirrah Cod and Breaksea Cod. Western Rock Lobsters are also particularly vulnerable to predation during seasonal moults in November–December and to a lesser extent during April–May. The high biomass of Western Rock Lobsters and their vulnerability to predation suggest that they are an important trophic pathway for a range of inshore species that prey upon juvenile lobsters. As an abundant and wide-ranging consumer, the Western Rock Lobster is likely to play an important role in ecosystem processes on the shelf waters in the region. The ecological role of Western Rock Lobster is best understood in shallow waters (<10 m) where it can significantly reduce the densities of invertebrate prey, such as epifaunal gastropods, through its varied and highly adaptable diet. However, there is a lack of similar studies in deeper water (>20 m). The little information available for deep water populations suggests that lobsters forage primarily on animal prey, which is dominated by crustaceans such as decapod crabs and amphipods.

5.5.2 Commercial Fisheries

5.5.2.1 Commonwealth-Managed Fisheries

Commonwealth fisheries are managed by the Australian Fisheries Management Authority (AFMA) under the Commonwealth *Fisheries Management Act 1991*, with the fisheries typically operating within 3 nm to 200 nm offshore (i.e. to the extent of the Australian Fishing Zone [AFZ]).

Five Commonwealth-managed commercial fisheries have management areas that intersect with the EMBA (Table 5-17). However, not all the fisheries are active within the full extents of the management areas. Based on historical fishing effort data (Patterson et al. 2018):

- North West Slope Trawl Fishery (NWSTF) is likely to be active in waters >200 m off the Pilbara and Kimberley coasts (Figure 5-22)
- Southern Bluefin Tuna Fishery (SBTF) is active within waters in the Great Australian Bight and south-eastern Australia; however, the spawning grounds for Southern Bluefin Tuna are located in the north-east Indian Ocean (Figure 5-23)
- Western Deepwater Trawl Fishery (WDTF) is likely to be active in waters >200 m off the Gascoyne coast (Figure 5-24)
- Western Skipjack Tuna Fishery (WSTF), has had no active fishing operations since the 2008–2009 season
- Western Tuna and Billfish Fishery (WTBF), is likely to be active in Commonwealth waters off the Gascoyne, Mid-West and Southwest coasts (Figure 5-25).

Therefore, based on previous data, no active fishing effort from Commonwealth-Managed Fisheries is expected to occur within the immediate vicinity of the Corowa Development (i.e. within the Project Area or Light Area) (Table 5-17). A summary of the three fisheries that may be active within the Hydrocarbon Area and the wider EMBA are summarised in Table 5-18.

Table 5-17 Management Areas for Commonwealth-managed Fisheries within the Corowa Development EMBA

Fishery	EMBA	Project Area	Light Area	Hydrocarbon Area
North West Slope Trawl Fishery	✓ (a)	X	✓ (n)	✓ (a)
Southern Bluefin Tuna Fishery	✓ (n)	✓ (n)	✓ (n)	✓ (n)
Western Deepwater Trawl Fishery	✓ (a)	X	X	✓ (a)
Western Skipjack Tuna Fishery	✓ (n)	✓ (n)	✓ (n)	✓ (n)
Western Tuna and Billfish Fishery	✓ (a)	✓ (n)	✓ (n)	✓ (a)

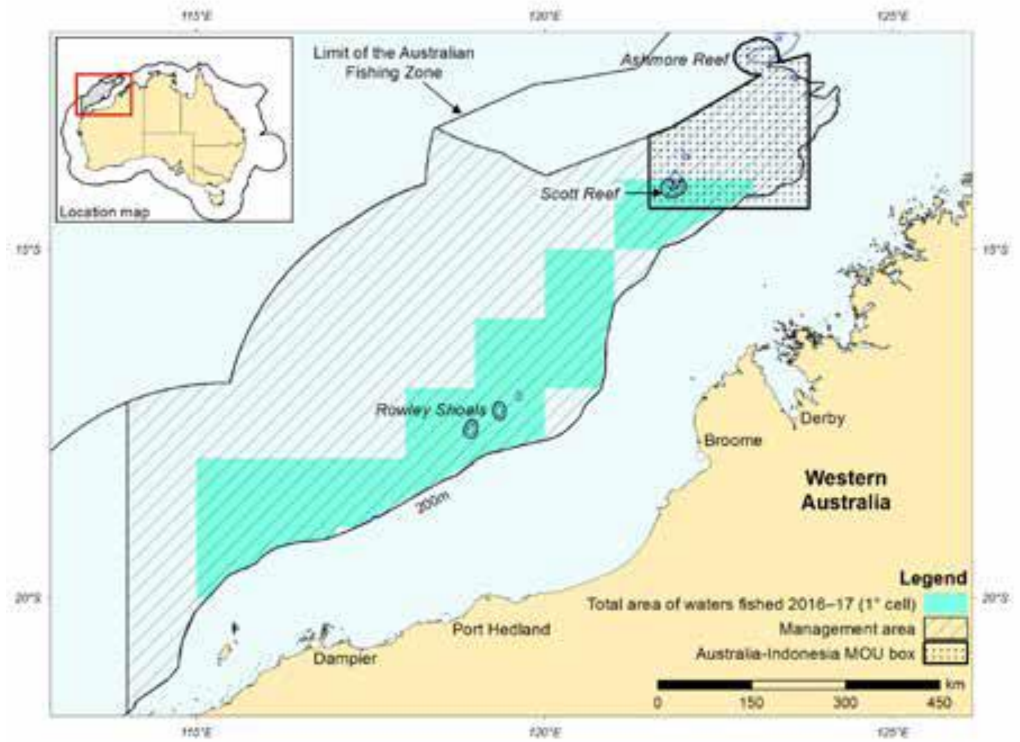
✓ = Present within area; X = not present within area

(a) = Management area present and active fishing expected; (n) = Management area present and no active fishing expected

Table 5-18 Commonwealth-managed Fisheries with Active Fishing Effort within the Corowa Development EMBA

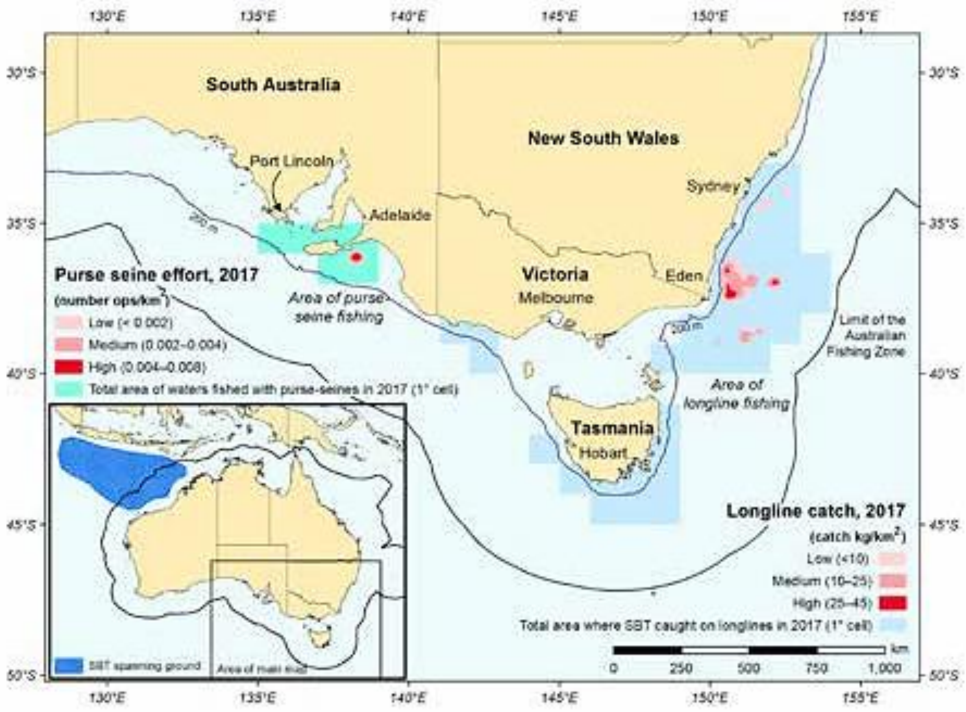
Fishery	Boundary	Method	Season	Permits / Vessels	Target Species	Main Landing Ports
NWSTF	200 m isobath to AFZ, Exmouth to Mitchell Plateau	Demersal trawl gear	Year-round	2016–2017 season: 4 permits, 2 active vessels	Scampi (*Metanephrops australiensis, M. boschmai, M. velutinus*)	Darwin (NT) Point Samson (WA)
WTBF	In the AFZ and high seas of the Indian Ocean, from Cape York to SA/VIC border	Pelagic longline, minor line and purse seine	Year-round	2017 season: 95 boat SFR permits, 4 active vessels	Bigeye Tuna (*Thunnus obesus*) Yellowfin Tuna (*T. albacares*) Broadbill Swordfish (*Xiphias gladius*) Striped marlin (*Tetrapturus audux*)	Fremantle (WA) Geraldton (WA)
WDTF	200 m isobath to AFZ, Exmouth to Augusta	Demersal trawl gear	1 July – 30 June	2016–2017 season: 4 permits, 1 active vessel	Deepwater Bugs (*Ibacus* spp.) Ruby Snapper (*Etelis carbunculus, Etelis* spp.)	Carnarvon (WA) Fremantle (WA)

SFR = Statutory fishing right



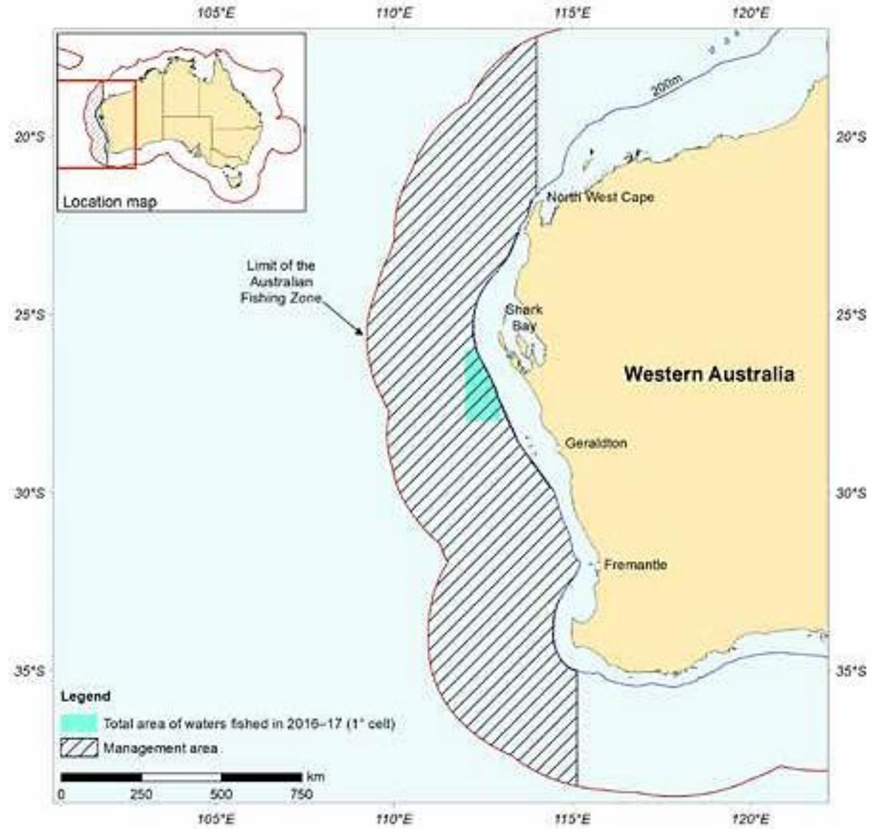
Source: Patterson et al. 2018

Figure 5-22 Management Area for the North West Slope Trawl Fishery, and Area Fished during 2016–2017



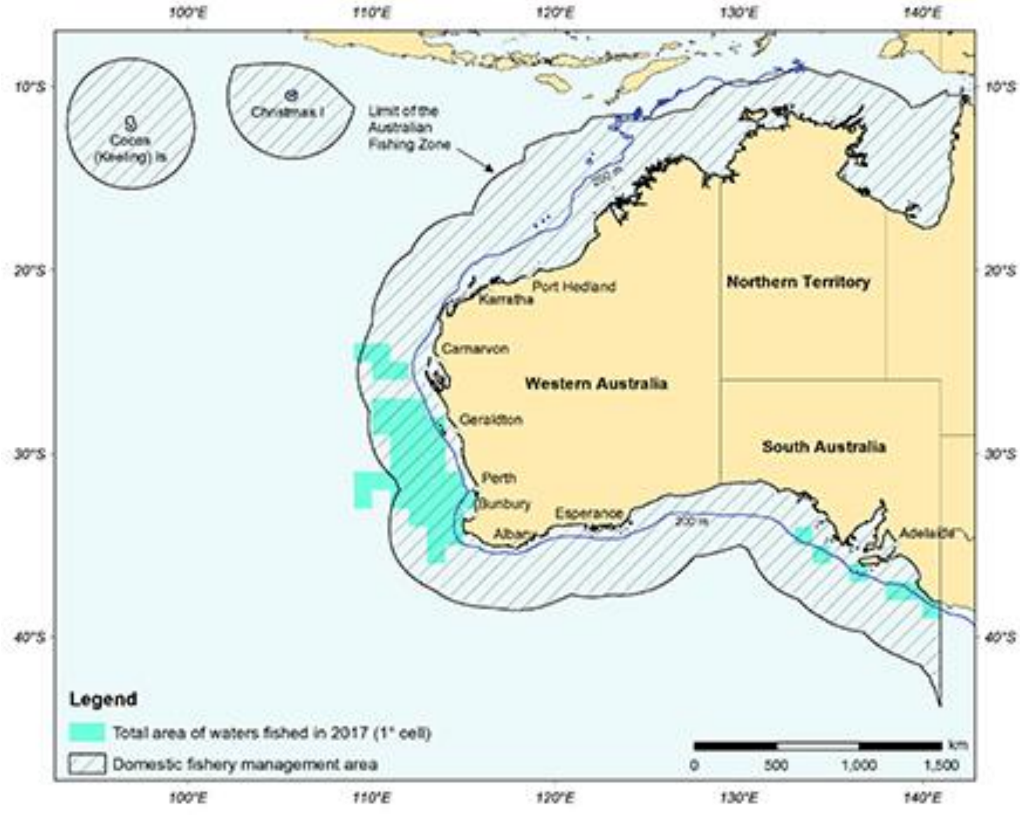
Source: Patterson et al. 2018

Figure 5-23 Management Area for the Southern Bluefin Tuna Fishery, with Indian Ocean Spawning Ground



Source: Patterson et al. 2018

Figure 5-24 Management Area for the Western Deepwater Trawl Fishery, and Area Fished during 2016–2017



Source: Patterson et al. 2018

Figure 5-25 Management Area for the Western Tuna and Billfish Fishery, and Area Fished during 2017

5.5.2.2 State-Managed Fisheries

State commercial fisheries are managed by the WA Department of Primary Industries and Regional Development (DPIRD) under the *Fish Resources Management Act 1994*[14] (WA) and the *Pearling Act 1990* (WA). The Offshore Constitutional Settlement (OCS) allows for some individual fisheries to be managed under relevant State government, with fishing areas extending into both Commonwealth and State waters.

The State fisheries are grouped into bioregions, with the Corowa Development occurring with the Gascoyne region (Gaughan and Santoro 2019). Several State-managed commercial fisheries have management areas that intersect with the EMBA (Table 5-19). However, it is noted that not all the fisheries are active within the full extents of their respective management areas. A general summary of State fisheries that may be present within the EMBA is provided in Table 5-20.

The FishCube database (DPIRD 2019) indicates eight State fisheries may be active within the 60 nm grid block (No. 21140) that directly intersects with the Corowa Development:

- Exmouth Gulf Prawn Managed Fishery (EGPMF)
- Mackerel Managed Fishery (MMF)
- Onslow Prawn Managed Fishery (OPMF)
- Pilbara Line Fishery (PLF)
- Pilbara Trap Managed Fishery (PTMF)
- Western Australian Sea Cucumber Fishery (SCF)
- Marine Aquarium Fish Managed Fishery (MAFMF)
- Specimen Shell Managed Fishery (SSMF).

However, it is noted that the Corowa Development is located approximately in the centre of this 60 nm block, which extends south past Exmouth and east to Ashburton, and as such fishing effort within the block is not necessarily indicative of fishing activity within the planned activity areas (i.e. Project Area and Light Area) for the Corowa Development.

Fishing effort data for this block within the previous five-year period (2014–2018), typically shows low and variable activity from these fisheries:

- The EGPMF is the state fishery with the highest catch and fishing days within this grid block (e.g. 838 fishing days and a catch of 617,355 kg for 2018); however, this fishery is focused within Exmouth Gulf and therefore activity does not intersect with the Project Area, and is considered unlikely to be active within the Light Area.
- Minor fishing activity (10 fishing days and a 1,652 kg catch) was recorded in 2018 for the MMF, but nothing in the four years before this. The MMF focusses coastal areas around reefs, shoals and headlands; therefore, no fishing effort is expected to occur within the Project Area, however some may occur within the Light Area.
- No activity for the OPMF was recorded during the last five years, therefore no activity is expected within the Project or Light Areas (the Project Area is also beyond this fisheries management area boundary).
- Activity for the PLF varied between three to four vessels, and annual catches of 8,561–24,126 kg during the five-year period. While situated at the southern extent of this fishery, active fishing within the Project and/or Light Area is possible. The PLF is managed under the Prohibition on Fishing by Line from Fishing Boats (Pilbara Waters) Order 2006 with the

[14] As at 25 July 2019, it was identified that the *Aquatic Resources Management Act 2016* (WA) required some modifications to meet its intention and necessitated a delay in the timing of migration to this new Act (Gaughan and Santoro 2019)

exemption of nine fishing vessels for any nominated five-month block period within the year. No activity for the PTMF was recorded during the last five years, therefore no activity is expected within the Project or Light Areas.

- The SCF occurs within State waters only, and so the Project Area is beyond this fisheries management area boundary. No activity for the SCF was recorded during the last five years, therefore no activity is expected within the Light Area.
- The MAFMF and SSMF occur within State waters only, and therefore no activity would occur within the Project Area for either fishery as it is beyond the fisheries management area boundary. No activity for the MAFMF was recorded during the last five years, therefore no activity is expected within the Light Area. Low effort (≤3 licences with low catch volumes) has been recorded for the SSMF within this grid block for three of the last five years; however, it is known that the fishery is focused on areas around population centres and within shallow coastal waters and as such, no activity is expected to occur within the Light Area.

Therefore, based on management boundaries and the previous reported fishing effort, minimal commercial fishing activity is expected to occur within the planned activities areas for the Corowa Development:

- Project Area: potential low-level activity of the PLF
- Light Area: potential low levels of activity for the PLF, MMF and SSMF.

A summary of commercial fishery management areas and fishery status (active/not active) for the EMBA and Sub-Areas is provided in Table 5-19.

Table 5-19 Management Areas for State-managed Fisheries within the Corowa Development EMBA

State-managed Fishery	EMBA	Project Area	Light Area	Hydrocarbon Area
Gascoyne Coast Bioregion				
Shark Bay Blue Swimmer Crab Fishery	✓(a)	X	X	✓(n)
Inner Shark Bay Scalefish Fishery	✓(a)	X	X	X
Gascoyne Demersal Scalefish Fishery	✓(a)	X	X	✓(a)
West Coast Deep Sea Crustacean Fishery	✓(a)	✓(n)	✓(n)	✓(a)
Exmouth Gulf Prawn Fishery	✓(a)	X	✓(n)	✓(a)
Shark Bay Prawn and Scallop Managed Fisheries	✓(a)	X	X	✓(n)
North Coast Bioregion				
North Coast Crab Fishery	✓(a)	✓(n)	✓(n)	✓(n)
Beche-De-Mer (Sea Cucumber) Fishery	✓(a)	X	X	✓(a)
Pearl Oyster Fishery	✓(n)	✓(n)	✓(n)	✓(n)
Mackerel Managed Fishery	✓(a)	✓(n)	✓(a)	✓(a)
North Coast Demersal Scalefish Fisheries				
Pilbara Fish Trawl (Interim) Managed Fishery	✓(a)	✓(n)	✓(n)	✓(a)
Pilbara Trap Managed Fishery	✓(a)	✓(n)	✓(n)	✓(a)
Pilbara Line Fishery	✓(a)	✓(a)	✓(a)	✓(a)
North Coast Prawn Fisheries				
Onslow Prawn Managed Fishery (OPMF)	✓(a)	X	✓(n)	✓(a)

State-managed Fishery	EMBA	Project Area	Light Area	Hydrocarbon Area
Nickol Bay Prawn Managed Fishery (NBPMF)	✓(a)	X	X	✓(a)
Broome Prawn Managed Fishery (BPMF)	✓(a)	X	X	X
West Coast Bioregion				
Octopus Fishery	✓(a)	X	X	✓(a)
West Coast Demersal Scalefish Fishery	✓(a)	X	X	✓(a)
West Coast Purse Seine Fishery	✓(a)	X	X	✓(a)
Abrolhos Island and Mid West, South West Trawl Fishery	✓(a)	X	X	✓(a)
Roe's Abalone Fishery	✓(a)	X	X	✓(n)
West Coast Rock Lobster Fishery	✓(a)	X	X	✓(a)
Statewide Bioregion				
The Specimen Shell Managed Fishery (SSMF)	✓(a)	X	✓(n)	✓(a)
Marine Aquarium Fish Managed Fishery (MAFMF)	✓(a)	X	✓(n)	✓(a)
Pearling and Aquaculture				
Pearling / Aquaculture Leases	✓(a)	X	✓(a)	✓(a)

✓ = Present within area; X = not present within area

(a) = Management area present and active fishing expected; (n) = Management area present and no active fishing expected

Table 5-20 State-managed Fisheries with Active Fishing Effort within the Corowa Development EMBA

Fishery	Fishery Area	Method/s	Season (if specified)	Target Species
Gascoyne Coast Bioregion				
Shark Bay Blue Swimmer Crab Fishery	Within Shark Bay	Commercial traps and trawls	Trawl season: Mar/April – Sept/Oct	Blue Swimmer Crab (*Portunus armatus*)
Inner Shark Bay Scalefish Fishery	Eastern Gulf, Denham Sound and Freycinet Estuary in inner Shark Bay	Beach seine, mesh net		Whiting (mostly Yellowfin with some Goldenline), Sea Mullet (*Mugil cephalus*), Tailor (*Pomatomus saltatrix*) and Western Yellowfin Bream (*Acanthopagrus morrisoni*)

Fishery	Fishery Area	Method/s	Season (if specified)	Target Species
Gascoyne Demersal Scalefish Fishery	Continental shelf waters	Mechanised handlines	Year-round (May – Aug for Pink Snapper)	Pink Snapper (*Chrysophrys auratus*) Goldband Snapper (*Pristipomoides multidens*)
West Coast Deep Sea Crustacean Fishery	Continental shelf edge waters (>150 m, mostly 500–800 m) of the Gascoyne Coast and West Coast Bioregions	Baited pots operated in a longline formation	Year-round (for 2016)	Crystal (snow) Crabs (*Chaceon albus*) Giant (King) Crabs (*Pseudocarcinus gigas*) Champagne (Spiny) Crabs (*Hypothalassia acerba*)
Exmouth Gulf Prawn Managed Fishery	Within Exmouth Gulf	Low opening, otter prawn trawl systems	Season arrangements are developed each year, depending on environmental conditions, moon phases and the fishery-independent pre-season surveys	Western King Prawns (*Penaeus latisulcatus*) Banana Prawns (*Penaeus merguiensis*) Brown Tiger Prawns (*Penaeus esculentus*) Endeavour Prawns (*Metapenaeus endeavouri*)
Shark Bay Prawn Managed Fishery	Within inner Shark Bay	Low opening, otter prawn trawl systems	Varies each year depending on environmental conditions	Western King Prawns (*Penaeus latisulcatus*) Brown Tiger Prawns (*Penaeus esculentus*) Endeavour (*Metapenaeus endeavouri*) Coral Prawns (*Metapenaeopsis* sp.)
Shark Bay Scallop Managed Fishery	Within Shark Bay	Otter trawls	Dependant on stock and catch levels	Saucer Scallops (*Ylistrum balloti*)
North Coast Bioregion				
North Coast Crab Fishery (Pilbara Developmental Crab Fishery)	Coastal embayments and estuaries between Geographe Bay and Port Hedland	Hourglass traps	Hot weather restricts fishing effort to between April and November	Blue Swimmer Crabs (*Portunus armatus*)
Beche-De-Mer (Sea Cucumber) Fishery	State waters only, from Exmouth to NT border	Diving and wading	Year-round during neap tides	Sandfish (*Holothuria scabra*) Redfish (*Actinopyga echinites*
Pearl Oyster Managed Fishery	Shallow coastal waters along North West Shelf	Drift diving	March – June	Silver-lipped Pearl Oyster (*Pinctada maxima*)

Fishery	Fishery Area	Method/s	Season (if specified)	Target Species
Mackerel Managed Fishery (MMF)	Coastal areas around reefs, shoals and headlands. Cape Leeuwin to NT border	Near-surface trolling gear Jig fishing	All year round	Spanish Mackerel (*Scomberomorus commerson*)
North Coast Demersal Scalefish Fisheries				
Pilbara Demersal Scale Fisheries (PDSF) includes • Pilbara Fish Trawl (Interim) Managed Fishery • Pilbara Trap Managed Fishery • Pilbara Line Fishery	Exmouth to south end of Eighty Mile Beach, Commonwealth waters only	Trawl, trap and line fishing	PLF is restricted to a nominated 5-month block period	Bluespotted Emperor (*Lethrinus punctulatus*) Red Emperor (*Lutjanus sebae*) Rankin Cod (*Epinephelus multinotatus*)
North Coast Prawn Fisheries				
Onslow Prawn Managed Fishery (OPMF)	Western part of the North West Shelf from Exmouth Gulf to Cape Londonderry	High or low opening, otter prawn trawl systems	Generally March to Nov	Western King Prawns (*Penaeus latisulcatus*) Brown Tiger Prawns (*Penaeus esculentus*) Endeavour Prawns (*Metapenaeus endeavouri*)
Nickol Bay Prawn Managed Fishery (NBPMF)	Western part of the North West Shelf from Exmouth Gulf to Cape Londonderry	High or low opening, otter prawn trawl systems	Year-round, designated nursery areas open in May and close Aug – Nov	Banana Prawns (*Penaeus merguiensis*)
Broome Prawn Managed Fishery (BPMF)	Waters off Broome	High or low opening, otter prawn trawl systems	Up to nine weeks during Northern Prawn Fishery closure period, usually 1 June to mid-August	Western King Prawns (*Penaeus latisulcatus*) Coral Prawns (*Metapenaeopsis* sp.)
West Coast Bioregion				
Octopus Fishery	Waters south from Shark Bay	Trigger trap, unbaited / passive pots		Octopus (*Octopus* aff. *tetricus*)
West Coast Demersal Scalefish Fishery	Waters south from Shark Bay; inshore (20–250 m water depth) and offshore (>250 m) demersal habitats	Line (hand-line, drop-line), hooks		~100 different species. Inshore species include: West Australian dhufish (*Glaucosoma hebraicum*), Pink

Fishery	Fishery Area	Method/s	Season (if specified)	Target Species
				Snapper (*Chrysophrysauratus*), Redthroat Emperor (*Lethrinus miniatus*), Bight redfish (*Centroberyx gerrardi*) and Baldchin Groper (*Choerodon rubescens*) Offshore species include: Eightbar Grouper (*Hyporthodus octofasciatus*), Hapuku (*Polyprion oxygeneios*), Blue-eye Trevalla (*Hyperoglyphe antarctica*) and Ruby Snapper (*Etelis carbunculus*)
West Coast Purse Seine Fishery	Waters extending offshore from Perth metropolitan area	Seine		Main captures are pilchards (*Sardinops sagax*) and the Tropical Sardine (*Sardinella lemuru*)
Abrolhos Island and Mid West, South West Trawl Fishery	Waters extending around Abrolhos Islands to mainland (waters ≤200 m deep)	Trawl		Scallops (*Amusium balloti*)
Roe's Abalone Fishery	Shallow coastal waters from Shark Bay south along the WA coast	Diving and wading	1 April to 31 March	Roe's Abalone (*Haliotis roei*)
West Coast Rock Lobster Fishery	Waters from North West Cape to Cape Leeuwin	Pots	Year-round	Western Rock Lobster (*Panulirus cygnus*)
Statewide Bioregion				
The Specimen Shell Managed Fishery (SSMF)	Covers the entire WA coastline, some concentration adjacent to population centres	By hand by divers or by coastal wading		224 different Specimen Shell species
Marine Aquarium Fish Managed Fishery (MAFMF)	All State waters between NT border and SA border, typically more active south of Broome and	SCUBA or surface supplied air (hookah) from small vessels		>950 species of marine aquarium fishes, as well as coral, live rock, algae, seagrass and invertebrates

Fishery	Fishery Area	Method/s	Season (if specified)	Target Species
	around Capes region			
Pearling and Aquaculture				
Pearling / Aquaculture Leases	Coastal waters of Exmouth Gulf, Broome, Dampier Peninsula, Buccaneer Archipelago, Roebuck Bay and Montebello Islands	Farm leases for hatchery-bred pearl oysters		Blacklip Oyster (*Pinctada margitifera*) Pearl Oyster (*P. maxima*)

5.5.2.3 Traditional Indonesian Fishing

A Memorandum of Understanding (MoU) between Australia and the Republic of Indonesia has existed since 1974 and allows traditional Indonesian fishers to fish in an area known as the 'MoU Box'. The MoU defines 'traditional fishermen' as fishers who have traditionally taken fish and sedentary organisms in Australian waters using traditional fishing methods and non-motorised sailing vessels. Under the MoU, the taking of protected wildlife including marine turtles, Dugongs and clams is prohibited, as is fishing within the Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve. Fishers may access the reefs of Cartier Island, Scott Reef, Seringapatam Reef and Browse Island, and visit Ashmore Reef for access to fresh water and to visit graves (DEWHA 2008).

5.5.3 Marine Tourism and Recreation

Charter fishing, marine fauna watching, and cruising are the main commercial tourism activities, and fishing, diving, snorkelling and other nature-based activities are the main recreational activities that may occur within the EMBA (Table 5-21).

Table 5-21 Marine Tourism and Recreation within the Corowa Development EMBA

Activity	EMBA	Project Area	Light Area	Hydrocarbon Area
Recreational fishing	✓	X	✓	✓
Charter vessel tours	✓	X	✓	✓
Cruises	✓	X	X	✓
Recreational diving, snorkelling, and other nature-based activities	✓	X	✓	✓

✓ = Present within area; X = not present within area

Recreational fishing in Australia is a multi-billion-dollar industry. Most recreational fishing typically occurs in nearshore coastal waters (shore or inshore vessels), and within bays and estuaries. Offshore fishing (>5 km from the coast) only accounts for ~4% of recreational fishing activity in Australia, and charter fishing vessels are likely to account for the majority of this offshore fishing activity. The highest recreational fishing effort is typically concentrated near towns, and the closest to the Corowa Development are coastal areas off Point Samson and Coral Bay (DEWHA 2008).

The charter fishing industry in WA is regulated by DPIRD with licences required to operate (except within AMPs where licences are regulated by the Director of National Parks). Charter fishing is a popular activity, with many fishing boat tours operating from Exmouth. Prime game-fishing locations can be found are around offshore atolls and reefs, including the Rowley Shoals (DEWHA 2008). Activities conducted on charter tours are not restricted to fishing, and may also include diving, snorkelling, marine fauna watching and sightseeing (DEWHA 2008). However, except for charter fishing (which can operate in both State and Commonwealth waters), most marine tourism activities typically occur in State waters.

Whale watching is popular, particularly during the southward migration of Humpback Whales from September to late November, with numerous adults and calves in Exmouth Gulf during this period (DEWHA 2008). Dolphin and Dugong tours are more common further south, with popular locations within Shark Bay (DEWHA 2008).

Other recreational activities, such as diving and snorkelling, are typically undertaken within State waters. Primary dive locations within the vicinity of the Corowa Development are within the State Ningaloo MP and the Muiron Islands MMA (DEWHA 2008).

Exmouth is occasionally used by the cruise ship industry; however, given the size of existing infrastructure and facilities available at Exmouth, this limits the size and number of vessels that use the marina.

5.5.4 State Protected Areas

5.5.4.1 Marine

There are ten State marine protected areas within EMBA (Table 5-22, Figure 5-26). The closest State marine protected areas to the Corowa Development are the Muiron Islands Marine Management Area (MMA) and the Ningaloo Marine Park (MP), ~20 km and 40 km from the expected position of the MOPU respectively (Figure 5-26). A summary of the description and values of these protected areas is provided below.

Table 5-22 State Marine Protected Areas within the Corowa Development EMBA

State Marine Protected Area	EMBA	Project Area	Light Area	Hydrocarbon Area
Eighty Mile Beach Marine Park	✓	X	X	X
Rowley Shoals Marine Park	✓	X	X	X
Montebello Islands Marine Park	✓	X	X	✓
Barrow Islands Marine Park and Marine Management Area	✓	X	X	✓
Muiron Islands Marine Management Area	✓	X	✓	✓
Ningaloo Marine Park	✓	X	X	✓
Shark Bay Marine Park	✓	X	X	X
Hamelin Pool Marine Nature Reserve	✓	X	X	X
Jurien Bay Marine Park	✓	X	X	X
Marmion Marine Park	✓	X	X	X

✓ = Present within area; X = not present within area

The Ningaloo Marine Park was originally gazetted in 1987, and then amended in November 2004 to include the whole of the Ningaloo Reef. The Muiron Islands Marine Management Area was also gazetted in November 2004. The Ningaloo Marine Park and Muiron Islands Marine Management Area are located off the North West Cape of WA and cover areas of ~263,343 ha and 28,616 ha respectively. These protected areas are managed simultaneously, with the same objectives, strategies and targets (CALM 2005).

Ningaloo Reef is the largest fringing coral reef in Australia (CALM 2005). Temperate and tropical currents converge in the Ningaloo region resulting in a high biological diversity, including areas of mangroves, coral reefs, algae and filter-feeding communities and abundant species of fish, turtles, Whale Sharks, Dugongs, whales and dolphins (including some with recognised conservation status). The region is also known for its high ambient water quality (CALM 2005).

The Muiron Islands Marine Management Area also contains a very diverse marine environment, with coral reefs, filter-feeding communities and macroalgal beds. The island group includes South Muiron and North Muiron islands (which are separated by a deep-water navigable channel) and Sunday Island, which is smaller and further east. They are low limestone islands (maximum height of 18 m above sea level, with some areas of sandy beaches, macroalgae and seagrass beds in the shallow waters (particularly on the eastern sides) and coral reef up to depths of 5 m, which surrounds both sides of South Muiron Island and the eastern side of North Muiron Island. The marine fauna and flora of the Muiron Islands is in some cases similar to the Ningaloo Reef; however, the intertidal rock platforms on the western shores are of particular interest as this habitat type is a feature of a different biogeographic zone (west coast south of Cape Cuvier), which is uncommon in the tropics. In addition, the Islands are important seabird and Green Turtle nesting areas (CALM 2005).Large proportions of the tropical species are at the southern limit of their geographic range within both of the reserves; conversely, a few temperate southern Australian or endemic west coast species are at the northern limit of their range within the reserves (e.g. the Western Rock Lobster) (CALM 2005).

The Ningaloo area also has a high social significance, for a variety of recreational pursuits and for nature-based tourism that centres on the reserve’s natural attractions. Nature-based activities known to occur include wildlife viewing, boating, fishing, diving, snorkelling, and a variety of coastal uses (CALM 2005). The seasonal aggregations of marine fauna (Whale Sharks, manta rays, sea turtles and whales) and the annual mass spawning of coral provide unique opportunities for visitors to observe these key features within the reserves (CALM 2005). Cultural heritage is also acknowledged within the region, due to the long history of use and occupation of the area by Aboriginal groups (CALM 2005).

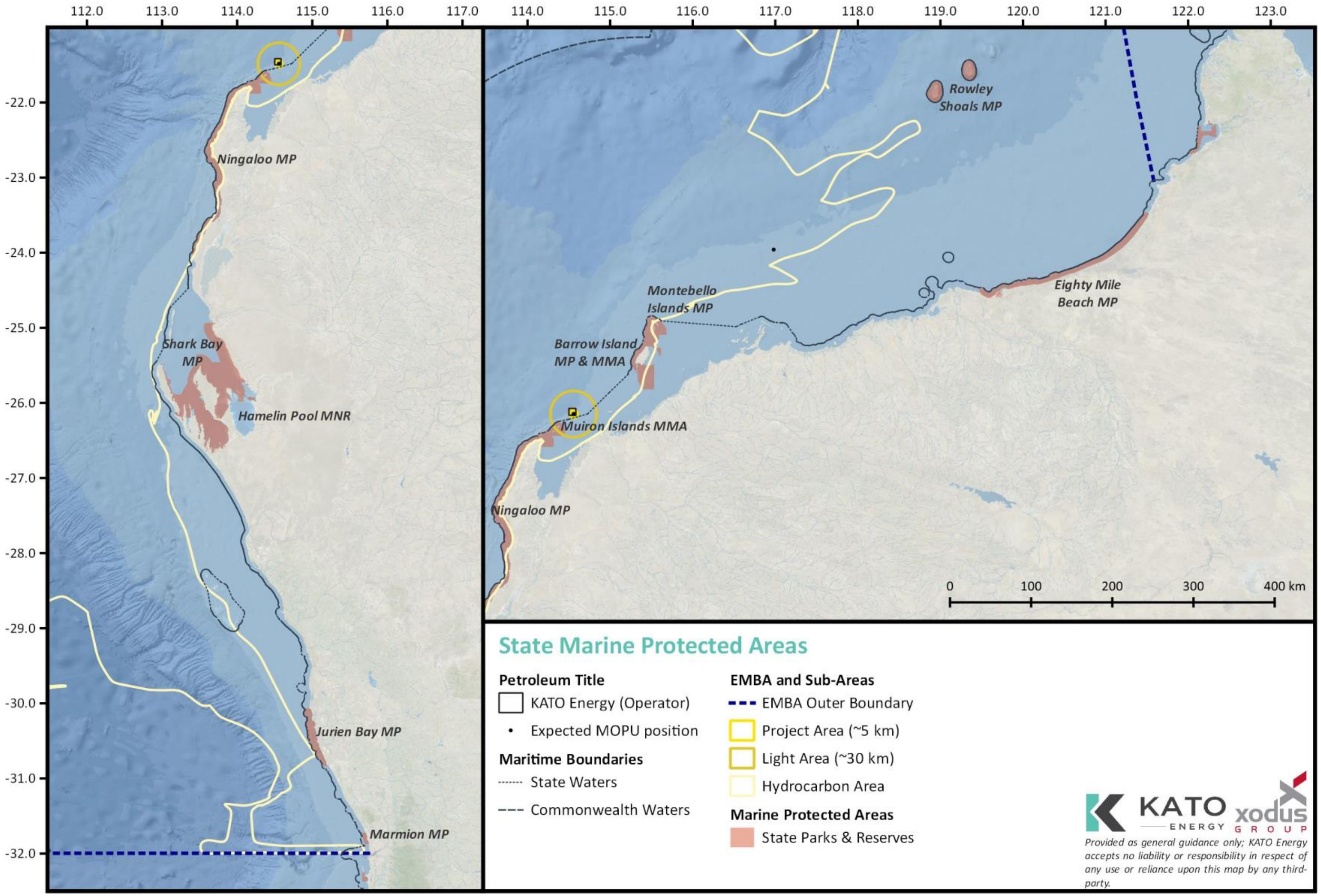


Figure 5-26 State Marine Protected Areas

5.5.4.2 Terrestrial

There are eight State terrestrial protected areas within EMBA (Table 5-23, Figure 5-27). The closest State terrestrial protected areas to the Corowa Development are the Pilbara Inshore Islands Nature Reserves and Cape Range National Park, ~14 km and 79 km from the expected position of the MOPU respectively (Figure 5-27). A summary of the description and values of these protected areas is provided below.

Table 5-23 State Terrestrial Protected Areas within the Corowa Development EMBA

State Marine Protected Area	EMBA	Project Area	Light Area	Hydrocarbon Area
Murujuga National Park	✓	X	X	X
Dampier Archipelago Island Reserves	✓	X	X	X
Pilbara Inshore Islands Nature Reserves	✓	X	✓	✓
Cape Range National Park	✓	X	X	✓
Francois Peron National Park	✓	X	X	X
Dirk Hartog Island National Park	✓	X	X	X
Houtman Abrolhos Islands National Park	✓	X	X	X
Nambung National Park	✓	X	X	X

✓ = Present within area; X = not present within area

The Management Plan for the Pilbara Inshore Islands Nature Reserves is currently being prepared and is expected to be released late-2019. The Pilbara Inshore Islands Nature Reserves are mostly small, remote islands that are important breeding and resting places for migratory shorebirds, seabirds and turtles (including some with recognised conservation status) (DBCA 2017). Four species of marine turtle (Green, Loggerhead, Hawksbill and Flatback) nest on inshore islands with major nesting beaches on located on the Muiron, Locker, Thevenard, Serrurier and Sholl islands (DBCA 2017). Around one million Wedge-tailed Shearwaters migrate to the area each year, visiting the islands (particularly Muiron and Serrurier) from July onwards to prepare burrows for nesting (nesting occurs from November) (DBCA 2017). The shearwaters will also forage in the area around the islands. Other bird species that use the islands throughout the year include the Beach Stone-curlew, pied and Sooty Oystercatcher and Fairy Tern.

Cape Range National Park covers an area of 50,581 ha of the Cape Range peninsula on the North West Cape (DEC 2010). The conservation values of the park include ancient and relict subterranean fauna, diverse habitats, and the presence of species occurring at the limits of their geographic range or as geographically isolated populations (DEC 2010). The park covers an area of landform sequence from the modern-day Ningaloo Reef to the fossilised remnants of former reef and past shorelines of Cape Range and associated wave cut terraces. This landform sequence, plus the flora and fauna it supports, is unique and provides a visible history to the evolution of reefs, changing sea levels and the movement of the continents over time (DEC 2010). The park is also highly valued for the scenic quality of its rugged coastline bordered by the Ningaloo Reef, and its recreation qualities (DEC 2010).

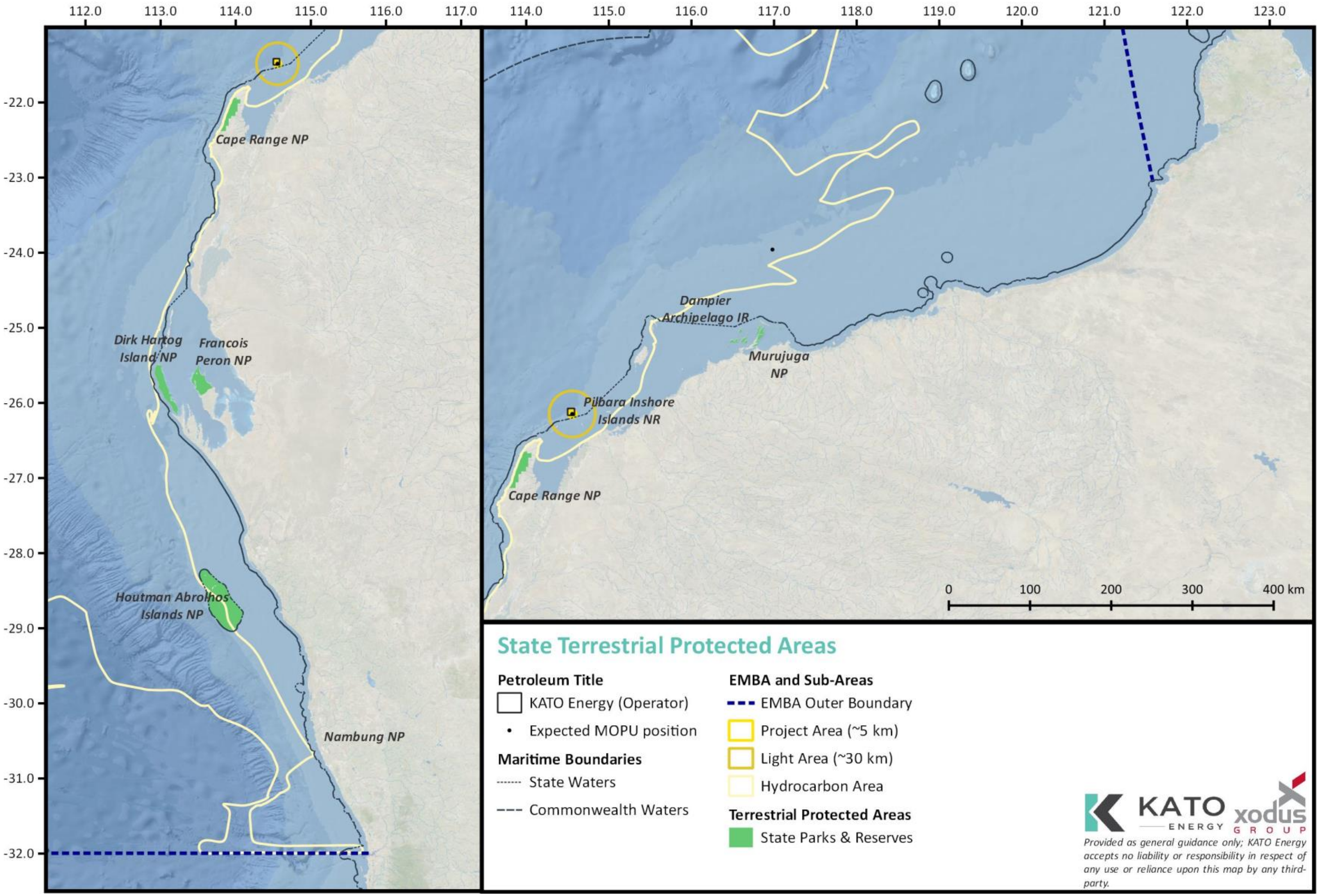


Figure 5-27 State Terrestrial Protected Areas

5.5.5 Marine and Coastal Industries

Several other industries or users may be present within the EMBA (Table 5-24). Commercial fisheries and tourism/recreation have been described separately (Sections 5.5.2 and 5.5.3 respectively).

Table 5-24 Marine and Coastal Industries within the Corowa Development EMBA

Industry or User	EMBA	Project Area	Light Area	Hydrocarbon Area
Petroleum exploration and production	✓	X	✓	✓
Ports	✓	X	X	X
Commercial shipping	✓	✓	✓	✓
Defence	✓	✓	✓	✓
Submarine telecommunication cables	✓	X	X	✓

✓ = Present within area; X = not present within area

The Corowa Development is within the Northern Carnarvon Basin, one of the most heavily explored and developed basins in Australia. The Northern Carnarvon, Browse and Bonaparte basins together comprise most of Australia's natural gas reserves (DEWHA 2008). The Carnarvon Basin supports >95% of WA's oil and gas production, and accounts for ~63% of Australia's total production of crude oil, condensate and natural gas (DEWHA 2008).

Oil and gas facilities within the vicinity of the Corowa Development include BHP's Pyrenees FPSO (~46 km), Santos' Ningaloo Vision FPSO (~49 km), Woodside's Ngujima-Yin FPSO (~51 km) and BHP's Stybarrow Development (~75 km; note this is in cessation operations and the FPSO has left the field) (Figure 5-28). Onshore processing hubs include Ashburton North (Wheatstone LNG), Varanus Island, Barrow Island (Gorgon LNG), and Woodside's Burrup Hub near Dampier. There are also several submerged pipelines associated with petroleum fields and facilities with onshore processing hubs (e.g. the Macedon and Wheatstone gas pipelines; Figure 5-28).

The largest ports within the EMBA are the Ports of Dampier and Port Hedland (Figure 5-29). The Port of Dampier is one of the major tonnage ports in Australia, with prime export commodities of iron ore, LNG and salt. Port Hedland is the second largest Australian port, with its main bulk export commodities being iron ore and salt. The closest port to the Corowa Development is the Port of Ashburton; this port was constructed by the Wheatstone Joint Venture and is managed by the Pilbara Port Authority (Figure 5-29).

Commercial shipping traffic is high within the NWS with vessel activities including commercial fisheries, tourism, international shipping and oil and gas operations (Figure 5-30).

The Royal Australian Air Force (RAAF) have a base at Learmonth, and training and practice areas associated with this base extend offshore (Figure 5-31). The RAAF base and associated facilities occur on Commonwealth land. The Naval Communications Station Harold E. Holt is also located at North West Cape. This station communicates at very low frequencies with submarines in the Indian Ocean and the western Pacific.

Submarine telecommunications cables are underwater infrastructure linking Australia with other countries; the submarine communications cables carry the bulk of Australia's international voice and data traffic. There are international submarine cables that intersect with the EMBA, including:

- South-East Asia–Middle East–Western Europe 3 (SEA-ME-WE3) cable, with the closest landing ports being Perth and Jakarta
- Australia Singapore Cable, with landing ports in Perth, Christmas Island, Jakarta and Singapore

- Indigo-West Cable, with landing ports in Perth, Jakarta and Singapore
- The previous Jakarta–Surabaya–Australia (JASURAUS) cable, linking Port Hedland to Jakarta was decommissioned in 2012.

All of these communication cables are distant (>400 km) from the Corowa Development. Under the Commonwealth *Telecommunications Act 1997,* the Australian Communications and Media Authority can declare protection zones covering the cables to prohibit and/or restrict activities that may damage them. The protection zones are generally the area within 1.8 km (1 nm) either side of the cable and include both the waters and seabed within the area. Within the EMBA, the Perth Protection Zone extends approximately 112 km (60 nm) offshore from City Beach to water depths of 2,000 m, and 1 nm each side of the SEA-ME-WE3 cable.

National submarine cables within the EMBA include the North West Cable System, linking Port Hedland to Darwin with branching cables to some oil and gas facilities within the Browse, Bonaparte and Carnarvon Basins.

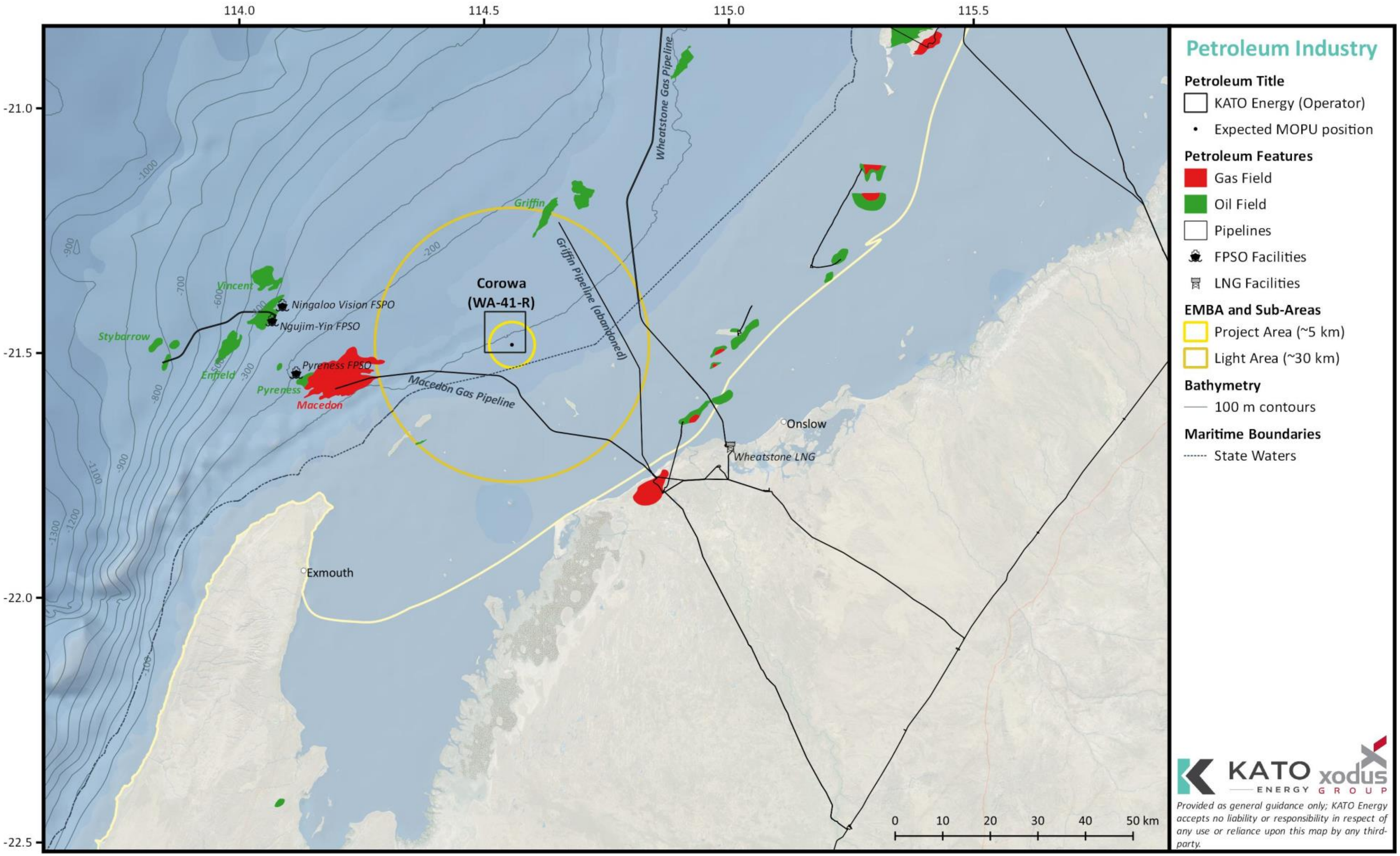


Figure 5-28 Petroleum Industry Facilities and Features

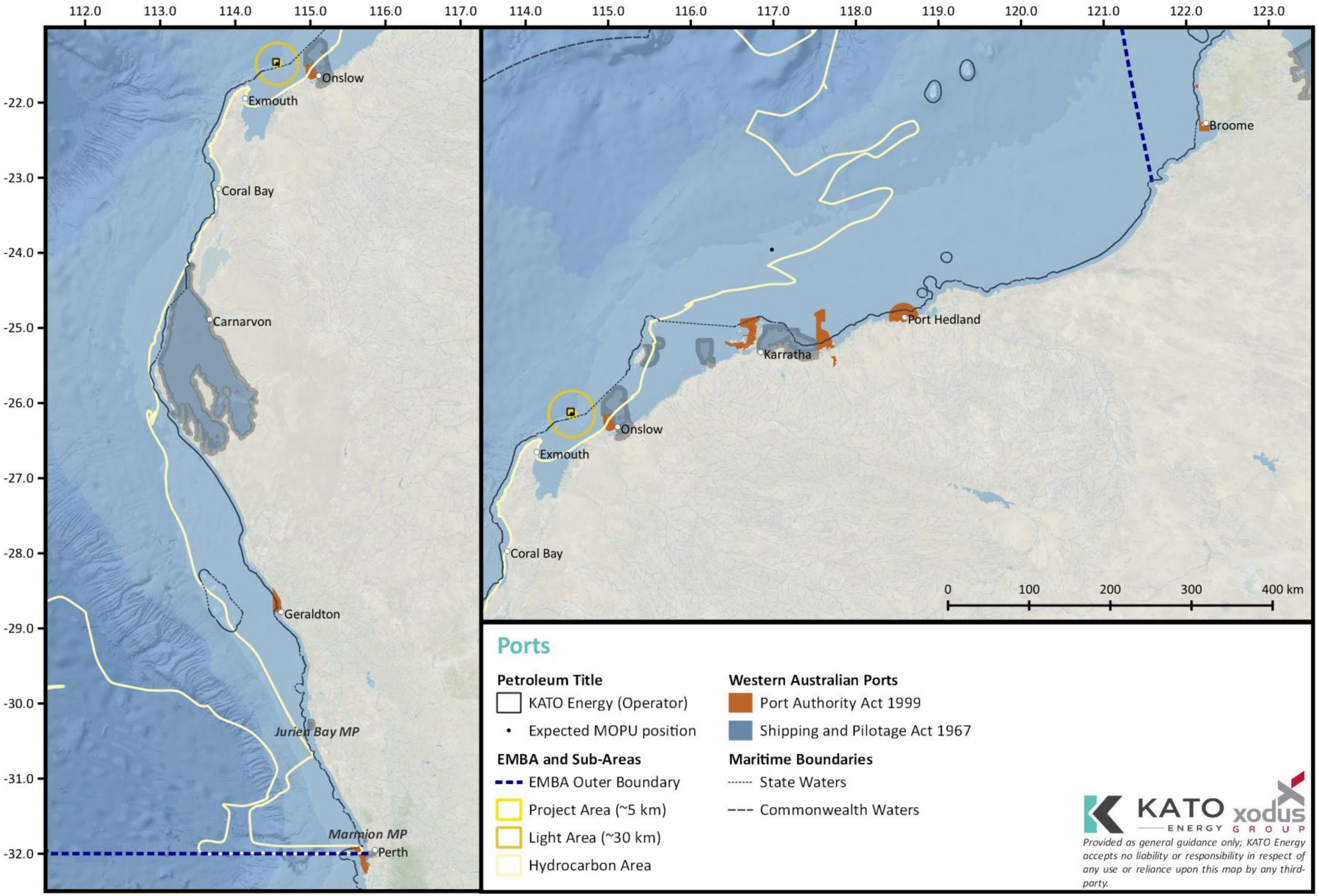


Figure 5-29 Port Facilities

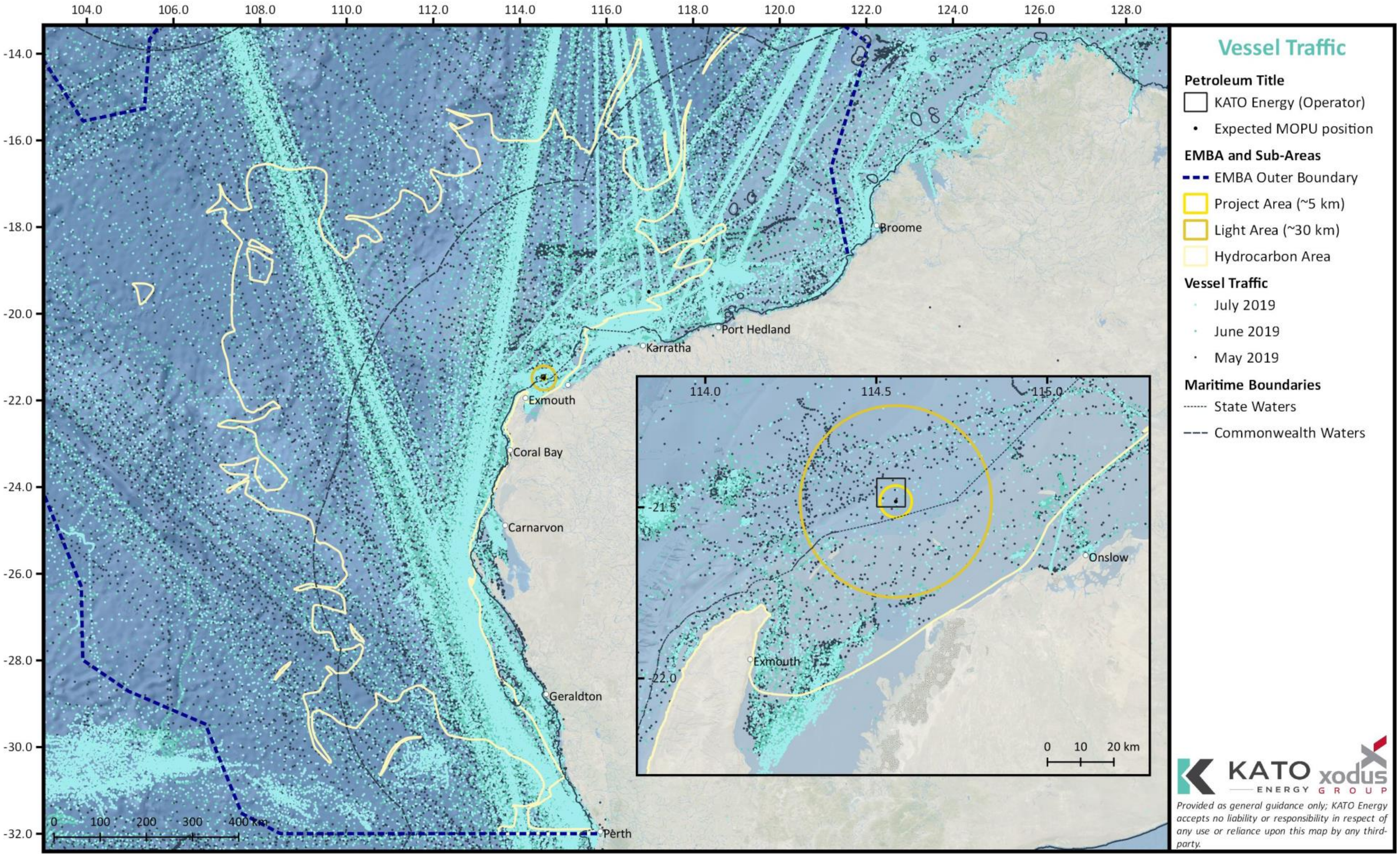


Figure 5-30 Commercial Shipping Traffic

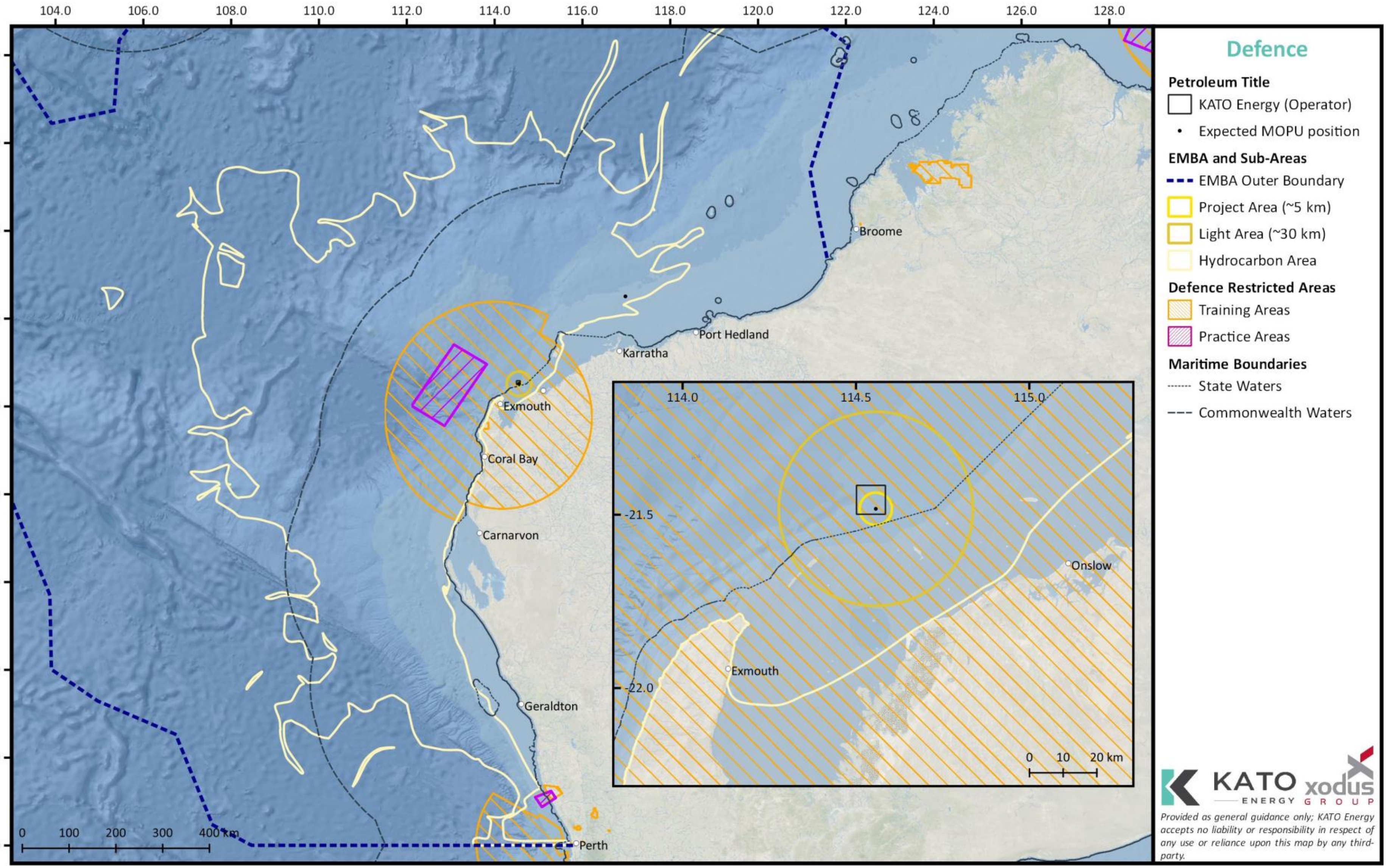


Figure 5-31 Defence Training Areas

5.5.6 Heritage and Cultural Features

Several marine or coastal heritage and cultural places and values may be present within the EMBA (Table 5-25, Appendix A); key features are further described below.

Table 5-25 Heritage and Cultural Features within the Corowa Development EMBA

Feature	EMBA	Project Area	Light Area	Hydrocarbon Area
World Heritage Properties*				
Class: Natural				
The Ningaloo Coast	✓	X	✓	✓
Shark Bay	✓	X	X	X
National Heritage Places*				
Class: Natural				
The Ningaloo Coast	✓	X	✓	✓
Shark Bay	✓	X	X	X
Class: Indigenous				
Dampier Archipelago (including Burrup Peninsula)	✓	X	X	X
Class: Historic				
Cape Inscription (Dirk Hartog Landing Site)	✓	X	X	X
Batavia Shipwreck (Houtman Abrolhos)	✓	X	X	X
HMAS Sydney II and *HSK Kormoran* Shipwrecks	✓	X	X	✓
Commonwealth Heritage Places				
Class: Natural				
Mermaid Reef – Rowley Shoals	✓	X	X	X
Ningaloo Marine Area (Commonwealth waters)	✓	X	X	✓
Scott Reef and Surrounds (Commonwealth area)	✓	X	X	X
Class: Historic				
HMAS Sydney II and *HSK Kormoran* Shipwrecks	✓	X	X	✓
Aboriginal Heritage Places				
Registered sites	✓	X	X	✓
Indigenous Protected Areas				
State terrestrial protected areas that are proclaimed as Indigenous Protected Areas	✓	X	X	X
Underwater Cultural Heritage				
Historic shipwrecks (>75 years)	✓	X	✓	✓
Shipwrecks	✓	X	X	✓
Sunken aircraft	✓	X	X	X
In situ artefact	✓	X	X	X

*✓ = Present within area; X = not present within area; *= Matter of National Environmental Significance*

The EPBC Act enhances the management and protection of Australia's heritage places, and provides for listings under three categories:

- World Heritage, places considered as the best examples of world cultural and natural heritage and that have been included in the World Heritage List or declared by the Minister to be a World Heritage property
- National Heritage, places of natural, historic or Indigenous heritage value
- Commonwealth Heritage, places of natural, historic or Indigenous heritage value on Commonwealth lands and waters.

World Heritage Properties and National Heritage Places are both listed as MNES under the EPBC Act. There are two World and six National heritage places within the EMBA (Table 5-25, Figure 5-32). The closest World and National heritage areas to the Corowa Development is the Ningaloo Coast, ~20 km from the expected position of the MOPU (Figure 5-32); a summary of the description and values of this heritage area is provided below.

Aboriginal heritage sites in WA are protected under the *Aboriginal Heritage Act 1972* (WA), whether or not they are registered with the Department of Planning, Lands and Heritage (DPLH). Those that have been formally registered with the DPLH are shown on Figure 5-32, and include are recognised for a variety of reasons including artefacts, middens, meeting places, hunting places, engravings or mythological significance. While sea country is a recognised value (e.g. see value descriptions of AMPs in Table 5-14), the registered site list is land-based sites.

Indigenous Protected Areas (IPA) are a component of Australia’s National Reserve System (i.e. the network of formally recognised parks, reserves and protected areas across Australia). IPAs recognise Aboriginal people as landowners and managers and supports them to look after biodiversity hotspots and highly sensitive areas they want protected (KLC 2019). As well as protecting biodiversity, Indigenous Protected Areas deliver environmental, cultural, social, health and wellbeing and economic benefits to Indigenous communities (DoEE 2019c). The boundary of the Karajarri IPA partially occurs within the extent of the EMBA (Table 5-25, Figure 5-32). This IPA was declared in May 2014 and covers an area of 24,797 km^2 in the southern Kimberley and will help strengthen the Karajarri people’s culture and heritage (KLC 2019).

Australia’s underwater cultural heritage is protected under the Commonwealth *Underwater Cultural Heritage Act 2019*; this legislation protects shipwrecks, sunken aircraft and other types of underwater heritage. Multiple known shipwreck and historic (>75 years old) shipwreck sites occur within the EMBA (Table 5-25, Figure 5-32). The *Batavia*, wrecked in 1629 offshore from the Houtman Abrolhos Islands, and the *HMAS Sydney II* and *HSK Kormoran*, both wrecked in 1941 offshore from Shark Bay, are also listed on the National Heritage list, is also listed on the National Heritage list. There is a single record of a sunken aircraft (offshore from 80 Mile Beach) and in situ artefact (offshore of Point Samson) within the EMBA (Table 5-25). Some underwater cultural heritage sites are also within a declared protection zone, where entry and/or activities may be restricted; three of these occur within the EMBA and are associated with historic shipwrecks: *HSK Kormoran*, *HMAS Sydney II* and *Zuytdorp* (Figure 5-33).

5.5.6.1 Ningaloo Coast

The Ningaloo Coast is recognised as both a World Heritage Area (WHA) and included on both the National and Commonwealth Heritage lists. The area includes both land and State and Commonwealth marine waters (Figure 5-32).

The Ningaloo Coast includes both a marine component (which is dominated by the Ningaloo Reef) and a land component (which extends into the limestone karst system of Cape Range). Values of the Ningaloo Coast are varied and include physical, biotic, and historic attributes. Together Ningaloo Reef and Cape Range, along with related interdependent marine and terrestrial ecosystems, form a functionally integrated limestone structure (DoEE 2019c). The Ningaloo Coast is important in several ways:

- biologically, through the combination of high terrestrial endemism and a rich marine environment
- structurally, as a large nearshore coral reef off a limestone karst system
- climatically, for the juxtaposition of a tropical marine setting and an arid coast
- topographically, as a barrier reef lying alongside a steep limestone range.

The Ningaloo Coast has a high level of terrestrial species endemism and high marine species diversity and abundance (UNESCO 2019).

The waters of the Ningaloo Coast include a diversity of habitats including reef, open ocean, estuaries and mangroves. The most dominant marine habitat is the Ningaloo Reef, which supports both tropical and temperate marine fauna and flora. Approximately 300–500 Whale Sharks aggregate annually coinciding with mass coral spawning events and seasonal localised increases in productivity (UNESCO 2019).

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 (UNESCO 2019). 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. Above ground, the Cape Range Peninsula belongs to an arid ecoregion recognised for its high levels of species richness and endemism, particularly for birds and reptiles (UNESCO 2019).

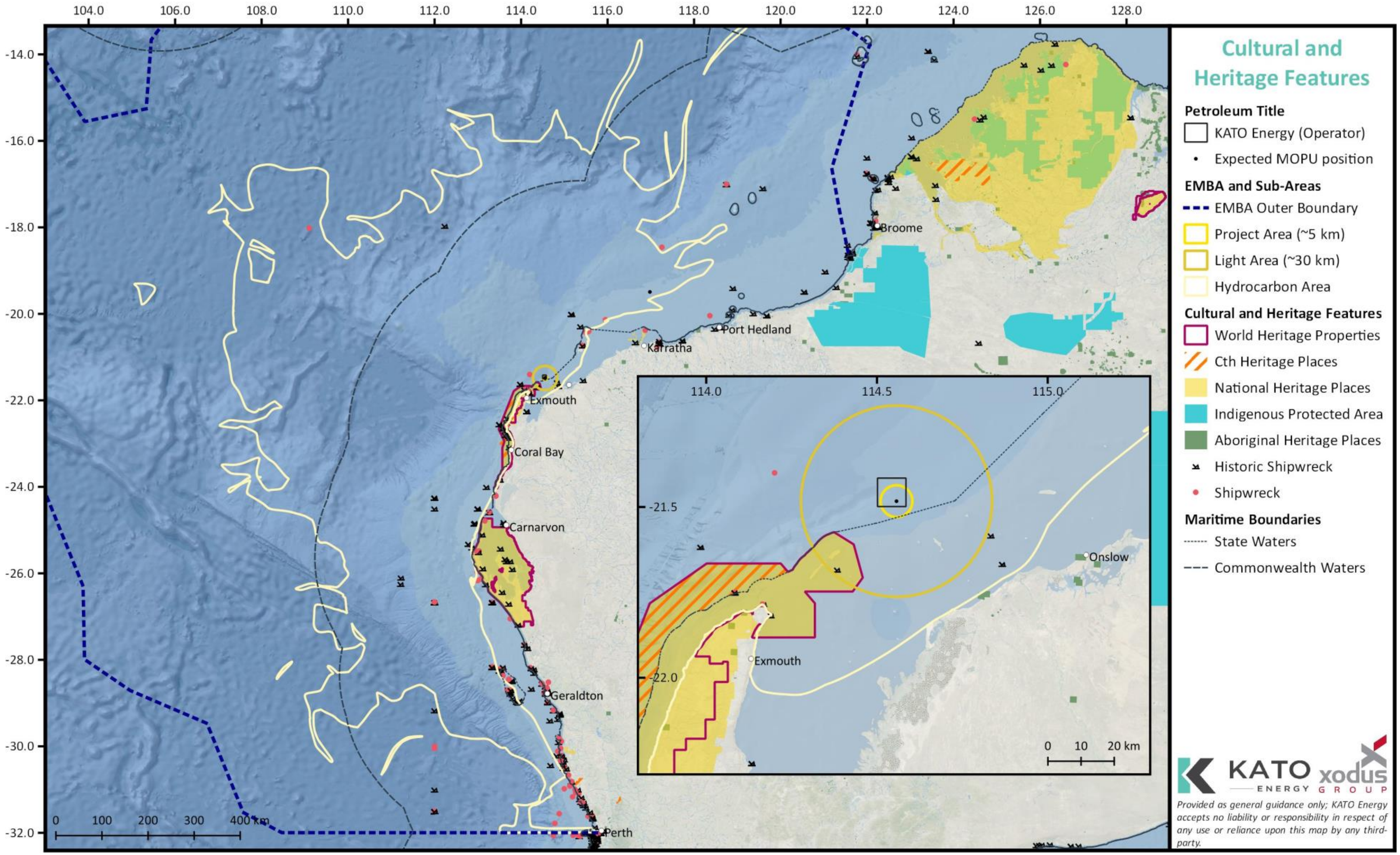
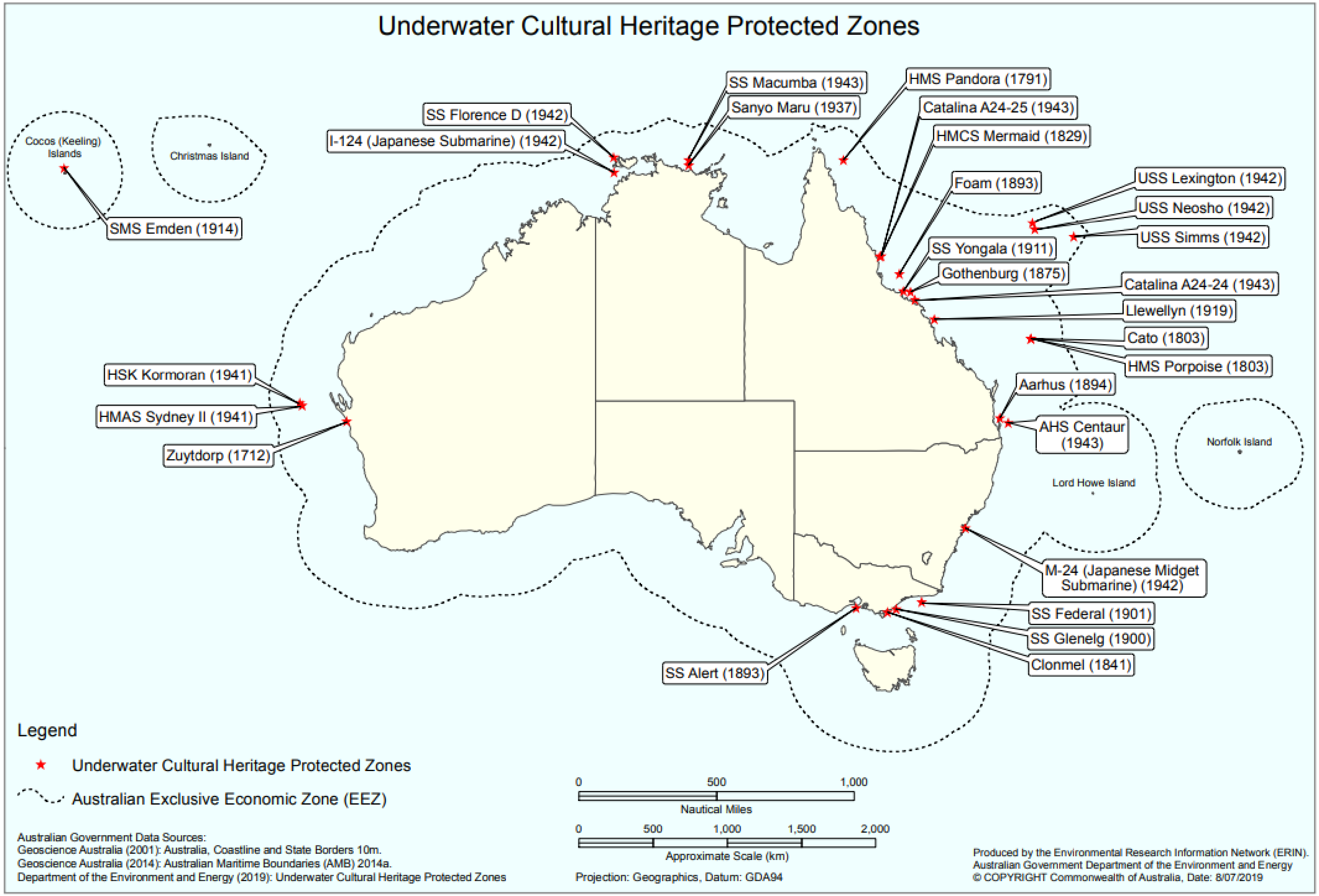


Figure 5-32 Cultural and Heritage Features



Source: DoEE 2019c

Figure 5-33 Underwater Cultural Heritage Protected Zones

6 Environmental Impact and Risk Assessment Methodology

The OPGGS(E)R requires a description of the methodology used to identify and assess the environmental impacts and risks associated with the activities described in Section 3.

6.1 Risk Assessment Methodology

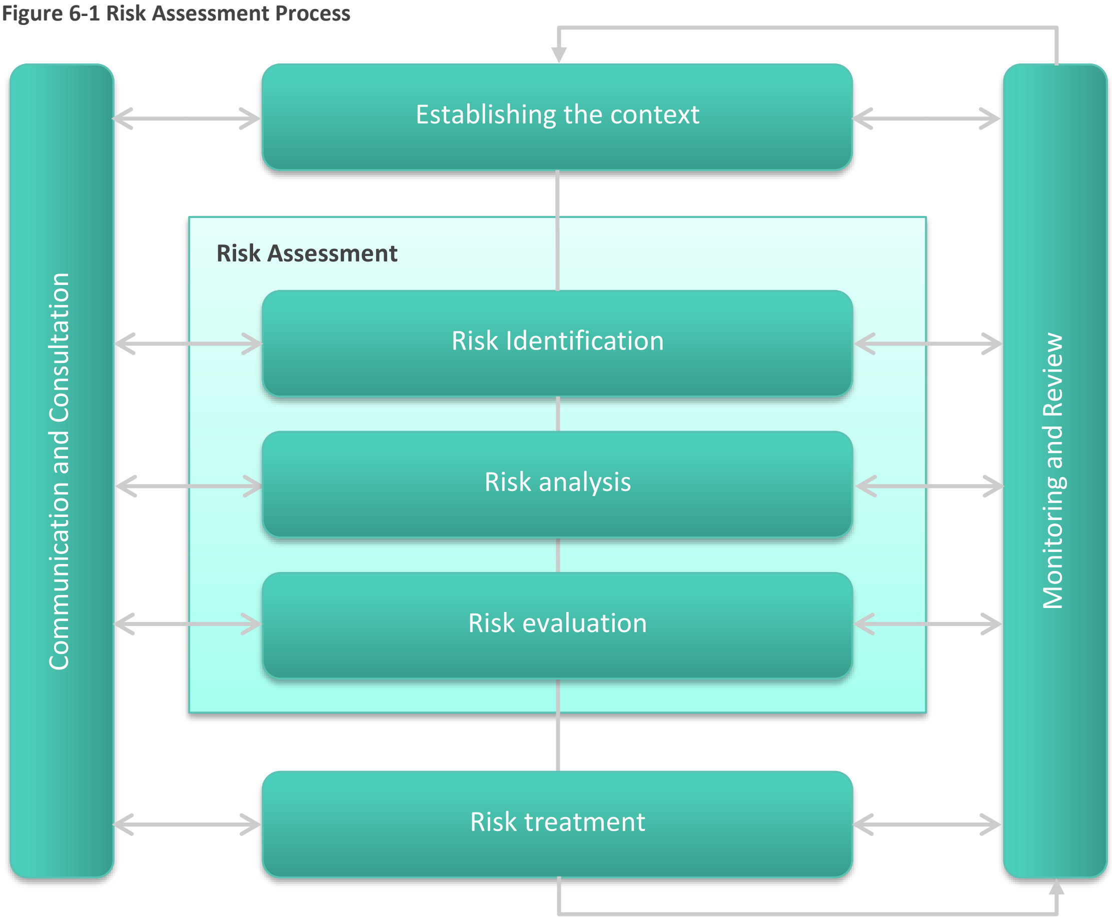
The risk assessment for this OPP was undertaken in accordance with KATO's Risk and Change Management Procedure (KAT-000-GN-PP-002) (KATO 2020a) using the KATO Environmental Risk Matrix (Figure 6-2).

The risk assessment has been undertaken to identify the sources of risk (aspect) and potential environmental impacts associated with the activity and to assign a level of significance or risk to each impact. This assessment subsequently assists in prioritising mitigation measures to ensure that the environmental impacts are managed to as low as reasonably practicable (ALARP). Risk has been assessed in terms of likelihood and consequence, where consequence is defined as the outcome or impact of an event, and likelihood as a description of the probability or frequency of the identified consequence occurring. Following identification of practicable mitigation measures, the residual risk of each impact is reassigned and assessed for environmental acceptability.

This approach is consistent with the processes outlined in ISO 31000:2009 Risk Management – Principles and Guidelines (Standards Australia/Standards New Zealand 2009) and Handbook 203:2012 Managing Environment-related Risk (Standards Australia/Standards New Zealand 2012).

Figure 6-1 shows the key steps used for the risk assessment.

Figure 6-1 Risk Assessment Process



6.2 Establish the Context

6.2.1 Identification and Description of the Petroleum Activity

The activities associated with the Corowa Development are described in Section 3. For the purposes of description and systematic evaluation, these activities have been grouped into these typical project phases (which correspond to the headings in Section 3.4):

- Survey
- Drilling
- Installation, hook-up and commissioning
- Operations
- Decommissioning.

These phases are further categorised by typical activities (shown in the heading of Table 6-1).

Support activities are undertaken during all these phases, including:

- the actual facilities (i.e. MOPU, MODU, FSO)
- vessel operations
- helicopters
- ROVs and diving

All components of the petroleum activity and potential emergency conditions relevant to the scope of this OPP were described and evaluated.

6.2.2 Identification of Particular Environmental Values

Within the defined sub-areas of the Corowa Development, the environment has been described (Section 5) and the particular environmental values and sensitivities of the area identified. In accordance with Regulation 5 of the OPGGS Regulations guidelines. KATO considers the particular values and sensitivities relevant to this OPP as per the EPBC Act and the OPGGS(E)R to be:

- presence of Listed threatened species and ecological communities
- presence of Listed migratory species (protected under international agreements)
- values and sensitivities as part of the Commonwealth marine environment
- values of World heritage properties
- values of National heritage places
- ecological character of a declared RAMSAR wetland
- other values include social, economic and cultural values.

As part of establishing the context of the receiving environment, consideration is given to environmental legislation and other requirements. This includes legislation defining how an activity should be undertaken (i.e. requirements for sewage discharges), legislation determining control measures to limit known impacts (such as accidental release legislation), and management plans, guidelines and conservation advices relating to the protection of threatened species or protected sites. These requirements are described in Section 2 of this OPP.

6.2.3 Identification of Relevant Environmental Aspects

After describing the petroleum activity, an assessment was carried out to identify potential interactions between the petroleum activity and the receiving environment through the identification of environmental aspects. The outcomes of stakeholder consultation also contributed to this scoping process.

Environmental aspects were categorised as resulting from planned or unplanned activities.

Aspects resulting from planned activities are systematically mapped against Activities in Table 6-1. These aspects correspond to the headings in Section 7.1.

Aspects from unplanned activities are systematically mapped against Activities in Table 6-2, and correspond to the headings in Section 3.4.

Note: Potential interactions with safety, health, and assets are outside the scope of this OPP.

Table 6-1 Scoping of Relationship between Activities and Aspects: Planned

Activity	Survey		Drilling						Installation, Hook-up and Commissioning				Operations					Decommissioning					Support Activities (all phases)					
Aspect	Geophysical survey	Geotechnical survey	MODU positioning	Top-hole drilling	BOP installation & testing	Bottom-hole drilling	Completions	Well clean-up & flowback	MOPU	CALM buoy and moorings	Flowlines	FSO	Hydrocarbon extraction	Hydrocarbon processing, storage, offloading	Inspections	Maintenance and repair	Well intervention	Inspection and Cleaning	Well P&A	Removal of subsea infrastructure	Disconnection of FSO & MOPU	As-left survey	MODU operations	MOPU operations	FSO operations	VESSEL operations	Helicopters	ROV & Diving
Physical Presence – Interaction with Other Users									✓	✓	✓	✓											✓	✓	✓	✓	✓	
Physical Presence – Seabed Disturbance		✓	✓	✓					✓	✓	✓					✓	✓	✓	✓	✓	✓					✓		
Emissions – Light								✓						✓									✓	✓	✓	✓		
Emissions – Atmospheric								✓	✓					✓									✓	✓	✓	✓		
Emissions – Underwater Noise	✓			✓		✓	✓										✓		✓				✓	✓	✓	✓	✓	
Planned Discharge – Drilling cuttings and Fluids				✓		✓	✓	✓		✓							✓		✓									
Planned Discharge – Cement				✓		✓				✓							✓		✓									
Planned Discharge – Commissioning Fluids											✓	✓								✓	✓							
Planned Discharge – Produced Formation Water														✓														
Planned Discharge – Cooling Water and Brine																							✓	✓	✓	✓		
Planned Discharge – Deck drainage and Bilge																							✓	✓	✓	✓		
Planned Discharge – Sewage, Greywater and Food waste																							✓	✓	✓	✓		

Table 6-2 Scoping of Relationship between Activities and Aspects: Unplanned

ACTIVITY	Survey		Drilling						Installation, Hook-up and Commissioning				Operations					Decommissioning					Support Activities (all phases)					
Aspect	Geophysical survey	Geotechnical survey	MODU positioning	Top-hole drilling	BOP installation & testing	Bottom-hole drilling	Completions	Well clean-up & flowback	MOPU	CALM buoy and moorings	Flowline & risers	FSO	Hydrocarbon extraction	Hydrocarbon processing, storage, export	Inspections	Maintenance and repair	Well intervention	Inspection and Cleaning	Well P&A	Removal of subsea infrastructure	Disconnection of FSO & MOPU	As-left survey	MODU operations	MOPU operations	FSO operations	VESSEL operations	Helicopters	ROV & Diving
Introduction of IMS			✓						✓	✓		✓						✓					✓	✓	✓	✓		
Physical Presence – Interaction with Marine Fauna	✓	✓																							✓	✓	✓	
Physical Presence – Unplanned Seabed Disturbance									✓	✓	✓							✓	✓	✓	✓		✓	✓	✓	✓		✓
Unplanned Discharge – Solid Waste																							✓	✓	✓	✓		
Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons)																							✓	✓	✓	✓	✓	✓
Accidental Release – Corowa Light Crude Oil				✓		✓	✓	✓					✓	✓	✓	✓	✓		✓	✓			✓	✓	✓			
Accidental Release – Marine Diesel/Gas Oil																							✓	✓	✓	✓		

6.3 Risk Assessment

6.3.1 Impact and Risk Identification

Based upon an understanding of these environmental interactions, relevant impacts or risks resulting from each aspect were defined. Environmental receptors identified as particular values and sensitivities (described in Section 5) with the potential to be exposed to an aspect and subsequent impacts or risks were then summarised, enabling a systematic evaluation to be undertaken.

A systematic scoping of the relationships between Aspects, Impacts and Risks, and Receptors has been undertaken, and is shown in Table 6-3 for planned activities, and Table 6-4 for unplanned activities. Each interaction is identified in the table as:

X Impact or risk analysis (described in Section 6.3.2) indicated that an impact is either not predicted to occur or predicted to have a negligible/less than Minor (1) consequence. An explanation is provided in the appropriate assessment in Sections 7.1 and 7.2.

✓ Impact or risk analysis (described in Section 6.3.2) indicated that an impact is predicted to occur. A detailed evaluation of the impact or risk (described in Section 6.3.3) is provided in the appropriate assessment in Sections 7.1 and 7.2.

Table 6-3 Scoping of Relationships between Aspects, Impacts and Risks, and Receptors: Planned

	Receptors	Physical						Ecological							Social, economic and cultural							
Aspects	**Impacts**	**Water quality**	**Sediment quality**	**Air quality**	**Climate**	**Ambient light**	**Ambient noise**	**Plankton**	**Benthic habitat and communities**	**Coastal habitats and communities**	**Seabirds and shorebirds**	**Fish**	**Marine mammals**	**Marine reptiles**	**KEFs**	**AMPs**	**Commercial Fisheries**	**Tourism and Recreation**	**State protected area – Marine**	**State protected area – Terrestrial**	**Industries**	**Heritage and Cultural features**
Physical Presence – Interaction with Other Users	Changes to the functions, interests or activities of other users																✓	X			✓	
Physical presence – Seabed disturbance	Change in water quality	✓																				
	Change in habitat								✓													
	Injury/mortality to fauna							X	✓			✓	X	X								
	Changes to the functions, interests or activities of other users																X					
Emissions – Light	Change in ambient light					✓																
	Change in fauna behaviour										✓	✓	X	✓								
	Changes to the functions, interests or activities of other users																X		✓			✓
	Change in aesthetic value																		✓			✓
	Change in air quality			✓																		

	Receptors	Physical						Ecological							Social, economic and cultural							
Aspects	Impacts	Water quality	Sediment quality	Air quality	Climate	Ambient light	Ambient noise	Plankton	Benthic habitat and communities	Coastal habitats and communities	Seabirds and shorebirds	Fish	Marine mammals	Marine reptiles	KEFs	AMPs	Commercial Fisheries	Tourism and Recreation	State protected area – Marine	State protected area – Terrestrial	Industries	Heritage and Cultural features
Emissions – Atmospheric	Climate change				✓																	
	Injury/mortality to fauna							X	X	X	X	X	X	X	X	X			X			
	Change in ecosystem dynamics							X	X	X	X	X	X	X	X	X			X			
	Changes to the functions, interests or activities of other users														X	X	X	X	X	X		
Emissions – Underwater Noise	Change in ambient noise						✓															
	Injury/mortality to fauna							X	X			✓	✓	X								
	Change in fauna behaviour							X	X			✓	✓	✓								
	Changes to the functions, interests or activities of other users																X					
Planned Discharge – Drilling cuttings and Fluids	Change in water quality	✓																				
	Change in sediment quality		✓																			
	Injury/mortality to fauna							X	✓			X	X	X								

Aspects	Receptors	Physical						Ecological							Social, economic and cultural							
	Impacts	Water quality	Sediment quality	Air quality	Climate	Ambient light	Ambient noise	Plankton	Benthic habitat and communities	Coastal habitats and communities	Seabirds and shorebirds	Fish	Marine mammals	Marine reptiles	KEFs	AMPs	Commercial Fisheries	Tourism and Recreation	State protected area – Marine	State protected area – Terrestrial	Industries	Heritage and Cultural features
	Changes to the functions, interests or activities of other users																X					
Planned Discharge – Cement	Change in water quality	✓																				
	Change in sediment quality		✓																			
	Change in habitat								✓													
	Injury/mortality to fauna							X	✓			X	X	X								
Planned Discharge – Commissioning Fluids	Change in water quality	✓																				
	Change in sediment quality		✓																			
	Injury/mortality to fauna							X	X			X	X	X								
	Changes to the functions, interests or activities of other users																X					
Planned Discharge – Produced	Change in water quality	✓																				
	Change in sediment quality		✓																			

Aspects	Receptors	Physical						Ecological							Social, economic and cultural							
	Impacts	Water quality	Sediment quality	Air quality	Climate	Ambient light	Ambient noise	Plankton	Benthic habitat and communities	Coastal habitats and communities	Seabirds and shorebirds	Fish	Marine mammals	Marine reptiles	KEFs	AMPs	Commercial Fisheries	Tourism and Recreation	State protected area – Marine	State protected area – Terrestrial	Industries	Heritage and Cultural features
Formation Water	Injury/mortality to fauna							✓				X	X	X								
	Changes to the functions, interests or activities of other users																X					
Planned Discharge – Cooling Water and Brine	Change in water quality	✓																				
	Change in sediment quality		✓																			
	Injury/mortality to fauna							✓				X	X	X								
	Changes to the functions, interests or activities of other users																X					
Planned Discharge – Deck drainage and Bilge	Change in water quality	✓																				
	Injury/mortality to fauna							X				X	X	X								
	Changes to the functions, interests or activities of other users																X					
Planned Discharge – Sewage,	Change in water quality	✓																				
	Change in fauna behaviour							X	X		X	X	X	X								

	Receptors	Physical						Ecological							Social, economic and cultural							
Aspects	**Impacts**	**Water quality**	**Sediment quality**	**Air quality**	**Climate**	**Ambient light**	**Ambient noise**	**Plankton**	**Benthic habitat and communities**	**Coastal habitats and communities**	**Seabirds and shorebirds**	**Fish**	**Marine mammals**	**Marine reptiles**	**KEFs**	**AMPs**	**Commercial Fisheries**	**Tourism and Recreation**	**State protected area – Marine**	**State protected area – Terrestrial**	**Industries**	**Heritage and Cultural features**
Greywater and Food waste	Changes to the functions, interests or activities of other users																*X*					
	Change in aesthetic value																	*X*				

Table 6-4 Scoping of Relationships between Aspects, Impacts and Risks, and Receptors: Unplanned

	Receptors	Physical						Ecological							Social, economic and cultural							
Aspects	Impacts	Water quality	Sediment quality	Air quality	Climate	Ambient light	Ambient noise	Plankton	Benthic habitat and communities	Coastal habitats and communities	Seabirds and shorebirds	Fish	Marine mammals	Marine reptiles	KEFs	AMPs	Commercial Fisheries	Tourism and Recreation	State protected area – Marine	State protected area – Terrestrial	Industries	Heritage and Cultural features
Introduction of IMS	Changes in ecosystem dynamics								✓	✓												
	Changes to the functions, interests or activities of other users																✓				✓	
Physical Presence – Interaction with Marine Fauna	Injury/mortality to fauna											✓	✓	✓			X					
Physical Presence – Unplanned Seabed disturbance	Change in water quality	✓																				
	Change in habitat								✓													
	Injury/mortality to fauna							X				X										
	Changes to the functions, interests or activities of other users																X					
Unplanned Discharge – Solid Waste	Change in water quality	✓																				
	Injury/mortality to fauna										✓	✓	✓	✓								

Aspects	Receptors / Impacts	Physical						Ecological							Social, economic and cultural							
		Water quality	Sediment quality	Air quality	Climate	Ambient light	Ambient noise	Plankton	Benthic habitat and communities	Coastal habitats and communities	Seabirds and shorebirds	Fish	Marine mammals	Marine reptiles	KEFs	AMPs	Commercial Fisheries	Tourism and Recreation	State protected area – Marine	State protected area – Terrestrial	Industries	Heritage and Cultural features
	Changes to the functions, interests or activities of other users																X					
	Change in aesthetic value																	X				
Minor LOC – Chemicals and Hydrocarbons	Change in water quality	✓																				
	Change to sediment quality		X																			
	Injury/mortality to fauna							X				X	X	X								
	Changes to the functions, interests or activities of other users																X					
Accidental Release – Corowa Light Crude Oil	Change in water quality	✓													✓	✓			✓			✓
	Change in sediment quality		✓												X	X				✓		✓
	Change in habitat								✓	✓					✓	✓			✓	X		✓
	Injury/mortality to fauna							✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	X		✓
	Change in fauna behaviour								✓	✓	✓	✓	✓	✓	✓	✓			✓	X		✓
	Changes to the functions, interests or activities of other users														✓	✓	✓	✓	✓	X	✓	✓
	Change in aesthetic value									✓						✓		✓	✓			✓

Aspects	Receptors / Impacts	Physical						Ecological							Social, economic and cultural							
		Water quality	Sediment quality	Air quality	Climate	Ambient light	Ambient noise	Plankton	Benthic habitat and communities	Coastal habitats and communities	Seabirds and shorebirds	Fish	Marine mammals	Marine reptiles	KEFs	AMPs	Commercial Fisheries	Tourism and Recreation	State protected area – Marine	State protected area – Terrestrial	Industries	Heritage and Cultural features
Accidental Release – Marine Diesel/Gas Oil	Change in water quality	✓													✓	✓			✓			✓
	Change in sediment quality		✓												X	X	X					X
	Change in habitat								✓	X					✓	✓			✓	X		✓
	Injury/mortality to fauna							✓	X	✓	✓	✓	✓	✓	✓	✓			✓	X		✓
	Change in fauna behaviour								X	✓	✓	✓	✓	✓	✓	✓			✓	X		✓
	Changes to the functions, interests or activities of other users															✓	✓	✓	✓	X	✓	✓
	Change in aesthetic value									✓						✓		✓	✓			✓

6.3.2 Impact and Risk Analysis

After identifying all potential impacts and risks, and the affected receptor(s), each impact and risk was analysed. The analysis was undertaken in accordance with KATO's Risk and Change Management Procedure (KATO 2020a) which involves determining the consequence of each impact and the likelihood of that consequence occurring and using these categories to determine the overall risk level.

The level of consequence is determined by the potential level of impact based on:

- the spatial scale or extent of potential impact or risk of the environmental aspect within the receiving environment
- the nature of the receiving environment (from Section 5) (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 environmental impact or risk 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 criteria of acceptability.

Consequence levels are determined according to the KATO Environmental Risk Matrix (Figure 6-2).

Table 6-5 provides consequence definitions to support the level determined.

Table 6-5 Consequence Definitions

Level	Consequence Description	Guidance
6	Catastrophic	Permanent environmental landscape-scale impact over extensive area. Permanent loss of ecosystem or extinction of species.
5	Severe	Severe or extensive impact; widespread and persistent on ecosystem or threatened species.
4	Major	Major impact; widespread and long-term on ecosystem or threatened species.
3	Serious	Serious impact; localised and long-term; or widespread and short-term on ecosystem or threatened species.
2	Moderate	Moderate impact; localised and short-term on ecosystem or threatened species
1	Minor	Limited/minor impact; localised and temporary on non-threatened species or their habitat.

For each planned impact arising from normal and abnormal operating conditions, the final impact ranking reflects the consequence level.

For unplanned aspects, in addition to the consequence assessment (as per Table 6-5), a likelihood evaluation was also undertaken. Once the consequence of an impact on affected receptor(s) was understood, the likelihood (probability) of a defined consequence occurring as a result of that activity was determined. The likelihood of a particular consequence occurring was identified using one of the six likelihood categories.

Table 6-6 provides further definition and guidance around likelihood rankings to support the risk level determined.

Table 6-6 Likelihood Definitions

Likelihood value	Likelihood Description	Guidance
A	Extremely Unlikely	• Rare or unheard of. • Not known to occur in a comparable activity internationally but plausible. • Frequency: Less than once per 100 years.
B	Very Unlikely	• Reasonable to expect that will not occur. • Has occurred once or twice within the industry. • Frequency: Between once per 100 years and once per 10 years.
C	Unlikely	• Exceptional conditions may allow to occur. • Known to occur in a comparable activity internationally but unlikely. • Frequency: Between once per 10 years and once per year.
D	Likely	• Conditions may allow to occur. • Has occurred or could occur in a comparable activity in Australia. • Frequency: Between once every year and 4 times a year.
E	Very Likely	• Can reasonably be expected to occur. • Has occurred or could occur frequently in the company or a comparable organisation. • Frequency: At least once per month.
F	Almost certain	• Expected to occur. • Has occurred frequently at the facility or a comparable facility. • At least once per week.

The assessment of likelihood and consequence takes into account control measures that are required by legislation, or that have been adopted by KATO as 'Good Practice'.

6.3.3 Risk Evaluation

Once the consequence and likelihood of impact consequence has been analysed, risks are evaluated to determine risk level. The KATO Environmental Risk Matrix (Figure 6-2) was applied following the detailed evaluation of potential impacts and risks from the activities covered in this OPP. This matrix uses consequence and likelihood rankings, which when combined, result in a risk level between Extreme and Low. Risk assessment outcomes are based solely on risk assessment to the environment.

Risk to company reputation, regulatory compliance, stakeholder expectations, or community relationships were considered but not risk assessed.

6.4 Risk Treatment

Risk treatment involves the consideration and possible adoption of management or control measures, which are selected to reduce either the consequence of an impact or the likelihood of that impact consequence occurring. Control measures are often required by legislation or are considered 'Good Practice' within the oil and gas or offshore industry and therefore are adopted regardless of the evaluated risk level.

The requirements for further risk treatment beyond good practice and legislative control measures depend upon the outcomes of the impact and risk evaluation. Further evaluation and potential adoption of additional control measures will be undertaken during the development of EP/s, as part of the ALARP assessment process. The risk treatment and determination of ALARP for the planned impacts and unplanned risks is shown in Table 6-7 (KATO 2020a).

Table 6-7 Risk treatment for planned impacts and unplanned risks

Consequence Ranking	Minor	Moderate	Serious	Major	Severe	Catastrophic
Planned Aspects	Broadly acceptable	Broadly acceptable with additional control measures and management approval / if ALARP		Unacceptable		
Risk Ranking	**Low**	**Medium**	**High**	**Very High**	**Extreme**	
Unplanned Aspects	Broadly acceptable		Broadly acceptable with additional control measures and management approval / if ALARP		Unacceptable	

Consideration of additional control measures may include an engineering risk assessment, where a comparative assessment of risks, costs and environmental benefits is undertaken for identified control measures. Where high levels of risk are identified, KATO may choose to implement the precautionary approach, meaning that conservative assumptions replace uncertain analysis during cost benefit calculations, and environmental considerations take precedent.

Likelihood →			Extremely unlikely	Very unlikely	Unlikely	Likely	Very likely	Almost certain
		Guidance	Rare or unheard of	Reasonable to expect not to occur	Exceptional conditions may allow to occur	Conditions may allow to occur	Conditions may reasonably allow to occur	Expected to occur
Consequence ↓	Guidance	Level	A	B	C	D	E	F
Catastrophic	Permanent environmental landscape-scale impact over extensive area. Permanent loss of ecosystem or extinction of species.	6	High	High	Very High	Very High	Extreme	Extreme
Severe	Severe or extensive impact; widespread and persistent on ecosystem or threatened species.	5	Medium	High	High	Very High	Very High	Extreme
Major	Major impact; widespread and long-term on ecosystem or threatened species.	4	Medium	Medium	High	High	Very High	Very High
Serious	Serious impact; localised and long-term; or widespread and short-term on ecosystem or threatened species.	3	Low	Medium	Medium	High	High	Very High
Moderate	Moderate impact; localised and short-term on ecosystem or threatened species.	2	Low	Low	Medium	Medium	High	High
Minor	Limited/minor impact; localised and temporary on non-threatened species or their habitat.	1	Low	Low	Low	Medium	Medium	High

Figure 6-2 KATO Environmental Risk Matrix

6.5 Acceptability

The Environment Regulations (Regulation 5A) requires that the Corowa Development 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.*

KATO has defined a set of criteria to allow them to determine acceptability of an impact or risk, following risk treatment. Where an impact or risk is not considered acceptable, further control measures are required to lower the risk, or alternative development options will be considered. The KATO acceptability criteria considers:

- Principles of Ecological Sustainable Development (ESD)
- Internal Context
- External Context
- Other requirements.

These criteria are described in the following subsections.

6.5.1 Principles of ESD

Principles of ESD as defined in Section 3A of the EPBC Act include:

- decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations
- 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 principle of inter-generational equity – that the present generation should ensure the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations
- the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
- improved valuation, pricing and incentive mechanisms should be promoted.

These principles are reflected in the Environmental Performance Outcomes set for the project, which have been set to align with the definitions provided in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013).

6.5.2 Internal Context

KATO has an Integrated Management System, referred to as the KATO IMS. The KATO IMS includes Standards and Procedures relevant to the way they work.

Where relevant, Standards and Procedures in the KATO IMS that are relevant to either the activity, impact, control or receptor will be described within the internal context, and contribute towards the assessment of acceptability.

6.5.3 External Context

External context considers stakeholder expectations, understood on the basis of project-specific stakeholder engagement.

KATO has commenced preliminary stakeholder consultation, which is described in detail in Section 10. Where objections and claims have been raised, these are considered in the assessment of acceptability of related impacts and risks.

6.5.4 Other Requirements

Aside from internal and external context, other requirements must be considered in the assessment of acceptability. These include:

- Environmental legislation (described in Section 2.3)
- Policies and Guidelines (described in Section 2.4)
- International Agreements (described in Section 2.5)
- EPBC Management Plans (described in Section 2.2.1)
- Australian Marine Park designations (described in Section 2.2.1.2).

6.5.5 Environmental Performance Outcomes

The OPGGS(E)R define environmental performance outcomes (EPOs) to mean:

> *'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'.*

As such, the process of defining an appropriate EPO, has relied on the required levels of performance or guidance sourced from:

- legislation (such as the OPGGS Act)
- regulator guidance notes such as the Matters of National Environmental Significance– Significant Impact Guidelines (DoE 2013) or OPP Content Requirements (NOPSEMA 2019)
- Recovery Plans or Conservation Advice for specific protected species
- may be the result of specific agreements or expectations with other relevant stakeholders (e.g. fishers or other marine users.

Table 6-8 provides the definition of significant impact used when developing the EPOs for receptors identified as being relevant to this OPP.

Table 6-8 Source of Definition of Significant Impact and Environmental Performance Outcomes for Receptors

Matter of NES		Source of guidance			Receptor		Corowa Development EPO
		Significant Impact Criteria (DoE 2013)	NOPSEMA OPP Guidance for Acceptable levels*	Additional protection from Recovery Plan /Conservation Advice /Management Plan	Receptor	Specific Protected Species / Sensitivity / Value	
Listed Threatened Species and Ecological Communities	Critically Endangered and Endangered Species	An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will: • lead to a long-term decrease in the size of a population • reduce the area of occupancy of the species • fragment an existing population into two or more populations • adversely affect habitat critical to the survival of a species • disrupt the breeding cycle of a population • modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline • result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat • introduce disease that may cause the species to decline, or • interfere with the recovery of the species.	Listed threatened species: The survival and conservation status of listed threatened species and ecological communities will be promoted and enhanced, including through the conservation of critical habitat and other measures contained in any recovery plans.	Blue Whale/Pygmy Blue Whale: Recovery Plan (CoA 2015a): 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.	Marine mammals	Marine mammals: • Blue Whale/Pygmy Blue Whale – E • Southern Right Whale – E	**EPO1:** Noise emissions are managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging BIA. **EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. *Note: breeding cycle and recovery of the species have been grouped, as both relate to population and species recovery.* **EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO7:** To not result in an introduced marine species becoming established in the marine environment. *Note: a combination of wording for the CE/E and V and Commonwealth marine area MNES categories has been used to capture the introduction of IMS.*
				Recovery Plan for Marine Turtles (CoA 2017): • Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival (nesting and internesting). • Manage anthropogenic activities in Biologically Important Areas to ensure that biologically important behaviour can continue.	Marine reptiles	Marine reptiles: • Short-nosed Seasnake – CE • Loggerhead – E • Leatherback – E • Olive Ridley Turtles – E	
				N/A	Fish	Fish: • N/A	
				N/A	Seabirds and shorebirds	Seabirds and Shorebirds: • Curlew Sandpiper – CE • Bar-tailed Godwit (Northern Siberian) – CE • Eastern Curlew, Far Eastern Curlew – CE • Red Knot – E • Southern Giant Petrel – E	
	Vulnerable Species	An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will: • lead to a long-term decrease in the size of an important population • reduce the area of occupancy of an important population • fragment an existing important population into two or more populations • adversely affect habitat critical to the survival of a species • disrupt the breeding cycle of an important population		N/A	Marine mammals	Mammals: • Sei Whale – V • Fin Whale – V • Humpback Whale – V	**EPO1:** Noise emissions are managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging BIA. **EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO4**: To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of
				Recovery Plan for Marine Turtles (CoA 2017): • Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival • Manage anthropogenic activities in Biologically	Marine reptiles	Marine reptiles: • Green – V • Hawksbill – V • Flatback – V	

Matter of NES		Source of guidance			Receptor		Corowa Development EPO
		Significant Impact Criteria (DoE 2013)	NOPSEMA OPP Guidance for Acceptable levels*	Additional protection from Recovery Plan /Conservation Advice /Management Plan	Receptor	Specific Protected Species / Sensitivity / Value	
		• modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline • result in invasive species that are harmful to a critically endangered or endangered species becoming established in the vulnerable species' habitat • introduce disease that may cause the species to decline, or • interfere with the recovery of the species.		Important Areas to ensure that biologically important behaviour can continue.			habitat to the extent that the listed threatened species is likely to decline. **EPO7:** To not result in an introduced marine species becoming established in the marine environment.
				N/A	Fish	Fish: • Great White Shark – V • Dwarf Sawfish, Qld Sawfish – V • Green Sawfish, Dindagubba, Narrowsnout Sawfish – V • Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish – V • Whale Shark – V • Grey Nurse Shark – V	
				N/A	Seabirds and shorebirds	Seabirds and Shorebirds: • Bar-tailed Godwit (Western Alaskan) – V • Australian Fairy Tern – V	
Listed migratory species	Listed migratory species	An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will: • substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species • result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or • seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	The survival and conservation status of listed migratory species and their critical habitat will be promoted and enhanced.	N/A	Marine Fauna: • Seabirds and Shorebirds • Fish • Marine mammals • Marine reptiles	Migratory species not already listed above as threatened: • Seabirds and Shorebirds (Table 5-4) • Fish (Table 5-6) • Marine mammals (Table 5-8) • Marine reptiles (Table 5-11)	**EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.
Commonwealth marine environment	Commonwealth Marine Environment	An action is likely to have a significant impact on the environment in a Commonwealth marine area if there is a real chance or possibility that the action will: • result in a known or potential pest species becoming established in the Commonwealth marine area • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth marine area results • have a substantial adverse effect on a population of a marine species or cetacean including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution • result in a substantial change in air quality or water quality (including temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health	Marine environmental quality: The quality of water, sediment and biota are maintained so that environmental values are protected.	N/A	Physical: • Water quality • Sediment quality • Air quality • Ambient light • Ambient noise	N/A	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. *Note: 'Other marine users' have been grouped with the 'social amenity and human health' criteria.*
			Benthic communities and habitat: Benthic communities and habitats are protected so that biological diversity and ecological integrity are maintained.	N/A	Ecological: • Benthic habitat and communities • Coastal habitat and communities	N/A	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. *Note: In lieu of equivalent criteria or guidance for 'State marine areas', these areas have been treated as equivalent to 'Commonwealth marine area'.*
			Marine Fauna:	N/A	Ecological:	N/A	**EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species

Matter of NES	Source of guidance			Receptor		Corowa Development EPO
	Significant Impact Criteria (DoE 2013)	NOPSEMA OPP Guidance for Acceptable levels*	Additional protection from Recovery Plan /Conservation Advice /Management Plan	Receptor	Specific Protected Species / Sensitivity / Value	
	• result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected, or • have a substantial adverse impact on heritage values of the Commonwealth marine area, including damage or destruction of an historic shipwreck. A 'Commonwealth marine area' is defined in section 24 of the EPBC Act, and includes 'any part of the sea, including the waters, seabed, and airspace, within Australia's exclusive economic zone and/or over the continental shelf of Australia, that is not State or Northern Territory waters; stretches from 3 to 200 nautical miles from the coast.'	Marine fauna are protected so that biological diversity and ecological integrity are maintained.		Non-listed marine fauna: • Benthic habitat and communities • Coastal habitat and communities • Plankton • Non-listed birds • Non-listed fish • Non-listed marine mammals Non-listed marine reptiles		including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution. *Note: 'Non-listed' species is used to capture all species not listed threatened, or migratory (not covered by other MNES categories and 'Commonwealth marine area').* **EPO13**: To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.
		The ecosystem functioning and integrity of Commonwealth marine areas will be maintained and protected in conformity with relevant marine bioregional plans and plans of management for Australian Marine Parks.	N/A	Social, Economic and Cultural: • KEFs • Tourism and Recreation • Heritage and cultural features	KEFs: • Ancient coastline at 125 m depth contour • Canyons linking the Argo Abyssal Plain with the Scott Plateau • Canyons linking the Abyssal Plain and the Cape Range peninsula • Cth waters adjacent to Ningaloo Reef • Continental slope demersal fish communities • Exmouth Plateau • Glomar Shoals • Mermaid Reef and Cth water surrounding Rowley Shoals • Seringapatam Reef and Cth waters in the Scott Reef complex • Wallaby Saddle • Cth marine environment within and adjacent to west coast inshore lagoons • Mesoscale eddies • Perth Canyon and adjacent shelf break • Western demersal slop and associated fish communities • Western Rock Lobster Cth marine environment surrounding the Houtman Abrolhos islands	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area. *Note: KEFs are defined as part of the Commonwealth marine area. 'State' has bene included in lieu of any equivalent guidance, and to expand the EPO to include the whole EMBA.*
		N/A	North-west Marine Parks Network Management Plan 2018 (DNP 2018): • the protection and conservation of biodiversity and other natural, cultural and heritage values of marine	Social, Economic and Cultural: AMPs	• Kimberley AMP • Argo-Rowley Terrace AMP • Mermaid Reef AMP • Eighty Mile Beach AMP • Dampier AMP • Montebello AMP • Ningaloo AMP	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area. *Note: AMPs are defined as part of the Commonwealth marine area. 'State' has been included in lieu of any*

Matter of NES		Source of guidance			Receptor		Corowa Development EPO
		Significant Impact Criteria (DoE 2013)	NOPSEMA OPP Guidance for Acceptable levels*	Additional protection from Recovery Plan /Conservation Advice /Management Plan	Receptor	Specific Protected Species / Sensitivity / Value	
				parks in the North-west Network ecologically sustainable use and enjoyment of the natural resources within marine parks in the Northwest Network, where this is consistent with the first objective.		• Gascoyne AMP • Carnarvon Canyon AMP • Shark Bay AMP • Abrolhos AMP • Jurien AMP • Two Rocks AMP • Perth Canyon AMP	*equivalent guidance, and to expand the EPO to include the whole EMBA.* **EPO12:** To not result in a change that may have an adverse effect on the protection and conservation of biodiversity, ecological processes and other natural, cultural and heritage values of marine parks and protected areas. Note: AMPs and State Protected Areas have been grouped, as they are both recognised to have high conservation value. The EPO is a combination of wording from an example AMP management plan and a State Protected Area management plan.
			N/A	Management Plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area (CALM 2005) conservation objectives: • to maintain the marine biodiversity of the reserves • to maintain ecological processes and life support systems (i.e. key ecosystem structure and function)	Social, Economic and Cultural: • State Protected Areas – Marine • State Protected Areas – Terrestrial	• Eighty Mile Beach Marine Park • Rowley Shoals Marine Park • Montebello Islands Marine Park • Barrow Island Marine Park and Marine Management Area • Muiron Islands Marine Management Area • Ningaloo Marine Park • Shark Bay Marine Park • Hamlin Pool Marine Nature Reserve • Jurien Bay Marine Park • Marmion Marine Park • Terrestrial (refer Table 5-23)	Refer to individual receptors (e.g. marine turtles) for relevant EPOs to biological values. **EPO12:** To not result in a change that may have an adverse effect on the protection and conservation of biodiversity, ecological processes and other natural, cultural and heritage values of marine parks and protected areas. *Note: AMPs and State Protected Areas have been included in one EPO, as they are both recognised to have high conservation value. EPO is a combination of wording from an AMP management plan and a State Protected Area – Marine management plan.*
World Heritage properties	World Heritage properties	An action is likely to have a significant impact on the World Heritage values of a declared World Heritage property if there is a real chance or possibility that it will cause: • one or more of the World Heritage values to be lost • one or more of the World Heritage values to be degraded or damaged, or • one or more of the World Heritage values to be notably altered, modified, obscured or diminished.	The outstanding universal value of world heritage properties will be identified, protected, conserved and transmitted to future generations.	N/A	Social, Economic and Cultural: • Heritage and cultural features	• Ningaloo Coast WHA • Shark Bay WHA	**EPO13:** To not result in a change that may cause one or more of the World Heritage values or National Heritage values of a declared World Heritage property or National Heritage place to be lost, degraded or damaged, or notably altered, modified, obscured or diminished. *Note: World Heritage properties and National Heritage places have been grouped, as the significant impact criteria wording is the same.*
National heritage places	National Heritage places	An action is likely to have a significant impact on the National Heritage values of a National Heritage place if there is a real chance or possibility that it will cause: • one or more of the National Heritage values to be lost • one or more of the National Heritage values to be degraded or damaged, or • one or more of the National Heritage values to be notably altered, modified, obscured or diminished.	The outstanding value to the nation of national heritage places will be protected, conserved and transmitted to future generations of Australians.	N/A	Social, Economic and Cultural: • Heritage and cultural features	• Ningaloo Coast • Dampier Archipelago (including Burrup Peninsula) • Shark Bay • Dirk Hartog Landing Site 1616 - Cape Inscription Area • *Batavia* Shipwreck Site and Survivor Camps Area 1629 – Houtman Abrolhos • *HSK Kormoran* • *HMAS Sydney II*	**EPO13:** To not result in a change that may cause one or more of the World Heritage values or National Heritage values of a declared World Heritage property or National Heritage place to be lost, degraded or damaged, or notably altered, modified, obscured or diminished. *Note: World Heritage properties and National Heritage places have been grouped, as the significant impact criteria wording is the same.*

Matter of NES		Source of guidance			Receptor		Corowa Development EPO
		Significant Impact Criteria (DoE 2013)	NOPSEMA OPP Guidance for Acceptable levels*	Additional protection from Recovery Plan /Conservation Advice /Management Plan	Receptor	Specific Protected Species / Sensitivity / Value	
Non-MNES Values							
Non-MNES Values	Other marine users of the petroleum title	OPGGS Act Section 280(2): • To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted	Socioeconomic features of the environment: • The values of the Commonwealth marine area are protected for other users. • The rights of other users of the marine environment are not compromised. • Any disruption to the activities of other users of the marine environment is managed responsibly.	N/A	Social, Economic and Cultural: • Commercial Fisheries • Tourism and Recreation • Industries	N/A	**EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.
	Other marine users within EMBA	Significant Impact Criteria: An action is likely to have a significant impact on the environment in a Commonwealth marine area if there is a real chance or possibility that the action will: • result in a substantial change in air quality or water quality (including temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health		N/A	Social, Economic and Cultural: • Commercial Fisheries • Tourism and Recreation • Industries • AMPs • State Protected Areas – Marine • State Protected Areas – Terrestrial • Heritage and cultural features	• AMPs (refer Table 5-13) • State Protected Areas – Marine (refer Table 5-22) • State Protected Areas – Terrestrial (refer Table 5-23) • Heritage features (refer Table 5-25)	**EP10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. *Note: 'Other marine users' have been grouped with the 'social amenity and human health' criteria.*
	Heritage / Social	Significant Impact Criteria: An action is likely to have a significant impact on the environment in a Commonwealth marine area if there is a real chance or possibility that the action will: • have a substantial adverse impact on heritage values of the Commonwealth marine area, including damage or destruction of an historic shipwreck.		N/A	Social, Economic and Cultural: • Tourism and Recreation • Heritage and cultural features • AMPs • KEFs • State Protected Areas – Marine • State Protected Areas – Terrestrial	• AMPs (refer Table 5-13) • State Protected Areas – Marine (refer Table 5-22) • State Protected Areas – Terrestrial (refer Table 5-23) • Heritage features (refer Table 5-25)	**EPO17**: To not result in an impact to heritage values or social surroundings, including damage or destruction of a historic shipwreck.
	Climate	EPBC Policy Statement 'Indirect consequences' of an action: Section 527E of the EPBC Act (DSEWPaC 2013): Defines the impact of a primary action as: 'an event or circumstance which is: • a direct consequence of the action • an indirect consequence of the action, if the action is a substantial cause of the event or circumstance.'	N/A	N/A	Physical: • Climate	N/A	**EPO18**: To not significantly contribute to Australia's annual greenhouse gas emissions.

** OPP Content Requirements (NOPSEMA 2019)*

7 Environmental Impact and Risk Assessment

Section 7 is organised into aspects resulting from:

- planned activities – Section 7.1
- unplanned activities – Section 7.2.

Each Aspect subsection is structured as described in Table 7-1.

Table 7-1 Structure and Purpose of Section 7

Content	Purpose
Aspect source	Describes the Corowa Development phases and activities that may result in the aspect occurring. If modelling has been undertaken, this are summarised here.
Impact or risk analysis and evaluation	Describes the potential impacts arising from that aspect.
	Systematically identifies the potential receptors impacted. Receptors marked 'X' have been determined to be subject to impacts that are considered negligible. An explanation of the reasoning behind this assessment for each receptor marked 'X' is given in a table.
	Those receptors marked '✓' have been carried through into a detailed impact and risk assessment, structured by receptor category: • physical • ecological • social, economic and cultural.
Consequence and Acceptability	Summarises the overall consequence level for that aspect, and provides a demonstration of acceptability
	Provides a summary table of the impact and risk evaluation for that aspect, for each receptor, showing: • Environmental Performance Outcomes • Adopted control measures • Consequence, likelihood and risk level.

7.1 Planned

7.1.1 Physical Presence – Interaction with Other Users

The physical presence of vessels and facilities associated with Corowa Development has the potential to interact with other marine users through the disturbance of commercial and recreational activities.

7.1.1.1 Aspect Source

Throughout the Corowa Development, phases and activities that may interact with other marine users include:

Installation, Hook-up and Commissioning	MOPU; CALM buoy and mooring arrangements; flowlines; FSO
Support Activities (all phases)	MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations

Installation, Hook-up and Commissioning; Support Activities

The facilities, infrastructure and support operations associated with all phases of the Corowa Development may interact with other marine users through the displacement of their activities.

A variety of vessels will operate throughout the duration of the Corowa Development, which is expected to be approximately five years (shown in Table 3-13). This number will peak during drilling, commissioning and decommissioning at approximately ten support vessels. Throughout normal operations (~2–4.5 years), only one to two support vessels are expected. Vessels transiting to and from the Project Area are not included in the scope of this OPP and operate under the Commonwealth *Navigation Act 2012*.

Interactions between other marine users and the petroleum activities may occur at any time during this period.

Under the OPGGS Act, a petroleum safety zone (PSZ) may extend to a distance of 500 m around a well, structure or equipment, within which different vessels are prohibited.

Helicopters will be used during all phases of the Corowa Development to transport personnel to and from vessels and facilities offshore. One to two round trips per day between the mainland and the facilities are expected during drilling, five to eight round trips per week during operations. Increased air traffic has the potential to temporarily displace other avian users within the area.

Decommissioning

The base case for decommissioning is complete removal of all above-mudline infrastructure from the Project Area. However, some smaller inert seabed fixtures, such as grout bags, concrete mattress and clump weights, may need to be left in situ as they can be difficult to retrieve.

The OPGGS Act (Section 572(3)) states that a titleholder:

> *'must remove from the title area all structures that are, and all equipment and other property that is, neither used nor to be used in connection with the operations.'*

However, this obligation is subject to other provisions of the Act and allows titleholders to identify and seek approval for alternative arrangements, such as leaving some smaller objects in situ. In this case, approval under the Commonwealth *Environment Protection (Sea Dumping) Act 1981* would be sought prior to decommissioning.

7.1.1.2 *Impact Analysis and Evaluation*

An interaction with other marine users as a result of the physical presence of the Corowa Development has the potential to result in this impact:

- changes to the functions, interests or activities of other users.

Table 7-2 identifies the potential impacts to receptors as a result of the physical presence of the Corowa Development. Receptors marked '*X*' are subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-3 provides a summary and justification for those receptors not evaluated further.

Table 7-2 Identification of Receptors Potentially Impacted by Physical Presence – Interaction with Other Users

Impacts	Commercial Fisheries	Tourism and Recreation	Industry
Changes to the functions, interests or activities of other users	✓	*X*	✓

Table 7-3 Justification for Receptors Not Evaluated Further for Physical Presence – Interaction with Other Users

Tourism and Recreation	*X*
Changes to the functions, interests, or activities of other users Charter fishing, diving, snorkelling, whale, marine turtle and dolphin watching plus cruising are the main commercial tourism activities in and adjacent to the North-west Marine Region (DEWHA 2008). Apart from offshore charter fishing, these activities are generally centred around shallow coastal waters or around areas of fauna aggregation, generally within state waters. Due to the distance offshore (~50 km) and water depth (~90 m) at Corowa, tourism and recreation activities within the Project Area are expected to be highly infrequent. Therefore, impacts are not expected and have not been evaluated further.	

Analysis and evaluation of impacts to receptors are outlined below, by receptor type.

7.1.1.2.1 Social Receptors

These socioeconomic receptors have the potential to be impacted through an interaction with the petroleum activities being undertaken during the Corowa Development:

- commercial fisheries
- industry.

Impacts to the above receptors include:

- changes to the functions, interests or activities of other users.

Table 7-4 provides a detailed evaluation of the impact of interactions with other users as a result of the physical presence to receptors.

Table 7-4 Impact and Risk Assessment for Social Receptors from Physical Presence – Interaction with Other Users

Commercial Fisheries	✓
Changes to the functions, interests, or activities of other users The Corowa Development has the potential to displace fishers from the Project Area through the implementation of the PSZ, and presence of support vessels. The FishCube database (DPIRD 2019) was interrogated for the 60 nm grid block 21140 that intersect with the Project Area. While some Commonwealth and State commercial fisheries have management area boundaries that intersect with the Corowa Development, only one State-managed fishery (the Pilbara Line Fishery) has had any active fishing effort recorded recently within the area and therefore may potentially be considered active within the Project Area for the Corowa Development (Sections 5.5.2.1 and 5.5.2.2). The loss of fishing grounds due to the presence of the exclusion zone is limited to a small area (500 m radius), for the life of the project. A 2 km radius cautionary zone will be established around the MOPU, which will include all the Corowa Development infrastructure (FSO, flowline, CALM buoy). This cautionary zone is to ensure that fishing and third-party vessels are aware of the presence of KATO facilities, support vessels, and infrastructure such as mooring chains; but does not necessarily exclude them from the area. It would also be a temporary loss of fishing grounds, given the short duration of the project life (~5 years). 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. The base case for decommissioning is complete removal of all above-mudline infrastructure from the Project Area. However, some smaller inert seabed fixtures, such as grout bags, concrete mattress and clump weights, may need to be left in situ as they can be difficult to retrieve. If these objects are left in situ, they would present a low risk profile to commercial fishers, as they are of inert material (i.e. concrete), are relatively low profile (<0.5 high), and are likely to gradually be covered by benthic sediment. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data	

shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). This fishery does not use trawl nets, and the potential for remaining objects to snag nets or impact fishing in any way is very low. The one active fishery in the Project Area (Pilbara Line Fishery) is a line fishery, not trawl, and it is bottom (or demersal) trawls that drag along the sea floor that are of highest risk to snag on objects. Given the details above, the consequence of interactions with other users causing a change in the functions, interests or activities of other users of Commonwealth- and State-managed fisheries has been assessed as **Minor (1)**.	
Industry	✓
Changes to the functions, interests, or activities of other users The presence of the Corowa Development may impact shipping activity due to exclusion of vessels from areas designated as a PSZ. Also, the presence of vessels such as support tugs, pipelaying vessels and shuttle tankers and can create navigational hazards that can disturb other marine activities. ISVs and support vessels installing flowlines and the CALM buoy and mooring arrangements have restricted manoeuvrability and may create an additional navigational risk. Local vessels may have to alter course as a result, increasing journey time and fuel consumption. Very little shipping activity occurs in the Project Area, as identified through Australian Maritime Safety Authority (AMSA) vessel tracking data (AMSA 2019). The closest port to the MOPU location is the Port of Ashburton (~50 km away) which was purpose built for the construction phase of the Wheatstone Project and now serves as a general cargo and LNG loading facility. Exmouth Port is situated ~70 km away, which has limited vessel movements of <10 arrivals per day. Approximately half these movements are commercial fishing vessels with the remainder being pleasure craft, tugs and other oil and gas support vessels (Exmouth Port 2019). Petroleum facilities within the vicinity of the Corowa Development include the BHP-operated Pyrenees FPSO (~46 km), the Santos-operated Ningaloo Vision FPSO (~49 km) and the Woodside-operated Ngujima-Yin FPSO (~51 km). Avian users may also be temporarily displaced by helicopter movements from the mainland to the facilities, most likely helicopter movements to other manned offshore petroleum facilities. Whether the flight paths and times would be impacted depends on which airport is used and flight timings. For the operations phase (2–4.5 years), the expected flight frequency is only 5–8 round trips per week. The Corowa Development is within the Department of Defence's North West Exercise Area (NWXA); however, stakeholder engagement confirmed that the DoD have no objections to the proposed activities, but require notification prior to commencement to ensure KATO activities do not conflict with Defence training (Section 10). The PSZ is limited to 500 m, so any required deviations would be minor and thus have negligible impact on travel times or fuel use of these vessels. A 2 km radius cautionary zone will be established around the MOPU, which will include all the Corowa Development physical infrastructure. This cautionary zone is to ensure that industry and other third-party vessels are aware of the presence of KATO facilities, support vessels, and infrastructure such as mooring chains; but does not necessarily exclude them from the area. Due to the relatively short duration of the project life (~5 years), this is also a temporary restriction. Given the details above, the consequence of interactions with other users causing a change in the functions, interests or activities of other users has been assessed as **Minor (1).**	

7.1.1.3 Consequence and Acceptability

The consequence of Physical Presence – Interaction with Other users has been evaluated as **Minor (1)** for all potentially impacted receptors and considered **acceptable** based on an evaluation against the criteria in Table 7-5.

Table 7-5 Demonstration of Acceptability for Physical Presence – Interaction with Other Users

Acceptability Criteria	Justification
To meet the principles of ESD	• The development will not significantly impact on commercial fishing as situated outside areas that have historically been fished. • Tourism and vessel traffic are not expected or low within the Project Area. • The exclusion zone is a 500 m radius, within which third-party vessels may be prohibited. A 2 km cautionary zone will be established around the MOPU, containing Corowa Development physical infrastructure. • This cautionary zone is to ensure that fishing and third-party vessels are aware of the presence of KATO facilities, support vessels, and infrastructure such as mooring chains so that potential hazards are recognised; but does not necessarily exclude them from the area. This is a small area third parties are excluded from (500 m radius), for a relatively short project life (~5 years).
Internal context	• There are no specific KATO internal requirements with respect to interactions with other users or potentially impacted receptors.

External context	• Stakeholder engagement to date confirmed that various agencies require notification prior to commencement of activities (Section 10); specifically:
	  ○ AHO; to update Navigational Charts and provide Notice to Mariners
	  ○ AMSA Joint Rescue Coordination Centre (JRCC) Australia; to request an AUSCOAST Warning (radio/navigation warnings)
	  ○ DoD confirmed the Corowa Development is within the North West Exercise Area (NWXA); however, stakeholder engagement confirmed that the DoD have no objections to the proposed activities, but require notification prior to commencement to ensure KATO activities do not conflict with Defence training.
	  ○ WAFIC recommended consulting with fisheries when project information is known, during development of the EP/s; i.e. project timing, location and exact exclusion/cautionary zones. WAFIC communicated preference to minimise exclusion areas where possible, and use of cautionary zones.

Other requirements	• Vessel operations undertaken as a part of this activity will adhere to the Commonwealth *Navigation Act 2012*, MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act. This Act regulates navigation and shipping including Safety of Life at Sea (SOLAS), including specific requirements for navigational lighting. Although the Act does not apply to the operation of petroleum facilities, it may apply to some support vessels. • Under the Chapter 6, Part 6.6 of the OPGGS Act, a petroleum safety zone (PSZ) <500 m will be set following assessment by NOPSEMA, within which certain vessels are prohibited. • With respect to physical presence – disturbance to other users, activities associated with the Corowa Development will not be conducted in a manner inconsistent with protecting the values of the Commonwealth marine area for other users.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-6.

Table 7-6 Summary of Impact Assessment for Physical Presence – Interaction with Other Users

Receptor	Impact	EPOs	Adopted Control Measures	Consequence
Commercial Fisheries	Changes to functions, activities and interests	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.	**CM01**: Vessels to adhere to the navigation safety requirements including the Commonwealth *Navigation Act 2012* and any subsequent Marine Orders. **CM02**: Notify Australian Hydrographic Office (AHO) of activities and movements prior to activity commencing. **CM03:** Pre-start notifications will be provided to relevant stakeholders at appropriate timing, including presence of exclusion and cautionary zones.	Minor
Industry				Minor

7.1.2 Physical Presence – Seabed Disturbance

Seabed disturbance associated with the Corowa Development has the potential to impact benthic habitats and demersal fish through smothering, alteration of benthic habitats plus localised and temporary increase in turbidity near the seabed.

7.1.2.1 Aspect Source

Throughout the Corowa Development, phases and activities that may interact with other receptors include:

Survey	geotechnical survey
Drilling	MODU positioning; top-hole drilling
Installation, Hook-up and commissioning (IHC)	MOPU; CALM buoy and mooring arrangements; flowlines
Operations	maintenance and repair; well intervention
Decommissioning	well P&A; removal of subsea infrastructure; disconnection of FSO and MOPU
Support Activities (all phases)	vessel operations

Survey

A geotechnical survey of the well location and mooring spread may be required before the MODU or MOPU are mobilised to the Project Area to confirm the stability of seabed sediments.

A seabed site investigation frame is typically 3 m x 3 m (i.e. <10 m^2). Conservatively assuming that multiple sample and locations may be required if the target location is deemed unsuitable, the total seabed disturbance footprint is expected to be <100 m^2.

The seabed in the area comprises fine sediments and strong currents predicting impacts to be temporary and quick recovery. The purpose of the geotechnical survey is to identify locations for the infrastructure, so it is assumed that these small areas of seabed disturbance will be included in the footprint of the actual infrastructure, with the exception of any unsuitable locations surveyed. The area of disturbance and impact caused by core samples from any unsuitable sample sites will be insignificant (<10 m^2 each) and therefore are not discussed further in this section.

Transponders may be used to accurately position the MOPU or MODU. Transponders are attached to temporary clump weights and then lowered onto the seabed, which are recovered once the MOPU or MODU is installed.

Drilling

Drilling activities will be undertaken by either a dedicated MODU or MOPU with drilling capability. Each will have a jack-up rig with three support legs, which will be lowered to the seabed to raise and stabilise the platform for drilling operations. Each of the three independent support legs will have a rig foot attached at the base. For the purposes of impact assessment, the base case (of separate MOPU and MODU) will be used, which has the largest total footprint (Table 7-7). Each facility will have three rig feet, totalling 1,500 m^2 for each facility. If two drilling campaigns are undertaken, the rig feet may not be positioned in exactly the same location on the seabed as for the first campaigns; therefore, double the seabed footprint is assumed for the MODU (3,000 m^2).

The presence of the support legs may alter current speeds and direction, which in turn may cause scouring in the localised area.

A single vertical wellbore that may contain up to four drill strings is proposed at the Corowa Development area, which will cause a minor disturbance on the seabed. Conductor casings are commonly 30" (762 mm) to 42" (1067 mm) in diameter for offshore wells, which will result in maximum hole size of ~48" (1220 mm) – giving an estimated seabed disturbance of 100 m^2.

Drilling activities will also result in the discharge of cement and drilling cuttings to the seabed, with the environmental impacts and risks associated with this activity provided in Sections 7.1.7 and 7.1.6 respectively.

Installation, Hook-up and Commissioning

Seabed disturbance associated with installation of the MOPU is described above.

The Corowa Development will use a CALM buoy, which will act as a single point mooring for the FSO or shuttle tankers. The CALM buoy will also deliver hydrocarbons to the FSO or shuttle tankers via the subsea flowline from the MODU. The CALM buoy will be positioned via a six-chain catenary anchoring system, and will likely have 3 x 2 mooring legs equally spaced 120 degrees.

If the gravity anchor option is chosen, each gravity anchor will likely be a structure (concrete or steel with a skirt for lateral stability) lowered to the seabed and filled with chain or weights as ballast. During installation, the gravity anchors and two mooring chains attached to each anchor will be lowered and positioned on the seabed. Once the CALM buoy has been floated into place, the mooring chains will be retrieved from the seabed and connected to the buoy.

If drilled and grouted anchor piles is selected, a <1.5 m hole ~25 m deep is drilled, and casing inserted, which is then pumped with grout and mooring lines connected (giving a footprint of ~60 m^2 per hole).

The mooring chains are <600 m long, and a corridor of 5 m has been assumed to calculate the total footprint from the CALM buoy anchor array, giving a total of 9,720 m^2 (with details listed in Table 7-7).

Small movements of the anchor chain may occur due to tidal and wave activity, which may temporarily displace upper seabed sediments, and which may, in turn, cause a localised increase in turbidity. As per the support legs of the MODU or MOPU, the anchors and chains may cause localised scouring.

A ~1.5 km 6" diameter flowline will transport hydrocarbons from the MOPU to the CALM buoy. The flowline will be laid directly on the seabed with a total disturbance area of 7,530 m^3. Stabilisation may be required for the flowline, which would involve grout bags or concrete mattresses. The footprint on the seabed of grout bags or mattresses is typically confined to a small area directly below the flowline. The footprint of a mattress depends on the size of the mattress being used but typically covers an area of 100 m^2 each. A similar flowline installation of 1.7 km (Quadrant 2017) on soft sediments required approximately three 3 m x 6 m mattresses for the complete flowline.

Table 7-7 details elements of seabed disturbance by the flowline.

Operations

Activities similar to those described in installation, hook-up and commissioning may be required for maintenance and repair, and activities similar to drilling for well intervention.

Decommissioning

In alignment with Section 572 of the OPGGS Act, the wells will be plugged and abandoned (P&A) post-production during the decommissioning phase.

The base case for decommissioning is complete removal of all above-mudline infrastructure from the Project Area. However, there potentially a need to leave some smaller inert seabed fixtures in situ, such as grout bags, concrete mattress and clump weights. Removal of subsea infrastructure will be evaluated at the end of project life.

The OPGGS Act (Section 572(3)) states that a titleholder:

> *'must remove from the title area all structures that are, and all equipment and other property that is, neither used nor to be used in connection with the operations.'*

However, this obligation is subject to other provisions of the Act and allows titleholders to identify and seek approval for alternative arrangements, such as leaving some infrastructure in situ (e.g. grout bags). In this case, approval under the Commonwealth *Environment Protection (Sea Dumping) Act 1981* would be sought prior to decommissioning.

The area of seabed disturbance will be similar to the area of planned seabed disturbance, for installed infrastructure, anchors and flowlines.

Support Operations

It may be required that support vessels anchor within the Corowa Development area. This will be achieved by mooring to one of three preinstalled Dead Man Anchors (DMA), which are suitable for resisting large horizontal loads, likely concrete clump weights with a footprint of 25 m^2 (Table 7-7). The location of the DMAs will be determined in FEED but will be within the 5 km buffer of the Project Area.

The total area of direct seabed disturbance from all components of subsea infrastructure and planned seabed disturbance (such as anchoring) is shown in Table 7-7, allowing for an overestimation of 50%.

Table 7-7 Total Area of Seabed Disturbance from Subsea Infrastructure

Subsea Infrastructure	Total Area Seabed Disturbance
Wells	100 m^2
MOPU	1,500 m^2
MODU (if separate MODU required)	3,000 m^2, assuming two drilling campaigns
Flowline (subsea)	Total of 7,530 m^2 assuming: • 1.5 km long flowline • 5 m wide disturbance corridor • mattresses/grout bags will be within the 5 m corridor • 30 m^2 FLET
CALM buoy and mooring arrangement	Total 9,720 m^2 assuming: • each leg (comprising two chains) of 600 m x 5 m disturbance area (3,000 m^2) • three legs total 9,000 m^2 • three gravity anchors of 240 m^2 each, totals 720 m^2 (as mooring option with largest seabed footprint).
Dead Man's Anchors (DMA) for support vessels	Total 75 m^2 assuming: • 25 m^2 for each DMA • three DMAs
Total Area	**21,925 m^2 (0.021935 km^2)** Including 50% contingency – **0.0329 km^2**

7.1.2.2 Impact Analysis and Evaluation

Seabed disturbances generated by the Corowa Development have the potential to result in these impacts:

- change in water quality
- change in habitat.

As a result of a change in water quality and habitat, further impacts may occur, including:

- injury / mortality to fauna.

Table 7-8 identifies the potential impacts to receptors as a result of seabed disturbance from the physical presence of the Corowa Development. Receptors marked '*X*' are subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-9 provides a summary and justification for those receptors not evaluated further.

Table 7-8 Receptors Potentially Impacted by Physical Presence – Seabed Disturbance

Impacts	Ambient water quality	Plankton	Benthic habitat and communities	Fish	Commercial fisheries
Change in water quality	✓				
Change in habitat			✓		
Injury / mortality to fauna		*X*	✓	✓	

Impacts	Ambient water quality	Plankton	Benthic habitat and communities	Fish	Commercial fisheries
Changes to the functions, interests or activities of other users					*X*

Table 7-9 Justification for Receptors Not Evaluated Further for Physical Presence – Seabed Disturbance

Plankton	***X***
Injury / mortality to fauna 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 (DEWHA 2008). Phytoplankton production at the depths present at the Corowa Development are likely to be low as it is near photic zone (100 m) with sparse nutrient levels (DEWHA 2007). A change in water quality as a result of seabed disturbance is unlikely to lead to injury or mortality of plankton at a measurable level and will not result in a change in the viability of the population or ecosystem. Therefore, no impacts to plankton from seabed disturbance are expected and have not been evaluated further.	
Commercial Fisheries	***X***
Changes to the functions, interests or activities of other users The installation and decommissioning of subsea structures and facilities, and anchoring operations will be conducted at a very slow pace so any fish species present will general exhibit avoidance behaviour. The loss of substrate due to the footprint of the installed subsea structures is considered insignificant considering the vast area of similar substrate present within the NWS. A reduction in water quality due to the presence of subsea installations, as previously detailed, has been shown to be brief and highly localised. Therefore, any impacts on fish species or their food sources is considered to be Minor (as evaluated in Section 7.1.2.2.2). The total area of direct seabed disturbance from the Corowa Development is conservatively estimated as 0.0329 km^2, well within the 5 km radius of the Project Area (78.5 km^2). This is an insignificant area compared to the size and scale of commercial fisheries. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). While fish may potentially be impacted by seabed disturbance, this area of influence is highly localised and of an insignificant area, and is not expected to result in a change in the viability of the population of commercially important species. Therefore, impacts to commercial fisheries from physical presence – seabed disturbance are not expected, and have not been evaluated further.	

Impacts to receptors are assessed below, by receptor type.

7.1.2.2.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of seabed disturbance include:

- ambient water quality.

Table 7-10 provides a detailed evaluation of the impact of seabed disturbance from the physical presence of the activities to physical receptors.

Table 7-10 Impact and Risk Assessment for Physical Receptors from Physical Presence – Seabed Disturbance

Ambient Water Quality ✓
<u>Change in water quality</u> Water quality change occurs when seabed sediments enter the water column (turbidity). After a period, the suspended sediments settle and the turbidity in the water column returns to pre-disturbance levels. During the period where sediments are suspended in the water column, the ambient water quality will be impacted. Impacts to ambient water quality will be localised, within the region of the MODU/MOPU (or combined MODPU), the CALM buoy anchors and chains plus the 1.5 km flowline. Temporary increases in suspended sediments and turbidity levels are expected to occur during the positioning of the MODU/MOPU or combined MODPU plus associated subsea infrastructure. Note that the flowline will not be buried or trenched but positioned directly onto the seabed, but may require stabilisation. Stabilisation may comprise sandbags or concrete mattresses, which may temporarily increase suspended sediments and turbidity levels during installation, but these effects will be localised and temporary. Small movements in the CALM buoy anchor chain due to environmental conditions (e.g. currents and significant waves) may occur and cause localised sediment resuspension. During any decommissioning activities of subsea infrastructure, the level of suspended sediments and increased turbidity levels are expected to be the same as during installation. During vessel anchoring increases in suspended sediments and turbidity levels will also be temporary. Anchoring within the development area will not cause a long-term change in water quality. Although no trenching activities are planned during the Corowa Development, a previous study, using this method, details sediment settlement rates. During pipeline trenching operations for Chevron's Wheatstone project average turbidity levels of 15 Formazin Turbidity Units (FTU)) were recorded up to 70 m from the source with a maximum recorded level of 80 FTU. The average turbidity levels were three times the background levels of 5 FTU. However, the survey reported that within two hours of operations ceasing, turbidity levels returned very close to normal background levels (Chevron Australia 2014 cited in ConocoPhillips 2018). Water column turbidity in the NWS is subject to natural variability. Tropical cyclones in the NWS are known to substantially modify offshore hydrodynamic conditions and are a major driver of sediment dynamics, impacting benthic and pelagic habitats and changing water column turbidity (Dufois et al. 2017). Flash flooding and intermittent coastal discharge and will also impact turbidity levels (Tian et al. 2009). Wave-driven sediment resuspension generates high turbidity levels within coastal zones, commonly exceeding 50 mg/L (Larcombe et al. 1995, Whinney 2007, Browne et al. 2013), but coastal communities appear generally well adapted to deal with these extrinsic stresses. Given the details above, the consequence of seabed disturbance causing a change in water quality has been assessed as **Minor (1)**, as increases in suspended sediments and turbidity will be localised to subsea infrastructure, are only likely to occur during installation, and turbidity will return to background levels within minutes to hours.

7.1.2.2.2 Ecological Receptors

Ecological receptors with the potential to be impacted as a result of seabed disturbance:

- benthic habitat and communities
- fish.

The above receptors may be impacted from:

- change in habitat
- injury / mortality to fauna.

Table 7-11 provides a detailed evaluation of the impact of seabed disturbance to ecological receptors.

Table 7-11 Impact and Risk Assessment for Ecological Receptors from Physical Presence – Seabed Disturbance

Benthic Habitat and Communities ✓
<u>Change in habitat</u> Activities associated with the Corowa Development will result in a change in habitat due to the localised and small-scale seabed disturbance. The continental shelf areas that exist within the Project Area are dominated mostly by sands with a small proportion of gravels (DWHA 2008). The sandy substrates on the shelf within the Project Area are thought to support low-density benthic communities of bryozoans, molluscs and echinoids. Sponge communities are also sparsely distributed on the shelf, being found only in areas of hard substrate (DEWHA 2008) (See Section 5.4 for existing environment). A pre-drilling study (Thales 2001) confirms the seabed in the Corowa Development area is consistent and composed of partially exposed cemented carbonates overlaid by a fine to coarse grained sedimentary veneer. Therefore, permanent damage to rocky structures is highly unlikely. The presence of subsea infrastructure will cause changes in water movement, which will in turn result in localised scouring and minor disturbance of the seabed. Due to the fine to coarse grained nature of sediments within the development area, it is expected that sections of the CALM buoy anchor chains and flowline may become buried over time because of natural sediment movement. The total area of direct seabed disturbance from subsea infrastructure and installation is 0.0329 km^2. In comparison, Woodside's proposed Scarborough Development has an expected footprint of 12.9 km^2 in Commonwealth waters (Woodside 2019). Due to the short project life of the Corowa Development (~5 years) the disturbance is also temporary. Relative to the surrounding environment, this is a small area and seabed disturbance will not cause impact to any Matters of National Environmental Significance (MNES) or Key Ecological Features (KEF). <u>Injury / mortality to fauna</u> Rig feet, flowlines plus the CALM buoy and mooring arrangements will be present throughout the project life of the Corowa Development, and may result in injury or mortality to epifauna and infauna through loss of habitat, smothering or decreased water quality. Subsea surveys and fauna reviews within the NWS area (RPS 2012; Woodside 2005) have shown sparse populations of filter and deposit-feeding epibenthic fauna plus a diverse but broadly representative infaunal community, dominated by polychaete worms and crustaceans. Possible macroinvertebrates within the Project Area include species of arthropod (prawn, lobsters) and molluscs (squid, octopus). Mobile benthic taxa, such as echinoderms or sessile taxa such as sponges may be present, but in sparse numbers. A lack of seabed features within the Corowa Development also suggests sparse benthic assemblages (See Section 5.4). An EPBC PMST did not identify any epifaunal of infaunal threatened or migratory species, or any threatened ecological communities within the Project Area. When considering the disturbance footprint of the Corowa Development infrastructure against the widespread nature of soft sediment infauna communities, the potential loss of habitat that may lead to injury or mortality is considered **Minor**. Any disturbance to benthic habitats and communities by the installation or removal of subsea structures is expected to be localised and likely to recover over a short period. Kukert (1991) showed that ~50% of the macrofauna on the bathyal sea floor were able to burrow back to the surface through 4–10 cm of rapidly deposited sediment. Dernie et al. (2003) conducted a study that showed the full recovery of soft sediment assemblages from physical disturbance could take between 64 and 208 days. Mobile invertebrates are generally less vulnerable than sessile taxa to sedimentation, as they are able to move to areas with less sediment accumulation or by more efficiently physically removing particles (Fraser 2017). Sessile invertebrates are particularly vulnerable to sedimentation because they are generally unable to reorientate themselves to mitigate a build-up of particulates. However, some sessile taxa, including species of sponges and bivalves, have the capacity to filter out or to physically remove particulates (Roberts et al. 2006, Pineda 214 et al. 2016). Filter feeders that live in coastal waters, bivalves in particular, are highly adaptable in their response to increased turbidity and can maintain their feeding activity over a wide range of particulate loads. Studies by Newell et al. (2016) on disturbances by dredging found that community structures of

benthic infauna were unaffected outside the immediate area of dredging. Whilst intense activities such as dredging will not take place at the Corowa Development it suggests that the low-level impacts within the Project Area will be localised and will not affect communities much beyond the installed infrastructure. The total area of direct seabed disturbance from subsea infrastructure and installation is 0.0329 km^2, making it localised. The disturbance is also temporary, due to the short project life of the Corowa Development (~5 years). There are no Management Plans, Recovery Plans or Conservation Advice related to benthic habitats and communities within the Project Area. No important or substantial area of benthic habitats and communities is expected to be modified, destroyed, fragmented, isolated or disturbed. Given the details above, the consequence of seabed disturbance causing a change in habitat in the benthic habitat and communities or injury / mortality to fauna has been assessed as **Minor (1)** as habitats are expected to recover rapidly once any temporary and localised activity has taken place.
Fish ✓
<u>Injury / mortality to fauna.</u> Installed subsea infrastructure will be present throughout the operational life of the Corowa Development and may result in injury or mortality to fish through smothering, loss of habitat, decreased water quality and/or reduction in food source. The installation and decommissioning of subsea structures plus anchoring operations will be conducted at a very slow pace so any fish species present will general exhibit avoidance behaviour. The loss of substrate due to the footprint of the installed subsea structures is considered insignificant considering the vast area of similar substrate present within the NWS. A reduction in water quality due to the presence of subsea installations, as previously detailed, has been shown to be brief and highly localised. Therefore, any impacts on fish species or their food sources is considered to be highly unlikely. The potential impact area for seabed disturbance is restricted to within the Corowa Project Area, which is situated within a foraging BIA for the Whale Shark. The Project Area including 5 km buffer is 78.5 km^2, and the direct area of seabed disturbance is 0.0329 km^2, which is insignificant when compared to the size of the BIA (218,911 km^2). Within the NWS, Whale Sharks are primarily found in seasonal aggregations around Ningaloo Reef, between March and June. However, they have also been reported from oceanic and coastal waters across the region (Wilson et al. 2006). Around Ningaloo, Whale Sharks spend daylight hours near the surface and nights at depths of 30–80 m. In oceanic waters, they routinely move between the sea surface and depth, and spend over half their time at depths greater than 30 m and off the outer NWS, they spend much of their time swimming near the seafloor and make dives to over 1000 m depth (DSEWPaC 2012). Whilst the Project Area is within a foraging BIA, interactions with Whale Sharks are very unlikely due to its distance from the preferred foraging areas around Ningaloo reef and deeper oceanic waters. Whilst the recovery plan for the Whale Shark (DEH 2005a) ceased to be in effect from 1 October 2015, it stated that the main threat to the Whale Shark occurs outside Australian waters. Whilst habitat damage was listed as a future threat this refers to loss of reef and habitat through fisheries. It is not expected that Whale Sharks could be directly impacted by this small area of seabed disturbance All EPBC PMST listed species are highly mobile, therefore, none are expected to be affected by minor seabed disturbance. Given the details above, the consequence of seabed disturbance causing injury / mortality to fish species has been assessed as **Minor (1)** as effects will be localised and extremely brief.

7.1.2.3 Consequence and Acceptability

The consequence of Physical Presence – Seabed Disturbance has been evaluated as **Minor (1)** for all potentially impacted receptors and is considered **acceptable** when assessed against the criteria in Table 7-12.

Table 7-12 Demonstration of Acceptability for Physical Presence – Seabed Disturbance

Acceptability Criteria	Justification
To meet the principles of ESD	• The impacts of seabed disturbance from the Corowa Development will be comparable with existing facilities on the NWS and will not result in a notable change to the localised habitat and/or level of water quality. • Benthic habitat and communities within the Project Area are expected to be sparse, with no impacts on any Matters of National Environmental Significance (MNES) or Key Ecological Features (KEF). • The total area of direct seabed disturbance from subsea infrastructure and installation is 0.0329 km^2, making it localised. • Seabed disturbance is temporary, due to the short project life of the Corowa Development (~5 years). • Recolonisation will be rapid following any disturbance. • A reduction in water quality will be highly localised and very brief. • Impacts on Whale Shark BIA foraging areas are not predicted and are insignificant.
Internal context	• There are no specific KATO internal requirements with respect to seabed disturbance or potentially impacted receptors.
External context	• No stakeholder concerns have been raised with respect to seabed disturbance or potentially impacted receptors.

Other requirements	• A Sea Dumping Permit under the Commonwealth *Environment Protection (Sea Dumping) Act 1981* would be sought if required, if any objects may be left in situ.
	• There are no specific management actions relevant to seabed disturbance (habitat damage) identified in the Whale Shark (*Rhincodon typus*) Recovery Plan 2005–2010.
	• These Recovery Plans / Conservation Advices identify habitat degradation / modification (seabed disturbance) as a key threat:
	  ○ Approved conservation advice for *Pristis clavata* (Dwarf Sawfish) (TSSC 2009b)
	  ○ Sawfish and river shark multispecies recovery plan (Commonwealth of Australia 2015b)
	  ○ Approved conservation advice for Green Sawfish (TSSC 2008a)
	  ○ Approved Conservation Advice for *Pristis pristis* (Largetooth Sawfish) (DoE 2014a)
	  ○ Conservation advice *Rhincodon typus* (Whale Shark) (TSSC 2015d)
	  ○ Whale Shark (*Rhincodon typus*) recovery plan 2005–2010 (DEH 2005a).
	• The above Recovery Plans / Conservation Advices identify these relevant conservation actions:
	  ○ Implement measures to reduce adverse impacts of habitat degradation and/or modification; or
	  ○ No explicit relevant management actions.
	• With respect to physical presence – disturbance to other users, activities associated with the Corowa Development will not be conducted in a manner inconsistent with a Recovery Plan, threat abatement plan or Conservation Advice for listed threatened species, or with protecting biological diversity and ecological integrity of benthic communities and habitats

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-13.

Table 7-13 Summary of Impact Assessment for Physical Presence – Seabed Disturbance

Receptor	Impacts	EPOs	Adopted control measures	Consequence
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.		Minor
Benthic habitats and communities	Change in habitat Injury / mortality to fauna	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO6:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species.	**CM04**: Mooring analysis will be undertaken, which will include an environmental sensitivity and seabed topography analysis. **CM05**: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below the mudline and removed.	Minor
Fish	Injury / mortality to fauna	**EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor

7.1.3 Emissions – Light

The operations of vessels and facilities associated with the Corowa Development will generate artificial light emissions.

Light is typically described in these terms:

- lumens – a measure of the amount of light from a source emitted in total regardless of direction
- candela – the amount of light emitted in a particular direction
- lux – a measurement of light intensity (or illuminance) received at a location, i.e. takes into account light within an area, 1 Lux is equivalent to 1 Lumen/m^2 (Appendix B).

Light is a form of energy that is emitted over a particular band of frequencies and wavelengths of the electromagnetic spectrum. The visible range (for humans) is typically 400–700 nm, with ultraviolet below this wavelength range, and infra-red above it. Fauna perceive light differently to humans, and their visible spectrum can vary between ~300 nm and >700 nm depending on the species (CoA 2019); i.e. it can extend into the ultraviolet and infra-red spectra.

Therefore, 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.

7.1.3.1 Aspect Source

Throughout the Corowa Development the use of lighting and flaring will be required for operational and safety purposes during these activities:

Drilling	well clean-up and flowback
Operations	hydrocarbon processing, storage and offloading (flaring)
Support Activities (all phases)	MODU operations, MOPU operations, FSO operations, support vessel operations

Drilling

Wellbore and casing clean-up and flowback is required at various stages of the drilling activity to test the reservoir and to ensure the contents of the well are free of contaminants before the next stage of drilling. Prior to production, the well will be cleaned up to remove any remaining drilling or completion fluids, debris and solids coming out of the formation and perforations.

During the clean-up process, fluids are circulated back to the MODU or MOPU, and flaring of hydrocarbon gas may be required. The flaring of flammable gas will result in the production of light emissions. Flaring during drilling could be undertaken from either the MODU or the MOPU.

Operations

During the production phase of the Corowa Development, continuous flaring of excess gas will be required to allow for hydrocarbon production and processing (as per the comparative assessment undertaken in Section 4.3.1 for excess gas after use as fuel gas). The flaring of flammable gas will result in the production of light emissions.

The MOPU flare tower will likely be a 45^{o} to 60^{o} to the horizontal cantilevered structure, external to the MOPU hull perimeter, extending 30–40 m from the hull. An analogous facility has a flare tower tip height of 80 m, which is the height used for the purposes of exposure assessment (Section 7.1.3.2.2).

Operations are expected to occur over a relatively short period of 2–4.5 years, with an estimated peak flaring rate of 15–17 MMscfd during the initial 7–12 months (P50–P10 estimates) of operations, and then declining rapidly as the reservoir is depleted (Figure 7-1; Section 4.3.1).

An analogue of a similar continuous operational flare is the Tamarind-operated Galoc FPSO in the Philippines. Figure 7-2 shows the Galoc FPSO disposing of natural gas from an oil field at ~15 MMscfd with a flame height of ~18–20 m. The flare from the Corowa Development will be of a comparable nature and scale during the initial 7–12 months (P50–P10 estimates) of operational flaring (peak flaring). Using the facility flaring analogue and the Gas Processors Suppliers Association Engineering Data Book (1998), it has been calculated that the expected maximum rate of flaring during operations for the Corowa Development will result in a flare flame height of ~20–25 m above the MOPU flare tower tip in calm conditions. Therefore, the height of the top of the flame during the maximum rate of flaring is ~100–105 m above sea level.

After the initial 7–12 months of operational flaring, and through to the end of field life, the rate of flaring is expected to reduce rapidly (Figure 7-1; Section 4.3.1). By month 10–17 (P50–P10 estimates) of operations, the flare rate is estimated at 5 MMscfd (off-peak flaring), which would result in a 4 m flame height. Therefore, the height of the top of the flame during this rate of flaring is ~84 m above sea level. This further reduces to a pilot flare only with a flame height of ~1 m at 22–36 months of operation (P10-P50).

Final design for flaring will be determined during FEED, including investigations of best practice design and assessments to reduce light emissions to ALARP.

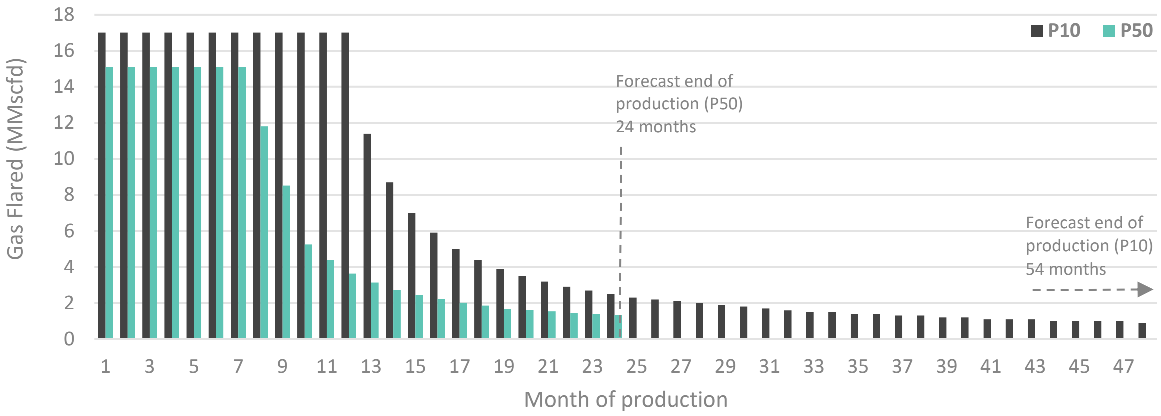


Figure 7-1 Expected Flaring Profiles (P10 and P50) for the Corowa Development

Figure 7-2 Galoc FPSO (Philippines) Flaring Day (left) and Night (right) at ~15 MMscf/d

Support Activities

Throughout the Corowa Development, external lighting will be required on vessels and facilities (e.g. MOPU, MODU, FSO) for safe navigation and to facilitate 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). Final design for facility and vessel lighting will be determined during FEED, including investigations of best practice design and assessments to reduce artificial light emissions to ALARP.

7.1.3.2 Modelling and Exposure Assessment

Two areas have been defined for describing artificial light emissions for the Corowa Development, a Visible Light Exposure Area and a Potential Impact Area (Table 7-14). Desktop modelling of visible light and light intensity has been undertaken (Xodus Group 2019a; Appendix B) and the results summarised in Sections 7.1.3.2.2 and 7.1.3.2.3 respectively.

In addition to desktop modelling, the draft National Light Pollution Guidelines (CoA 2019) were also used in determining areas for potential impact assessment. The decision-tree presented within the guidelines requires an impact assessment to be undertaken if important habitat for listed species occurs within 20 km of the artificial light source. An important habitat is defined within the guidelines as 'those areas necessary for an ecologically significant proportion of a listed species to undertake important activities such as foraging, breeding, roosting or dispersal' (CoA 2019). Important habitat can vary depending on the species, but may include BIAs, habitat critical to the survival of a species (e.g. for marine turtles as defined in CoA 2017) and important habitat for migratory species (as defined in DoE 2013).

Table 7-14 Description of Corowa Development Artificial Light Exposure and Potential Impact Areas

Corowa Development Artificial Light Areas	Description
Visible Light Exposure Area	The exposure area for light emissions is based on the extent of visible light that has been estimated to occur from vessels and facilities associated with the Corowa Development. The visibility of an artificial light does not necessarily imply a measurable change in ambient light (or any subsequent potential impact). The threshold for this area is whether any part of the facility is visible as a dot on the horizon.
Potential Impact Area	The potential impact area for light emissions is based on the modelled extent of a measurable change in ambient light that may occur from facilities and activities associated with the Corowa Development. The threshold used to define this area is equivalent to ambient light on a moonless clear night sky (0.001 lux), beyond this threshold no impact is assumed. This is the area relevant to the impact assessment for planned light emissions (Section 7.1.3.3). The relevant values and sensitivities present within this area are described in the 'Light Area' as defined within Section 5.

Light emissions from support operations (FSO, vessels) associated with the Corowa Development have not been included in the desktop modelling and exposure assessment due to the smaller scale and/or temporary and transient nature of vessel movements. The MOPU and MODU are the tallest and most lit structures on the Corowa Development and therefore the light will be visible and measurable for the greatest distance; hence these structures were used for the purposes of source characterisation and impact assessment.

7.1.3.2.1 Light Characteristics

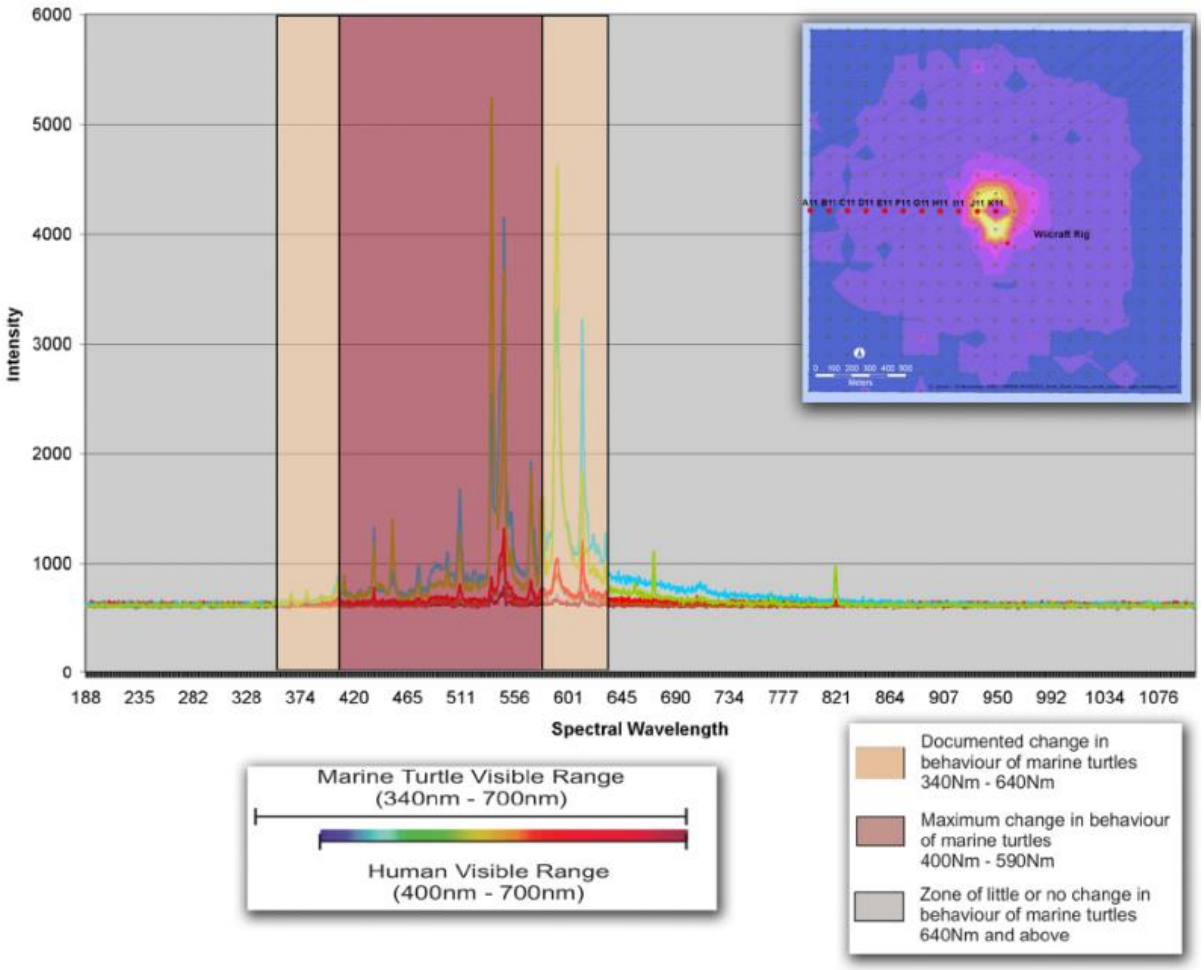
As described in Section 7.1.3.1, two main sources of light emissions are associated with the Corowa Development:

- facility lighting (i.e. navigational, task and safety lighting on vessels and facilities)
- gas flare.

The type of light being emitted and how this may be perceived by fauna is summarised below.

Corowa Development Light Characteristics

Light emissions due to facility lighting from the MODU and MOPU for the Corowa Development is expected to be comparable to that of the Woodside-operated Torosa drilling rig used during previous light measurements and modelling investigations completed by ERM (2010). Previous measurements of facility lighting emitted from an offshore drilling rig has indicated that the peak spectral signature was within the 530–620 nm wavelength range (Figure 7-3) (SKM 2008; Woodside 2014).



Source: SKM 2008; Woodside 2014

Figure 7-3 Spectral Signatures as Measured from an Offshore Drilling Rig

In contrast to facility lighting, the majority of light energy emitted from natural gas flares is in the range greater than 600 nm wavelength (Figure 7-4) due to the temperature of natural gas combustion at ~2,000 Kelvin (Elvidge et al. 2016; Fisher 2017; Plank 1914). Natural gas flares have also been measured to have a higher peak spectral signature than facility lighting, typically within the invisible infra-red range (750–900 nm), with lower levels of light emitted within the lower (and visible) wavelength ranges (Hick 1995; Pendoley 2000). It has also been noted that flow rates did not appear to change the spectral signature of gas flares (Hick 1995; Pendoley 2000). These wavelengths are expected to be comparable to the gas flare from the Corowa Development.

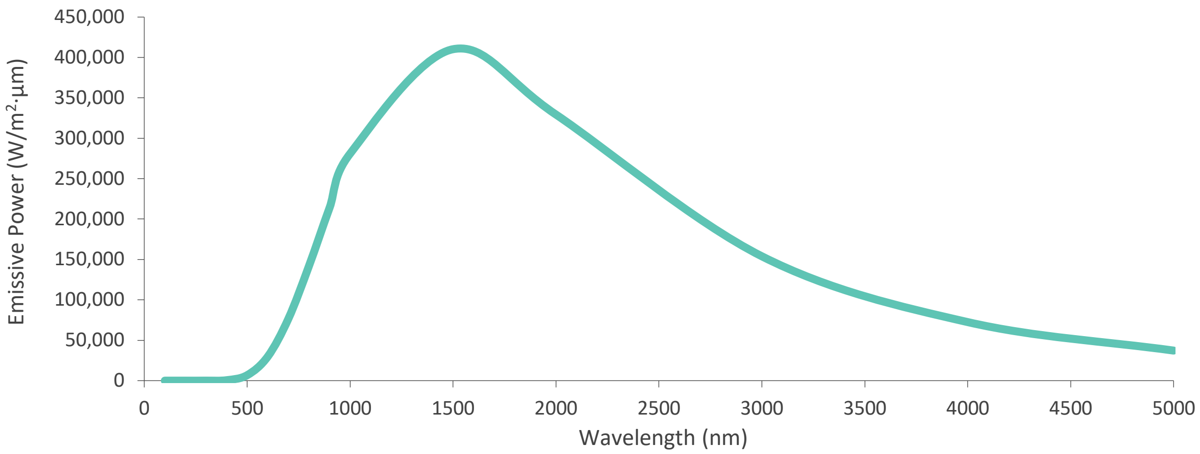
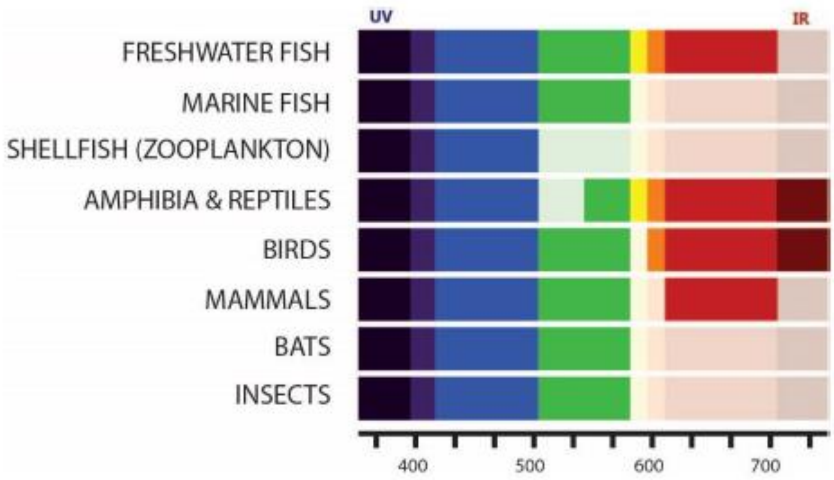


Figure 7-4 Spectral Signature Predicted from the Gas Flare (according to Planks equation at 2,000 Kelvin) and Green Turtle Sensitive Fauna Range

Fauna and Artificial Light Emissions

The visible spectrum for humans is ~400–700 nm, whereas the visible spectrum for fauna can vary between ~300 nm and >700 nm depending on the species (Figure 7-5; CoA 2019). Fauna perceive light differently to humans, with most sensitive to the ultraviolet, violet and blue light wavelengths (Figure 7-5; CoA 2019). Being sensitive to light within a specific range of wavelengths means that the fauna can perceive light at that wavelength, and it is likely they will respond to that light source.

From the above discussion, peak light emissions from both facility lighting and gas flares are not expected to occur within these lower wavelength bands of blue, violet and ultraviolet light.



Source: CoA 2019 (© Pendoley Environmental)

Figure 7-5 Different Fauna Groups' Ability to Perceive Different Wavelengths of Light

7.1.3.2.2 Visible Light Exposure Area

Light from the Corowa Development may be visible direct from the source or from sky glow; both are described below.

Line of Sight Estimates for Facility and Flare Lighting

A line of sight analysis was conducted for the MOPU and MODU to determine the potential extent of visible light (Xodus Group 2019a; Appendix B). The visibility of an artificial light does not necessarily imply a measurable change in ambient light (and therefore a potential impact).

The analysis was completed using assumed heights of these facilities, with final designs being confirmed during FEED. The line of sight assessment showed that the maximum distances light may be visible extends up to ~36.5 km for a 25 m high flame from the flare (i.e. the flare height associated with the peak flare rate during the initial 7–12 months (P50–P10 estimates) of operational flaring) (Table 7-15).

Table 7-15 Line of Sight Assessment for Facility Lighting and Flare

Facility infrastructure	Height of Facility Lighting / Flare	Maximum Distance light is visible (Line of Sight)
Facility		
Main deck lights	32 m	20.2 km
Process module lights	50 m	25.2 km
Lighting on the flare tower/drilling rig	80 m	31.9 km
Derrick (navigation lights)	99 m	35.5 km
Flare		
25 m high flame from the flare (17 MMscfd)	105 m	36.5 km
4 m high flame from the flare (5 MMscfd)	84 m	32.7 km
1 m high flame from the flare (pilot flare)	81 m	32.1 km

Because the flare height reduces over time as the field is depleted (Figure 7-1; Section 4.3.1), the initial visible distance of 36.5 km will drop towards 32.1 km, which is associated with the small pilot flare (~1 m height). This is close to the height of the flare tower, therefore is visible for a similar distance (31.9 km) (Table 7-15). The small navigation light/s on the derrick is the tallest source of facility lighting present throughout the whole Corowa Development, and is estimated to be visible to a distance of 35.5 km (Table 7-15).

The line of sight assessment indicates that the MOPU and MODU will likely be visible as a small object or light on the horizon from some of the neighbouring offshore islands, including the Muiron Islands and Serrurier Island (Figure 7-6). This is not dissimilar to the manner that the FPSO facilities off Exmouth are visible from the North West Cape. Being visible does not necessarily result in a measurable change in ambient light or an impact to light sensitive fauna (changes to ambient light and potential impact to fauna are discussed below).

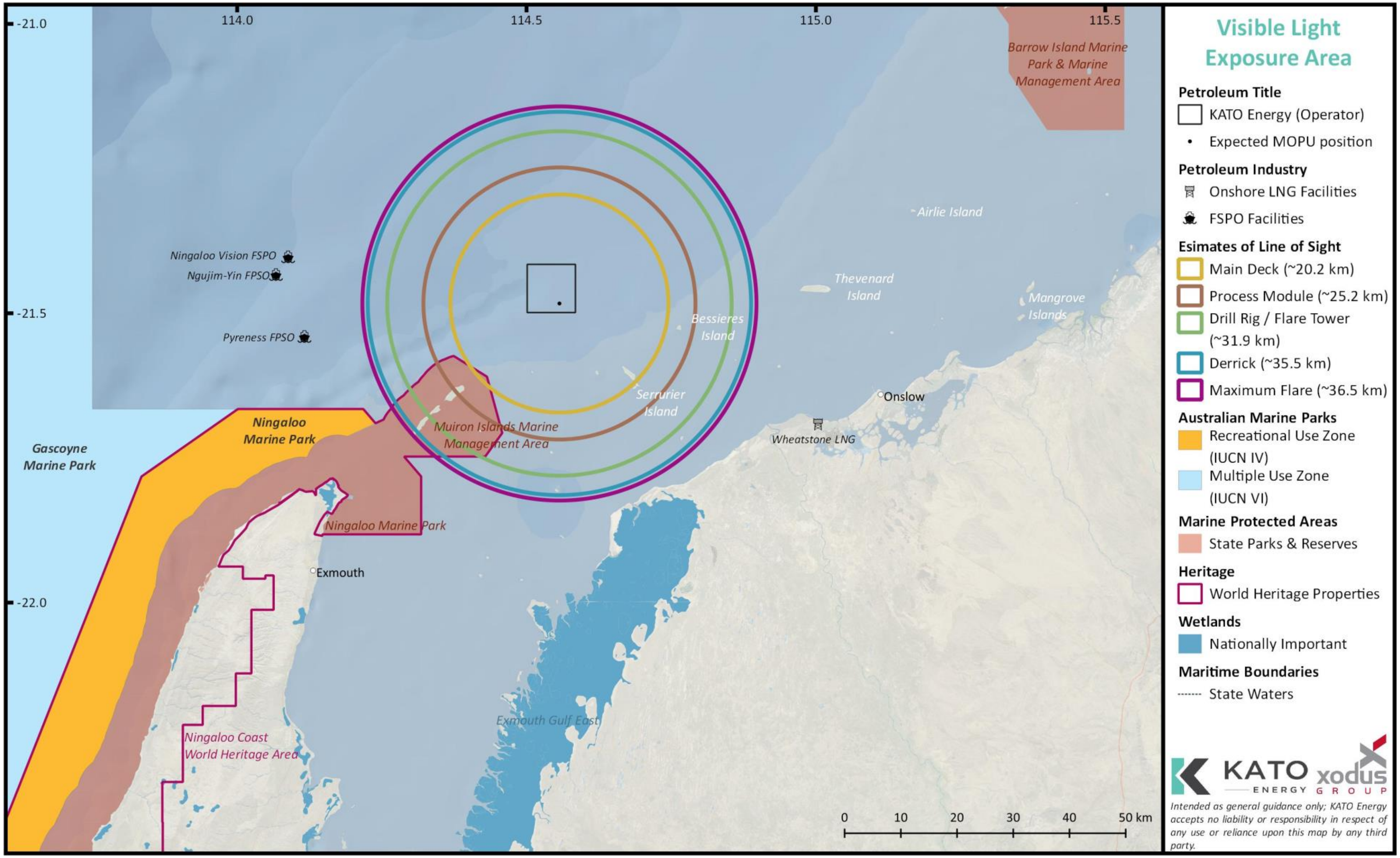


Figure 7-6 Visible Light Exposure Area for the Corowa Development

Sky Glow

Sky glow is the diffuse luminance of the night sky; in the context of light pollution, arises from using artificial light sources (including gas flares). Light propagating into the atmosphere directly from upward directed or incompletely shielded sources, or after reflection from the ground or other surfaces, is partially scattered back toward the ground, producing a diffuse glow. Different light sources produce differing amounts of visual sky glow. Natural light sources can also contribute to sky glow.

Sky glow brightness decreases steeply with distance from the light source due to geometric effects of Earth curvature and atmospheric absorption. An approximation is given by Walker's Law:

$$intensity \propto \frac{1}{distance^{2.5}}$$

Therefore, at greater distances from the source, the brightness of sky glow falls rapidly, largely due to extinction and geometric effects caused by the curvature of the Earth.

In low light (e.g. night) conditions, the eye becomes nearly or completely dark-adapted (scotopic); this is known as the Purkinje shift[15]. The scotopic eye becomes more sensitive to blue and green light, and much less sensitive to yellow and red light, compared to the light-adapted (photopic) eye. The Purkinje shift has a more dominant effect on the amount of visual sky glow observed compared to the Rayleigh effect[16] (Luginhuhl et al. 2014; Aube et al. 2013). This sensitivity to the shorter wavelength light is also common to marine fauna, such as turtles and some bird species, that are active during night (Figure 7-5).

Due to this shift mechanism, white light (i.e. light sources rich in shorter wavelengths) will produce a much brighter visual sky glow (~3 times more) compared to a low-pressure amber light or flare. As noted previously, the majority of radiation emission from natural gas flares is in the range greater than 600 nm wavelength; i.e. it is dominated by the orange/red visible and infra-red emissions. Therefore, facility lighting, particularly if white lights are used, have the potential to produce a brighter sky glow (Imbricata Environmental 2018).

7.1.3.2.3 Potential Impact Area

Light intensity (or light illuminance) can be described as the light brightness as perceived by a receiving receptor (e.g. human or marine fauna). Light intensity decreases exponentially as distance increases from the source of the light.

Typical light illuminance values from natural light sources are described in Table 7-16; these are considered to be representative of ambient light levels in the vicinity of the Corowa Development and wider NWS region.

Table 7-16 Summary of Natural Light Illuminance

Light Type	Light Illuminance (Lux)
Direct sunlight	100,00–130,000
Full daylight, indirect sunlight	10,000–20,000
Overcast day	1,000
Very dark day	100
Twilight	10

[15] The Purkinje shift is the tendency for the peak luminance sensitivity of the eye to shift toward the blue end of the colour spectrum at low illumination levels as part of dark adaptation (Frisby 1980; Purkinje 1825).

[16] Rayleigh scattering is the scattering of light by particles and is typically greater for the shorter wavelengths (e.g. blue lights).

Light Type	Light Illuminance (Lux)
Deep twilight	1
Full moon	0.1
Quarter moon	0.01
Moonless clear night sky[17]	0.001
Moonless overcast night sky	0.0001

Source: ERM 2010

The two sources of light emissions associated with the Corowa Development (facility lighting and the gas flare) will have differing areas of potential impact over the life of the project.

Three scenarios were modelled to quantify the potential impact area from facility lighting and the flare (Xodus Group 2019a; Appendix B):

- flare light emissions for a 17 MMscfd gas flare rate (representing peak flaring during initial period of operations)
- flare light emissions for a 5 MMscfd gas flare rate (representing an off-peak flaring estimated to occur at approximately month 10 (P50 estimate) or month 17 (P10 estimate) of operational flaring)
- facility light emissions.

The minimum threshold used to describe a change in ambient light conditions within this light assessment is an illuminance equivalent to ambient light on a moonless clear night sky (0.001 Lux) (Xodus 2019a; Appendix B).

Light Illuminance Estimates for the Gas Flare

Unlike facility lighting, which is provided for the purpose of 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. Therefore, analogue gas flares from other facilities were identified to assist in the quantification of light emissions from the operational flare for the Corowa Development. A flare light assessment was conducted by Xodus Group (Appendix B), with the methods and results summarised below.

Of the three analogues that were identified, the gas flare from the Obigbo oil production facility in Nigeria was selected as the most appropriate for comparison, as it is a continuous flare that is used for the same purpose (flaring gas from an oil production facility) and has a flare rate in same order of magnitude to the peak rate expected for the Corowa Development (Xodus Group 2019a; Appendix B). Studies describing the levels of light intensity (illuminance levels) and flaring rates (Isichei et al. 1976; Nwaob 2005; European Commission 2014) were also available for the Obigbo facility. This information allowed for the characteristics of the Obigbo flare to be scaled for characterisation of other flares; this data provided the basis for the flare light intensity modelling (Xodus Group 2019a; Appendix B).

Light modelling uses the inverse square law of illumination and does not consider scatter, absorption or other atmospheric phenomenon; therefore, results are considered conservative and appropriate for the purpose of environmental impact assessment (Xodus Group 2019a; Appendix B).

[17] Impact threshold used in this impact assessment is 0.001 lux; beyond this threshold no impact to light-sensitive fauna is assumed.

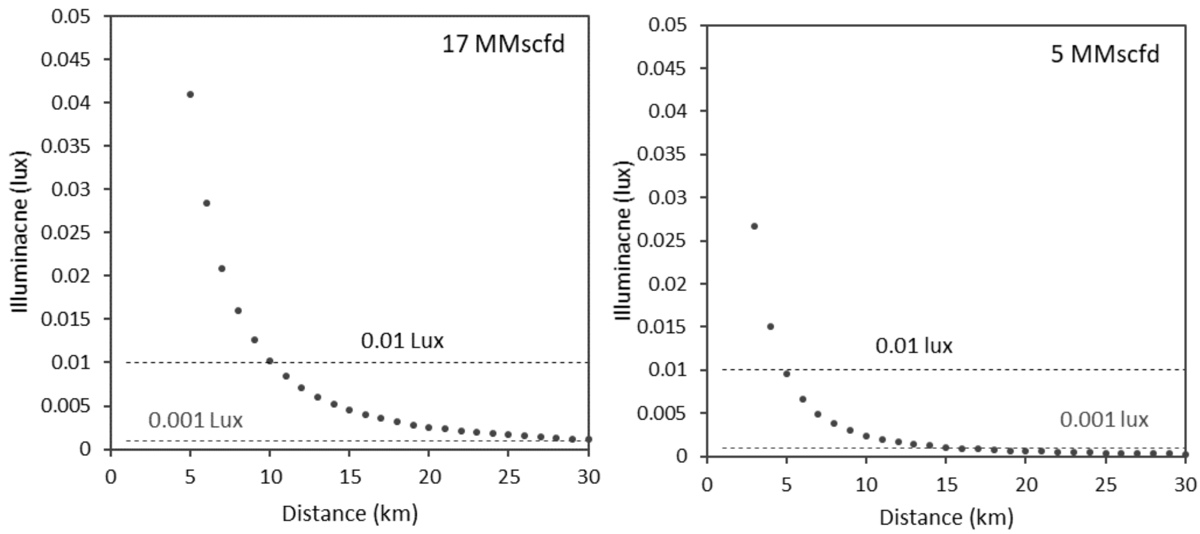
Modelled light intensity (illuminance) levels for the Corowa Development during peak flaring conditions (i.e. 17 MMscfd) predicted (Xodus Group 2019a; Appendix B):

- light intensity levels greater than 0.1 Lux may occur up to 3.2 km from the expected position of the MOPU, this is comparable to ambient light levels during full moon to twilight
- between 3.2 km and 10 km from the expected position of the MOPU, the model predicted light intensity levels comparable to ambient light levels during a quarter moon to full moon night sky (0.01 Lux to 0.1 Lux)
- between 10 km and 30 km, light intensity levels were predicted to be between 0.01 Lux and 0.001 Lux, which is comparable to ambient light intensity levels between a moonless clear night sky and a quarter moon
- beyond 30 km there was no measurable change to the ambient light intensity levels (i.e. less than 0.001 Lux).

Modelled light intensity (illuminance) levels for the Corowa Development during off-peak flaring 5 MMscfd predicted (Xodus Group 2019a; Appendix B):

- light intensity levels greater than 0.1 Lux may occur up to 1.5 km from the expected position of the MOPU, this is comparable to ambient light levels during full moon to twilight
- between 1.5 km and 4.9 km from the expected position of the MOPU, the model predicted light intensity levels comparable to ambient light levels during a quarter moon to full moon night sky (0.01 Lux to 0.1 Lux)
- between 4.9 km and 12.7 km, light intensity levels were predicted to be between 0.01 Lux and 0.001 Lux, which is comparable to ambient light intensity levels between a moonless clear night sky and a quarter moon
- beyond 12.7 km there was no measurable change to the ambient light intensity levels (i.e. less than 0.001 Lux).

These modelled light intensity curves are shown graphically in Figure 7-7. Figure 7-8 and Figure 7-9 show the predicted radii for 17 MMscfd and 5 MMscfd respectively.



Source: Xodus Group 2019a

Figure 7-7 Modelled Light Intensity (illuminance) for Flaring during Operations for the Corowa Development for Peak Flaring of 17 MMscfd (left) and 5 MMscfd (right)

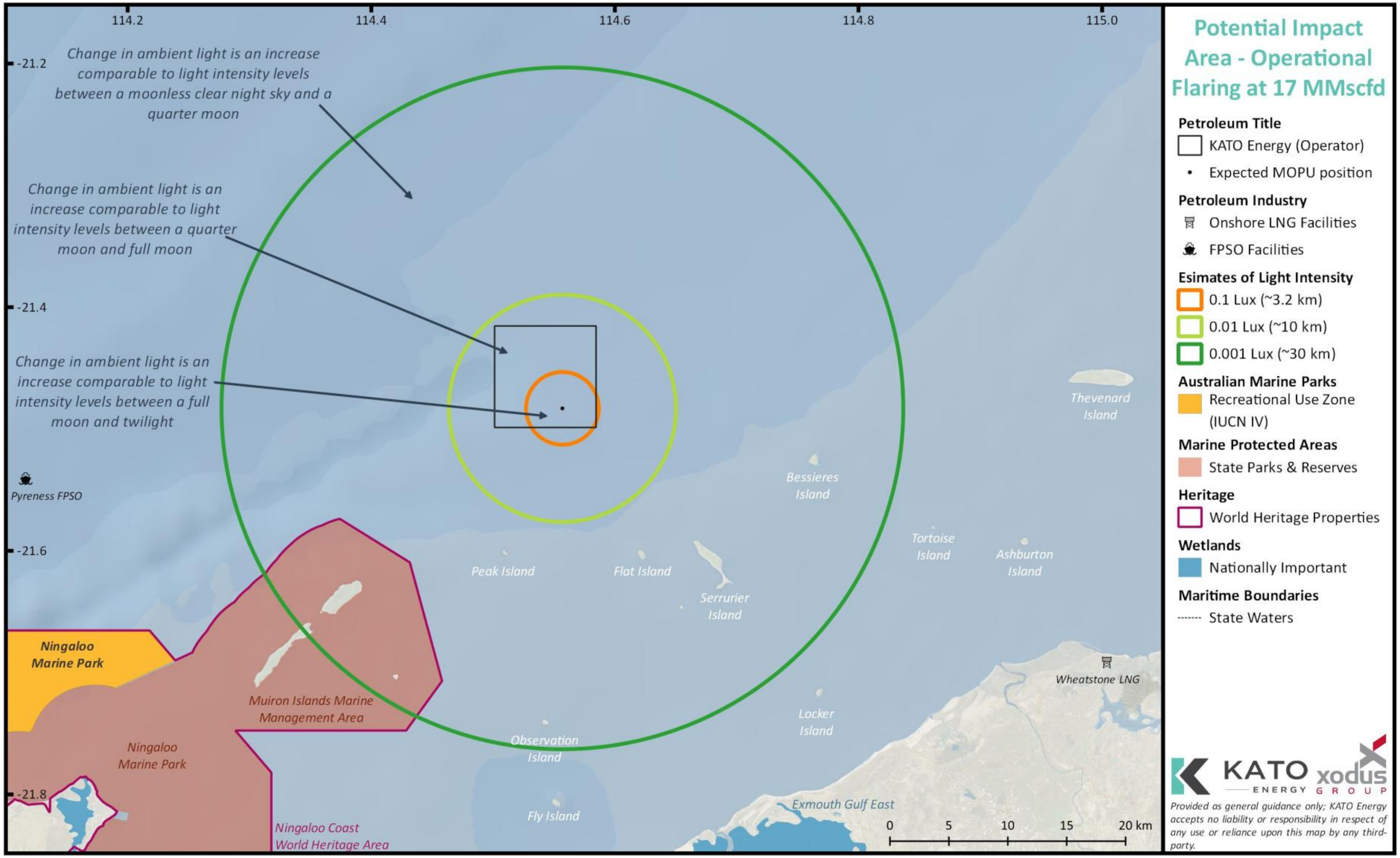


Figure 7-8- Potential Impact Area – Modelled Light Intensity Levels during Peak Flaring at a Rate of 17 MMscfd

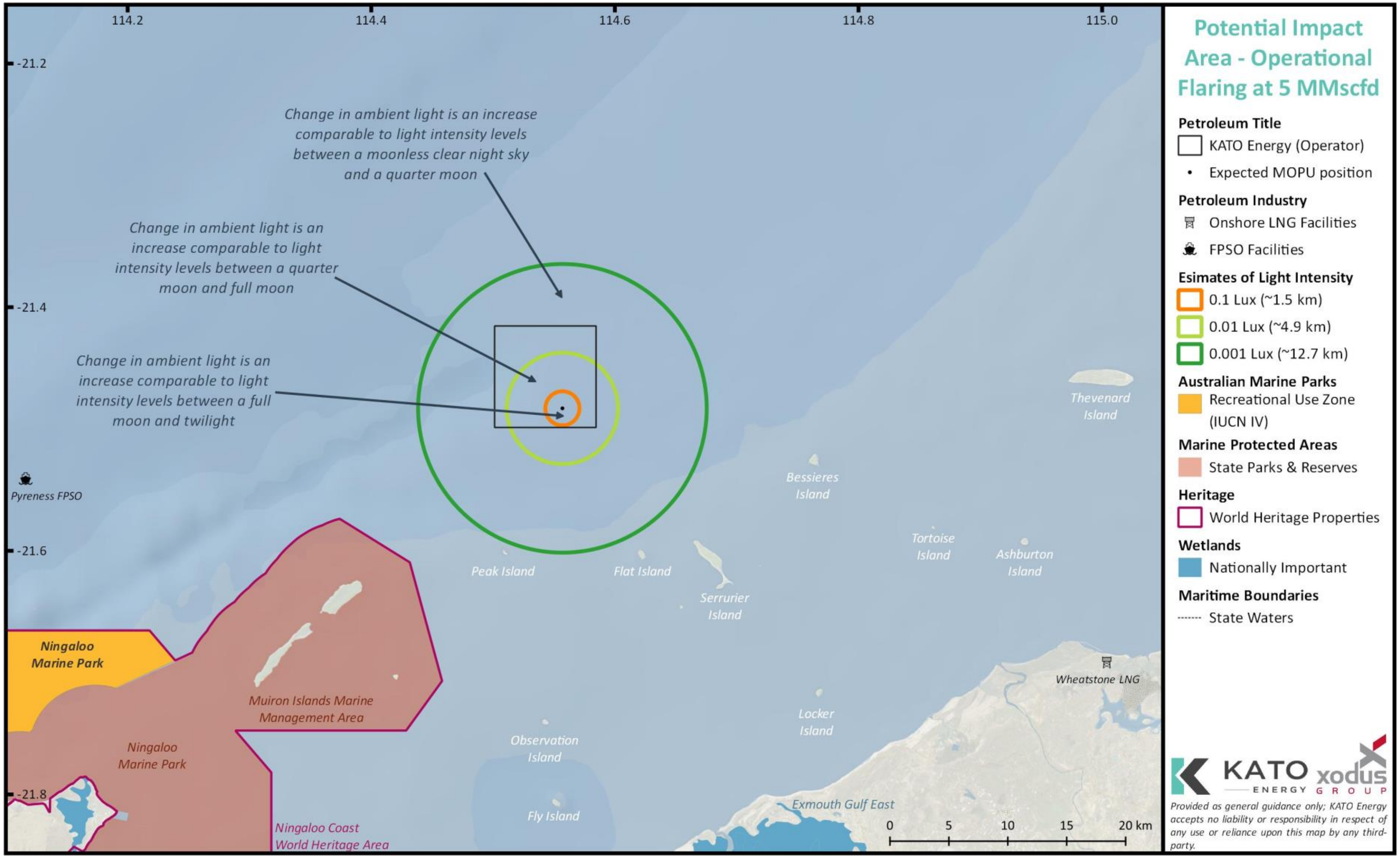


Figure 7-9 Potential Impact Area – Modelled Light Intensity Levels during Off-peak Flaring at a Rate of 5 MMscfd

Light Intensity Estimates for Facility Lighting

Light emissions from the facility lighting from the MODU and MOPU for the Corowa Development is expected to be comparable to that of the Torosa drilling rig used during previous light intensity modelling completed by ERM (2010). The MODU and MOPU will have a similar lit surface area as the drilling rig modelled and be lit to a similar light level required for safe operation of the rig. Therefore, using modelling results from ERM (2010) is considered appropriate for the KATO light intensity assessment for facility lighting (i.e. this does not take into consideration the flare, which is discussed above). The ERM (2010) modelling assessment predicted:

- light intensity levels greater than 0.1 Lux up to 800 m from the rig, comparable to ambient light levels during full moon to twilight.
- between 800 m and 1.2 km from the drilling rig, the model predicted light intensity levels comparable to ambient light levels during a quarter moon to full moon night sky (0.01 Lux to 0.1 Lux).
- between 1.2 km and 12.6 km, light intensity levels were predicted to be between 0.01 Lux and 0.001 Lux, which is comparable to ambient light intensity levels between a moonless clear night sky and a quarter moon.
- beyond 12.6 km there was no measurable change to the ambient light intensity levels (i.e. less than 0.001 Lux).

The above predicted Lux levels from the modelling align with measured Lux levels recorded during a development drilling campaign off the Western Australian coast using a rig similar to the MOPU. The light intensity of the drilling rig lighting was highest at 8.9 Lux, 100 m from the rig, and lowest at 0.03 Lux at the extremities of the survey grid ~1.4 km from the rig (Woodside 2014).

The light intensity assessment indicates that the lighting on the MOPU and MODU may have a measurable change to ambient light conditions of up to 12.6 km (Figure 7-10). This measurable change in light from the facility lighting does not extend over the neighbouring chains of offshore islands.

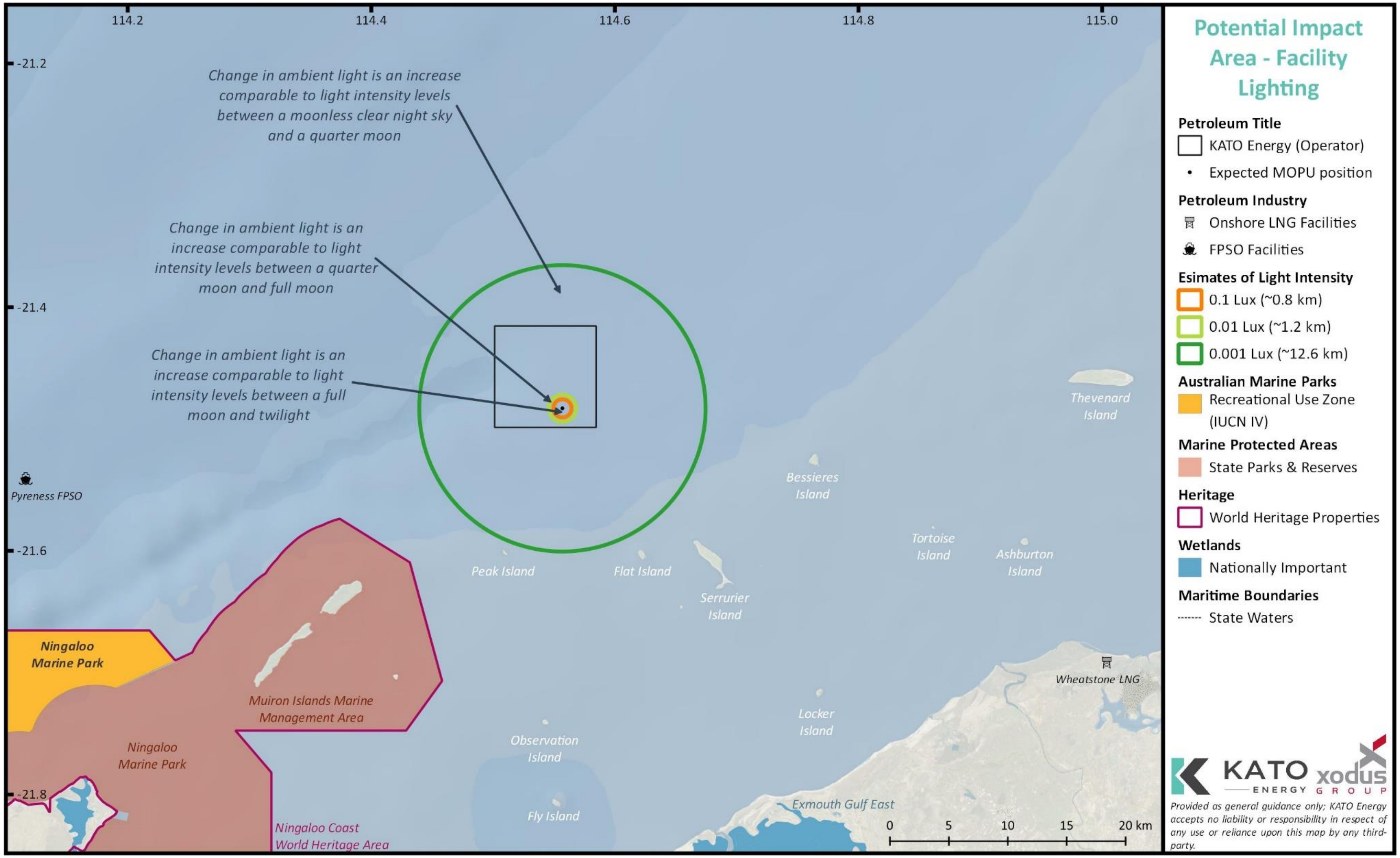


Figure 7-10 Potential Impact Area – Modelled Light Intensity Levels for Facility Lighting from the MOPU and MODU

7.1.3.2.4 Summary

The above analysis of available literature and modelling provided the basis for defining a Potential Impact Area, for the purposes of impact assessment. This area has been defined to include the worst-case extents of predicted measurable changes to ambient light based on planned activities (Section 3.4), and is the area relevant to the impact and risk assessment for planned light emissions (Section 7.1.3).

The maximum distances of the potential impact area for artificial light emissions from the Corowa Development are:

- Flaring:
  - ~30 km during peak (17 MMscfd) operational flaring (first 7–12 months)
  - reducing to ~12.7 km for a 5 MMscfd flare rate (after 10–17 months) and continuing to decrease below this as the reservoir continues to deplete and flaring rates reduces further
- Facility:
  - ~12.6 km over the life of the project.

Due to the changing flare characteristics over the operational life of the Corowa Development, this will initially be the dominant source of light defining the extent of the potential area of impact. However, beyond months 10–17 (P50–P10 estimates) of operational flaring, the amount of light emitted and the predicted light intensity (luminance) from the gas flare will have reduced to at or below the amount of light emitted and predicted light intensity from the facility lighting.

Therefore, at this point and for the rest of the project life, the facility lighting will be the dominant source of light that defines the outer extent of the potential area of impact (Figure 7-11). That is, once the flare rate is less than 5 MMscfd, the facility lighting will define the outer extent of the potential impact area.

It is also noted that the 20 km distance indicated within the draft National Light Pollution Guidelines (CoA 2019) falls between the estimated extent of measurable changes to ambient conditions (that was defined as <0.001 Lux) from peak flaring (30 km) and facility lighting (12.6 km) (Figure 7-11).

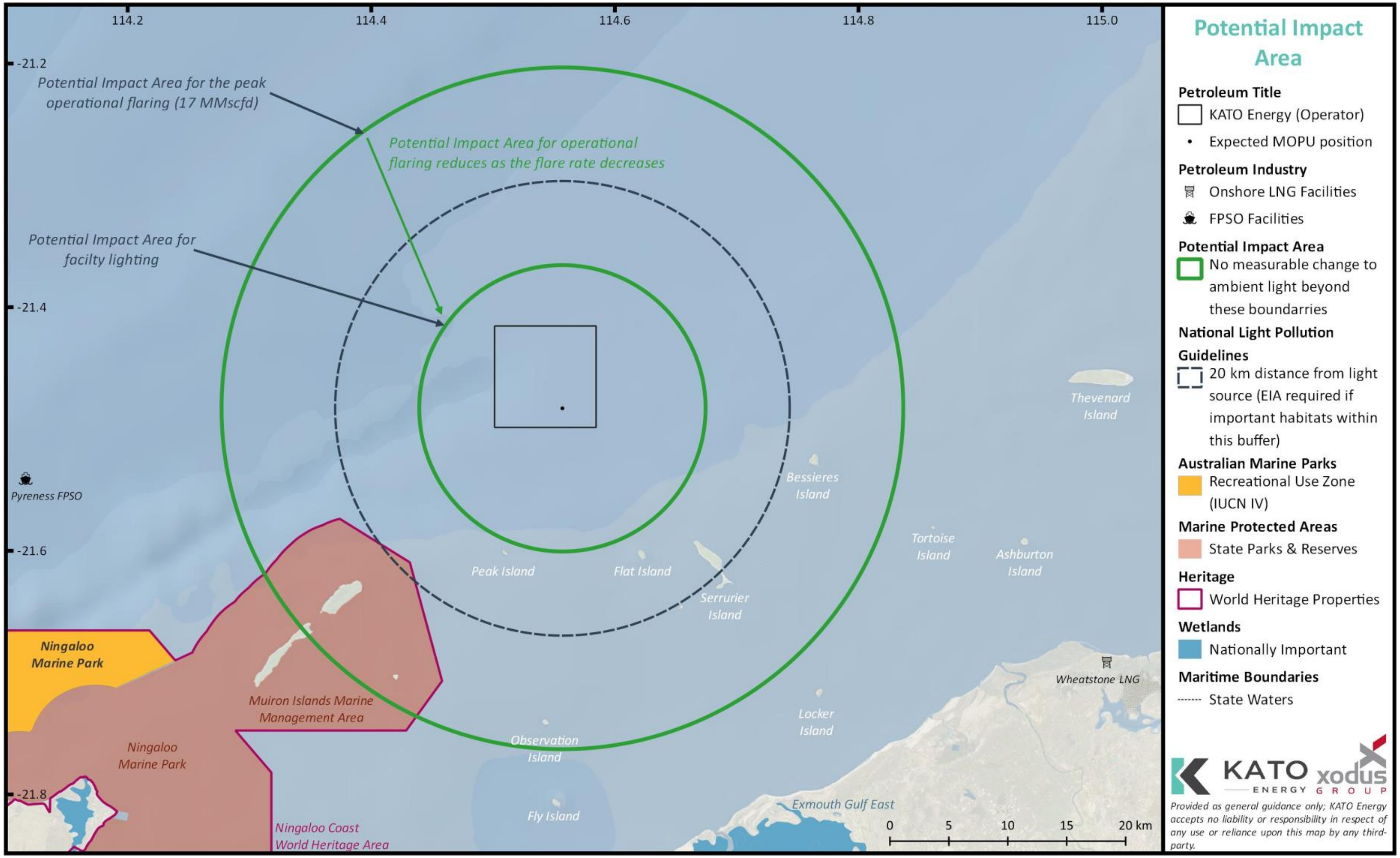


Figure 7-11 Potential Impact Area for Light Emissions from the Corowa Development as Flare Rate Reduces Over Time

7.1.3.3 Impact Analysis and Evaluation

Light emissions generated by the Corowa Development have the potential to result in this impact:

- a change in ambient light.

As a result of a change in ambient light, further impacts may occur, including:

- a change in fauna behaviour
- injury/mortality to fauna
- changes to the functions, interests or activities of other users
- change in aesthetic value.

Table 7-17 identifies the potential impacts to receptors as a result of light emissions from the Corowa Development. Receptors marked '*X*' are subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-18 provides a summary and justification for those receptors not evaluated further.

Table 7-17 Receptors Potentially Impacted by Emissions – Light

Impacts	Ambient light	Seabirds and shorebirds	Fish	Marine reptiles	Commercial fisheries	State Protected Areas – Marine	Heritage features
Change in ambient light	✓					✓	✓
Change in fauna behaviour		✓	✓	✓		✓	✓
Injury/mortality to fauna		✓					
Changes to the functions, interests or activities of other users					*X*	✓	✓
Change in aesthetic value						✓	✓

Table 7-18 Justification for Receptors Not Evaluated Further for Emissions – Light

Commercial Fisheries	***X***
As outlined above, a measurable change in light from ambient conditions may occur up to a maximum distance of 30 km from the Corowa Development during the initial peak period of operational flaring and then reduce in spatial extent over time to a distance of 12.6 km (this is expected to occur by approximately month 10 (P50) or month 17 (P10)), and then remain at this 12.6 km for the remainder of the project life. While fish may be attracted to lights, this area of influence is small, and this small change in aggregation and predation is not expected to result in a change in the viability of the population of commercially important species or ecosystem. Therefore, impacts to commercial fisheries from light emissions are not expected, and have not been evaluated further.	

Impacts to receptors are assessed below, by receptor type.

7.1.3.3.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of a change in ambient light include:

- ambient light.

Table 7-19 provides a detailed evaluation of the impact or risk of light emissions to physical receptors.

Table 7-19 Impact and Risk Assessment for Physical Receptors from Emissions – Light

Ambient Light ✓
<u>Change in ambient light</u> The operations of vessels and facilities associated with the Corowa Development will generate artificial light emissions, which will result in a change in the ambient light environment within the vicinity of the sources. As outlined above, a measurable change in light from ambient conditions may occur up to a maximum distance of 30 km from the Corowa Development during the initial period of operational flaring and then reduce in spatial extent over time to a distance of 12.6 km [this is expected to occur by approximately month 10 (P50) or month 17 (P10)], and then remain at this 12.6 km for the remainder of the project life. While lights may be visible beyond these distances (e.g. line of sight estimates for the different parts of the facility range between ~20–35 km), they are not increasing the measurable ambient light at these distances. Light emissions from the Corowa Development is not predicted to impact ambient light conditions on the mainland, but some of the offshore islands (including northern Muiron Island, Serrurier Island and Bessieres Island) are within the potential impact area within the initial period of operational flaring. This change in ambient conditions would be an increase in light comparable to between a moonless clear night sky and a quarter moon. Beyond this initial period of operation, no measurable light on offshore islands was predicted to occur from the Corowa Development (project life expected to be ~5 years). There are no Management Plans related specifically to ambient light. While a change in ambient light conditions within the vicinity of the Corowa Development is predicted to occur, this will decrease during the operational life, and in the offshore ocean environmental this does not reflect a significant change. Given the details above, the consequence of light emissions causing a change in ambient light has been assessed as **Minor (1)**, due to the restricted area of operation and relatively short project life.

7.1.3.3.2 Ecological Receptors

Ecological receptors with the potential to be impacted as a result of a change in ambient light include:

- seabirds and shorebirds
- fish
- marine reptiles.

The above receptors may be impacted from:

- a change in fauna behaviour
- injury/mortality to fauna.

Table 7-20 provides a detailed evaluation of the impact of light emissions to ecological receptors.

Table 7-20 Impact and Risk Assessment for Ecological Receptors from Emissions – Light

Seabirds and Shorebirds ✓
<u>Change in fauna behaviour</u> Many seabirds (including most shearwaters, petrels and albatross species) are active at night, and many nocturnal seabird species are sensitive to the disorientating influences of artificial light (Montevecchi 2006; Rodríguez et al. 2019). Vulnerability to artificial lighting varies between different species and age classes and according to the influence of season, lunar phase and weather conditions. Artificial lights can confuse

species, result in attraction, injury or mortality via collision or becoming grounded (Rodríguez et al. 2019; Wiese et al. 2001).

In general, young birds (fledglings) are more likely to become disorientated by artificial light sources. Fledglings have been observed being affected by lights up to 15 km away (CoA 2019). Fledgling seabirds may also not take their first flight if their nesting habitat never becomes dark (CoA 2019). Emergence during darkness is believed to be a predator-avoidance strategy and artificial lighting may make the fledglings more vulnerable to predation (CoA 2019). It is thought that if artificial lights override the sea-finding cues of a fledgling and initially disorient its path, they may not be able to imprint their natal colony, preventing them from returning to nest when they mature (CoA 2019).

Migratory shorebirds may use less preferable roosting sites to avoid lights, which may put them at a greater risk of predation where lighting makes them visible at night, or compromise their ability to undertake long-distance migrations integral to their life cycle (CoA 2019). The mechanism of birds being attracted to light is not proven, but it is proposed that the artificial lighting may override the internal magnetic compass of migratory shorebirds or nocturnal seabirds (Gauthreaux and Belser 2006). During studies conducted in the North Sea, Marquenie et al. (not dated) noted that birds travelling within a 5 km radius of illuminated offshore platforms deviated from their route and either circled or landed on the nearby platform; beyond this distance it was assumed that light source strengths were not sufficient to attract birds.

In all seabirds, their photopic vision (light-adapted) is most sensitive in the long wavelength range (590–740 nm, orange to red) while their scotopic (dark-adapted) vision is more sensitive to short wavelengths (380–485 nm, violet to blue) (CoA 2019). The eyes of the Wedge-tailed Shearwater are characterised by a high proportion of cones that a sensitive to shorter wavelengths (CoA 2019). For the Corowa Development, peak light emissions from both facility lighting and gas flares are not expected to occur within these lower and more sensitive wavelength bands of blue, violet and ultraviolet light (i.e. not within the sensitive ranges for scotopic vision). However, the intensity of light may be a more important cue than colour for seabirds; very bright light will attract them, regardless of colour (CoA 2019).

A measurable change in light from ambient conditions may occur up to a maximum distance of 30 km from the Corowa Development during the initial period (up to 10–17 months) of peak operational flaring. This potential area of impact includes a change in light at some of the offshore islands (e.g. northern Muiron Island, Serrurier and Bessieres islands, at an increase comparable to between a moonless clear night sky and a quarter moon. This light during this initial period is due to the gas flare. However, it is also noted that both the northern Muiron Island and Bessieres Island are >20 km from the Corowa Development, which is the distance indicated within the Draft National Light Pollution Guidelines (CoA 2019) as being relevant to potential impacts. The potential impact area will reduce in spatial extent over time to a distance of 12.6 km (this is expected to occur by approximately month 10 [P50] or month 17 [P10]), and then remain at this 12.6 km for the remainder of the project life (project life expected to be ~5 years). Therefore after 10–17 months of operation, there is no measurable light predicted to occur from the Corowa Development over these offshore islands.

The offshore islands (e.g. Muiron Islands, Serrurier Island) within the vicinity of the Corowa Development are known breeding locations for some species of migratory birds (e.g. Wedge-tailed Shearwater). The potential impact area for light associated with the Corowa Development also intersects with breeding BIAs for the Wedge-tailed Shearwater and Lesser Crested Tern. However, the BIA for the Lesser Crested Tern is associated with breeding on Thevenard Island, which is ~43 km from the expected position of the MOPU and beyond any measurable increase in artificial light from the Corowa Development. Conversely, Serrurier Island is ~17 km, and Muiron Islands are ~23 km from the expected MOPU location, and both are within breeding BIAs for the Wedge-tailed Shearwater. Presence of the Wedge-tailed Shearwater is seasonal, typically occurring between mid-August to April in the Pilbara. The main fledgling period for shearwaters in Australia is during April/May (CoA 2019). The Draft National Light Pollution Guidelines currently apply to marine turtles, seabirds and migratory shorebirds (CoA 2019).

Given the location of the Corowa Development, all artificial light sources are offshore and >15 km distance from breeding islands, and therefore are not predicted to adversely impact the nesting of adult birds or emergence of fledglings. In addition, the light emitted from the gas flare is expected to be >600 nm (with a peak at 750–900 nm), which is beyond the more sensitive wavelengths for bird species. Therefore, minimal attraction or disruption of bird behaviour on the offshore islands is predicted as a result of the Corowa Development. It is also noted that the low levels of measurable changes in light at the offshore islands are not predicted to occur over the whole project life (approximately five years).

It is possible that nocturnally active seabirds and/or migrating birds may be affected by light-spill and make alterations to their normal behaviours. Procellariforms (shearwaters, petrels and albatross) species forage at night on bioluminescent prey, and therefore are attracted to light of any kind (Imber 1975; Wiese et al. 2001). Marquenie (2013) estimated that a change in migratory behaviour of birds was limited to <5 km from the source. Therefore, this type of impact is expected to be spatially restricted to the immediate vicinity of the MOPU and MODU and affect only individuals (rather than populations).

Fauna injury/mortality

High rates of fallout, or the collision of birds with structures, has been reported in seabirds nesting adjacent to urban or developed areas and at sea where seabirds interact with offshore oil and gas platforms (CoA 2019). Gas flares can also attract seabirds, potentially due to both the light and noise of the flare, and the birds can become disoriented, grounded or be injured or killed.

As above, this potential impact is expected to be spatially restricted to the immediate vicinity of the MOPU and MODU and affect only individuals, if any, rather than populations.

Given the details above, the consequence of light emissions causing a change in the behaviour, or injury/mortality of seabirds and shorebirds has been assessed as **Moderate (2)**, due to expected impacts to be localised to within 30 km to 12.6 km radius (peak flaring and facility lighting) of the MOPU. Impacts are also predicted to be short-term, with peak flaring for 7–12 months, and a project life of ~5 years.

Fish ✓

Change in fauna behaviour

Fish may move towards light sources as a product of instinctual attraction to light or to prey on other species aggregating at the edges of artificial light halos. Experiments using light traps have found that some fish and zooplankton species are attracted to light sources (Meekan et al. 2001), with traps drawing catches from up to 90 m (Milicich et al. 1992).

Exposure to artificial light may also alter reproduction in some species; for example, clownfish eggs incubated under constant light do not hatch (CoA 2019). As there is no significant benthic habitat within the immediate vicinity of the Corowa Development, it is not expected that abundant fish spawning would occur in the area. Therefore, changes in fish reproduction are not considered a credible impact and is not discussed further.

The Corowa Development is located within a foraging BIA for Whale Sharks. Foraging activity in the area occurs from July to November, however it is centred on the 200 m isobath, which is ~26 km further offshore than the MOPU (which is in ~90 m of water). Light has also not been identified as a key threat for the Whale Shark (TSSC 2015d). Individuals may be found in the shallower waters of the Corowa Development area but at significantly lower numbers. It is not expected that Whale Sharks could be directly impacted by light emissions.

The draft Light National Pollution Guidelines does not specifically address light impacts to fish species, although it is recognised that light can cause changes in fish assemblages (CoA 2019).

Given the details above, the consequence of light emissions causing a change in the behaviour of fish species has been assessed as **Minor (1)** as impacts are predicted to be localised.

Marine Reptiles ✓

Change in fauna behaviour

Marine turtles use light as an orientation cue, and therefore artificial light has the potential to inhibit nesting by adult females and disrupt the orientation and sea-finding behaviour of hatchlings (CoA 2019; CoA 2017; EPA 2010). The general guidance is that turtles require naturally illuminated beaches for successful nesting and sea-finding behaviour (CoA 2017; Limpus et al. 2015; Robertson et al. 2016).

Adult males and females aggregate off nesting beaches to mate and then the female comes ashore at night to nest. An individual adult will generally only nest every two to five years but can produce several clutches of eggs during a breeding year. Turtles may actively avoid lighted beaches when selecting a nesting location. Lights that exclude wavelengths below 540 nm appear to not affect nesting density on beaches (CoA 2019).

Once emerged from the nest, turtle hatchlings rely on visual cues to orient themselves. Sea-finding occurs when hatchlings orient away from dark, elevated horizons (Limpus 1971; Salmon et al. 1992) towards a vertically low but horizontally broad light horizon (Lohmann et al. 1997). Artificial lighting may adversely affect hatchling sea-finding behaviour in two ways: disorientation – where hatchlings crawl on circuitous paths; or misorientation – where they move in the wrong direction, possibly attracted to artificial lights (CoA 2019). Hatchlings have been observed to respond to artificial light up to 18 km away during sea finding (CoA 2019).

The attractiveness of hatchlings to light differs by species, but in general, artificial lights most disruptive to hatchlings are those rich in short wavelength blue and green light, and lights least disruptive are those emitting long wavelength pure yellow-orange light (CoA 2019). Loggerhead Turtles are particularly attracted to light at 580 nm, Green Turtles are attracted to light at <600 nm (but with a preference to blue light at 400–450 nm) and Flatback Turtles are also attracted to light at <600 nm (but with a preference to blue to ultraviolet light at 365–450 nm) (CoA 2019). However, lights of any wavelength can affect hatchling behaviour (Limpus and Kamrowski 2013; Limpus et al. 2015; Robertson et al. 2016); if the longer wavelength lights are bright enough, they can elicit a similar response to the shorter wavelength lights (CoA 2019).

Artificial lights may also disrupt dispersal of hatchlings in nearshore waters by slowing or changing their dispersal pattern, which may subsequently influence predation rates (CoA 2019). As there is no coastal or nearshore artificial lighting associated with the Corowa Development this is not considered a credible impact and is not discussed further. Once in the water, hatchling navigation is understood to be predominantly related to wave motion, currents and the Earth's magnetic field (Lohmann and Lohmann 1992), rather than light.

A measurable change in light from ambient conditions may occur up to a maximum distance of 30 km from the Corowa Development during the initial period (up to 10–17 months) of peak operational flaring. This potential area of impact includes a change in light at some of the offshore islands (e.g. northern Muiron Island, Serrurier and Bessieres Islands; Figure 7-9) at an increase comparable to between a moonless clear night sky and a quarter moon. This light during this initial period is due to the gas flare. However, it is also noted that both the northern Muiron Island and Bessieres Island are >20 km from the Corowa Development, which is the distance indicated within the Draft National Light Pollution Guidelines (CoA 2019) as being relevant to potential impacts. The potential impact area will reduce in spatial extent over time to a distance of 12.6 km (this is expected to occur by approximately month 10 [P50] or month 17 [P10]), and then remain at this 12.6 km for the remainder of the project life (project life expected to be ~5 years). Therefore after 10–17 months of operation, there is no measurable light predicted to occur from the Corowa Development over these offshore islands.

Given the location of the Corowa Development, all artificial light sources are offshore from nesting beaches, and therefore are not predicted to adversely impact the nesting of adult turtles, or the orientation cues for emerging hatchlings. In addition, the light emitted from the gas flare is expected to be >600 nm (with a peak at 750–900 nm), which is beyond the known sensitive wavelengths for turtle species. It is also noted that the low levels of measurable changes in light at the offshore islands are not predicted to occur over the whole project life (~5 years). Therefore minimal attraction or disruption or turtle behaviour on nesting beaches or within nearshore areas is predicted as a result of the Corowa Development.

Previous experiments have indicated that light intensities of >0.05 Lux have had observed impacts on hatchlings (Pendoley 2005); this is well above the intensities that may be present on the offshore islands (0.01–0.001 Lux) during the initial 10–17 months of operation of the Corowa Development (Figure 7-10).

The potential impact area for light associated with the Corowa Development also intersects with internesting BIAs and Critical Habitat for some threatened and migratory marine turtle species. Internesting areas vary between 20–60 km from a nesting beach for the different turtle species (Flatback Turtles have a higher internesting buffer than other species). Internesting areas can provide shelter and foraging sites for the turtles between nesting events. Light has not been identified as a threat to adult turtles away from nesting beaches (i.e. there is no inhibition of orientation cues noted in open waters). However it is also noted that the peak wavelengths of light emissions from the Corowa Development are not within the sensitive range for turtle species, and so even in close proximity significant adverse impact are not predicted to occur.

The Recovery Plan for marine turtles in Australia (CoA 2017a) identifies light pollution as a threat, and the Draft National Light Pollution Guidelines currently apply to marine turtles, seabirds and migratory shorebirds (CoA 2019).

Given the details above, the consequence of light emissions causing a change in the behaviour of reptile species has been assessed as **Moderate (2)**, due to expected impacts to be localised to within 30 km to

12.6 km radius (peak flaring and facility lighting) of the MOPU. Impacts are also predicted to be short-term, with peak flaring for 7–12 months, and a project life of ~5 years.

7.1.3.3.3 Social, Economic and Cultural Receptors

Social, economic and cultural receptors have the potential to be impacted as a result of impacts to physical or ecological receptors.

Impacts to the identified receptors include:

- a change in ambient light
- a change in fauna behaviour
- changes to the functions, interests or activities of other users
- change in aesthetic value.

Table 7-131 provides a detailed evaluation of the impact of an accidental release of Corowa light crude oil to social, economic and cultural receptors.

Table 7-21 Impact and Risk Assessment for Social, Economic and Cultural Receptors from Emissions – Light

State Protected Areas – Marine; Heritage Features ✓
Marine protected areas (including marine parks and heritage listed places) may be vulnerable to a change in ambient characteristics. As the values and sensitivities of these protected places are a combination of quality, habitat, marine fauna and flora, and human use, the impact pathways are varied. Refer to impact assessments for related individual receptors, including ambient light and marine fauna. A measurable change in light from ambient conditions may occur up to a maximum distance of 30 km from the Corowa Development during the initial period of operational flaring. This potential area of impact includes a change in light within part of the Muiron Islands Marine Management Area and Ningaloo Coast World and National Heritage Area (Figure 7-11) at an increase comparable to between a moonless clear night sky and a quarter moon. However, the extent of the area of a measurable change in ambient light reduces over time to a distance of 12.6 km (this is expected to occur by approximately month 10 [P50) or month 17 (P10)), and then remain at this 12.6 km for the remainder of the project life. Therefore, this Marine Management Area and Heritage area is only within this area of potential change for a small period at the beginning of operational flaring. The reserves represent an important area for nature-based tourism activities (CALM 2005). However, as described in previous sections, significant and/or long-term impact to marine fauna (such as turtles, seabirds and shorebirds) that are considered values of theses protected marine areas, is not predicted to occur. The visible light assessment indicated that the MOPU and MODU will likely be visible as a small object or light on the horizon from some of the offshore islands, including the Muiron Islands and Serrurier Island, but not from the mainland. Lights being visible do not necessarily equate to a measurable change in ambient light but can change the aesthetic value of a place. The visibility of the Corowa Development is not expected to be dissimilar to the manner that the existing FPSO facilities off Exmouth are also visible from the North West Cape. There is no permanent human presence on these islands at night, and as such the visible impact to human-perceived aesthetics is expected to be minimal. It is also noted that the low levels of measurable changes in light at the offshore islands are not predicted to occur over the whole project life (~5 years). Artificial light emissions from the Corowa Development are not expected to be inconsistent with the ability to maintain the values of the Muiron Island Marine Management Area or the protection and management requirements of the Ningaloo Coast World Heritage Area. Given the details above, the consequence of light emissions causing any permanent and/or significant impacts to State Protected Areas – Marine and/or Heritage Features has been assessed as **Moderate (2)**, due to the small change (increase in light between a moonless clear night sky and quarter moon) and the temporary period of change.

7.1.3.4 Consequence and Acceptability Summary

The worst-case consequence of light emissions from the Corowa Development has been evaluated as **Moderate (2)**, which was for marine reptiles (specifically turtles), seabirds and shorebirds, and State Protected Areas and Heritage features. This is considered **acceptable** when assessed against the criteria in Table 7-22.

Table 7-22 Demonstration of Acceptability for Emissions – Light

Acceptability Criteria	Justification

To meet the principles of ESD	• The maximum distances of the potential impact area for artificial light emissions from the Corowa Development are:
	  ○ Flaring:
	    ▪ ~30 km during peak (17 MMscfd) operational flaring (first 7–12 months)
	    ▪ reducing to ~12.7 km for a 5 MMscfd flare rate (after 10–17 months) and continuing to decrease below this as the reservoir continues to deplete and flaring rates reduces further.
	  ○ Facility: ~12.6 km over the life of the project.
	• Therefore, beyond 10–17 months and for the rest of project life (~5 years) project life, once the flare rate is less than 5 MMscfd, the facility lighting will define the outer extent of the potential impact area at 12.6 km.
	• The generation of light emissions will be relatively short-term, due to the short project life of the Corowa Development (~5 years), with operational flaring only expected for 2–4.5 years and dropping below the level of facility lighting after 10–17 months.
	• Behavioural disturbance to migratory or nocturnally active birds due to the flare is expected to be localised (e.g. up to 5 km from the MOPU) and temporary (2–4.5 years of operational flaring) and occur on an individual rather than population level given the transient nature of birds within the Potential Impact Area.
	• A measurable change in light from ambient conditions may occur at some of the offshore islands (northern Muiron Island, Serrurier and Bessieres Islands) during the initial 10–17 months of operational flaring. This change in measurable light is estimated to be at an increase comparable to between a moonless clear night sky and a quarter moon.
	  ○ However, given the distance from the light source to these islands, and the type of light emitted, minimal adverse impacts to nesting of adult birds or emergence of fledglings is predicted.
	  ○ Similarly, as all artificial light sources are offshore from nesting beaches, these are not predicted to adversely impact the nesting of adult turtles, or the orientation cues for emerging hatchlings.

Internal context	• KATO Artificial Light Management Plan KAT-000-PO-PP-102 (KATO 2020g)
External context	• No stakeholder concerns have been raised with respect to light emissions or potentially impacted receptors.
Other requirements	• The Draft National Light Pollution Guidelines currently apply to marine turtles, seabirds and migratory shorebirds, and include requirements for impact assessment, best practice lighting design and an artificial light management plan. • Lighting will be limited the minimum required for navigational and safety requirements, with the exception of emergency events.

Acceptability Criteria	Justification
	• Requirements of the Recovery Plan for marine turtles in Australia (CoA 2017a) identifies light pollution as a threat, and identifies these relevant conservation actions: ○ 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. • There is no conservation advice or recovery plan for the Wedge-tailed Shearwater. • With respect to light emissions, Corowa activities will not be conducted in a manner inconsistent with the management plan for or management principles of Australian World Heritage properties or National Heritage places, specifically the Ningaloo Coast, or in a manner inconsistent with respect to the management plan for, or objectives of the marine parks and reserves, and the principles of the marine parks and reserves zoning (specifically Muiron Islands).

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-23.

Table 7-23 Summary of Impact Assessment for Emission – Light

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient light	Change in ambient light	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM06**: Lighting will be sufficient for navigational, safety and emergency requirements (e.g. requirements contained in AMSA Marine Order Part 30 and Facility Safety Cases). **CM07**: Best practice design of the flare will be investigated in FEED to reduce flare height. **CM08:** An Artificial Light Management Plan will be developed in alignment with the Draft National Light Pollution Guidelines (DoEE 2019).	Minor
Seabirds and shorebirds	Change in fauna behaviour	**EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed		Moderate

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Fish		threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		Minor
Marine Reptiles				Moderate
State Protected Area – Marine	Change in ambient light Change in fauna behaviour Changes to the functions, interests or activities of other users Change in aesthetic value	**EPO14:** To not result in a change that may have an adverse effect on the protection and conservation of biodiversity, ecological processes and other natural, cultural and heritage values of marine parks and protected areas. **EPO15:** To not result in a change that may cause one or more of the World Heritage values or National Heritage values of a declared World Heritage property or National Heritage place to be lost, degraded or damaged, or notably altered, modified, obscured or diminished.		Moderate
Heritage features				Moderate

7.1.4 Emissions – Atmospheric Emissions

Atmospheric emissions produced during the Corowa Development can be classified into two categories:

- atmospheric pollutants
- greenhouse gas emissions.

For the purposes of the impact assessment, atmospheric pollutants are defined as gases or particulates produced from facilities, vessels or machinery, which are discharged to the atmosphere and pose a recognised level of adverse effect on flora, fauna and/or human health. Atmospheric emissions that most commonly suit these criteria include:

- oxides of nitrogen (NO_x)
- carbon monoxide (CO)
- sulphur dioxide (SO_2) and oxides of sulphur (SO_x)
- volatile organic compounds (VOCs) (methane)
- non-methane VOC's (benzene, xylenes, toluene, ethylbenzene)
- particulate matter that is less than 10 microns (PM_{10}).

Greenhouse gas (GHG) emissions refers to gases that trap heat within the atmosphere through the absorption of longwave radiation reflected from the Earth's surface. The most common GHGs include:

- carbon dioxide (CO_2)
- nitrous oxide (N_2O)
- methane (CH_4)
- sulphur hexafluoride (SF6)
- hydrofluorocarbons (HFCs)
- perfluorocarbons (PFCs).

7.1.4.1 Aspect Source

Throughout the Corowa Development, atmospheric emissions including atmospheric pollutants and greenhouse gas emissions will be generated during these phases and activities:

Drilling	well clean-up and flowback
Installation, Hook-up and Commissioning	MOPU
Operations	hydrocarbon processing, storage and offloading
Support Activities (all phases)	MODU operations; MOPU operations; FSO operations; Vessel operations

Drilling, Operations

Although the target hydrocarbon of the reservoir is crude oil, the reservoir is expected to produce associated gas at a ratio of gas to oil of 700 standard cubic feet per storage tank barrel of oil produced. This associated gas will be flared. Flaring and/or venting operations and may occur during hydrocarbon processing, storage and offloading activities.

Flaring and/or venting will occur during wellbore clean-up and flowback activities. During drilling operations, very small quantities of gas may break out of the drilling fluid during processing of the returned drilling fluid. Once drilling is complete, the wellbore will contain a volume of drilling fluid and require clean-up, which involves displacing the drilling fluid to surface, followed by flowing the well to surface.

Flaring will be undertaken throughout the operations phase during hydrocarbon processing, storage and offloading activities. During hydrocarbon processing, excess gas that is not used as fuel gas on board the MOPU will be sent directly to the flare stacks to be flared. Flaring or venting of gas may also occur on board the FSO during storage and offloading activities. This will be achieved through the routing of accumulated gas in the storage tanks to onboard vents or flare stacks.

Gas produced from the reservoir during operations that exceeds that able to be used as fuel gas on the MOPU will be flared. Emissions from the burning of fuel, flaring and venting will be emitted to the atmosphere. Atmospheric emissions will include greenhouse gases (CO_2 and small amounts of CH_4 and N_2O) as well as atmospheric pollutants NO_x, SO_x, VOC and PM_{10}.

Installation, Hook-up and Commissioning

Another source of atmospheric emissions associated with the proposed Development is the venting of nitrogen during pressure testing of process pipework during commissioning activities of the MOPU.

It is anticipated that 2,000 sm^3 of nitrogen would be vented. This is only planned to be undertaken once during project life; however, if major repairs are required on the MOPU, recommissioning of process equipment may be undertaken, which would vent a similar volume.

Support Activities

During the drilling and operational phases of the Corowa Development, atmospheric emissions will be released to the surrounding environment through the burning of fuel for power and heat generation to allow for facility operation.

The MOPU, MODU, FSO and support vessels used during the Corowa Development will produce atmospheric emissions from the use of fuel for onboard generators and engine operation. Vessels and facilities require the use of onboard generators for power generation. Engine operation on board facilities and vessels using marine fuel; i.e. marine diesel oil (MDO) or marine gas oil (MGO).

MDO and MGO are required for operations such as transport, sewage treatment and desalination to occur. Both atmospheric pollutants and GHGs' will be produced through the burning of fuel.

7.1.4.1.1 *Modelling and Exposure Assessment – Atmospheric Pollutant Emissions*

The content and ratios of atmospheric pollutant emissions are highly dependent on fuel type used. For example, SO_x and particulate matter content is higher in MDO than MGO.

Atmospheric emissions have been calculated using NGERs methodology. The NGERs National Greenhouse Account Factors 2018 for greenhouse gases and emissions factors is consistent with the National Pollutant Inventory Oil and Gas Extraction and Production Methodology for other atmospheric pollutants. Vessel emission information was sourced either from vessel providers or actual fuel consumption during a 2018 Australian well installation program.

Emissions have previously been modelled by Environ (2014) for a natural gas and fuel oil burning heat and power facility for another operator. NO_x is considered the primary pollutant of interest due to the large volume of pollutant emitted compared to other pollutants for the Corowa Development. The NEPM Ambient Air Quality Measures relevant to NO_x emissions state an annual maximum concentration exposure standard of 0.03 ppm (56 $\mu g/m^3$) and a maximum one-hour concentration of 0.120ppm (226 $\mu g/m^3$) for NO_x (as NO_2) with maximum allowable exceedances of 1 day a year. WHO air quality guideline for NO_2 are 40 $\mu g/m^3$ annual mean.

The Environ study shows a maximum one-hour ground level concentration 67% of the NEPM criteria in the immediate vicinity of the facility and the annual average is 14% of the criteria. Across the 15 km x 15 km model domain the annual average NO_x concentration is equal to 5% of the NEPM. At a distance of 3 km from the facility ground level concentration are predicted to be below 4% of NEPM criteria. A study on far-field impacts of NOx emissions from a large offshore gas production and compression facility by BP (2013) with comparable emissions characteristics to the Corowa development shows that within 40 km of the source background annual average NO_x levels are increased by ~0.1 µg/m³ (0.0001 ppm). This represents an increase of 2% over typical background levels.

The volume of atmospheric pollutants emitted from the facilities noted in the Environ and BP studies are comparable to those from the Corowa Development. Given the nature and scale of these emissions it is considered appropriate to use these studies to predict atmospheric pollutant NO_x emission attenuation of the aggregated emissions from the MOPU, MODU, FSO and support vessels.

7.1.4.1.2 Modelling and Exposure Assessment – Greenhouse Gas Emissions

GHG emissions are measured as tonnes of carbon dioxide equivalence (CO_2-e). This means that the amount of a GHG that a business emits is measured as an equivalent amount of CO_2, which has a global warming potential of one.

The direct (Scope 1) and indirect (Scope 2 and 3) GHG emissions have been calculated for the Corowa Development. Definition of Scope 1, 2, and 3 emissions as well as the scope boundary of greenhouse gas emissions estimates are described in Appendix C (Xodus Group 2019b). The Department of the Environment and Energy (DoEE) have provided advice for primary approvals that are assessed under the EPBC Act, rather than OPGGS(E)R, such as the Corowa Development. This Commonwealth guidance has been used as the basis for the calculation of GHG emissions from the Corowa Development; to estimate maximum emissions, from the Project Area and, to the extent it can be predicted, from elsewhere as it is transported and combusted, in Australia or overseas.

GHG Emissions – Direct (Scope 1)

Scope 1 GHG emissions are those released to the atmosphere as a direct result of an activity, or series of activities at a facility level, sometimes referred to as direct emissions. Examples include emissions produced from power generation and from burning diesel fuel in vessels.

Similar to other oil and gas developments in the NWS (i.e. Macedon, Gorgon, Vincent and Greater Enfield), Corowa will emit GHG emissions made up almost entirely of CO_2, as opposed to methane and nitrous oxide. Significant emissions of other sources of GHG such as hydrofluorocarbons, perfluorocarbons or sulphur hexafluoride are not planned to be emitted by the Corowa Development.

The National Greenhouse and Energy Reporting (NGER) (Measurement) Determination 2008 an instrument under the Commonwealth *National Greenhouse and Energy Reporting (NGER) Act 2007* is designed for use by companies and individuals to estimate greenhouse gas emissions.

All emissions factors and energy content figures used to calculate emissions were sourced from the NGER (Measurement) Determination 2008 (as amended 2019) and the API Compendium of GHG Emissions Methodologies (API 2009). The Corowa Greenhouse Gas Assessment Report details the calculation methodology, calculation inputs and results of greenhouse gas estimates for the Corowa Development (Xodus Group 2019b, Appendix C). Results from the study are summarised in Table 7-24 which provides the calculation of direct GHG emissions (Scope 1) for the life of the Corowa Development including all phases of development described in Section 3.

Table 7-24 Direct (Scope 1) GHG Emissions Inventory – Assumptions, Methodology and Estimation

Emissions Source	Calculation			GHG Emissions for Project Life ($T\ CO_2$-e)			
Activity	Estimation Methodology	Inputs	Emission Factor Used	CO_2	CH_4	N_2O	Total
Vessel operations (all phases)	NGER (Measurement) Determination 2008: Transport fuel emissions	Activity type, vessel type and numbers as per section 3, daily fuel consumption and duration	Fuel oil and diesel oil	90,049	86	734	90,869
Helicopter operations (all phases)	NGER (Measurement) Determination 2008: Transport fuel emissions	Helicopter type, fuel consumption, flight distance, flight speed	Kerosene for use in an aircraft	1,220	0	11	1,231
Flaring (all phases)	NGER (Measurement) Determination 2008: Crude oil production (flared emissions)	Oil and gas production rate, duration of flaring, gas composition (molecular weight)	Gas Flared	848,441	242,412	9,090	1,106,528
Electrical Power Generation MOPU, MODU and FSO (all phases)	NGER (Measurement) Determination 2008: Stationary energy emission	Power generation method, fuel type, gas composition (molecular weight), fuel energy content, energy efficiency	Unprocessed natural gas and diesel oil	86,346	114	247	86,716
Process Heating (all phases)	NGER (Measurement) Determination 2008: Stationary energy emission	Heat generation method, fuel type, gas composition (molecular weight), fuel energy content, energy efficiency	Unprocessed natural gas	27,788	54	16	27,858
Fugitive Emissions (All phases)	NGER (Measurement) Determination 2008: Crude oil production (non-flared) – fugitive leaks emissions of methane API Compendium of GHG	Oil Throughput	Fixed Roof Tank Offshore Oil Production	-	23,757	-	23,757

Emissions Source	Calculation			GHG Emissions for Project Life (T CO_2-e)			
Activity	Estimation Methodology	Inputs	Emission Factor Used	CO_2	CH_4	N_2O	Total
	Emissions Methodologies: Facility-Level Average Emission Factors Approach						
Approximate Total Direct Emissions							**1,300,000 (1.3 MT CO_2-e)**

Assumptions:

- *Assumed four years of production for P10 outcome.*
- *Flaring emissions assumed to be P10 reservoir outcome.*
- *All emissions factors and energy content figures sourced from NGER (Measurement) Determination 2008 Schedule 1Helicopter characteristics from a representative helicopter (https://www.polarisaviation.com/wp-content/uploads/2015/06/S76-C-Specs-Sheet.pdf)*
- *Internal combustion power generation assumed to be 35% thermal efficiency.*
- *Turbine power generation assumed to be 35% thermal efficiency.*
- *Vessel fuel burn data sourced from 2018 data from well construction activities in Australian waters using MODU and AHTSs.*
- *ISV fuel burn from a representative vessel (http://www.dofman.no/Files/System/dof2008/pdf/csv/Skandi_Hercules.pdf)*

The calculated direct (Scope 1) emissions from the Corowa Development total 1.3 MT CO_2-e for the total field life of all phases of the project, with the most optimistic reservoir outcome (P10) assuming four years of operation. This figure has been used for the purposes of impact assessment, as the most conservative estimate.

Direct (Scope 1) annual emissions for the best estimate reservoir outcome (P50) is 0.8 MT CO_2-e/year for the first year, falling to 0.27 T CO_2-e/year in the second year of operation.

Figure 7-12 shows the breakdown of GHG emissions by project phase for the Corowa Development.

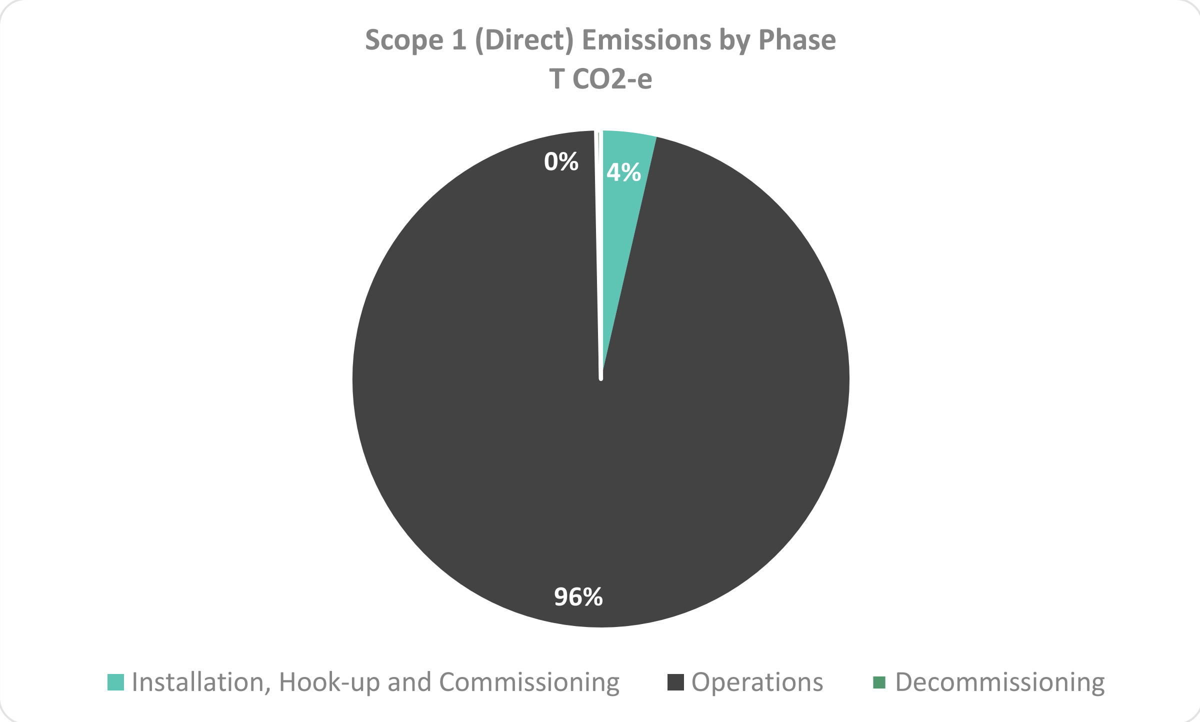


Figure 7-12 Direct (Scope 1) Emissions Calculations by Corowa Development Phase

As the operations phase presents the largest source of GHG emissions (1.28 MT CO_2-e), Figure 7-13 shows the breakdown of emissions by source. The greatest contributor is from flaring, which comprises 88% of GHG emissions during the operations phase (1.1 MT CO_2-e). A comparative analysis was undertaken on the gas strategy, on alternatives for associated gas. Section 4.3.1 demonstrates that use as fuel gas and flaring for excess gas are the selected options.

Western Australia is the first Australian jurisdiction to join the World Bank's Zero Routine Flaring by 2030 initiative, to more efficiently manage natural gas resources and reduce greenhouse gas emissions. However, the Corowa Development is expected to be decommissioned before 2030.

In an analysis of worldwide gas flaring volumes between 2014 and 2018, the World Bank ranks Australia as 30th (NOAA Colorado School of Mines 2018).

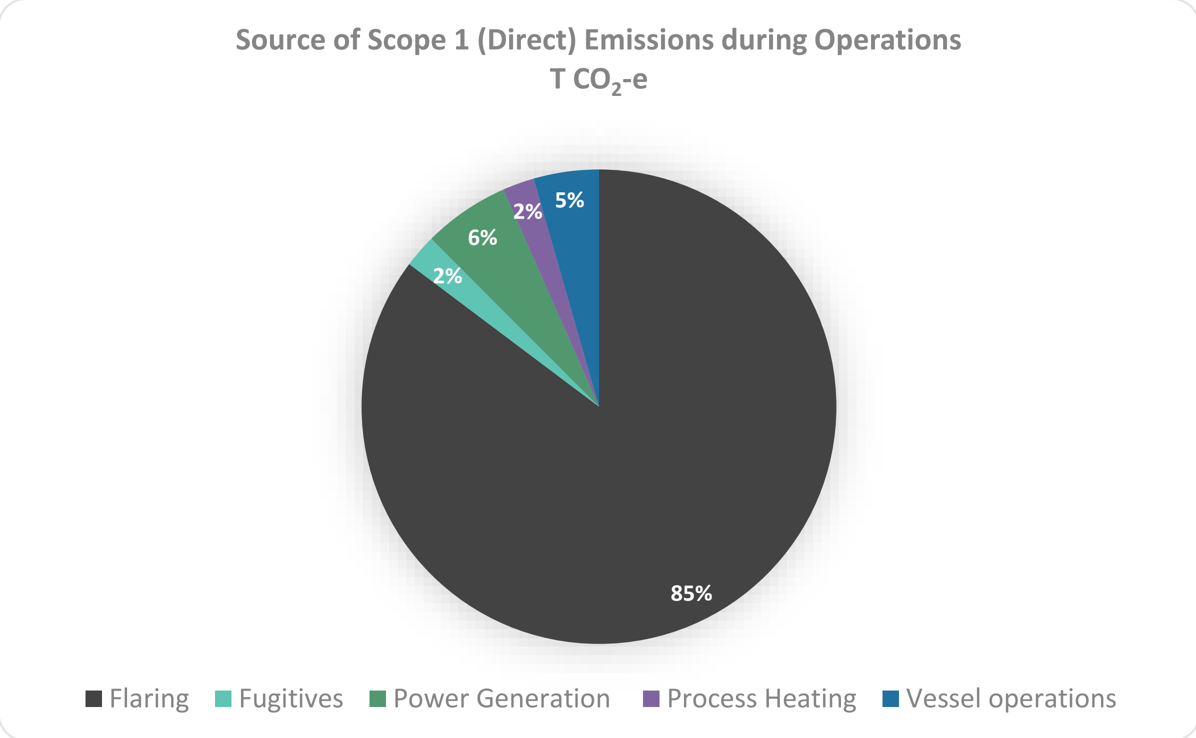


Figure 7-13 Source of Direct (Scope 1) Emissions during Operations Phase

The National Inventory Report 2017 Volume 1 (DoEE 2019) provides an emissions inventory for the States and Australia, which is submitted under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Table 7-25 provides a comparison between Corowa Development direct (Scope 1) emissions against the total GHG inventory for WA and Australia.

Table 7-25 Comparison of Corowa Development Direct Emissions with WA and Australia Annual GHG Inventory

Source of Emissions – Operations	% of WA's Annual GHG Emissions^	% of Australia's Annual GHG Emissions^
Maximum annual emissions of the Corowa Development*	0.14%	0.91%
Maximum emissions of total field life of Corowa Development#	0.24%	1.55%
Assumptions: ** Using first year of high estimate (P10 profile)* *# <4.5 years for high estimate (P10 profile)* *^ Source: National Inventory Report 2017 Volume 1 (DoEE 2019)*		

GHG Emissions – Indirect (Scope 2 and 3)

Indirect emissions associated with the transport, refining and consumption of oil products by customers) are described below. Details on the calculation methodology, inputs and detailed results are presented in Appendix C (Xodus Group 2019b).

The NGERS scheme defines Scope 2 emissions as those released to the atmosphere from the indirect consumption of an energy commodity. For example, 'indirect emissions' come from using electricity produced by the burning of coal at another facility.

No indirect Scope 2 emissions are associated with the Corowa Development—KATO will not purchase power from an external provider, instead generating all its power requirements directly.

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. Relevant to Corowa, this is the transportation of exported oil, and the subsequent burning of that oil for energy by the customer.

Scope 3 greenhouse gas emissions are not reported under the NGER Scheme but have been estimated using Australia's National Greenhouse Accounts. For Corowa, oil will most likely be exported to international markets.

Table 7-26 provides the calculation of indirect GHG emissions (Scope 3) for the life of the Corowa Development. Indirect emissions associated with delivering the crude oil, refining the oil into end products and the consumption of these products by the end customer are calculated as 4.57 MT CO_2e.

The energy content factor used in the calculation of oil product carbon intensity sourced from NGER (Measurement) Determination 2008 for 'crude oil including crude oil condensates' was 45.3 GJ/t. Therefore, the Corowa Development has been estimated to emit 19.8 gCO_2-e/MJ of product, or 10.4 kg CO_2-e/stb.

Table 7-26 Indirect (Scope 3) GHG Emissions Inventory – Assumptions, Methodology and Estimation

Emissions Source	Calculation			GHG Emissions for Project Life
Activity	**Estimation Methodology**	**Inputs**	**Emission Factor Used**	**Total (T CO_2-e)**
Oil Transport	NGER (Measurement) Determination 2008: Crude oil transport	Oil Throughput	Crude oil transport	1,255
Oil Refining	NGER (Measurement) Determination 2008: Crude oil refining	Oil Throughput	Crude oil refining	1,226
Oil Storage	NGER (Measurement) Determination 2008: Crude oil refining	Oil Throughput	Fixed roof tank	216
Consumer Use	NGER (Measurement) Determination 2008: Appendix 4 Scope 3 emission factors	Oil Throughput	Crude oil including crude oil condensates	4,568,895
TOTAL Indirect (Scope 3) Emissions				**4,571,593 (4.57 MT CO_2-e)**

Assumptions:

All emissions factors and energy content figures sourced from NGER (Measurement) Determination 2008 Schedule 1Conservatively assumes all oil produced is used as fuel rather than manufactured into secondary products (plastics, chemicals etc.).

7.1.4.2 Impact Analysis and Evaluation

Atmospheric emissions generated throughout the Corowa Development have the potential to result in these impacts:

- change in ambient air quality
- change in climate.

As a result of a change in ambient air quality, further impacts may occur, including:

- climate change.

Table 7-27 identifies the potential impacts to receptors as a result of atmospheric emissions of the Corowa Development.

Receptors marked '*X*' are subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-28 provides a summary and justification for those receptors not evaluated further.

Table 7-27 Identification of Receptors Potentially Impacted by Emissions – Atmospheric

Impacts	Ambient air quality	Climate	Plankton	Benthic habitats and communities	Coastal habitats and communities	Fish	Seabirds and shorebirds	Marine mammals	Marine reptiles	KEFs	AMPs	Commercial Fisheries	State Protected Areas	Tourism and recreation
Change in air quality	✓													
Climate change		✓												
Injury/ mortality to fauna			*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*		*X*	
Change in ecosystem dynamics			*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*		*X*	
Changes to the functions, interests or activities of other users										*X*	*X*	*X*	*X*	*X*

Table 7-28 Justification for Receptors Not Evaluated Further for Emissions – Atmospheric

Ecological Receptors: Plankton, Benthic habitats and communities, Coastal habitats and communities, Fish, Seabirds and Shorebirds, Marine Mammals, Marine reptiles	***X***
Injury /mortality to fauna; Change in ecosystem dynamics Changes to climate and oceanographic processes 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. Climate change is predicted to increase ocean acidification, which may affect the calcium carbonate structure of animals at the base of the marine food web. This may in turn affect prey availability. Global warming and associated changes in sea level are likely to have a long-term impact on the breeding, staging and non-breeding	

grounds of migratory shorebirds and seabirds (Harding et al. 2007). Changes in abundance and distribution of prey and fish species may lead to continual changes in foraging methods and spatial and temporal distribution of foraging effort. Climate change may also influence the scale and severity of other threats, in turn directly influencing survival and breeding parameters. The 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. The International Panel on Climate Change recognises climate change as a major contributor to Australian marine ecosystem changes since 2007 (DoEE 2018f).

EPBC Policy Statement 'Indirect consequences' of an action: Section 527E of the EPBC Act (DSEWPaC 2013) defines an impact of a primary action (i.e. the Corowa Development) as:

'an event or circumstance which is:

- a direct consequence of the action
- an indirect consequence of the action, if the action is a substantial cause of the event or circumstance.'

Because the maximum annual direct GHG emissions from Corowa is predicted to emit only 0.14% of Australia's annual GHG emissions, the primary action (Corowa Development) does not represent a 'substantial cause' of the circumstance (climate change). Therefore, climate change is not considered an indirect consequence of the Corowa Development for the purposes of Section 527E of the EPBC Act (DSEWPaC 2013).

Further to this, the EPBC Policy Statement provides guidance where the circumstance (i.e. climate change) is a consequence of another action taken by a different person (secondary action) that was not taken at the request of KATO.

KATO have calculated use of oil and refinery products by consumer (indirect Scope 3 emissions), but do not consider this constitutes a 'secondary action' as per the EPBC Policy Statement document (DSEWPaC 2013).

Climate change would only be considered an 'impact' of the Corowa Development for the purposes of section 527E if:

- 'the primary action facilitates the secondary action 'to a major extent'
- the secondary action is within the contemplation of the person taking the primary action or is a reasonably foreseeable consequence of the primary action.'

Corowa oil will be purchased by a refinery, likely in Asia, which will blend the oil and refine petroleum-based products, which may be sold directly to customers or used in subsequent manufacturing processes and on-sold, eventually releasing GHG emissions. The contribution of Corowa to oil refinery products and the global oil market is a small proportion of supply and does not facilitate 'to a major extent' the indirect consequences of producing and consuming oil and petroleum fuel products. Corowa's total recoverable oil is equivalent to 0.02% – 0.03% of annual global oil production (best and high estimate respectively; US Energy Information Administration 2019).

The total GHG emissions from both direct (Scope 1) and indirect (Scope 3) for the whole project life of the Corowa Development is equivalent to 0.011% of global annual CO_2-e emissions in 2017 (UN Environment 2018).

Climate change as a consequence of GHG emissions from all industries and nations is not facilitated 'to a major extent' by the Corowa Development. The proportion of annual GHG emissions from the Corowa Development compared to even one nation's annual emissions (0.91% of Australia's annual inventory) is too small for it to be considered a 'substantial cause' of a complex, global phenomena. The time frame of emissions is also relatively short, at ~5 years for project life.

Therefore, any changes to climate as a result of the Corowa Development are not expected to result in injury /mortality to fauna or change in ecosystem dynamics and therefore are not evaluated further.

Social, Economic and Cultural Receptors: KEFs, AMPs, Commercial Fisheries, Tourism and Recreation, State Protected Areas – Marine, State Protected Areas – Terrestrial	***X***

<u>Change in ecosystem dynamics; Injury / mortality to fauna; Changes to the functions, interests or activities of other users</u>

Changes to climate can impact natural systems such as AMPs, KEFs and State Protected Areas. The potential impact of climate change to the conservation values of these areas have been evaluated under separate Ecological Receptors above.

Climate can cause changes to the functions, interests or activities of other users through changes to conservation values of natural systems of the above, which could lead to a reduction in marine-based tourism and recreation, and commercial fisheries.

Because the maximum annual direct GHG emissions from Corowa is predicted to emit only 0.14% of Australia's annual GHG emissions, the primary action (Corowa Development) does not represent a 'substantial cause' of the circumstance (climate change). Therefore, climate change is not considered an indirect consequence of the Corowa Development for the purposes of Section 527E of the EPBC Act (DSEWPaC 2013).

Climate change as a consequence of GHG emissions from all industries and nations is not facilitated 'to a major extent' by the Corowa Development. The proportion of GHG emissions from the Corowa Development compared to even one nation (Australia, at 0.91%) is too small for it to be considered a 'substantial cause' of a complex, global phenomena. The duration of emissions is also relatively short term (~5 years).

Therefore, any changes to climate as a result of the Corowa Development are not expected to result in change in ecosystem dynamics, injury /mortality to fauna or changes to the functions, interests or activities of other users, and therefore impacts to social, economic and cultural receptors have not been evaluated further.

Impacts to receptors are assessed below, by receptor type.

7.1.4.2.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of the production of atmospheric emissions include:

- ambient air quality
- climate.

Table 7-29 provides a detailed evaluation of the impact or risk of atmospheric emissions to physical receptors.

Table 7-29 Impact and Risk Assessment for Physical Receptors from Atmospheric Emissions

Ambient Air Quality ✓
Change in air quality
The release of atmospheric emissions during activities will result in a localised decline in air quality due to the increased presence of gases and particulates. As outlined above, emissions generated during activities include NO_x, CO, SO_2, VOC's (benzene, xylenes, toluene, ethylbenzene), non-VOC's, particulate matter, CO_2, N_2O, CH_4, SF_6, HFCs and PFCs. The presence of these emissions in the air may be odorous, toxic, or aesthetically unpleasing.
Air quality at the Corowa Development is expected to be high and typical to that of an unpolluted offshore environment. Emissions generated during activities will be similar to that generated during other activities undertaken in the North West region and result in a localised decrease in air quality at the point of release. Released emissions will dissipate quickly through wind action. Concentrations of NO_2 not expected to be above NEPM levels at any point throughout the development.
Approximately 2,000 sm^3 nitrogen will be vented during commissioning of the MOPU. Nitrogen makes up 78% of the Earth's atmospheric gas composition, and due to the open and dispersive environment at the Project Area, any change or effect on local air quality is expected to disperse rapidly and will therefore be short-term and limited to the point source of the emission. No measurable change or effect on local air quality is anticipated.

Given the details above, the consequence of atmospheric emissions causing a change in air quality has been assessed as **Minor (1)**, given that a change in ambient air quality will be highly localised and will return to background levels after emissions cease.
Climate ✓
Climate change GHG emissions generated during the Corowa Development through combustion and flaring will contribute to the overall concentration of GHG's in the Earth's atmosphere. Total GHG emissions generated during the Corowa Development will be comparatively less than other oil and gas operations occurring within the North West Shelf region due to the scale and short duration of the development and operations (~5 years). GHG emissions from the Corowa development are expected to have a negligible contribution to climate change. Because the maximum annual direct GHG emissions from Corowa is predicted to emit only 0.14% of Australia's annual GHG emissions, the primary action (Corowa Development) does not represent a 'substantial cause' of the circumstance (climate change). Therefore, climate change is not considered an indirect consequence of the Corowa Development for the purposes of Section 527E of the EPBC Act (DSEWPaC 2013). Climate change as a consequence of GHG emissions from all industries and nations is not facilitated 'to a major extent' by the Corowa Development. The proportion of annual GHG emissions from the Corowa Development compared to even one nation's annual emissions (0.91% of Australia's annual inventory) is too small for it to be considered a 'substantial cause' of a complex, global phenomena. The time frame of emissions is also relatively short, at ~5 years for project life. Therefore, any changes to climate as a result of the GHG emissions from the whole project life of the Corowa Development are not substantial on a national or state scale. Given the details above, the consequence of atmospheric emissions causing climate change has been assessed as **Minor (1)**, due to the relatively low contribution of GHGs' to the atmosphere from planned activities and the short duration of emissions.

7.1.4.3 Consequence and Acceptability

The consequence of Emissions – Atmospheric Emissions has been evaluated as **Minor (1)** for all potentially impacted receptors and is considered **acceptable** when assessed against the criteria in Table 7-30.

Table 7-30 Demonstration of Acceptability for Emissions – Atmospheric Emissions

Acceptability Criteria	Justification
To meet the principles of ESD	• The release of atmospheric emissions during activities will result in a localised decline in air quality due to the increased presence of gases and particulates. • Maximum annual direct GHG emissions from the Corowa Development only comprise 0.91% of Australia's annual GHG emission (conservatively using the high P10 estimate). Therefore, the primary action (Corowa Development) does not represent a 'substantial cause' of the circumstance (climate change), and climate change is not considered an indirect consequence of the Corowa Development for the purposes of Section 527E of the EPBC Act. • The duration of emissions is relatively short, with the Development life only 5 years, and the operations phase (source of 97% of emissions) only two to 4.5 years (for best and high estimate). • Background concentrations of pollutants within the permit area are low. • The location of the Corowa Development is a significant distance from sensitive receptors.
Internal context	• There are no specific KATO internal requirements with respect to atmospheric emissions or potentially impacted receptors.

Acceptability Criteria	Justification
External context	• Discussion on KATO's proposed gas strategy, and estimated greenhouse gas emissions held with the National Inventory Systems and International Reporting Branch of DoEE. • No stakeholder concerns have been raised with respect to air emissions or potentially impacted receptors.

Other requirements	• Activities undertaken during the Corowa Development will adhere to the requirements of the Commonwealth *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*.
	• The Commonwealth *National Greenhouse and Energy Reporting Act 2007* and *National Greenhouse and Energy Reporting Regulations 2008* requires reporting of emissions.
	• The WA government is signing up to the World Bank's 'Zero Routine Flaring by 2030' initiative. The Corowa Development will be decommissioned prior to 2030.
	• The Paris Agreement has established a framework for managing global climate change that relies on nations setting Nationally Determined Contributions and establishing domestic policies to meet them. Corowa will be subject to domestic laws that reflect Australia's commitment under the Paris Agreement.
	• North-west Marine Parks Network Management Plan 2018 (DNP 2018) identifies climate change as a pressure, with no explicit relevant management actions.
	• These Conservation Advices / Recovery Plans identify climate (and oceanography) variability and change as a key threat:
	  ○ Conservation advice *Balaenoptera borealis* Sei Whale (TSSC 2015a)
	  ○ Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 2015–2025 (CoA 2015a)
	  ○ Conservation advice *Balaenoptera physalus* Fin Whale (TSSC 2015b)
	  ○ Approved Conservation Advice for *Megaptera novaeangliae* (Humpback Whale) (TSSC 2015c)
	  ○ Conservation Management Plan for the Southern Right Whale (DSEWPaC 2011)
	  ○ Recovery plan for marine turtles in Australia (CoA 2017)
	  ○ Conservation advice for *Dermochelys coriacea* (Leatherback Turtle) (TSSC 2009a)
	  ○ Recovery plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013a)
	  ○ Conservation advice *Rhincodon typus* (Whale Shark) (TSSC 2001)
	  ○ Conservation advice *Calidris canutus* (Red Knot) (TSSC 2016a)
	  ○ National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011)
	• These conservation advices and recovery plan identify the following conservation actions:
	  ○ Continue to meet Australia's international commitments to reduce greenhouse gas emissions; or
	  ○ No explicit relevant management actions.
	• In regard to atmospheric emissions, activities associated with the Corowa Development will not be conducted in a manner inconsistent with a Recovery Plan, threat abatement plan or Conservation Advice for a listed threatened species or ecological community.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-31.

Table 7-31 Summary of Impact Assessment for Emissions – Atmospheric Emissions

<table>
<tr><th>Receptor</th><th>Impacts</th><th>EPOs</th><th>Adopted Control Measures</th><th>Consequence</th></tr>
<tr><td>Ambient air quality</td><td>Change in air quality</td><td rowspan="2">EPO10: To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.
EPO18: To not significantly contribute to Australia's annual greenhouse gas emissions.</td><td rowspan="2">CM09: Compliance with AMSA Marine Order 97 (Marine pollution prevention — air pollution).
CM10: Restrictions on import and use of Ozone Depleting Substances (ODS) for refrigeration and air conditioning systems as per the Commonwealth Ozone Protection and Synthetic Greenhouse Gas Management Act 1989.
CM11: Use of associated gas as fuel gas during operations is optimised to enable the safe and economically efficient operation of the facility.
CM12: Reporting of GHG emissions are required as per the National Greenhouse and Energy Reporting (NGER) Scheme.
CM13: Operations designed to be optimised to enable the safe and economically efficient operation of the facility.</td><td>Minor</td></tr>
<tr><td>Climate</td><td>Climate change</td><td>Minor</td></tr>
</table>

7.1.5 Emissions – Underwater Noise

Underwater noise emissions can be the product of anthropogenic sources, which can be either impulsive (i.e. pulsed) or continuous (i.e. non-pulsed). These emissions differ from ambient noise, which are dominated by natural physical (wind, waves, rain) and biological (echolocation, communication) sources.

Multiple metrics are commonly used to express sound levels and assess potential impacts to marine fauna; therefore, any comparisons between specific sound level values must be made using the same measures.

Underwater noise is measured using the decibel scale (dB), which is a logarithmic scale used to measure the amplitude or loudness of a sound. dB is a ratio relevant to a reference level of 1 micropascal (dB re 1 µPa) underwater and 20 µPa in air. Underwater noise is typically measured as Sound Pressure Level (SPL), which can represent multiple types of measurements, including zero-to-peak pressure (0-pk, or PK), peak-to-peak pressure (pk-pk), and root-mean-square (RMS), which is an average repressure over a duration of time. RMS is commonly associated with continuous sounds.

For environmental impact thresholds, Sound Exposure Level (SEL) can also be used, which can be the exposure over one second (SEL) or cumulative (SELcum), typically over 24 hours. SEL is a metric used to describe the amount of acoustic energy that may be received by a receptor (such as a marine animal) from an event. Sound source level and frequency of sound generated varies considerably between different sources.

Due to the continuous non-pulsed properties of continuous noise, the risk and severity of potential impact to marine fauna is lower than that for impulsive noise. In the oil and gas industry, activities that produce continuous noise include vessels, drilling, and ROVs.

Impulsive noise is a series of pulsed noise events, most common in industrial construction or exploration. In the oil and gas industry, activities that produce impulsive noise include seismic acquisition, VSP, pile driving, blasting (single pulse), multibeam echo sounder (MBES), and sonar.

7.1.5.1 Aspect Source

Throughout the Corowa Development, noise will be generated as part of normal operations during these phases and activities:

Survey	geophysical survey (sonar)
Drilling	top-hole drilling; bottom-hole drilling; completions (VSP)
Operations	well intervention
Decommissioning	well P&A
Support Activities (all phases)	MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations

Survey

A geophysical survey may be required before Corowa Development infrastructure is installed and commissioned. Such a survey would ensure suitable seabed conditions exist for the legs of the MODU or MOPU, flowline, and the CALM buoy anchor array. Underwater noise emissions associated with geotechnical surveys may include techniques that involve using high-frequency sonar to provide high-resolution bathymetry and geophysical data, such as side-scan sonar (SSS), sub-bottom profiler (SBP) or MBES. Sonar generates high-frequency acoustic emissions that attenuate rapidly in the underwater environment. The geophysical survey is expected to take one to two days to complete. Table 7-32 details typical frequencies and noise levels emitted by each source type.

Drilling

During the positioning of subsea structures, long-based (LBL) transponders may be placed on the seabed. During the ROV operations, ultra-short-based (USBL) systems may be used for positioning. Typical noise levels and frequencies of positional equipment are detailed in Table 7-32.

Table 7-32 Typical Sound Source Levels and Frequencies of Survey and Positional Equipment

Activity	Source	Frequency	Sound Source Level	Sound Type	Reference
Survey	SSS	100–675 kHz	229 dB re 1 µPa RMS @ 1 m	Impulsive	Geoscience Australia 2019b Tritech 2019 MacGillivray et al. 2013
	SBP	3 Hz–100 kHz	200 dB re 1 µPa RMS @ 1 m	Impulsive	Geoscience Australia 2019b MacGillivray et al. 2013
	MBES	30–100 kHz	218 dB re 1 µPa RMS @ 1 m	Impulsive	MacGillivray et al. 2013
Drilling	LBL	19–34 kHz	187–202 dB re 1 µPa @ 1 m	Impulsive	Sonardyne 2019

Activity	Source	Frequency	Sound Source Level	Sound Type	Reference
	USBL	19–34 kHz	187–196 dB re 1 µPa @ 1 m (PK)	Impulsive	Sonardyne 2019
	VSP	5–200 Hz	238 dB re 1 µPa @ 1 m (zero to peak SPL) ~228 dB re 1 µPa RMS @ 1 m[18]	Impulsive	Mathews 2012 McCauley and Kent 2008 SLR 2017 Green 1997

Drilling operations are likely to produce mid-frequency underwater sounds, as detailed in Table 7-32, with most noise generated by drill string vibrations. Up to four wells may be drilled over approximately five months for the initial campaign, and an additional four months if infill drilling is required.

VSP (a pulsed noise source) may be used to evaluate the wells. Typical outputs are detailed in Table 7-32. The duration of this testing will be very short term (<24 hours per well), and use relatively small airguns that generate low sound energy levels.

Decommissioning

During the decommissioning of the Corowa Development, production tubing, well and surface casings, and the conductor and wellhead below the seabed will be cut. Increased noise levels may occur as a result of these mechanical cutting operations.

Support Activities (all phases)

Operation of the MODU and MOPU facilities will produce noise from on-board machinery such as generators, air compressors, pumps and motors; however, all this machinery above water thus reducing the level of transmission. The MODU and MOPU will produce low-intensity, low-frequency (<2 kHz) noise emissions. The MODU will emit routine acoustic emissions during the drilling phase (~9 months if two drilling campaigns are required); the MOPU will emit acoustic emissions for the entire duration of the Corowa Development.

Various vessels (listed in Table 3-13) will operate throughout the duration (~5 years) of the Corowa Development. This number will peak with up to ten support vessels during drilling, commissioning and decommissioning. During normal operations (~2–4.5 years), only one to two support vessels are expected. Table 7-33 details typical noise emissions for vessels, which may include the FSO, offtake/shuttle tankers, support and anchor laying vessels. During normal operating conditions (vessel idling or standard operations within the Project Area) the low vessel noise would only be detectable over a short distance [>94 dB re 1µPa RMS at 3000 m (Table 7-37)]. During tanker offloading when dynamic positioning thrusters may be used; short-term increased underwater noise levels may be emitted while the tanker is kept on station with the FSO and CALM buoy. Offloading is expected to occur every 15–20 days, with each offloading process expected to take ~48–72 hours.

Support vessels will be used during all phases of the Corowa Development. Shipping noise generally dominates ambient noise at frequencies from 20 to 300 Hz (Richardson et al. 1995). High-frequency components of the sound source spectrum rapidly dissipate with distance from the sound source, allowing the lower frequency wavelengths to travel further distances.

[18] Converted value of *zero to peak SPL* to *RMS* using Green (1997) which states RMS levels are, in effect, average levels over the duration of the seismic pulse. The difference between the two measures averages about 10 dB.

However, noise emissions from ROV thrusters and propulsion will be lower frequency, intermittent, and minimal and therefore are not discussed further.

Helicopters will service the MODU, MOPU and the FSO (up to one to two round trips per day from the mainland to the facilities during drilling; five to eight round trips per week during production operations). The generation of underwater noise from helicopters will be brief, typically during take-off and landing, with peak received levels diminishing with increased altitude.

Noise emitted from helicopter operations is typically below 500 Hz (Richardson et al. 1995). Richardson et al. (1995) reports that helicopter noise was audible in air for four minutes before it passed over underwater hydrophones, but only detectable underwater for 38 seconds at 3 m depth and 11 seconds at 18 m depth.

Table 7-33 Indicative Noise Emissions for Project Activities

Source	Frequency	Sound Source Level	Sound Type	Reference
MODU (Drilling)	4 Hz–100 kHz	100–190 dB re 1 µPa RMS @ 1 m	Continuous	McCauley R.D. 1998 WDCS 2004 Gales 1982
MOPU/ (Non-Drilling)	4 Hz–100 kHz	85–135 dB re 1 µPa RMS @ 1 m	Continuous	McCauley R.D. 1998 WDCS 2004 Gales 1982
Vessels/ FSO	20–300 Hz	165–184 dB re 1 µPa RMS @ 1 m	Continuous	Hannay et al. 2004 Richardson et al. 1995
Helicopters	500 Hz	162 dB re 1 µPa RMS @ 1 m	Continuous	Richardson et al. 1995 WDCS 2004

7.1.5.2 Impact Analysis and Evaluation

Underwater noise emissions generated by the Corowa Development have the potential to result in this impact:

- change in ambient noise.

As a result of a change in ambient noise, further impacts may occur, including:

- change in fauna behaviour
- injury/mortality to fauna.

Table 7-34 identifies the potential impacts to receptors as a result of underwater sound from the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-35 provides a summary and justification for those receptors not evaluated further.

Table 7-34 Receptors Potentially Impacted by Emissions – Underwater Noise

Impacts	Ambient noise	Plankton	Benthic habitats and communities	Fish	Marine mammals	Marine reptiles	Commercial fisheries
Change in ambient sound	✓						
Change in fauna behaviour		X	X	✓	✓	✓	
Injury/mortality to fauna		X	X	✓	✓	X	
Changes to the functions, interests or activities of other users							X

Table 7-35 Justification for Receptors Not Evaluated Further for Emissions – Underwater Noise

Plankton ***X***

Injury/mortality to marine fauna

Noise emissions that may cause behavioural change in plankton species within the Corowa Development area will be from acoustic sources during the geophysical survey and from VSP before installation and during drilling phases. These short-term noise emissions will occur from a few hours to a few days.

Few studies have reported negative impacts of impulsive noise on zooplankton (including meroplankton or temporary members of the plankton such as fish eggs and larvae, and invertebrate and coral larvae), and none from more than 10 m away from an airgun. This suggests the range of chronic effects on fish eggs and larvae due to seismic discharges is likely to be restricted to <10 m (Table 7-8). Popper et al. (2014) presented a threshold of >210 dB re 1 µPa2.s (SEL) or 207 dB re 1 µPa (PK) for mortality and potential mortal injury. The activity with the greater sound emissions proposed in the Corowa Development is SSS, which is predicted to have a source level of 229 dB re 1 µPa @ 1 mRMS. Matthews (2012) predicts noise levels are expected to attenuate rapidly to below 160 dB re 1 µPa2.s (SEL) within 500 m from a 228 dB re 1 µPa @ 1 m RMS source. Therefore, while it is possible that very localised injury may occur directly around the VSP source array, physical injury or mortality to plankton at a population level will not occur. Therefore, the impacts from noise emissions to plankton injury/mortality are not assessed further.

Change in fauna behaviour

Noise emissions that may cause behavioural change in plankton species within the Corowa Development area will be from acoustic sources during the geophysical survey and from VSP before installation and during drilling phases. These short-term noise emissions will occur from a few hours to a few days. There is a moderate risk of behavioural effects to fish eggs and larvae within tens of metres of the source (Popper et al. 2014), whilst McCauley et al. (2017) reports impacts up to 1.2 km from a 150 cui airgun. It is possible that zooplankton, including free-swimming larvae, could move either vertically or horizontally within the water column in response to a stimulus such as underwater noise.

Plankton have a patchy distribution linked to localised and seasonal productivity that produces sporadic bursts in populations (DEWHA 2008). The oligotrophic waters of the project area are typical of the wider offshore region supporting low phytoplankton biomass and relatively low primary productivity (Woodside 2005). Sound emissions on sparse plankton populations are unlikely to cause a significant change in behaviour at a measurable level. Therefore, the potential impacts from noise emissions on plankton are not evaluated further.

Benthic Habitats and Communities ***X***

Injury/mortality to fauna

Benthic fauna including crustaceans and bivalves are only susceptible to underwater noise when close to the source (less than a few metres) (McCauley 1994). The benthic habitat within the Project Area does not represent a diverse population or contain any sensitive benthic communities. Previous installations indicate

that underwater noise generated by operational platforms does not appear to have a detrimental effect on benthic communities. Inspections of various platforms have shown subsea infrastructure acts as artificial reefs with associated diverse benthic habitats and communities. Sound emissions from all activities are not expected to cause a change in behaviour in benthic habitats and communities and therefore are not evaluated further.	
Marine reptiles	***X***
Injury/mortality to fauna Underwater sound emissions such as SSS and VSP from the Corowa Development will not cause injury or mortality to marine reptiles. Popper et al. (2014) described injury thresholds for turtles (>207 dB PK); however, no thresholds were described for behavioural disturbance. VSP modelling presented in the fish evaluation section below shows that noise emissions from SSS and VSP are expected to attenuate below these thresholds within a very short range (<50 m). In addition these activities are likely to occur over short periods (SSS ~ 1 week; VSP <24 hours per well) through the duration of the development. Therefore, incidental occurrences of marine turtles near the geotechnical survey or drilling activity are likely to cause movement away from the noise source with any potential impact on turtles considered minimal with no physical injury or mortality to marine reptiles are expected. Therefore, the impacts from acoustic emissions to the injury or mortality of marine reptiles are not evaluated further.	
Commercial Fisheries	***X***
Changes to the functions, interests or activities of other users Commercial fish species may be present in the operational area (Section 5.5.2) but noise from a vessel, MOPU and MODU undertaking offshore activities would be equivalent to a fishing vessel, hence impacts to commercial fish species are not expected. VSP will occur over a very short duration (24 hours per well) and previous modelling (Woodside 2003) showed sound levels from VSP achieved background levels at a distance of 3 km. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). Any potential impacts to fish will be localised and temporary and no impacts to commercial fisheries are expected, and therefore are not evaluated further.	

Impacts to receptors are assessed below, by receptor type.

7.1.5.2.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of sound emissions include:

- ambient noise.

Table 7-36 provides a detailed evaluation of the impact of noise emissions from the physical presence of the activities to physical receptors.

Table 7-36 Impact and Risk Assessment for Physical Receptors from Emissions – Underwater Noise

Ambient Noise	✓
Change in ambient noise Anthropogenic underwater noise emitted during the activities associated with the Corowa Development will result in a change in ambient noise levels. Underwater broadband ambient noise 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 vocalise near-simultaneously in reasonably close proximity to each other) (INPEX 2009). Low-frequency ambient noise 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 (INPEX 2009). The dominant contributor above 50,000 Hz is thermal noise from	

pressure fluctuations. Background noise levels in the Corowa Development area are expected to be similar to nearby development areas, which have been recorded as ranging between 90 dB and 110 dB re 1 µPa, representing the typical range for calm to windy conditions (Shell 2018).

Acoustic sources detailed in Table 7-32 and Table 7-33 represent the range of anthropogenic sound levels during the Corowa Development. Proposed SSS surveys (229 dB re 1 µPa RMS @ 1 m) may be undertaken before subsea structure is installed and will last no more than a few days as part of a geophysical survey. SSS equipment generates sound pulses with high frequencies (100–500 kHz), which are expected to decrease rapidly through the water column. SSS (229 dB re 1 µPa @ 1 m RMS) is typically conducted over a short duration (~1 week). The sound source from SSS is typically a short, discrete, non-continuous low-frequency pulse generated by a single or small series of airguns.

The MODU will produce low-intensity continuous sound during drilling operations with previous studies recording underwater noise levels of 100–190 dB re 1 µPa RMS @ 1 m. This has been shown to reduce to 85–135 dB re 1 µPa RMS @ 1 m once drilling and commissioning are complete, with the MOPU having comparable lower noise emissions during the operational phase. An assessment of noise levels from 18 oil and gas platforms (Gales 1982) found the strongest noise levels were low frequency (4–38 Hz), with sound levels of 110 to 130 dB re 1 µPa @ 30 m. Corowa Development drilling operations are expected to take approximately six months to complete.

Underwater noise generated by vessels is expected to be greatest during the installation, hook-up and commissioning phase plus the decommissioning phase due to the increased number of support vessels required within the Corowa Development area. The commissioning and decommissioning phases are expected to each take approximately one month. As the Corowa Development enters the operational phase, noise levels will reduce with fewer support vessels on site and these will generally be running at idle. Broadband levels ranging from 165 to 184 dB re 1µPa RMS @ 1 m have previously been reported for vessels involved in marine exploration activities.

Information on underwater sound for helicopters is limited. The intensity of the received sound depends upon the source level, altitude, and depth of the receiver. Richardson et al. (1995) reports figures for a Bell 214 helicopter being audible in air for four minutes before it passed over underwater hydrophones, but detectable underwater for only 38 seconds at 3 m depth and 11 seconds at 18 m depth. The maximum received level was 149 dB re 1µPa RMS. Sound generated by helicopters is of a very short duration (take-off and landing) compared to vessel, MODU/MOPU and FSO operations, which are considered dominant continuous noise sources. Therefore, helicopter noise was not investigated further.

A spherical spreading model (Richardson et al. 1995) can be used to calculate received levels at different distances. This model is highly simplified and does not consider directionality, reflection, refraction or absorption of sound at the seabed. However, spherical spreading is a useful method to estimate distances to received levels but should be used cautiously. Table 7-37 details the calculated distances of these operations based on a maximum noise source level as described in Table 7-32.

Table 7-37 Predicted Noise Levels at Nominated Distances from Source

Distance (m)	SSS – (impulsive) (dB re 1µPa RMS)	VSP – (impulsive) (dB re 1µPa RMS)	MODU Drilling – (Continuous) (dB re 1µPa RMS)	MODU Operations – (Continuous) (dB re 1µPa RMS)	Vessels - (Continuous) (dB re 1µPa RMS)
1	229	228	190	135	184
50	195	194	157	102	151
500	175	174	136	81	130
1000	169	168	130	75	124
1500	165	164	126	71	120
3000	160	158	120	45	94

Given the details above, the consequence of underwater noise causing a change in ambient noise has been assessed as **Minor (1)**, given that all operations will be conducted according to standard industry practices

and that significantly increased noise levels from acoustic sources (VSP, SSS) will be temporary and likely to occur only prior to or during installation.

7.1.5.2.2 Ecological Receptors

Ecological receptors with the potential to be impacted as a result of underwater noise emissions include:

- fish
- marine mammals
- marine reptiles.

The above receptors may be impacted from:

- a change in fauna behaviour
- injury/mortality to fauna.

Table 7-38 provides a detailed evaluation of the impact of sound emissions to ecological receptors.

Table 7-38 Impact and Risk Assessment for Ecological Receptors from Emissions – Underwater Noise

Fish ✓
<u>Injury/ mortality to fauna</u>
Sound emissions that are within hearing frequency range and that have the potential to cause physical injury or mortality in fish species are expected to be impulsive acoustic sources during an initial geophysical survey such as SBP, or during VSP in the drilling phase. The frequency of a typical SSS survey will have no overlap with fish optimum hearing range but may have potential for physical impact, such as damage to swim bladders but only at very close range to the source (Richardson et al. 1995). High-frequency impulsive sound from SSS will attenuate rapidly in the water column and be detectable only in a very short range (<100 m). Frequencies involved with SBP and VSP are within optimum hearing range for fish species; however, both activities will be limited in duration (<24 hours per well).
Impulsive underwater noise has the potential to result in recoverable injury (PTS) for fish (with and without a swim bladder) at >207 dB re 1 µPa2 s (SEL), or TTS at >186 dB re 1 µPa2 s (SEL) (Popper et al. 2014). The impulsive noise from SSS, SBP or VSP may exceed thresholds for recoverable injury at very close range to the source (within tens of metres). SSS activities associated with the Corowa Development are expected to reach 160 dB re 1 µPa (SPL) within 3000 m as per modelling in Table 7-32. SSS will likely only occur for about one week during any geophysical survey with noise levels localised and temporary.
Other noise sources of similar levels have been shown to have rapid attenuation rates. The VSP source (typically 750 cui and comprising three 250 cui airguns) is expected to generate a noise level around 238 dB re 1 µPa @ 1 m (zero to peak SPL) (~228 dB re 1 µPa RMS @ 1 m) with most noise concentrated at low (<100 Hz) frequencies. Empirical measurements of an equivalent small-sized airgun array (440 cui) undertaken by Curtin University of Marine Science and Technology (Galindo-Romero et al. 2013) demonstrated that the source would attenuate to 160 dB re 1 µPa^2.s (SEL) within 500 m, equating to a total of 56 dB attenuation over 500 m. Modelling of VSP activities associated with the Corowa Development show noise levels are expected to reach 160 dB re 1 µPa (RMS) within 3000 m. Although bathymetry profiles, seabed characteristics and sound speed profiles result in variation in sound propagation underwater, measurements of seismic survey signals from 49 sets of sound transmission sources and 24 seismic sources found that sound from <1000 cui airguns decayed to less than 160 dB re 1 µPa2.s (SEL) within 1 km from source (McCauley et al. 2016). Matthews (2012) indicates that for airguns with a 250 cui source that are discharged about five times at 20-second intervals, sound levels of ~238 dB re 1 µPa (PK) are generated at 1 m (Matthews 2012), with frequencies <200 Hz. Sound levels are expected to attenuate rapidly to about 180 dB re 1 µPa (PK) within 100 m (Matthews 2012) and reach background levels (modelled at 120 dB re 1 µPa) at a distance of 3 km. VSP uses significantly smaller airguns that typical seismic exploration airguns. The modelling provides a range of examples to demonstrate that the acoustic emissions from VSP are expected to attenuate to below levels that may cause physical injury within very short range (<100 m). SBP will only occur for a few days during any geophysical survey with VSP expected to

take <24 hours per well (maximum of four wells). Noise levels for SBP and VSP will be localised and temporary.

Guideline noise level criteria from Popper et al. 2014 provide impact thresholds for shipping and other continuous noise sources to Type 3 fish (swim bladder involved in hearing) at 170 dB re 1 µPa (SPL) over 48 hours for recoverable injury, and 158 dB re 1 µPa (SPL) over 12 hours for TTS. In the absence of more conclusive studies, these impact thresholds were applied.

Modelling was undertaken for Woodside's Scarborough Development (Woodside 2019) in water depths >900 m, which predicted that during operation of the Floating Production Unit (FPU) , recoverable injury and TTS to Type 3 fish (swim bladder involved in hearing) may occur within 0.36 km and 0.78 km (R_{max}) from the FPU respectively. Sound attenuates faster in shallow water and thus this modelling is considered a conservative comparison for the Corowa Development, which is in ~90 m water depth.

Continuous noise from the Corowa Development will not exceed thresholds that have the potential to result in a recoverable injury in fish that have high or medium hearing sensitivity of Peak SPL ~207 dB re1µPa (Popper et al. 2014). Therefore, the risk of physical impact to fish from continuous underwater noise is negligible. There is a low risk to fish from shipping and continuous noise (including MODU and MOPU operations) with behavioural changes at near and intermediate distances from the sound source.

Given the details above, the consequence of underwater noise causing injury/mortality to fish has been assessed as **Minor (1)**, given that relatively high-energy sources from geophysical surveys and VSP will be completed over a very short period, with continuous noise levels from the MODU, MOPU, FSO and vessels localised.

<u>Change in fauna behaviour</u>

Sound emissions that have the potential to cause a change in behaviour in fish species (and within hearing frequency range) are expected to be impulsive acoustic sources during an initial geophysical survey such as SSS, SBP or VSP, or continuous noise from the FPU or support vessels. It is expected that most fish (including sharks and rays) will exhibit avoidance behaviour from either a continuous or impulsive sound source if it reaches levels that may cause behavioural or physiological effects.

Behavioural responses are expected to be short-lived, with duration of effect less than or equal to the duration of exposure. For some fish, strong 'startle' responses have been observed at sound levels of 200 to 205 dB re 1 µPa, indicating that sounds at or above this level may cause fish to move away from the sound source. Other studies (McCauley et al. 2003) have found that active avoidance may occur in some fish species at sound levels of ~161–168 dB re 1 µPa SPL (~186–193 PK). While fish may initially be startled and move away from the sound source, once the source moves on fish would be expected to move back into the area.

Potential effects from underwater noise will be restricted to a small area and short duration. The Corowa Development area buffer (7 km) overlaps with the south-western part of the foraging BIA for EPBC listed Whale Sharks. Whilst the SSS and VSP activities may occur during the Whale Shark season (March-August) however, potential behavioural impacts will be temporary, restricted to a few days and localised. The EPBC Conservation Advice for Whale Sharks does not list underwater noise as a threat to Whale Sharks. Therefore, the impacts have not been evaluated further.

There is a paucity of data about responses of sharks, including Whale Sharks, and rays to underwater noise. It is expected that the potential impacts to Whale Sharks associated with impulsive noise will be the same as for other fish. Given Whale Sharks do not have swim bladders, they are categorised as fish that are less sensitive to noise (Type 1 fish without swim ladder) and therefore, unlikely to be impacted by impulsive noise unless at close distances to the source location (Popper et al. 2014).

Given the temporary nature of the SSS and VSP, potential impacts may occur to a small proportion of the resident or transient fish populations, and would be localised and temporary. The Whale Shark BIA overlaps with the Project Area and short-term behavioural disturbance is possible. Underwater sound emissions are not listed as a threat in the IUCN Red List listing (Pierce and Norman 2016) or the Conservation advice *Rhincodon typus* (Whale Shark) (TSSC 2001). No direct impact to Whale Sharks from noise emission are expected.

Overall, the impacts to fish from noise emissions is assessed as having no lasting effects at population levels and evaluated as **acceptable**.

Given the details above, the consequence of underwater noise causing physical impact or a change in fish behaviour has been assessed as **Minor (1)**, given that relatively high-energy sources from geophysical surveys and VSP will be completed over a very short period, with continuous noise levels from the MODU, MOPU, FSO and vessels localised.

Marine Mammals ✓

Injury/ mortality to fauna

Noise emissions that are within hearing frequency range and that have the potential to cause physical injury or mortality to marine mammal species are expected to be impulsive acoustic sources during an initial geophysical survey such as SSS, SBP or during VSP in the drilling phase. These activities may cause the greatest acoustic emissions during the Corowa Development but are likely to occur for only relatively short periods (SSS and SBP < 1 week; VSP <24 hours per well).

Southall et al. (2007) has assigned species of cetaceans and pinnipeds to one of five functional hearing groups based on behavioural psychophysics, evoked potential audiometry, auditory morphology, and (for pinnipeds) the medium in which they listen. Pinnipeds are not expected within the Corowa Development area and therefore these two groups are not discussed further. Cetacean species have been grouped as low frequency (**LF**), mid frequency (**MF**), and high frequency (**HF**). Table 7-39 details the receptor group's optimum frequency hearing range and compares this with sound source frequencies to assess any overlaps.

Table 7-39 Sensitive Receptors Hearing Frequencies Compared with Source Frequencies

Receptor Group	Optimum Hearing Frequency	SSS 100 kHz – 675 kHz	SBP 3 Hz – 100 kHz1	MBES 30 kHz – 100 kHz	VSP 5–100 Hz	MODPU 4 Hz to 100 kHz	Vessels 20 Hz to 300 Hz
LF Cetaceans (baleen whales i.e. Blue and Humpback Whales)	7 Hz to 22 kHz	LF optimum hearing not within SSS range	LF optimum hearing within SBP range	LF optimum hearing not within MBES range	LF optimum hearing within VSP range	LF optimum hearing within MOPU/ MODU range	LF optimum hearing within vessel range
MF Cetaceans (dolphins, toothed whales, beaked whales)	150 Hz to 160 kHz	MF optimum hearing within SSS range	MF optimum hearing within SBP range	MF optimum hearing not within MBES range	MF optimum hearing not within VSP range	MF optimum hearing within MOPU/ MODU range	MF optimum hearing within vessel range
HF Cetaceans (porpoises, river dolphins)	200 Hz to 180 kHz	HF optimum hearing within SSS range	HF optimum hearing within SBP range	HF optimum hearing within MBES range	HF optimum hearing not within VSP range	HF optimum hearing within MOPU/ MODU range	HF optimum hearing within vessel range

(Source: Geoscience Australia 2019b; Tritech 2019; MacGillivray et al. 2013 McCauley R. D. 1998; WDCS 2004; Gales 1982)

Permanent hearing loss (PTS) is considered injurious in marine mammals, but there are no published data on the sound levels that cause PTS in these animals. Onset levels of PTS are typically extrapolated from temporary hearing threshold shift (TTS) onset levels and assumed growth functions (Southall et al. 2007). Only a few studies have investigated TTS in marine mammals in response to exposure to impulsive sounds (Lucke et al. 2009; Kastelein et al. 2018; Finneran et al. 2015; NMFS 2018; NOAA 2016). A summary of exposure criteria for the onset of TTS and PTS is detailed in Table 7-40.

Table 7-40 Noise Exposure Criteria for Onset of TTS and PTS

Hearing group	PTS onset thresholds (received level)		TTS onset thresholds (received level)	
	Impulsive	Non-impulsive	Impulsive	Non-impulsive
Low-frequency cetaceans	Lpk, flat: 219 dB LE, LF, 24h: 183 dB	LE, LF, 24h: 199 dB	Lpk, flat: 213 dB LE, LF, 24h: 168 dB	LE, LF, 24h: 179 dB
Mid-frequency cetaceans	Lpk, flat: 230 dB LE, MF, 24h: 185 dB	LE, MF, 24h: 198 dB	Lpk, flat: 224 dB LE, MF, 24h: 170 dB	LE, MF, 24h: 178 dB
High-frequency cetaceans	Lpk, flat: 202 dB LE, HF, 24h: 155 dB	LE, HF, 24h: 173 dB	Lpk, flat: 196 dB LE, HF, 24h: 140 dB	LE, HF, 24h: 153 dB

(Source: NMFS 2018; NOAA 2016)

The low-frequency group includes baleen whales (e.g. Humpback and Blue Whales), which communicate with low-frequency sounds and therefore are considered to be the most sensitive of the cetaceans to anthropogenic low-frequency noise. The EPBC protected matters database search shows that five species of cetaceans listed as either Endangered, Vulnerable or Migratory, which are in the low-frequency group may occur within the Project Area (Blue Whale, Southern Right Whale, Humpback Whale, Minke Whale and Bryde's Whale). The Project Area overlaps with BIAs for Humpback Whale migration and Blue Whale distribution.

Activities with the highest noise emissions that have the possibility to cause injury or mortality in marine mammals are acoustic sources such as SSS, during an initial geophysical survey and subsequent well integrity inspections involving the use of VSP (Table 7-40). However, surveys involving SSS and MBES are unlikely to affect low-frequency cetaceans as their respective frequencies do not overlap.

SBP and VSP surveys may overlap the hearing range of low-frequency cetaceans. However, modelling shows that impulsive noise levels for VSP will meet the NOAA (2016) and NMFS (2018) thresholds to cause TTS (168 dB re 1 µPa RMS) at 1000 m from the source (Table 7-37). A reduction in noise levels to below the NOAA (2016) and NMFS (2018) thresholds is expected to be a similar for SBP emissions. SBP and VSP will produce significantly less energy than large scale offshore seismic surveys plus both activities will be very short in duration, with any geophysical survey taking <1 week (weather dependant) to complete, and VSP taking between <24 hours per well.

Emissions from the MODU/MOPU and vessels will be within the range of low frequency grouped species. Modelling shows (Table 7-37) that during the drilling phase, continuous noise levels from the MODU decrease to the NOAA (2016) and NMFS (2018) threshold of 168 dB re 1 µPa RMS at <50 m from the source. The drilling phase is expected to last ~5 months (and potentially an additional 4 months if infill drilling is required). During the production phase the threshold for continuous noise is within 50 m of the source. The modelling also shows emissions from vessels will reach threshold levels at <50 m. Note: Modelling for vessels was based on maximum levels (active thrusters) with vessels expected to be operating at idle for the majority of the operational time and therefore at much reduced noise levels.

Mid-frequency species are within the hearing range of lower frequency SSS however favoured ranges of 325 kHz and 675 kHz (Tritech 2019) are outside the mid-frequency range.

SBP is also within the mid-frequency range however noise levels that could cause injury or mortality to marine mammals would only occur close to the source (<50 m). Although VSP is outside the mid-frequency hearing range compression waves could still impact these species but only at very close distances to the source. Modelling for emissions from MODU/MOPU and vessels for mid-frequency species is as per low-frequency species as detailed above with noise thresholds within 50 m of the source. The Corowa Project Area does not overlap with any BIAs for EPBC listed mid or high-frequency cetaceans. PTS for cetaceans from impulsive noise may occur at noise levels as low as 202 dB (SEL) for high-frequency dolphins over an exposure period of 24 hours. However, no species within the high-frequency range (porpoises, river dolphins) are expected within the Project Area. Therefore, high-frequency emissions are not discussed further.

The presence of dugongs within the Corowa Development area is very unlikely due to the water depths and lack of seagrass habitat. It is possible, although very unlikely, for dugongs to be present within the project area as they move from one feeding ground to another. However, it is likely they would exhibit avoidance behaviour during any elevated noise emissions. The Project Area does not intercept with the dugong BIA.

McCauley (1998; 2004) indicates that continuous noise sources from MODU and vessel operations are expected to fall below 120 dB re 1 µPa RMS within 4 km of the MODU/vessel. Cetaceans are very unlikely to be injured or suffer mortality by vessel operations. The Corowa Development intercepts with the Humpback Whale migration BIA and the Blue Whale distribution BIA. Blue Whales may be transient through the area between July and November, and Humpback Whales may be present in the area between June and October as they migrate between northern breeding grounds and southern feeding grounds. Incidental occurrences of marine mammals near the drilling activity are likely to cause movement away from the noise source, so any potential impact on these species is considered to be minimal.

The Department of Environment EPBC Act (1999) Conservation Management Plan for the Blue Whale identifies noise interference as a potential threat to Blue Whales and includes a conservation management action:

- anthropogenic noise in biologically important areas will be managed such that any Blue Whale continues to use the area without injury, and is not displaced from a foraging area (DoE 2015).

The Project Area does not overlap with a foraging area for Blue Whales and therefore, there will be no displacement of Blue Whales from a foraging area.

The EPBC Act (1999) Conservation Advice for the Humpback Whale identifies noise interference as a potential threat to Humpback Whales. Management actions under the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales may include:

- using shutdown and caution zones
- pre and post activity observations
- using marine mammal observers.

Given the details above, the consequence of underwater noise causing injury or mortality to marine mammals has been assessed as **Moderate (2)**, given that relatively high-energy sources from geophysical surveys and VSP will be completed over a very short period, with continuous noise levels from the MODU, MOPU, FSO and vessels localised.

Change in fauna behaviour

A change in ambient noise levels generated by the Corowa Development has the potential to change the behaviour of resident and migratory marine mammal species.

Sound is a primary sensory cue for most marine mammals especially for cetaceans. Cetaceans have some of the most refined hearing of all mammals, capable of sophisticated, sensitive and auditory processing, which enables them to passively and actively acquire information about their environment (Mooney et al. 2012). An increase in ambient noise levels can cause changes in behaviour that may result in adverse effects on the wellbeing of marine mammals. Observed responses to anthropogenic sound in cetaceans include altered swimming direction, increased swimming speed (including pronounced ‘startle’ reactions), changes to surfacing, breathing and diving patterns, avoidance of the sound source area (NRC 2003). However, for most free-ranging marine mammals, behavioural responses are often difficult to observe. Table 7-41 details the marine mammal acoustic thresholds behavioural disruption as defined by the National Marine Fisheries Service (2018) and NOAA (2016).

Table 7-41 Noise Exposure Criteria for Onset of Behavioural Response

Hearing group	Behavioural response	
	Impulsive	Non-impulsive
Low-frequency cetaceans	160 dB re 1 µPa RMS	120 dB re 1 µPa RMS
Mid-frequency cetaceans		
High-frequency cetaceans		

(Source: NMFS 2018; NOAA 2016)

As previously stated, the low-frequency group includes baleen whales (e.g. Humpback and Blue Whales), which communicate with low-frequency sounds and therefore are considered to be the most sensitive of the cetaceans to anthropogenic low-frequency noise. The EPBC protected matters database search shows that five species of cetaceans listed as either Endangered, Vulnerable or Migratory, which are in the low-frequency group may occur within the Project Area (Blue Whale, Southern Right Whale, Humpback Whale, Minke Whale and Bryde's Whale). The Project Area overlaps with BIAs for Humpback Whale migration and Blue Whale distribution.

Activities with the highest noise emissions that are likely to cause a change in behaviour in marine mammals are acoustic sources such as SSS, during an initial geophysical survey and subsequent well integrity inspections involving the use of VSP (Table 7-32). However, surveys involving SSS and MBES are unlikely to affect low-frequency cetaceans as their respective frequencies do not overlap.

SBP and VSP surveys may overlap the hearing range of low-frequency cetaceans. However, modelling shows that impulsive noise levels for VSP will drop below the NOAA (2016) threshold to cause a behavioural change of 160 dB re 1 µPa RMS within 3000 m of the source (Table 7-37). A reduction in noise levels to below the NOAA (2016) threshold is expected to be a similar for SBP emissions. SBP and VSP will produce significantly less energy than large scale offshore seismic surveys plus both activities will be very short in duration, with any geophysical survey taking <1 week (weather dependant) to complete, and VSP taking between <24 hours per well.

Emissions from the MODU/MOPU and vessels will be within the range of low frequency grouped species. Modelling shows (Table 7-37) that during the drilling phase, continuous noise levels from the MODU decrease to the NOAA (2016) threshold of 120 dB re 1 µPa RMS at ~3000 m. The drilling phase is expected to last ~5 months (and potentially an additional 4 months if infill drilling is required). During the production phase the threshold for continuous noise is within 50 m of the source. The modelling also shows emissions from vessels will reach threshold levels at ~1500m. Note: Modelling for vessels was based on maximum levels (active thrusters) with vessels expected to be operating at idle for the majority of the operational time and therefore at much reduced noise levels.

As previously detailed, mid-frequency species are within the hearing range of lower frequency SSS however favoured ranges of 325 kHz and 675 kHz (Tritech 2019) are outside the mid-frequency range. SBP is also within the mid-frequency range however noise levels that could cause a change in behaviour would only occur close to the source (<50 m). Although VSP is outside the mid-frequency hearing range compression waves could still impact these species but only at very close distances to the source. Modelling for emissions from MODU/MOPU and vessels for mid-frequency species is as per low-frequency species as detailed above. The Corowa project area does not overlap with any BIAs for EPBC listed mid or high-frequency cetaceans. No species within the high-frequency range (porpoises, river dolphins) are expected within the Project Area. Therefore, high-frequency emissions are not discussed further.

The presence of Dugongs within the Corowa Development area is very unlikely due to the water depths and lack of seagrass habitat. It is possible, although very unlikely, for Dugongs to be present within the project area as they move from one feeding ground to another. However, it is likely they would exhibit avoidance behaviour during any elevated noise emissions. The Project Area does not intercept with the Dugong BIA.

Richardson et al. (1995) and Southall et al. (2007) report that behavioural avoidance by baleen whales may occur from 140 dB re 1 µPa RMS and even possibly higher than 160 dB re 1 µPa RMS. McCauley (1998;

2004) indicates that continuous noise sources from MODU and vessel operations are expected to fall below 120 dB re 1 µPa RMS within 4 km of the MODU/vessel. Cetaceans are not likely to be significantly affected by drilling noise, although sound emitted may induce avoidance behaviour and minor route alterations. The Corowa Development intercepts with the Humpback Whale migration BIA and the Blue Whale distribution BIA. Blue Whales may be transient through the area between July and November, and Humpback Whales may be present in the area between June and October as they migrate between northern breeding grounds and southern feeding grounds. Incidental occurrences of marine mammals near the drilling activity are likely to cause movement away from the noise source, so any potential impact on these species is considered to be minimal.

The Department of Environment EPBC Act (1999) Conservation Management Plan for the Blue Whale identifies noise interference as a potential threat to Blue Whales and includes a conservation management action:

- anthropogenic noise in biologically important areas will be managed such that any Blue Whale continues to use the area without injury, and is not displaced from a foraging area (DoE 2015).

The Project Area does not overlap with a foraging area for Blue Whales and therefore, there will be no displacement of Blue Whales from a foraging area.

The EPBC Act (1999) Conservation Advice for the Humpback Whale identifies noise interference as a potential threat to Humpback Whales. Management actions under the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales may include:

- using shutdown and caution zones
- pre and post activity observations
- using marine mammal observers.

Given the details above, the consequence of underwater noise causing a change in marine mammal behaviour has been assessed as **Moderate (2)**, given that relatively high-energy sources from geophysical surveys and VSP will be completed over a very short period, with continuous noise levels from the MODU, MOPU, FSO and vessels localised.

Marine Reptiles ✓

Change in fauna behaviour

A change in ambient noise generated by the Corowa Development has the possibility to change the behaviour of resident and migratory reptile species.

The Short-nosed Sea Snake (*Aipysurus apraefrontalis*) is listed as Critically Endangered under the EPBC Act. The species primarily occurs on the reef flats or in shallow waters of the outer reef edges to depths of 10 m (Minton and Heatwole 1975). Given its preference for shallow waters the Short-nosed Sea Snake is not expected to occur in the Project Area, which has a depth of ~90 m.

Electro-physical studies have indicated that the best hearing range for marine turtles is between 100–700 Hz (Bartol and Musick 2003; Popper et al. 2014). Other preliminary measures of hearing in sea turtles indicated that the hearing range was 50–1200 Hz (Lavender et al. 2012). Behaviour changes for marine turtles subjected to an acoustic source have been reported at 166 dB re 1µPa RMS @ 1 m, with a noticeable increase in swimming behaviour, with behaviour becoming increasingly erratic at 175 re 1µPa RMS (McCauley et al. 2000). O'Hara (1990) also reports avoidance behaviour at levels of 175–176 re 1µPa RMS.

The EPBC protected matters database shows that five species of turtle listed as either Endangered (Loggerhead Turtle, Leatherback Turtle) or Vulnerable (Green Turtle, Hawksbill Turtle, Flatback Turtle) or Migratory may occur within the Project Area with numerous reserves, feeding and nesting grounds nearby. The closest is Serrurier Island, located ~17 km from the MOPU location, which is a Nature Reserve; the Muiron Islands are ~23 km away and are a Class A Nature Reserve. Four species of marine turtle (Green, Loggerhead, Hawksbill and Flatback) nest on the Pilbara inshore islands, with major nesting beaches on the Muiron and Serrurier islands. The Corowa Project Area intercepts with nesting BIAs for the Green Turtle, Hawksbill Turtle and Flatback Turtle.

The highest noise emissions that could cause a change in behaviour in marine turtles are likely to be acoustic sources during any initial geophysical survey and subsequent well integrity inspections involving the use of VSP. Noise emissions from SSS and MBES have been detailed as the highest (Table 7-32) during a geotechnical survey. Frequencies used in SSS range between 100 and 675 kHz with favoured ranges around

325 kHz and 675 kHz (Tritech 2019) and MBES ranging between 30 and 100 kHz. These frequencies are outside the normal hearing range of turtles (100–1200 Hz) and therefore are very unlikely to cause a change in behaviour. The lower frequencies of VSP (5–100 Hz) and SBP (3 Hz to 100 kHz) are at a level that could be detected by marine turtles. Although Table 7-32 states emissions of 228 dB re 1µPa RMS @ 1 m for VSP the modelling detailed in Table 7-37 shows these noise levels decreasing to 164 dB re 1µPa RMS at 1500 m from the source. These noise levels are below the 166 dB re 1µPa RMS noise level known to cause a change in behaviour in marine turtles (McCauley et al. 2000). Geophysical surveys are expected to take one to three field days (weather dependant) to complete, and VSP taking between <24 hours per well. The MODU/MOPU and vessels operating within the Project Area will have noise emissions within the frequency range of marine turtles and possibly above the threshold to cause a change in behaviour in turtles. Popper et al. (2014) states continuous noise of any level that is detectable by fish or turtles can mask signal detection, and thus may have a pervasive effect on behaviour. However, no data exists that studies a change in behaviour of turtles from the effects of continuous noise from ships (Popper et al. 2014) with current values based on fish studies. During the drilling phase of operations noise levels from the MODU may range between 100 and 190 dB re 1 µPa RMS @ 1 m. However, modelling (Table 7-37) shows this falls below the 166 dB re 1µPa RMS threshold known to cause a behavioural change in marine turtles within 50 m from an impulsive source. The drilling phase of the Corowa Development is expected to take ~6 months, with the production phase (MOPU) emitting reduced noise levels ranging between 85–135 dB re 1 µPa RMS @ 1 m. Modelling for vessels within the project area (Table 7-37) also shows noise levels drop below the 166 dB re 1µPa RMS threshold within 50 from the source. Helicopters may cause a "startle" response in turtles swimming or resting on the surface exhibited by rapid diving. However, noise impacts on marine turtles from helicopters will be temporary and only during the take-off and landing phase. Richardson et al. (1995) reports helicopter noise being audible in air for four minutes before it passed over underwater hydrophones, but detectable underwater for only 38 seconds at 3 m depth and 11 seconds at 18 m depth. The maximum received level was 149 dB re 1µPa RMS. The Australian Government Recovery Plan for Marine Turtles in Australia (CoA 2017) identifies noise interference as a potential threat to marine turtles. A conservation management action is to improve understanding of the impacts of anthropogenic noise on marine turtle behaviour and biology. Given the details above, the consequence of underwater noise causing a change in marine reptile (turtles) behaviour has been assessed as **Moderate (2)**, due to turtles hearing frequency range, high attenuation rates of sound in the water column and short duration of noise in water. Also, continuous noise levels from the MODU/MOPU, FSO and vessels and higher noise levels (which will only occur during the drilling phase) will be localised.

7.1.5.3 Consequence and Acceptability Summary

The worst-case consequence of Emissions – Underwater Noise from the Corowa Development has been evaluated as **Moderate (2)**, which was for a change in behaviour and injury / mortality to fauna for fish and marine mammals; and change in behaviour of marine reptiles. This is considered **acceptable** when assessed against the criteria in Table 7-42.

Table 7-42 Demonstration of Acceptability for Emissions – Underwater Noise

Acceptability Criteria	Justification
To meet the principles of ESD	• Acoustic emissions from the Corowa Development will be highly localised, and the main noise-generating activities will be of short duration (SSS <1 week, VSP for <24 hours per well; drilling for ~5 months, and an additional 4 months if an infill drilling campaign is required). • Offshore activities involving drilling, vessels, helicopters and commercial sonar noise are widely undertaken both nationally and internationally. • Impacts from underwater noise are well understood with potential impacts identified.
Internal context	• There are no specific KATO internal requirements with respect to noise emissions or potentially impacted receptors.

Acceptability Criteria	Justification
External context	• No stakeholder concerns have been raised with respect to light emissions or potentially impacted receptors.

Other requirements	• OPGGS Act 2006 (Cth)
	• EPBC Regulations 2000 – Part 8 Division 8.1 interacting with cetaceans – The Australian Guidelines for Whale and Dolphin Watching
	• EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales
	• Conservation Management Plan for the Blue Whale 2015–2025 (Department of Environment 2015):
	  ○ anthropogenic noise in biologically important areas will be managed such that any Blue Whale continues to use the area without injury, and is not displaced from a foraging area (DoE 2015)
	  ○ the project area does not overlap with a foraging area for Blue Whales and therefore, there will be no displacement of Blue Whales from a foraging area.
	• The EPBC Act (1999) Conservation Advice for the Humpback Whale identifies noise interference as a potential threat to Humpback Whales. Management actions under the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales may include:
	  ○ using shutdown and caution zones
	  ○ pre and post activity observations
	  ○ using marine mammal observers.
	• Conservation Advice for *Balaenoptera borealis* (Sei Whale) (Threatened Species Scientific Committee 2015a) includes:
	  ○ anthropogenic noise and acoustic disturbance has a minor consequence rating (TSSC 2015a)
	• Conservation Advice for *Balaenoptera physalus* (Fin Whale) (Threatened Species Scientific Committee 2015b) includes:
	  ○ anthropogenic noise and acoustic disturbance has a minor consequence rating (TSSC 2015b)
	• Recovery Plan for marine turtles in Australia (CoA 2017) includes:
	  ○ manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival (CoA 2017)
	  ○ manage anthropogenic activities in Biologically Important Areas to ensure that biologically important behaviour can continue (CoA 2017)
	• Recovery Plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013b)
	  ○ The Project Area does not overlap with a foraging BIA for White Shark.
	• The EPBC Conservation Advice for Whale Sharks does not list underwater noise as a threat to Whale Sharks.
	• In regard to underwater noise emissions, activities associated with the Corowa Development will not be conducted in a manner inconsistent with a Recovery Plan, threat abatement plan or Conservation Advice for a listed threatened species or migratory species.

A summary of the impact analysis and evaluation, including adopted control measures adopted and EPOs, is provided in Table 7-43.

Table 7-43 Summary of Impact Assessment for Emissions – Underwater Noise

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient noise	Change in ambient noise	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO1:** Noise emissions are managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging BIA. **EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	**CM14**: Vessels will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the Project Area. **CM15**: VSP operations will adhere to the EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines. **CM16**: Equipment will be maintained in accordance with the manufacturer's specifications, facility planned maintenance system and regulatory requirements.	Minor
Fish	Injury / mortality to fauna			Minor
	Change in fauna behaviour			Minor
Marine mammals	Injury / mortality to fauna			Moderate
	Change in fauna behaviour			Moderate
Marine reptiles	Change in fauna behaviour			Moderate

7.1.6 Planned Discharge – Drilling Cuttings and Fluids

Drilling operations will result in the generation of drilling cuttings and fluids, which will be discharged to the marine environment at the surface or subsea.

7.1.6.1 Aspect Source

Throughout the Corowa Development, drilling cuttings and fluids will be discharged to the marine environment during these phases and activities:

Drilling	top-hole drilling; bottom-hole drilling; completions; well clean-up and flowback
Installation, Hook-up and Commissioning	CALM buoy and mooring installation
Operations	well intervention
Decommissioning	well P&A

Drilling

During drilling operations, drilling cuttings and fluids will be discharged to the marine environment. Up to four wells may be drilled during the development, which will take approximately five months for the initial campaign, and an additional four months if an infill drilling campaign is required. Depending on the drilling phase and hole section of these wells, cuttings and fluids may be discharged either at the surface or subsurface, with the potential for additional bulk discharges of drilling fluids at the surface (non-routine activity). Discharges may also vary in composition and will often be discharged as a mixture of drilling cuttings and fluids. Details of drilling cuttings and fluids are outlined below.

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. These drilling cuttings may be discharged either at the surface or at the seabed.

During drilling of the main conductor hole section of the well, cuttings (and drilling fluids) will be released directly to the seabed in the vicinity of the well site (subsea) as drilling is undertaken. Volumes of cuttings discharged subsea are expected to be ~75 m^3 per well.

Following the completion of the installation of the main conductor (riser) of the well, the remainder of the top-hole, bottom-hole and horizontal well sections will be drilled through the main conductor, allowing the cuttings to be routed back to the MODU or MODPU, forming a closed-circuit system.

Cuttings are then processed within the solids control equipment (SCE), with drilling fluids separated from the cuttings and recirculated back for further use. The cuttings are processed further through shale shakers and centrifuges to remove course and fine material. Processed cuttings are discharged at the surface below the water line. Volumes of cuttings discharged during the bottom-hole section are estimated to be ~350 m^3 per well, with variations expected depending on the depth of the well.

Fluids

Fluids used during drilling operations include:

- drilling fluids
- control fluids
- completion fluids.

Drilling Fluids

Drilling fluids are used during the drilling activities to provide a range of functions, including transport drilling cuttings to the surface, wellbore stability, control of formation pressures plus lubrication and cooling of the drill bit.

Drilling operations for the main conductor hole will use either seawater and/or water-based mud (WBM) and would be discharged directly to the environment. Once the main conductor is installed, the drilling fluids will be brought to surface and treated through the MODU or MOPU mud systems and re-used. It is likely for the remaining top-hole sections drilling operations will use either seawater and/or WBM, with synthetic-based muds (SBM) likely to be used for deeper sections.

The drilling fluid system for each well is yet to be finalised but are likely to be a combination of seawater, WBM and SBM. SBM has increased lubricity, greater cleaning abilities with less viscosity than WBM plus can withstand greater heat without breaking down. SBM combine the technical advantages of oil-based drilling fluids (OBF) with the low persistence and toxicity of WBM. WBM typically include:

- sodium chloride
- potassium chloride
- bentonite (clay)/guar (as sweeps)
- naturally occurring water soluble polymers
- barium sulphate (barite) and calcium carbonate.

Pre-hydrated bentonite 'gel' sweeps are likely to be discharged to the marine environment during drilling of the conductor and surface casing. For top-hole drilling, the drilling fluid used may be seawater, treated with caustic soda (NaOH) and/or soda ash (Na_2CO_3) to increase pH and alkalinity. The estimated discharge during top-hole drilling is 50 m^3 per well of WBM or seawater, and gel sweeps.

The remaining top-hole and bottom-hole drilling may use SBM or WBM depending on technical feasibility and safety, and drilling technical requirements (refer to Section 4.3.5). If SBM is used, there is no planned discharge of SBM to the marine environment during drilling. If WBM is used, a maximum of 159 m^3 of WBM per well could be discharged to the marine environment at the end of the drilling operations. This fluid is recycled where possible to use for subsequent wells.

SBM base fluid will typically include a hydrocarbon, ether, ester, or acetal as a base. SBM may also contain:

- organophilic clays
- barite
- lime
- aqueous chloride
- rheology modifiers fluid loss control agents
- emulsifiers.

Excess WBM will may be discharged to the seabed during drilling operations, however no whole SBM will be discharged into the marine environment. SBM that cannot be recovered from drilling cuttings will be recycled or disposed of at a land-based facility.

Control Fluids

Control fluids (hydraulic fluids) are required to operate pressure control equipment such as the BOP. For the Corowa Development, the BOP will be positioned topside on the MOPU conductor deck, here will be no routine discharges to the marine environment as part of normal operation. The downhole safety valve will likely be closed circuit, but even if not, it will discharge to the annulus of the well and not the marine environment.

Therefore, control fluids discharges are not expected and are not discussed further.

Completion Fluids

Well completion fluids are required to ensure that the wellbores and casings are clear of solids, debris and other containments. Completion fluids usually comprise a brine (often chlorides of calcium, potassium or sodium) with additives that may include:

- biocide
- bromides
- hydrate inhibitor (methanol, MeOH), monoethylene glycol (MEG)
- oxygen scavenger
- surfactant.

Completion fluids may be discharged to the sea with an expected volume of ~400 m^3 per well.

Installation, Hook-up and Commissioning

If the drilled and grouted anchor pile option is selected as the mooring methodology for the CALM buoy, three shallow 25 m holes will be drilled to insert the casing and grout. Seawater will be used as drilling fluid, and a small 45 m^3 discharge of drilling cuttings is expected per hole.

Operations

Throughout the expected two to 4.5 years of operations, 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 plus well workovers. Subsea discharges, which may occur during maintenance and repair activities, are not expected to be indifferent to discharges described above for drilling operations, but volumes may slightly vary. Discharged fluids during maintenance and repair activities include:

- completion fluids.

Decommissioning

During well P&A, discharges may occur during the installation of cement plugs for reservoir isolation deep in the well, and one cement plug at the mudline. Running of perforating guns down the wellbore may also be necessary to ensure the cement plugs are fully integrated across the wellbore and/or communication between annulus for flushing the casing strings to surface.

Subsea discharges will also occur through the cutting of the well casing and production tubing at the mudline (seabed surface). The cutting will be done above and after the installed cement plug within the well, just below mudline. Discharges from the well during the above activities are not dissimilar to fluids described above, however, volumes will be significantly smaller. Discharged fluids during well P&A include:

- treated seawater (with caustic soda or soda ash)
- completions fluids
- drilling fluids.

When the above-mudline section of the main conductor is removed after cutting, a small volume (~25 m^3) of inhibited seawater will be released to the marine environment.

7.1.6.2 Impact Analysis and Evaluation

Drilling cuttings and fluids discharged to the marine environment during the Corowa Development have the potential to result in these impacts:

- change in water quality
- change in sediment quality.

As a result of a change in water and sediment quality, further impacts may occur, including:

- injury/mortality to fauna.

Table 7-44 identifies the potential impacts to receptors as a result of a planned discharge of drilling cuttings and fluids at the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-45 provides a summary and justification for those receptors not evaluated further.

Table 7-44 Receptors Potentially Impacted by a Planned Discharge – Drilling cuttings and Fluids

Impacts	Ambient water quality	Ambient sediment quality	Plankton	Benthic habitats and communities	Fish	Marine mammals	Marine reptiles	Commercial fisheries
Change in water quality	✓							
Change in sediment quality		✓						
Injury/mortality to fauna			*X*	✓	*X*	*X*	*X*	
Changes to the functions, interests or activities of other users								*X*

Table 7-45 Justification for Receptors Not Evaluated Further for Planned Discharge – Drilling cuttings and Fluids

Plankton	***X***
Injury/mortality to fauna A reduction in water quality through increased turbidity and increased toxicity, caused by the discharge of drilling cuttings and fluids within the Project Area, will have a negligible effect on plankton populations at a measurable level. Jenkins and McKinnon (2006) identified suspended sediment concentrations greater than 500 mg/L will likely result in a measurable impact to larvae species of most fish species, with concentrations of 100mg/L effecting larvae species of most fish if exposed to for longer than 96 hours. Previous studies (Neff 2010) showed 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. Drilling fluids dilute 100-fold within 10 m of the discharge source (Vik, Dempsey and Nesgard 1996), therefore it can be predicted that drilling fluid concentrations will fall below acute toxicity thresholds of 10,000 ppm within 100 m of the discharge source, assuming that fluids concentrations upon release are 100% and assuming a conservative current speed of 0.1 m/s. Plankton have a patchy distribution linked to localised and seasonal productivity that produces sporadic bursts in populations (DEWHA 2008). The oligotrophic waters of the Project Area are typical of the wider offshore region supporting low phytoplankton biomass and relatively low primary productivity (Woodside 2005). A change in water quality as a result of drilling cuttings and fluids is unlikely to lead to injury or mortality of plankton at a measurable level and will not result in a change in the viability of the population or ecosystem. Therefore, no impacts to plankton from drilling cuttings or fluids discharges are expected and have not been evaluated further.	

Fish, Marine Mammals and Marine Reptiles	*X*
Injury/mortality to fauna 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. Neff et al. (2000) states that drilling cuttings are of little risk to water column biota due to WBM having low toxicity levels and will be rapidly diluted near the source. The EPBC PMST lists one species of shark as Vulnerable (Grey Nurse Shark) and four as Vulnerable/Migratory (Dwarf Sawfish, Green Sawfish, White Shark and Whale Shark) that are likely to occur within the area. The Project Area is situated within a BIA migratory area for the Whale Shark. The recovery plan for the Whale Shark (DEH 2005a) (ceased to be in effect from 1 October 2015) listed pollution as a future threat. However, it stated that the main threat to the Whale Shark occurs outside Australian waters. All species listed are highly mobile, therefore, none are expected to be affected by negligible increases in toxicity and short-term turbidity increases. The EPBC PMST shows that three species of marine mammal listed as either Vulnerable (Sei Whale, Fin Whale and Humpback Whale) and two species listed as Endangered (Blue Whale and Southern Right Whale) that are known or may occur within the Project Area. The Project Area sits within a BIA migratory area for Humpback Whales. The recovery plan for Humpback Whales (DEH 2005b) (ceased to be in effect from 1 October 2015) listed pollution as a threat although this is primarily in relation to run-off from land-based agriculture and outputs from aquaculture. The EPBC PMST also shows that three species of turtle listed as either Vulnerable (Green Turtle, Hawksbill Turtle and Flatback Turtle) or Endangered (Loggerhead Turtle and Leatherback Turtle) have habitat, congregation or congregation known to occur within area. A single species of snake (Short-nosed Sea Snake) listed as critically endangered may also occur within the area but is unlikely as they prefer shallower waters to forage. The Project Area sits within three BIA for marine turtle species. The Recovery Plan for Marine Turtles in Australia, (DOEE 2017a) identifies chemical and terrestrial discharge as a threat, although this is again mostly in relation to pollution from agricultural, terrestrial industrial and domestic sources. Because drilling cuttings and fluid discharges within the Corowa Project Area will be localised and rapidly diluted, and fish, marine mammals and marine reptile species will be transitory in nature, the impacts of these discharges will be negligible and therefore are not discussed further. All activities will be conducted in accordance with management actions outlined in the relevant recovery plans. Therefore, impacts are not expected and have not been evaluated further.	
Commercial Fisheries	***X***
Changes to the functions, interests or activities of other users As impacts to fish have not been expected from drilling cuttings and fluid discharges, indirect impacts to commercial fisheries are not expected. The radius of direct disturbance from drilling cuttings and fluids discharges is conservatively estimated at 200 m, well within the 5 km radius of the Project Area. This is an insignificant area compared to the size and scale of commercial fisheries. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). Therefore, impacts to commercial fisheries from planned discharge of drilling cuttings and fluids are not expected, and have not been evaluated further.	

7.1.6.2.1 Physical receptors

Physical receptors with the potential to be impacted as a result of discharges of drilling cuttings and fluids:

- ambient water quality
- ambient sediment quality.

Table 7-46 provides a detailed evaluation of the impact of discharges of drilling cuttings and fluids to physical receptors.

Table 7-46 Impact and Risk Assessment for Physical Receptors from Planned Discharges – Drilling cuttings and Fluids

Ambient Water Quality ✓
<u>Change in water quality</u> Following discharge of drilling cuttings and adhered drilling fluids during the drilling phase, key physiochemical stressors associated with a change in water quality include increased turbidity and resulting chemical toxicity and sedimentation within the water column. In addition, discharges of drilling fluids during maintenance and repair and well P&A during later stages of the Corowa Development may also result in chemical toxicity within the water column. During drilling of the main conductor hole, discharges will occur at the seabed, resulting in a localised increase in turbidity immediately around the wellhead (of ~75 m^3 per well). The cuttings and adhered fluids will settle rapidly within close proximity to the wellhead, with finer particles (~10% of the discharge volume) dispersing further within ocean currents. Although turbidity and chemical concentrations will be high around the wellhead, drilling cuttings and drilling fluids are expected to settle and disperse rapidly, resulting in short-term and highly localised change in water quality at the seabed. During the drilling of the remaining top-hole, bottom-hole, horizontal sections following the main conductor installation, the drilling cuttings and adhered fluids will be processed on the MODU at the surface. The drilling cuttings will be discharged to the environment and the fluid treated and recycled. Volumes of drilling fluid discharged will be less than that of the top-hole section and will result in a wider area of distribution, although the cuttings pile depth will be much thinner (IPGP 2016). When discharged to the marine environment, large cuttings particles (90% of the discharge mass) generally form a plume and rapidly settle to the seafloor near to the release point (Hinwood et al. 1994), decreasing in volume and becoming patchy in distribution as distance from the source increases (Nedwed 2006; Balcom 2012). Cuttings may also entrain in seawater and reach neutral buoyancy. A study undertaken by Hinwood (1994) indicates that a drilling cuttings and fluids plume will have diluted by a factor of at least 10,000 within 100 m of the point of discharge point. In addition, Neff (2005) indicates that within well-mixed ocean waters (similar to that of the Project Area), drilling cuttings and fluids will have diluted by over 100-fold within 10 m of the discharge point. The dilution factor determined by Neff (2005) of 10,000 is widely accepted within industry. Using this dilution factor, it has been predicted that discharges of cuttings and adhered fluids will reach 100 mg/L within 100 m of the MODPU 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, 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. Neff (2005), states that although total drilling cuttings discharge volumes associated with drilling a well are large, environmental impacts within the water column are low due to the intermittent nature of such discharges. Discharges of drilling cuttings and fluids will also result in a change in water quality through chemical toxicity and oxygen depletion. Fluids comprise a small percentage of the total discharge of drilling cuttings and fluids and may comprise drilling fluids adhered to cuttings, completion fluids, subsea control fluids and well annular fluids. Completion fluids, subsea control fluids and well annular fluids discharged are expected to be similar to or less toxic than that of drilling fluids and will be released in smaller volumes. Because of the rapid dilution of the drilling mud and cuttings plume in the water column, harm to communities of water column plants and animals is unlikely and has never been demonstrated (Neff 2005). Neff (2010) states that the lack of toxicity 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. If drilled and grouted anchor piles are selected as the option to moor the CALM buoy, the cuttings discharge is minor in comparison (45 m^3 per hole), and uses seawater as drilling fluid, meaning no additives or introduced contaminants to impact water quality. Ambient water quality in the Project Area is expected to be high and typical of the offshore marine environment. In the high-energy shelf waters, any changes in water quality will be quickly dispersed and settle resulting in localised impacts to water quality. Planned discharges of drilling cuttings and fluids will

occur at both the surface and seabed, but will occur in short periods, with no long-term or continuous discharges planned. This will allow water quality to quickly recover, with no long-term changes to ambient water quality expected.

Given the details above, the consequence of drilling cuttings and fluids causing a change in ambient water quality has been assessed as **Minor (1)**, due to rapid dispersal and the short duration of planned activities.

Ambient Sediment Quality ✓

Change in sediment quality

A change in sediment quality is defined as an alteration in the condition of the sediment from its previous state. Changes in sediment quality may occur as a result of the addition of toxins and sediments to the seafloor from both subsea discharges and surface discharges. Toxins may accumulate within benthic sediment as a result of chemical additives within drilling fluids. Increased sedimentation as a result of cuttings material 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 is dependent on a range of factors including:

- fluid type adhered to cuttings (WBM or SBM)
- amount of fluid retained on cuttings
- particle size distribution of cuttings
- water depth
- current speed and direction at varying depths.

Drilling cuttings and fluids discharged during drilling operations are expected to result in the greatest change in sediment quality, as cuttings tend to clump together and settle rapidly, with thicker cuttings piles generally located downstream from the discharge. This is especially evident for SBM (if used). Deposition of sediments is expected to be highly localised around the well site (Neff 2005). Field studies summarised by IAOGP (2016), found that cuttings and adhered WBM could be detected either visually or through increases in barium concentrations within 10–150 m of the source. Cuttings piles were generally <50 cm in depth.

Surface discharges from the drilling facility will undergo greater dispersion of smaller cuttings within the water column, therefore resulting in a thinner layer near the well site. Cuttings and adhered fluids typically disperse slower and cover a wider area when WBM are used rather than SBM (IAOGP 2016). IAOGP (2016) describe that for WBM discharges from a single well within waters greater than 300 m, there may be no detectible traces in sediment at any distance from the well. Discharges of SBM from the surface settle rapidly, under and downstream from the discharge source in clumps and may be patchy in distribution, covering a smaller area than that of WBM discharge plumes (CSA 2004; CSA 2006). Surface discharges of SBM within water depths <300–400 m are generally deposited within ~100–200 m downstream of the discharge source (CSA 2004; Dorn et al. 2007; Correa et al. 2010).

The four wells that may be drilled for the Corowa Development are very close together (all four wells within a 10 m x 10 m footprint); therefore the cuttings piles from each one will overlap. Hence a conservative maximum impact radius of 200 m is assumed, giving a footprint of 0.125 km^2. This is well within the 5 km buffer that comprises the Project Area.

SBM can contain components that may bioaccumulate. However, Melton et al. (2000) suggests that given the ability for organisms to oxidise and expel aromatics, hydrocarbons are not expected to bioconcentrate. The physical and chemical persistence of drilling cuttings and fluids within the seafloor sediment is dependent on the energy of the seafloor (i.e. currents) and the reactivity and biodegradation rate of drilling materials. A majority of mineral within drilling cuttings are stable and insoluble within water with most organic chemicals within both WBM and SBM being biodegradable (IAOGP 2016). Studies at three continental slope locations where drilling was undertaken in water depths between 37 and 119 m found that within a year, concentrations of barium and chemicals from WBM and SBM discharges reduced by 2.4 to 80% for barium and 65 to 99% for chemicals within 100m of the discharge source.

If drilled and grouted anchor piles are selected as the option to moor the CALM buoy, the cuttings discharge is minor in comparison (45 m^3 per hole), and uses seawater as drilling fluid, meaning no additives or introduced contaminants to impact sediment quality.

Sediment quality within the Project Area is expected to be high and typical of a pristine offshore Western Australian seabed with sediment condition expected to be uniform across the wider permit area with no significant values or sensitivities. Given the details above, the consequence of drilling cuttings and fluids causing a change in ambient sediment quality has been assessed as **Minor (1)**, with discharges expected to be limited to close to the discharge source, the highest concentrations limited to within close proximity to the well site and sediment quality is expected to reach pre-drilling conditions within a relatively short time frame (>1 year).

7.1.6.2.2 Ecological Receptors

Ecological receptors with the potential to be impacted as a result of a planned discharge of cement include:

- benthic habitats and communities.

The above receptors may be impacted from:

- change in habitat
- injury / mortality to fauna.

Table 7-47 provides a detailed evaluation of the impact of a planned discharge of drilling cuttings and fluids to ecological receptors.

Table 7-47 Impact and Risk Assessment for Ecological Receptors from Planned Discharge – Drilling cuttings and Fluids

Benthic Habitats and Communities ✓
Change in habitat A loss of benthic habitat from smothering and increased toxicity of sediments and ambient water through the discharge of drilling cuttings and fluids within the Project Area, will have a negligible effect on benthic habitats and communities. As described in Change in Sediment Quality, surface discharges of SBM within water depths less than 300–400 m are generally deposited within ~100–200 m downstream of the discharge source (CSA 2004; Dorn et al. 2007; Correa et al. 2010). The 1 to 3 wells that will be drilled for the Corowa Development are very close together (all within a 10 m x 10 m footprint); therefore the cuttings piles from each one will overlap. Hence a conservative maximum impact radius of 200 m is assumed, giving a footprint of 0.125 km^2. This is well within the 5 km buffer that comprises the Project Area. Loss of benthic habitat from drilling cuttings will be limited to a radius of ~200 m from the wellbore, which is considered negligible considering the extent of the sparse seabed communities within the NWS. Given the details above, the consequence of a planned discharge in drilling cuttings and fluids causing a change in habitat has been assessed as **Minor (1)**, given the localised impact and sparse habitat that may be affected. Injury / mortality to fauna Impacts to mobile benthic fauna (e.g. crabs, shrimps, demersal fish) are not expected given their ability to avoid effected areas (IOGP 2016). Studies (Balcom et al. 2012; IOGP 2016) have concluded that impacts to benthic habitats and communities as a result of drilling cuttings and fluids discharges are minimal, resulting in highly localised impacts with benthic environments rapidly recovering to post-drilling conditions. Benthic organisms are generally well adapted to changes in sediment quality, especially burrowing species. Benthic habitat within the Corowa Development area will be representative of the NWS seabed environment and is expected to be flat, uniform and undulating comprising mainly of sandy and muddy sediments. Benthic communities are also expected to be similar to that of the wider region comprising low-density communities of bryozoans, molluscs and echinoids. Pre-hydrated bentonite 'gel' sweeps are also likely to be discharged to the marine environment during top-hole drilling, of ~50 m^3 per well (of gel sweeps, WBM or seawater). Bentonite is a type of clay, usually combined with sodium, potassium calcium, and is non-toxic. Top-hole drilling may use seawater as a drilling fluid with additives of caustic soda (NaOH) and/or soda ash (Na_2CO_3) to increase pH and alkalinity. These inorganic salts are slightly toxic to freshwater plants and animals with effects in these species caused by

ionic or pH effects. Because of the high ionic strength and buffer capacity of seawater, it is unlikely that these inorganic salts would be toxic to marine organisms at the concentrations at which they occur in WBM (Neff 2005). Although chemicals can usually be detected within the sediment surrounding the discharge site, impacts to benthic flora and fauna from WBM adhered to cuttings are generally subtle (Cranmer 1988; Neff et al. 1989; Hyland et al. 1994; Daan and Mulder 1996; Currie and Isaacs 2005; OSPAR 2009; Bakke et al. 2013). No EPBC listed threatened benthic communities or species are present within the Corowa Project Area. A change in benthic habitats and communities as a result of planned discharges of drilling cuttings and fluids is unlikely at a measurable level are expected to be limited to close proximity of the discharge source (~200 m); and not result in a change in the viability of the population or ecosystem. Given the details above, the consequence of a planned discharge in drilling cuttings and fluids causing injury or mortality to non-threatened benthic habitats and communities has been assessed as **Minor (1)**, given the localised impact and sparse populations that may be affected.

7.1.6.3 Consequence and Acceptability

The consequence of Planned Discharge – Drilling cuttings and Fluids has been evaluated as **Minor (1)** for all potentially impacted receptors and is considered **acceptable** when assessed against the criteria in Table 7-48.

Table 7-48 Demonstration of Acceptability for Planned Discharge – Drilling Cuttings and Fluids

Acceptability Criteria	Justification
To meet the principles of ESD	• Discharges of drilling cuttings and fluids will result in a temporary and localised change in water quality through increased turbidity and toxicity. • The predominantly dispersive nature and low toxicity of drilling cuttings and fluids discharges and the location of the Corowa Development within the high-energy offshore marine environment means that impacts will be localised. • Discharges of drilling cuttings and fluids will result in a temporary and localised change in sediment quality through sediment deposition and toxicity, with a conservative direct disturbance radius of 200 m, giving a footprint of 0.125 km^2, which is within the Project Area 5 km buffer.
Internal context	• KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)
External context	• No stakeholder concerns have been raised with respect to drilling cuttings and fluids or potentially impacted receptors.
Other requirements	• In regard to drill cutting and fluids, activities undertaken throughout the Corowa Development will not be conducted in a manner inconsistent with protecting biological diversity and ecological integrity of benthic communities and habitats.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-49.

Table 7-49 Summary of Impact Assessment for Planned Discharge – Drilling cuttings and Fluids

Receptor	Impact	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM18**: Solid removal and treatment equipment will be used to reduce and minimise the amount of residual fluid contained in drilled cuttings prior to discharge to the marine environment. **CM19:** Drilling and cementing procedures to standard industry practices will be developed that will describe specific well locations, design and fluid volumes.	Minor
Ambient sediment quality	Change in sediment quality			Minor
Benthic habitats and communities	Change in habitat	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor
	Injury / mortality to fauna			Minor

7.1.7 Planned Discharge – Cement

Planned discharges of cement may cause localised changes to water and sediment quality, which may in turn impact on epifauna and infauna populations.

7.1.7.1 Aspect Source

Throughout the Corowa Development, phases and activities that use cement and that may interact with other receptors include:

Drilling	Top-hole drilling; bottom-hole drilling
Installation, Hook-up and Commissioning	CALM buoy and mooring arrangements
Operations	well intervention
Decommissioning	well P&A

Drilling; Installation, Hook-up and Commissioning; Operations; Decommissioning

Cement is used to permanently seal annular spaces between casings and borehole walls and provide structural support. Cement is also used to seal formations to prevent loss of drilling fluid and for operations ranging from flushing drilling fluids from casings, setting kick-off plugs, maintenance and repair to well P&A.

Minor volumes of cement will be released at the seabed during installation of the main conductor at the seabed (estimated 30 m^3 maximum overspill). Once the main conductor has been installed, all further displaced fluids will be returned to the MODU.

Upon completing each cementing activity, the cementing head and blending tanks are cleaned, which results in a release of cement contaminated water to the marine environment of <0.8 m^3 per well. Also, in the unlikely event that cement products become contaminated by drilling fluids, the entire volume may need to be recovered to surface and discharged to sea (estimated maximum volume of 15 m^3).

Following planned surface discharges from washing the cement unit a change in water quality may occur with an increase in turbidity and chemical toxicity. Terrens et al. (1998) suggests that once the cement has hardened, the chemical constituents are locked into the cement. The extent of this hazard is limited to the subsurface waters directly adjacent to the displaced subsea cement.

If drilled and grouted anchor piles are selected as the mooring methodology for the CALM buoy, three shallow ~25 m holes will be drilled to insert the casing, and grout will be pumped into and around the casing. There may be a small overflow at the top of the casing onto the surrounding seabed.

Well P&A procedures are designed to isolate the well and prevent the release of wellbore fluids into the marine environment. During abandonment, cement may be set within the wellbore to install a permanent reservoir and surface barrier. The main conductor will be in place, so all further displaced fluids will be returned to the MODU.

7.1.7.2 Impact Analysis and Evaluation

Activities involving cement at the Corowa Development have the potential to result in these impacts:

- change in water quality
- change in sediment quality.

As a result of a change in water and sediment quality, further impacts may occur, including:

- change in habitat
- injury / mortality to fauna.

Table 7-50 identifies the potential impacts to receptors as a result of a planned discharge of cement at the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor). Table 7-51 provides a summary and justification for those receptors not evaluated further.

Table 7-50 Receptors Potentially Impacted by Planned Discharge – Cement

Impacts	Ambient water quality	Ambient sediment quality	Plankton	Benthic habitats and communities	Fish	Marine mammals	Marine Reptiles	Commercial Fisheries
Change in water quality	✓							
Change in sediment quality		✓						
Change in habitat				✓				
Injury/ mortality to fauna			X	✓	X	X	X	
Changes to the functions, interests or activities of other users								X

Table 7-51 Justification for Receptors Not Evaluated Further for Planned Discharge – Cement

Plankton, Fish, Marine Mammals and Marine Reptiles ***X***

Injury/ mortality to fauna

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. A reduction in water quality and increased turbidity through the discharge of cement within the Project Area is unlikely to result in the mortality of plankton or other mobile marine fauna. Modelling undertaken by de Campos et al. (2017) and BP (2013) showed average deposition of 0.05 mg/m^2 and <5 mg/L respectively of material on the seabed. These levels are significantly lower than levels of suspended sediments >500 mg/L likely to produce a measurable impact upon larvae of most fish species (Jenkins and McKinnon 2006).

Plankton have a patchy distribution linked to localised and seasonal productivity that produces sporadic bursts in populations (DEWHA 2008). The oligotrophic waters of the project area are typical of the wider offshore region supporting low phytoplankton biomass and relatively low primary productivity (Woodside 2005). A change in water quality as a result of cement is unlikely to lead to injury or mortality of plankton at a measurable level and will not result in a change in the viability of the population or ecosystem. Therefore, no impacts to plankton from cement discharges are expected and are not discussed further.

Because cement discharges within the Corowa Project Area will be localised and rapidly diluted, and fish, marine mammals and marine reptile species will be transitory in nature, the impacts of these discharges will be negligible and therefore are not discussed further.

As cement discharges will have negligible impacts on plankton populations, indirect impacts to higher trophic levels are very unlikely. Therefore, no impacts to these species are expected from cement discharges and have not been evaluated further.

Commercial Fisheries ***X***

Changes to the functions, interests or activities of other users

As impacts to fish have not been expected from planned discharges of cement, indirect impacts to commercial fisheries are not expected.

The radius of direct disturbance from cement discharge is conservatively estimated at 50 m, giving a footprint of 0.011 km^2, which is well within the 5 km radius of the Project Area. This is an insignificant area compared to the size and scale of commercial fisheries. Eight State- and Commonwealth-managed fisheries

intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). Therefore, impacts to commercial fisheries from planned discharge of cement are not expected, and have not been evaluated further.

Impacts to receptors are assessed below, by receptor type.

7.1.7.2.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of a planned discharge of cement include:

- ambient water quality
- ambient sediment quality.

The above receptors may be impacted from:

- change in water quality
- change in sediment quality.

Table 7-52 provides a detailed evaluation of the impact of planned discharges of cement to physical receptors.

Table 7-52 Impact and Risk Assessment for Physical Receptors from Planned Discharge – Cement

Ambient Water Quality ✓
Change in water quality
A planned release of cement has the potential to increase turbidity within the water column and introduce chemical toxicity. Small volumes (0.8 m^3) of a cement/water mix may be released in surface waters during equipment washing with possible overspill of mixed cement (30 m^3) on the seabed as part of drilling operations.
Modelling undertaken by de Campos et al. (2017) showed a release of 18 m^3 of cement wash water resulted in average deposition of 0.05 mg/m^2 of material on the seabed, with particulate matter deposited within the three-day simulation period. BP modelling (2013) of larger cement discharges (~78 m^3 over a one-hour period) suggested that within two 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.
The possibility of chemical toxicity from a planned cement discharge comes from chemical additives added to the dry cement mix. Therefore, the risk of chemical toxicity is most likely to occur at the seabed as part of overspill of mixed cement during drilling operations. Low toxicity additives are likely to be selected and rated through the Offshore Chemical Notification Scheme (OCNS) to ensure the lowest practicable impact on the environment. Any discharges are to be highly localised and temporary as rapid deposition rates in the BP (2013) study detailed above suggests. Terrens et al. (1998) also suggests that once the cement has hardened, the chemical constituents are locked into the cement. CIN (2005) also states that once cement has set it is essentially inert and not likely to have chronic toxicity effects. Toxic chemical levels will also be subject to rapid dispersion and high dilution rates in the open ocean.
Given the details above, the consequence of cement discharges causing a change in ambient water quality has been assessed as **Minor (1)**, given the localised and temporary nature of increased turbidity and low toxicity levels.
Ambient Sediment Quality ✓
Change in sediment quality
A planned release of cement has the potential to smother and alter the benthic substrate permanently.
Chevron (2018) indicated that planned cement discharges from overflow during drilling operations may affect the seabed around the well to a radius of ~10 m–50 m. This is an area of 0.007 km^2 for an individual

well, which is an insignificant area when compared to the expanse of the seabed present in the North West Shelf. The seabed entry point of all the four wells will be within an ~10 m by 10 m footprint (i.e. within a total footprint of <100 m^2); therefore, the cement overspill from each well is likely to overlap. Assuming a conservative maximum impact radius of 50 m (plus including the <10 m separation between the wells), gives a footprint of 0.011 km^2. This is well within the 5 km buffer that comprises the Project Area. Background toxicity levels are expected to be minimal as once the cement has hardened the chemical constituents will be locked into the cement (Terrens et al. 1998), with no potential for chronic exposure. There are no Management Plans, Recovery Plans or Conservation Advice related to sediment quality within the Project Area. No important or substantial area of seabed is expected to be modified, destroyed, fragmented, isolated or disturbed. The Project Area is not situated in a KEF. Given the details above, the consequence of cement discharges causing a change in sediment quality has been assessed as **Minor (1)**, given the permanent alteration of the seabed will be very localised (within 60 m of the wells).

7.1.7.2.2 Ecological Receptors

Ecological receptors with the potential to be impacted as a result of a planned discharge of cement include:

- benthic habitats and communities.

The above receptor may be impacted from:

- change in habitat
- injury / mortality to fauna.

Table 7-53 provides a detailed evaluation of the impact of a planned discharge of cement to ecological receptors.

Table 7-53 Impact and Risk Assessment for Ecological Receptors from a Planned Discharge of Cement

Benthic Habitats and Communities ✓
Change in habitat Activities associated with the Corowa Development will result in a change in habitat due to the localised and small-scale overspill of cement. A pre-drilling study (Thales 2001) confirms the seabed in the Corowa Development area is consistent and composed of partially exposed cemented carbonates overlaid by a fine to coarse grained sedimentary veneer. The extents of smothering are discussed above in *Change in sediment quality*, with affects localised to within ~60 m of the drilling site, giving a total footprint of 0.011 km^2. The benthic habitat does not represent a diverse population or contain any sensitive benthic communities with sessile species expected to be sparsely distributed. Given the localised impact (<60 m) and sparse habitat that may be affected the likelihood of a change in non-threatened benthic habitats has been rated as **Minor (1)**. Injury / mortality to fauna The planned release of cement from overspill as part of the drilling or plugging process has the potential to cause injury or mortality to benthic habitats and communities mainly through the process of smothering. The sandy substrates on the shelf within the Project Area are thought to support low-density benthic communities of bryozoans, molluscs and echinoids. Sponge communities are also sparsely distributed on the shelf, being found only in areas of hard substrate (DEWHA 2008; Section 5.4). The extents of smothering are discussed above, with affects localised to within ~60 m of the drilling site, giving a total footprint of 0.011 km^2. Mobile epifaunal and infauna species are unlikely to be affected as can

move away from the disturbance. The benthic habitat does not represent a diverse population or contain any sensitive benthic communities with sessile species expected to be sparsely distributed. Relative to the surrounding environment, this is a small area and seabed disturbance will not cause impact to any Matters of National Environmental Significance (MNES) or Key Ecological Features (KEF). The EPBC PMST did not identify any sensitive or vulnerable species within the area and the Project Area is not situated in an area considered a key ecological feature (KEF). There are no Management Plans, Recovery Plans or Conservation Advice related to epifauna and infauna within the Project Area. Therefore, no important or substantial areas of epifauna or infauna habitat are expected to be modified, destroyed, fragmented, isolated or disturbed. Given the details above, the consequence of cement discharges causing a change in habitat in the benthic habitat and communities or injury / mortality to fauna has been assessed as **Minor (1)** given the localised impact and sparse populations that may be affected.

7.1.7.3 Consequence and Acceptability Summary

The worst-case consequence of a Planned Discharge – Cement has been evaluated as **Minor (1) f**or impacts to all receptors (localised minor impact on non-threatened species or their habitat), and is considered **acceptable** when assessed against the criteria Table 7-54.

Table 7-54 Demonstration of Acceptability for Planned Discharge – Cement

Acceptability Criteria	Justification
To meet the principles of ESD	• Cement overspill from drilling operations will impact and alter the seabed within the vicinity of the drilling site but will result in a very small area of disturbance. • Assuming a conservative maximum impact radius of a total of 60 m gives a footprint of 0.011 km^2. This is well within the 5 km buffer around the MOPU that comprises the Project Area. • Soft sediment communities with sparse population of benthic habitats and communities present within the Corowa Development area are unlikely to be affected by cement overspill of chemical toxicity.
Internal context	• KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)
External context	• No stakeholder concerns have been raised with respect to cement discharges or potentially impacted receptors.
Other requirements	• Low toxicity additives to be selected and rated through the Offshore Chemical Notification Scheme (OCNS). • With respect to planned discharges of cement, activities associated with the Corowa Development will not be conducted in a manner inconsistent with protecting biological diversity and ecological integrity of benthic communities and habitats.

A summary of the impact analysis and evaluation, including adopted control measures adopted and EPOs, is provided in Table 7-55.

Table 7-55 Summary of Impact Assessment for Planned Discharge – Cement

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM19**: Drilling and cementing procedures to standard industry practices will be developed that will describe specific well locations, design and fluid volumes.	Minor
Ambient sediment quality	Change in sediment quality			Minor
Benthic habitats and communities	Change in habitat	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor
	Injury / mortality to fauna			Minor

7.1.8 Planned Discharge – Commissioning Fluids

7.1.8.1 Aspect Source

Throughout the Corowa Development, commissioning fluids will be discharged to the marine environment during these activities:

Installation, hook-up and commissioning	flowlines; FSO; MOPU
Decommissioning	disconnection of FSO and MOPU

Installation, Hook-up and Commissioning

Commissioning fluids are expected to comprise seawater, corrosion inhibitors, oxygen scavengers, biocide, MEG and fluorescein dye. Chemicals are required to avoid metal corrosion, prevent bacterial growth and the accumulation of scale on internal surfaces, all aimed at maintaining pipeline integrity.

These additives will be selected using the globally accepted hazard assessment tool (the OSPAR Harmonised Mandatory Control Scheme (HMCS)) and where practicable preference will be given to products with an Offshore Chemical Notification Scheme (OCNS) ranking with the lowest toxicity.

The commissioning fluids will be used on all facilities. For example, after installation, the 1.5 km subsea flowline, dynamic riser and the floating marine hose (between CALM buoy and FSO) will be leak tested to assess structural integrity. This fluid will remain in the flowline to provide corrosion protection prior to the introduction of hydrocarbons. During the FEED phase of the project the chemical type, concentration and volumes will be determined. The base case is for commissioning fluid to be displaced to the FSO or the first shuttle tanker on commencement of production, but it may be discharged to the marine environment in a single event.

The volume of commissioning fluid is expected to be ~70 m^3, allowing for double the total inventory of the flowline and hoses (volume to be confirmed in FEED).

In the event a cyclone shutdown is required during operations, the full flowline volume will be displaced to the FSO with either treated seawater or produced formation water (PFW). After the FSO remobilises to the Project Area, the flowlines will be reconnected to the FSO, and the flowline contents (treated seawater or PFW) would be displaced to the FSO for treatment within the FSO bilge system (i.e. not discharged directly to the marine environment).

Decommissioning

Commissioning fluids may be used during the decommissioning of the flowline and marine hoses. Similar compositions and volumes are expected as per installation and testing. Oil will be displaced to the FSO by inhibited seawater or PFW. As the flowline and marine hoses are recovered onto a reel on the vessel, the contents will be discharged to the marine environment, comprising ~30 m^3, 5 m^3 and 24 m^3 of inhibited seawater or PFW (for the subsea flowline, marine hose and export hose respectively).

7.1.8.2 Impact Analysis and Evaluation

Planned discharges of installation and commissioning during the Corowa Development have the potential to result in these impacts:

- change in water quality
- change in sediment quality.

As a result of a change in water and sediment quality, further impacts may occur, including:

- injury/mortality to fauna.

Table 7-56 identifies the potential impacts to receptors as a result of a discharge of installation and commissioning fluids from the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-57 provides a summary and justification for those receptors not evaluated further.

Table 7-56 Receptors Potentially Impacted by Planned Discharge – Commissioning Fluids

Impacts	Ambient water quality	Ambient sediment quality	Plankton	Benthic habitats and communities	Fish	Commercial Fisheries
Change in water quality	✓					
Change in sediment quality		✓				
Injury/mortality to fauna			*X*	*X*	*X*	
Changes to the functions, interests or activities of other users						*X*

Table 7-57 Justification for Receptors Not Evaluated Further

Plankton	***X***
Injury/mortality to fauna 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 (DEWHA 2008). Phytoplankton production at the depths present at the Corowa Development where discharges of commissioning fluids are planned will be low as it is near the photic zone with sparse nutrient levels. A change in water quality as a result of commissioning fluids is unlikely to lead to injury or mortality of plankton at a measurable level and will not result in a change in the viability of the population or ecosystem. Therefore, no impacts to plankton from planned discharge of installation and commissioning fluids are expected and have not been evaluated further.	
Benthic Habitats and Communities	***X***
Injury/mortality to fauna There are no important or substantial areas of benthic habitats and communities identified within the Project Area that are expected to be modified, destroyed, fragmented, isolated or disturbed by commissioning fluid discharges. There are also no Management Plans, Recovery Plans or Conservation Advice related to benthic habitats and communities within the Project Area. The Project Area has sparse populations of filter and deposit-feeding epibenthic fauna plus a diverse but broadly representative infaunal community, dominated by polychaete worms and crustaceans. Possible macroinvertebrates within the Project Area include species of arthropod (prawn, lobsters) and molluscs (squid, octopus). Mobile benthic taxa, such as echinoderms or sessile taxa such as sponges may be present, but in sparse numbers. The habitats and communities that may be impacted by the commissioning fluid discharge are widely distributed in the region and are not considered to be of high conservation value. The discharge of commissioning water will not physically modify benthic habitats. Benthic biota within these habitats may experience injury or mortality due to toxic effects, however, rapid recovery rates are expected to occur through natural recruitment. No KEFs have been identified within the plume of the commissioning fluid discharge. Commissioning fluid discharges are unlikely to lead to injury or mortality of benthic habitats and communities at a measurable level and will not result in a change in the viability of the population or ecosystem. Therefore, impacts to benthic habitats and communities from commissioning fluids are not expected, and have not been evaluated further.	

Fish, Marine Mammals and Marine Reptiles	X
Injury/mortality to fauna Potential impacts to fish, marine mammals and marine reptiles from commissioning fluid discharges are expected to be limited to avoidance of the discharge plume, which will be localised to the flowline and risers. The EPBC PMST lists one species of shark as Vulnerable and four as Vulnerable/Migratory (including the Whale Shark) that are likely to occur within the area. The Corowa Project Area is situated within a BIA for the Whale Shark. Whilst pollution was listed as a future threat at present pollution does not have an impact on the numbers of Whale Sharks visiting Australian waters (DEH 2005a). All species listed within the EPBC PMST are highly mobile, therefore, none are expected to be affected by commissioning fluid discharges. Activities will be conducted in accordance with all applicable management actions. Commissioning fluid discharges are unlikely to lead to injury or mortality of fish species at a measurable level and will not result in a change in the viability of the population or ecosystem. As no impacts from commissioning fluids are expected to fish species, impacts have not been evaluated further. 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 Because commissioning fluid discharges within the Corowa Project Area will be localised and rapidly diluted, and fish, marine mammals and marine reptile species will be transitory in nature, the impacts of these discharges will be negligible and therefore are not discussed further.	
Commercial Fisheries	X
Changes to the functions, interests or activities of other users As impacts to fish have not been expected from planned discharges of commissioning fluids, indirect impacts to commercial fisheries are not expected. The radius of direct disturbance from cement discharge is conservatively estimated at 50 m, gives a footprint of 0.011 km^2, which is well within the 5 km radius of the Project Area. This is an insignificant area compared to the size and scale of commercial fisheries. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). Commissioning fluid discharges are unlikely to lead to injury or mortality of commercial fish species at a measurable level and will not result in a change in the viability of the population or ecosystem Therefore, impacts to commercial fisheries from planned discharge of commissioning fluids are not expected, and have not been evaluated further.	

7.1.8.2.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of discharges of commissioning fluids include:

- Ambient water quality
- Ambient sediment quality.

Table 7-58 provides a detailed evaluation of the impact or risk of commissioning fluids to physical receptors.

Table 7-58 Impact and Risk Assessment for Physical Receptors from Planned Discharges – Commissioning Fluids

Ambient Water Quality	✓
Change in water quality A planned release of commissioning fluids may result in an impact on ambient water quality, as discharges may include corrosion inhibitors, oxygen scavengers, biocide, MEG, methanol and/or fluorescein dye. Commissioning discharges are typically short in duration and do not have the potential for significant impacts over an extended period. Modelling by Chevron (2015) for the Wheatstone Project predicted that	

the discharge plume of 220,000 m^3 would dilute to below lethal concentration levels (LC_{50} of 0.06 ppm) at 3.5 km from the discharge location. Modelling for Shell (2018) for the CRUX Platform set an impact threshold of 1 ppm of biocide, assuming that concentrations below this threshold would not result in significant environmental impacts. This threshold is consistent with published acute toxicity test data for aquatic species for typical biocides that may be used (Shell 2018). For a release of 48,600 m^3 of commissioning water, modelling found that the 1 ppm threshold was at ~5.7 km from the discharge source. Volumes of commissioning fluids discharged at the Corowa Development will be insignificant compared to these modelled studies. Flowline specifications are still in the design stage. The volume of commissioning fluid is expected to be ~70 m³, allowing for double the total inventory. During decommissioning a total of ~59 m^3 of inhibited seawater or PFW would be discharged from the subsea flowline, marine hose and export hose, as they are retrieved onto a reel. The discharge of commissioning fluids may result in the suspension of sediments thereby increasing turbidity levels at the source of the discharge. Increased turbidity will be localised and temporary with suspended sediments likely to settle quickly. Chevron (2014) reported that within two hours of high impact trenching activities operations ceasing, turbidity levels returned very close to normal background levels. The levels of suspended sediments from commissioning fluid discharge will be negligible in comparison. Given the details above, the consequence of commissioning fluids causing a change in ambient water quality has been assessed as **Minor (1)**, as single event discharges during commission and decommission phases plus rapid mixing by ocean currents will ensure discharges will be localised and temporary.
Ambient Sediment Quality ✓
A planned release of commissioning fluids may result in a reduction in ambient sediment quality, as discharges may include chemicals as previously detailed above, including biocide. The residual biocide in the commissioning treated seawater has the potential to be acutely toxic to a range of marine biota. However, biocides routinely used in the oil and gas industry do not bioaccumulate and are expected to be consumed by microorganisms (e.g. bacteria) once discharged to the marine environment (Shell 2018). Modelling as detailed above shows that any toxic effects of commissioning fluids will be localised and diluted by ocean currents and therefore unlikely to substantial modify, destroy or disturb sediments within the Project Area. Given the details above, the consequence of commissioning fluids causing a change in ambient sediment quality has been assessed as **Minor (1)**, given that discharges will be localised, infrequent and will be rapidly diluted.

7.1.8.3 Consequence and Acceptability

The consequence of Planned Discharge – Commissioning Fluids has been evaluated as **Minor (1)** for all potentially impacted receptors**,** and is considered **acceptable** when assessed against the criteria in Table 7-59.

Table 7-59 Demonstration of Acceptability for Planned Discharge – Commissioning Fluids

Acceptability Criteria	Justification
To meet the principles of ESD	• Discharges will be of a very low volume (~70 m^3) compared to other pipelines within the NWS of significantly longer length. • Discharges will be localised and temporary causing a minor reduction in water and sediment quality. • The discharge plume will not impact on any KEF.
Internal context	• KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)
External context	• No stakeholder concerns have been raised with respect to discharges of installation and commission fluids, or potentially impacted receptors.

Acceptability Criteria	Justification
Other requirements	• Low toxicity additives to be selected and rated through the Offshore Chemical Notification Scheme (OCNS). • In regard to discharges of commissioning fluids, activities undertaken throughout the Corowa Development will not be conducted in a manner inconsistent with maintaining the environmental values of marine environmental quality.

A summary of the impact analysis and evaluation, including adopted control measures adopted and EPOs, is provided in Table 7-60.

Table 7-60 Summary of Impact Assessment for Planned Discharge – Commissioning Fluids

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness.	Minor
Ambient sediment quality	Change in sediment quality			Minor

7.1.9 Planned Discharge – Produced Formation Water

Formation water is naturally occurring water found in the same formations as oil and gas. When the oil and gas flow to the surface, this water is also brought to the surface with the hydrocarbons. After treatment, this waste product, known as produced formation water (PFW), is discharged to the marine environment.

The composition of PFW contains various substances that have been dissolved from the geologic formations including inorganic substances (e.g. salts, trace metals), and organic substances (e.g. hydrocarbons), and this composition can vary over the reservoir life (OSPAR 2014, OGP 2005). Irrespective of the variations in the chemical composition of produced waters, they have very low intrinsic toxicity (OGP 2005).

7.1.9.1 Aspect Source

Throughout the Corowa Development, PFW will be discharged to the marine environment during these phases and activities:

Operations	hydrocarbon processing, storage and offloading

Operations

Throughout the operations phase of the Corowa Development (during hydrocarbon processing), hydrocarbons from the wells will be routed to the processing module on board the MOPU where PFW will be separated from the crude oil and gas.

The PFW is then treated on board the MOPU to remove some of the salt, scale and fine particulate matter; when PFW is discharged it may contain residual amounts of hydrocarbon, corrosion inhibitor, salts (dissolved and precipitated), and fines.

PFW typically increases in volumes toward the end of reservoir life, as hydrocarbons are depleted, and the well 'waters out'. Therefore, the largest volumes are only for a short duration before the well is shut-in and plug and abandoned (as it becomes uneconomical). The maximum PFW discharge rate for the Corowa Development is 178 m^3/hour.

The discharge point will be at or below the lowest anticipated sea level, from a pipe within one of the legs of the MOPU. The depth depends on the final design of the MOPU.

The temperature of the PFW discharge may vary between 45 °C and 65 °C. Residual total petroleum hydrocarbon (Oil-in-Water) will be discharged as part of the PFW discharge stream. For the purpose of impact assessment, Oil-in-Water of less than 29 mg/L has been assumed (actual discharge concentrations will be reduced to ALARP and are likely to be less than this but will be determined during FEED).

7.1.9.1.1 Discharge Modelling and Exposure Assessment

Visual Plumes (VPLUMES) is a set of mixing zone models developed by the United States Environment Protection Agency (US EPA) that can simulate single and merging submerged plume behaviour (Frick et al. 2003). The following two models, available within the VPLUMES package, were used to model various scenarios of PFW discharges from the MOPU (Xodus Group 2019c; Appendix D), to quantify the spatial extent of the discharge plume:

- The three-dimensional Updated Merge (UM3) model, which is a Lagrangian initial dilution model that incorporates the projected-area-entrainment (PAE) hypothesis. The UM3 model was used to simulate mixing of the PFW discharge from the MOPU within the near-field.
- The Brooks algorithm, which is a simple dispersion calculation that is a function of travel time and initial plume width. The Brooks algorithm was used to predict centreline dilution and plume width of the PFW discharge within the far-field.

It is acknowledged that the Brooks algorithm is a simplified approach to far-field modelling; however, given that external processes (e.g. waves) that would enhance mixing are not taken into account, it is considered to provide a conservative estimate and therefore is appropriate for use in impact analysis.

The major constituents of PFW are inorganic salts (which make it similar to seawater). Insoluble salts may form on discharge and precipitate out; however, these are of a relatively inert nature. Minor constituents such as trace elements occur at very low concentrations and their contribution to the overall flux to the marine environment is very small (OGP 2005). PFW also contains insoluble oil droplets (i.e. dispersed oil) from the reservoir that the surface treatment facilities are not able to remove. Compounds that are soluble in water will typically dilute rapidly once released into the marine environment, while particulate material (e.g. fine sediments, corrosion products) and insoluble products (e.g. dispersed oil) will persist and may eventually sink to the sediments (OGP 2005).

For the PFW discharge, the critical parameters that have the potential to impact the marine environment are the temperature differential and the residual hydrocarbons. These environmental thresholds have been used within the discharge modelling to support exposure and mixing zone assessments:

- **Hydrocarbon:** A Predicted No Effect Concentration (PNEC) for dispersed oil in PFW has been defined at 70.5 µg/L (OSPAR 2014). This PNEC was developed from toxicity data from marine species from five taxonomic groups (OSPAR 2014, Smit et al. 2009). The PNEC values for naturally occurring substances within PFW were compiled in support of OSPAR Recommendation 2012/5 and Guidelines 2012/7 (OSPAR 2012a; OSPAR 2012b).

- **Temperature:** The World Bank Group's Environmental Health and Safety (EHS) Guidelines for Offshore Oil and Gas Development (IFC 2015) define a guideline for cooling-water discharges as:

  > *'The effluent should result in a temperature increase of no more than 3°C at edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 m from point of discharge.'*

  These EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice. The EHS Guidelines do not specify a temperature guideline for PFW discharges, and so this cooling-water discharge guideline has been adopted as also being appropriate for PFW discharges.

Multiple scenarios (Table 7-61) were modelled, including variations in both discharge characteristics (temperature, volume and discharge depth) and ambient conditions (current velocity) to evaluate the differences in plume mixing behaviour and spatial extent to reach environmental thresholds. Final configuration of the PFW discharge from the MOPU will occur during FEED.

Table 7-61 PFW Discharge Modelling Parameters

Parameter	Description / Value				
Outlet characteristics					
Number of ports	1				
Port orientation	Vertical down				
Port diameter	6" (0.15 m)				
Port depth	2 m	10 m	30 m	50 m	75 m
Water depth	90 m				
Discharge characteristics					
Flow type	Continuous				
Flow rate	178 m^3/hour (0.05 m^3/s)				
Temperature	45 °C		65 °C		
Salinity	37				
Oil-in-Water (OIW)	29 mg/L				

Source: Xodus Group 2019c

The discharge modelling showed these mixing behaviours for PFW from the MOPU (Xodus Group 2019c):

- Both discharges are initially buoyant compared to ambient seawater (the 65 °C more than the 45 °C discharge), but for discharges at depths (typically ≥30 m) the discharged PFW plume is not predicted to reach the surface during the initial dilution phase (i.e. where mixing is due to density differences) as it will have reached an equilibrium density to ambient conditions at some depth in the water column
- The PFW discharge plume is never predicted to interact with the seabed, even from the deepest modelled discharge (i.e. 75 m depth or 15 m above seabed)
- Mixing required to meet the hydrocarbon threshold varies between 31 m and 896 m for the 45 °C discharge (Table 7-62), and 31 m and 1,220 m for the 65 °C discharge (Table 7-63). The

hydrocarbon threshold is met under either near-field or far-field mixing depending on the combination of discharge and ambient conditions.

- The temperature threshold is met within the near-field mixing zone for all scenarios. The near-field mixing zone varies between 8 m and 896 m for the 45 °C discharge (Table 7-64), and 3 m and 871 m for the 65 °C discharge (Table 7-65).

Therefore, the maximum horizontal distance predicted to be needed to reach the hydrocarbon and temperature thresholds is 1,220 m and 896 m from the MOPU respectively (Figure 7-15).

Table 7-62 Mixing Behaviour of PFW Discharge (178 m³/hour at 45 °C) to meet the Oil Threshold

Discharge Depth (m)	0	10	30	50	75
Low ambient current (0.05 m/s)					
Approx. horizontal distance required to reach oil threshold (~411 dilutions)	**250 m**	**140 m**	**<31 m**	**<89 m**	**160 m**
Approx. width of plume at this distance	61 m	40 m	<22 m	<42 m	44 m
Type of mixing required for to dilute PFW to oil threshold	NF + FF	NF + FF	NF	NF	NF + FF
Moderate ambient current (0.2 m/s)					
Approx. horizontal distance required to reach oil threshold (~411 dilutions))	**520 m**	**<87 m**	**<313 m**	**<359 m**	**190 m**
Approx. width of plume at this distance	29 m	<14 m	<27 m	<28 m	16 m
Type of mixing required for to dilute PFW to oil threshold	NF + FF	NF	NF	NF	NF + FF
High ambient current (0.5 m/s)					
Approx. horizontal distance required to reach oil threshold (~411 dilutions)	**840 m**	**<314 m**	**<884 m**	**<896 m**	**<201 m**
Approx. width of plume at this distance	16 m	<12 m	<20 m	<20 m	<8 m
Type of mixing required for to dilute PFW to oil threshold	NF + FF	NF	NF	NF	NF

NF = near-field, FF = far-field

Table 7-63 Mixing Behaviour of PFW Discharge (178 m³/hour at 65 °C) to meet the Oil Threshold

Discharge Depth (m)	0	10	30	50	75
Low ambient current (0.05 m/s)					
Approx. horizontal distance required to reach oil threshold (~411 dilutions)	**295 m**	**170 m**	**80 m**	**<31 m**	**55 m**
Approx. width of plume at this distance	67 m	40 m	30 m	<26 m	27 m
Type of mixing required for to dilute PFW to oil threshold	NF + FF	NF + FF	NF + FF	NF	NF + FF
Moderate ambient current (0.2 m/s)					
Approx. horizontal distance required to reach oil threshold (~411 dilutions)	**740 m**	**<40 m**	**<124 m**	**<348 m**	**<75 m**
Approx. width of plume at this distance	39 m	<12 m	<24 m	<37 m	<13 m
Type of mixing required for to dilute PFW to oil threshold	NF + FF	NF	NF	NF	NF

Discharge Depth (m)	0	10	30	50	75
High ambient current (0.5 m/s)					
Approx. horizontal distance required to reach oil threshold (~411 dilutions)	**1,220 m**	**<135 m**	**<388 m**	**<871 m**	**<187 m**
Approx. width of plume at this distance	22 m	<11 m	<21 m	<27 m	<10 m
Type of mixing required for to dilute PFW to oil threshold	NF + FF	NF	NF	NF	NF

NF = near-field, FF = far-field

Table 7-64 Mixing Behaviour of PFW Discharge (178 m³/hour at 45 °C) to meet the Temperature Threshold

Discharge Depth (m)	0	10	30	50	75
Low ambient current (0.05 m/s)					
Dilution achieved under near-field mixing only	71	187	431	1,423	175
Approx. horizontal extent of near-field mixing zone	**8 m**	**15 m**	**31 m**	**89 m**	**20 m**
Plume temperature at the edge of near-field mixing zone	28.2 °C	28.0 °C	27.7 °C	27.7 °C	27.1 °C
Criteria of Δ3°C variation from ambient conditions met	Yes	Yes	Yes	Yes	Yes
Moderate ambient current (0.2 m/s)					
Dilution achieved under near-field mixing only	127	633	2,361	2,406	377
Approx. horizontal extent of near-field mixing zone	**28 m**	**87 m**	**313 m**	**359 m**	**82 m**
Plume temperature at the edge of near-field mixing zone	28.1 °C	28.0 °C	27.7 °C	27.7 °C	27.0 °C
Criteria of Δ3°C variation from ambient conditions met	Yes	Yes	Yes	Yes	Yes
High ambient current (0.5 m/s)					
Dilution achieved under near-field mixing only	154	1,211	3,194	3,258	506
Approx. horizontal extent of near-field mixing zone	**63 m**	**314 m**	**884 m**	**896 m**	**201 m**
Plume temperature at the edge of near-field mixing zone	28.1 °C	27.9 °C	27.7 °C	27.6 °C	27.1 °C
Criteria of Δ3°C variation from ambient conditions met	Yes	Yes	Yes	Yes	Yes

Table 7-65 Mixing Behaviour of PFW Discharge (178 m³/hour at 65 °C) to meet the Temperature Threshold

Discharge Depth (m)	0	10	30	50	75
Low ambient current (0.05 m/s)					

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	33	111	329	770	404
Approx. horizontal extent of near-field mixing zone	**3 m**	**7 m**	**22 m**	**31 m**	**30 m**
Plume temperature at the edge of near-field mixing zone	29.1 °C	28.3 °C	27.9 °C	27.7 °C	27.6 °C
Criteria of Δ3°C variation from ambient conditions met	Yes	Yes	Yes	Yes	Yes
Moderate ambient current (0.2 m/s)					
Dilution achieved under near-field mixing only	67	476	1,871	4,325	556
Approx. horizontal extent of near-field mixing zone	**11 m**	**40 m**	**124 m**	**348 m**	**75 m**
Plume temperature at the edge of near-field mixing zone	28.5 °C	28.0 °C	27.7 °C	27.7 °C	27.2 °C
Criteria of Δ3°C variation from ambient conditions met	Yes	Yes	Yes	Yes	Yes
High ambient current (0.5 m/s)					
Dilution achieved under near-field mixing only	83	966	3,389	5,854	744
Approx. horizontal extent of near-field mixing zone	**25 m**	**135 m**	**388 m**	**871 m**	**187 m**
Plume temperature at the edge of near-field mixing zone	28.4 °C	28.0 °C	27.7 °C	27.7 °C	27.2 °C
Criteria of Δ3°C variation from ambient conditions met	Yes	Yes	Yes	Yes	Yes

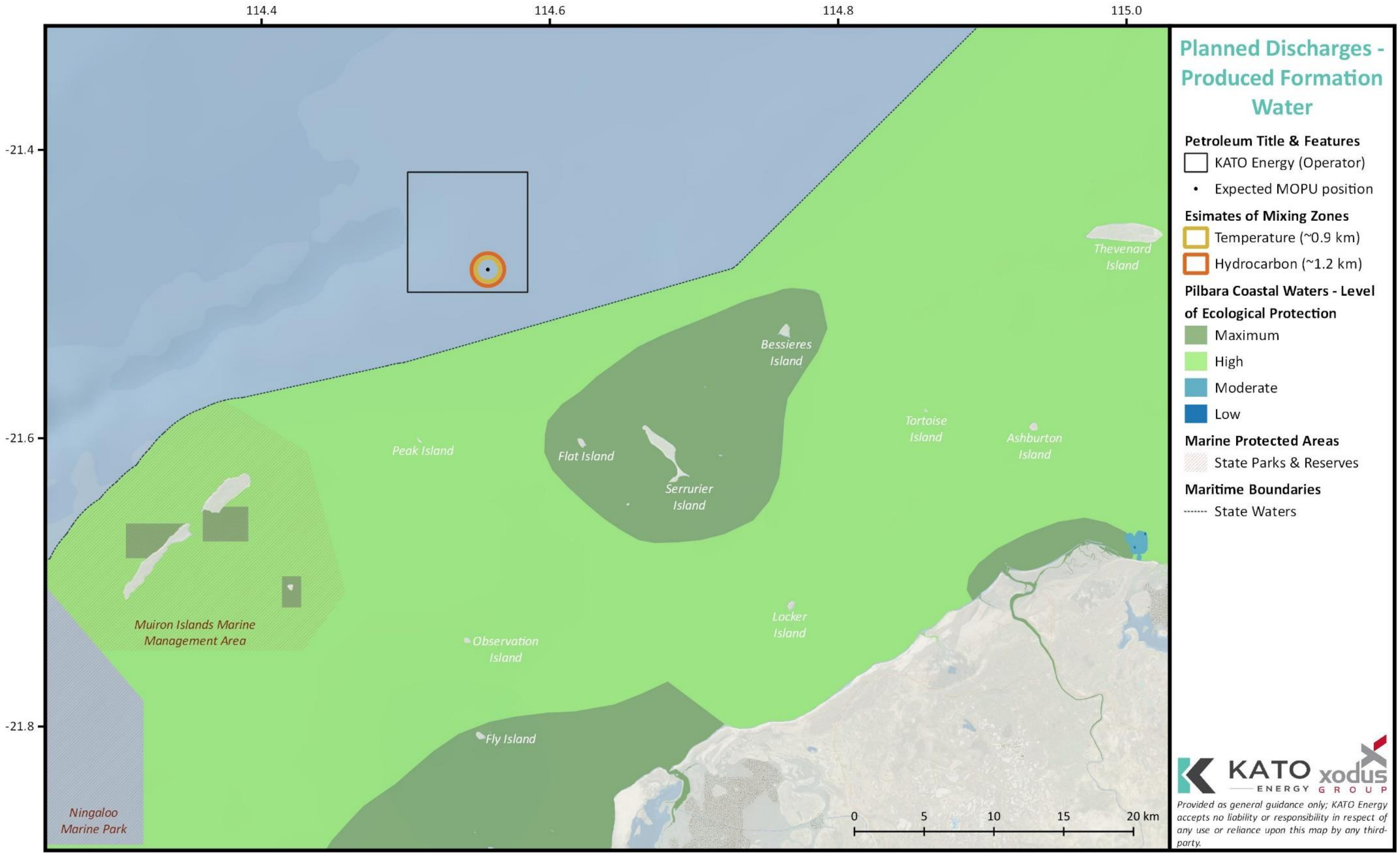


Figure 7-14 Mixing Zones for Temperature and Hydrocarbons for Produced Formation Water Discharge

7.1.9.2 Impact Analysis and Evaluation

Produced formation water discharged to the marine environment during the Corowa Development has the potential to result in these impacts:

- change in water quality
- change in sediment quality.

As a result of a change in water, further impacts may occur including:

- injury/mortality to fauna.

Table 7-8 identifies the potential impacts to receptors as a result of discharges of produced formation water from the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-67 provides a summary and justification for those receptors not evaluated further.

Table 7-66 Receptors Potentially Impacted by Planned Discharge – Produced Formation Water

Impacts	Ambient water quality	Ambient sediment quality	Plankton	Fish	Marine mammals	Marine reptiles	Commercial Fisheries
Change in water quality	✓						
Change in sediment quality		✓					
Injury / mortality to fauna			✓	*X*	*X*	*X*	
Changes to the functions, interests or activities of other users							*X*

Table 7-67 Justification for Receptors Not Evaluated Further

Fish, Marine Mammals and Marine Reptiles	***X***
Injury/mortality to fauna A change in water quality is unlikely to result in injury or mortality to marine fauna resulting from changes in temperature or exposure to toxins or chemicals in PFW discharges. Although unlikely, discharges have the potential to affect local pelagic communities in the immediate proximity of the discharge, specifically through: • • toxic effects on marine organisms (hydrocarbons, chlorine) • • thermal effects (elevated water temperature) Potential receptors to changes in water quality resulting from toxic effects of PFW discharges are likely to be transient marine fauna, including fish, whales and reptiles found in surface waters and the water column within the Project Area. Impacts to pelagic fish are likely to be caused by exposure to dissolved hydrocarbons (e.g. BTEX hydrocarbons) or metals across gill structures. Impacts could also occur through ingestion of hydrocarbon droplets. Whilst PAHs is of most concern, in terms of long-term exposure, the elimination of PAHs is generally very efficient in fish and other vertebrates. The bioaccumulation of PAH within these taxa do not generally reflect their level of exposure (Van der Oost, Beyer and Vermeulen 2003). Larger mobile pelagic species such as marine mammals and marine reptiles are expected to be subjected to very low levels of chemicals for a very short time as they swim near the discharge plume. As transient species, they are not expected to experience any chronic or acute effects. Uptake of dissolved hydrocarbons is also less likely since these animals are air breathing and do not possess gill structures that promote cellular uptake of dissolved constituents.	

Modelling of long-term routine discharges of PFW (Table 7-63) predicted a worst-case maximum horizontal distance of 1,220 m until the hydrocarbon threshold is reached, and 896 m until the temperature threshold is reached. As hydrocarbons within the PFW discharge will be localised, toxic impacts on fish, marine mammals and reptiles are expected to be negligible and are not discussed further.

Elevated water temperatures have the potential to induce minor physical stress in marine fauna and may result in potential mortality if exposure is prolonged. The effects of thermal discharges on the marine environment can be sub-divided into direct effects (those organisms directly affected by changes in the temperature regime) and secondary effects (those arising in the ecosystem as a result of the changes in the organisms directly affected). Bamber (1995a cited in Langford et al. 1998) identified three aspects in which changes to the temperature regime were important to the ecology of the receiving environment:

- mean temperature (which varies with distance from the outfall)
- maximum temperature (clearly important if it approaches the thermal lethal limit of an organism)
- temperature fluctuation and rate of change.

The heat in a PFW discharge will dissipate in the marine environment as the plume mixes with the water column with some energy also lost to the atmosphere if the plume is buoyant (UK Marine SCA 2019). Modelling of long-term routine discharges of PFW predicted that ocean temperatures will return to background levels within a maximum of 896 m from the discharge (Xodus Group 2019c). The modelling also shows for all scenarios a rapid decrease in the temperature within a few metres from the source. Therefore, physical stress or mortality by reaching a thermal limit is considered extremely unlikely on fish, marine mammals or reptiles with rapid temperature fluctuations also confined to a few metres from the source of the discharge. Although unlikely, pelagic fauna may encounter a small plume of elevated water temperature. As the modelling shows temperatures rapidly drop close to the source, the slightly elevated temperature levels are unlikely to cause injury or mortality to pelagic species. Motile species not suited to the localised increase in temperature will exhibit avoidance behaviour, limiting potential impacts with such behaviour termed as behavioural thermoregulation (UK Marine SCA 2019).

No secondary or indirect effects on marine species from an increase in water temperature are expected due to the rapid mixing and dilution of warmer waters by wave action and local currents.

The Corowa Development Project Area is located within a foraging BIA for Whale Shark. Habitat degradation / modification is listed as a threat in the Conservation Advice, however, PFW are not expected to result in a change in habitat due to the highly dispersive nature of such discharge plumes.

The EPBC PMST lists one species of shark as Vulnerable (Grey Nurse Shark) and four as Vulnerable/Migratory (Dwarf Sawfish, Green Sawfish, White Shark and Whale Shark) that are likely to occur within the area. The Corowa Project Area is situated within a BIA for the Whale Shark. Whilst the recovery plan for the Whale Shark (DEH 2005a) ceased to be in effect from 1 October 2015 it stated that the main threat to the Whale Shark occurs outside Australian waters. Whilst pollution was listed as a future threat, at present it does not have an impact on the numbers of Whale Sharks visiting Australian waters (DEH 2005a). All fish species listed are highly mobile, therefore, none are expected to be affected by a planned discharge of PFW.

The EPBC PMST shows that three species of marine mammal listed as either Vulnerable (Sei Whale, Fin Whale and Humpback Whale) and two species listed as Endangered (Blue Whale and Southern Right Whale) that are known or may occur within the Project Area. The Project Area sits within a migratory BIA for Humpback Whales. The recovery plan (DEH 2005b) (ceased to be in effect from 1 October 2015) listed pollution as a threat although this is primarily in relation to run-off from land-based agriculture, oil spills and outputs from aquaculture. Discharges of PFW will be conducted in accordance with all applicable management actions to ensure impacts are negligible.

The EPBC PMST shows that three species of turtle listed as either Vulnerable (Green Turtle, Hawksbill Turtle and Flatback Turtle) or Endangered (Loggerhead Turtle and Leatherback Turtle) have habitat, congregation or congregation known to occur within area. A single species of snake (Short-nosed Sea Snake) listed as critically endangered may also occur within the area. The Project Area sits within three BIA for marine turtle species. The Recovery Plan for Marine Turtles in Australia, (CoA 2017) identifies chemical and terrestrial discharge as a threat, although this is mostly in relation to pollution from agricultural, terrestrial industrial and domestic sources.

Modelling of long-term routine discharges of PFW (Table 7-75) predicted a worst-case maximum horizontal distance of 1,220 m until the oil threshold is reached, and 896 m until the temperature threshold was

reached. The temperature differential falls below guideline (and generally well below guidelines levels) well within this distance. Therefore, any potential impacts to water quality are expected to be limited to within 1,220 m of the discharge source, and has a narrow maximum diameter of 67 m. 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. Therefore, impacts to fish, marine mammals and marine reptiles from PFW discharges are not expected, and have not been evaluated further.	
Commercial Fisheries	***X***
Changes to the functions, interests or activities of other users As impacts to fish are not expected from planned discharges of PFW, indirect impacts to commercial fisheries are not expected. Any potential impacts to water quality are expected to be limited to within 1,220 m of the discharge source. This is well within the 5 km radius of the Project Area. This is an insignificant area compared to the size and scale of commercial fisheries. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). Therefore, impacts to commercial fisheries from planned discharge of PFW are not expected, and have not been evaluated further.	

7.1.9.2.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of a planned discharged of produced formation water include:

- ambient water quality.

Table 7-68 provides a detailed evaluation of the impact of produced formation water discharge activities to physical receptors.

Table 7-68 Impact and Risk Assessment for Physical Receptors from Planned Discharge – Produced Formation Water

Ambient Water Quality	✓
Change in water quality A change in water quality will occur following PFW discharges due to the addition hydrocarbon, corrosion inhibitor, salts (dissolved and precipitated), and fines into the water column resulting in increased toxicity levels plus increased water temperature within the vicinity of the discharge points. BTEX compounds are the most common hydrocarbon component of PFW (Neff et al. 2011). They are highly volatile and therefore do not persist in the environment due to rapid evaporation and dilution (Ekins et al. 2005). Whilst BTEX is known to be toxic to marine organisms and has been shown to result in developmental defects (Fucik et al. 1995) it does not significantly bioaccumulate (Neff 2002). AS PFW typically only increases in volumes toward the end of reservoir life, as hydrocarbons are depleted, impacts from BTEX will be localised to within a few hundred metres of the discharge point during the later stages of operations. PAHs have a greater potential to accumulate in the marine environment than BTEX (Neff et al. 2011) but are generally removed from the water column through volatilisation to the atmosphere upon reaching the sea surface, particularly the lower molecular weight fractions (Schmeichel 2017). Corrosion inhibitors may be present within PFW brine discharges but at very low dosages. Potential impacts associated with the low volumes of corrosion inhibitors within the PFW discharge will be confined to the source of the discharge where concentrations are highest. Remaining volumes released within the discharge stream are highly reactive and will discharge rapidly within the water column. Modelling of long-term routine discharges of PFW (Table 7-75) predicted a worst-case maximum horizontal distance of 1,220 m until the oil threshold is reached, and 896 m until the temperature threshold was	

reached. The temperature differential falls below guideline (and generally well below guidelines levels) well within this distance. Therefore, any potential impacts to water quality are expected to be limited to within 1,220 m of the discharge source. There are currently no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. According to the Marine Bioregional Plan for the North west Marine Region the region is widely used by a range of industries including widescale and longstanding petroleum activities. Given the details above, the consequence of PFW causing a change in ambient water quality has been assessed as **Moderate (2)**, given that discharges will dissipate and disperse rapidly within the water column with highest concentrations of chemicals and elevated temperatures within close proximity to the discharge source.
Ambient Sediment Quality ✓
Change in sediment quality Modelling of the PFW discharge predicts that the plume from the deepest discharge point (i.e. 15 m above the seabed) will not intersect with the seabed. Any insoluble constituents of the PFW discharge, such as salts or sediments, may eventually settle out of the water column and are expected to rapidly disperse. These constituents are considered relatively inert, however there is potential to pose an impact to ambient sediment quality. While dispersed oil is an insoluble component that may also eventually settle out of the water column, given the relatively rapid mixing of the plume once discharged, the oil is not expected to accumulate in quantities that would significantly adversely affect sediment quality or that could result in a toxic affect to benthic habitats or communities. Sediment quality within the Project Area is expected to be high and typical of a pristine offshore Western Australian seabed with sediment condition expected to be uniform across the wider permit area with no significant values or sensitivities. There are currently no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. According to the Marine Bioregional Plan for the North west Marine Region the region is widely used by a range of industries including widescale and longstanding petroleum activities. Given the details above, the consequence of PFW causing a change in ambient sediment quality has been assessed as **Minor (1)**, given that discharges will dissipate and disperse rapidly within the water column with only inert contaminants expected to settle out of the water column to the seabed.

7.1.9.2.2 Ecological Receptors

Ecological receptors with the potential to be impacted as a result of a change in ambient water and sediment quality include:

- plankton.

The above receptors may be impacted from:

- injury / mortality to fauna.

Table 7-69 provides a detailed evaluation of the impact of PFW on ecological receptors.

Table 7-69 Impact and Risk Assessment for Ecological Receptors from Planned Discharge – Produced Formation Water

Plankton ✓
Injury/mortality to fauna A change in water quality due to PFW discharges may cause injury or mortality to plankton species through increased toxicity levels and increased water temperatures. PFW will be rapidly mixed with receiving waters and dispersed by ocean currents. As such, any potential impacts are expected to be limited to the source of the discharge where concentrations are highest. Early life stages of fish (embryos, larvae) and other plankton would be most susceptible to the toxic exposure from chemicals in PFW discharges, as they are less mobile and therefore can become exposed to the plume at the outfall. This in turn may also affect the population of prey species. Phytoplankton

communities in the NWS region are characterised by smaller taxa (e.g. cyanobacteria), while shelf waters are dominated by larger taxa such as diatoms (Hanson, Waite, Thompson and Pattiaratchi 2007). Zooplankton assemblages within the Project Area consist of the larvae of deepwater and pelagic taxa such as tuna (family Scombridae) and lanternfish (family Myctophidae) (Beckley, Muhling and Gaughan 2009).

Generally, phytoplankton are not sensitive to hydrocarbons, however they can accumulate it rapidly because of their small size and high surface area to volume ratio, and can pass oil onto the animals that consume them (Hook et al. 2016). Studies have shown that a hydrocarbon concentration above 50 ppb can inhibit algal growth, cause motility and can interfere with metabolic processes (Hook and Osbourne 2012; Bretherton et al. 2018). However, other studies have demonstrated that some phytoplankton are unaffected or even stimulated by exposure to weathered oil (Özhan et al. 2014a; Bretherton et al. 2018). Zooplankton may be impacted by ingestion and dermal contact, which can cause an impact to motility, a decline in egg production or mortality (Hook et al. 2016). These studies focused on the effect of oil spills with the residual hydrocarbons present in PFW at much lower concentrations. Studies show that zooplankton exposed to low molecular weight hydrocarbons exhibit acute toxic effects (Almeda et al. 2013; Jiang et al. 2010). In particular, PAHs are of concern due to their solubility, toxicity and relatively persistent compared to BTEX. The concentrations and durations of exposure required to induce these effects is unlikely to occur in the Project Area due to the rapid dilution of PFW and rapid mixing of ocean waters.

Modelling of PFW discharges predicts the oil dilution factor is reached at 1,220 m and has a narrow maximum diameter of 67 m. Therefore, any impacts would be limited to the immediate source of the discharge, where concentrations are highest. Plankton have a patchy distribution linked to localised and seasonal productivity that produces sporadic bursts in populations (DEWHA 2008). The oligotrophic waters of the project area are typical of the wider offshore region supporting low phytoplankton biomass and relatively low primary productivity (Woodside 2005). Any impacts within the area would be temporary as plankton populations are able to rapidly recover once the activity ceases. Plankton species have high levels of natural mortality and a rapid replacement rates (UNEP 1985).

The impact to plankton species from a change in temperature also varies from species to species. Vijverberg, (1980) showed that changes in the temperature due to discharges from a desalination plant on plankton lead to a positive effect on reproduction biology and the growth rate of several species of plankton. However, thermal stress was the major source of copepod mortality reported by Choi et al. (2012) with mortality caused by a difference of ~5°C. Modelling for the Corowa Development shows a rapid decrease in temperatures near the discharge source and temperature thresholds are met within 896 m of the source. Therefore, impacts to plankton species by temperature variations are expected to be localised to the discharge source of the PFW.

As planktonic productivity within the permit area is low and given the relatively small area of impact as a result of PFW discharges, impacts to plankton are not expected to result in a significant impact with no population-level declines or reduction in ecological productivity and diversity within Commonwealth marine areas. Plankton populations are expected to rapidly recover by natural action within the affected area once activities cease. As impact to plankton species are predicted to be localised and temporary, marine fauna that rely on plankton as a prey species are also unlikely to affected (i.e. no secondary impacts are expected).

Given the details above, the consequence of a planned discharge of PFW resulting in injury / mortality to plankton species has been assessed as **Moderate (2)**, given that discharges will dissipate and disperse rapidly within the water column with highest concentrations of chemicals and elevated temperatures within close proximity to the discharge source.

7.1.9.3 Consequence and Acceptability

The worst-case consequence of Planned Discharge – Produced Formation Water has been evaluated as **Moderate (2)** for ambient water quality and plankton and is considered **acceptable** when assessed against the criteria in Table 7-70.

Table 7-70 Demonstration of Acceptability for Planned Discharge – Produced Formation Water

Acceptability Criteria	Justification
To meet the principles of ESD	• Modelling of PFW discharges predicts a maximum horizontal extent of 1,220 m until the oil threshold is reached, and 896 m for the temperature threshold. This is within the 5 km radius of the MOPU designated the Project Area, and therefore is within the 78.5 km^2 area of planned activities. • Due to the nature of PFW once within the marine environment, discharge plumes will occupy only a small portion of the water column. • PFW discharge volumes during the Corowa Development will be comparable with, or smaller than, discharges from other operations on the North West Shelf, and will not result in a noticeable change in water quality for the wider regional area. • Impacts as a result of toxicity to marine fauna are not expected. Due to the localised nature of impacts to planktonic species that may be prey to other species, any impacts to pelagic predators as a result of reduced food supply are considered unlikely. • PFW discharges are not expected to result in a substantial adverse effect on a population of plankton, including its life cycle and special distribution, with no lasting effects due the expected rapid dilution and mixing of discharge plumes within the offshore marine environment and rapid replacement rate of planktonic organisms.
Internal context	• There are no specific KATO internal requirements with respect to discharges of PFW, or potentially impacted receptors.
External context	• No stakeholder concerns have been raised with respect to discharges of PFW or potentially impacted receptors.
Other requirements	• There are currently no Management Plans, Recovery Plans or Conservation Advice related specifically to PFW or plankton. • Regarding planned discharges of PFW, activities associated with the Corowa Development will not be conducted in a manner inconsistent maintaining the environmental values of marine environmental quality.

A summary of the impact analysis and evaluation, including adopted control measures adopted and EPOs, is provided in Table 7-71.

Table 7-71 Summary of Impact Assessment for Planned Discharge – Produced Formation Water

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM20**: A management framework for produced formation water discharges will be developed.	Moderate
Ambient sediment quality	Change in sediment quality			Minor
Plankton	Injury / mortality to fauna	**EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Moderate

7.1.10 Planned Discharge – Cooling Water and Brine

Cooling water (CW) and brine are routinely discharged to the marine environment from facilities and vessels.

7.1.10.1 Aspect Source

Throughout the Corowa Development cooling water (CW) and brine will be intermittently discharged to the marine environment during these activities:

Support Activities (all phases)	MODU operations; MOPU operations; FSO operations; vessel operations

Support Activities (all phases)

Cooling Water

The processing facilities and the machinery on board the MODU, MOPU, FSO and vessels throughout all phases of the Corowa Development will 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 heat exchange medium most commonly used is seawater, however in some instances, a different fluid may be used within a closed circuit and further cooled by seawater within a separate seawater cooler (hence is known as cooling water).

In an open system the ambient seawater is drawn up from the ocean and de-oxygenated and sterilised through electrolysis. The water is then circulated through the heat exchangers to various machinery (to aid in the cooling process) before it is then discharged overboard. The discharge stream will be warmer than ambient ocean temperature and contain a range of chemicals including biocides and scale inhibitors. Biocides and oxygen scavengers are generally used in low dosages to avoid pipework fouling and are usually consumed during the inhibition process, resulting in very low concentrations being discharged.

CW will be discharged throughout the entire course of the Corowa Development with the dominant source of the discharge and quantities dependant on the phase of operations.

The discharge point for the MODU and MOPU will be below the lowest anticipated sea level, from a pipe within one of the support legs. The depth depends on the final design of the MOPU. The discharge point on vessels and the FSO is also likely to be below the water line but will be vessel specific.

Brine

Most MOPU, MODU, FSO and vessels used in the oil and gas industry have capability for either reverse osmosis (RO), desalination or distillation of seawater to produce demineralised potable water. The process of converting seawater to potable water will result in the production and subsequent discharge of reject brine to the marine environment.

Volumes of produced and discharged reject brine are relatively low, with salinity levels typically 20% to 50% higher than that of the surrounding seawater (depending on technique) (Woodside 2014). Reject brine discharges may also contain traces of biocides and scale inhibitors of which are used in the same way as described for CW (Woodside 2014). Brine will be discharged throughout all phases of the Corowa Development. Maximum brine discharge will occur during the drilling phase with volumes up to ~168 m^3/day.

7.1.10.1.1 Cooling Water – Modelling and Exposure Assessment

Visual Plumes (VPLUMES) is a set of mixing zone models developed by the United States Environment Protection Agency (US EPA) that can simulate single and merging submerged plume behaviour (Frick et al. 2003). The following two models, available within the VPLUMES package, were used to model various scenarios of CW discharge from the MOPU (Xodus Group 2019c; Appendix D), to quantify the spatial extent of the discharge plume:

- The three-dimensional Updated Merge (UM3) model, which is a Lagrangian initial dilution model that incorporates the projected-area-entrainment (PAE) hypothesis. The UM3 model was used to simulate mixing of the CW discharge from the MOPU within the near-field.
- The Brooks algorithm, which is a simple dispersion calculation that is a function of travel time and initial plume width. The Brooks algorithm was used to predict centreline dilution and plume width of the CW discharge within the far-field.

It is acknowledged that the Brooks algorithm is a simplified approach to far-field modelling; however, given that external processes (e.g. waves) that would enhance mixing are not taken into account, it is considered to provide a conservative estimate and therefore is appropriate for use in impact analysis.

For CW, the critical parameters that have the potential to impact the marine environment are the temperature differential (i.e. heat) and the residual chlorine (from treatment to prevent biofouling of pipework). These environmental thresholds have been used within the discharge modelling to support exposure and mixing zone assessments:

- Chlorine: The default guideline value (DGV) for chlorine in marine waters is defined at 3 ppb within the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018). This DGV is noted as being a 'low reliability' value; classification is mainly based on the number and type (e.g. chronic, acute or both) of data used to derive the DGV, as well as the fit of the statistical (SSD) model to the data (ANZG 2018).
- Temperature: The World Bank Group's Environmental Health and Safety (EHS) Guidelines for Offshore Oil and Gas Development (IFC 2015) define a guideline for CW discharges as: "*The effluent should result in a temperature increase of no more than 3°C at edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 m from point of discharge*." These EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice.

Multiple scenarios (Table 7-72) were modelled, including variations in both discharge characteristics (temperature, volume and discharge depth) and ambient conditions (current velocity) to evaluate the differences in plume mixing behaviour and spatial extent to reach environmental thresholds. Final configuration of the CW discharge from the MOPU will occur during FEED.

Table 7-72 CW Discharge Modelling Parameters

Parameter	Description / Value				
Outlet characteristics					
Number of ports	1				
Port orientation	Vertical down				
Port diameter	10" (0.254 m)				
Port depth	2 m	10 m	30 m	50 m	75 m
Water depth	90 m				
Discharge characteristics					
Flow type	Continuous				
Flow rate	440 m^3/hour (0.12 m^3/s)		80 m^3/hour (0.0280/ m^3/s)		
Temperature	45 °C		65 °C		

Salinity	35
Residual Chlorine	2,000 ppb

The discharge modelling showed these mixing behaviours for CW from the MOPU (Xodus Group 2019c):

- The larger volume (440 m^3/day) has a greater port exit velocity and Froude number compared to the lower volume (80 m^3/day), and therefore momentum (and not just buoyancy) has an effect on mixing with the near-field.
- Both discharges are initially buoyant compared to ambient seawater (the 65°C more than the 45°C discharge), but for discharges at depths (typically ≥30 m) the discharged CW plume is not predicted to reach the surface during the initial dilution phase (i.e. where mixing is due to density differences) as it will have reached an equilibrium density to ambient conditions at some depth in the water column.
- The CW discharge plume is never predicted to interact with the seabed, even from the deepest modelled discharge (i.e. 75 m depth or 15 m above seabed).
- The size of the near-field mixing zone (i.e. the initial dilution phase) varies between 6 m and 877 m for the 440 m^3/day at 45 °C discharge (Table 7-75), and 1 m and 859 m for the 80 m^3/day at 65 °C discharge (Table 7-76).
- Mixing required to meet the chlorine threshold varies between 135 m and 1,975 m for the 440 m^3/day at 45 °C discharge (Table 7-73), and 30 m and 1,390 m for the 80 m^3/day at 65 °C discharge (Table 7-74). The chlorine threshold is met under either near-field or far-field mixing depending on the combination of discharge and ambient conditions.
- The temperature threshold is met within the near-field mixing zone for all scenarios (Table 7-75, Table 7-76), with the exception of the 80 m^3/day at 65 °C near-surface discharge under low ambient currents (Table 7-76).
- Mixing required to meet the temperature threshold varies between 135 m and 1,975 m for the 440 m^3/day at 45 °C discharge (Table 7-73), and 30 m and 1,390 m for the 80 m^3/day at 65 °C discharge (Table 7-74). However, for this scenario the temperature threshold would be met within 20 m of the discharge outlet (as predicted from far-field modelling). This is well below the 100 m distance referred to in the EHS Guidelines (IFC 2015) for cases where the initial mixing zone is not defined. This secondary part of the guideline is considered appropriate for this particular scenario given the conditions (i.e. near-surface discharge, low port exit velocity and low Froude number, and low ambient current) are not conducive for initial mixing to occur.

Therefore, the maximum horizontal distance predicted to be needed to reach the chlorine and temperature thresholds is 1,975 m and 877 m from the MOPU respectively (Figure 7-15).

Table 7-73 Mixing Behaviour of a CW Discharge (440 m^3/day at 45 °C) to meet the Chlorine Threshold

Discharge Depth (m)	2	10	30	50	75
Low ambient current (0.05 m/s)					
Approx. horizontal distance required to reach chlorine threshold (~667 dilutions)	**555 m**	**435 m**	**315 m**	**220 m**	**360 m**
Approx. width of plume at this distance	164 m	126 m	97 m	86 m	114 m
Type of mixing required for to dilute CW to chlorine threshold	NF + FF	NF + FF	NF + FF	NF + FF	NF + FF

Discharge Depth (m)	2	10	30	50	75
Moderate ambient current (0.2 m/s)					
Approx. horizontal distance required to reach chlorine threshold (~667 dilutions)	**1,280 m**	**550 m**	**<135 m**	**<354 m**	**645 m**
Approx. width of plume at this distance	84 m	48 m	<28 m	<41 m	46 m
Type of mixing required for to dilute CW to chlorine threshold	NF + FF	NF + FF	NF	NF	NF + FF
High ambient current (0.5 m/s)					
Approx. horizontal distance required to reach chlorine threshold (~667 dilutions)	**1,975 m**	**650 m**	**<415 m**	**<877 m**	**940 m**
Approx. width of plume at this distance	45 m	22 m	<23 m	<30 m	25 m
Type of mixing required for to dilute CW to chlorine threshold	NF + FF	NF + FF	NF	NF	NF + FF

NF = near-field, FF = far-field

Table 7-74 Mixing Behaviour of a CW Discharge (80 m³/day at 65 °C) to meet the Chlorine Threshold

Discharge Depth (m)	2	10	30	50	75
Low ambient current (0.05 m/s)					
Approx. horizontal distance required to reach chlorine threshold (~667 dilutions)	**480 m**	**250 m**	**90 m**	**<29 m**	**<82 m**
Approx. width of plume at this distance	118 m	55 m	29 m	<23 m	<36 m
Type of mixing required for to dilute CW to chlorine threshold	NF + FF	NF + FF	NF + FF	NF	NF
Moderate ambient current (0.2 m/s)					
Approx. horizontal distance required to reach chlorine threshold (~667 dilutions)	**1,150 m**	**200 m**	**<100 m**	**<340 m**	**<102 m**
Approx. width of plume at this distance	60 m	15 m	<17 m	<29 m	<12 m
Type of mixing required for to dilute CW to chlorine threshold	NF + FF	NF + FF	NF	NF	NF
High ambient current (0.5 m/s)					
Approx. horizontal distance required to reach chlorine threshold (~667 dilutions)	**1,390 m**	**<116 m**	**<354 m**	**<859 m**	**<177 m**
Approx. width of plume at this distance	24	<8 m	<16 m	<22 m	<8m
Type of mixing required for to dilute CW to chlorine threshold	NF + FF	NF	NF	NF	NF

NF = near-field, FF = far-field

Table 7-75 Mixing Behaviour of a CW Discharge (440 m³/day at 45 °C) to meet the Temperature Threshold

Discharge Depth (m)	2	10	30	50	75
Low ambient current (0.05 m/s)					
Dilution achieved under near-field mixing only	38	74	181	350	169
Approx. horizontal extent of near-field mixing zone	**6 m**	**9 m**	**23 m**	**27 m**	**27 m**
Plume temperature at the edge of near-field mixing zone	28.4 °C	28.2 °C	27.9 °C	27.7 °C	27.4 °C
Criteria of Δ3°C variation from ambient conditions met	Yes	Yes	Yes	Yes	Yes
Moderate ambient current (0.2 m/s)					
Dilution achieved under near-field mixing only	91	275	1,018	2,177	300
Approximately horizontal extent of near-field mixing zone	**23 m**	**47 m**	**135 m**	**354 m**	**78 m**
Plume temperature at the edge of near-field mixing zone	28.2 °C	28.0 °C	27.7 °C	27.7 °C	27.1 °C
Criteria of Δ3°C variation from ambient conditions met	Yes	Yes	Yes	Yes	Yes
High ambient current (0.5 m/s)					
Dilution achieved under near-field mixing only	130	520	1,783	2,914	407
Approx. horizontal extent of near-field mixing zone	**58 m**	**150 m**	**415 m**	**877 m**	**195 m**
Plume temperature at the edge of near-field mixing zone	28.1 °C	28.0 °C	27.7 °C	27.7 °C	27.1 °C
Criteria of Δ3°C variation from ambient conditions met	Yes	Yes	Yes	Yes	Yes

Table 7-76 Mixing Behaviour of a CW Discharge (80 m³/day at 65 °C) to meet the Temperature Threshold

Discharge Depth (m)	2	10	30	50	75
Low ambient current (0.05 m/s)					
Dilution achieved under near-field mixing only	9	73	480	1,128	2,309
Approx. horizontal extent of near-field mixing zone	**1 m**	**3 m**	**22 m**	**29 m**	**82 m**
Plume temperature at the edge of near-field mixing zone	32.1 °C	28.5 °C	27.9 °C	27.7 °C	27.6 °C
Criteria of Δ3°C variation from ambient conditions met	Yes[1]	Yes	Yes	Yes	Yes

Discharge Depth (m)	2	10	30	50	75
Moderate ambient current (0.2 m/s)					
Dilution achieved under near-field mixing only	32	492	2102	6128	961
Approx. horizontal extent of near-field mixing zone	**3 m**	**27 m**	**100 m**	**340 m**	**102 m**
Plume temperature at the edge of near-field mixing zone	29.1 °C	28.0 °C	27.7 °C	27.7 °C	27.4 °C
Criteria of Δ3°C variation from ambient conditions met	Yes	Yes	Yes	Yes	Yes
High ambient current (0.5 m/s)					
Dilution achieved under near-field mixing only	85	1281	4518	8379	1025
Approx. horizontal extent of near-field mixing zone	**15 m**	**116 m**	**354 m**	**859 m**	**177 m**
Plume temperature at the edge of near-field mixing zone	28.4 °C	28.0 °C	27.7 °C	27.7 °C	27.3 °C
Criteria of Δ3°C variation from ambient conditions met	Yes	Yes	Yes	Yes	Yes

Note:

1 *This threshold is met within the far-field mixing zone – by 20 m from the discharge point, the plume is predicted to have diluted 16 times, which is enough to reduce the temperature differential below Δ3°C. This is well below the 100 m distance referred to in the EHS Guidelines (IFC 2015) for cases where the initial mixing zone is not defined. This secondary part of the guideline is considered appropriate for this modelled scenario given the conditions (i.e. near-surface discharge, low port exit velocity and low Froude number, and low ambient current) are not conducive for initial mixing to occur.*

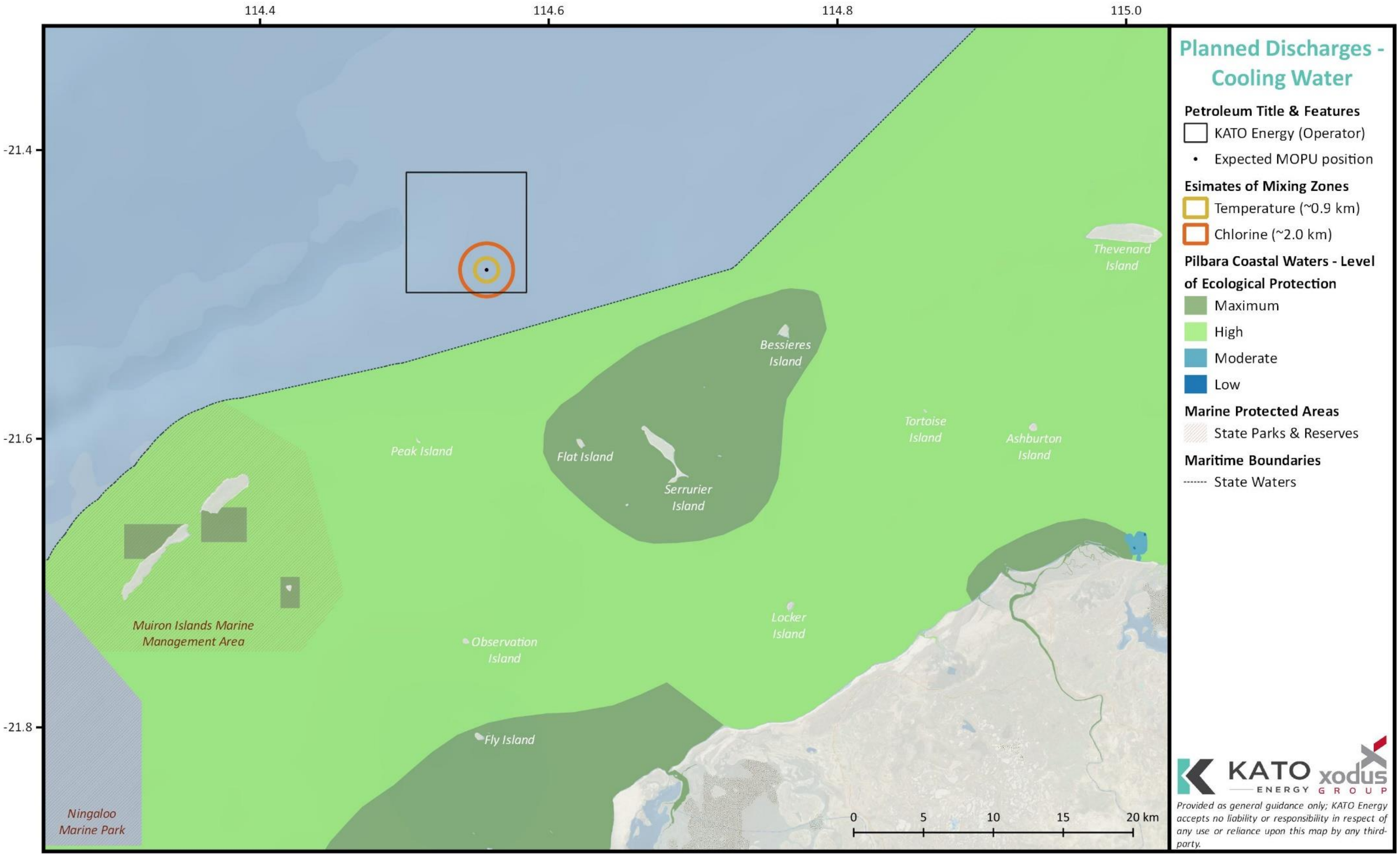


Figure 7-15 Mixing Zones for Chlorine and Temperature from CW Discharge from the MOPU

7.1.10.1.2 Brine – Modelling and Exposure Assessment

The desalination of seawater results in a discharge of seawater with a slightly elevated salinity. The volume of the discharge is dependent on the requirement for fresh (or potable) water and would vary between the vessels and the number of people on board the MODU / MOPU. A membrane reverse osmosis unit typically discharges between 50% and 70% of intake flows as brine. Using this rate and the assumption of a maximum 0.45 m^3/person of sewage and greywater (NERA 2017), total brine discharge per day for different phases of the Corowa Development can be estimated based on expected POB (not including support vessels not permanently in Project Area; Table 3-12).

Table 7-77 summarises estimated brine discharge volumes by project phase.

Table 7-77 Estimated Total Daily Brine Discharges

Phase	Max Indicative POB	Approx. total brine discharge (m^3/day)	Duration of phase
Drilling	160	168	Initial campaign – 5 months Infill drilling (if required) – additional 4 months
Operations	30	31.5	2–4.5 years
Commissioning, Decommissioning and Workovers	60	63	~3–6 months (x 3 events)

The daily brine discharges in Table 7-77 are less than those estimated for INPEX's Ichthys gas Field Development (INPEX 2018) at 185 m^3/day and insignificant when compared to the Gorgon Gas Development and Jansz Feed Gas Pipeline (Chevron 2015) of 1700 m^3/day to 2550 m^3/day.

The brine water discharge stream generated through RO systems is elevated in salinity typically by ~10–50% when compared to seawater. Woodside undertook brine wastewater discharge modelling (vertical, horizontal and temperature) for their Torosa South-1 appraisal well drilled near Scott Reef (Woodside 2008). Vertical modelling indicated that most of the discharged volume remains in the upper water column (in the upper 10 m) due to the neutral buoyancy of the discharge, but a small portion penetrates below the water surface, where it rapidly dissipates through the water column due to strong currents. Results showed that the concentration of the discharge stream reduced to 1% of its original concentration at no less than 50 m from the discharge point under any condition (Woodside 2008).

7.1.10.2 Impact Analysis Evaluation

CW and brine discharged during the Corowa Development have the potential to result in these impacts:

- change in water quality
- change in sediment quality.

As a result of a change in water quality, further impact(s) may occur, including:

- injury/mortality to fauna

Table 7-78 identifies the potential impacts to receptors as a result of discharges of CW and brine from the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-79 provides a summary and justification for those receptors not evaluated further.

Table 7-78 Receptors Potentially Impacted by Planned Discharge – CW and Brine

Impacts	Ambient water quality	Ambient sediment quality	Plankton	Fish	Marine mammals	Marine reptiles	Commercial Fisheries
Change in water quality	✓						
Change in sediment quality		X					
Injury / mortality to fauna			✓	X	X	X	
Changes to the functions, interests or activities of other users							X

Table 7-79 Justification for Receptors Not Evaluated Further

Ambient Sediment Quality	*X*

Change in sediment quality

Brine is discharged in relatively small volumes; given the expected rapid dilution and water depths of ~90 m, there is not expected to be an interface with the seabed from brine discharge. Modelling of CW discharge predicts that the plume from the scenario with the deepest discharge point (75 m) will not intersect with the seabed. Therefore, changes to sediment quality is not considered a credible impact, and there is no potential impact to ambient sediment quality from either brine or CW discharges. This impact has not been evaluated further.

Fish, Marine Mammals and Marine Reptiles	*X*

Injury/mortality to fauna

A change in water quality is unlikely to result in injury or mortality to marine fauna resulting from changes in temperature, increases in salinity or exposure to toxins or chemicals in the discharged CW or brine. Although unlikely, discharges have the potential to affect local pelagic communities in the immediate proximity of the discharge, specifically through:

- toxic effects on marine organisms (chlorine)
- thermal effects (elevated water temperature)
- elevated salinity levels (38,500–40,000 ppm)

Hypochlorite generation systems are commonly for sea water treatment in CW and desalination systems, producing and injecting chlorine for water bacteria management and water disinfection requirements. Chlorine persistence within the marine environment is short due to its reactive nature. Potential receptors to changes in water quality resulting from toxic effects of brine and CW discharges are likely to be transient marine fauna, including fish, whales and reptiles found in surface waters and the water column within the Project Area. Sublethal impacts to fish as a result of chlorine exposure may occur and include declined growth rates in some juvenile fish species, modification of blood composition and changes to the permeability of membranes. Capuzzo et al. (1977) identified that lethal exposure concentration required for juvenile Atlantic fish were 550–650 ppb, however, these concentrations of chlorine would only be present within the immediate vicinity of the discharge source. Larger pelagic species are mobile; at worst, it is expected that they would be subjected to very low levels of chemicals for a very short time as they swim near the discharge plume. As transient species, they are not expected to experience any chronic or acute effects. It has also been suggested (Abarno and Miossec 1992) that mobile organisms can detect low-level concentrations of chlorine and actively avoid such areas.

Modelling of CW discharges (Table 7-75) predicts that a maximum spatial extent of 877 m for the initial dilution phase of mixing, with the temperature differential becoming within guideline (and generally well below guidelines levels) well within this distance. The model predicted a worst-case maximum horizontal distance until chorine dilution factor is reached, was 1,975 m from the discharge source on the MOPU. Therefore, any potential impacts to water quality are expected to be limited to within 1,975 m of the discharge source.

As chlorine discharges will be localised and temporary, toxic impacts on fish, marine mammals and reptiles are expected to be negligible and are not discussed further.

Elevated water temperatures have the potential to induce minor physical stress in marine fauna and may result in potential mortality if exposure is prolonged. The effects of thermal discharges on the marine environment can be sub-divided into direct effects (those organisms directly affected by changes in the temperature regime) and secondary effects (those arising in the ecosystem as a result of the changes in the organisms directly affected). Bamber (1995a cited in Langford et al. 1998) identified three aspects in which changes to the temperature regime were important to the ecology of the receiving environment:

- mean temperature (which varies with distance from the outfall)
- maximum temperature (clearly important if it approaches the thermal lethal limit of an organism)
- temperature fluctuation and rate of change.

The heat in a cooling-water discharge will dissipate in the marine environment as the plume mixes with the water column with some energy also lost to the atmosphere if the plume is buoyant (UK Marine SCA 2019).Modelling of long-term routine discharges of CW (Table 7-75) predicted that ocean temperatures will return to background levels within a maximum of 877 m from the discharge. The modelling also shows for all scenarios a rapid decrease in the temperature within a few metres from the source. Therefore, physical stress or mortality by reaching a thermal limit is considered extremely unlikely on fish, marine mammals or reptiles with rapid temperature fluctuations also confined to a few metres from the source of the discharge. Although unlikely, pelagic fauna may encounter a small plume of elevated water temperature. As the modelling shows temperatures rapidly drop close to the source, the slightly elevated temperature levels are unlikely to cause injury or mortality to pelagic species. Motile species not suited to the localised increase in temperature will exhibit avoidance behaviour, limiting potential impacts with such behaviour termed as behavioural thermoregulation (UK Marine SCA 2019).

No secondary or indirect effects on marine species from an increase in water temperature are expected due to the rapid mixing and dilution of warmer waters by wave action and local currents.

It is expected that brine discharges could result in an increased salinity level ranging between 20–50% (Woodside 2014) but high mixing and dispersion will limit these levels to the point of discharge (Azis et al. 2003). Stenohaline marine animals (those that cannot tolerate a wide fluctuation in salinity levels) generally react to salinity changes by exhibiting avoidance behaviours (Gunter et al. 1974). Euryhaline marine animals (i.e. marine turtles) are adapted to a wide range of salinities from estuarine, brackish to marine waters (Kültz 2015). It is anticipated that migratory marine mammals and sharks can tolerate changes in salinity of ~25%.

The EPBC PMST lists one species of shark as Vulnerable (Grey Nurse Shark) and four as Vulnerable/Migratory (Dwarf Sawfish, Green Sawfish, White Shark and Whale Shark) that are likely to occur within the area. The Corowa Project Area is situated within a BIA for the Whale Shark. Whilst the recovery plan for the Whale Shark (DEH 2005a) ceased to be in effect from 1 October 2015 it stated that the main threat to the Whale Shark occurs outside Australian waters. Whilst pollution was listed as a future threat, at present it does not have an impact on the numbers of Whale Sharks visiting Australian waters (DEH 2005a). All fish species listed are highly mobile, therefore, none are expected to be affected by a planned discharge of CW or brine.

The EPBC PMST shows that three species of marine mammal listed as either Vulnerable (Sei Whale, Fin Whale and Humpback Whale) and two species listed as Endangered (Blue Whale and Southern Right Whale) that are known or may occur within the Project Area. The Project Area sits within a migratory BIA for Humpback Whales. The recovery plan (DEH 2005b) (ceased to be in effect from 1 October 2015) listed pollution as a threat although this is primarily in relation to run-off from land-based agriculture, oil spills and outputs from aquaculture. Minor discharges of CW and brine will be conducted in accordance with all applicable management actions to ensure impacts are negligible.

The EPBC PMST shows that three species of turtle listed as either Vulnerable (Green Turtle, Hawksbill Turtle and Flatback Turtle) or Endangered (Loggerhead Turtle and Leatherback Turtle) have habitat, congregation or congregation known to occur within area. A single species of snake (Short-nosed Sea Snake) listed as critically endangered may also occur within the area. The Project Area sits within three BIA for marine turtle

species. The Recovery Plan for Marine Turtles in Australia, (CoA 2017) identifies chemical and terrestrial discharge as a threat, although this is mostly in relation to pollution from agricultural, terrestrial industrial and domestic sources. CW and brine discharge activities will be conducted in accordance with all applicable management actions to ensure impacts are negligible. As impacts to fish, marine mammals and marine reptiles from CW and brine discharges are considered negligible, impacts have not been evaluated further.
Commercial Fisheries **X**
Changes to the functions, interests or activities of other users As impacts to fish are not expected from planned discharges of CW and brine, indirect impacts to commercial fisheries are not expected. Any potential impacts to water quality are expected to be limited to within 1,975 m of the discharge source. This is well within the 5 km radius of the Project Area. This is an insignificant area compared to the size and scale of commercial fisheries. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). Therefore, impacts to commercial fisheries from planned discharge of CW and brine are not expected, and have not been evaluated further.

7.1.10.2.1 Physical receptors

Physical receptors with the potential to be impacted as a result of CW and brine discharges include:

- ambient water quality.

Table 7-80 provides a detailed evaluation of the impact of CW and brine on physical receptors.

Table 7-80 Impact and Risk Assessment for Physical Receptors from Planned Discharge – Cooling Water and Brine

Ambient Water Quality ✓
Change in water quality A change in water quality will occur following CW and brine discharges due to the addition of biocides (i.e. chlorine) and scale inhibitors into the water column resulting in increased toxicity levels, increased salinity levels and increased water temperature within the vicinity of the discharge points. Chemical additives such as biocides and scale inhibitors, which may be present within CW and brine discharges at low dosages. These additives are usually consumed during the inhibition process resulting in little or no residual chemicals remaining upon discharge. Remaining volumes released within the discharge stream are highly reactive and will discharge rapidly within the water column. Modelling of CW discharge suggests a worst-case mixing distance of 1,975 m from the MOPU for chlorine to be below the defined DGV (ANZG 2018). The lower volume of brine discharges are expected to mix well within this distance. Therefore toxicity changes to water quality are limited and will be restricted to close to the discharge source where concentrations are highest. Salinity levels of reject brine are typically 20–50% higher than that of surrounding ocean waters. Brine water discharged during the Corowa Development will be significantly lower than that of other approved activities within Australian waters including desalination plants located within coastal environments and other larger oil and gas operations. Water quality monitoring at the Southern Seawater Desalination Plant, which has approval to discharge 208,000 m^3 of brine water per day into King Bay, found that salinity was within 1 ppt of background concentrations at 50 m from the diffuser (Water Corporation 2017). Developments closer the Project Area such as the Gorgon Gas Development and Jansz Feed Gas Pipeline (Chevron 2015) had brine discharges of between 1700 m^3/day to 2550 m^3/day during construction (Chevron 2015), which are significantly larger than those proposed at Corowa. Brine dispersion modelling for the Gorgon Project predicted that salinity and chemicals would be rapidly diluted to near ambient levels within 10 to 20 m of the outfall (RPS 2009). Modelling undertaken for Woodside’s (2019) Scarborough Project suggests that the salinity levels from RO discharges will fall below impact threshold levels (40-fold dilution) within 4 m of the discharge point confirming localised impacts.

Modelling of CW discharges (Table 7-75) predicts that a maximum spatial extent of 877 m for the initial dilution phase of mixing, with the temperature differential becoming within guideline (and generally well below guidelines levels) well within this distance. The model predicted a worst-case maximum horizontal distance until chorine dilution factor is reached, was 1,975 m from the discharge source on the MOPU. Therefore, any potential impacts to water quality are expected to be limited to within 1,975 m of the discharge source. Given the details above, the consequence of CW and brine discharges causing a change in ambient water quality has been assessed as **Minor (1)**, given that discharges will dissipate and disperse rapidly within the water column with highest concentrations of chemicals, salinity and elevated temperatures within close proximity to the discharge source.

7.1.10.2.2 Ecological receptors

Ecological receptors with the potential to be impacted as a result of CW and brine discharges include:

- plankton.

The above receptors may be impacted from:

- injury / mortality to fauna.

Table 7-81 provides a detailed evaluation of the impact of CW and brine discharges to ecological receptors.

Table 7-81 Impact and Risk Assessment for Ecological Receptors from Planned Discharge – Cooling Water and Brine

Plankton ✓
Injury/mortality to fauna A change in water quality due to CW and brine discharges may cause injury or mortality to plankton species through increased toxicity levels, salinity levels and increased water temperatures. Discharged brine water sinks through the water column where its rapidly mixed with receiving waters and dispersed by ocean currents. As such, any potential impacts are expected to be limited to the source of the discharge where concentrations are highest. Early life stages of fish (embryos, larvae) and other plankton would be most susceptible to the toxic exposure from chemicals in the brine discharges, as they are less mobile and therefore can become exposed to the plume at the outfall. This in turn may also affect the population of prey species. Phytoplankton communities in the NWS region are characterised by smaller taxa (e.g. cyanobacteria), while shelf waters are dominated by larger taxa such as diatoms (Hanson, Waite, Thompson and Pattiaratchi 2007). Zooplankton assemblages within the Project Area consist of the larvae of deepwater and pelagic taxa such as tuna (family Scombridae) and lanternfish (family Myctophidae) (Beckley, Muhling, and Gaughan 2009). A study by Hirayama and Hirano (1970) on power plant discharges found that some species of plankton (*S. costatum*) were killed by chlorine at a concentration of 1.5 – 2.3 ppm when exposed for exactly 5 and 10 minutes respectively, while others (*Chlamydomonas sp.*) were not irreversibly damaged even at 20 ppm chlorine or more with the same exposure period. This suggests a range of tolerances to chlorine concentrations with Hirayama and Hirano (1970) concluding residual chlorine discharging into the open sea should not cause great damage to marine phytoplankton in that area. Modelling predicted a worst-case maximum horizontal distance until the chorine dilution factor is reached was 1,975 m from the discharge source on the MOPU. The maximum plume width was predicted to be 164 m. Plankton have a patchy distribution linked to localised and seasonal productivity that produces sporadic bursts in populations (DEWHA 2008). The oligotrophic waters of the project area are typical of the wider offshore region supporting low phytoplankton biomass and relatively low primary productivity (Woodside 2005). Any impacts within the area would be temporary as plankton populations are able to rapidly recover once the activity ceases. Plankton species have high levels of natural mortality and a rapid replacement rates (UNEP 1985). Effects from increased salinity on planktonic communities in areas of high mixing and dispersion are generally limited to the point of discharge only (Azis et al. 2003). Studies on pelagic phytoplankton show salinity tolerances are highly variable among species and are also dependent on the magnitude of the

salinity increase and exposure time (Petersen et al. 2018; Belkin et al. 2017; Frank et al. 2017; Rothing et al. 2016; Del-Pilar-Ruso 2018; Fernández-Torquemada and Sánchez-Lizaso 2005; Park et al. 2011) Relative abundances and growth rates of phytoplankton, zooplankton also do not seem to be significantly impacted at salinities of 10% above ambient. The impact to plankton species from a change in temperature also varies from species to species. Vijverberg, (1980) showed that changes in the temperature due to discharges from a desalination plant on plankton lead to a positive effect on reproduction biology and the growth rate of several species of plankton. However, thermal stress was the major source of copepod mortality reported by Choi et al. (2012) with mortality caused by a difference of ~5°C. Modelling for the Corowa Development shows a rapid decrease in temperatures near the discharge source and temperature thresholds are met within 877 m of the source. Therefore, impacts to plankton species are expected to be localised and temporary. As planktonic productivity within the permit area is low and given the relatively small area of impact as a result of routine CW and brine discharges, impacts to plankton are not expected to result in a significant impact with no population-level declines or reduction in ecological productivity and diversity within Commonwealth marine areas. Plankton populations are expected to rapidly recover by natural action within the affected area once activities cease. As impact to plankton species are predicted to be localised and temporary, marine fauna that rely on plankton as a prey species are also unlikely to affected (i.e. no secondary impacts are expected). Given the details above, the consequence of CW and brine discharges causing injury / mortality to plankton species has been assessed as **Minor (1)**, given that discharges will dissipate and disperse rapidly within the water column with highest concentrations of chemicals, salinity and elevated temperatures within close proximity to the discharge source.

7.1.10.3 Consequence and Acceptability

The worst-case consequence of Planned Discharge – Cooling Water and Brine was evaluated as **Minor (1)** for all receptors.

The impacts overall have been determined to be acceptable based on an evaluation against the criteria in Table 7-82.

Table 7-82 Demonstration of Acceptability for Planned Discharge – Cooling Water and Brine

Acceptability Criteria	Justification
To meet the principles of ESD	• For CW, the maximum horizontal extent is predicted as 1,975 m for the chlorine threshold and 877 m for the temperature threshold. • This is within the 5 km radius of the MOPU designated the Project Area, and therefore is within the 78.5 km^2 area of planned activities. • Monitoring and modelling undertaken for other projects has identified that salinity levels for brine discharges are achieved close to the discharge source. • Due to the nature of CW and brine discharges once within the marine environment, discharge plumes will occupy only a small portion of the water column. • Discharges of CW and brine from vessels and facilities will not be inconsistent with environmental performance outcomes. • CW and brine discharge volumes during the Corowa Development will be comparable with, or smaller than, discharges from other operations on the North West Shelf, and will not result in a noticeable change in water quality for the wider regional area. • Impacts as a result of toxicity to marine fauna are not expected. Due to the localised nature of impacts to planktonic species that may be prey to other species (<164 m plume width), any impacts to pelagic predators as a result of reduced food supply are considered unlikely.

Acceptability Criteria	Justification
	• CW and brine discharges are not expected to result in a substantial adverse effect on a population of plankton, including its life cycle and special distribution, with no lasting effects due the expected rapid dilution and mixing of discharge plumes within the offshore marine environment and rapid replacement rate of planktonic organisms.
Internal context	• KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)
External context	• No stakeholder concerns have been raised with respect to planned discharges of CW and brine or potentially impacted receptors.
Other requirements	• Regarding planned discharges of CW and brine, activities undertaken throughout the Corowa Development will not be conducted in a manner inconsistent with maintaining the environmental values of marine environmental quality

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-83.

Table 7-83 Summary of Impact Assessment for Planned Discharge – Cooling Water and Brine

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM16**: Equipment will be maintained in accordance with the manufacturer's specifications, facility planned maintenance system and regulatory requirements. **CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness.	Minor
Plankton	Injury / mortality to fauna	**EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor

7.1.11 Planned Discharge – Deck Drainage and Bilge

Deck drainage and bilge water has the potential to change water quality within the Project Area by introducing water and fluids that may contain small amounts of chemicals and hydrocarbons.

7.1.11.1 Aspect Source

Throughout the Corowa Development, phases and activities where planned discharges from project vessels and facilities may interact with other receptors include:

Support activities (all phases)	MODU operations; MOPU operations; FSO operations; vessel operations

Support Activities (all phases)

Vessels usually have a closed and open drainage system. The closed drainage system collects contaminated streams from the processing system and liquids from equipment and piping during maintenance and routes the hazardous waste to the closed drain tank/s. This collected water is disposed via the produced water system. The open drainage system collects non-contaminated liquids, as summarised below.

Deck drainage generally comprises water and fluids that have resulted from rainfall, ocean spray and water used in the washdown process. 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 drains are normally discharged directly to the marine environment.

Potentially contaminated streams can be diverted to a bilge/slops tank for initial treatment first (such as an oil-water separator) (e.g. if there is an emergency or unplanned release of hydrocarbon). For high water flows beyond the capacity of the slops tank (e.g. firewater deluge or storm), the first flush is recovered to the slops tank, and the overflow goes directly to the open drain system, with this overflow considered to be uncontaminated deck drainage.

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 so that discharge of hydrocarbons to the marine environment is avoided. 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 (OWS), before being discharged into the sea, usually to reduce any oily residue to below 15 ppm or where there are no visible signs of oil. Discharge is infrequent.

The MODU, MOPU, FSO and vessels will be equipped with firefighting foam extinguishing capability as a part of safety-critical requirement. Several types of firefighting foams are available, including Aqueous Film Forming Foam (AFFF) 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. They will be discharged through the open drain system.

Previous modelling by Shell (2010) indicates that upon release, hydrocarbon and other chemical concentrations are rapidly diluted and expected to be below Predicted No Effect Concentration (PNEC) within a relatively short time period, within less than 100 m of the discharge. That is, the concentration of any bilge or deck drainage discharge will rapidly fall below levels, which will adversely affect the marine environment and will most likely not occur during long-term or short-term exposures.

7.1.11.2 Impact Analysis and Evaluation

Deck drainage and bilge generated by the Corowa Development have the potential to result in this impact:

- change in water quality.

As a result of a change in water quality, further impacts may occur, including:

- injury / mortality to fauna.

Table 7-84 identifies the potential impacts to receptors as a result of deck drainage and bilge discharges from the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-85 provides a summary and justification for those receptors not evaluated further.

Table 7-84 Impact / Receptor Matrix for Planned Discharge – Deck Drainage and Bilge

Impacts	Water quality	Plankton	Fish	Marine mammals	Marine reptiles	Commercial Fisheries
Change in water quality	✓					
Injury/mortality to fauna		X	X	X	X	
Changes to the functions, interests or activities of other users						X

Table 7-85 Justification for Receptors Not Evaluated Further for Planned Discharge – Deck Drainage and Bilge

Plankton, Fish, Marine Mammals and Marine Reptiles	X
<u>Injury/mortality to fauna</u> Levels of containments within deck washdown, rainwater and deck drainage are likely to be insignificant. OSPAR (2014) indicates that the predicted no effect concentration (PNEC) for marine organisms exposed to dispersed oil is 70.5 ppb. This PNEC is based upon NOECs after exposure to certain concentrations for an extended period that was greater than seven days (OSPAR 2014). Due to wave action and ocean currents any low-level contaminants will be quickly diluted and dispersed with no or negligible environmental impact. Shell (2009) conducted modelling that showed discharges of hydrocarbon and other chemical concentrations will be rapidly diluted and expected to be below PNEC within a relatively short time period , and will meet UNEP (1999) standards within 70 m of their discharge. Species with limited mobility (i.e. plankton, fish embryo and larvae) are extremely unlikely to be impacted by any effects of temporary and localised increases in turbidity and low toxicity due to the rapid dilution. As no significant impacts are expected to plankton species, impacts on higher trophic levels are also unlikely. Larger fauna have the mobility to avoid any localised increase in turbidity. Bilge water will be treated prior to discharge via an OWS with a maximum concentration of 15 ppm oil-in-water being achieved prior to discharge and therefore will have negligible impacts on marine fauna. Firefighting foams may be released as part of system testing or during an emergency event. Elevated biological oxygen demand (BOD) caused by firefighting foams could result in depletion of dissolved oxygen from the water column and cause potential harm to marine fauna. Within the marine environment wave action and ocean currents will dilute and disperse the foam before significant oxygen depletion occurs. BOD and increased toxicity are usually associated with terrestrial water ways with low mixing (McDonald et al. 1996). The EPBC PMST lists one species of shark as Vulnerable (Grey Nurse Shark) and four as Vulnerable/Migratory (Dwarf Sawfish, Green Sawfish, White Shark and Whale Shark) that are likely to occur within the area. The Corowa Project Area is situated within a foraging BIA for the Whale Shark. Whilst the recovery plan for the Whale Shark (DEH 2008a) ceased to be in effect from 1 October 2015 it stated that the main threat to the Whale Shark occurs outside Australian waters. Whilst pollution was listed as a future threat at present pollution does not have an impact on the numbers of Whale Sharks visiting Australian waters (DEH 2005a). All species listed are highly mobile, therefore, none are expected to be affected by minor deck drainage or bilge discharges. The EPBC PMST shows that three species of marine mammal listed as either Vulnerable (Sei Whale, Fin Whale and Humpback Whale) and two species listed as Endangered (Blue Whale and Southern Right Whale) that are known or may occur within the Project Area. The Project Area sits within a migratory BIA for Humpback Whales. The recovery plan (DEH 2005b) (ceased to be in effect from 1 October 2015) listed pollution as a threat although this is primarily in relation to run-off from land-based agriculture, oil spills and outputs from aquaculture. Deck drainage and bilge activities will be conducted in accordance with all applicable management actions to ensure impacts are negligible. The EPBC PMST shows that three species of turtle listed as either Vulnerable (Green Turtle, Hawksbill Turtle and Flatback Turtle) or Endangered (Loggerhead Turtle and Leatherback Turtle) have habitat, congregation or congregation known to occur within area. A single species of snake (Short-nosed Sea Snake) listed as	

critically endangered may also occur within the area. The Project Area sits within three BIA for marine turtle species. The Recovery Plan for Marine Turtles in Australia, (CoA 2017) identifies chemical and terrestrial discharge as a threat, although this is mostly in relation to pollution from agricultural, terrestrial industrial and domestic sources. Deck drainage and bilge activities will be conducted in accordance with all applicable management actions to ensure impacts are negligible. A change in water quality as a result of deck drainage and bilge water discharges are unlikely to lead to injury or mortality of marine fauna at a measurable level and will not result in a change in the viability of the population or ecosystem. Therefore, no impacts from deck drainage and bilge water discharges are expected and have not been evaluated further.	
Commercial Fisheries	***X***
<u>Changes to the functions, interests or activities of other users</u> As impacts to fish are not expected from planned discharges of deck drainage and bilge, indirect impacts to commercial fisheries are not expected. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). As these discharges within the Corowa Project Area will be localised and rapidly diluted, the area of influence is highly localised and of an insignificant area, and is not expected to result in a change in the viability of the population of commercially important species. Therefore, impacts to commercial fisheries from deck drainage and bilge discharges are not expected, and have not been evaluated further.	

Impacts to receptors are assessed below, by receptor type.

7.1.11.2.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of deck drainage and bilge include:

- ambient water quality.

Table 7-86 provides a detailed evaluation of the impact or risk of deck drainage and bilge to physical receptors.

Table 7-86 Impact and Risk Assessment for Physical Receptors from Planned Discharge – Deck Drainage and Bilge

Ambient Water Quality	✓
<u>Change in water quality</u> The release of deck drainage and treated bilge into the marine environment will result in a change in water quality by increasing turbidity and introduce a range of low-level chemicals. Deck drainage water and bilge water generally comprises a mixture of fresh water, sea water, oil, sludge, chemicals and various other fluids. Discharges will be highly localised and infrequent with high dilution and dispersion rates due to wave and ocean currents. Therefore, decreased turbidity is expected to very short term, hours rather than days. Bilge water will be treated prior to discharge via an OWS with a maximum concentration of 15 ppm oil-in-water being achieved prior to discharge. The remaining oil residue will be retained on board for onshore disposal. The volume of deck drainage will vary depending on the amount of cleaning operations and weather conditions. Modelling by Shell (2010) indicates that, hydrocarbon and other chemical concentrations released to the marine environment are rapidly diluted and expected to be below Predicted No Effect Concentration (PNEC) within a relatively short time period and within less than 70 m of the discharge. It is expected that regular testing of the firefighting system will occur; however, this will often only test the water system, testing with AFFF will likely be every 3 months (for a very short time period). BOD is very high for all firefighting foams and can be of considerable environmental concern (DEHP 2016). Elevated BOD can result in depletion of dissolved oxygen from the water column and cause potential harm to marine fauna. BOD effects are delayed as the microbes present will take time to adapt to degrade the organic content. Therefore, it can be period of one to several days before BOD related oxygen depletion effects escalate (IPEN 2018). Within the marine environment wave action and ocean currents will dilute and disperse the	

foam before significant oxygen depletion occurs. Oxygen depletion from BOD is usually associated with terrestrial water ways with low mixing. The level and type of discharges will be similar to other platforms operating in the NWS with standard industry practices undertaken. Given the details above, the consequence of deck drainage and bilge causing a change in ambient water quality has been assessed as **Minor (1)**, given that discharges will be of relatively small volumes, infrequent and have low levels of toxicity, due to rapid dilution.

7.1.11.3 Consequence and Acceptability Summary

The consequence of Planned Discharge – Deck drainage and Bilge has been evaluated as **Minor (1)** for all potentially impacted receptors and is considered **acceptable** when assessed against the criteria Table 7-87.

Table 7-87 Demonstration of Acceptability for Planned Discharge – Deck Drainage and Bilge

Acceptability Criteria	Justification
To meet the principles of ESD	• Discharge of deck drainage water and bilge water from vessels and other facilities is a well understood, controlled by standard industry practices. Discharges will be comparable to existing projects and developments within the NWS area • Discharge of deck drainage water and bilge water will either be treated prior to discharge or be of such a low level of toxicity that any detectable levels will be rapidly diluted and dispersed within the marine environment with not lasting effects on water quality • Impacts to plankton and fish species from toxic chemicals and bioaccumulation are unlikely due to the highly localised discharge that will comprise extremely low volumes and levels of toxicity
Internal context	• KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)
External context	• No stakeholder concerns have been raised with respect to deck drainage or bilge discharges or potentially impacted receptors.
Other requirements	• Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* – Section 26F (implements MARPOL Annex I). • Commonwealth *Navigation Act 2012* – Chapter 4 (Prevention of Pollution). • AMSA Marine Orders Part 91 (Marine Pollution Prevention – Oil) 2014. • With respect to a planned discharge of deck drainage and bilge water, activities associated with the Corowa Development will not be conducted in a manner inconsistent with maintaining the environmental values of marine environmental quality.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-88.

Table 7-88 Summary of Impact Assessment for Planned Discharge – Deck Drainage and Bilge

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM16**: Equipment will be maintained in accordance with the manufacturer's specifications, facility planned maintenance system and regulatory requirements. **CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM21**: Compliance with AMSA Marine Order Part 91 (Marine Pollution Prevention – Oil) to prevent accidental pollution and pollution from routine operations.	Minor

7.1.12 Planned Discharge – Sewage, Greywater and Food Waste

Discharges of Sewage, greywater and food waste have the potential to reduce water quality within the operational area by introducing small amounts of chemicals plus increased nutrient loads.

7.1.12.1 Aspect Source

Throughout the Corowa Development, phases and activities that involve planned discharges of sewage, greywater and food waste that may interact with other receptors include:

Support Activities (all phases)	MODU operations; MOPU operations; FSO operations; vessel operations

Support Activities (all phases)

Sewage and greywater will be produced as a result of ablution, laundry and galley facilities from platforms and vessels. This waste will be treated prior to discharge to the environment as per guidelines under the MARPOL 73/78 Annex IV and Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*. The composition of sewage and greywater may include chemicals including nutrients (e.g. ammonia, nitrite, nitrate and orthophosphate), which can lead to eutrophication (NERA 2017).

MODU, MOPU and vessels typically discharge between 0.04 and 0.45 m^3 of treated wastewater (consisting of sewage and greywater) per day per person (EMSA 2016). Using the maximum suggested rate 0.45 m^3/per person per day, a combined crew of ~160 during the drilling phase and ~30 during the operations phase would equate to treated discharges of 72 m^3 and 13.5 m^3 per day respectively.

Discharged wastewaters will be dispersed by wind-driven surface water currents plus wave action and rapidly mixed through the surface layer of water. Previous monitoring of wastewater discharges has demonstrated that a 10 m^3 sewage discharge over 24 hrs from a stationary source in shallow water, reduced to ~1% of its original concentration within 50 m of the discharge location (Woodside 2008).

Food waste will be produced by galley facilities on board the operational facilities and vessels. Food waste will be macerated to a size small enough to pass through a 25 mm mesh (as required under MARPOL) and discharged overboard. The average volume of food waste discharged into the marine environment it is expected to be in the region of 1–2 kg per person per day (NERA 2017). This would be an estimated total of 320 kg during the drilling phase and 60 kg during production per day using crew totals previously described.

7.1.12.2 Impact or Analysis and Evaluation

Sewage, greywater and food waste generated by the Corowa Development have the potential to result in this impact:

- change in water quality.

As a result of a change in water quality, further impacts may occur, including:

- change in fauna behaviour
- change in aesthetic value.

Table 7-89 identifies the potential impacts to receptors as a result of seabed disturbance from the sewage, greywater and food waste discharges from the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-90 provides a summary and justification for those receptors not evaluated further.

Table 7-89 Receptors Potentially Impacted by Planned Discharge – Sewage, Greywater and Food Waste

Impacts	Water quality	Plankton	Benthic habitats and communities	Seabirds and shorebirds	Fish	Marine mammals	Marine reptiles	Commercial fisheries	Tourism and recreation
Change in water quality	✓								
Change in fauna behaviour		*X*	*X*	*X*	*X*	*X*	*X*		
Changes to the functions, interests or activities of other users								X	
Change in aesthetic value									*X*

Table 7-90 Justification for Receptors Not Evaluated Further for Planned Discharge – Sewage, Greywater and Food Waste

Plankton	***X***
The introduction of sewage, greywater or food waste within surface waters is unlikely to result in the change in the behaviour of plankton. Plankton have a patchy distribution linked to localised and seasonal productivity that produces sporadic bursts in populations (DEWHA 2008). The oligotrophic waters of the project area are typical of the wider offshore region supporting low phytoplankton biomass and relatively low primary productivity (Woodside 2005). With the introduction of nutrients, plankton populations could rapidly increase but would return to previously levels once these introduced nutrients have been used. A change in water quality as a result of sewage, greywater or food waste is unlikely to lead to a significant change in plankton at a measurable level and will not result in a change in the viability of the population or ecosystem. Therefore, no impacts to plankton from sewage, greywater or food waste discharges are expected and have not been evaluated further.	

Benthic Habitats and Communities	X
The introduction of sewage, greywater or food waste within surface waters is unlikely to result in the change in the behaviour of benthic habitats and communities. The discharges will be mixed and diluted by significant wave action and localised ocean currents in surface and near-surface waters with discharges likely to disperse quickly over a small area. Sewage, greywater or food waste discharges are unlikely to reach the seabed in significant concentrations. Therefore, these discharges are unlikely to lead to a significant change in benthic habitats and communities at a measurable level and will not result in a change in the viability of the population or ecosystem. KEF features have not been identified for this impact as they will be confined to surface waters. As no impacts to benthic habitats and communities from sewage, greywater or food waste discharges are expected, it has not been evaluated further.	
Seabirds and Shorebirds, Fish, Marine Mammals and Marine Reptiles	***X***
<u>Change in fauna behaviour</u> Discharges of organic matter, such as those present in sewage, greywater or food waste can lead to an increase in scavenging behaviour in fauna. Discharges will be localised and temporary as they will be quickly broken down by microbial action and dispersed by wave action and local ocean currents. Sewage solids will be broken down during treatment before being discharged, which will aid the breakdown process. Likewise, food scraps are required under MARPOL to be macerated to a size small enough to pass through a 25 mm mesh before being discharged. The EPBC PMST has identified six species of bird that are known to have a large foraging range and therefore may be exposed to these discharges. Wedge-tailed Shearwaters migrate to the Serrurier and Muiron islands from July onwards with adult birds feeding during the day and return to the islands every evening. However, the Serrurier and Muiron islands are ~17 km and 23 km distance respectively from the expected MOPU position. With high dilution rates, any potential change to scavenging behaviour from seabirds is expected to be incidental. The EPBC PMST lists one species of shark as Vulnerable (Grey Nurse Shark) and four as Vulnerable/Migratory (Dwarf Sawfish, Green Sawfish, White Shark and Whale Shark) that are likely to occur within the area. The Corowa Project Area is situated within a BIA for the Whale Shark. Whilst the recovery plan for the Whale Shark (DEH 2005a) ceased to be in effect from 1 October 2015 it stated that the main threat to the Whale Shark occurs outside Australian waters. Whilst pollution was listed as a future threat, at present it does not have an impact on the numbers of Whale Sharks visiting Australian waters (DEH 2005a). All species listed are highly mobile, therefore, none are expected to be affected by minor sewage, greywater or food discharges. The EPBC PMST shows that three species of marine mammal listed as either Vulnerable (Sei Whale, Fin Whale and Humpback Whale) and two species listed as Endangered (Blue Whale and Southern Right Whale) that are known or may occur within the Project Area. The Project Area sits within a migratory BIA for Humpback Whales. The recovery plan (DEH 2005b) (ceased to be in effect from 1 October 2015) listed pollution as a threat although this is primarily in relation to run-off from land-based agriculture, oil spills and outputs from aquaculture. Minor sewage, greywater and food discharge activities will be conducted in accordance with all applicable management actions to ensure impacts are negligible. The EPBC PMST shows that three species of turtle listed as either Vulnerable (Green Turtle, Hawksbill Turtle and Flatback Turtle) or Endangered (Loggerhead Turtle and Leatherback Turtle) have habitat, congregation or congregation known to occur within area. A single species of snake (Short-nosed Sea Snake) listed as critically endangered may also occur within the area. The Project Area sits within three BIA for marine turtle species. The Recovery Plan for Marine Turtles in Australia, (CoA 2017) identifies chemical and terrestrial discharge as a threat, although this is mostly in relation to pollution from agricultural, terrestrial industrial and domestic sources. Sewage, greywater and food discharge activities will be conducted in accordance with all applicable management actions to ensure impacts are negligible. A change in water quality as a result of minor sewage, greywater or food discharges are unlikely to cause a change in behaviour of marine fauna at a measurable level and will not result in a change in the viability of the population or ecosystem. Therefore, no impacts from minor sewage, greywater or food discharges are expected, and have not been evaluated further.	

Commercial Fisheries	*X*
Changes to the functions, interests or activities of other users As impacts to fish are not expected from planned discharges of sewage, greywater and food waste, indirect impacts to commercial fisheries are not expected. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). A change in water quality as a result of minor sewage, greywater or food discharges are unlikely to cause a change in behaviour of marine fauna at a measurable level and will not result in a change in the viability of the population or ecosystem. Therefore, impacts to commercial fisheries from minor sewage, greywater or food discharges are not expected, and have not been evaluated further.	
Tourism and Recreation	***X***
Planned discharges of sewage, greywater and food waste from platforms or vessels within the Corowa Project Area are unlikely to cause a change in aesthetic value and impact on local tourism and recreation activities. Discharges of this nature will be rapidly diluted and dispersed by wave action and ocean currents resulting in only localised and temporary impacts. Popular tourism and recreation activities within the North-west Marine region include diving, snorkelling, recreational fishing, wildlife watching and yachting. Apart from offshore charter fishing, these activities are generally centred around shallow coastal waters or around areas of fauna aggregation, generally within state waters. Due to the distance offshore (~50 km) and water depth (~90 m) at the Corowa Development location, tourism and recreation activities within the Project Area are expected to be highly infrequent. Therefore, impacts are not expected and have not been evaluated further.	

Impacts to receptors are assessed below, by receptor type.

7.1.12.2.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of sewage, greywater and food waste include:

- water quality.

Table 7-91 provides a detailed evaluation of the impact of sewage, greywater and food waste to seabed disturbance from the physical presence of the activities to receptors.

Table 7-91 Impact and Risk Assessment for Physical Receptors from Planned Discharge – Sewage, Greywater and Food Waste

Ambient Water Quality	✓
Change in water quality A planned discharge of sewage, greywater and food waste may result in an impact on ambient water quality, as discharges can include chemicals including nutrients (e.g. ammonia, nitrite, nitrate and orthophosphate), which can lead to an increased nutrient load and eutrophication. Eutrophication can result in increased growth of primary producers such as phytoplankton, which in turn increases the BOD, resulting in changes in biological diversity. Waters in the region of the Corowa Development will be subject to significant wave action and localised ocean currents resulting in the rapid mixing of surface and near-surface waters where discharges of sewage, greywater and food waste may occur. Discharges are likely to disperse quickly over a small area. Therefore, nutrients from these discharges will not accumulate or lead to eutrophication due to the highly dispersing environment. 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 as again discharges will be diluted and dispersed by wave action and local currents with particulate matter subject to predation from local fauna. Infrastructure and vessels are expected to discharge a total of ~72 m^3 of sewage and greywater per day during installation, hook-up and commissioning, which will reduce to ~135 m^3 during the operational phase.	

Previous studies (Woodside 2008) monitored a sewage discharge of 10 m^3 over 24 hours from a stationary source. It found that the sewage discharge was reduced to ~1% of its original concentration within 50 m. Beyond this and at monitoring locations of various depths downstream of the source no elevations in total nitrogen, total phosphorous and selected metals were recorded above background levels. The study states that this is a comparatively small discharge but 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. Discharges will disperse and dilute rapidly, with concentrations of wastes significantly dropping with distance from the discharge point. Previous studies have quantified the high levels of dilution, which are in the order of ~200,000–640,000 for effluents discharged behind large ships (USEPA 2002; Loehr et al. 2006). The discharge and subsequent level of dilution was shown to be acceptable for mitigating localised toxicity impacts to marine fauna from changes in water quality. Given the details above, the consequence of sewage greywater and food waste causing a change in water quality has been assessed as **Minor (1)**, given that sewage, greywater and food waste discharges will be infrequent, have low levels of toxicity and will be rapidly diluted.

7.1.12.3 Consequence and Acceptability Summary

The consequence of Planned Discharge of sewage, greywater and food waste has been evaluated as **Minor (1)** for all potentially impacted receptors and is considered **acceptable** when assessed against the criteria Table 7-92.

Table 7-92 Demonstration of Acceptability for Planned Discharge – Sewage, Greywater and Food Waste

Acceptability Criteria	Justification
To meet the principles of ESD	• Discharge of sewage, greywater and food waste from vessels and other facilities is a well understood activity, controlled by standard industry practices. Discharges will be comparable to existing projects and developments within the NWS area • Discharge of sewage, greywater and food waste will either be treated prior to discharge and will be rapidly consumed, diluted and dispersed within the marine environment with not lasting effects on water quality • Impacts to plankton, benthic habitats and communities and marine fauna are unlikely due to the highly localised discharge, which will be rapidly consumed, diluted and dispersed within the marine environment • Impacts to tourism and recreation are unlikely due to the project's remote location and the low-intensity tourism in the area
Internal context	• KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)
External context	• No stakeholder concerns have been raised with respect to sewage, greywater and food waste or potentially impacted receptors
Other requirements	• Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* – Section 26D (which implements MARPOL Annex I to IV) • Commonwealth *Navigation Act 2012* – Chapter 4 (Prevention of Pollution) • AMSA Marine Order 96 (Marine pollution prevention – sewage) 2013 regulates sewage treatment discharge • AMSA Marine Order 95 (Marine pollution prevention – garbage) 2013 regulates the discharge of putrescible (food) waste • With respect to a planned discharge of sewage, greywater and food waste, activities associated with the Corowa Development will not be conducted in a manner inconsistent with maintaining the environmental values of marine environmental quality

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in

Table 7-93.

Table 7-93 Summary of Impact Assessment for Planned Discharge – Sewage, Greywater and Food Waste

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM16**: Equipment will be maintained in accordance with the manufacturer's specifications, facility planned maintenance system and regulatory requirements. **CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM22:** Compliance with Marine Order 96 (Marine pollution prevention – sewage) 2013. **CM23:** Compliance with Marine Order 95 (Marine pollution prevention – garbage) 2013.	Minor

7.2 Unplanned

7.2.1 Unplanned Introduction of IMS

Invasive marine species (IMS) are species introduced into environments in which they do not occur naturally, which if they are able to establish themselves can become pests by out-competing indigenous marine species. IMS can include fish, seastars, crabs, molluscs, worms, sponges, microscopic dinoflagellates, shellfish, algae, bacteria and viruses.

Marine pests are introduced to Australian waters and translocated within Australian waters in various ways, including ballast water discharged from vessels and facilities, biofouling on hulls and inside internal seawater pipes of vessels and facilities, as well as marine debris and ocean currents.

7.2.1.1 Aspect Source

Throughout the Corowa Development, these phases and activities have the potential to introduce an IMS:

Drilling	MODU positioning
Installation, Hook-up and Commissioning	MOPU; CALM buoy and mooring arrangements; FSO
Decommissioning	Inspection and cleaning
Support activities (all phases)	MODU operations; MOPU operations; FSO operations; vessel operations

Drilling; Installation, Hook-up and Commissioning; Support Activities (all phases)

IMS could be transported to the Corowa Development from two types of location:

- international waters via:
  - installation of the MOPU, MODU and/or FSO, if these facilities come from international fabrication yards / international ports
  - support vessels (i.e. AHTs, ISV) sourced from international ports, or used to tow the above from international ports
  - tankers from international ports.
- domestic ports via:
  - supply vessels (2–3 times per month from North-West WA ports)
  - locally sourced support vessels (e.g. ISV, tugs).

Vessels have been identified as the most important vector for transport of IMS. Research suggests that the most significant mechanism of IMS translocation is vessel biofouling (Hewitt et al. 1999 2004; Mineur et al. 2007), which was previously thought to be ballast water discharges.

Ballast Water

It is estimated that 25% of Australia's established IMS was the result of ballast water exchange (DAWR 2019).

Vessels (including the FSO and shuttle/export tankers) may be required to adjust their ballast during installation, loading and offloading operations to maintain stability, balance and trim. During the uptake of ballast water from the surrounding environment in an international or domestic location, it is possible for a vessel to take in water that contains planktonic biota, including holoplankton, gametes, spores and larvae. This biota may then be discharged at the vessel's or platform's new location during ballast water exchange.

For the Corowa Development, this means that vessels could potentially discharge ballast water containing this biota in the Project Area. If this species was transferred directly onto subsea structures or to the seafloor, it could become established as an IMS.

The Australian Ballast Water Management Requirements (DAWR 2017, version 7) provides Australia's commitment to the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Ballast Water Convention) (IMO 2017). This provides guidance on how vessel operators should manage ballast water when operating within Australian seas to comply with the Commonwealth *Biosecurity Act 2015*. In brief it ensures that:

- a vessel has a Ballast Water Management Plan and Ballast Water Management Certificate
- ballast water exchange conducted in an acceptable area
- use of low risk ballast water (such as fresh potable water, high seas water or fresh water from an on-board freshwater production facility)
- retention of high-risk ballast water on board the vessel
- all operations are recorded in the Ballast Water Record System and reporting obligations are met.

Vessels may be required to undertake ballast water exchange within the Project Area. Should this be the case, ballast water exchange will only occur via the acceptable methods detailed in the Australian Ballast Water Management Requirements (DAWR 2017, version 7) and in accordance with the Commonwealth *Biosecurity Act 2015*.

Biofouling

IMS have also been imported in biofouling communities via biofouling on vessel hulls and in damp or fluid-filled spaces (niche areas) such as anchor lockers, bilges, sea chests or internal seawater systems (DAFF 2003). Approximately 75% of identified IMS are believed to have been introduced through biofouling rather than in ballast water (Bax et al. 2003). All facilities and vessels that are regularly submerged will have some degree of biofouling, which can range through primary, secondary to tertiary levels unless cleaned or treated prior to arrival to the project area (DAFF 2009).

Of all the Corowa Development vessels or facilities, the MODU and MOPU has the greatest risk of accumulating biofouling, as they are likely to have been stationary for the longest period. These facilities also provide ideal pest translocation conditions because of their slow towing speeds (typically around 2 knots) and therefore could be responsible for transferring pest species over long distances very rapidly (DAFF 2003).

It may be possible for an IMS to transfer between offshore support vessels and installed infrastructure or vice versa. Tugs involved in anchor handling that tow between locations and, in turn enter ports, are particularly vulnerable to IMS colonisation.

Anchors and chains may also have been submerged or immersed for a considerable period in overseas waters and may also be a source of biofouling and possible IMS unless appropriately cleaned or treated. Installed permanent moorings may provide marine pests with submerged and semi-submerged surfaces to which they may attach themselves (DAFF 2003). In many cases, these structures remain undisturbed for long periods before they are lifted up for maintenance or re-positioning. All craft that pass near or handle them may be at risk of infection from a fouled mooring or buoy.

Biofouling is managed under the Commonwealth *Biosecurity Act 2015*, via the National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry (Marine Pest Sectoral Committee 2018), and the National biofouling management guidelines for commercial vessels (Marine Pest Sectoral Committee 2018) for export tankers.

Decommissioning

The Honeybee production system (i.e. MOPU, FSO and associated infrastructure) may be mobilised to Corowa directly from international waters, or from a previous KATO development (in the north-west region of WA). Following completion of the Corowa Development, the MOPU, FSO and associated infrastructure will relocate to the next field.

Movement of vessels or facilities between similar marine biogeographic regions can present a high risk of marine pest translocation (DAFF 2009). As described in the National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry (DAFF 2009), the risk is increased if the vessel or facility:

- is heavily biofouled
- has been inactive or operated at low speeds for an extended period before the move between regions
- has a worn, ineffective or aged antifouling coating
- has areas where no antifouling coating is applied
- has operated in a port or area where a known or potential marine pest is known to occur.

The facilities and infrastructure associated with the Corowa Development will qualify for a number of these criteria (such as inactivity), therefore a higher risk is assumed.

About three to six months before decommissioning, an inspection will be undertaken of subsea infrastructure (CALM buoy and mooring arrangements) and the 'wetsides' (i.e. submerged parts) of the MOPU and FSO. Depending on the results of the inspection, removal of marine growth on subsea infrastructure and wetsides may be undertaken in situ at the Project Area, prior to demobilisation and redeployment at the next field.

In-water cleaning can manage biofouling to minimise biosecurity risks. However, in-water cleaning can physically damage some antifouling coatings, shorten coating service life and release a pulse of biocide into the marine environment. In-water cleaning can also facilitate the release of invasive marine species (IMS) into the surrounding environment.

As the biofouling on the honeybee system would be acquired over the project life at the same location as the cleaning is undertaken (i.e. at Corowa Project Area), it is considered 'regional' biofouling. The Anti-fouling and in-water cleaning guidelines (DoA 2015) provides guidance on cleaning methodologies appropriate for different types of biofouling and types of anti-foul coatings.

Cleaning methods may include brushing, scraping (soft tools), water jet and air jet (blast) systems, or technologies that kill, rather than remove biofouling; e.g. by heat or suffocation (wrapping in plastic or canvas).

Marine hoses and mooring chains would be retrieved and stored on board vessels or the FSO, and would be spray-washed using seawater (DAFF 2009).

Establishment of IMS

IMS are thought to be one of the most serious anthropogenic threats to global marine biodiversity (Wells 2018). However, successful IMS colonisation requires these three stages (Marine Pest Sectoral Committee 2018):

- colonisation and establishment of the marine pest on a vector (vessel, equipment or structure) in a donor region (a home port, harbour or coastal project site where a marine pest is established)
- survival of the settled marine pests on the vector during the voyage from the donor to the recipient region
- colonisation (for example, by reproduction or dislodgement) of the recipient region by the marine pest, followed by successful establishment of a viable new local population.

The risk of an IMS being able to successfully establish itself will depend on depth, distance from the coast, water movement and latitude. The probability of successful IMS settlement and recruitment will decrease in well-mixed, deep ocean waters away from coastal habitats. An IMS travelling through several latitudes will also have to survive significant temperature and salinity changes. Hewitt (2002) suggests that the higher diversity of native tropical community (such as those in the Pilbara) confers increased resistance to invasions through an increase in biotic interactions and could explain the inability of species to invade tropical environments. The Australian Government Bureau of Resource Sciences (BRS) established that the relative risk of an IMS incursion around the Australian coastline decreases with distance from the shoreline. Modelling conducted by BRS (2007) estimates:

- 33% chance of colonisation at 3 nm
- 8% chance at 12 nm
- 2% chance at 24 nm.

In comparison, the Project Area is ~27 nm from shore.

Within Australia, over 250 exotic marine species have been introduced with most having little impact, but some species have become aggressive pests in certain locations (DoA 2019a). The typical habitat of the ten species currently listed on the Marine Pest website (DoA 2019b) is shallow marine waters.

7.2.1.2 Risk Evaluation

IMS introduced during the Corowa Development have the potential to result in this impact:

- change in ecosystem dynamics.

As a result of a change in ecosystem dynamics, further impacts may occur, including:

- change in the functions, interests or activities of other users.

Table 7-94 identifies the potential impacts to receptors as a result of an IMS from the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-94 Receptors Potentially Impacted by the Introduction of an IMS

Impacts	Benthic habitats and communities	Coastal habitats and communities	Commercial Fisheries	Industry
Change in ecosystem dynamics	✓	✓		
Change in the functions, interests or activities of other users			✓	✓

Impacts to receptors are assessed below, by receptor type.

7.2.1.2.1 Ecological Receptors

Ecological receptors with the potential to be impacted as a result of an IMS:

- benthic habitats and communities
- coastal habitats and communities.

The above receptors may be impacted from:

- change in ecosystem dynamics.

Table 7-95 provides a detailed evaluation of the impact of an IMS to ecological receptors.

Table 7-95 Impact and Risk Assessment for Ecological Receptors from Introduction of IMS

Benthic Habitats and Communities ✓

Change in ecosystem dynamics

The introduction of an IMS through either ballast water exchange or biofouling has the potential to cause impacts to benthic habitats and communities through a change in ecosystem dynamics. Changes in ecosystem dynamics cause by the introduction of IMS can include:

- predation on native and farmed species
- out-competing native species for space and food
- alter nutrient cycles and lead to a loss of diversity in local species.

The biofouling, which may be found on and in a vessel, reflects the vessel's design, construction, maintenance and operations. Generally, the longer a vessel or facility has been in water, the greater the size and complexity of its biofouling community. If a vessel has been inactive or has operated intermittently or continually at low speeds it may accumulate substantial biofouling in as little as a month – this is the case for the FSO in field.

Depending on the order in which KATO develops the individual fields, the MOPU, MODU and FSO will mobilise to the Corowa Development either from:

- an international fabrication yard after refurbishment and pre-commissioning (i.e. from international waters)
- from the previous field, in the north-west of WA (i.e. from Commonwealth waters).

If the facilities and vessels come from international waters, they will undergo biofouling mitigation treatments such as dry-docking, cleaning and antifouling renewal as required by the Commonwealth *Biosecurity Act 2015*, before entering Australian waters.

If coming from domestic waters, before the facilities demobilise from the previous Development's Project Area, the OPP that governs that Development requires that:

- Inspection and in-water cleaning is undertaken, as per the Anti-fouling and in-water cleaning guidelines (DoA 2015).

As required by the Commonwealth *Biosecurity Act 2015* and the National biofouling management guidelines for commercial vessels for export tankers (Marine Pest Sectoral Committee 2018), international tankers will exchange ballast water as they cross into Australian territorial waters, before they arrive in the Project Area. This will significantly reduce the likelihood of introduction of IMS through ballast water exchange.

Support vessels will generally not be alongside the MOPU or MODU for more than a few hours at a time (4–8 hours), and will not come into direct contact with the MODU or MOPU's submersed pontoons. Support vessels present in the Project Area for more than this time will moor at one of three dead man's anchors, which for safety reasons will be located a few kilometres away from the weathervaning FSO.

When international export tankers or shuttle tankers connect to the FSO or CALM buoy to offtake oil, it is expected to take 48–72 hours to offload (depending on export strategy). There will be a separation of 70 m between the vessels (due to a support vessel/tug keeping the mooring hawser taut).

During towing or relocation of the MOPU and FSO there will only be the transfer of the towing lines and/or the mooring hawser between the vessels. The FSO will be self-propelled to the next field. However, for transfer of the CALM and Mooring system, the CALM buoy may be held adjacent to a support vessel (e.g. AHT) and the mooring chain and baskets will be recovered and loaded onto the back deck of the support vessel.

Due to these separation distances, it is considered unlikely that an IMS could successfully transfer onto the MOPU, MODU or FSO from biofouling on a support vessel or tanker, or during relocation to the next field.

However, it has been suspected that domestic vessels could introduce an IMS to a facility – for example post-arrival in the field, INPEX's Ichthys FPSO was found to have been colonised by *Didemnum perlucidum*, a marine pest already widely distributed around the ports of Western Australia and Northern Territory (Gust et al. 2019). It was considered likely to have colonised the facilities from a domestic transfer post-arrival in Australian waters (Gust et al. 2019).

To minimise the risk of transfer of IMS between KATO fields, wetsides and subsea infrastructure will be inspected and cleaned in situ at the Project Area before relocation to the next field. In-water cleaning can physically damage some antifouling coatings and shorten coating service life, and can facilitate the release of IMS through the release of biological material into the water. The Anti-fouling and in-water Cleaning Guidelines (DoA 2015) contain a decision support tool to guide evaluation of biofouling type and selection of cleaning methodology, such as methods to ensure minimal release of biological material into the water, and appropriate disposal of cleaning debris.

Marine hoses and mooring chains would be retrieved and stored on board vessels or the FSO during transit to the next site, allowing marine growth to dry out, although some biota can survive in damp shaded deposits attached to unwashed anchors (DAFF 2009). Seawater spray-washing of anchors and cables during site retrieval operations is the simplest mechanism to remove accumulated biofouling and reduce the risk of transferring marine pests in the form of biofouling (DAFF 2009).

Bax et al. (2003) states that rather than just blend into their new environment, many invasive species will significantly change it. This can occur through increasing the predation pressure on native organisms or modifying the habitat by smothering or providing new structural habitat such as Japanese seaweeds (Bax et al. 2003). IMS introduction primarily occurs in shallow waters with high levels of slow-moving or stationary shipping traffic such as ports. IMS colonisation also requires a suitable habitat in which to establish itself such as rocky and hard substrates or subsea infrastructure, especially with pre-existing biofouling.

The Project Area does not present a benthic habitat or community structure that is favourable to IMS survival. The Corowa Development is in relatively deep waters of ~90 m with low light level expected at the seabed. Macroalgae IMS would require light to survive and thrive, which will be minimal at the seabed within the Corowa Development area. Previous studies of the Corowa Development area (Thales 2001) have shown that the seabed is consistent and composed of partially exposed cemented carbonates overlain by a fine to coarse grained sedimentary veneer. Rocky or hard outcrops are not likely in the area, which is one of the major requirements in the ability of an IMS to establish itself. The sandy substrates on the NWS within this bioregion are thought to support low-density benthic communities of bryozoans, molluscs and echinoids. Sponge communities are also sparsely distributed (DEWHA 2008). Previous studies (Thales 2001) within the Project Area have also shown sparse populations of filter and deposit-feeding epibenthic fauna, polychaete worms, crustaceans and echinoderms. A lack of seabed features within the Corowa

Development area also suggests sparse benthic assemblages as areas of hard substrate generally supporting a more diverse epibenthic population (Heyward et al. 2001).

Benthic habitats and communities are at risk from IMS through competition for resources and being subject to predation. However, IMS colonisation is not normally associated with the open ocean due to the increased water depth, high level of water movement causing dispersal plus sparse benthic populations making it difficult for an IMS to spread.

Due to the lack of hard substrate and sparse nature of epifauna and infauna and depths present at the Project Area it is very unlikely that an IMS would be able to establish. There is currently no documented evidence of an IMS establishing in deeper offshore waters. BRS (2007) estimated the probability of an IMS incursion as 2% chance at 24 nm, which was also based on a 50 m deep contour. The Project Area is ~27 nm from shore, and is also in ~90 m water depth, further decreasing the probability of incursion. In the unlikely event an IMS was able to colonise the Project Area, it is expected that any colony would remain fragmented and isolated and only be able to survive within the vicinity of the MODU, MOPU and associated infrastructure (FSO, CALM buoy and mooring arrangements).

The species of concern noted within recent IMS studies (Wells 2018) and currently recorded on the Australian National IMS (NIMPCG 2009a; NIMPCG 2009b) and DoF (2014a) pest list, is the ascidian *Didemnum perlucidum*, also known as the white colonial sea squirt. Following the initial report of *D. perlucidum* in 2010, it was found throughout WA from Esperance to Darwin. *D. perlucidum* is widespread in the Pilbara and has been reported from Exmouth Boat Harbour, Mangrove Passage near Onslow, Barrow Island and Dampier (Bridgwood et al. 2014, cited in Wells 2018). Whilst there has been recent interest in this species potentially being translocated within Australian waters by a MODU, a visual inspection found no obvious invasive marine pests (EPA 2019). Although three small white-coloured growth-forms resembling the Didemnidae family were found, according to BFS (2019), these colonies were not displaying any invasive characteristics and the presence of significant colonies in the inaccessible hull locations was considered unlikely.

Despite the widespread findings, within the Pilbara region *D. perlucidum* has only been recorded on artificial surfaces and in shallow waters <20 m with Muñoz et al. (2013, unpublished data, cited in DoF 2014b) stating that it is commonly found in the upper 1–3 m of the water column. The larvae of *D. perlucidum* have only a very short-range active dispersal capacity, commonly settling only a few metres from the parent colony (DoF 2014b).

An independent risk assessment by BFS (2019) indicated the transfer of Didemnum spp. between a platform and support vessels was unlikely, and that the risk of *D. perlucidum* being translocated from a vessel (to another surface) was small considering vessel history, age of antifouling coating and operating profile. Therefore, it is unlikely *D. perlucidum* will be able to translocate within the Project Area or settle and colonise within the local benthic habitat.

Relatively few introductions of IMS have been detected in tropical waters, and even fewer marine pest species (Coles and Eldredge 2002; Hewitt 2002; Huisman et al. 2008; Freestone et al. 2011). IMS may be unsuccessful in establishing because they have been weakened by a lack of nutrition during their transit through the oligotrophic waters of the open ocean (Wells 2018). Also, they may be unable to establish in higher diversity environments of native tropical communities because of increased resistance to invasions through an increase in biotic interactions (Hewitt 2002).

An EPBC PMST did not identify any threatened or migratory benthic species, or any threatened ecological communities within the Project Area. The Project Area is not located within a key ecological habitat; however, the 'ancient coastline at 125 m depth contour' KEF is located to the northwest and is directly adjacent to the Project Area (the KEF occurs at just over 5 km from the expected position of the MOPU). The closest land masses to the Corowa Development (proposed well site) are the Serrurier and Muiron Islands at ~17 km and 28 km distance respectively. Therefore, it is considered unlikely that an IMS would be able to spread to nearshore environments and any sensitive marine features present in the region.

Given the details above, the consequence of a successful IMS colonisation causing a change in ecosystem dynamics to benthic habitats and communities has been assessed as **Serious (3)**, with the impact assessed as **Very Unlikely (B)** to occur due to the unfavourable conditions at the Project Area required for colonisation (noting that it is believed to have occurred before from domestic traffic).

Coastal Habitats and Communities ✓
Change in ecosystem dynamics The introduction of an IMS through either ballast water exchange or biofouling has the potential to cause a change to coastal habitats and communities. IMS impacts have previously been detailed above. Macroalgae communities and seagrasses generally grow in intertidal and shallow subtidal waters where there is sufficient light. Seagrasses can be found in sediments in sheltered coastal areas such as bays, lees of island and fringing coastal reefs (DEWHA 2008; Kilminster et al. 2018). Macroalgae communities are generally found on subtidal rocky substrates and can occur throughout Australian nearshore waters. Current threats to both include destruction of and alterations to, coastal habitats, sea level rise, pollution and the invasion by non-native species (Thomson et al. 2012). Seagrass and macroalgae communities will not be present in the Project Area due to the relatively deep depths present and lack of suitable substrate. The closest known macroalgae habitat occurs around Muiron Islands (~23 km away from the MOPU), and seagrass habitat is known to occur within the more sheltered areas within Exmouth Gulf and inner Ningaloo reef. The introduction of an IMS to a coastal habitat or community within the Pilbara region by Corowa Development activities is very unlikely. Only a small proportion of introduced marine species become invasive (Wells 2018) with relatively few introductions of IMS having been detected in tropical waters, and even fewer marine pest species (Coles and Eldredge 2002; Hewitt 2002; Huisman et al. 2008; Freestone et al. 2011). IMS may be unable to establish themselves in higher diversity environments of native tropical communities because of increased resistance to invasions through an increase in biotic interactions (Hewitt 2002). Due to the sparse nature of the benthic habitats and lack of nutrients in the waters of the NWS an IMS is very unlikely to be able to translocate from the Project Area to a coastal habitats or communities naturally. Whilst support vessels have the highest probability of translocating and IMS to the Project Area from a local port, or vice versa, implemented controls will significantly reduce this possibility. Controls include ballast water management to Australian regulations and biofouling management to negate support vessels as a pathway for IMS translocation. While introduction of IMS to ports has potential to lead to establishment of IMS in state waters, impacts to receptors in state waters are considered out of scope of this OPP. In addition, support vessels are unlikely to be alongside the MODU or MOPU for more than 4–8 hours at a time, will not come into contact with submersed pontoons, thereby greatly reducing the possibility of transferring an IMS. Given the details above, the consequence of a successful IMS colonisation causing a change in ecosystem dynamics to benthic habitats and communities has been assessed as **Serious (3)**, with the impact assessed as **Very Unlikely (B)** to occur due to the remote location, the distance to the closest communities plus the relatively deep water and sparse nature of the seabed of the Project Area.

7.2.1.2.2 Social, Economic and Cultural Receptors

Social, economic and cultural receptors have the potential to be impacted as a result of impacts to physical or ecological receptors. Social, economic and cultural receptors with the potential to be impacted by the introduction of an IMS to ecological receptors include:

- fisheries
- industry.

Impacts to the above receptors include:

- changes to the functions, interests or activities of other users.

Table 7-96 provides a detailed evaluation of the impact of an IMS to social, economic and cultural receptors.

Table 7-96 Impact and Risk Assessment for Social, Economic and Cultural Receptors from Introduction of IMS

Fisheries ✓
<u>Changes to the functions, interests or activities of other users</u>
The introduction of an IMS in the Corowa Development is unlikely to impact on fisheries within the region. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). All the pest species listed on the DoA (2019b) website inhabit shallow waters and coastal habitats. Therefore, they are very unlikely to be able to colonise the benthic habitat within the Project Area and spread to adjacent fisheries, due to the deeper depths present. Many IMS species also require a suitable substrate on which to settle such as a hard or rock surface. As this type of substrate is lacking at the Project Area, settlement and colonisation is very unlikely. It is expected that any IMS that has managed to avoid dispersal within the open ocean and settle within the Project Area would remain fragmented, isolated and only be able to survive within the vicinity of the MODU, MOPU and associated infrastructure. Given the details above, the consequence of a successful IMS colonisation to cause changes to the functions, interests or activities of other users of Commonwealth- and State-managed fisheries has been assessed as **Moderate (2)** with the impact assessed as **Very unlikely (B)** due to the unsuitability of the environment for colonisation and the low level of fishing activity in the area.
Industry ✓
<u>Changes to the functions, interests or activities of other users</u>
The most significant industry within the vicinity of the Project Area is petroleum exploration and production. Petroleum facilities within the vicinity of the Corowa Development include the BHP-operated Pyrenees FPSO (~46 km), the Santos-operated Ningaloo Vision FPSO (~49 km), the Woodside-operated Ngujima-Yin FPSO (~51 km), and the Chevron-operated onshore Wheatstone LNG (~55 km away, south of Onslow). Although the introduction of an IMS to an adjacent facility is very unlikely if it were to establish itself it could act as a base for further translocation. Translocation and establishment of an IMS is considered very unlikely due to unsuitable environments that exist between developments. Sparse benthic habitats and open ocean environments, as previously detailed, are not well suited to the spread of an IMS. Also, standard industry practices such as ballast water exchange, biofouling management would make the transport of an IMS very unlikely. Whilst there is the possibility of a permanent mooring to provide a substrate for an IMS to settle and colonise there appears to be no evidence that buoys or moorings have been implicated in a marine pest incursion. It is suggested that standard industry inspection, maintenance protocols and guidelines be considered, particularly in the very unlikely event of a marine pest outbreak or if the structure is to be relocated (DAFF 2003). The CALM buoy moorings and dead man's anchors are intended to be retrieved and re-used, and will not be left in the field. Given the details above, the consequence of a successful IMS colonisation causing a change in the functions, interests or activities of other users involved in petroleum activities has been assessed as **Moderate (2)** with the impact assessed as **Very unlikely (B)** to occur, due to the unfavourable environment and standard industry practices in put in place to prevent colonisation.

7.2.1.3 Consequence and Acceptability Summary

The worst-case consequence of the introduction of an IMS to the Corowa Development area has been evaluated as **Serious (3)**, which was for benthic habitats and communities plus coastal habitats and communities. The impact ranking has been calculated as **Medium** and is considered **acceptable** when assessed against the criteria in Table 7-97.

Table 7-97 Demonstration of Acceptability for Unplanned Introduction of IMS

Acceptability Criteria	Justification
To meet the principles of ESD	• The ability for an IMS to establish itself is unlikely due to the sparse nature of benthic habitats and communities and unfavourable oceanic conditions within the Project Area. • If an IMS is able to establish itself at the Corowa Development area it is very unlikely to be able to spread due to the fragmented and sparse habitat. • The Project Area is situated a significant distance from any KEFs and sensitive habitats. • The Project Area is 27 nm from shore, which BRS (2007) estimated the probability of an IMS incursion as 2% chance at 24 nm, which was also based on shallower water (50 m, compared to 90 m). • An EPBC PMST did not identify any benthic habitats or communities threatened or migratory species, or any threatened ecological communities within the Project Area.
Internal context	• KATO Introduced Marine Pest Management (KAT-000-EN-PP-002) (KATO 2020i) (including Biofouling Management Plan/s)

External context	• Comments received from Marine and Aquatic Biosecurity Animal Biosecurity Branch, Animal Division, Australian Government Department of Agriculture (dated 1 July 2019) that:
	  o Biosecurity considerations should be included in future planning
	  o marine biosecurity risks associated with biofouling and ballast water are relevant to all vessels, including installations
	• Comments from Conveyances and Ports Compliance Division, Department of Agriculture (dated 1 July 2019): Supplied Department of Agriculture's Offshore Installation – biosecurity guide for initial reference.

Other requirements	• Biosecurity obligations administered by the Department of Agriculture include ballast water and biofouling requirements under the Commonwealth *Biosecurity Act 2015* and under the International Maritime Organisation (IMO). This includes the:
	  o Australian Ballast Water Management Requirements Version 7 (DAWR 2017)
	  o National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry (Marine Pest Sectoral Committee 2018)
	  o IMO Biofouling Guidelines
	• Specifically, this includes ballast water exchange, biofouling and IMS management for all infrastructure and vessels prior to entering the Project Area, including:
	  o under the Commonwealth *Biosecurity Act 2015*, pre-arrival information must be reported through MARS before arriving in Australian waters
	  o biofouling management plan and record book
	  o Offshore Biofouling Risk Assessment Register, which considers biofouling and ballast water related risks including the DoF (2019) Biofouling Risk Assessment Tool, which may lead to IMS inspections by suitably qualified personnel
	  o Australian Ballast Water Management Requirements including ballast water treated via a ballast water treatment system (with Type Approval Certificate) and ballast water record system will be maintained with all ballast water discharges to be reported

Acceptability Criteria	Justification
	- antifouling system certification for vessels is current and in accordance with AMSA Marine Order Part 98 (Antifouling systems) - vessels moving between Australian ports and offshore installations, within Australian waters, will manage ballast water in accordance with Australia's domestic ballast water requirements. The acceptable area for a ballast water exchange between an installation and an Australian port is in sea areas >500 m from the offshore installation, and >12 nm from the nearest land (as per DAWR, Australian Ballast Water Management Requirements Version 7) • Antifouling and In-water Cleaning Guidelines (DoA 2015), including: - evaluation of contamination and biosecurity risk of in-water cleaning - guidance and recommendations 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 - cleaning location, cleaning before demobilisation of facilities - reporting of any suspected IMS discovered during inspection or cleaning - Biofouling Management Plan. • National biofouling management guidelines for the petroleum production and exploration industry (DAFF 2009) including: - evaluation of biofouling risk of types of structures/facilities - guidance on biofouling management and decommissioning • Activities associated with Corowa Development will not be conducted in a manner inconsistent with protecting biological diversity and ecological integrity of benthic communities and habitats, or with protecting the values of the Commonwealth marine area for other users.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-98.

Table 7-98 Summary of Impact Assessment for Unplanned Introduction of IMS

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
Benthic habitats and communities	Change in ecosystem dynamics	**EPO7:** To not result in an introduced marine species becoming established in the marine environment. **EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have a substantial adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution.	**CM24**: Requirements of the Australian Ballast Water Management Requirements Version 7 to be met. **CM25**: Requirements of the National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry to be met. **CM26**: Inspection and in-water cleaning of marine growth will be undertaken as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015) on relocatable subsea infrastructure and MOPU and FSO wetsides before demobilisation from Project Area, including methods to ensure minimal release of biological material into the water. **CM27**: A Biofouling Management Plan will be developed as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015).	Serious	Unlikely	Medium
Coastal habitats and communities				Serious	Very unlikely	Medium
Commercial Fisheries	Changes to the functions, interests or activities of other users	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO15:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Moderate	Very unlikely	Low
Industry				Moderate	Very unlikely	Low

C=consequence L=Likelihood RL=Risk Level

7.2.2 Physical Presence – Interaction with Marine Fauna

The physical presence of the petroleum activities associated with Corowa Development has the potential to result in an unplanned interaction with marine fauna.

7.2.2.1 Aspect Source

Throughout the Corowa Development, an unplanned interaction with marine fauna may occur during these phases and activities:

Site Survey	geophysical survey; geotechnical survey
Support Activities (all phases)	MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations

Site Survey

A geophysical survey may be required prior to any infrastructure being installed at the Corowa Development. During this survey underwater noise emissions will be produced. The impacts of acoustic emissions are discussed in Section 7.1.5.

Support Activities (all phases)

Facilities and vessels will be present within the Project Area for the duration of the development. The type, number of vessels and facilities present within the Project Area plus the duration of activities is dependent on the phase of the development. Vessels will include offshore support vessels, anchor handling and possibly a dedicated pipe laying vessel to install the flowline. It is expected that vessel presence will be highest during commissioning and decommissioning phases (expected to last ~3 months each) and the drilling phase (~5 months for the initial campaign, and an additional 4 months if an infill drilling campaign is required).

A variety of vessels will operate throughout the duration of the Corowa Development, which is expected to be approximately five years (with estimated transit frequency shown in Table 3-13). This number will peak during drilling, commissioning and decommissioning at approximately <10 support vessels. Throughout normal operations (~2–4.5 years), only one to two support vessels are expected. Larger vessels will also be present within the Project Area for offloading; depending on the export strategy selected, export / shuttle tankers will be Panamax, Aframax, or Suezmax-sized vessels. The FSO will remain stationary during operations, moored to the CALM buoy.

Vessels travelling to and from the Project Area are not included in the scope of this OPP, and operate under the Commonwealth *Navigation Act 2012*.

The physical presence of vessels within the marine environment has the potential to interact with marine fauna through such means as a collision. Ship strike can result in impact trauma or propeller wounds, which may cause injury or mortality to marine fauna. Collisions between larger vessels with reduced manoeuvrability and large, slow-moving cetaceans occur more frequently where high vessel traffic and cetacean habitat occurs (Whale and Dolphin Conservation Society 2006). Laist et al. (2001) identifies that larger vessels with reduced manoeuvrability moving in excess of 10 knots may cause fatal or severe injuries to cetaceans, with the most severe injuries caused by vessels travelling faster than 14 knots. There is limited data regarding strikes to marine turtles and Whale Sharks, possibly due to lack of collisions being noticed and lack of reporting; however, marks observed on animals show that strikes have occurred (Peel et al. 2016, Peel et al. 2018).

Noise from helicopters involved in transporting people may induce a startle response in some marine fauna during take-off and landing. Noise levels from helicopters are discussed in Section 7.1.5.

7.2.2.2 Risk Evaluation

An interaction with marine fauna as a result of the physical presence of the Corowa Development has the potential to result in this impact:

- injury/mortality to fauna.

Table 7-99 identifies the potential impacts to receptors as a result of interactions with marine fauna at the Corowa Development. Receptors marked 'X' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor). Table 7-102 provides a summary and justification for those receptors not evaluated further.

Table 7-99 Identification of Receptors Potentially Impacted by Physical Presence – Interaction with Marine Fauna

Impacts	Fish	Marine mammals	Marine reptiles	Commercial Fisheries
Injury/mortality to fauna	✓	✓	✓	
Changes to the functions, interests or activities of other users				X

Table 7-100 Justification for Receptors Not Evaluated Further for Physical Presence – Interaction with Marine Fauna

Commercial Fisheries	*X*
Changes to the functions, interests or activities of other users The physical presence of support vessels in the Project Area have the potential to result in unplanned collision with large fish species. Any impacts on fish species or their food sources is considered to be Minor (as evaluated in Section 7.2.2.2.1). This evaluation has focused on the large species, such as sharks and Whale Sharks, which are not the commercial species targeted in the NWS. The 5 km radius of the Project Area (78 m^2) is an insignificant area compared to the size and scale of commercial fisheries. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2), and none target the key species of concern for vessel collision. Therefore, impacts to commercial fisheries from physical presence – interaction with marine fauna are not expected, and have not been evaluated further.	

Analysis and evaluation of potential impacts to receptors are outlined below, by receptor type.

7.2.2.2.1 Ecological Receptors

Ecological receptors with the potential to be impacted by the physical presence of petroleum activities resulting in an interaction with marine fauna include:

- fish
- marine mammals
- marine reptiles.

The above receptors may be impacted from:

- injury/mortality to fauna.

Table 7-101 provides a detailed evaluation of the impact of interaction with marine fauna to ecological receptors.

Table 7-101 Impact and Risk Assessment for Ecological Receptors from Physical Presence – Interaction with Marine Fauna

Fish ✓
Injury/mortality to fauna The physical presence of support vessels in the Project Area have the potential to result in unplanned collision with large fish species. Vessel movements will be at very slow speeds (<8 knots) during support operations in the Project Area with interactions and vessel collision unlikely. Support vessels or tugs will guide the shuttle/export tankers in. While within the Project Area, support vessels will either moor alongside the MOPU/MODU/FSO, or moor to a dead man's anchor. Studies have found that fauna mortality in the event of a vessel strike is directly linked to vessel speed (Jensen and Silber 2004; Laist et al. 2001) with the most severe injuries caused by vessels travelling faster than 14 knots. The EPBC PMST lists one species of shark as Vulnerable (Grey Nurse Shark) and four as Vulnerable/Migratory (Dwarf Sawfish, Green Sawfish, White Shark and Whale Shark) that are likely to occur within the area. The Corowa Project Area is situated within a foraging BIA for the Whale Shark. Within the NWS, Whale Sharks are primarily found in seasonal aggregations around Ningaloo Reef, between March and June. However, they have also been reported from oceanic and coastal waters across the region (Wilson et al. 2006). Around Ningaloo, Whale Sharks spend daylight hours near the surface and nights at depths of 30–80 m. Studies have shown that >40% of their time is in the upper 15 m of the water column with Gleiss et al. (2013) indicating that Whale Sharks spent 10 to 40% of their time swimming in surface waters. In oceanic waters, they routinely move between the sea surface and depth, and spend over half their time at depths greater than 30 m. Off the outer NWS, they spend much of their time swimming near the seafloor and make dives to over 1000 m depth (DSEWPaC 2012). It is possible that Whale Sharks could be susceptible to collision from vessels due to the amount of time they spend swimming at the surface but is very unlikely within the Project Area. Whilst the Project Area is within a foraging BIA, interactions with Whale Sharks are very unlikely due to its distance from the preferred foraging areas around Ningaloo reef and deeper oceanic waters. The foraging BIA for Whale Sharks is 218,911 km^2, which is insignificant compared to the 78.5 km^2 of the Project Area. Whilst data on the global population of Whale Sharks is not available (DEH 2005a), yearly numbers in Ningaloo Marine Park are estimated to vary between 300 and 500 individuals (Meekan et al. 2006). The likelihood of one of these individuals transiting through the Project Area is highly remote. Whilst the recovery plan for the Whale Shark (DEH 2005a) ceased to be in effect from 1 October 2015, it stated that the main threat to the Whale Shark occurs outside Australian waters, which is commercially harvested by a number of other range states. Whilst disturbance was listed as a future threat this refers to tourism and research vessels. All EPBC PMST listed species are highly mobile, therefore, none are expected to be subject to vessel collision. It is likely that fish would be disturbed by the noise emissions from project activities and avoid the area, thus the likelihood of getting close enough for a collision is very low. Vessel activities will be conducted in accordance with all applicable management actions to ensure impacts are negligible. The Gorgon Gas Development involved the construction of a total of ~200 km of trunkline to Barrow Island, which crossed the 200 m contour of the primary Whale Shark migration route. During the three-year pipeline construction period of constant vessel movements, there were no reported incidents of interaction with marine fauna due to vessel strike (Chevron 2016). Vessel movements in the Corowa Project Area will be slow, and the total number of vessels relatively small (expected maximum of ten during peak times). During the operations phase (2–4.5 years), only one to two support vessels are expected to be required, making a trip to the Project Area only ~2–3 times per month. Given the details above, the consequence of an unplanned interaction with marine fauna causing injury / mortality to individual fish been assessed as **Minor (1)**, with the impact assessed as **Unlikely (C)** to occur, given that the magnitude of potential impacts is considered to result in short-term and localised impacts to fish on an individual level; the Project Area represents a small portion of the total BIA foraging area for Whale Sharks and that vessel movements within the Project Area are expected to be slow and limited.

Marine Mammals ✓
<u>Injury/mortality to fauna</u> As marine mammals are known to inhabit surface waters to breathe, feed, breed etc. they are vulnerable to vessel strike. Marine mammals at risk from vessel strike within the North-west region include cetaceans (both whales and dolphins) and sirenians (Dugongs). As outlined above, vessel speed is an important factor when determining the likelihood of vessel strike occurring, with studies identifying whale strike, resulting in fatality, increasing from 20% at vessel speeds of 8.6 knots to 80% at 15 knots (Vanderlaan and Taggart 2007). In addition, behavioural responses of individuals to vessel presence may also influence the likelihood of fauna strike. Whales are expected to exhibit avoidance behaviour from vessel noise, however, studies suggest limited behavioural response to approaching vessels (McKenna et al. 2015). In addition, mating, nursing or feeding individuals may be more vulnerable to vessel strike as they are less aware of their surroundings (Laist et al. 2001). Large cetaceans (whales) account for a high proportion of deaths from vessel strikes than that of smaller cetaceans such as dolphins (CoA 2017). However, vessel movements in the Corowa Development area will be at slow speeds during most operations (~10 knots transit speeds; ~2 knots during installation phases) with the possibility of collisions with larger marine mammals unlikely. The EPBC PMST shows that three species of marine mammal are listed as Vulnerable (Sei Whale, Fin Whale and Humpback Whale) and two species are listed as Endangered (Blue Whale and Southern Right Whale) that are known to or may occur within the Project Area. The Project Area sits within a BIA migratory area for Humpback Whales. The population estimate of Humpback Whales on the west coast of Australia is ~28,800 (Salgado Kent et al. 2012). Although there is potential for interaction with many Humpback Whales during the migration season, potential collision is unlikely due to controls and migration routes. From May to July Humpback Whales migrate northwards to their tropical calving grounds in the Kimberley and between September and November they return south to their feeding grounds in the Antarctic. DEWHA (2008) suggests that Humpback Whales use the ancient coastline at ~120 m depth as a possible migratory pathway during their northern migration, which would take individuals north of the Project Area, which is situated in water depths of ~90 m. A study by Double et al. (2010) found that most tagged Humpbacks with calves, in the region between Camden Sound and Exmouth Gulf, had median distances from the coastline of WA <25 km and therefore the whales were frequently in very shallow water of <40 m. The Project Area is situated ~50 km from the coastline in 90 m of water and based on this study (Double et al. 2010) it is suggested that many Humpbacks will travel south of the Project Area during their return migration. Conservation Advice for Humpback Whales (TSSC 2015c) lists vessel disturbance and strike as a key threat however as previous studies (Peel et al. 2016; Peel et al. 2018) have suggested that mortality from a vessel strike is most likely from vessels travelling at high speeds (>15 knots). The Project Area also sits within a BIA distribution area for the Pygmy Blue Whale and Blue Whale. The northern migration of the Pygmy Blue Whale passes Exmouth between April and August and continues north to Indonesia. The southern migration occurs between October and late December, where they will appear close to the coast in the Exmouth / Montebello Islands area. The migration patterns of Blue Whales are not well understood as they inhabit deep offshore waters but appear to be highly diverse (DoE 2015b). The Conservation Management Plan for both of these species (DoE 2015b) also lists vessel disturbance and as threat. However, the threat of collision is mostly concerning small pleasure craft, large container ships and navy vessels travelling at high speeds. Vessel movements within the Project Area will be conducted at slow speeds and in accordance with all applicable management actions, therefore collisions are unlikely. The movements and distributions of Sei Whales are unpredictable and not well documented (CoA 2005). The available information suggests that Sei Whales have the same general pattern of migration as most other baleen whales including Blue and Fin Whales, although the timing is generally later, and the current scientific view is that the species does not go to such high latitudes. Sei Whales are not often found near coasts and the species is infrequently recorded in Australian waters (CoA 2005), therefore their presence in the Project Area is extremely unlikely. Fin Whales have been recorded in WA waters, but the available information suggests that the species is more commonly present in deeper waters (CoA 2005), therefore their presence in the Project Area is extremely unlikely. Whilst Southern Right Whales have been recorded as far north as Exmouth previously, there presence this far north is rare and unlikely to be present within the Project Area.

Twelve species of dolphin were also identified in the PMST search, none of which are listed as vulnerable or endangered. No BIAs for small cetaceans were identified as intersecting with the Project Area. Species within the permit area are expected to be migratory or transient in nature, with the majority of dolphin species preferring coastal waters.

Dugongs have been found to spend nearly half of their time within the upper 1.5m of the water column with speed also the main factor influencing collision risk (Hodgson 2014). Dugong presence within the development area is extremely unlikely with their distribution favouring shallow seagrass habitats, which is not present within the Project Area. The closest seagrass habitats to the Project Area are situated in coastal areas of the Exmouth Gulf at >50 km distance.

The Conservation Advice for Humpback Whales (TSSC 2015c) and Conservation Management Plan for the Blue Whale (DoE 2015b) recognise the risk of vessel strike on those species. The draft National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (CoA 2017) states that large, high-speed vessels, in particular, have become a major concern as they are capable of travelling at speeds of up to 35–40 knots, which correlates to an increase in collisions. According to Laist et al. (2001), 89% of incidences where the whale was severely hurt or killed occurred at vessel travelling speeds greater than 14 knots, and were most serious in large vessels (>80 m).

The International Whaling Commission (IWC) has compiled a database of the worldwide occurrence of vessel strikes to cetaceans, within which Australia constitutes ~7% (35 reports) of the reported worldwide vessel strike records involving large whales (IWC 2010). Most records are the last 20 years, which correspond with the beginning of formal reporting of vessel strike incidents in Australia. Peel et al. (2018) found 76 previously unrecorded reports of vessel strikes in Australia, although spatial analysis showed the vast majority of incidents since 1874 are on the east coast of Australia, with the NWS only showing records from 1997.

The Gorgon Gas Development involved the construction of a total of ~200 km of trunkline to Barrow Island, and is the largest resource project in Australia. During the three-year pipeline construction period of constant vessel movements, there were no reported incidents of interaction with marine fauna due to vessel strike (Chevron 2016).Vessel movements in the Corowa Project Area will be slow, and the total number of vessels relatively small (expected maximum of ten during peak times). During the operations phase (~2–4.5 years), only one support vessel is expected to be required, making a trip to the Project Area only ~2–3 times per month.

Given the details above, the consequence of an unplanned interaction with marine fauna causing injury / mortality to individual marine mammals has been assessed as **Minor (1)**, with the impact assessed as **Unlikely (C)** to occur, given that the consequence of a strike on a single animal will not greatly affect the overall population and that vessel movements within the Project Area are expected to be slow and limited.

Marine Reptiles ✓

Injury/mortality to fauna

Vessel disturbance is listed as a threat in the Recovery Plan for Marine Turtles of Australia 2017 (CoA 2017). There is limited data regarding strikes to fauna such as turtles, possibly due to lack of collisions being noticed and lack of reporting (Peel et al. 2016). Turtles are most vulnerable to vessel strike whilst resting or returning to the surface to breath. However, turtles have been shown to spend only 3 to 6% of their time at the surface with dive times of between 15 to 60 minutes (Milton and Lutz 2003). Through physiological and behavioural studies in the laboratory and on nesting beaches turtle vision has been shown to be able to identify closing vessels in clear water. However, Hazel et al. (2007) also states that most turtles cannot be relied upon to avoid vessels travelling faster than 4 km/h. Vessel movements within the Project Area are likely to be conducted in clear waters and at slow speeds, therefore turtles are likely to exhibit avoidance behaviour from slow-moving vessels.

The EPBC PMST shows that three species of turtle listed as either Vulnerable (Green Turtle, Hawksbill Turtle and Flatback Turtle) or Endangered (Loggerhead Turtle and Leatherback Turtle) have habitat or congregation known to occur within area. The Project Area sits within three BIAs for marine turtle species. Incidental presence of marine turtles may occur with the Serrurier Island, a major Green Turtle rookery, situated ~17 km from the project location and Peak Island, a Loggerhead rookery, ~26 km from the project location. It is unlikely that turtles will be feeding within the Project Area due to the sparse nature of the seabed (see Section 5.4.7). The Recovery Plan for Marine Turtles in Australia, (CoA 2017) identifies vessel disturbance as a threat. However, this is primarily an issue in shallow coastal foraging habitats and

internesting areas where there are high numbers of recreational and commercial craft (Hazel and Gyuris 2006; Hazel et al. 2007), areas of marine development (BHP 2011; Chevron 2015) plus highly populated areas. Vessel activities will be conducted in accordance with all applicable management actions to ensure impacts are negligible. The EPBC PMST shows a single species of snake (Short-nosed Sea Snake) listed as critically endangered may also occur within the area. However, seasnake species tend to prefer shallower coral reef and inshore habitats where they able to forage. Therefore, it is considered unlikely that seasnakes will be present within the Project Area. The Gorgon Gas Development involved the construction of a total of ~200 km of trunkline to Barrow Island, and is the largest resource project in Australia. During the three-year pipeline construction period of constant vessel movements, there were no reported incidents of interaction with marine fauna due to vessel strike (Chevron 2016). Vessel movements in the Corowa Project Area will be slow, and the total number of vessels relatively small (expected maximum of ten during peak times). During the operations phase (~2–4.5 years), only one to two support vessels are expected to be required, making a trip to the Project Area only ~2–3 times per month. Given the details above, the consequence of an unplanned interaction with marine fauna causing injury / mortality to individual marine reptiles has been assessed as **Minor (1)**, with the impact assessed as **Unlikely (C)** to occur, given that the consequence of a strike on a single animal will not greatly affect the overall population and that vessel movements within the Project Area are expected to be slow and limited.

7.2.2.3 Consequence and Acceptability

The worst-case consequence of Physical Presence – Interaction with Marine Fauna was evaluated as **Minor (1)**, which was for all the above receptors. The impact ranking has been calculated as **Low** and is considered **acceptable** when assessed against the criteria in Table 7-102.

Table 7-102 Demonstration of Acceptability for Physical Presence – Interaction with Marine Fauna

Acceptability Criteria	Justification
To meet the principles of ESD	• Vessel movements in the Corowa Project Area will be slow, and the total number of vessels relatively small (expected maximum of ten during peak times). During the operations phase (~2–4.5 years), only one to two support vessels are expected to be required, making a trip to the Project Area only ~2–3 times per month. • Vessel movements will not significantly contribute to the total marine activity within the wider area. • Species potentially at risk have a wide distribution and have a relatively low-density presence within the Corowa Project Area resulting in unlikely interactions with activities. • Control measures in place to appropriately manage vessel movements within the Project Area.
Internal context	• There are no specific KATO internal requirements with respect to interactions with marine fauna, or potentially impacted receptors.
External context	• No stakeholder concerns have been raised with respect to interactions with marine fauna or potentially impacted receptors.
Other requirements	• Activities throughout the Corowa Development will adhere to the requirements of the EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans. • Objectives of the draft National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (CoA 2017) is to acquire data, determine risks of vessel strike, and identify mitigation measures. • Conservation Advice for Humpback Whales (TSSC 2015c) includes:

Acceptability Criteria	Justification
	○ inform vessel operators of best practice behaviours and regulations for interacting with Humpback Whales (TSSC 2017) ○ ensure the risk of vessel strike on Humpback Whales is considered when assessing actions that increase vessel traffic in areas where Humpback Whales occur and, if required appropriate mitigation measures are implemented to reduce the risk of vessel strike • The Conservation Management Plan for the Blue Whale (DoE 2015b) includes: ○ 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, appropriate mitigation measures are implemented. ○ 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, appropriate mitigation measures are implemented. • Vessel strikes are required to be reported in the National Vessel Strike Database under: ○ Conservation Management Plan for the Blue Whale 2015–2025 (DoE 2015b) ○ Conservation Management Plan for the Southern Right Whale 2011–2021 (DSEWPaC 2012a) ○ Conservation Advice for the Humpback Whale 2015–2020 (TSSC 2015c) ○ Conservation Advice for *Balaenoptera borealis* (Sei Whale) (TSSC 2015a) ○ Conservation Advice for *Balaenoptera physalus* (Fin Whale) (TSSC 2015b). • In regard to physical presence – interaction with marine fauna interactions, activities undertaken throughout the Corowa Development will not be conducted in a manner inconsistent with a Recovery Plan, threat abatement plan or Conservation Advice for a listed threatened.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-103.

Table 7-103 Summary of Impact Assessment for Physical Presence – Interaction with Marine Fauna

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
Fish	Injury / mortality to fauna	**EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs.	**CM13**: Vessels will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the	Minor	Unlikely	Low

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
Marine Mammals		**EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	Project Area.	Minor	Unlikely	Low
Marine Reptiles				Minor	Unlikely	Low

C=Consequence L=Likelihood RL=Risk Level

7.2.3 Physical Presence – Unplanned Seabed Disturbance

Unplanned seabed disturbance associated with the Corowa Development may be the result of dropped objects from vessels or operational platforms plus anchor dragging that results in localised changes to the existing physical environment.

7.2.3.1 Aspect Source

Throughout the Corowa Development, unplanned seabed disturbance may occur through the result of these activities:

Installation, Hook-up and commissioning	MOPU; CALM buoy and mooring arrangements; flowlines
Decommissioning	Inspection and cleaning; well P&A; removal of subsea infrastructure; disconnection of MOPU/FSO
Support Activities (all phases)	MODO operations; MOPU operations; FSO operations; vessel operations; ROV operations

Installation, Hook-up and Commissioning

Unplanned seabed disturbance from dropped objects are most likely to be from small handheld tools, chains, anchors, pipes and chemical containers. Seabed disturbance resulting from these dropped objects are likely to be localised to the area of the installed MODU, MOPU and flowline with a very small area of impact.

The CALM buoy anchor array will be designed to withstand extreme weather events such as cyclone force conditions. In the unlikely event of one or more of the six moorings failing the CALM buoy may move off station resulting in an unplanned disturbance of the seabed. The extent of the disturbance of the seabed will depend on the total drift or movement of the anchor chain.

Support Activities

Dropped objects may occur during support operation of the facilities and vessels, similar to installation.

Although ROV operations are not intended to impact with the sea floor it may be necessary for the unit to operate close to or on the sea floor in an emergency or unplanned event such as recovering a dropped object. A typical work class ROV has a footprint of ~6 m^2.

Decommissioning

Cleaning of marine growth will be undertaken on the relocatable systems (CALM buoy and mooring arrangements, and wetsides of the MOPU and FSO) before removal of subsea infrastructure. This may involve ROV and diving operations. If marine growth is removed in situ at the Project Area, it may drop down and land on the seabed. However, the Anti-fouling and In-water Cleaning Guidelines (DoA 2015) requires that methods are used to ensure minimal release of biological material into the water.

Dropped objects may occur during decommissioning, similar to installation.

7.2.3.2 Risk Evaluation

Unplanned seabed disturbances generated by the Corowa Development have the potential to result in these impacts:

- change in water quality
- change in benthic habitats and communities.

As a result of a change in water quality plus benthic habitats and communities, further impacts may occur, including:

- injury / mortality to fauna.

Table 7-104 identifies the potential impacts to receptors as a result of unplanned seabed disturbance from the physical presence of the Corowa Development. Receptors marked ‘*X*’ have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-105 provides a summary and justification for those receptors not evaluated further.

Table 7-104 Receptors Potentially Impacted by a Physical Presence – Unplanned Seabed Disturbance

Impacts	Ambient water quality	Plankton	Benthic habitats and communities	Fish	Commercial fisheries
Change in water quality	✓				
Change in habitat			✓		
Injury / mortality to fauna		*X*	✓	*X*	
Changes to the functions, interests or activities of other users					*X*

Table 7-105 Justification for Receptors Not Evaluated Further for Physical Presence – Unplanned Seabed Disturbance

Plankton	***X***
Injury / mortality to fauna 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 (DEWHA 2008). Phytoplankton production at the depths present at the Corowa Development are likely to be low as it is near the photic zone with sparse nutrient levels. A change in water quality as a result of unplanned seabed disturbance is unlikely to lead to injury or mortality of plankton at a measurable level and will not result in a change in the viability of the population or ecosystem. Therefore, no impacts to plankton from unplanned seabed disturbance are expected and have not been evaluated further.	
Fish	***X***
Injury / mortality to fauna Section 7.1.2 (Planned – Seabed Disturbance) demonstrated that the installation of infrastructure including the MODU, MOPU, CALM buoy anchor array and the flowline would have Minor consequences on fish populations within the Project Area. Impacts from a dropped object or dragging anchor are likely to be negligible in comparison to those of the installed infrastructure. Fish species within the Corowa Development area are expected to be mobile, exhibit avoidance behaviour and to be present within the water column rather than sedentary. Therefore, no significant impacts to fish species from unplanned seabed disturbance are expected and have not been evaluated further.	
Commercial Fisheries	***X***
Changes to the functions, interests or activities of other users As impacts to fish are not expected from unplanned seabed disturbance, indirect impacts to commercial fisheries are not expected. Fish species within the Corowa Development area are expected to be mobile, exhibit avoidance behaviour and to be present within the water column rather than sedentary, no significant impacts to fish species from unplanned seabed disturbance are expected. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). The 5 km radius of the Project Area (78.5 km^2) is an insignificant area compared to the size and scale of commercial fisheries. Therefore, impacts to commercial fisheries from unplanned seabed disturbance are not expected, and have not been evaluated further.	

Impacts to receptors are assessed below, by receptor type.

7.2.3.2.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of unplanned seabed disturbance include:

- ambient water quality
- benthic habitats and communities.

Table 7-106 provides a detailed evaluation of the impact of unplanned seabed disturbance to physical receptors.

Table 7-106 Impact and Risk Assessment for Physical Receptors from Unplanned Seabed Disturbance

Ambient Water Quality ✓
Change in water quality Water quality change occurs when seabed sediments enter the water column (turbidity). After a period, the suspended sediments settle and the turbidity in the water column returns to pre-disturbance levels. During the period where sediments are suspended in the water column, the ambient water quality will be impacted. The most likely event of an unplanned seabed disturbance is from a dropped object such as tool or equipment. Dropped objects will be localised and within the region of the MODU/MOPU (or combined MODPU), the CALM buoy anchors and the flowline or vessels operating within the Project Area. Suspended sediments as a result of such an unplanned event are likely to be localised (<10 m^2) and temporary with turbidity levels expected to return to background levels within hours as per studies completed by Chevron Australia (2014). A mooring failure on the CALM buoy would likely cause the greatest impact and volume of temporarily suspended sediment by the movement of chains or a dragging anchor. This is highly unlikely as the CALM buoy array is designed to maintain position even if two of the six moorings fail. In the extremely unlikely event that this were to occur turbidity levels caused by the movement of anchors or chains would return to background levels within hours. ROV operations near or on the seabed may result in the suspension of sediments and an increase in turbidity. However, the effects will be highly localised and temporary and with a footprint of ~5.76 m^2 considered insignificant. Given the details above, the consequence of unplanned seabed disturbance causing a change in water quality has been assessed as **Minor (1)**, with the impact assessed as **Unlikely (C)** to occur, given that any disturbance will be confined to a small area with turbidity levels returning to background values within hours.

7.2.3.2.2 Ecological Receptors

Ecological receptors with the potential to be impacted as a result of an unplanned seabed disturbance:

- benthic habitats and communities.

The above receptors may be impacted from:

- change in habitat
- injury / mortality to fauna.

Table 7-107 provides a detailed evaluation of the impact of unplanned seabed disturbance to ecological receptors.

Table 7-107 Impact and Risk Assessment for Ecological Receptors from Unplanned Seabed Disturbance

Benthic habitats and communities ✓
Change to habitat Unplanned seabed disturbance, such as a dropped object or dragging anchor may result in a change in habitat through localised sedimentation and possible permanent modification of the seabed. If a dropped object cannot be retrieved, then there may also be a permanent alteration and loss of benthic habitat. A pre-spud study (Thales 2001) confirms the seabed in the Corowa Development area is consistent and composed of partially exposed cemented carbonates overlain by a fine to coarse grained sedimentary veneer. Therefore, permanent damage to rocky structures from an unplanned event is highly unlikely. Also due to the nature of sediments within the project area, it is expected that any disturbance of the seabed caused by an unplanned event is expected to be of a small area (<10 m^2), temporary and likely to recover over a short period. If a dropped object cannot be retrieved it is likely that the object will be colonised and

therefore will offset any loss of local benthic habitat. The level of impact from a dragged anchor will be determined by the distance travelled by the anchor and associated chains however it is considered very unlikely to cause a significant loss in habitat. The scale of habitat loss through dropped objects or a dragged anchor is considered very small when compared to the vast area of soft substrate habitats within the NWS. See Section 7.1.2 (Planned Seabed Disturbance) for details on studies on recovery rates of soft sediment disturbance. The Project Area is not situated in an area considered a KEF therefore these features are not discussed further. Injury / mortality to fauna An unplanned event such as a dropped object or anchor dragging has the potential to cause a minor loss of substrate and smothering. The environment at the Project Area has sparse populations of filter and deposit-feeding epibenthic fauna plus a diverse but broadly representative infaunal community, dominated by polychaete worms and crustaceans. Epifauna and infauna within mobile soft sediments are adapted to minor seabed disturbance and can recover relatively quickly from any smothering or seabed disturbance. Section 7.1.2 (Planned Seabed Disturbance) details recovery rates for epifauna and infauna within the Project Area resulting from seabed disturbance. There are no Management Plans, Recovery Plans or Conservation Advice related to epifauna and infauna within the Project Area. No important or substantial area of epifaunal or infauna habitat is expected to be modified, destroyed, fragmented, isolated or disturbed. Given the details above, the consequence of an unplanned seabed disturbance causing a change in habitat in benthic habitat and communities or injury / mortality to fauna has been assessed as **Minor (1)**, with the impact assessed as **Unlikely (C)** to occur due to the small impact to the local habitat plus quick recovery.

7.2.3.3 Consequence and Acceptability Summary

The consequence of Physical Presence – Unplanned Seabed Disturbance has been evaluated as **Minor (1)** for all potentially impacted receptors. The impact ranking has been calculated as **Low** and is considered **acceptable** when assessed against the criteria in Table 7-108.

Table 7-108 Demonstration of Acceptability for Physical Presence – Unplanned Seabed Disturbance

Acceptability Criteria	Justification
To meet the principles of ESD	• The impacts of seabed disturbance from Corowa will be comparable with existing facilities on the North West Shelf, and not result in a notable change to the localised habitat and/or level of water quality. • Infauna and epifauna communities within the project area will be sparse with impacts localised to the installed subsea structures. • Recolonisation will be rapid following disturbance. • A reduction in water quality will be highly localised and very brief. • Impacts on Whale Shark foraging BIA will be negligible.
Internal context	• There are no specific KATO internal requirements with respect to seabed disturbance or potentially impacted receptors.
External context	• No stakeholder concerns have been raised with respect to unplanned seabed disturbances or potentially impacted receptors.
Other requirements	• The Anti-fouling and In-water Cleaning Guidelines (DoA 2015) requires that methods are used to ensure minimal release of biological material into the water during in-water cleaning. • There are no specific management actions relevant to seabed disturbance (habitat damage) identified in the Whale Shark (Rhincodon typus) Recovery Plan 2005–2010. • These Recovery Plans / Conservation Advices identify habitat degradation / modification (seabed disturbance) as a key threat:

Acceptability Criteria	Justification
	○ Approved conservation advice for *Pristis clavata* (Dwarf Sawfish) (TSSC 2009b) ○ Sawfish and river shark multispecies recovery plan (CoA 2015b) ○ Approved conservation advice for Green Sawfish (TSSC 2008a) ○ Approved Conservation Advice for *Pristis pristis* (Largetooth Sawfish) (DoE 2014a) ○ Conservation advice *Rhincodon typus* (Whale Shark) (TSSC 2015d) ○ Whale Shark (*Rhincodon typus*) recovery plan 2005–2010 (DEH 2005a). • The above Recovery Plans / Conservation Advices identify these relevant conservation actions: ○ Implement measures to reduce adverse impacts of habitat degradation and/or modification; or ○ No explicit relevant management actions. • With respect to physical presence – unplanned seabed disturbance, activities associated with the Corowa Development will not be conducted in a manner inconsistent with a Recovery Plan, threat abatement plan or Conservation Advice for listed threatened species, or with protecting biological diversity and ecological integrity of benthic communities and habitats.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-109.

Table 7-109 Summary of Impact Assessment for Physical Presence – Unplanned Seabed Disturbance

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM04**: Mooring analysis will be undertaken that will include an environmental sensitivity and seabed topography analysis. **CM05**: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below the mudline and removed. **CM25**: Inspection and in-water cleaning of marine growth will be undertaken as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015) on relocatable subsea infrastructure and MOPU and FSO wetsides before demobilisation from Project Area, including methods to ensure minimal release of biological material into the water.	Minor	Unlikely	Low
Benthic habitats and communities	Change in habitat Injury / mortality to fauna	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example,		Minor	Unlikely	Low

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
		breeding, feeding, migration behaviour, life expectancy) and spatial distribution.				

C=Consequence L=Likelihood RL=Risk Level

7.2.4 Unplanned Discharge – Solid Waste

Hazardous and/or non-hazardous solid waste stored on board facilities and vessels may be accidentally lost overboard.

7.2.4.1 Aspect Source

Throughout the Corowa Development, solid waste may be accidentally discharged during these phase and activities:

Support activities (all phases)	MODU operations; MOPU operations; FSO operations; vessel operations

Support Activities (all phases)

Solid waste used on board facilities and vessels are handled and stored on board and are transported to shore to be disposed of at licensed facilities. If wastes are inappropriately handled or stored whilst offshore, they may be accidentally discharged to the marine environment. Waste may be accidentally released due to improper or unsuitable waste storage, human error, or failure of waste storage equipment.

Solid waste may be considered hazardous if it has toxic, reactive, corrosive or ignitable properties, such as:

- contaminated material (e.g. rags, oil filters, personal protective equipment)
- paint cans, printer cartridges, batteries, fluorescent tubes, aerosol cans
- process wastes.

Non-hazardous wastes may still pose a threat to receptors if released to the environment, via ingestion, entanglement or smothering; examples include:

- plastics
- glass
- wood, paper, cardboard
- metal (e.g. cans, scrap steel, aluminium).

There is potential for the unplanned discharge of solid waste throughout all phases of the Corowa Development.

7.2.4.2 Risk Evaluation

Unplanned discharges of solid waste during the Corowa Development have the potential to result in these impacts:

- change in water quality
- injury/mortality to fauna.

As a result of a change in water quality, further impact may occur:

- change in aesthetic value.

Table 7-110 identifies the potential impacts to receptors as a result of unplanned discharges of solid waste from the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-111 provides a summary and justification for those receptors not evaluated further.

Table 7-110 Receptors Potentially Impacted by Unplanned Discharge – Solid Waste

Impacts	Ambient water quality	Seabirds and shorebirds	Fish	Marine mammals	Marine reptiles	Tourism and recreation	Commercial fisheries
Change in water quality	✓						
Injury/mortality to fauna		✓	✓	✓	✓		
Change in aesthetic value						*X*	
Changes to the functions, interests or activities of other users							*X*

Table 7-111 Justification for Receptors Not Evaluated Further for Unplanned Discharge – Solid Waste

Tourism and Recreation	***X***
Change in aesthetic value The accidental release of waste during the Corowa Development may result in aesthetically unpleasing conditions as a product of waste within the natural environment. However, due to the distance of the development offshore (~55 km), and the concentration of tourism and recreation activities within shallow coastal waters it is unlikely that any released waste will reach shoreline areas. Therefore, impacts to tourism and recreation have not been evaluated further.	

Commercial Fisheries	***X***
Changes to the functions, interests or activities of other users An unplanned discharge of solid waste may impact marine fauna through ingestion and entanglement of waste, in particular turtles and seabirds, rather than fish. The Grey Nurse Shark is the only threatened fish species that has been identified as being sensitive to interactions with marine debris and listed within the EPBC PMST for the Project Area; this is not a commercial species targeted by fisheries present in the NWS. Therefore, any impacts on fish species or their food sources is considered to be Minor (as evaluated in Section 7.2.4.2.1). Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). The 5 km radius of the Project Area (78.5 km^2) is an insignificant area compared to the size and scale of commercial fisheries. While fish may potentially be impacted by an unplanned discharge of solid waste, this area of influence is highly localised and of an insignificant area, and is not expected to result in a change in the viability of the population of commercially important species. Therefore, impacts to commercial fisheries from unplanned discharge of solid waste are not expected, and have not been evaluated further.	

7.2.4.2.1 Physical Receptors

The physical receptor with the potential to be impacted as a result of an unplanned discharge of solid waste includes:

- ambient water quality.

Table 7-112 provides a detailed evaluation of the impact of unplanned discharges of solid waste from the physical presence of the activities to physical receptors.

Table 7-112 Impact and Risk Assessment for Physical Receptors from Unplanned Discharge – Solid Waste

Ambient Water Quality	✓
Change in water quality Unplanned discharges of hazardous waste may leach into the marine environment causing localised contamination and increased toxicity within the water column. The magnitude of water quality change depends on the nature of the discharge. These discharges usually comprise solid waste items such as oily rags and residue from paint cans lost overboard and therefore are of relatively low levels. Due to wave action and local ocean currents minor releases of residual hazardous waste will be rapidly mixed and diluted. Therefore, no long-term changes in water quality are expected. Given the details above, the consequence of an unplanned discharge of solid waste causing a change in water quality has been assessed as **Minor (1)** with the impact assessed as **Very unlikely (B)** to occur, as the magnitude of the potential impact is considered to result in short-term and localised changes in water quality.	

7.2.4.2.2 Ecological Receptors

Ecological receptors with the potential to be impacted as a result of an unplanned discharge of solid waste include:

- seabirds and shorebirds
- fish
- marine mammals
- marine reptiles.

Table 7-113 provides a detailed evaluation of the impact or risk of an unplanned discharge of solid waste on ecological receptors.

Table 7-113 Impact and Risk Assessment for Ecological Receptors from Unplanned Discharge – Solid Waste

Seabirds and Shorebirds, Fish, Marine Mammals and Marine Reptiles ✓
Injury/mortality to fauna An unplanned discharge of solid waste may impact marine fauna through ingestion and entanglement of waste. Marine fauna that ingest or become entangled in solid waste may be subject to physical harm, which may limit feeding/foraging behaviours, resulting in death. Turtles and seabirds in particular are often subject to such impacts, with entanglement being a relatively common occurrence and plastic waste being mistaken as food (i.e. plastic bags as jellyfish). Under the EPBC Act (2003), injury / fatality of vertebrate marine life as a result of entanglement or ingestion of marine debris was listed as a key threatening process. The Threat Abatement Plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (DoEE 2018a) identifies EPBC Act listed species that have been scientifically documented as being sensitive to interactions with marine debris (DoEE 2018a). EPBC listed species identified in the PMST for the Corowa Permit Area, which may be impacted by a discharge of solid waste, include 25 species of migratory birds (e.g. sandpipers, frigatebirds, Osprey). This included three species listed as critically endangered including two that are migratory (Curlew Sandpiper, Eastern Curlew) and four species listed as endangered, including two that are marine and migratory (Red Knot, Southern Giant Petrel). The Southern Giant Petrel is the only threatened bird species that has been identified as being sensitive to interactions with marine debris and listed within the EPBC PMST for the Project Area. The closest land masses to the Corowa Development area are the Serrurier and Muiron islands at ~17 km and 23 km distance respectively. Wedge-tailed Shearwaters migrate to the area each year, particularly the Muiron and Serrurier islands, from July onwards. During the day the adult birds are out feeding and return to the islands every evening. The Project Area is within a BIA for the Wedge-tailed Shearwater however there is no adopted or made Recovery Plan for this species. Given the distance of the activities from the Serrurier and Muiron islands any presence of seabirds and shorebirds within the Project Area is expected to be of a transitory and incidental nature only. As activities will be conducted in accordance with all applicable management actions, including the Threat Abatement Plan (DoEE 2018a), impacts from solid waste on birds are very unlikely. The EPBC PMST lists one species of shark as Vulnerable (Grey Nurse Shark) and four as Vulnerable/Migratory (includes the Whale Shark) that are likely to occur within the area. The Grey Nurse Shark (west population) is the only threatened shark species that has been identified as being sensitive to interactions with marine debris and listed within the EPBC PMST for the Project Area. The Corowa Project Area is situated within a BIA migratory area for the Whale Shark. Whilst the recovery plan for the Whale Shark (DEH 2005a) ceased to be in effect from 1 October 2015 it stated that the main threat to the Whale Shark occurs outside Australian waters. Whilst pollution and marine debris was listed as a future threat, at present, these do not have an impact on the numbers of Whale Sharks visiting Australian waters (DEH 2005a). As activities will be conducted in accordance with all applicable management actions, including the Threat Abatement Plan (DoEE 2018a), impacts from solid waste on shark species are very unlikely. The EPBC PMST shows that three species of marine mammal listed as Vulnerable (Sei Whale, Fin Whale, Humpback Whale) and two species listed as Endangered (Blue Whale, Southern Right Whale) are known or may occur within the Project Area. All five whale species listed within the EPBC PMST for the Project Area have also been identified as being sensitive to interactions with marine debris under the Threat Abatement Plan (DoEE 2018a). The Project Area sits within a BIA migratory area for Humpback Whales. The recovery plan for the Humpback Whale (DEH 2005b) (ceased to be in effect from 1 October 2015) listed pollution as a threat although this is primarily in relation to run-off from land-based agriculture and outputs from aquaculture. As activities will be conducted in accordance with all applicable management actions, including the Threat Abatement Plan (DoEE 2018a), impacts from solid waste on marine mammals are very unlikely. A single species of snake (Short-nosed Sea Snake) listed as critically endangered may occur within the area but its presence is unlikely as they tend to inhabit reef areas and shallow waters. The EPBC PMST shows that three species of turtle listed as either Vulnerable (Green Turtle, Hawksbill Turtle and Flatback Turtle) or two as Endangered (Loggerhead Turtle and Leatherback Turtle) have habitat, congregation or congregation known to occur within area. All five turtle species listed within the EPBC PMST for the Project Area have also been identified as being sensitive to interactions with marine debris under the Threat Abatement Plan

(DoEE 2018a). The Project Area sits within three BIA for marine turtle species. The Recovery Plan for Marine Turtles in Australia, (CoA 2017) identifies marine debris as a threat. Debris most likely to effect marine turtles through entanglement and/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). As activities will be conducted in accordance with all applicable management actions, including the Threat Abatement Plan (DoEE 2018a), impacts from solid waste on marine reptiles are very unlikely. Given the details above, the consequence of an unplanned discharge of solid waste causing injury / mortality to seabirds, shorebirds, fish, marine mammals and marine reptiles has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur, given the low occurrence of unplanned discharges of solid waste with impacts considered on an individual basis, with no population or ecosystem level impacts expected.

7.2.4.3 Consequence and Acceptability

The consequence of Unplanned Discharge – Solid Waste has been evaluated as **Minor (1)** for all potentially impacted receptors. The impact ranking has been calculated as **Low** and is considered **acceptable** when assessed against the criteria in Table 7-114.

Table 7-114 Demonstration of Acceptability for Unplanned Discharge – Solid Waste

Acceptability Criteria	Justification
To meet the principles of ESD	• Unplanned discharges are unlikely and will be a low volume. • Control measures will be in place to lower the incidence of unplanned discharges.
Internal context	• There are no specific KATO internal requirements with respect to unplanned discharges of solid waste discharges or potentially impacted receptors.
External context	• No stakeholder concerns have been raised with respect solid waste discharges or potentially impacted receptors.
Other requirements	• With respect to appropriate vessel class, vessel operations throughout the Corowa development will adhere to various Marine Orders including Marine Order 95 – Garbage, to prevent garbage entering the marine environment. • American Petroleum Institute (API) Recommended Practice 14G: Recommended Practice for Fire Prevention and Control on Open Type Offshore Production Platforms describes safe handling and storage of materials such as dirty rags, garbage, waste oil, and chemicals. • Requirements of the Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (DoEE 2018a), though there are no explicit management actions for non-fisheries related industries. These Recovery Plans / Conservation Advices identify marine debris as a key threat: • Recovery plan for marine turtles in Australia (DoEE 2017a) • Approved conservation advice for *Dermochelys coriacea* (Leatherback Turtle) (TSSC 2009a) • Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (DoE 2014b) • National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011) The above Recovery Plans / Conservation Advices identify these relevant conservation actions:

Acceptability Criteria	Justification
	• reduce impacts from marine debris; or • no explicit relevant management actions; marine debris recognised as a threat. • In regard to unplanned discharges of solid waste, activities undertaken throughout the Corowa development will not be conducted in a manner inconsistent with a Recovery Plan, threat abatement plan or Conservation Advice for a listed threatened species.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-115.

Table 7-115 Summary of Impact Assessment for Unplanned Discharge – Solid Waste

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM23**: Compliance with AMSA Marine Order 95 (Marine Pollution Prevention – Garbage). **CM28**: Compliance with API Recommended Practice 14G: Recommended Practice for Fire Prevention and Control on Fixed Open Type Offshore Production Platforms.	Minor	Very Unlikely	Low
Seabirds and shorebirds	Injury / mortality to fauna	**EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life		Minor	Very Unlikely	Low
Fish				Minor	Very Unlikely	Low
Marine mammals				Minor	Very Unlikely	Low
Marine reptiles				Minor	Very Unlikely	Low

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
		expectancy) and spatial distribution.				

C=Consequence L=Likelihood RL=Risk Level

7.2.5 Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons)

During activities associated with the Corowa Development, minor volumes chemicals or hydrocarbons may be released or accidentally spilled to the marine environment resulting in a change in water quality.

7.2.5.1 Aspect Source

Throughout the Corowa Development, phases and activities during which an unplanned discharge of chemicals or hydrocarbons could may interact with other receptors include:

Support Activities (all phases)	MODU operations; MOPU operations; FSO operations; vessel operations; ROV operations; helicopter operations

Support Activities (all phases)

Minor unplanned discharges during MODU, MOPU, FSO and vessel support activities may occur as a result of:

- vessel equipment, bulk storage or package chemical leak (deck spill)
- bunkering activities
- ROV hydraulic hose leak.

Vessel Equipment, Bulk Storage or Package Chemical Leak (Deck Spill)

Hydrocarbons and chemicals will be stored onboard facilities and vessels for future use within storage tanks, bunded areas and chemical cabinets. A minor loss of containment (MLOC) is when a fluid or other material that is usually contained, escapes from that place. Causes of MLOC can include mechanical integrity failures, poor process design, inadequate hazard analysis, unexpected or uncontrolled reactions, mishandling or human error (Vaughen 2010). In most cases, a MLOC will be captured by a drainage system and diverted to a bilge tank or similar where it can be treated or transported back to shore for safe disposal. In the unlikely event a MLOC is not captured within a closed system, it will likely be discharged to the marine environment, leading to a release of hydrocarbons or chemicals to the ocean surface. Possible MLOC scenarios are outlined in Table 7-116.

Types of fluids that may be present on the facilities and vessels associated with the Corowa Development include:

- non-process chemicals
- non-process hydrocarbons
- process chemicals.

Details of the hydrocarbons and chemicals that may be present during the Corowa Development are outlined in Table 7-116.

Table 7-116 Potential MLOC Hydrocarbons and Chemicals at the Corowa Development

Chemical Type	Chemical Material	Chemical Use	Credible MLOC Volume	Potential Cause of MLOC
Non-process chemicals	Wash chemicals Cleaning chemicals Solvents	General maintenance	~1 m^3, based on typical intermediate bulk container (IBC) size.	Bulk transfer: • partial or total failure of bulk transfer hose or fittings • failure of dry-break couplings • human error Storage within chemical cabinets and bunded storage areas: • damage to chemical containers.
Non-process hydrocarbons	Hydraulic fluids	Hydraulically powered machinery (e.g. ROV's, cranes, winches)	~0.02 m^3 based on typical capacity of hydraulic hoses	Machinery: • failure of hydraulic hoses (i.e. burst hose) • minor leaks from process component • operator error (i.e. pinched ROV hydraulic hose) Bulk transfer and bunkering: • partial or total failure of bulk transfer hose or fittings • failure of dry-break couplings • accidental spills during refuelling of hydraulic hoses
	MDO	General vessel or facility operations (e.g. transit, power generation)	~50 m^3 of MDO during bunkering – i.e. transfer rate x 15 minutes	
Process chemicals	Drilling fluids (WBM/ SBM) MEG Cement	Drilling Operations Cementing	~25 m^3 of chemicals during bulk transfer, based on largest isotainer size	Storage in ISO tanks: • tank rupture • corrosion Bulk transfer and bunkering: • partial or total failure of bulk transfer hose or fittings • failure of dry-break couplings

As detailed in Table 7-116, bunkering and bulk transfer of hydrocarbons and chemicals have the potential to result in the highest credible spill volume. As MDO is generally more toxic and damaging to the marine environment than that of process chemicals, a discharge of MDO at the surface during bunkering is considered the worst-case credible spill scenario.

Planned discharges of cement are assessed in Section 7.1.7, at greater volumes.

Bunkering

Bunkering of hydrocarbons to the MODU, MOPU and FSO by support/supply vessels will be required at all stages of the Corowa Development. During bunkering, an accidental release of MDO to the marine environment may occur through partial or total failure of the bulk transfer hose or associated dry-break couplings. As the development is still in the design stage vessels and equipment details are unknown, therefore the worst-case scenario of a 50 m^3 release of MDO is used. The predicted maximum volumes of MDO lost from a dry-break coupling failure (50 m^3) are expected to be less than that released during vessel collision (~500 m^3), therefore modelling of a 50 m^3 release of MDO were not undertaken to support the impact assessment.

ROV Hydraulic Hose Leak

Hydraulic fluids are required to operate tools and manipulators on subsea ROV units. Hydraulic fluids are likely to be relatively non-toxic and water-based. Fluid volumes on the ROV units are limited (typically <20 L [0.02 m^2]) with shutdown systems designed to limit the loss of fluid in the event of a leak in the hydraulic system.

7.2.5.2 Risk Evaluation

The presence of hydrocarbons and chemicals in the marine environment following an unplanned minor loss of containment has the potential to result in these impacts:

- change in water quality
- change in sediment quality.

As a result of a change in water and sediment quality, further impacts may occur, including:

- injury/mortality to fauna

Table 7-117 identifies the potential impacts to receptors as a result of an unplanned minor loss of containment from the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-118 provides a summary and justification for those receptors not evaluated further.

Table 7-117 Receptors Potentially Impacted by Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons)

Impacts	Ambient water quality	Ambient sediment quality	Plankton	Benthic habitats and communities	Fish	Marine mammals	Marine reptiles	Commercial Fisheries
Change in water quality	✓							
Change in sediment quality		*X*						
Injury/mortality to fauna			*X*	*X*	*X*	*X*	*X*	
Changes to the functions, interests or activities of other users								*X*

Table 7-118 Justification for Receptors Not Evaluated Further for Unplanned Discharge – Minor Loss of Containment

Ambient Sediment Quality	***X***
<u>Change in sediment quality</u> Hydrocarbons or chemicals from a MLOC are unlikely to result in a change in sediment quality. A MLOC resulting from facilities or vessels within the Project Area will likely remain on the surface in the vicinity of the discharge point. Hydrocarbons, chemicals and associated toxins are unlikely to reach the seabed at depths present in the Project Area (~90 m) as they will be rapidly mixed and diluted by wave action and surface currents. Therefore, analysis of a change in sediment quality has not been evaluated further.	

Benthic Habitats and Communities	**X**
Injury/mortality to fauna As stated above, hydrocarbons or chemicals from a MLOC will likely remain on the surface in the vicinity of the discharge point and are unlikely to reach the seabed due to rapid mixing and dilution by wave action and surface currents. Therefore, impacts to benthic habitats and communities will be negligible and have not been evaluated further.	
Plankton, Fish, Marine Mammals and Marine Reptiles	***X***
Injury/mortality to fauna A reduction in water quality by the introduction of toxins as a result of a MLOC are unlikely to have an impact on plankton populations. With rapid dilution rates, minor discharges of hydrocarbons or chemical impacts on plankton populations will be localised and short term. Low-nutrient levels within the Project Area results in sparse populations of plankton species throughout the NWS (DEWHA 2008). 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 (DEWHA 2008). Therefore, plankton populations are expected to recover quickly from any impacts of a MLOC. As no impacts to plankton populations are expected by a MLOC they are not discussed further. Fish species are unlikely to be affected by a MLOC as they are highly mobile and will be able to avoid any plumes associated with the discharge. Whilst the Project Area is within a BIA migratory area for the Whale Shark impacts from a MLOC are extremely unlikely as discharges will be rapidly mixed and diluted. Although the recovery plan for the Whale Shark (DEH 2005a) ceased to be in effect from 1 October 2015 it stated that the main threat to the Whale Shark occurs outside Australian waters. Whilst pollution was listed as a future threat, at present pollution does not have an impact on the numbers of Whale Sharks visiting Australian waters (DEH 2005a). As no impacts to fish populations are expected by a MLOC they are not discussed further. Marine mammals and marine turtles are very unlikely to be affected by a MLOC from the Corowa Development. Due to the small volumes involved in a MLOC, hydrocarbons or chemicals will quickly evaporate or be diluted due to wave action and local ocean currents. Marine mammals and turtles are also able to exhibit avoidance behaviour and will be able to move away from any temporary release of hydrocarbon or chemical. The Project Area is situated in a BIA migratory area for the Humpback Whale and a BIA migratory area for thee species of marine turtle. The recovery plans for all four species lists pollution as a threat, however this mostly in relation to pollution from agricultural, terrestrial industrial and domestic sources. As all activities will be conducted in accordance with all applicable management actions and no impacts to plankton, fish, marine mammal or marine reptile populations are expected by a MLOC, they have not been evaluated further.	
Commercial Fisheries	***X***
Changes to the functions, interests or activities of other users As impacts to fish are not expected from a MLOC, indirect impacts to commercial fisheries are not expected. Due to the small volumes involved in a MLOC, hydrocarbons or chemicals will quickly evaporate or be diluted due to wave action and local ocean currents. Marine fauna found in the water column, such as fish, marine mammals and marine reptiles, are expected to actively avoid plumes and associated toxicity within the water column. Eight State- and Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the Pilbara Line Fishery is active in the area (Section 5.5.2). The 5 km radius of the Project Area is an insignificant area compared to the size and scale of commercial fisheries Therefore, impacts to commercial fisheries from a MLOC are not expected, and have not been evaluated further.	

Impacts to receptors are assessed below, by receptor type.

7.2.5.2.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of a minor loss of containment include:

- ambient water quality.

Table 7-119 provides a detailed evaluation of the impact of an unplanned minor loss of containment to physical receptors.

Table 7-119 Impact and Risk Assessment for Physical Receptor(s) from Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons)

Ambient Water Quality ✓
<u>Change in water quality</u> A minor loss of containment of hydrocarbons or chemicals has the potential to result in a change in water quality in both surface waters and the pelagic environment, through the introduction of toxic substances. Impacts to ambient water quality are likely to be localised and temporary based upon the volumes associated with minor releases (typically <0.2 m^3 but up to 50 m^3). Any impacts to surface and pelagic waters are expected to be less than those associated with a larger diesel spill resulting from a vessel collision. Due to the relatively small volumes involved in a MLOC any hydrocarbons or chemicals would either quickly evaporate or be mixed and diluted due to wave action and local ocean currents. Woodside (RPS APASA, cited in Woodside 2016) modelled a surface spill volume of 8 m^3 in the offshore waters of northwest Western Australia. The modelling set an exposure threshold of 10g/m^2, which has previously been used as an approximate lower limit for harmful exposures to birds and marine mammals (NOPSEMA 2019). Results indicated that exposure to surface hydrocarbons above the 10 g/m^2 threshold were limited to the immediate vicinity of the release site, with little potential to extend beyond 1 km. Therefore, it was considered that there was no potential for contact with sensitive receptors above surface threshold concentrations from an 8 m^3 spill of marine diesel within the Operational Area. There are no Management Plans, Recovery Plans or Conservation Advice related to water quality within the Project Area. Given the details above, the consequence of a minor loss of containment (Chemicals and Hydrocarbons) causing a change in water quality has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur given effects will be localised and extremely brief.

7.2.5.3 Consequence and Acceptability

The consequence of Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons) has been evaluated as **Minor (1)** for all potentially impacted receptors. The impact ranking has been calculated as **Low** and is considered **acceptable** when assessed against the criteria in Table 7-120.

Table 7-120 Demonstration of Acceptability for an Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons)

Acceptability Criteria	Justification
To meet the principles of ESD	• There will be no lasting effects on any receptors; any effects will be localised and temporary. • MLOC are likely to be small volumes (<0.2 m^3), which will rapidly evaporate or be mixed and diluted. • The use of hydrocarbons and chemicals offshore is well practised. Understanding of potential spill sources and the control measures required to manage these is well understood. • Offshore transfer operations are a well-practised and regulated offshore activity. Understanding of potential spill sources and the control measures required to manage these is well understood.

Acceptability Criteria	Justification
Internal context	• KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)
External context	• No stakeholder concerns have been raised with respect to interaction with other users or potentially impacted receptors.
Other requirements	• API Recommended Practice 14G: Recommended Practice for Fire Prevention and Control on Fixed Open Type Offshore Production Platforms describes safe handling and storage of matter. • Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class), describes emergency response activities. • With respect to Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons), activities associated with the Corowa Development will not be conducted in a manner inconsistent maintaining the environmental values of marine environmental quality.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-121.

Table 7-121 Summary of Impact Assessment for Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons)

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO13**: To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM28**: Compliance with API Recommended Practice 14G: Recommended Practice for Fire Prevention and Control on Fixed Open Type Offshore Production Platforms. **CM29:** Emergency response activities will be implemented in accordance with a vessel's valid and appropriate Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class). **CM30**: Spill response equipment will be present and maintained. **CM31**: Bunkering procedures will be implemented to prevent minor loss of containment.	Moderate	Very unlikely	Low

C=Consequence L=Likelihood RL=Risk Level

7.2.6 Accidental Release – Corowa Light Crude Oil

During activities associated with the Corowa Development, an accidental release of Corowa crude (a light crude oil) may occur.

7.2.6.1 Aspect Source

Throughout the Corowa Development, phases and activities that may interact with other receptors include:

Drilling	Top-hole drilling; bottom-hole drilling; completions; well clean-up and flowback
Operations	hydrocarbon extraction; hydrocarbon processing, storage and offloading; inspections; maintenance and repair; well intervention
Decommissioning	well P&A; removal of subsea infrastructure
Support Activities (all phases)	MODU operations; MOPU operations; FSO operations

Drilling

During drilling pressure is maintained in the wellbore to prevent the flow of formation/reservoir fluids into the wellbore. This requires estimating formation fluid pressures, the strength of the subsurface formations, and using casing and mud density to offset those pressures in a predictable fashion (Schlumberger 2019). If uncontrolled, an unplanned entry of water, gas or oil into the wellbore may expand and rise rapidly due to being lighter than the surrounding fluids and the resulting decreasing wellbore pressure. To retain control of the formation fluids, a blowout preventor (BOP) may be closed. By closing the BOP and then increasing the mud density it is then possible to reopen the BOP and retain pressure control of the formation. Although very unlikely, a failure in this system may result in a loss of well control (LOWC) and an accidental release of Corowa light crude oil.

Operations

During the operational phase, hydrocarbons extracted from the reservoir will flow from the wellbore to the MOPU for processing. Stabilised crude is then be exported via the subsea flowline between the MOPU and the CALM buoy to the FSO (or shuttle tanker). The risers, flowline, floating marine hose and floating export hose (used to offload to export tankers) will contain hydrocarbons during production operations. A loss of containment from these flowline and hoses may lead to the release of hydrocarbons to the marine environment; ranging from a pinhole leak due to corrosion of the flowline to full-bore rupture of the flowline, which could be caused by a significant event such as an extreme weather event or dragging anchor.

During operations, there is also the possibility of undertaking well intervention on the well(s). This may be required for maintenance, repair or replacement of downhole parts. Such interventions fall into two categories:

- light intervention; tools or sensors lowered into a live well while pressure is contained at the surface
- heavy intervention; production may stop at the formation before making major equipment changes

If an infill drilling campaign is required, there is potential that drilling activities could be conducted over and in close proximity to live wells; i.e. simultaneous operations (SIMOPS). Therefore, control measures are identified to shut-in live wells during certain SIMOPS activities, to avoid an increased risk of a LOWC from the live wells.

During any of the above activities there is the remote possibility of an accidental release of Corowa light crude oil.

Decommissioning

At the end of a well's lifetime, it must be permanently plugged and abandoned (P&A). P&A operations usually consist of placing several cement plugs or barriers in the wellbore to isolate the reservoir and other fluid-bearing formations (Vrålstad 2019). An essential aspect of P&A is to ensure well integrity after abandonment (King and Valencia 2014). An incorrect design or application of P&A procedures could result in an accidental release of Corowa light crude oil.

Support Activities (all phases)

A variety of vessels will be used during all phases of the Corowa Development, including the FSO and export tankers. However, the type and number of vessels present within the Project Area and the duration of activities depends on the development phase. In the unlikely event of a vessel collision or a collision between a vessel and facility, the rupture of a storage tank on the MOPU, FSO or export tanker could be the source of an accidental hydrocarbon release.

Guidance identification of worst-case credible spills scenarios is given in AMSA's Technical guidelines for preparing contingency plans for Marine and Coastal Facilities (AMSA 2015).

KATO has identified the potential spill scenarios from each facility/vessel for Corowa light crude oil. There are three potential sources of an accidental release of Corowa crude:

- flowline / export hose (i.e. from subsea flowline or floating hoses)
- bulk storage tank (i.e. from bulk crude storage tank on topsides on the MOPU; or FSO)
- well (i.e. via LOWC).

The maximum credible scenario for each source is shown in Table 7-122.

Table 7-122 Potential Maximum Credible Spill Scenarios for Accidental Release – Corowa Light Crude Oil

Cause	Description	AMSA Basis of Credible Volume	Maximum Credible Volume and Duration
Flowline / Export hose failure	FSO specification will be to transfer 63,500 m^3 in 24 hours = 2,650 m^3/hour. Inventory of export hose assuming 12" x 300 m = 24 m^3. Assuming worst case, it will take 1 hour to detect/stop. Volume discharged will be ≈ 2,700 m^3.	Offshore Pipeline / Rupture. Based on ability to detect major faults but absence of block valves. Max daily flow rate x 1-hour x volume	2,700 m^3 released over 1 hour
Failure of Bulk Tank on FSO	The FSO is a modified oil tanker, therefore the oil tanker scenarios in AMSA (2015) apply. A grounding is not credible, due to water depth (~90 m). For collisions, there are major and non-major scenarios. Based on Table 11 of AMSA (2015), it is considered this poses a 'Non-major incident – slight grounding or collision', meaning the volume of one wing tank is the basis. Assumes penetration of external and internal hull at the water line and based	Considered a 'Non-major collision', as the FSO is: • moored and stationary • is within PSZ (non-Development vessels prohibited/restricted) • is tethered to export tanker, under control of tug. Therefore, 50% of the largest wing tank is used.	6,425 m^3 released over 1 hour

Cause	Description	AMSA Basis of Credible Volume	Maximum Credible Volume and Duration
	on the loss of contents of largest potentially impacted cargo tank. Based on the loss of contents of largest outside tank (including fuel tanks). The largest tanker to be used for the conversion will be an Aframax Tanker, between 80,000–120,000 DWT.	The guidance for a 100,000DWT vessel gives 5,500 m^3. Pro-rata up to 120,000 DWT gives ~6,500 m^3.	
LOWC	Predicted flow rates from the reservoir are based upon appraisal well data and reservoir modelling. To generate a well production profile in the event of a LOWC, the Petroleum Experts IPM suite was used (PROSPER for the well profiles, MBAL for the reservoirs, and GAP to combine all the information). KATO estimate that it would take 80 days to drill a relief well. The water depth and location of Corowa are very similar to the characteristics of the Montara LOWC location, for which a rig was mobilised, and a relief well drilled in 77 days. The location of Corowa is south-west of Montara, so an extra 3 days were allowed for to account for the longer steam to site. Figure 7-16 shows an indicative schedule.	Predicted flow rates per day x days estimated to get a relief rig on site + 20 days to cap well.	Total volume of 410,280 m^3 released over 80 days. A variable rate of 10,107–3,655 m^3/day was used to simulate depressurisation of the reservoir.

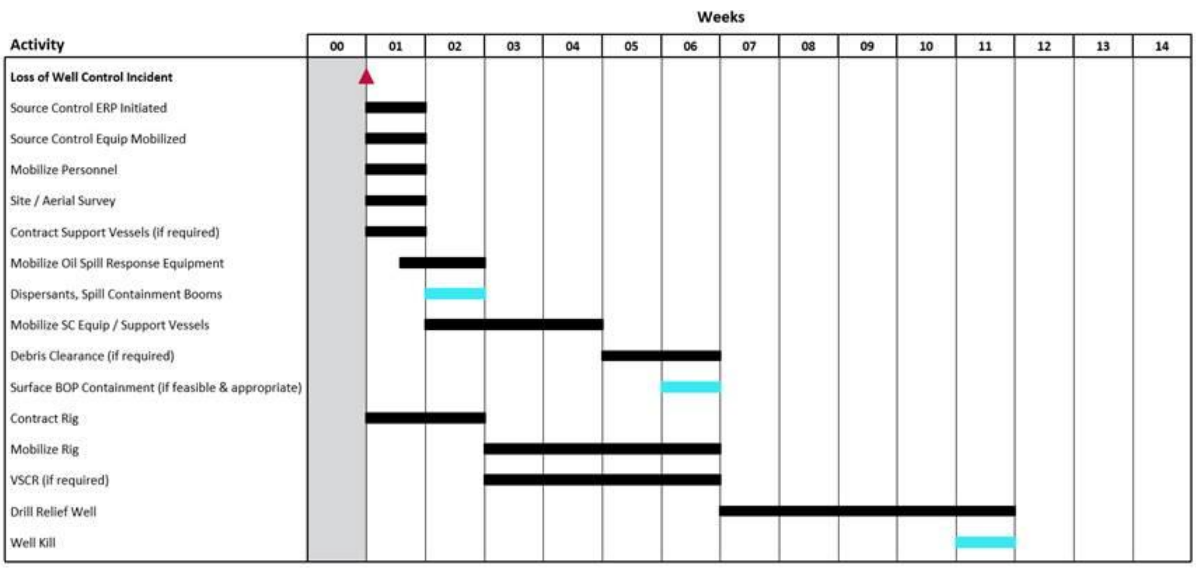


Figure 7-16 Indicative Schedule to Drill a Relief Well in the Event of a LOWC

The LOWC scenario poses the worst-case impact for Accidental Release – Corowa Light Crude Oil out of all the scenarios identified in Table 7-122. Therefore, the LWOC scenario is used for the purposes of impact assessment, and is carried through into spill modelling.

7.2.6.2 Spill Modelling and Exposure Assessment

Spill modelling has been used to predict the possible trajectories and fate of an accidental release of Corowa light crude oil from a LOWC (RPS 2019; Appendix E). These two models were used during the assessment:

- OILMAP – Near-field subsurface discharge modelling was undertaken using OILMAP, which predicts the droplet sizes that are generated by the turbulence of the discharge as well as the centreline velocity, buoyancy, width and trapping depth (if any) of the rising gas and oil plumes.
- SIMAP – Oil spill modelling was undertaken using a three-dimensional oil spill trajectory and weathering model, SIMAP (Spill Impact Mapping and Analysis Program), which is designed to simulate the transport, spreading and weathering of specific oil types under the influence of changing meteorological and oceanographic forces.

The spill scenario, oil characteristics and behaviours, environmental thresholds for impact assessment and predicted exposures are summarised below.

7.2.6.2.1 Scenario

The scenario selected for modelling is a subsea release of Corowa light crude oil following a LOWC (Table 7-123). This is considered the worst-case scenario for potential Corowa crude oil releases and therefore is representative of the greatest spatial extent of potential impacts.

Table 7-123 Loss of Well Control Event used for Spill Modelling

Scenario Description	Subsea release after loss of well control event
Spill Location	Expected position of MOPU, ~90 m water
Oil Released	Corowa light crude oil
Spill Duration	80 days
Total Volume Released	410,280 m^3
Flow Rate ^	10,107–3,655 m^3/day
Number of Model Simulations	50 during summer conditions (September to March) 50 during winter conditions (May to July) 50 during transitional conditions (April and August)

^ A variable (decreasing) flow rate was used in the modelling to simulate the depressurisation of the reservoir during an uncontrolled discharge.

7.2.6.2.2 Oil Characteristics

The Corowa crude is a non-persistent oil, with a low dynamic viscosity and low pour point (Table 7-124). The oil has relatively low (5.9%) residual component (i.e. the component that tends not to evaporate and that may persist in the marine environment) and a low (1.8%) aromatics component (i.e. the component that may dissolve into water).

Table 7-124 Characteristics of Corowa Crude Oil

Classification	Group I, Non-persistent oil				
API Gravity	50.3 °API				
Density	0.78 g/cm^3 at 15 °C				
Viscosity ^	2.05 cP at 20 °C				
Pour Point ^	-13 °C				
Component	**Volatile**	**Semi-volatile**	**Low volatility**	**Residual**	**Aromatics**
Boiling Point	**<180 °C**	**180–265 °C**	**265–380 °C**	**>380 °C**	**>380 °C**
Percentage of Total Oil	56.2	23.5	14.4	5.9	1.8
Percentage of Aromatic component only	0.5	1.2	0.1	0	N/A

^ The values used in spill modelling for viscosity was 0.54 cP at 20 °C, and for pour point was -42 °C. The difference in pour point is not expected to have any adverse impact on the model outcomes given that that both values (i.e. actual of -13 °C and modelled of -42 °C) are well below ambient seawater temperatures. The difference in viscosity values (i.e. actual of 2.05 cP and modelled at 0.54 cP) may have a small impact on model outcomes, however given that the smaller viscosity was modelled this would be a greater initial rate of spreading and therefore would be a more conservative outcome.

7.2.6.2.3 Oil Fate and Weathering

The fate of an oil in the marine environment depends on a number of factors including the physical and chemical properties of the hydrocarbon, the volume released, the prevailing environmental conditions and whether the oil remains at sea or accumulates on a shoreline (ITOPF 2014).

The main physical properties of an oil that affect the behaviour and persistence of the fresh Corowa crude are:

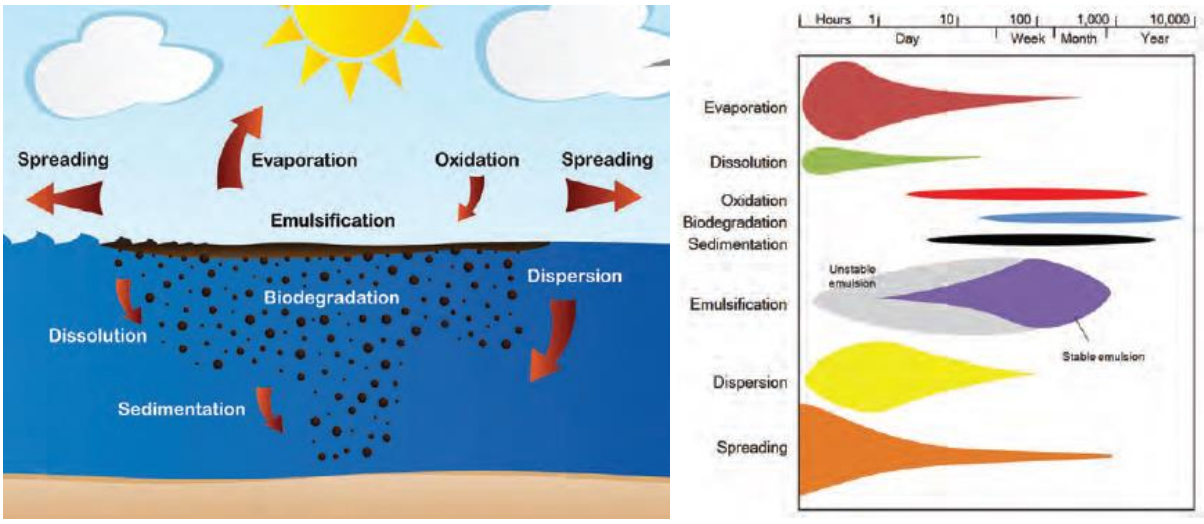
- *Specific gravity* – The Corowa crude has a specific gravity less than seawater and therefore will have the tendency to float.
- *Distillation characteristics (Volatility)* – The Corowa crude has a high proportion (94.1%) of volatile components that once on the surface will readily evaporate. Typical evaporation times once at the surface and exposed to the atmosphere are:
  - up to 12 hours for the volatile compounds (BP <180 °C)
  - up to 24 hours for the semi-volatile compounds (BP 180–265 °C)
  - several days for the low volatility compounds (BP 265–380 °C) (RPS 2019).

  There is a smaller proportion (5.9%) of the longer and more complex compounds (BP >380 °C) that tends to persist and be subject to relatively slow degradation rather than evaporate. These compounds may persist in the marine environment for weeks to months (RPS 2019).
- *Viscosity* – The Corowa crude has a low viscosity and will tend to flow and spread.
- *Pour point* – The Corowa crude has a pour point well below ambient seawater temperatures and therefore will stay in liquid form (i.e. it would not tend to form waxy solids).

Soluble aromatic hydrocarbons account for a very low proportion (1.8%) of the Corowa crude. During an energetic subsea release or any subsequent energetic mixing processes, these aromatic compounds (which include the BTEX and PAH compounds) are likely to dissolve into the water column. Volatile aromatic hydrocarbons that remain in the oil mixture at surface will tend to evaporate rapidly (RPS 2019).

Once released, varying weathering processes (e.g. spreading, evaporation, dispersion and dissolution) act on the oil, and the relative importance of these processes can change over time (Figure 7-17). Oil at surface will be subject to atmospheric weathering and will be transported by prevailing currents and wind. Oil that entrains or dissolves in the water column will be transported by prevailing currents and be subject to different weathering processes. As such, the different components of oil can follow different trajectory paths.

As oil weathers, its composition changes (French-McCay 2018). When oil is floating, the volatile components evaporate rapidly, and the remaining floating oil becomes more viscous and therefore spreading rates also reduce. Floating oil may also be entrained into the water column by breaking waves, or if the oil is from a subsurface release these droplets can entrain directly into the water column during the release. Soluble and semi-soluble hydrocarbons can also dissolve into the water column. However, the volatilisation rates of hydrocarbons from surface slicks are faster than the dissolution rates, and therefore dissolution from oil droplets in the water column is the main source of dissolved hydrocarbons (French-McCay 2018). The uptake of hydrocarbons by microorganisms (i.e. biodegradation) further reduces water column concentrations.

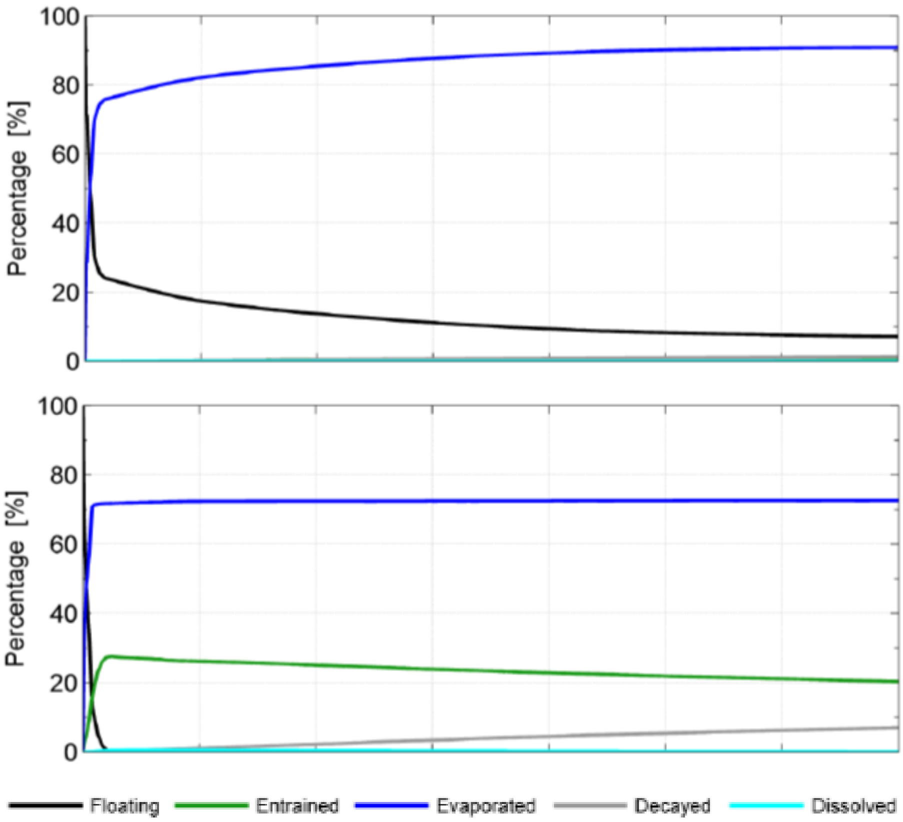


Source: ITOPF 2014

Figure 7-17 Weathering Processes that Act on an Oil at Sea Event (left) and a Schematic of Time-scale and Importance of each of these Processes on Crude Oil

Weathering tests for the Corowa crude were modelled to confirm expected behaviour of the oil once exposed to the water surface (RPS 2019). Two tests were done under a surface release scenario: one under constant low wind conditions (5 knots) and one under variable winds (4–19 knots).

Under the calmer conditions, by the end of the seven-day model run, 91% had evaporated, 7% of the oil remained on the sea surface, and a negligible amount had entrained (Figure 7-18). Under the variable wind conditions, <1% was predicted to remain on the sea surface, with 73% evaporating, 20% being entrained into the water column and 7% undergoing degradation (Figure 7-18). The variable wind scenario generated conditions that would entrain oil, which also led to a higher proportion dissolving. It also showed the Corowa crude was subject to slow degradation (<2% per day) rates, which would likely increase any area of exposure (RPS 2019).



Source: RPS 2019

Figure 7-18 Predicted weathering for a Surface Release of 50 m³ Corowa Crude under Constant Low (5 knot) [upper figure]and Variable (4–19 knots) [lower figure] Wind Conditions

7.2.6.2.4 Environmental Thresholds

Oil is a mixture of hydrocarbons of varying physical, chemical, and toxicological characteristics, and therefore, these components have varying fates and impacts (French-McCay 2018). Four components were modelled and used within the impact assessment:

- in-water (floating)
- in-water (dissolved)
- in-water (entrained)
- shoreline accumulation.

Air-breathing marine wildlife (e.g. birds, mammals and turtles) are primarily affected by floating oil and/or oil accumulated on a shoreline, whereas fish and invertebrates are primarily affected by entrained and dissolved oil components (French-McCay 2016).

The toxicity of an oil is related to the bioavailability of hydrocarbons and the duration of exposure (i.e. the more bioavailable the more toxic.) (French-McCay 2018). Soluble and semi-soluble hydrocarbons, due to their capacity are bioavailable, whereas insoluble compounds (i.e. entrained oil) are not bioavailable. Aromatic hydrocarbons are considered soluble and semi-soluble hydrocarbons dissolve and become bioavailable. In relatively fresh oil, some of the hydrocarbons in entrained oil droplets are also soluble/semi-soluble hydrocarbons that may dissolve and become bioavailable. However, as this entrained oil weathers, these potentially toxic components diminish to the point where the hydrocarbons in entrained oil are no longer bioavailable (cannot dissolve further) and are effectively non-toxic (French-McCay 2018).

The exposure values used in the spill modelling and impact assessment are described in Table 7-125 and are based on available guidance (e.g. NOPSEMA 2019) and literature (e.g. French-McCay 2018; 2016).

Table 7-125 Exposure Values used in Modelling and Impact Assessments for Accidental Hydrocarbon Release

Exposure Values	Qualitative Description	Environmental Relevance
In-water (floating)		
Low 1 g/m^2	1 ml within 1 m2 (~1/5th of a teaspoon within 1 m^2) Visible on surface with a rainbow oil appearance (BAOAC Code 2)	Floating oil is visible on the water surface and depending on thickness can vary from a rainbow appearance to metallic to a true oil colour (refer to Bonn Agreement Oil Appearance Code definitions in table notes). Visible oil can reduce the aesthetics of an area. Floating oil may impact marine fauna by coating or ingestion. Floating oil will typically have a lower toxicity due to the rapid change in composition over time from weather processes. Thresholds for ecological impacts have been estimated in the literature varying between 10–25 g/m^2. Scholten et al. (1996) indicate that floating oil at 25 g/m^2 would be harmful for seabirds, while Peakall et al. (1987) state that floating oil concentrations of <1 g/m^2 were not harmful to seabirds. Engelhardt (1983), Clark (1984), Geraci and St. Aubin (1988) and Jenssen (1994) indicate that floating oil at concentrations of >10 g/m^2 could impart a lethal dose to some wildlife. French-McCay (2016) suggest that 10 g/m^2 is an appropriate threshold for floating oil for marine biota. It is recognised that 'unfurred' animals (e.g. turtles) may be less vulnerable to floating oil as the adherence to bodies is less. For the purposes of assessment within this OPP: • 1 g/m^2 has been used as the criteria for defining the EMBA (see Section 5.1.1) and may be considered as a temporary change to ambient water quality and aesthetics. • 10 g/m^2 and 25 g/m^2 has been used as an exposure value for potential effects to marine fauna and associated social values.
Moderate 10 g/m^2	10 ml within 1 m^2 (~2 teaspoons within 1 m^2) Visible on surface with a metallic appearance (BAOAC Code 3)	
High 25 g/m^2	25 ml within 1 m^2 Visible on surface with a metallic appearance (BAOAC Code 3)	
In-water (dissolved)		
Low 10 ppb (instantaneous) ^	0.01 ml within 1 m^3 (~1/500th of a teaspoon within 1 m^3)	Dissolved hydrocarbons (including PAHs and BTEX) are bioavailable and may be taken up into organisms directly through external surfaces and gills, as well as through the digestive tract (French-McCay 2018). Laboratory studies have shown that the dissolved hydrocarbons exert the most effects on aquatic biota (Carls et al. 2008; Nordtug et al. 2011; Redman 2015). The toxicity of dissolved hydrocarbons is strongly related to the oil chemical composition, and it will vary as the oil weathers (French-McCay 2018). Based on available literature, thresholds based on acute lethality (LC50s) with multiple days of exposure (48–96 hours) generally range from about 10 ppb for sensitive early life stages to >300 ppb for less sensitive species and older life stages (French-McCay 2018). French-McCay (2002) indicates that an average 96-
Moderate 50 ppb (instantaneous)	0.05 ml within 1 m^3 (~1/100th of a teaspoon within 1 m^3)	
50 ppb (time-integrated)	As above, but consistently present within water for at least 96 hours	

Exposure Values	Qualitative Description	Environmental Relevance
High 400 ppb (instantaneous)	0.4 ml within 1 m^3 (<1/10th of a teaspoon within 1 m^3)	hour LC50 of 50 ppb has the potential to result in an acute lethal threshold to 5% of biota. Conservative thresholds suitable for shorter exposure periods (e.g. ≤3 hours) would be two to three orders of magnitude higher due to the accumulation of toxicant over time up to a critical tissue concentration that causes mortality (French-McCay 2018). For the purposes of assessment within this OPP: • 10 ppb has been used as the criteria for the defining the EMBA (see Section 5.1.1) and may be considered as a temporary change to ambient water quality. • 50 ppb has been used as an exposure value for potential toxic effects to sensitive species/life stages and potential sublethal effects for less sensitive species, noting that for toxicity effects to occur a time-integrated exposure is more relevant. • 400 ppb has been used as an exposure value for potential toxic effects to less sensitive species/life stages, noting that for toxicity effects to occur a time-integrated exposure is more relevant.
400 ppb (time-integrated)	As above, but consistently present within water for at least 96 hours	
In-water (entrained)		
Low 10 ppb (instantaneous) ^	0.01 ml within 1 m^3 (~1/500th of a teaspoon within 1 m^3)	Entrained oil is not bioavailable, but the droplets may coat external surfaces or be ingested. Entrained oil, especially when in weathered state, is typically not considered toxic. For entrained oil, a threshold of 100 ppb was considered extremely conservative, and 1,000 ppb would be sufficiently conservative for oil droplets of all oil types and all weathered states (French-McCay 2018). For the purposes of assessment within this OPP: • 10 ppb has been used as the criteria for defining the EMBA (see Section 5.1.1) and may be considered as a temporary change to ambient water quality. • 100 ppb has been used as an exposure value for potential sublethal effects to species (noting that for toxicity effects to occur a time-integrated exposure is more relevant) and associated social values. • 1,000 ppb has been used as an exposure value for potential toxic effects to species (noting that for toxicity effects to occur a time-integrated exposure is more relevant) and associated social values.
Moderate 100 ppb (instantaneous)	0.1 ml within 1 m^3 (~1/50th of a teaspoon within 1 m^3)	
100 ppb (time-integrated)	As above, but consistently present within water for at least 96 hours	
High 1,000 ppb (instantaneous)	1 ml within 1 m^3 (~1/5th of a teaspoon within 1 m^3)	
1,000 ppb (time-integrated)	As above, but consistently present within water for at least 96 hours	
Shoreline		
Low 10 g/m^2	10 ml within 1 m^2 (~2 teaspoons within 1 m^2)	Owens and Sergy (1994) indicate that volumes ashore of 100–1,000 g/m^2 have the potential to coat shoreline habitats. Consequently, it has been assumed that for benthic epifaunal

Exposure Values	Qualitative Description	Environmental Relevance
	Visible on surface with a metallic appearance (BAOAC Code 3)	invertebrates living in intertidal habitats on hard substrates, a threshold of >100 g/m^2 would be required to coat the animal, and subsequently likely impact its survival and reproductive capacity; loading <100 g/m^2 is less likely to have effect (French-McCay 2009).
Moderate 100 g/m^2	100 ml within 1 m^2 (~5 tablespoons within 1 m^2) Visible on the surface as a 'stain' or 'film' (BAOAC Code 4)	Lin and Mendelssohn (1996) indicate that hydrocarbon volumes >1,000 g/m^2 that come ashore during the growing season have the potential to significantly impact saltmarsh or mangrove plants. The impacts of surface hydrocarbons on wetlands are generally similar to those described for mangroves and saltmarshes. The degree of impact of oil on wetland vegetation are variable and complex, and can be both acute and chronic, ranging from short-term disruption of plant functioning to mortality (Corn and Copeland 2010).
High 1,000 g/m^2	1 L within 1 m^2 BAOAC Code 5 – continuous true colour	For the purposes of assessment within this OPP: • 10 g/m^2 has been used as the criteria for defining the EMBA (see Section 5.1.1) and may be considered as a temporary change to ambient sediment quality and aesthetics. • 100 g/m^2 has been used as an exposure value for potential effects to shoreline habitat and marine fauna. • 1,000 g/m^2 has been used as an exposure value for potential effects to vegetated coastal habitats.

<u>Bonn Agreement Oil Appearance Codes (BAOAC)</u>

1 – Sheen (~0.04–0.30 µm thick)

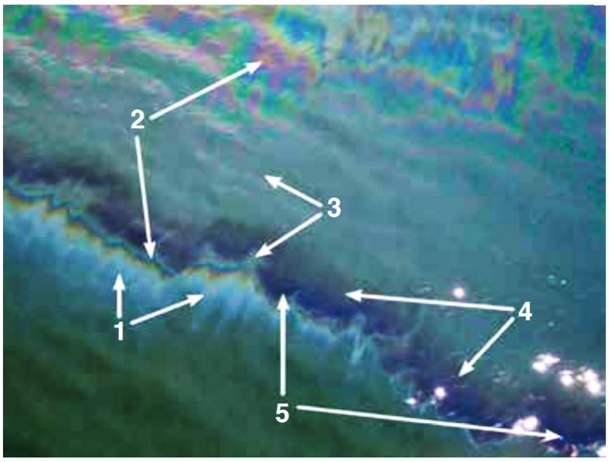
2 – Rainbow (~0.30–5.0 µm thick)

3 – Metallic (~5–50 µm thick)

4 – Discontinuous true colour oil (~50–200 µm thick)

5 – Continuous true colour oil (~ >200 µm thick)

^ For those exposure values used only for definition of the EMBA and not for impact assessments (i.e. 10 ppb for entrained and dissolved oil), no further discussion is presented in the OPP.



7.2.6.2.5 Predicted Exposure

The results from OILMAP and SIMAP modelling of the subsea release of Corowa crude are summarised below.

Near-field

The results of the OILMAP simulation for the subsea release predicted that the discharge will generate a cone of rising gas that will entrain the oil droplets and ambient sea water up to the water surface (RPS 2019). The diameter of the central cone of rising oil/water at the point of surfacing is predicted to be ~10.5 m (RPS 2019). The droplets generated during discharge will be subject to mixing due to lateral turbulence (from movement of the rising discharge plume) and vertical mixing from wave action on the surface. Once the droplets generated during discharge reach the surface layer (3–10 m depth, depending on conditions), the droplets will tend to surface due to their high buoyancy relative to other mixing processes (RPS 2019).

Far-field

Stochastic modelling results refer to the cumulative outputs from all model simulations, which for this scope was 150 unique model simulations, with 50 per seasonal period. Under different metocean and environmental conditions, each single model run (known as 'deterministic') differs in spill direction, extent and duration (i.e. area of exposure).

Figure 7-19 shows an example of three single model runs, with the dotted line representing the outer extent of 150 single model runs; i.e. the stochastic modelling. The stochastic results summarised below represent the total predicted area of potential exposure of all 300 model runs, and do not represent the actual exposure that would occur from a single individual event.

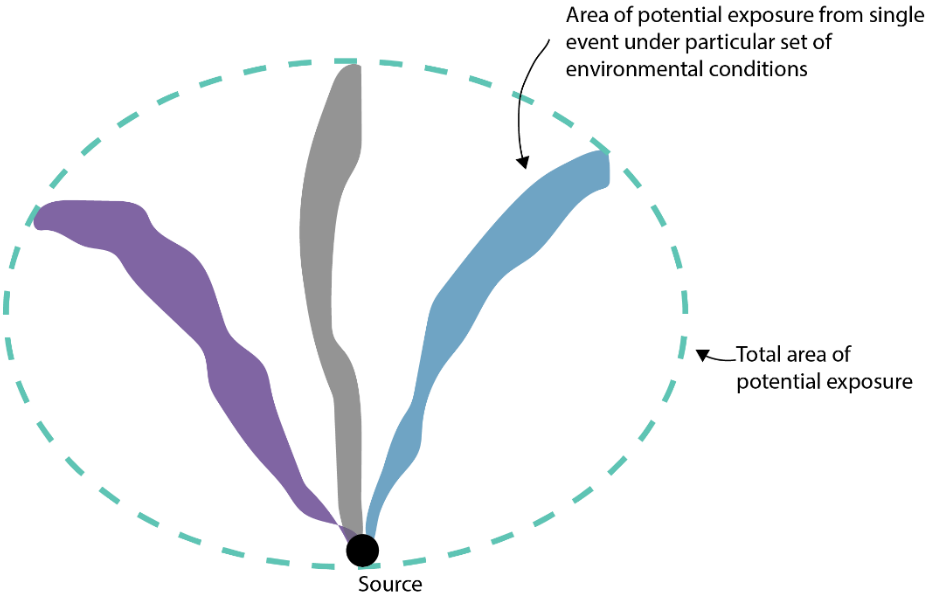


Figure 7-19 Deterministic and Stochastic Modelling

The fate of each hydrocarbon component also varies due to different trajectory influences and weathering characteristics (see previous sections). For example, the entrained oil typically includes the residual component of the released oil, and as it persists longer it will travel further from the spill source (Figure 7-20). Note that for the Corowa crude, this residual component represents a very small proportion (5.9%) of the total volume released. Similarly, dissolved hydrocarbons may occur when entrained and/or floating oil is present; however, due to their volatility they do not tend to persist and travel as far as entrained oil droplets (Figure 7-20). The Corowa crude has a very low proportion of aromatics (1.8%).

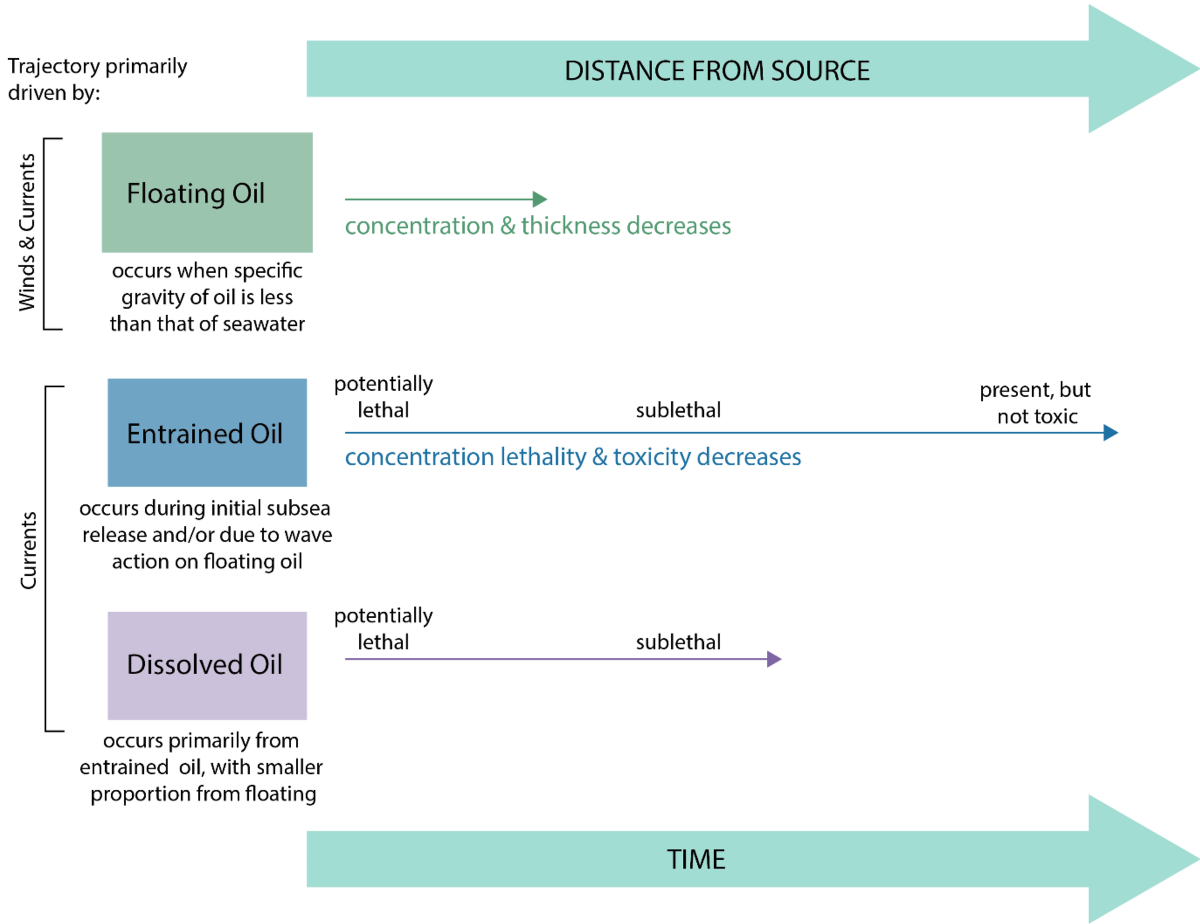


Figure 7-20 Oil Components and Typical Exposure Extent and Type of Impacts

The results of the stochastic modelling undertaken using SIMAP (RPS 2019) is presented in Table 7-126, Figure 7-21, Figure 7-23, Figure 7-25 and Figure 7-27 for each modelled hydrocarbon component. Receptors marked 'X' refer to where an exposure value is relevant to the receptor, but modelling predicts negligible interaction with the receptor.

Examples of individual spill scenarios (i.e. deterministic modelling) have also been shown for each modelled oil component (Figure 7-22, Figure 7-24, Figure 7-26, Figure 7-28)

Table 7-126 Summary of Stochastic Modelling Results for a LOWC (Accidental Release – Corowa Crude Oil)

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
Surface (floating)																		
Low 1 g/m^2	• Floating oil above 1 g/m^2 generally extends in a NE/SW and offshore trajectory from the spill source, with no floating oil above this exposure value predicted to occur within Exmouth Gulf (Figure 7-21). • Floating oil at this level is expected to be visually detectable but not have biological effects. • Maximum distance from the source predicted for floating oil above 1 g/m^2 is 1,167 km.	✓									✓		✓		✓	✓	✓	✓
Moderate 10 g/m^2	• Floating oil above 10 g/m^2 generally extends in a NE/SW and offshore trajectory from the spill source, with no floating oil above this exposure value predicted to occur within Exmouth Gulf or onto the shallower shelf area (including most of the region with the Pilbara inshore islands) (Figure 7-21). • Floating oil may occur from the spill source to offshore Barrow Island (>30 km from the island) and North West Cape (it may enter shallow nearshore areas along the western edge of the peninsula). • Maximum distance from the source predicted for floating oil above 10 g/m^2 is 476 km.	✓					✓		✓	✓	✓	✓	✓		✓			✓

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
	• The highest probabilities for oil contact at this threshold is within the Muiron Islands Marine Management Area (30–39% depending on seasonal conditions). • Probability of exposure to AMPs is relatively low: ~18–26% at Ningaloo MP and ~10–28% at Gascoyne MP and ≤2% for all others (except during the transitional season modelling where ~14% probability of exposure to the Shark Bay MP occurred, noting that floating oil at this distance away from the source occurred only in small irregular patches). • Would intersect with BIAs for turtles, seabirds, sharks and whales, with a low probability (~8–16%) of intersecting a Dugong BIA. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack, with a low probability (~10–20%) of intersecting the North-West Slope Trawl fishery.																	
High 25 g/m²	• Floating oil generally extends in a SW trajectory from the spill source, with no floating oil above this exposure value predicted to occur within Exmouth Gulf or onto the shallower shelf area (including most of the region with the Pilbara inshore islands) (Figure 7-21). • Maximum distance from the source predicted for floating oil above 25 g/m² is 393 km. • Probability of exposure to AMPs is relatively low: ~10% at Ningaloo MP and ~4–14% at Gascoyne MP and ≤2% for all others (except during the transitional	✓					✓		✓	✓	✓	✓	✓		✓			✓

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
	season modelling where ~4% probability of exposure to the Shark Bay MP occurred, noting that floating oil at this distance away from the source occurred only in small irregular patches). • Would intersect with BIAs for turtles, seabirds, sharks and whales, with a low probability (~2–8%) of intersecting a Dugong BIA. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack, with a low probability (~8–10%) of intersecting the North-West Slope Trawl fishery.																	
In-water (dissolved)																		
Moderate 50 ppb (instantaneous)	• Dissolved hydrocarbons above 50 ppb may extend NE/SW and offshore from the spill source, with no dissolved oil above this exposure value predicted to occur south of Exmouth within Exmouth Gulf (Figure 7-23). Predicted exposure only includes the northern extent of the Pilbara inshore island chain (e.g. Muiron, Serrurier, Peak Island). • Maximum distance from the source predicted for dissolved oil above 50 ppb is 597 km. • The highest occurrence of dissolved oil is generally expected to occur within the surface layer (0–10 m), with probabilities of exposure reducing with depth. • Limited benthic interaction is predicted to occur, with dissolved oil not expected to exceed depths of ~80 m below MSL (and typically remaining with	✓				✓		✓	✓	✓	✓	✓	✓		✓		✓	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
	surface layers; <10 m). Therefore, in shallower and nearshore areas some benthic interaction from entrained oil may potentially occur. • The probability of contact by dissolved hydrocarbons at this exposure value is predicted to be greatest at Muiron Islands MMA, Ningaloo MP (State and Commonwealth), Ningaloo Coast WHA, and Gascoyne MP (ranging from 65–93%). • Probability of contact within waters around the Pilbara inshore islands is ~26–30%. • Would intersect with BIAs for turtles, seabirds, sharks, whales and Dugongs. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack, and North-West Slope Trawl fishery.																	
Moderate 50 ppb (time-integrated)	• Maximum distance from the source predicted for dissolved hydrocarbons above the time-integrated threshold (i.e. 4,800 ppb.hr) is 102 km. However, it is noted that exposure is primarily within the immediate vicinity (up to 20 km) of the spill source, with discontinuous small patches occurring at distances beyond this. • No exposure predicted for waters around the Pilbara inshore islands (except Muiron Islands) or into Exmouth Gulf.					✓		✓	✓	✓	x	x	x		x		✓	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
	• No benthic interaction is predicted to occur, with dissolved hydrocarbons typically remaining with surface layers (<10 m). The vertical distribution of dissolved hydrocarbons indicates the plumes may come close to shore but tend to remain over the shelf slope. • Very low probability of exposure is predicted for waters within the Muiron Islands MMA (~0–2%) and the Ningaloo MP (~6%). • May intersect waters within BIAs for birds, turtles, sharks and whales (~74–92% probability, but a very low probability of exposure to Dugong BIA (6%). • May intersect waters within the Southern Bluefin Tuna, Western Skipjack Tuna and Western Tuna and Billfish fisheries (~74–92% probability).																	
High 400 ppb (instantaneous)	• Dissolved hydrocarbons above 400 ppb may extend NE/SW from the spill source, with no dissolved hydrocarbons above this exposure value predicted to occur within Exmouth Gulf, along North West Cape or onto the shelf area through the Pilbara inshore island chain (Figure 7-23). • Maximum distance from the source predicted for dissolved hydrocarbons above 400 ppb is 129 km. • The highest occurrence of dissolved oil is generally expected to occur within the surface layer (0–10 m), with probabilities of exposure reducing with depth. • Limited benthic interaction is predicted to occur, with dissolved oil not expected to exceed depths of ~30 m below MSL (and typically remaining with	✓				✓		✓	✓	✓	x	x	x		x		x	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
	surface layers; <10 m). Therefore, in shallower and nearshore areas some benthic interaction from entrained oil may potentially occur. • The probability of contact by dissolved hydrocarbons at this exposure value for marine protected areas (Muiron Islands MMA, Ningaloo MP, Ningaloo Coast WHA, and Gascoyne MP) is <1–2%. • Probability of contact within waters around the Pilbara inshore islands is <1%. • Relatively low probability (~30–37%) of contact is predicted with BIAs for turtles, seabirds, sharks and whales. • Relatively low probability (~30–37%) of contact with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack fisheries.																	
High 400 ppb (time-integrated)	• Dissolved oil above this time-integrated exposure value (i.e. 38,400 ppb.hr) is not predicted to occur.					x		x	x	x	x	x	x		x		x	
In-water (entrained)																		
Moderate 100 ppb (instantaneous)	• Entrained hydrocarbons above this exposure value may extend NE/SW and offshore from the spill source, with no entrained oil above this exposure value predicted to occur within the majority of Exmouth Gulf (Figure 7-25).	✓	X		X	✓		✓	✓	✓	✓	✓	✓		✓		✓	

Exposure Values	Predicted Extent of Exposure	Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
	Relevance to Receptors																	
	• Maximum distance from the source predicted for entrained hydrocarbons above 100 ppb is 1,173 km. • The highest occurrence of entrained oil is generally expected to occur within the surface layer (0–10 m), with probabilities of exposure reducing with depth. • Limited benthic interaction is predicted to occur, with entrained oil not expected to exceed depths of ~40 m below MSL (typically remaining with surface layers; <10 m). Therefore, in shallower and nearshore areas some benthic interaction from entrained oil may potentially occur. • The probability of contact by entrained hydrocarbons at this exposure value is predicted to be greatest within waters at Muiron Islands MMA, Ningaloo Coast WHA, Ningaloo MP (State and Commonwealth), Gascoyne MP with probabilities of 100% across all seasons. • Probability of contact within waters around the Pilbara inshore islands is ~87–95%. • Would intersect with BIAs for turtles, seabirds, sharks, whales and Dugongs. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack, and North-West Slope Trawl fishery.																	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
Moderate 100 ppb (time-integrated)	• Maximum distance from the source predicted for entrained hydrocarbons above the time-integrated threshold (9,600 ppb.hr) is 824 km. • The highest occurrence of entrained oil is generally expected to occur within the surface layer (0–10 m), with probabilities of exposure reducing with depth. • Limited benthic interaction is predicted to occur, with entrained oil not expected to exceed depths of ~30 m below MSL (typically remaining with surface layers; <10 m). Presence in waters up to 20 m depth may occur within the vicinity of the spill source (e.g. ~2–12% probability at Muiron Islands MMA, ~18–36% at Ningaloo MP / Ningaloo WHA), and up to 30 m depth at Ningaloo MP/ Ningaloo WHA but has <5% probability of occurrence. • Probability of this exposure and time threshold occurring within waters in the Pilbara inshore islands is ~50–56%, ~0–14% at Barrow Island and ~0–4% at Montebello Islands. • Probability of this exposure and time threshold occurring within marine protected areas is highest at Muiron Islands MMA (~94–96%), Ningaloo WHA (~90–98%), Ningaloo MP (State and Commonwealth) (~78–98%) and Gascoyne MP (~98%). • Would intersect with BIAs for turtles, seabirds, sharks, whales and Dugongs. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack, and North-West Slope Trawl fishery.				X	✓		✓	✓	✓	✓	✓	✓		✓		✓	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
High 1,000 ppb (instantaneous)	• Entrained oil above 1,000 ppb may extend NE/SW and offshore from the spill source, with no entrained hydrocarbons above this exposure value predicted to occur within Exmouth Gulf (Figure 7-25). • Maximum distance from the source predicted for entrained hydrocarbons above 1,000 ppb is 610 km. • No benthic interaction is predicted to occur, with entrained hydrocarbons typically remaining with surface layers (<10 m). The vertical distribution of dissolved oil indicates the plumes may come close to shore but tend to remain over the shelf slope. • The probability of contact by entrained hydrocarbons at this exposure value is predicted to be greatest within waters at Muiron Islands MMA, Ningaloo Coast WHA, Ningaloo MP (State and Commonwealth), Gascoyne MP with probabilities of 81–97% across all seasons. • Probability of contact within waters around the Pilbara inshore islands is ~30–45%. • Would intersect with BIAs for turtles, seabirds, sharks, whales and Dugongs. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack, and North-West Slope Trawl fishery.	✓	X		X	✓		✓	✓	✓	✓	✓	✓		✓		✓	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																	
		Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
High 1,000 ppb (time-integrated)	• Maximum distance from the source predicted for entrained hydrocarbons above the time-integrated threshold (96,000 ppb.hr) is 356 km. • No benthic interaction is predicted to occur, with entrained hydrocarbons typically remaining with surface layers (<10 m). • Probability of this exposure and time threshold occurring within waters in the Pilbara inshore islands is ~0–4%. • Probability of this exposure and time threshold occurring within marine protected areas is highest at Muiron Islands MMA (~10–12%), Ningaloo WHA (~26–42%), Ningaloo MP (State and Commonwealth) (~6–42%) and Gascoyne MP (~6–12%). • Would intersect with BIAs for turtles, seabirds, sharks, whales, and a lower probability of exposure to the Dugong BIA (~26–42%). • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack (~100%), and North-West Slope Trawl (~6–18%) fishery.				X	✓		✓	✓	✓	✓	✓	✓		✓		✓	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
Shoreline																		
Low 10 g/m^2	• Shoreline accumulation above 10 g/m^2 may occur in patches throughout the EMBA (Figure 7-27). Shoreline accumulation at this level is expected to be visual but not have biological effects. • Within the immediate vicinity of the Corowa Development this includes coastal areas from Coral Bay around the North West Cape to Exmouth (~73–99% and 26–47% probability respectively), the Pilbara inshore island chain between Muiron and Airlie islands (~55–85% probability), isolated patches on the western edge of Barrow Island (~2–10% probability), and the Lowendal and Montebello islands (<1–8% probability respectively). • Further south these low levels of shoreline accumulation may occur from deposited entrained oil droplets, in areas including Dorre Island (mouth of Shark Bay) and the Abrolhos Islands (~2–6% probability), and isolated (i.e. single model cell) occurrences between Shark Bay and Perth (<1–4% probability).		✓										✓	X	✓			✓

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and	Benthic habitat and	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas –	Heritage	Industry	Commercial Fisheries (State &	Tourism and Recreation
Moderate 100 g/m^2	• Shoreline accumulation above 100 g/m^2 may occur along the western shores of North West Cape (~49–85% probability) and through the Pilbara inshore island chain between Muiron and Ashburton islands (~49–70% probability) (Figure 7-27). • The coast between the tip of North West Cape and Exmouth has a ~6–8% probability of contact at this exposure value. No other shores within Exmouth Gulf are predicted to be exposed. • The worst-case maximum length of shoreline with concentrations >100 g/m^2 was 68 km along the western coast of North West Cape. • The maximum total volume of oil onshore during any of the simulations was 1,092 m^3.		✓	✓	✓		✓		✓					*X*				
High 1,000 g/m^2	• Shoreline accumulation above 1,000 g/m^2 may occur along the western coast of North West Cape (~13–34% probability) and through the Pilbara inshore island chain between Muiron and Serrurier islands (~15–30%) (Figure 7-27).		✓	✓	✓		✓		✓					*X*				

Receptors marked 'X' = exposure value is relevant to the receptor, but modelling predicts negligible interaction with receptor via the exposure pathway. Probabilities of exposure vary with seasons.

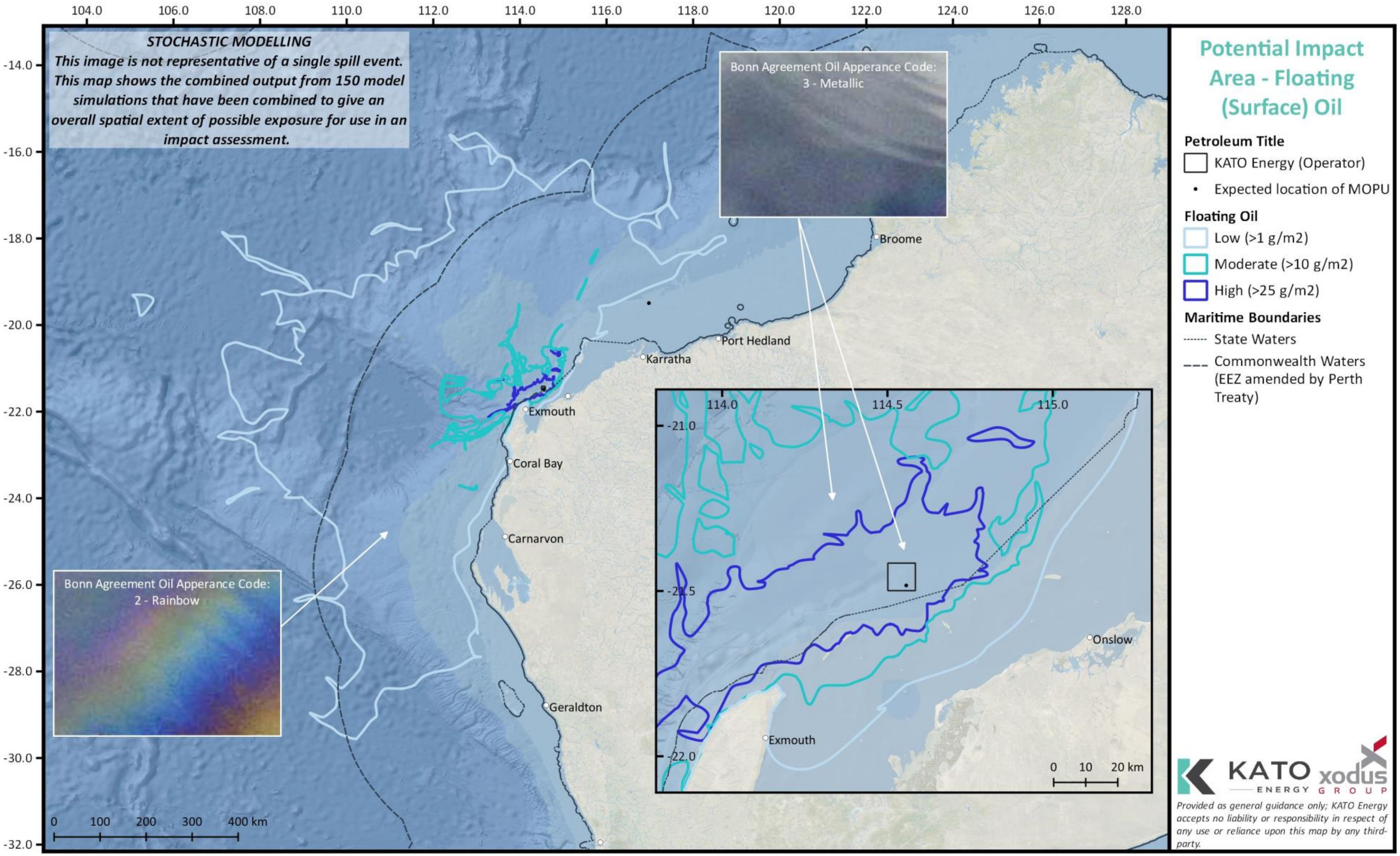


Figure 7-21 Potential Impact Area (stochastic modelling output) for Floating Oil from a Subsea Release of Corowa Light Crude

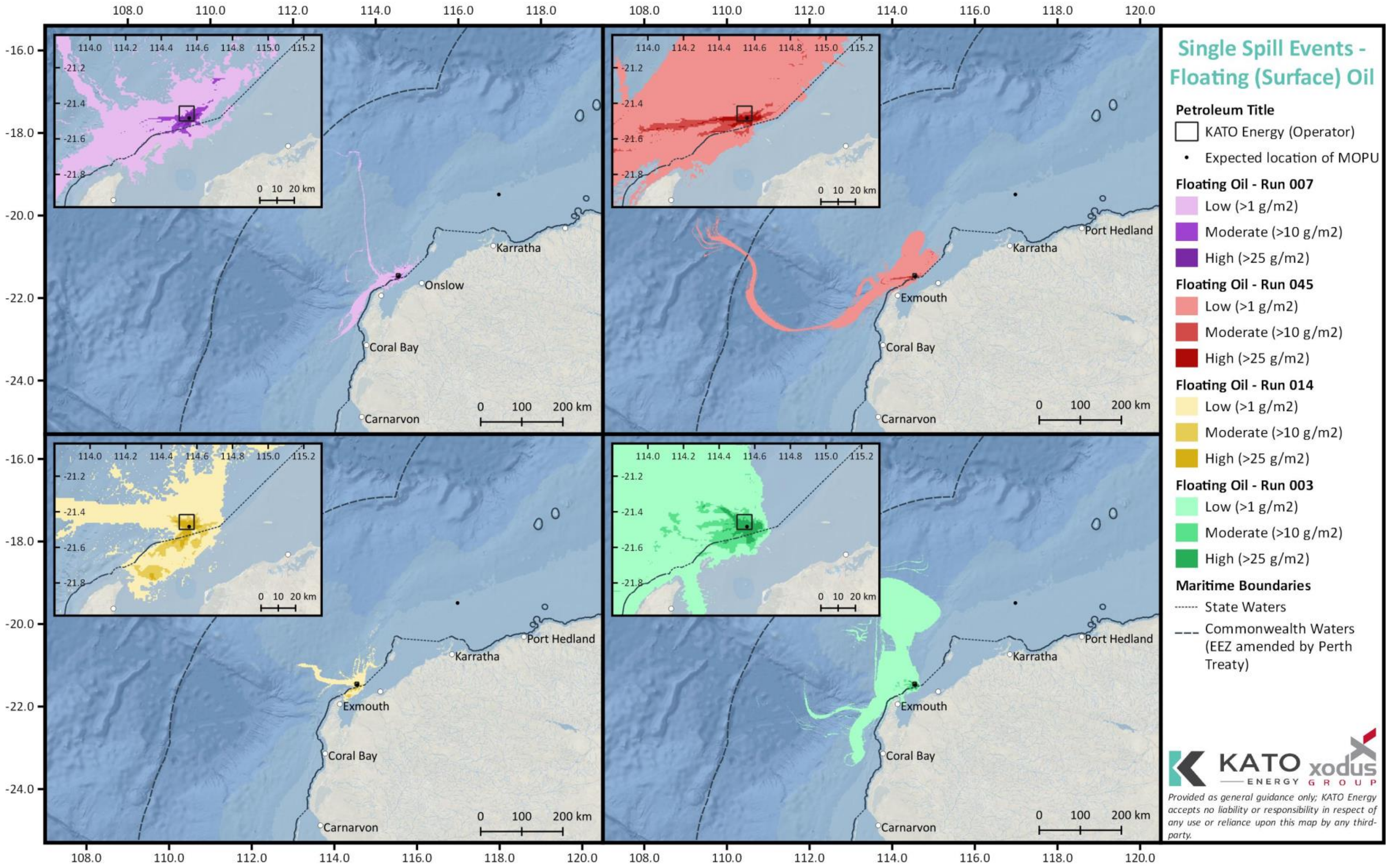


Figure 7-22 Examples of an Individual Spill Event (deterministic modelling output) for Floating Oil from a Subsea Release of Corowa Light Crude

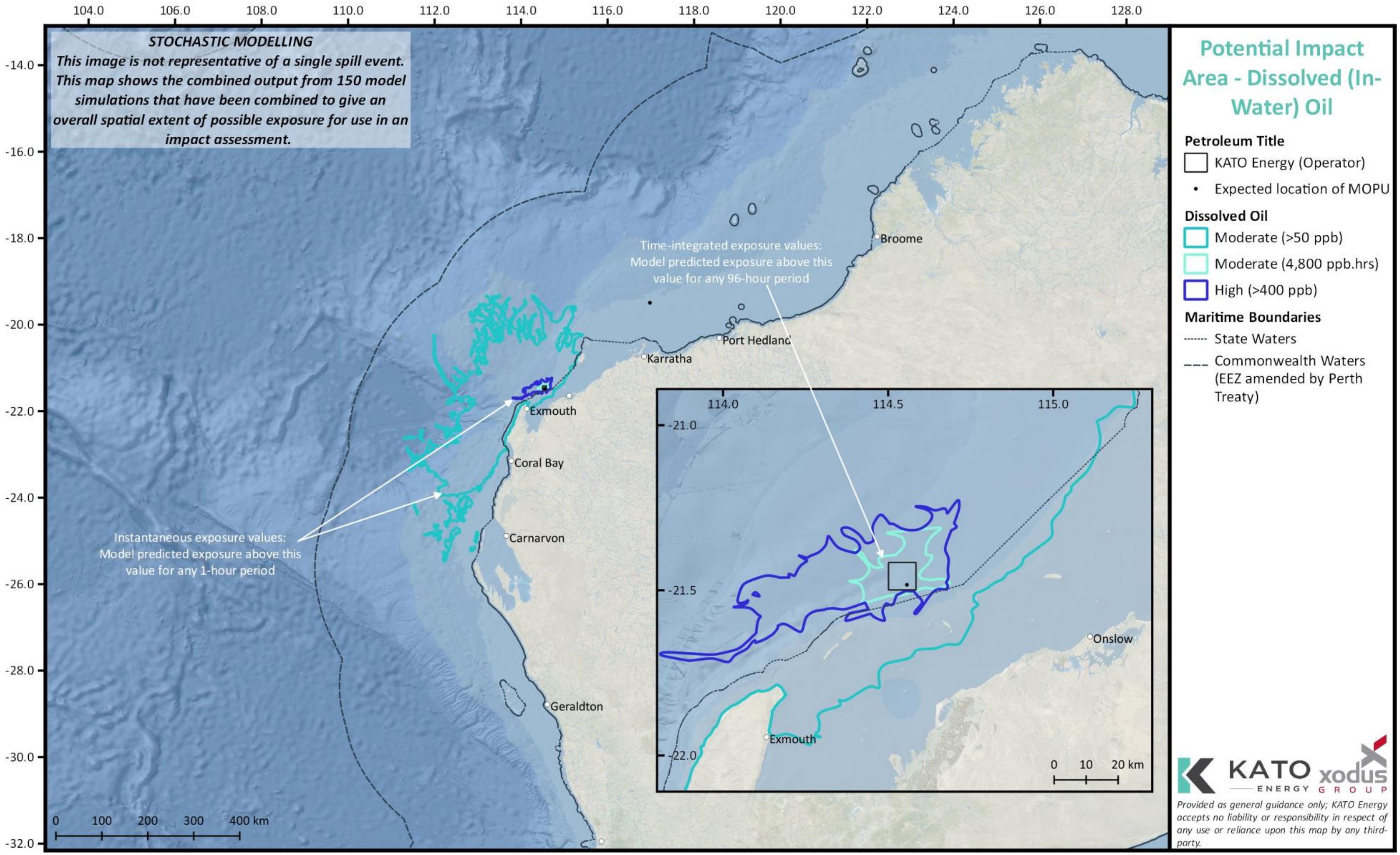


Figure 7-23 Potential Impact Area (stochastic modelling output) for Dissolved Oil from a Subsea Release of Corowa Light Crude

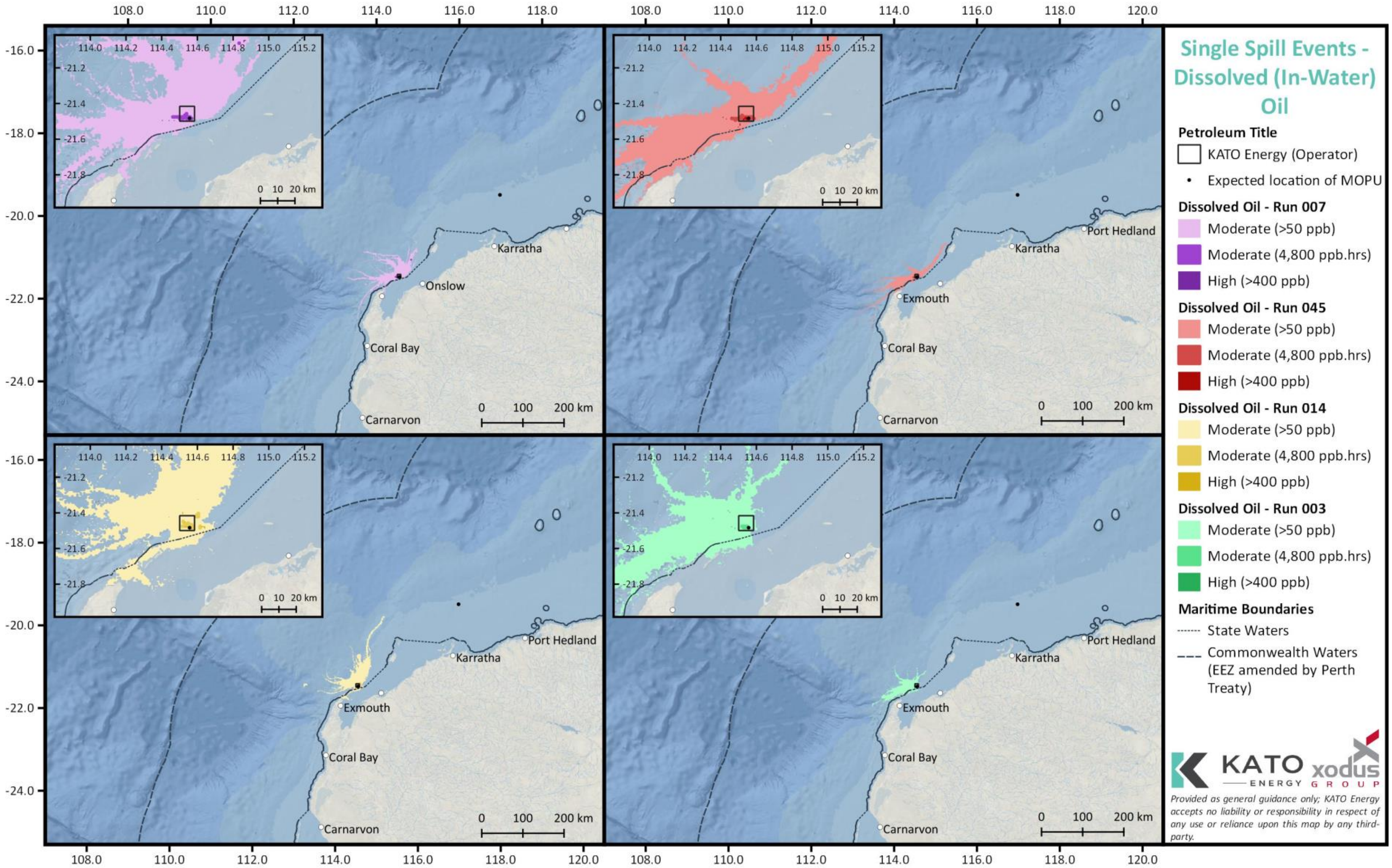


Figure 7-24 Examples of an Individual Spill Event (deterministic modelling output) for Dissolved Oil from a Subsea Release of Corowa Light Crude

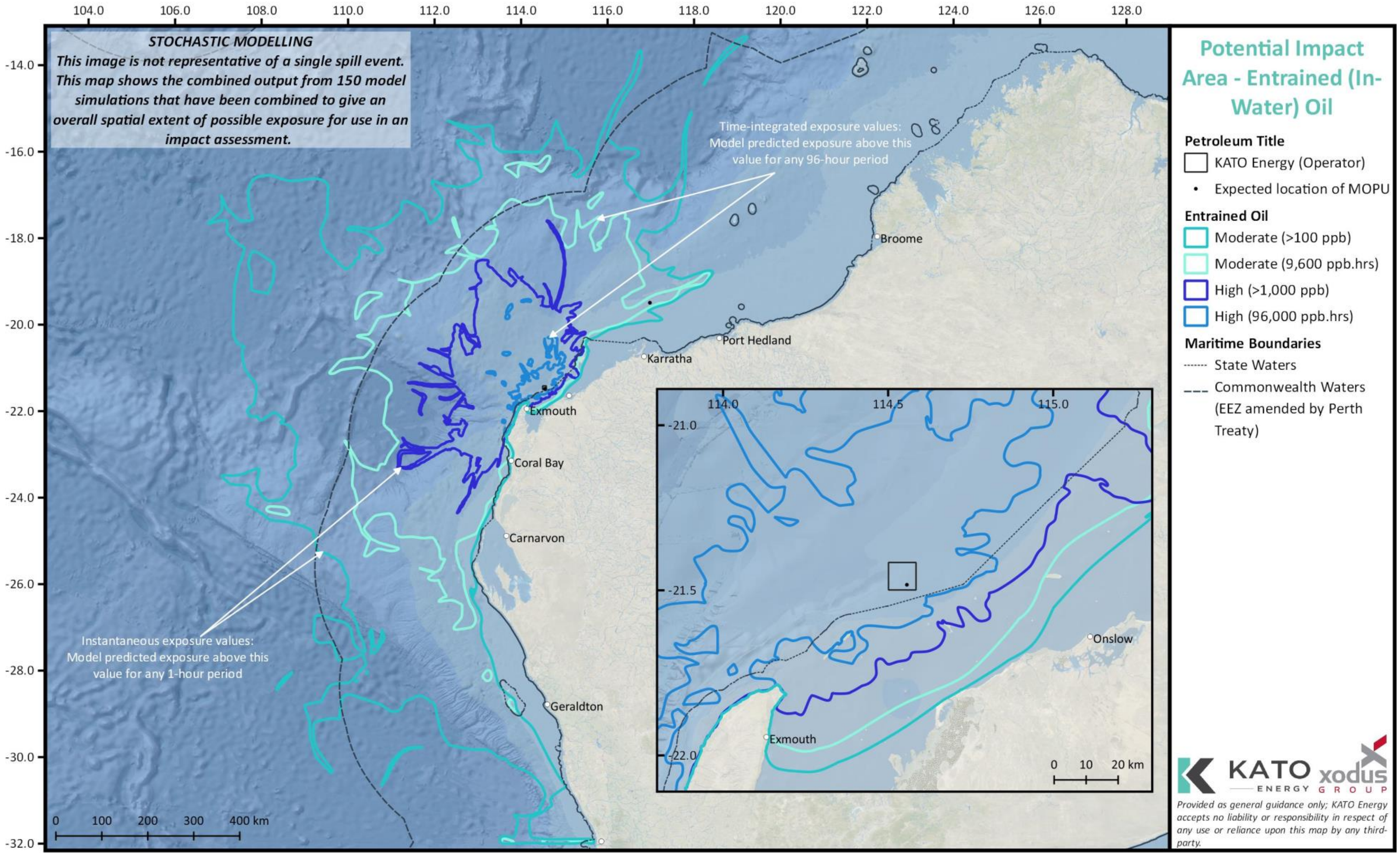


Figure 7-25 Potential Impact Area (stochastic modelling output) for Entrained Oil from a Subsea Release of Corowa Light Crude

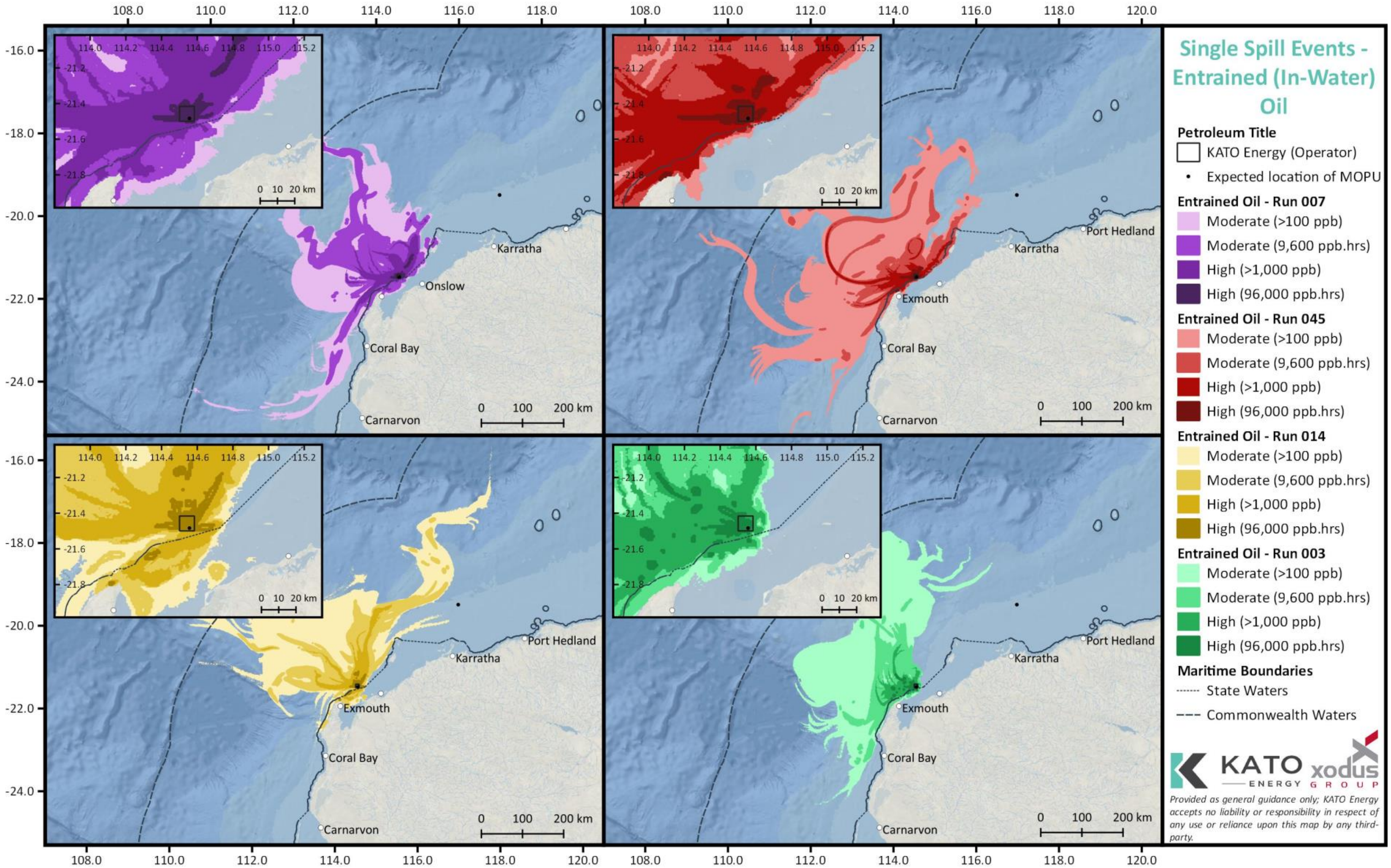


Figure 7-26 Examples of an Individual Spill Event (deterministic modelling output) for Entrained Oil from a Subsea Release of Corowa Light Crude

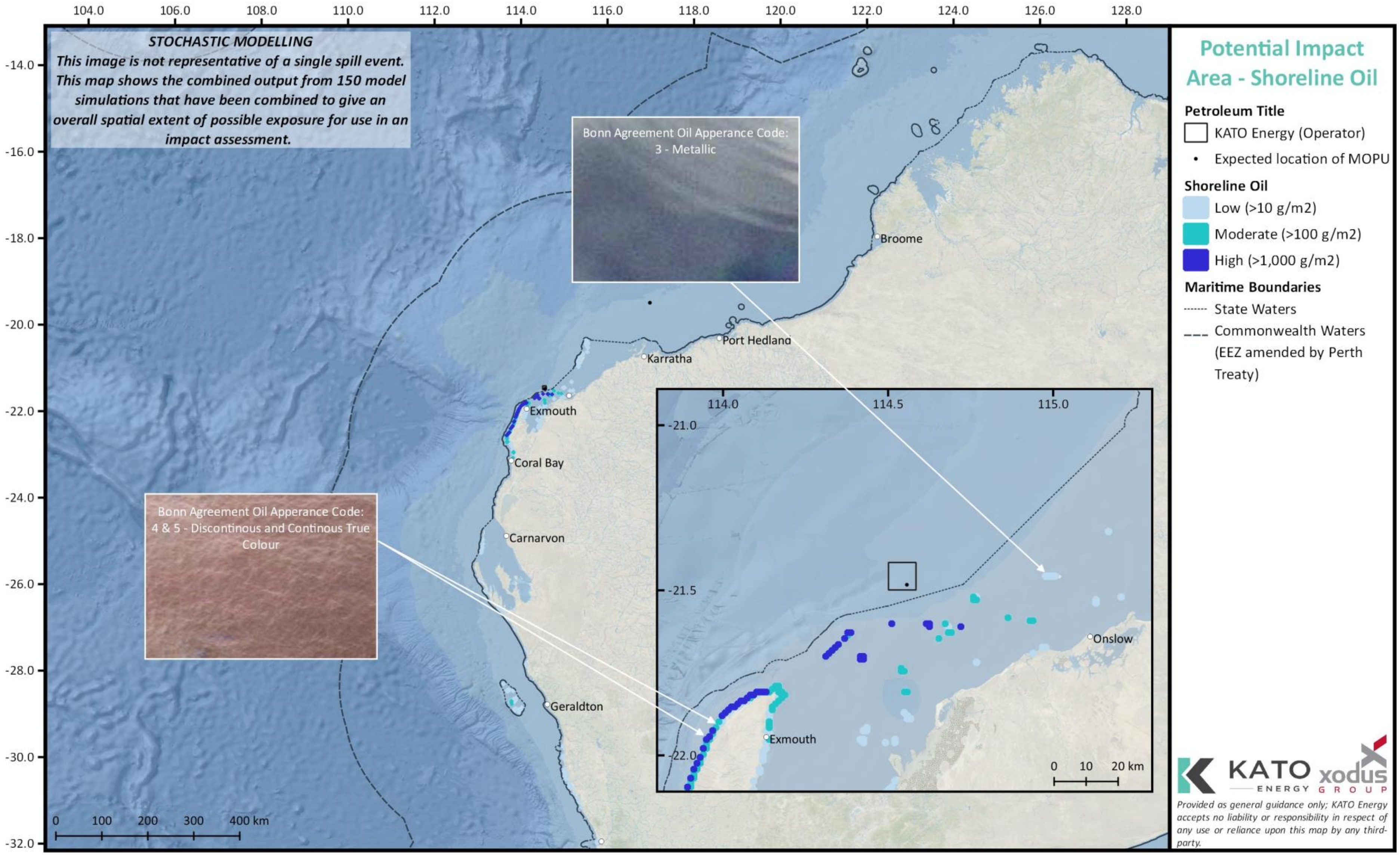


Figure 7-27 Potential Impact Area (stochastic modelling output) for Shoreline Oil from a Subsea Release of Corowa Light Crude

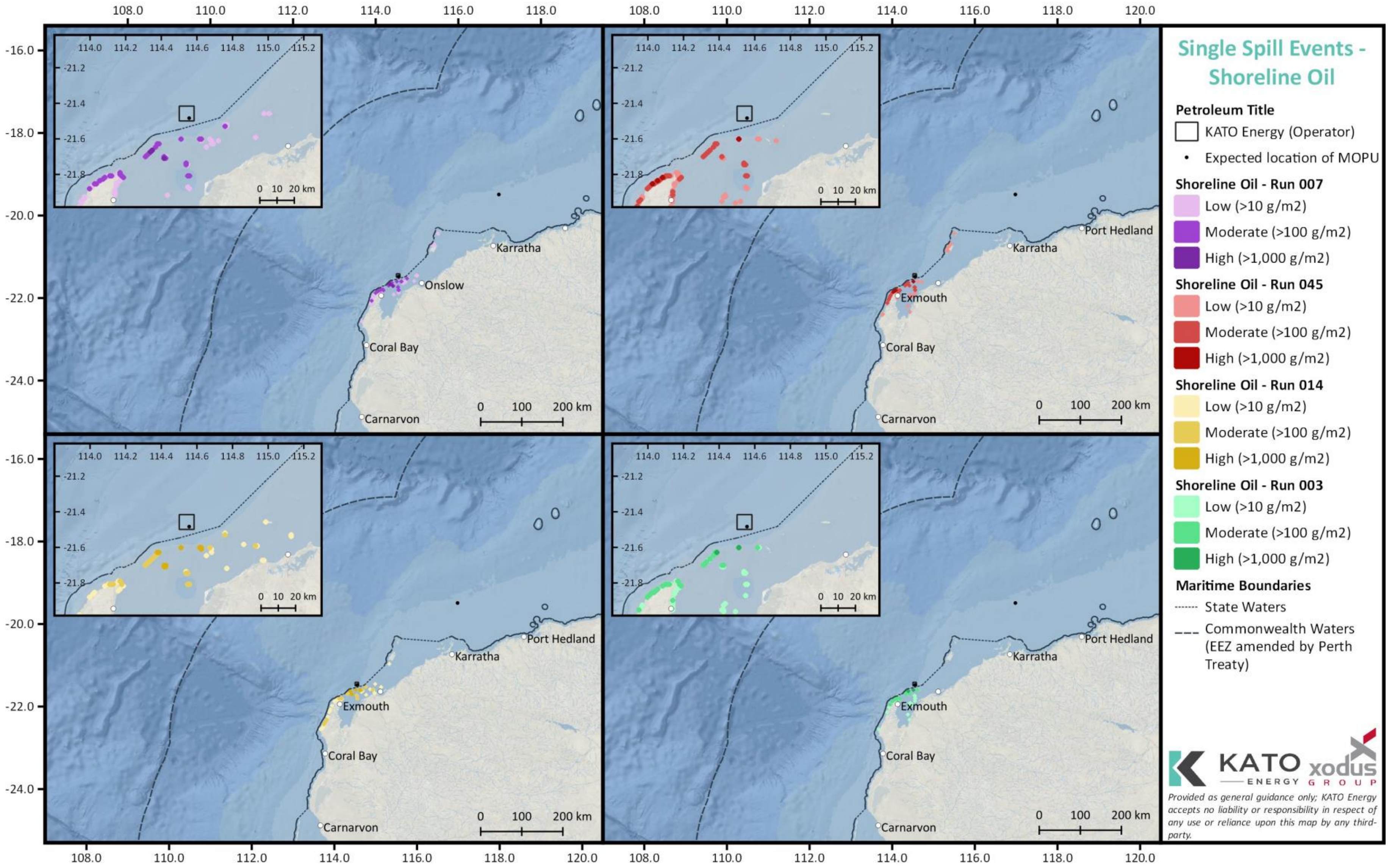


Figure 7-28 Examples of an Individual Spill Event (deterministic modelling output) for Shoreline Oil from a Subsea Release of Corowa Light Crude

7.2.6.3 Risk Evaluation

An accidental release of light crude oil generated by the Corowa Development has the potential to result in these impacts:

- change in water quality
- change in sediment quality
- change in habitat.

As a result of a change in water quality, sediment quality and/or habitat, further impacts may occur, including:

- change in fauna behaviour
- injury / mortality to fauna
- changes to the functions, interests or activities of other users
- change in aesthetic value.

Table 7-127 identifies the potential impacts to receptors as a result of an accidental release of light crude oil from the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-128 provides a summary and justification for those receptors not evaluated further.

Table 7-127 Receptors Potentially Impacted by Accidental Release – Corowa Light Crude Oil

Impacts	Ambient water quality	Ambient sediment quality	Plankton	Benthic habitat and communities	Coastal habitats and communities	Seabirds and shorebirds	Fish	Marine reptiles	Marine mammals	KEFs	Australian Marine Parks	Commercial Fisheries	Tourism and Recreation	State Protected Areas – Marine	State Protected Areas – Terrestrial	Industries	Heritage
Change in water quality	✓									✓	✓			✓			✓
Change in sediment quality		✓								*X*	*X*			✓			✓
Change in habitat				✓	✓					✓	✓			✓	*X*		✓
Injury / mortality to fauna			✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	*X*		✓
Change in fauna behaviour				✓	✓	✓	✓	✓	✓	✓	✓			✓	*X*		✓
Changes to the functions, interests or activities of other users											✓	✓	✓	✓	*X*	✓	✓
Change in aesthetic value					✓						✓		✓	✓			✓

Table 7-128 Justification for Receptors not Evaluated Further for Accidental Release – Corowa Light Crude Oil

State Protected Areas – Terrestrial	*X*
Terrestrial protected areas (Cape Range National Park and the nature reserves associated with some of the Pilbara inshore islands) occur within the area predicted to be exposed to shoreline accumulation. Shoreline accumulation from an oil spill will typically only extend to just above the high-tide mark. If the management boundaries of terrestrial protected areas extended to water limits, any impacts from hydrocarbons to the values and sensitivities of the reserves/parks will only occur at that boundary. Therefore, the area of impact to the terrestrial protected area would be negligible and is not evaluated further.	

Impacts to receptors are assessed below, by receptor type.

7.2.6.3.1 Physical Receptors

Table 7-129 provides a detailed evaluation of the impact of an accidental release of Corowa crude to physical receptors.

Table 7-129 Impact and Risk Assessment for Physical Receptors from Accidental Release – Corowa Light Crude Oil

Ambient Water Quality	✓
Change in water quality An accidental release has the potential to result in a change in water quality. However, following a release of oil into the marine environment, weathering processes begin to immediately transform the oil (TRBNRC 2003). The Corowa crude is classified as a non-persistent oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~94.1%) of volatile components and only a small (5.9%) residual component. Due to this volatility, once on the water surface most of this oil will evaporate; depending on wind conditions, the proportion of evaporated oil may vary between ~73–91% within several days of release (Section 7.2.6.2.3). During a subsea release some of the oil will entrain into the water column, with further entrainment occurring as a result of mixing from waves; again, depending on wind conditions the proportion of entrained oil may vary up to ~20% (Section 7.2.6.2.3). Entrained oil can persist for extended periods of time, however if it refloats it is subject to evaporation and is also subject to dissolution and natural degradation within the water column (noting the modelled weathering of the Corowa crude showed slow degradation at <2% per day). Stochastic modelling undertaken for the subsea release of the Corowa crude indicated that if/when entrained oil did occur it remained in the surface layers (predominantly within the 0–10 m depth, with some occasional and low probability of exposures to depths up to 30 m). The actual area of exposure for an individual spill event will be relatively small, with exposure shown to be transient and temporary due to the influence of waves, currents and weathering processes. Given the details above, the consequence of an accidental release of Corowa light crude oil causing a change in water quality has been assessed as **Minor (1)**, with the impact assessed as **Unlikely (C)** to occur, given that any change in water quality would be restricted to surface waters within a spatially restricted area, and that water quality within the EMBA is unlikely to permanently be significantly impacted.	
Ambient Sediment Quality	✓
Change in sediment quality An accidental release has the potential to result in a change in sediment quality. The Corowa field is in water ~85–90 m deep and the stochastic modelling did not indicate that benthic interaction from the released Corowa crude would occur. The deepest depth of entrained hydrocarbons reported in the modelling was a predicted <5% probability of 100 ppb at 30 m depth at the Ningaloo MP/ Ningaloo WHA. Therefore, the only potential exposure to sediments would occur in areas where shoreline accumulation is predicted to occur. The sediment within the intertidal zone and up to high-tide levels is	

where oil would accumulate on a shore, and the shallow nearshore areas would also then be potentially exposed to the floating and/or entrained oil components. The closest shoreline areas to the Corowa Development, that are also at risk of shoreline accumulation are, some of the Pilbara inshore islands, including Peak Island (~14 km), Serrurier Island (~17 km), and Muiron Islands (~23 km). The western side of North West Cape (~52 km away) is also predicted to be potentially exposed to shoreline accumulation. The actual area of exposure for an individual spill event will be relatively small, with exposure shown to be transient and temporary due to the influence of waves, currents and weathering processes. As previously noted, any oil that is on the surface would be subject to evaporation due to the high volatility of the Corowa crude. However, it is noted that residual oil may interact with sediment to form agglomerates or aggregates, which can persist for an extended period within the nearshore environment (Clement 2018). Given the details above, the consequence of an accidental release of Corowa light crude oil causing a change in sediment quality has been assessed as **Minor (1)**, with the impact assessed as **Unlikely (C)** to occur, given that any change in sediment quality would be restricted to intertidal and/or shallow nearshore zones within a spatially restricted area, and that sediment quality within the EMBA is unlikely to permanently be significantly impacted.

7.2.6.3.2 Ecological Receptors

The identified ecological receptors may be impacted from:

- change in habitat
- change in fauna behaviour
- injury / mortality to fauna
- change in aesthetic value.

Table 7-130 provides a detailed evaluation of the impact of an accidental release of light crude oil to ecological receptors.

Table 7-130 Impact and Risk Assessment for Ecological Receptors from Accidental Release – Corowa Light Crude Oil

Coastal Habitats and Communities ✓
An accidental release of light crude oil has the potential to result in: • change in habitat • change in fauna behaviour • injury / mortality to fauna • change in aesthetic value. Coastal habitats and communities may be vulnerable to shoreline accumulation from an oil spill. Stochastic modelling undertaken for the subsea release of the Corowa crude indicated that shoreline accumulation of oil was predicted to occur within an area extending along the western edge and around the northern tip of North West Cape, and some of the Pilbara inshore islands. No exposure was predicted at >100 g/m^2 for shorelines within Exmouth Gulf. **Shoreline habitats** Sandy beaches, rocky coasts and tidal flats are the common shoreline types within the area predicted to potentially be exposed to shoreline accumulation >100 g/m^2. Rocky coasts and sandy beaches are present on parts of the Pilbara inshore islands, while sandy beaches and tidal flats are the dominant shorelines of North West Cape and Exmouth Gulf region. These types of shorelines are known to provide foraging and/or nesting habitat for birds and turtles; these activities primarily occur above the high-tide zone. Shoreline habitats may also be inhabited by a diverse assemblage (although not always abundant) of infauna (including nematodes, copepods and polychaetes) and invertebrates (e.g. crustaceans). Oil can behave differently on these different shoreline types:

- Rocky coasts – the rocky headland type features on wave-exposed coasts of the offshore islands are likely to remain unoiled, as floating/entrained oil is held back by the action of the reflected waves.
- Sandy beaches – oil penetration into sandy sediments varies with particle size (i.e. greater penetration in coarser materials) and oil viscosity (the Corowa crude has a low viscosity and therefore the fresh oil has a tendency to spread; however, viscosity will increase, and this spreading tendency will reduce as the oil weathers).
- Tidal flats – oil behaviour is similar to sandy beaches but with less penetration into the sediment profile due to small particle sizes.

Where oil does accumulate, it is concentrated along the high-tide zone while the lower parts are often untouched (IPIECA 1995). Therefore, fauna using coastal areas above the high-tide zone are typically not impacted unless they travel through this zone to access the upper beach (e.g. turtles). If oil does penetrate the sediment, infauna may be exposed. Long-term depletion of sediment fauna could have an adverse effect on birds or fish that use beaches or tidal flats as feeding grounds (IPIECA 1999). However, repopulation and recovery of affected communities is expected to occur over a relatively short (~5 years) period (IPIECA 1995; IPIECA 1999). As the oil is weathered it becomes more viscous and less toxic, and may leave some residual oil on upper shores. This residue can remain as an unsightly stain for an extended period, but it is unlikely to cause ecological damage (IPIECA 1995). Whilst this unsightly stain may cause a change in the aesthetic value of the local environment, they will be temporary and due to the remote locations of coastal habitats and communities within the area, aesthetic impacts will be minor.

Vegetated habitat (Saltmarsh, Mangroves)

Coastal vegetation, including saltmarsh, mangroves and wetlands, may be vulnerable to shoreline accumulations of >1,000 g/m^2. The western shores of the North West Cape and some of the southern Pilbara Islands are the only areas that may be exposed to shoreline oil above this exposure value (Figure 7-27). No mangrove or saltmarsh habitat has been recorded on the islands; however, there are small patches of it present along the western coast of North West Cape (e.g. Mangrove Bay) (Figure 5-7).

Both saltmarsh and mangroves are considered sensitive to hydrocarbon exposure; however, these are typically more vulnerable to heavy or viscous oil, or emulsifications, that have the capacity to coat vegetation, and in the case of mangroves, block breathing pores and asphyxiate the subsurface roots (IPIECA 1993). Mangroves can also take up hydrocarbons from contact with leaves, roots or sediments, and it is suspected that this uptake causes defoliation through leaf damage and tree death (Wardrop et al. 1987). Acute impacts to mangroves can be observed within weeks of exposure, whereas chronic impacts may take months to years to detect.

The extent of coating of saltmarsh vegetation will vary with the tidal cycle, and penetration past the outer fringe of vegetation is dependent on the type of oil (e.g. lighter oils may penetrate deeper into the saltmarsh habitat). Many saltmarsh grasses have corrugated leaf surfaces, which can increase the holding capacity for oil. Previous evidence (from case histories and experiments) indicates varying levels of damage and recovery rates. Lighter more penetrating oils are more likely to cause acute toxic damage than heavy or weathered oils. However, where impact does occur recovery is expected to occur over a relatively short (~2 year) period (IPIECA 1994).

In low energy environments, hydrocarbons are unlikely to be removed naturally by wave action and may be deposited in layers by successive tides (NOAA 2014). Medium to heavy oils do not readily adhere to or penetrate the fine sediments but can pool on the surface or in animal burrows and root cavities, whereas light oils can penetrate the top layers of sediment.

Summary

The Corowa crude is classified as a non-persistent oil and has a high proportion (~94.1%) of volatile components and only a small (5.9%) residual component. Due to this volatility, once exposed to the atmosphere (e.g. on a shoreline) most of this oil is expected to evaporate within several days.

Given the details above, the consequence of an accidental release of Corowa light crude oil causing any permanent and/or significant impacts to coastal habitats and communities has been assessed as **Moderate (2)**, with the impact assessed as **Very Unlikely (B)** to occur given that exposure to hydrocarbons is expected to be short-term and restricted to the intertidal (up to high tide) zone.

Benthic Habitat and Communities ✓
An accidental release of light crude oil has the potential to result in: • change in habitat • injury / mortality to fauna • change in fauna behaviour. Benthic habitats and communities may be vulnerable to hydrocarbon exposure from an oil spill. The stochastic modelling undertaken for the subsea release of the Corowa crude indicated that benthic habitats are not typically predicted to be exposed as the oil remains within surface waters. However, for shallow nearshore areas extending along the western edge and around the northern tip of North West Cape, and some of the Pilbara inshore islands, benthic habitat exposure is possible. Bare sands, macroalgae and coral are habitat types known to occur around the Pilbara inshore islands and North West Cape. **Macroalgae** Macroalgae within the intertidal and shallow subtidal zone may be susceptible to impacts from hydrocarbons, ranging from potentially sublethal to lethal impacts. Toxicity effects can occur due to absorption of dissolved hydrocarbons into tissues (Runcie et al. 2019); the extent of a toxicity impact depends on concentration and duration of exposure. Reported toxic responses to oils have included a variety of physiological changes to enzyme systems, photosynthesis, respiration, and nucleic acid synthesis (Lewis and Pryor 2013). The toxicity of macroalgae to hydrocarbons varies for the different macroalgal life stages; the sensitivity of gametes, larva and zygote stages are more responsive to oil exposure than adult stages (Thursby and Steele 2003; Lewis and Pryor 2013). Physical contact with entrained hydrocarbon droplets could cause sublethal stress, causing reduced growth rates and reduced tolerance to other stress factors (Zieman et al. 1984). In macroalgae, oil can act as a physical barrier for the diffusion of CO_2 across cell walls (O'Brian and Dixon 1976). The effect of hydrocarbons however is largely dependent on the degree of direct exposure and how much of the hydrocarbon adheres to algae, which will vary depending on the oils physical state and relative 'stickiness'. Where impact does occur recovery is expected to occur. Recovery of algae is attributed to new growth being produced from near the base of the plant while the distal parts (which would be exposed to the oil contamination) are continually lost. Other studies have indicated that oiled kelp beds had a 90% recovery within 3–4 years of impact, however full recovery to pre-spill diversity may not occur for long periods after the spill (French-McCay 2004). **Coral** Corals within the intertidal and shallow subtidal zone may be susceptible to impacts from hydrocarbons, ranging from potentially sublethal to lethal impacts. Experimental studies and field observations indicate all coral species are sensitive to the effects of oil, although there are considerable differences in the degree of tolerance between species (e.g. NOAA 2010a). Differences in sensitivities may be due to the ease with which oil adheres to the coral structures, the degree of mucous production and self-cleaning, or simply different physiological tolerances. For example, laboratory and field studies have demonstrated that branching corals appear to have a higher susceptibility to hydrocarbon exposure than massive corals or corals with large polyps Physical oiling of coral tissue can cause a decline in metabolic rate and may cause varying degrees of tissue decomposition and death (Negri and Heyward 2000). Direct contact of coral by hydrocarbons may also impair respiration and photosynthesis by symbiotic zooxanthellae (Peters 1981; Knap et al. 1985). Chronic effects of oil exposure have been consistently noted in corals and, ultimately, can kill the entire colony. Chronic impacts include histological, biochemical, behavioural, reproductive and developmental effects. Reproductive stages of corals have been found to be more sensitive to oil toxicity. Fertilisation of coral species has been observed to be completely blocked in *Acropora tenuis* at heavy fuel oil concentrations of 150 ppb (Harrison 1994; 1999), with significant reductions in fertilisation of *A. millepora* and *A. valida* at concentrations between 580 and 5,800 ppb, in addition to developmental abnormalities and reduced survival of coral larvae at similar concentrations (Lane and Harrison 2000). Lower concentrations of less than 100 ppb crude oil were observed to inhibit larval metamorphosis in *A. millepora* (Negri and Heywood 2000).

Studies undertaken after the Montara incident included diver surveys to assess the status of Ashmore, Cartier and Seringapatam coral reefs. These found that other than a region-wide coral bleaching event caused by thermal stress (i.e. caused by sea water exceeding 32°C), the condition of the reefs was consistent with previous surveys, suggesting that any effects of hydrocarbons reaching these reefs was minor, transitory or sublethal and not detectable (Heyward et al. 2010). This is despite AMSA observations of surface slicks or sheen nears these shallow reefs during the spill (Heyward et al. 2010). Surveys in 2011 indicated that the corals exhibiting bleaching in 2010 had largely survived and recovered (Heyward et al. 2012), indicating that potential exposure to hydrocarbons while in an already stressed state did not have any impact on the healthy recovery of the coral.

Summary

The Corowa crude is classified as a non-persistent oil and has a high proportion (~94.1%) of volatile components and only a small (5.9%) residual component. Due to this volatility, once exposed to the atmosphere (e.g. on the surface) most of this oil is expected to evaporate within several days. Entrained and dissolved oil components may persist for periods of time greater than floating oil.

Given the details above, the consequence of an accidental release of Corowa light crude oil causing any permanent and/or significant impacts to benthic habitats and communities has been assessed as **Moderate (2)**, with the impact assessed as **Very unlikely (B)** to occur given that exposure of benthic habitats to hydrocarbons is expected to be restricted to intertidal and the shallow subtidal zone.

Plankton ✓

Injury / mortality to fauna.

Plankton may be vulnerable to hydrocarbon exposure from an oil spill. While plankton can occur throughout the water column, they are generally more abundant in the surface layers. Plankton forms the basis of the marine food web, and so any direct adverse impact may have subsequent indirect impacts further along the chain. However, a localised exposure is unlikely to affect plankton populations at the regional scale, and therefore regional indirect impacts are also not expected to occur. Surface waters of the NWS are typically low in nutrients, and so areas of vertical mixing (e.g. upwelling along the shelf edge) are likely to have a higher abundance of plankton.

Phytoplankton are typically not sensitive to the impacts of oil, though they do accumulate it rapidly (Hook et al. 2016). Oil can affect the rate of photosynthesis and inhibit growth in phytoplankton, depending on the concentration range. For example, photosynthesis is stimulated by low concentrations of fresh oil in the water column (10–30 ppb) but become progressively inhibited at concentrations >50 ppb. Conversely, photosynthesis can be stimulated at concentrations of <100 ppb for exposure to weathered oil (Volkman et al. 2004).

Zooplankton are vulnerable to hydrocarbons (Hook et al. 2016). Water column organisms may be impacted by oil via exposure through ingestion, inhalation and dermal contact (NRDA 2012), which can cause immediate mortality or declines in reproduction (Hook et al. 2016). However, reproduction by survivors or migration from unaffected areas is likely to rapidly replenish losses (Volkman et al. 2004). Entrained oil droplets are frequently in the food size spectra for zooplankton (Almeda et al. 2013). Lethal and sublethal effects, including narcosis, alterations in feeding, development, and reproduction have been observed in copepods exposed to petroleum hydrocarbons (Almeda et al. 2013). However, the effects on zooplankton can vary widely depending on intrinsic (e.g. species, life stage, size) and extrinsic (e.g. exposure value and duration) factors (Almeda et al. 2013).

The actual area of exposure for an individual spill event will be relatively small, with exposure shown to be transient and temporary due to the influence of waves, currents and weathering processes. Once background water quality is re-established, plankton takes weeks to months to recover (ITOPF 2011a).

Results from the stochastic modelling also showed that the time-integrated exposures (i.e. areas consistently exposed to an exposure value for ≥96 hours) were smaller than the equivalent instantaneous (i.e. areas exposed to an exposure value for 1 hour). As organisms require exposure to a toxicant over a period of time for toxic effects to occur, the majority of the area exposed to entrained and dissolved oils are expected to be representative of potential sublethal impacts only.

Given the details above, the consequence of an accidental release of Corowa light crude oil causing injury / mortality to plankton species has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur given that effects on plankton will be localised and temporary.

Seabirds and Shorebirds ✓

An accidental release of light crude oil has the potential to result in:

- injury / mortality to fauna
- change in fauna behaviour.

Seabirds and shorebirds may be vulnerable to hydrocarbon exposure from an oil spill. Birds at sea (e.g. foraging, resting) and onshore (e.g. roosting, nesting) have the potential to directly interact with surface oils. Seabird species most at risk include those that readily rest on the sea surface (e.g. shearwaters) and surface plunging species (e.g. terns, boobies). As seabirds are a top order predator, any impact on other marine life (e.g. krill, fish) may disrupt and limit food supply both for the maintenance of adults and the provisioning of young.

For seabirds, direct contact with hydrocarbons can foul feathers, which may subsequently result in hypothermia due to a reduction in the ability of the bird to thermo-regulate and impair waterproofing. Direct contact with surface hydrocarbons may also result in dehydration, drowning and starvation (DSEWPaC 2011b; AMSA 2013b). Increased heat loss as a result of a loss of waterproofing results in an increased metabolism of food reserves in the body, which is not countered by a corresponding increase in food intake, may lead to emaciation (DSEPWC 2011b). The greatest vulnerability in this case occurs when birds are feeding or resting at the sea surface (Peakall et al. 1987). Due to the location of their feeding habitats shorebirds are likely to be exposed to oil when it directly impacts the intertidal zone and onshore. Foraging shorebirds will be at potential risk of both direct impacts through contamination of individual birds (e.g. fouling of feathers) and indirect impacts (e.g. fouling and/or a reduction in prey items) (Clarke 2010). Oiling of birds can also suffer from damage to external tissues, including skin and eyes, as well as internal tissue irritation in their lungs and stomachs. In a review of 45 actual marine spills, there was no correlation between the numbers of bird deaths and the volume of the spill (Burger 1993).

Breeding birds (both seabirds and shorebirds) may be exposed to oil via direct contact or the contamination of the breeding habitat (e.g. shores of islands) (Clarke 2010). Bird eggs may subsequently be damaged if an oiled adult sits on the nest. Fresh crude was shown to be more toxic than weathered crude, which had a medial lethal dose of 21.3 mg/egg. Studies of contamination of duck eggs by small quantities of crude oil, mimicking the effect of oil transfer by parent birds, have been shown to result in mortality of developing embryos.

Toxic effects on birds may result where oil is ingested as the bird attempts to preen its feathers, or via consumption of oil-affected prey. Whether this toxicity ultimately results in mortality will depend on the amount consumed and other factors relating to the health and sensitivity of the particular bird species. Results from the stochastic modelling also showed that the time-integrated exposures (i.e. areas consistently exposed to an exposure value for ≥96 hours) were smaller than the equivalent instantaneous (i.e. areas exposed to an exposure value for 1 hour). As organisms require exposure to a toxicant over a period of time for toxic effects to occur, the majority of the area exposed to entrained and dissolved oils are expected to be representative of potential sublethal impacts only.

The Corowa crude is classified as a non-persistent oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~94.1%) of volatile components and only a small (5.9%) residual component. Due to this volatility, once on the water surface most of this oil will evaporate; depending on wind conditions, the proportion of evaporated oil may vary between ~73–91% within several days of release (Section 7.2.6.2.3). Modelling undertaken for the subsea release of the Corowa crude indicated that floating oil may extend in a NE/SW and offshore direction from the spill site, and potentially up to a maximum of 476 km; shoreline accumulation of oil was predicted to occur within an area extending along the western edge and around the northern tip of North West Cape, and some of the Pilbara inshore islands, specifically the Muiron and Serrurier islands, which are known as important nesting habitat for Wedge-tailed Shearwaters.

The area potentially at risk from floating and/or shoreline exposure includes offshore islands that are known nesting habitats for migratory bird species (some with associated BIAs, such as the Wedge-tailed Shearwater). However, the actual area of exposure for an individual spill event will be relatively small, with exposure shown to be transient and temporary due to the influence of waves, currents and weathering processes.

Given the details above, the consequence of an accidental release of Corowa light crude oil causing injury / mortality to fauna or a change in fauna behaviour in seabirds and shorebirds has been assessed as **Moderate (2)**, with the impact assessed as **Very Unlikely (B)** to occur given that effects will be localised and temporary, and are not expected to occur at a population level.

Fish ✓

An accidental release of light crude oil has the potential to result in:

- injury / mortality to fauna
- change in fauna behaviour.

Fish may be vulnerable to hydrocarbon exposure from an oil spill. Since fish do not generally break the sea surface, the risk from oil spills is more likely to occur from entrained and dissolved oil components.

Fish can be exposed to oil through a variety of pathways, including direct dermal contact (e.g. swimming through oil), ingestion (e.g. directly or via oil-affected prey/foods), and inhalation (e.g. elevated dissolved contaminant concentrations in water passing over the gills). Exposure to hydrocarbons entrained or dissolved in the water column can be toxic to fishes. Of the potential toxicants, monocyclic and polycyclic aromatic hydrocarbons (MAHs and PAHs) are generally regarded as the most toxic to fish; these toxicants form part of the dissolved oil component. Studies have shown a range of impacts including changes in abundance, decreased size, inhibited swimming ability, changes to oxygen consumption and respiration, changes to reproduction, immune system responses, DNA damage, visible skin and organ lesions, and increased parasitism. However, many fish species can metabolise toxic hydrocarbons, which reduces the risk of bioaccumulation (NRDA 2012). In addition, very few studies have demonstrated increased mortality of fish as a result of oil spills (Fodrie et al. 2014; Hjermann et al. 2007; IPIECA 1997).

Demersal fish are not expected to be impacted given the presence of entrained and dissolved oil is predicted in the surface layers only.

Pelagic free-swimming fish and sharks are unlikely to suffer long-term damage from oil spill exposure because dissolved/entrained hydrocarbons are typically insufficient to cause harm (ITOPF 2011). Pelagic species are also generally highly mobile and as such are not likely to suffer extended exposure (e.g. >40–96 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 (Volkman et al. 2004). 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 (King et al. 1996).

Fish are most vulnerable to oil during embryonic, larval and juvenile life stages. Oil exposure may result in decreased spawning success and abnormal larval development. Contact with oil droplets can mechanically damage feeding and breathing apparatus of embryos and larvae (Fodrie and Heck 2011). The toxic hydrocarbons in water can result in genetic damage, physical deformities and altered developmental timing for larvae and eggs exposed to even low concentrations over prolonged timeframes (days to weeks) (Fodrie and Heck 2011).

Marine fauna with gill-based respiratory systems, including Whale Sharks, are expected to have higher sensitivity to exposures of entrained oil. In addition, the tendency of Whale Sharks to feed close to surface waters increases the likelihood of exposure to surface slicks. A foraging BIA has been identified within the area at risk of potential exposure to surface, entrained and dissolved oils from a spill from the Corowa Development. Surface spills may also affect Whale Shark migration if attempting to travel through an area impacted by a spill. This displacement may cause stress in the animal and disrupt future migration to these areas (Taylor et al. 2007). However, Whale Sharks do not spend all their time in surface waters—they routinely move between surface and to depths or >30 m, and in offshore regions can spend most of their time near the seafloor (DSEWPaC 2012).

Given the details above, the consequence of an accidental release of Corowa light crude oil causing injury / mortality to fauna or a change in fauna behaviour in fish species has been assessed as **Moderate (2)**, with the impact assessed as **Very unlikely (B)** to occur given effects will be localised and temporary and are not expected to occur at a population level.

Marine Reptiles ✓
An accidental release of light crude oil has the potential to result in: • injury / mortality to fauna • change in fauna behaviour. Marine reptiles may be vulnerable to hydrocarbon exposure from an oil spill. Marine reptiles (e.g. turtles) can be impacted by surface exposure when they surface to breathe, and by shoreline accumulation when nesting. Marine turtles can be exposed to oil externally (e.g. swimming through oil slicks) or internally (e.g. swallowing the oil, consuming oil-affected prey, or inhaling of volatile oil related compounds). Marine turtles are vulnerable to the effects of oil at all life stages: eggs, hatchlings, juveniles, and adults. Oil exposure affects different life stages in different ways, and each life stage frequents a habitat with varied potential to be impacted during an oil spill. Effects of oil on turtles include increased egg mortality and developmental defects; direct mortality due to oiling in hatchlings, juveniles, and adults; and negative impacts to the skin, blood, digestive and immune systems, and salt glands. Several aspects of turtle biology and behaviour place them at particular risk, including a lack of avoidance (NOAA 2010b) and large pre-dive inhalations (Milton and Lutz 2003). Experiments on physiological and clinical pathological effects of hydrocarbons on Loggerhead Turtles (~15–18 months old) showed that the major physiological systems were adversely affected by both chronic and acute exposures (96-hour exposure to a 0.05 cm layer of South Louisiana crude oil versus 0.5 cm for 48 hours) (Lutcavage et al. 1995). Recovery from the sloughing skin and mucosa took up to 21 days, increasing the turtle's susceptibility to infection or other diseases (Lutcavage et al. 1995). Records of oiled wildlife during spills rarely include marine turtles, even from areas where they are known to be relatively abundant (Short 2011). An exception to this was the large number of marine turtles collected (613 dead and 536 live) during the Deepwater Horizon incident in the Gulf of Mexico, although many of these animals did not show any sign of oil exposure (NOAA 2011; 2013a). Of the dead turtles found, 3.4% were visibly oiled and 85% of the live turtles found were oiled (NOAA 2013b). Of the captured animals, 88% of live turtles were later released, suggesting that oiling does not inevitably lead to mortality. Protected and migratory turtle species (e.g. Flatback, Green, and Hawksbill Turtles) are known to nest on the Pilbara inshore islands, within the area that may be exposed to shoreline accumulation from an oil spill from the Corowa Development, specifically the Muiron and Serrurier islands. BIAs and critical habitat for nesting have also been identified for these species within the area. Turtles may experience oiling impacts on nesting beaches and eggs through chemical exposures resulting in decreased survival to hatching and developmental defects in hatchlings. Adult females crossing an oiled beach could cause external oiling of the skin and carapace; most oil is deposited in the high-tide zone, and most turtles nest well above this level. Turtle hatchlings may be more vulnerable to smothering as they emerge from the nests and make their way over the intertidal area to the water (AMSA 2015b). Hatchlings that contact oil residues while crossing a beach can exhibit a range of effects including impaired movement and bodily functions (Shigenaka 2003). Hatchlings sticky with oily residues may also have more difficulty crawling and swimming, rendering them more vulnerable to predation. Given the details above, the consequence of an accidental release of Corowa light crude oil causing injury / mortality to fauna or a change in fauna behaviour in marine reptile species has been assessed as **Moderate (2)**, with the impact assessed as **Very Unlikely (B)** to occur given effects will be localised and temporary and are not expected to occur at a population level.
Marine Mammals ✓
An accidental release of light crude oil has the potential to result in: • injury / mortality to fauna • change in fauna behaviour. Marine mammals may be vulnerable to hydrocarbon exposure from an oil spill. Marine mammals (e.g. cetaceans, Dugongs) can be impacted by surface exposure when they surface to breathe, and by entrained/dissolved components in the water column. Marine mammals can be exposed to oil externally (e.g. swimming through surface slick or entrained oil) or internally (e.g. swallowing the oil, consuming oil-affected prey, or inhaling of volatile oil related compounds).

Direct contact with surface oil is considered to have little deleterious effect on whales, possibly due to the skin's effectiveness as a barrier to toxicity. Furthermore, effect of oil on cetacean skin is probably minor and temporary (Geraci and St Aubin 1982). French-McCay (2009) identifies that a 10–25 µm oil thickness threshold has the potential to impart a lethal dose to the species; however, the study also estimates a probability of 0.1% mortality to cetaceans if they encounter these thresholds based on the proportion of the time spent at surface.

The physical impacts from ingested hydrocarbons with subsequent lethal or sublethal impacts are applicable; however, the susceptibility of cetaceans 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. As highly mobile species, in general it is very unlikely that these animals will be constantly exposed to concentrations of hydrocarbons in the water column for continuous durations (e.g. >48–96 hours) that would lead to chronic effects. Note also, many marine mammals appear to have the necessary liver enzymes to metabolise hydrocarbons and excrete them as polar derivatives. Results from the stochastic modelling also showed that the time-integrated exposures (i.e. areas consistently exposed to an exposure value for ≥96 hours) were smaller than the equivalent instantaneous (i.e. areas exposed to an exposure value for 1 hour). As organisms require exposure to a toxicant over a period of time for toxic effects to occur, the majority of the area exposed to entrained and dissolved oils are expected to be representative of potential sublethal impacts only.

Like turtles, cetaceans appear to not exhibit avoidance behaviours. Evidence suggests that many cetacean species are unlikely to detect and avoid spilled oil (Harvey and Dahlheim 1994, Matkin et al. 2008). There are numerous examples where cetaceans have appeared to incidentally encounter oil and/or not demonstrated any obvious avoidance behaviour; e.g. following the Exxon oil spill, Matkin et al. (2008) reported Killer Whales in slicks of oil as early as 24 hours after the spill.

Some whales, particularly those with coastal migration and reproduction, display strong site fidelity to specific resting, breeding and feeding habitats, as well as to their migratory paths. Migratory BIAs identified for the Pygmy Blue Whale and Humpback Whale occur within the area that may be exposed from an oil spill from the Corowa Development. If spilled oil reaches these biologically important habitats, the oil may disrupt natural behaviours, displace animals, reduce foraging or reproductive success rates and increase mortality.

Dugongs have smooth skin surfaces and therefore are less likely to be affected by oil adhering to their skin. If surfacing in a slick, the Dugongs may foul their sensory hairs (around their mouths) or their eyes; these could lead to inflammation/infections that then affect their ability to feed or breed (AMSA 2018). Dugongs may also ingest oil (directly, or indirectly via oil-affected seagrass), and depending on the amount and type of oil, the effects could be short-term to long-term/chronic (e.g. organ damage). However, it is noted that reports on oil pollution damage to Dugongs is rare (ITOPF 2014). There is a BIA for foraging, breeding, nursing and calving within the Exmouth Gulf and North West Cape region for Dugongs. The probability of exposure of this BIA to floating oil (at >10 g/m^2) was low, at 8–16%. The predicted distribution of entrained or dissolved oils did not enter deep into Exmouth Gulf, and so any exposure to these oil components would be in surface waters along the northern part of the Gulf or along North West Cape. Due to the oil remaining on the surface and/or within surface waters, no impact to seagrass and foraging sources is expected. In addition, due to the volatility of the oil, predicted lengths of exposure are expected to be minimal.

Given the details above, the consequence of an accidental release of Corowa light crude oil causing injury / mortality to fauna or a change in fauna behaviour in marine mammals has been assessed as **Moderate (2)**, with the impact assessed as **Very Unlikely (B)** to occur given effects will be localised and temporary and are not expected to occur at a population level.

7.2.6.3.3 Social, Economic and Cultural Receptors

Social, economic and cultural receptors have the potential to be impacted as a result of impacts to physical or ecological receptors.

Impacts to the identified receptors include:

- change in water quality
- change in sediment quality
- change in habitat
- injury / mortality to fauna
- change in fauna behaviour
- changes to the functions, interests or activities of other users
- change in aesthetic value.

Table 7-131 provides a detailed evaluation of the impact of an accidental release of Corowa light crude oil to social, economic and cultural receptors.

Table 7-131 Impact and Risk Assessment for Social, Economic and Cultural Receptors from Accidental Release – Corowa Light Crude Oil

Australian Marine Parks; State Protected Areas – Marine; Heritage Features ✓
An accidental hydrocarbon release of light crude oil has the potential to result in: • change in water quality • change in sediment quality • change in habitat • injury / mortality to fauna • change in fauna behaviour • changes to the functions, interests or activities of other users • change in aesthetic value. Marine protected areas (including marine parks and heritage listed places) may be vulnerable to hydrocarbon exposures from an oil spill. As the values and sensitivities of these protected places are a combination of quality, habitat, marine fauna and flora, and human use, the impact pathways are varied. Refer also to impact assessments for related receptors, including water quality, sediment quality, coastal and benthic habitats and communities and marine fauna. **Australian Marine Parks and State Protected Areas – Marine** Marine parks/reserves that may be exposed to floating oil are Ningaloo MP (State and Commonwealth), Gascoyne MP, Muiron Islands MMA. Floating oil can lead to temporary decrease in aesthetic values. Entrained and dissolved hydrocarbons are predicted to potentially travel a greater distance; however, both the exposure value and the probability of exposure occurring reduces with distance from the spill location. However, these oil components are predicted to remain within the surface layers (predominantly within the 0–10 m depth, with some occasional and low probability of exposures to depths up to 30 m). Therefore, impacts to pelagic values (e.g. marine fauna) are restricted to those in surface waters only. **Heritage Features** The Ningaloo Coast WHA may be exposed to floating, entrained, dissolved and shoreline oil components in the event of a spill of Corowa crude. Potential impacts range from a temporary decrease in aesthetic values to physical coating and/or toxicity effects associated with the values of the WHA (e.g. marine fauna, coastal habitats etc.). There are also known shipwrecks within the predicted area of entrained and dissolved oil exposure. However, both wrecks are situated in waters >2000 m. Stochastic modelling undertaken for the subsea release of the Corowa crude indicated that if/when entrained oil did occur it remained in the surface layers (predominantly within the 0–10 m depth, with some occasional and low probability of exposures to depths up to 30 m). Therefore, no impact to shipwrecks is expected to occur. **Summary** Given the details above, the consequence of an accidental release of Corowa light crude oil causing any permanent and/or significant impacts to AMPs, State Protected Areas – Marine and/or Heritage Features

has been assessed as **Moderate (2)**, with the impact assessed as **Very unlikely (B)** to occur given effects will be temporary and spatially restricted.

Key Ecological Features ✓

An accidental hydrocarbon release of light crude oil has the potential to result in:

- change in water quality
- change in habitat
- injury / mortality to fauna
- change in fauna behaviour.

The Corowa crude is classified as a non-persistent oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~94.1%) of volatile components and only a small (5.9%) residual component. Due to this volatility, once on the water surface most of this oil is expected to evaporate within several days. Weathering tests on Corowa light crude oil predicted that after 7 days, 91% had evaporated. Entrained and dissolved oil may persist for longer (compared to floating oil); however, hydrocarbons are predicted to remain within the surface layers (predominantly within the 0–10 m depth, with some occasional and low probability of exposures to depths up to 30 m).

Therefore, KEFs associated with seafloor features and/or benthic and demersal fauna and flora (e.g. ancient coastline at 125 m, continental slope demersal fish communities), are not expected to be impacted by a release of Corowa crude.

However, for those KEFs where values include marine waters and/or pelagic fauna (e.g. Commonwealth waters adjacent to Ningaloo Reef, Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula etc.), these may be vulnerable to a spill of Corowa crude.

The actual area of exposure for an individual spill event will be relatively small, with exposure shown to be transient and temporary due to the influence of waves, currents and weathering processes.

Refer also to impact assessments for related receptors, including water quality and marine fauna.

Given the details above, the consequence of an accidental release of Corowa light crude oil causing any permanent and/or significant impacts to KEFs within the EMBA has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur given that any change in water quality or habitat would be restricted to surface waters within a spatially restricted area, and similarly any change in pelagic fauna (see previous impact assessments) is not expected to occur at population levels.

Industry ✓

Changes to the functions, interests or activities of other users

Marine and coastal industries in the EMBA mainly comprise petroleum activities, commercial shipping and associated ports and defence activities.

Offshore petroleum activities in the region include Santos' Ningaloo Vision FPSO (~49 km), Woodside's Ngujima-Yin FPSO (~51 km), BHP's Pyrenees FPSO (~46 km) and BHP's Stybarrow Development (~75 km; note this is in cessation operations and the FPSO has left the field) and may potentially be exposed to in-water oil exposure. In the event of a large spill, an exclusion zone may be established around the spill-affected area. Any exclusion zone is likely to be localised to the source of the spill. Also, as light crude oil is subject to rapid evaporation the exclusion zone is likely to be temporary minimising the impacts to these developments.

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 (Forbes 2017).

Land-based processing hubs include Ashburton North (Wheatstone LNG), Varanus Island, Barrow Island (Gorgon LNG), and Woodside's Burrup Hub near Dampier; however, these are all beyond the predicted area of exposure of the modelled subsea release of Corowa crude.

The largest ports adjacent to the Corowa field are the Ports of Dampier and Port Hedland; however, these are all beyond the predicted area of exposure of the modelled subsea release of Corowa crude.

Defence practice and training areas extend offshore from Learmonth RAAF base. In-water hydrocarbon exposure is not expected to adversely impact the use of these areas.

Given the details above, the consequence of an accidental release of Corowa light crude oil causing a change in the functions, interests or activities of other users (Marine and Coastal Industries) has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur due to being beyond the predicted area of exposure of the modelled subsea release of Corowa crude and rapid evaporation so any exclusion zone is likely to be temporary.

Commercial Fisheries ✓

Changes to the functions, interests or activities of other users

Oil spills can damage fishery and mariculture resources through physical contamination, toxic effects on stock and by disrupting business activities. The nature and extent of the impact on seafood production depends on the characteristics of the spilled oil, the circumstances of the incident and the type of fishing activity or business affected.

Tainting is a change in the characteristic smell or flavour of fish and may be due to oil being taken up by the tissues or contaminating the surface catch (McIntyre et al. 1982). Taint in seafood renders it unfit for human consumption or unsellable due to public perception. Light oils and the middle boiling range of crude distillates are the most potent sources of taint (Whittle 1978). Tainting may not be a permanent condition but will persist if the organisms are continuously exposed; when exposure is terminated, depuration will quickly occur (McIntyre et al. 1982).

A major oil spill may result in the temporary closure of part of fishery management areas. It is unlikely that a complete fishery would be closed due to their large spatial extents, but the partial closure may still displace fishing effort. Oil spills may also foul fishing equipment (e.g. traps and trawl nets) and requiring cleaning or replacement; however, due to the volatility of the Corowa crude, this would only be expected for in the immediate vicinity of the wells, as the crude weathers rapidly with time and distance.

Five Commonwealth-managed commercial fisheries have management areas that intersect with the hydrocarbon exposure area (North West Slope Trawl Fishery (NWSTF), Southern Bluefin Tuna Fishery (SBTF), Western Deepwater Trawl Fishery (WDTF) and Western Tuna and Billfish Fishery (WTBF). The Western Skipjack Tuna Fishery (WSTF) has had no active fishing operations since the 2008–2009 season.

Based on historical fishing effort, the Commonwealth fisheries that may be active in the Corowa Development Areas have management areas from the 200 m isobath to the Australian Fishing Zone. Modelling of the Corowa crude indicates that oil at these depths is not expected to occur; however, oil is predicted to be present at the surface, which would still impact fishing effort, due to potential fouling of vessels and equipment, and exclusion from areas.

Historical data for State fisheries suggests that the only fishery with significant catch and fishing days around the Corowa Development is the Exmouth Gulf Prawn Managed Fishery. The modelling of the Corowa crude indicates that the oil does not extend into Exmouth Gulf, and therefore impacts to this fishery are not expected to occur. In the event of a spill, fishing would likely be excluded from impacted areas for some time, which would have a financial impact on commercial fisheries.

A review was conducted by the CSIRO on fisheries potentially affected by the Montara oil spill in 2009, in the Timor Sea (Young et al. 2011). Potential direct and indirect consequences for fisheries in the area of the spill were assessed to identify the ecological risk to species, and to the economic value of the species. The exposure-sensitivity approach suggested the following order of highest risk to species considered in this review: demersal cod followed by sea cucumbers and Southern Bluefin Tuna (SBT). However, when the ranks were weighted by economic importance, the order became: SBT, Red Emperor, demersal cod. The Montara oil is a Group 2/3 oil and is solid at temperatures <27 degrees. whereas Corowa light crude is Group 1, lighter and disperses and evaporates more rapidly.

Actual effects of hydrocarbons on marine fisheries yield or other ecological processes are not well known. There are multiple studies on toxicological effects of exposure to hydrocarbons for fish, including lethal and sublethal effects from laboratory, modelling and field studies (e.g. Bax 1987; Marty et al. 1997), which indicate there is a potential for long-term changes in development, reproduction and growth.

The Deepwater Horizon oil spill in April 2010 resulted in fisheries closures across the Gulf of Mexico (Mccrea-Strub et al. 2011). Because of concerns over food safety, in May 2010 NOAA initiated closures of federal waters to commercial and recreational fishing. By January 2011, 10,911 km^2 of federal waters around the well and parts of Louisiana State coastal waters remained closed to commercial and recreational fishing (Gohlke et al. 2011). Federal agencies, in collaboration with impacted Gulf states, developed a protocol to determine when it is safe to reopen fisheries based on sensory and chemical analyses of seafood. In April 2011, NOAA reopened all remaining federal waters (Gohlke et al. 2011). Continued analysis of Gulf seafood was recommended to determine potential long-term health impacts and restore consumer confidence in Gulf fisheries (Oil Spill Commission 2011). The Deepwater Horizon incident may differ from other spills because of the depth at which the LOWC occurred, and the unprecedented volume of dispersants used (Gohlke et al. 2011).

Given the details above, the consequence of an accidental release of Corowa light crude oil causing a change in the functions, interests or activities of other users (commercial fisheries) has been assessed as **Minor (1)** with the impact assessed as **Very Unlikely (B)** to occur, due to the low fishing activity within the EMBA.

Tourism and Recreation	✓

An accidental hydrocarbon release of light crude oil has the potential to result in:

- changes to the functions, interests or activities of other users
- change in aesthetic value.

Tourism is a key economic driver, generating more than 97,000 jobs and injecting $10 billion into the Western Australian economy by Gross State Product (Tourism WA 2016). Coastal and marine-based tourism is a significant portion of this income due to the majority of the towns, infrastructure and sites located along the coast (DoT 2018). Charter fishing, diving, snorkelling, whale, marine turtle and dolphin watching plus cruising are the main commercial tourism activities in and adjacent to the North-west Marine Region (DEWHA 2008). Apart from offshore charter fishing, these activities are generally centred around shallow coastal waters or around areas of fauna aggregation, generally within state waters.

Any disruption to activities such as vessel activities, fishing and diving can have follow-on effects on accommodation, tourism business and other companies who gain their livelihood from tourism. Coastal areas can be affected by oil spills due to public perception and reduction in amenity. Activities that are based around marine fauna and habitats are likely to be impacted the most (e.g. diving activities on coral reefs and other marine tourist operators).

Refer also to impact assessments for related receptors, including coastal and benthic habitats and communities and marine fauna.

Given the details above, the consequence of an accidental release of Corowa light crude oil causing a change in the functions, interests or activities of other users (tourism and recreation) and a change in aesthetic values, has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur, given that effects will be highly localised and temporary in nature.

7.2.6.4 Consequence and Acceptability Summary

The consequence of an accidental release of Corowa crude has been evaluated as **Moderate (2)** for the worst-case potentially impacted receptors (ecological and social, economic and cultural receptors).

Drilling and well intervention are standard offshore petroleum activities. The probability of a loss of well control is very low, in the order of 0.0001%, according to industry records (SINTEF 2017).

Regarding the failure of a bulk crude tank on the FSO, vessel collisions are rare, with only 37 collisions reported from 1200 marine incidents in Australian waters from 2005–2012 (Australian Transport Safety Bureau 2013). The FSO is stationary, and the only approaching vessels should be tankers and support vessels, which would approach at a slow speed (<5 knots). Non-project vessels would remain outside the PSZ. The worst-case likelihood was assessed as **Unlikely (C).**

The risk level for all receptors is **Low** and considered **acceptable** based on an evaluation against the criteria in Table 7-132.

Table 7-132 Demonstration of Acceptability for Accidental Release – Corowa Light Crude Oil

Acceptability Criteria	Justification
To meet the principles of ESD	• Corowa crude is classified as a non-persistent oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~94.1%) of volatile components and only a small (5.9%) residual component. • Weathering tests on Corowa light crude oil predicted that after 7 days, 91% had evaporated, 7% of the oil remained on the sea surface, and a negligible amount had entrained. • Mangrove Bay (on North West Cape) is the only area of saltmarsh and mangrove habitat that is predicted to be potentially be exposed to shoreline accumulation above the impact threshold, with IPIECA (1994) stating an expected recovery time of <2 years. • Shoreline accumulation above the impact threshold may occur along the western coast of North West Cape and through the Pilbara inshore island chain between Muiron and Serrurier islands, which are within BIAs for Wedge-tailed Shearwaters (breeding), and marine turtle species (internesting). • BIAs for Dugongs, Humpback Whales and Pygmy Blue Whales are within the area at risk of potential exposure to surface, entrained and dissolved oils. However, as highly mobile species, in general it is very unlikely that these animals will be constantly exposed to concentrations of oils in the water column for continuous durations (e.g. >48–96 hours) that would lead to chronic effects. • Ningaloo Coast WHA may be exposed to floating, entrained, dissolved and shoreline oil components in the event of a spill of Corowa crude. Potential impacts range from a temporary decrease in aesthetic values to physical coating and/or toxicity effects associated with the values of the WHA (e.g. marine fauna, coastal habitats etc.). • The Ningaloo MP (State and Commonwealth), Gascoyne MP, Muiron Islands MMA may be exposed to floating, entrained, dissolved oil. • KEFs where values include marine waters and/or pelagic fauna (e.g. Commonwealth waters adjacent to Ningaloo Reef, Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula) may be vulnerable to a spill of Corowa crude. • Modelling predicts that oil does not extend into the Exmouth Gulf, and therefore impacts to the only fishery with significant catch and fishing days (Exmouth Gulf Prawn Managed Fishery) are not expected.
Internal context	• KATO Marine Operations Procedure (KAT-000-PO-PP-101) (KATO 2020b)
External context	• No stakeholder concerns have been raised with respect to accidental release – light crude oil or potentially impacted receptors.
Other requirements	• Activities undertaken during the Corowa Development will adhere to the requirements for EPs and Oil Pollution Emergency Plans (OPEPs) under the OPGGS(E)R. • OPGGS Act requires an accepted Well Operations Management Plan (WOMP) in place for all wells, which describes well integrity risk management process and well control measures. • Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and the *Navigation Act 2012* implements the International Convention for the Prevention of Pollution from Ships (MARPOL).

Acceptability Criteria	Justification

	• The North-west and South-west Marine Parks Network Management Plan 2018 (DNP 2018) identify marine pollution as a pressure, with no explicit relevant management actions.
	• These Conservation Advices / Recovery Plans identify pollution as a key threat:
	  ○ Conservation advice *Balaenoptera borealis* Sei Whale (TSSC 2015a)
	  ○ Conservation advice *Balaenoptera physalus* Fin Whale (TSSC 2015b)
	  ○ Recovery plan for marine turtles in Australia (CoA 2017), identified as acute chemical discharge (oil pollution)
	  ○ Conservation advice *Calidris ferruginea* (Curlew Sandpiper) (DoE 2015a) identified as Habitat degradation/ modification (oil pollution)
	  ○ National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011)
	  ○ Conservation advice for *Sterna nereis* (Fairy Tern) (TSSC 2011b)
	• These Conservation Advices / Recovery Plans identify habitats degradation/modification as threat, which may be consequence of accidental release of hydrocarbon:
	  ○ Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Seasnake) (TSSC 2011a)
	  ○ Approved Conservation Advice for *Pristis clavata* (Dwarf Sawfish) (TSSC 2009a)
	  ○ Approved Conservation Advice for Green Sawfish (TSSC 2008a)
	  ○ Sawfish and River Shark multispecies recovery plan (CoA 2015b)
	  ○ Approved Conservation Advice for *Pristis* (Largetooth Sawfish) (DoE 2014a)
	  ○ Whale Shark (*Rhincodon typus*) recovery plan 2005–2010 (DEH 2005a)
	  ○ Conservation Advice *Calidris canutus* (Red Knot) (TSSC 2016a)
	  ○ Conservation Advice *Limosa lapponica baueri* (Bar-tailed Godwit (Western Alaskan)) (TSSC 2016b)
	  ○ Conservation Advice *Limosa lapponica menzbieri* (Bar-tailed Godwit (Northern Siberian)) (TSSC 2016c)
	  ○ Conservation Advice for *Numenius madagascariensis* (Eastern Curlew) (DoE 2015c)
	• These conservation advices and recovery plan identify these conservation actions:
	  ○ Minimise chemical and terrestrial discharge.
	  ○ Ensure spill risk strategies and response programs include management for turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs.
	  ○ Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.
	  ○ Ensure appropriate oil spill contingency plans are in place for the subspecies' breeding sites that are vulnerable to oil spills.
	  ○ Implement measures to reduce adverse impacts of habitat degradation and/or modification; or
	  ○ No explicit relevant management actions; oil pollution is recognised as a threat.
	• In regard to accidental release – Corowa light crude oil, activities associated with the Corowa Development will not be conducted in a manner inconsistent with:

Acceptability Criteria	Justification
	○ the objectives of the respective zones of the AMPs and the principles of the IUCN Area Categories applicable to the values of the AMPs ○ the management plan for, or management principles of, Australian World Heritage properties or National Heritage places ○ with a Recovery Plan, threat abatement plan or Conservation Advice for a listed threatened species ○ to the management plan for, or objectives of, State marine parks and reserves, and the principles of the marine parks and reserves zoning ○ protecting biological diversity and ecological integrity of benthic communities and habitats ○ protecting the values of the Commonwealth marine area for other users.

A summary of the impact analysis and evaluation, including control measures adopted and EPOs, is provided in Table 7-133.

Table 7-133 Summary of Impact Assessment for Accidental Release – Corowa Light Crude Oil

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
Ambient water quality	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO13**: To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	**CM03**: Pre-start notifications will be provided to relevant stakeholders at appropriate timing. **CM29** Emergency response activities will be implemented in accordance with a vessel's valid and appropriate Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class). **CM32:** NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place. **CM33:** Emergency response capability will be maintained in accordance with accepted EPs and OPEPs. **CM34:** NOPSEMA-accepted Well Operations Management Plan in place for all wells, in accordance with the	Minor	Unlikely	Low
Ambient sediment quality	Change in sediment quality			Minor	Unlikely	Low
Plankton	Injury / mortality to fauna	**EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species.		Minor	Very unlikely	Low
Benthic habitat and communities	Change in habitat Injury / mortality to fauna Change in fauna behaviour			Moderate	Very unlikely	Low
Coastal habitats and communities	Change in habitat			Moderate	Very unlikely	Low

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
	Injury / mortality to fauna Change in fauna behaviour Change in aesthetic value	**EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution.	*Offshore Petroleum and Greenhouse Gas Storage* Act requirements. **CM35**: Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken. **CM36**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, and vessel speed. **CM37**: If an infill drilling campaign is required, a simultaneous production and drilling (SIMOPS) workshop will be completed, and a procedure developed to manage and mitigate any additional risks due to concurrent activities. At a minimum, this will include shut-in of production and isolation of the reservoir during: • MODU approach and disconnection • handling of the BOP over existing wells • any drilling clash potential due to new wellbore proximity to an existing production wellbore.			
Seabirds and shorebirds	Injury / mortality to fauna Change in fauna behaviour			Moderate	Very unlikely	Low
Fish				Moderate	Very unlikely	Low
Marine reptiles				Moderate	Very unlikely	Low
Marine mammals				Moderate	Very unlikely	Low
Australian Marine Parks	Change in water quality Change in sediment quality Change in habitat Injury / mortality to fauna Change in fauna behaviour Changes to the functions, interests or activities of other users Change in aesthetic value			Moderate	Very unlikely	Low
State Protected Areas – Marine				Moderate	Very unlikely	Low
Heritage Features				Moderate	Very unlikely	Low

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
Key Ecological Features	Change in water quality Change in sediment quality Change in habitat Injury / mortality to fauna Change in fauna behaviour	**EPO14:** To not result in a change that may have an adverse effect on the protection and conservation of biodiversity, ecological processes and other natural, cultural and heritage values of marine parks and protected areas. **EPO15:** To not result in a change that may cause one or more of the World Heritage values or National Heritage values of a declared World Heritage property or National Heritage place to be lost, degraded or damaged, or notably altered, modified, obscured or diminished. **EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted. **EPO17**: To not result in an impact to heritage values or social surroundings, including damage or destruction of a historic shipwreck.		Minor	Very unlikely	Low
Industry	Changes to the functions, interests or activities of other users			Minor	Very unlikely	Low
Commercial fisheries	Changes to the functions, interests or activities of other users			Minor	Very unlikely	Low
Tourism and Recreation	Changes to the functions, interests or activities of other users Change in aesthetic value			Minor	Very unlikely	Low

C=Consequence, L=Likelihood, RL=Risk Level

7.2.7 Accidental Release – Marine Diesel/Gas Oil

During activities associated with the Corowa Development, an accidental release of fuel may occur.

7.2.7.1 Aspect Source

Throughout the Corowa Development, phases and activities that may interact with other receptors include:

Support Activities (all phases)	MODU operations; MOPU operations; FSO operations; vessel operations

Support Activities (all phases)

A variety of vessels will be used during all phases of the Corowa Development, including the FSO, export tankers and supply vessels. However, the type and number of vessels present within the Project Area and the duration of activities is dependent on the phase of the development. All facilities and vessels will carry quantities of hydrocarbons as fuel for propulsion and/or power generation, including Marine Diesel Oil (MDO) and/or Marine Gas Oil (MGO).

KATO has identified the potential spill scenarios from each facility/vessel for MDO/MGO. There are two potential sources of an accidental release of MDO/MGO:

- bulk storage tank (i.e. from storage tank on the MOPU, or FSO)
- vessel collision (i.e. between vessels and/or with the MOPU).

The maximum credible scenario for each source is shown in Table 7-134. Guidance identification of worst-case credible spills scenarios is given in AMSA’s Technical guidelines for preparing contingency plans for Marine and Coastal Facilities (AMSA 2015).

A vessel collision typically occurs as a result of:

- mechanical failure/loss of DP
- navigational error, or
- foundering due to weather.

Grounding is not considered credible due to the water depths (90 m) and absence of submerged features in the Project Area.

The vessel collision scenario poses the worst-case impact for Accidental Release – MDO/MGO out of the scenarios identified in Table 7-134. Therefore, this scenario is used for the purposes of impact assessment and is carried through into spill modelling.

Table 7-134 Potential Maximum Credible Spill Scenarios for Accidental Release – MDO/MGO

Cause	Description	AMSA Basis of Credible Volume	Maximum Credible Volume and Duration
Failure of Bulk MDO/ MGO Tank	Failure of a bulk fuel tank on the MOPU could result in the loss of containment resulting in the instantaneous surface release of diesel from one of the topsides diesel service tanks. As a loss from more than one tank simultaneously is not considered a credible event, the largest topsides tank is considered the maximum credible release.	Volume of largest fuel tank. Largest expected Fuel Oil Tank up to 250 m^3.	Total volume of 250 m^3 released over 1 hour.

Cause	Description	AMSA Basis of Credible Volume	Maximum Credible Volume and Duration
Vessel collision	A vessel collision could lead to loss of containment event and subsequent release of fuel. This could occur between any of the vessels and facilities in the field (i.e. support vessels, anchor handling tugs, FSO, MOPU, export tanker, or a third-party vessel). Based on the IMO's decision to implement a 0.50% sulphur cap on marine fuel from 2020, the assumption is being made that there will be no heavy fuel oils (HFO), which have sulphur levels much higher than this cap, in use or stored on board any of the contracted vessels. Both MDO and MGO may however be used during the development.	Volume of largest fuel tank. Largest vessel tank on board any vessel (including fuel supply vessel) or facility, that is credible to be contacted in a collision (i.e. in the hull or legs of the MOPU).	Total volume of 500 m^3 released over 6 hours.

7.2.7.2 Spill Modelling and Exposure Assessment

Spill modelling has been used to predict the possible trajectories and fate of an accidental release of MGO from a vessel collision (RPS 2019; Appendix E). This model was used during the assessment:

- SIMAP – Oil spill modelling was undertaken using a three-dimensional oil spill trajectory and weathering model, SIMAP (Spill Impact Mapping and Analysis Program), which is designed to simulate the transport, spreading and weathering of specific oil types under the influence of changing meteorological and oceanographic forces.

The spill scenario, oil characteristics and behaviours, environmental thresholds for impact assessment and predicted exposures are summarised below.

7.2.7.2.1 Scenario

The scenario selected for modelling is the surface release of MGO following the rupture of a vessel fuel tank (Table 7-135). This is considered the worst-case scenario for potential fuel releases and therefore is representative of the greatest spatial extent of potential impacts.

Table 7-135 Vessel Collision Event used for Spill Modelling

Scenario Description	Surface release after rupture of a vessel fuel tank
Spill Location	Expected position of MOPU, ~90 m water
Oil Released	MGO
Spill Duration	6 hours
Total Volume Released	500 m^3
Flow Rate	83.3 m^3/hour
Number of Model Simulations	100 during summer conditions (September to March) 100 during winter conditions (May to July) 100 during transitional conditions (April and August)

7.2.7.2.2 *Oil Characteristics*

The MGO selected for modelling is a light persistent oil, with a low dynamic viscosity and low pour point (Table 7-136). The oil has low (2.7%) residual component (i.e. the component that tends not to evaporate and that may persist in the marine environment) and a relatively low (4.6%) aromatics component (i.e. the component that may dissolve into water) (Table 7-136).

Table 7-136 Characteristics of MGO

Classification	Group II, Light persistent oil				
API Gravity	36.4 °API				
Density	0.84 g/cm^3 at 13 °C				
Viscosity	4.0 cP at 13 °C				
Pour Point	-36 °C				
Component	**Volatile**	**Semi-volatile**	**Low volatility**	**Residual**	**Aromatics**
Boiling Point	**<180 °C**	**180–265 °C**	**265–380 °C**	**>380 °C**	**>380 °C**
Percentage of Total Oil	16.4	49.0	31.9	2.7	4.6
Percentage of Aromatic component only	1.9	1.1	1.6	0	N/A

7.2.7.2.3 *Oil Fate and Weathering*

The fate of an oil in the marine environment depends on a number of factors including the physical and chemical properties of the hydrocarbon, the volume released, the prevailing environmental conditions and whether the oil remains at sea or accumulates on a shoreline (ITOPF 2014).

The main physical properties of an oil that affect the behaviour and persistence of the MDO/MGO are:

- *Specific gravity* – The MGO has a specific gravity less than seawater and therefore will have the tendency to float.
- *Distillation characteristics (Volatility)* – The MGO has a high proportion (97.3%) of volatile components that once on the surface will readily evaporate. Typical evaporation times once at the surface and exposed to the atmosphere are:
  - up to 12 hours for the volatile compounds (BP <180 °C)
  - up to 24 hours for the semi-volatile compounds (BP 180–265 °C)
  - several days for the low volatility compounds (BP 265–380 °C) (RPS 2019).

  There is a smaller proportion (2.7%) of the longer and more complex compounds (BP >380 °C) that tends to persist and be subject to relatively slow degradation rather than evaporate (RPS 2019).
- *Viscosity* – The MGO has a low viscosity and will tend to flow and spread.
- *Pour point* – The MGO has a pour point well below ambient seawater temperatures and therefore will stay in liquid form (i.e. it would not tend to form waxy solids).

Soluble aromatic hydrocarbons account for a low proportion (4.6%) of the MGO. The rate of dissolution of the aromatic hydrocarbons increases with an increase in surface area; i.e. they are higher in conditions that generate smaller oil droplets (such as breaking waves compared to a still surface slick). During energetic conditions, these aromatic compounds (which include the BTEX and

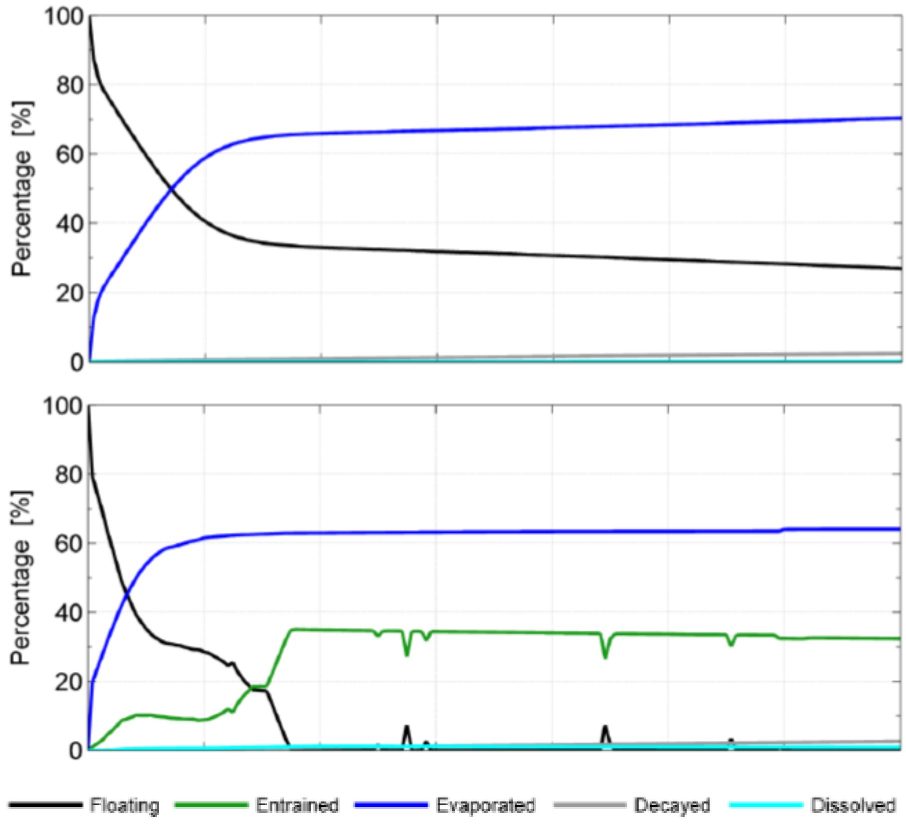
PAH compounds) are likely to dissolve into the water column. Aromatic hydrocarbons that remain in the oil mixture at surface will tend to evaporate rapidly due to their volatility (RPS 2019).

Once released, varying weathering processes (e.g. spreading, evaporation, dispersion and dissolution) act on the oil, and the relative importance of these processes can change over time. Refer to Section 7.2.6.2.3 for a description of general weathering processes.

Weathering tests for the MGO were modelled to confirm expected behaviour of the oil once exposed to the water surface (RPS 2019). Two tests were done under a surface release scenario, one under constant low wind conditions (5 knots) and one under variable winds (4–19 knots).

Under the calmer conditions, by the end of the seven-day model run, ~27% of the oil remained on the sea surface, ~71% had evaporated, a negligible amount had entrained, and ~2% undergoing degradation (Figure 7-29). Under the variable wind conditions, <1% was predicted to remain on the sea surface, with ~64% evaporating and ~32% being entrained into the water column and ~3% undergoing degradation (Figure 7-29). The variable wind scenario generated conditions that would entrain oil, which also led to a higher proportion dissolving.

The weathering tests also showed the MGO was subject to slow degradation (<1% per day) rates, which would likely increase any area of exposure (RPS 2019).



Source: RPS 2019X

Figure 7-29 Predicted Weathering for a Release of 50 m³ MGO under Constant Low (5 knot) [upper figure]and Variable (4–19 knots) [lower figure] Wind Conditions

7.2.7.2.4 Environmental Thresholds

Oil is a mixture of hydrocarbons of varying physical, chemical, and toxicological characteristics, and therefore, these components have varying fates and impacts (French-McCay 2018). Four components were modelled and used within the impact assessment:

- in-water (floating)
- in-water (dissolved)
- in-water (entrained)
- shoreline accumulation.

The same exposure values that were used for the accidental release of light crude oil impact assessment have been adopted for the accidental release of MDO/MGO impact assessment; refer to Section 7.2.6.2.4 for a description of environmental thresholds and exposure values.

7.2.7.2.5 Predicted Exposure

Stochastic modelling results refer to the cumulative outputs from all model simulations, which for this scope was 300 unique model simulations (100 per seasonal period). As such the results summarised below cover the predicted total area of potential exposure and do not represent the actual exposure that would result from a single individual event (Figure 7-19).

The fate of each hydrocarbon component also varies due to different trajectory influences and weathering characteristics (see previous sections). For example, the entrained oil typically includes the residual component of the released oil, and as it persists longer it will travel further from the spill source (Figure 7-20). Note that for the MGO, this residual component represents a very small proportion (2.7%) of the total volume released. Similarly, dissolved oils may occur when entrained and/or floating oil is present; however, due to their volatility they do not tend to persist and travel as far as entrained oil droplets (Figure 7-20). The MGO has a low proportion (4.6%) of aromatics.

The results of the stochastic modelling undertaken using SIMAP is presented in Table 7-137, Figure 7-30, Figure 7-32, Figure 7-34 and Figure 7-36 for each modelled oil component. Receptors marked 'X' refer to where an exposure value is relevant to the receptor, but modelling predicts negligible interaction with the receptor.

Examples of individual spill scenarios (i.e. deterministic modelling) have also been shown for each modelled oil component (Figure 7-31, Figure 7-33, Figure 7-35, Figure 7-37)

Table 7-137 Summary of Stochastic Modelling Results for Vessel Collision Event (Accidental Release – MDO/MGO)

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and communities	Benthic habitat and communities	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas – Terrestrial	Heritage	Industry	Commercial Fisheries	Tourism and Recreation
In-water (floating)																		
Low 1 g/m^2	• Floating oil above 1 g/m^2 generally extends in a NE/SW and offshore trajectory from the spill source (Figure 7-30). No floating oil above this exposure value predicted to occur within Exmouth Gulf. • Floating oil at this level is expected to be visually detectable but not have biological effects. • Maximum distance from the source predicted for floating oil above 1 g/m^2 is 178 km. • Probability of exposure of Pilbara inshore islands is low (~2–3%). • Probability of exposure to any AMP is very low (~3–8% for Ningaloo and Gascoyne MP, and <1% for all others). • Probability of exposure to any State marine protected area is low (~4–10% for Muiron Islands MMA, ~1–3% for Ningaloo MP, and <1% for all others). • Probability of exposure to Ningaloo Coast WHA is very low (~3–8%). • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack (~98–100% probability), with a very low probability (~2–4%) of intersection North-West Slope Trawl fishery.	✓									✓		✓		✓	✓	✓	✓

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and communities	Benthic habitat and communities	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas – Terrestrial	Heritage	Industry	Commercial Fisheries	Tourism and Recreation
Moderate 10 g/m^2	• Floating oil above 10 g/m^2 generally extends in a NE/SW from the spill source (Figure 7-30). No floating oil above this exposure value predicted to occur within Exmouth Gulf, or onto the shallower shelf area (including the region with the Pilbara inshore islands). • Maximum distance from the source predicted for floating oil above 10 g/m^2 is 50 km. • Probability of exposure of Pilbara inshore islands is very low (<1%). • Probability of exposure to any AMP is very low (<1%). • Probability of exposure to any State marine protected area is very low (~1–2% for Muiron Islands MMA, and <1% for all others). • Probability of exposure to Ningaloo Coast WHA is very low (<1%). • Would intersect with BIAs for turtles, seabirds, sharks and whales (~89–98% probability), with a very low probability (<1%) of intersecting a Dugong BIA. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack (~89–98% probability), with a very low probability (~<1%) of intersection North-West Slope Trawl fishery.	✓					✓		✓	✓	X	X	X		X		✓	X
High 25 g/m^2	• Floating oil above 25 g/m^2 may occur over an area within the immediate vicinity of the Corowa Development (Figure 7-30). No floating oil above this	✓					✓		✓	✓	X	X	X		X		✓	X

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and communities	Benthic habitat and communities	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas – Terrestrial	Heritage	Industry	Commercial Fisheries	Tourism and Recreation
	exposure value predicted to occur within Exmouth Gulf, or onto the shallower shelf area (including the region with the Pilbara inshore islands). • Maximum distance from the source predicted for floating oil above 25 g/m^2 is 18 km. • Probability of exposure of Pilbara inshore islands is very low (<1%). • Probability of exposure to any AMP or State marine protected area is very low (<1%). • Probability of exposure to Ningaloo Coast WHA is very low (<1%). • Would intersect with BIAs for turtles, seabirds, sharks and whales (~79–89% probability), with a very low probability (<1%) of intersecting a Dugong BIA. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack (~79–89% probability), with a very low probability (~<1%) of intersection North-West Slope Trawl fishery.																	
In-water (dissolved)																		
Moderate 50 ppb (instantaneous)	• Dissolved hydrocarbons above 50 ppb generally extends in a NE/SW and offshore direction from the spill source (Figure 7-32). No dissolved oil above this exposure value predicted to occur within Exmouth Gulf, or onto the shallower shelf area (including the region with the Pilbara inshore islands).	✓				✓		✓	✓	✓	✓	✓	✓		✓		✓	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and communities	Benthic habitat and communities	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas – Terrestrial	Heritage	Industry	Commercial Fisheries	Tourism and Recreation
	• Maximum distance from the source predicted for dissolved hydrocarbons above 50 ppb is 272 km. • The highest occurrence of dissolved oil is generally expected to occur within the surface layer (0–10 m), with probabilities of exposure reducing with depth. • Limited benthic interaction is predicted to occur, dissolved oil not expected to exceed depths of ~50 m (typically remaining with surface layers; <10 m). Therefore, in shallower and nearshore areas some benthic interaction from dissolved oil may potentially occur. • Probability of exposure to any AMP is very low (~1–3% for Ningaloo and Gascoyne MP, and <1% for all others). • Probability of exposure to any State marine protected area is very low (<1–1% for Muiron Islands MMA, ~1–2% for Ningaloo MP, and <1% for all others). • Probability of exposure to Ningaloo Coast WHA is very low (~2–3%). • Low probability of contact with BIAs for turtles, seabirds, sharks and whales (~8–10%), with a very low probability (~1–2%) of intersecting a Dugong BIA. • Low probability of contact with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack (~8–10% probability), and very low probability (~2–4%) with North-West Slope Trawl fishery.																	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and communities	Benthic habitat and communities	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas – Terrestrial	Heritage	Industry	Commercial Fisheries	Tourism and Recreation
Moderate 50 ppb (time-integrated)	• Dissolved hydrocarbons above this time-integrated exposure value (i.e. 4,800 ppb.hr) is not predicted to occur.					X		X	X	X	X	X	X		X		X	
High 400 ppb (instantaneous)	• Dissolved hydrocarbons above this exposure value is not predicted to occur.	X				X		X	X	X	X	X	X		X		X	
High 400 ppb (time-integrated)	• Dissolved hydrocarbons above this time-integrated exposure value (i.e. 38,400 ppb.hr) is not predicted to occur.					X		X	X	X	X	X	X		X		X	
In-water (entrained)																		
Moderate 100 ppb (instantaneous)	• Entrained hydrocarbons above 100 ppb generally extends in a NE/SW and offshore direction from the spill source (Figure 7-34). No dissolved hydrocarbons above this exposure value predicted to occur within Exmouth Gulf.	✓	X		X	✓		✓	✓	✓	✓	✓	✓		✓		✓	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																	
		Ambient water quality	Ambient sediment quality	Coastal habitats and communities	Benthic habitat and communities	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas – Terrestrial	Heritage	Industry	Commercial Fisheries	Tourism and Recreation
	• Maximum distance from the source predicted for entrained hydrocarbons above 100 ppb is 674 km. • The highest occurrence of entrained oil is generally expected to occur within the surface layer (0–10 m), with probabilities of exposure reducing with depth. • Limited benthic interaction is predicted to occur, with entrained oil not expected to exceed depths of ~60 m (typically remaining with surface layers; <10 m). Therefore, in shallower and nearshore areas some benthic interaction from entrained oil may potentially occur. • Probability of contact within waters around the Pilbara inshore islands (including Muiron Islands MMA) is ~1–5%. • Probability of exposure to any AMP is low (~8–11% for Ningaloo, ~11–13% for Gascoyne MP, <1–4% for Montebello MP, and <1–1% for all others). • Probability of contact with waters within the Ningaloo Coast WHA is ~8–11%. • May intersect with BIAs for turtles, seabirds, sharks and whales (~23–37% probability), with a low probability (~7–8%) of intersecting a Dugong BIA. • May intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack (~23–37% probability), and North-West Slope Trawl fishery (~15–23% probability).																	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and communities	Benthic habitat and communities	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas – Terrestrial	Heritage	Industry	Commercial Fisheries	Tourism and Recreation
Moderate 100 ppb (time-integrated)	• Maximum distance from the source predicted for entrained hydrocarbons above the time-integrated threshold (9,600 ppb.hr) is 172 km. • No benthic interaction is predicted to occur, with entrained hydrocarbons remaining with surface layers (<10 m). • Very low (<1–2%) probability of this exposure and time threshold occurring within Ningaloo MP (State and Commonwealth), Gascoyne MP, Muiron Islands MMA and Ningaloo Coast WHA. • Very low probability this exposure and time threshold occurring within BIAs for turtle, seabirds, sharks and whales (~7–14%) and Dugongs (<1–2%). • Very low probability this exposure and time threshold occurring within the fishery management areas Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack (~7–14% probability), and North-West Slope Trawl fishery (~1–2% probability).				X	✓		✓	✓	✓	✓	✓	✓		✓		✓	
High 1,000 ppb (instantaneous)	• Entrained hydrocarbons above 1000 ppb generally extends in a NE/SW and offshore direction from the spill source (Figure 7-34). No dissolved hydrocarbons above this exposure value predicted to occur within Exmouth Gulf or onto the shallower shelf area (including the region with the Pilbara inshore islands.	✓	X		X	✓		✓	✓	✓	✓	✓	✓		✓		✓	

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and communities	Benthic habitat and communities	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas – Terrestrial	Heritage	Industry	Commercial Fisheries	Tourism and Recreation
	• Beyond the immediate vicinity of the Corowa Development, occurrence of this exposure value is patchy and discontinuous. • Maximum distance from the source predicted for entrained hydrocarbons above 1,000 ppb is 304 km. • The highest occurrence of entrained oil is generally expected to occur within the surface layer (0–10 m), with probabilities of exposure reducing with depth. • Limited benthic interaction is predicted to occur, with entrained oil not expected to exceed depths of ~25 m (typically remaining with surface layers;<10 m). Therefore, in shallower and nearshore areas some benthic interaction from entrained oil may potentially occur. • Probability of contact within waters around the Pilbara inshore islands (including Muiron Islands MMA) is <1–1%. • Probability of exposure to any AMP is low (~1–2% for Ningaloo, ~2% for Gascoyne MP, and <1% for all others). • Probability of contact with waters within the Ningaloo Coast WHA is ~1–2%. • Low probability of contact with BIAs for turtles, seabirds, sharks and whales (~7–8%), with a very low probability (~1–2%) of intersecting a Dugong BIA. • Low probability of contact with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack (~7–8%																	

Exposure Values	Predicted Extent of Exposure	Ambient water quality	Ambient sediment quality	Coastal habitats and communities	Benthic habitat and communities	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas – Terrestrial	Heritage	Industry	Commercial Fisheries	Tourism and Recreation
	probability), and very low probability (~1–2%) with North-West Slope Trawl fishery.																	
High 1,000 ppb (time-integrated)	• Entrained hydrocarbons above this time-integrated exposure value (i.e. 96,000 ppb.hr) is not predicted to occur.				X	X		X	X	X	X	X	X		X		X	
Shoreline																		
Low 10 g/m^2	• Shoreline accumulation above 10 g/m^2 may occur along the north-western shores of North West Cape and through the Pilbara inshore islands (from Muiron to Bessieres Island) (Figure 7-36). • Probability of shoreline exposure is very low: ~5–7% for Pilbara inshore islands (including Muiron Islands) and ~2% for north-western North West Cape. • Shoreline accumulation at this level is expected to be visual detectable but not have biological effects. • The worst-case maximum length of shoreline with concentrations >10 g/m^2 was 23 km along the western coast of North West Cape.		✓										✓	X	✓			✓

The 17 receptor columns are grouped under the heading "Relevance to Receptors".

Exposure Values	Predicted Extent of Exposure	Relevance to Receptors																
		Ambient water quality	Ambient sediment quality	Coastal habitats and communities	Benthic habitat and communities	Plankton	Seabirds and shorebirds	Fish and Sharks	Marine reptiles	Marine mammals	Australian Marine Parks	Key Ecological Features	State Protected Areas – Marine	State Protected Areas – Terrestrial	Heritage	Industry	Commercial Fisheries	Tourism and Recreation
Moderate 100 g/m²	• Shoreline accumulation above 100 g/m² may occur along the north-western shores of North West Cape and through the Pilbara inshore islands (from Muiron to Bessieres Island) (Figure 7-36). • Probability of shoreline exposure is very low: ~2–4% for Pilbara inshore islands (including Muiron Islands) and <1–1% for north-western North West Cape. • The maximum total volume of oil onshore during any of the simulations was 185 m³ at the Muiron Islands.		✓	✓	✓		✓		✓					X				
High 1,000 g/m²	• Shoreline accumulation above 1,000 g/m² may occur along the north-western shores of Muiron Islands, Peak Island and Bessieres Island (Figure 7-36). • The highest probability of shoreline contact above this exposure threshold was ~1–2% at the Pilbara inshore islands (including Muiron Islands).		✓	X	X									X				

Receptors marked 'X' = exposure value is relevant to the receptor, but modelling predicts negligible interaction with receptor via the exposure pathway. Probabilities of exposure vary with seasons.

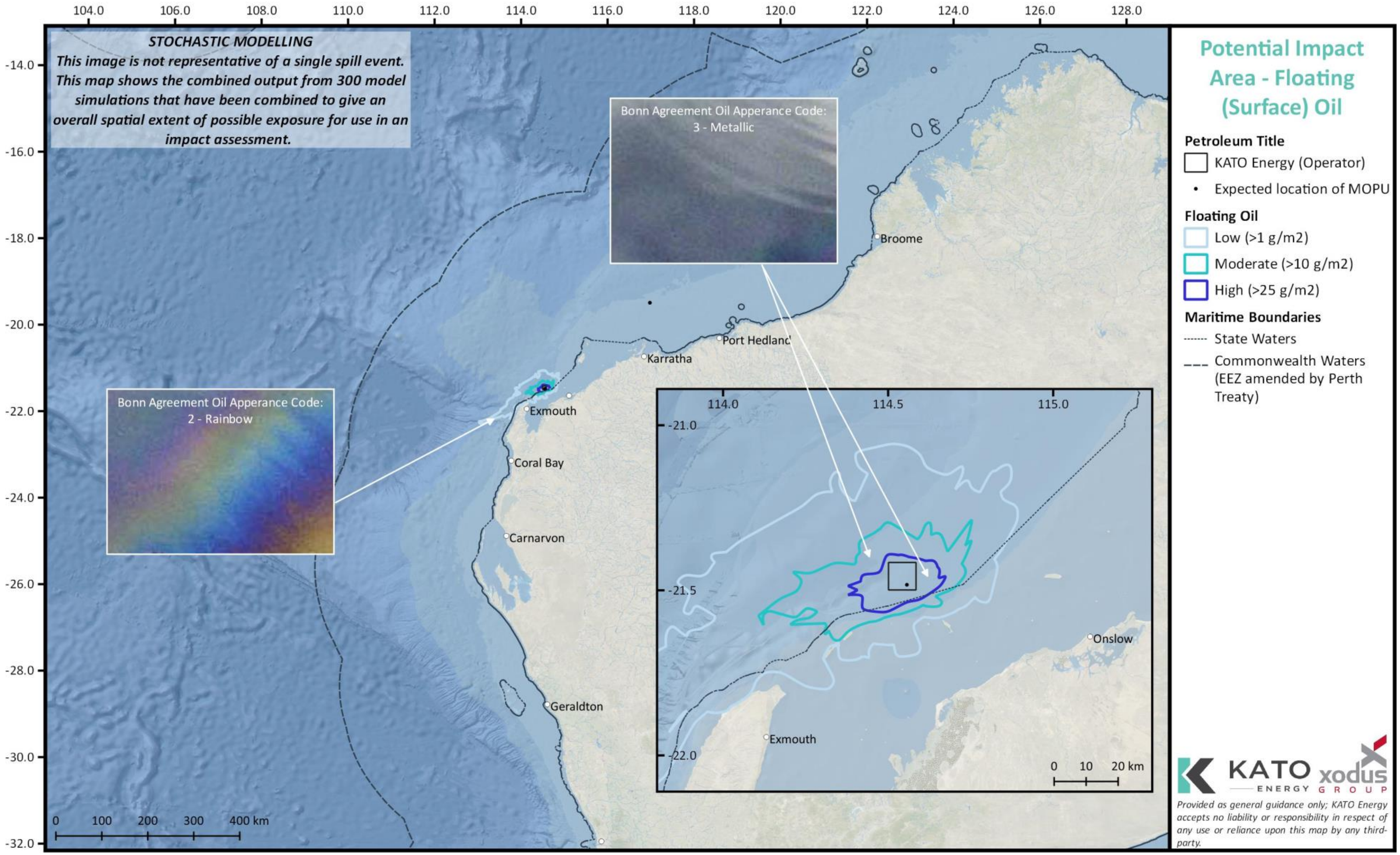


Figure 7-30 Potential Impact Area (stochastic modelling output) for Floating Oil from a Surface Release of MDO/MGO

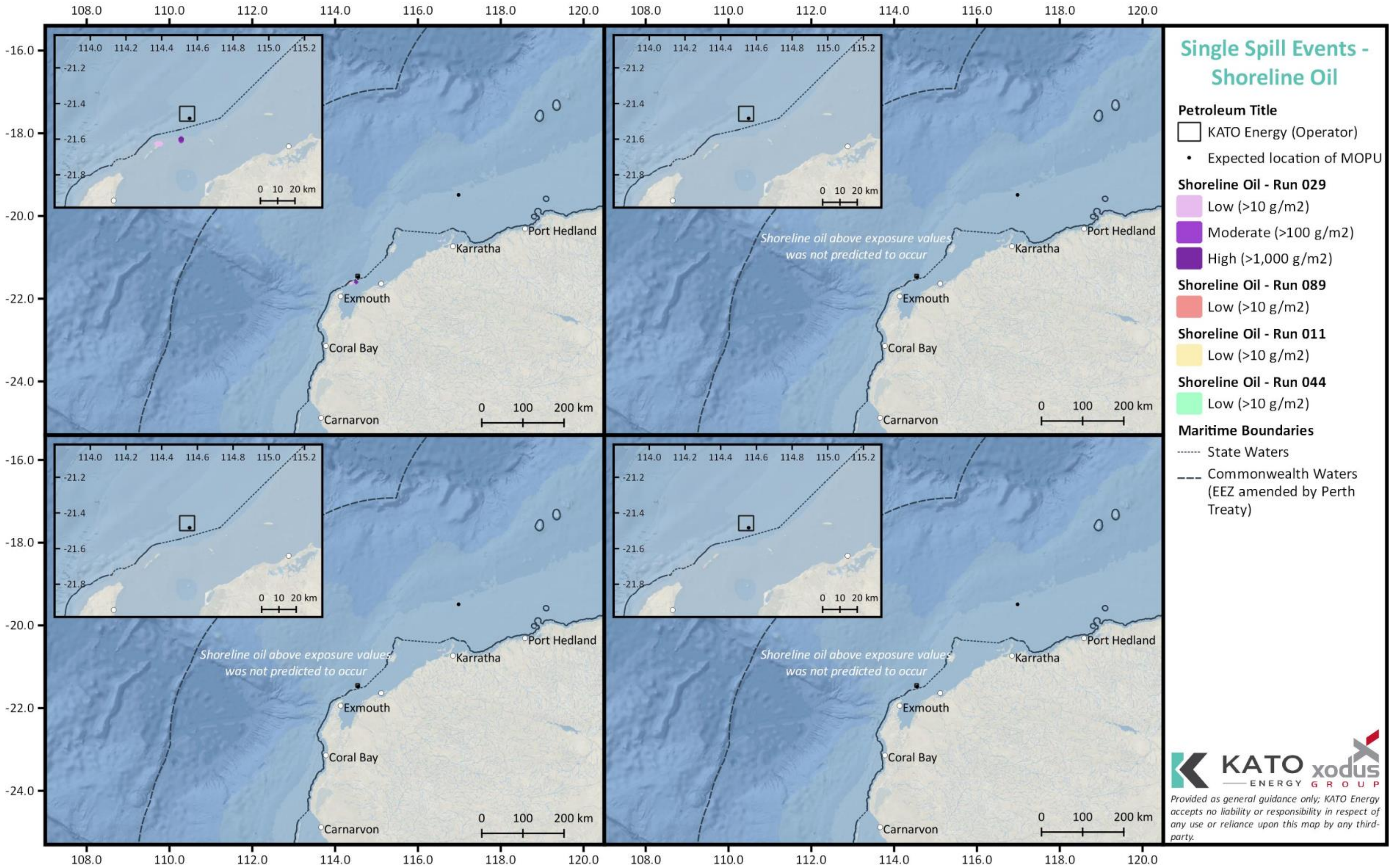


Figure 7-31 Examples of an Individual Spill Event (deterministic modelling output) for Floating Oil from a Surface Release of MDO/MGO

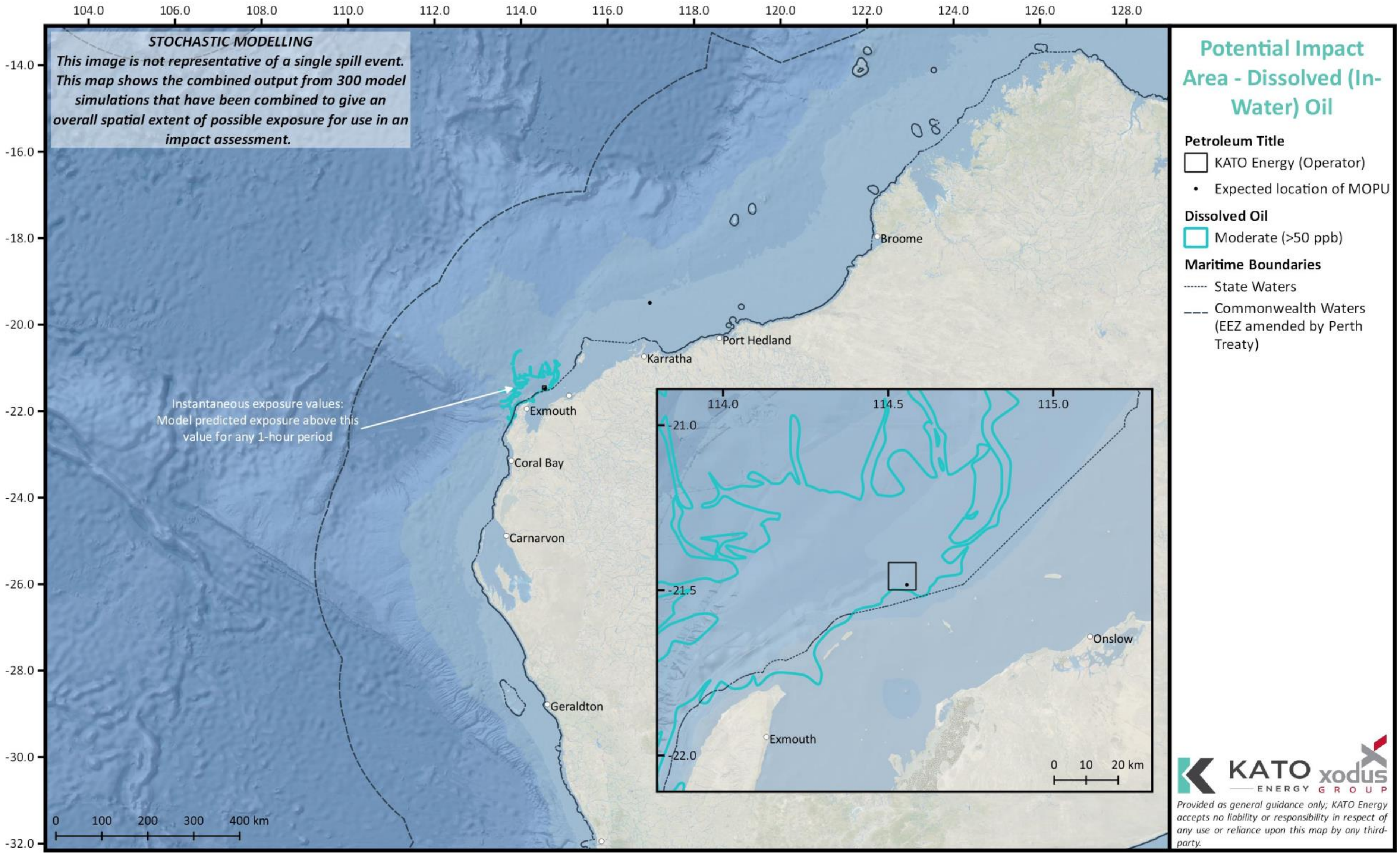


Figure 7-32 Potential Impact Area (stochastic modelling output) for Dissolved Oil from a Surface Release of MDO/MGO

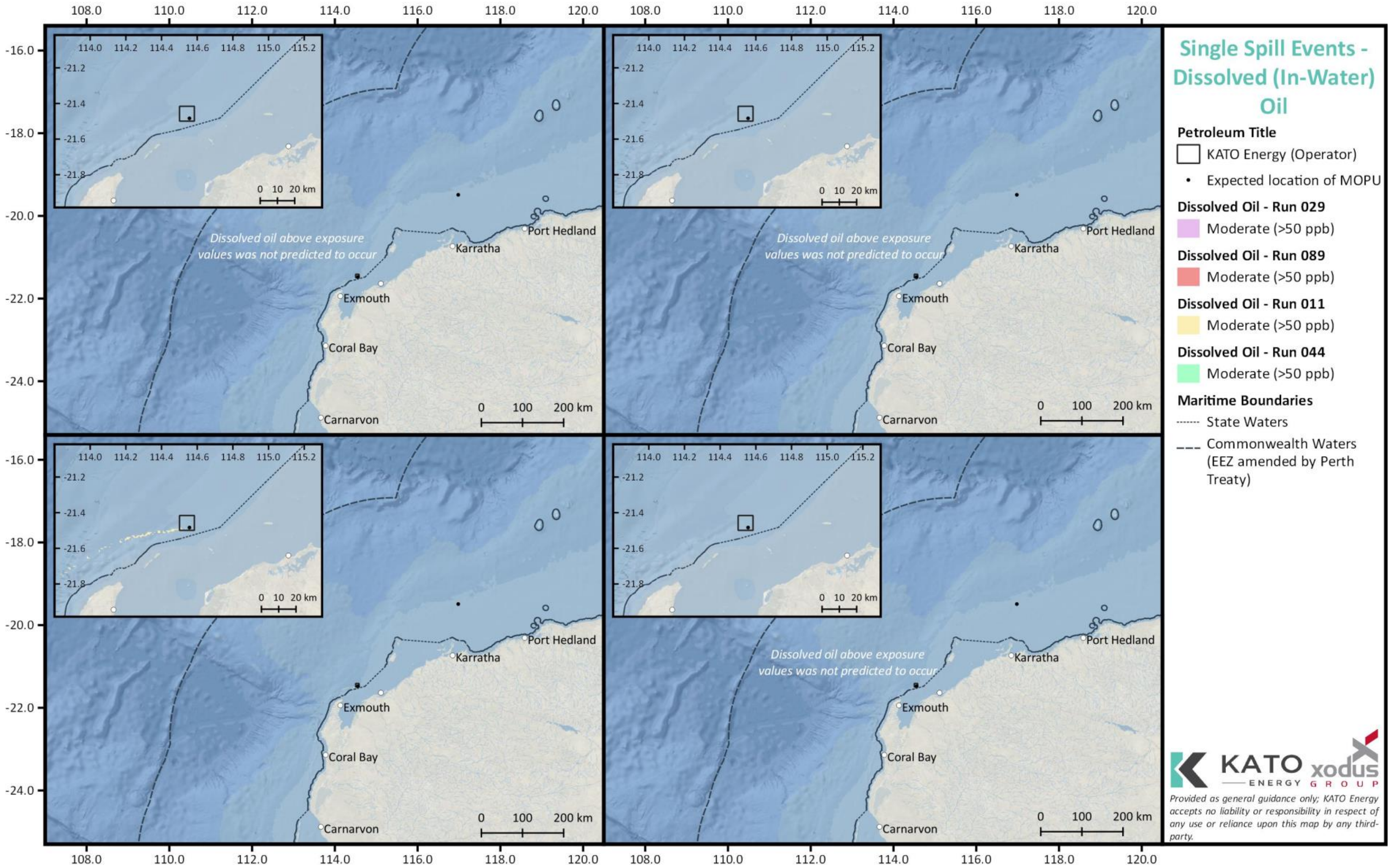


Figure 7-33 Examples of an Individual Spill Event (deterministic modelling output) for Dissolved Oil from a Surface Release of MDO/MGO

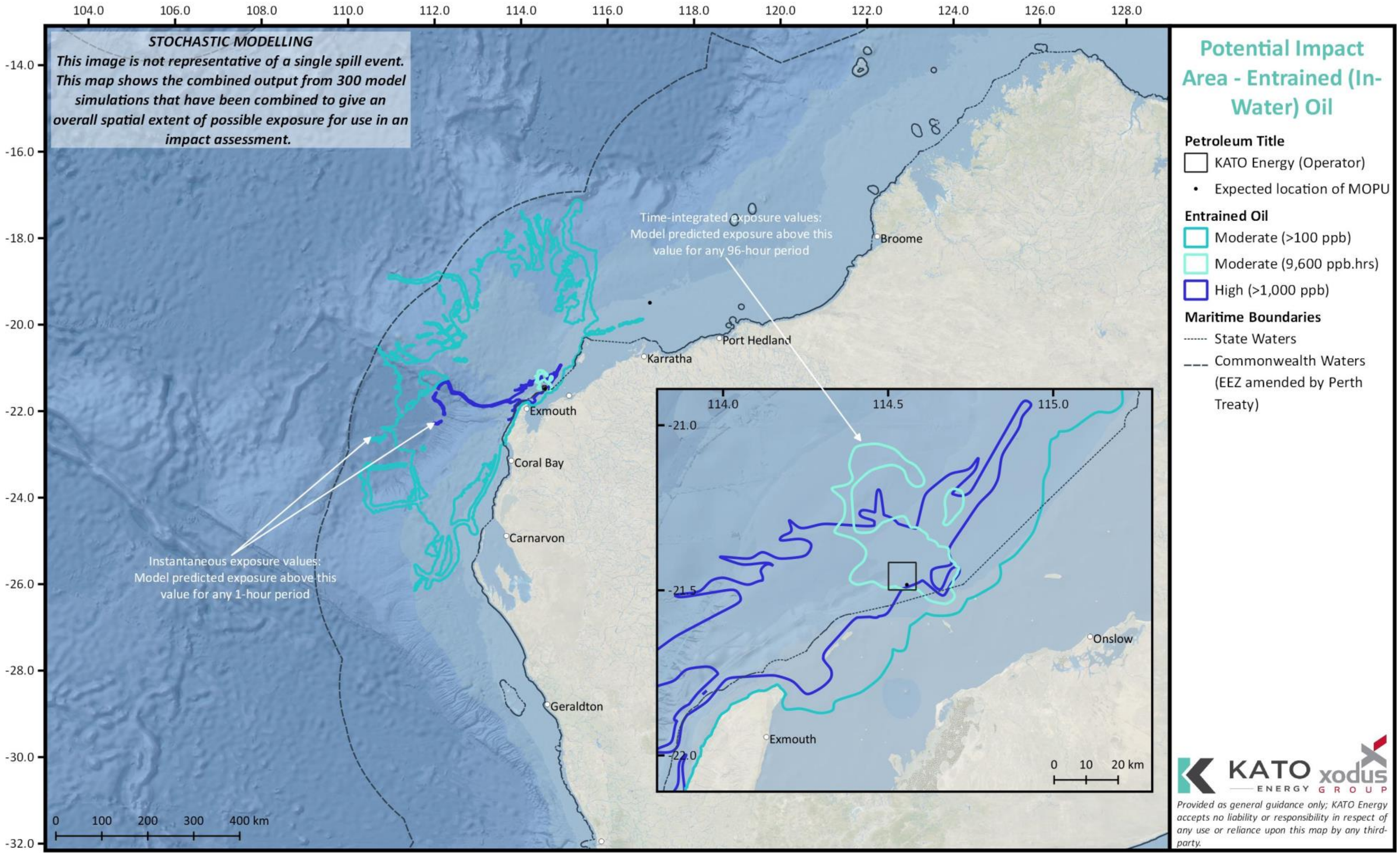


Figure 7-34 Potential Impact Area (stochastic modelling output) for Entrained Oil from a Surface Release of MDO/MGO

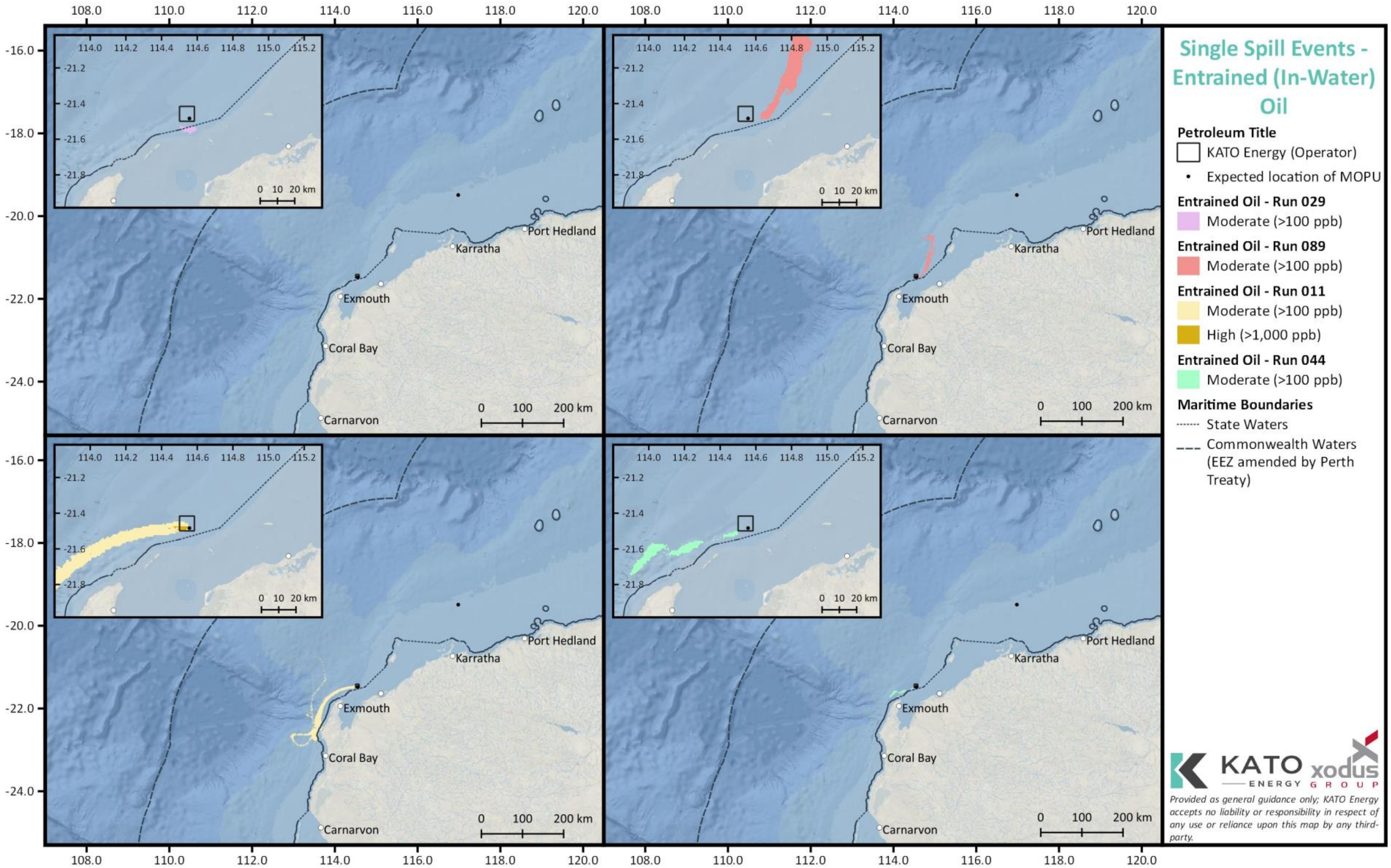


Figure 7-35 Examples of an Individual Spill Event (deterministic modelling output) for Entrained Oil from a Surface Release of MDO/MGO

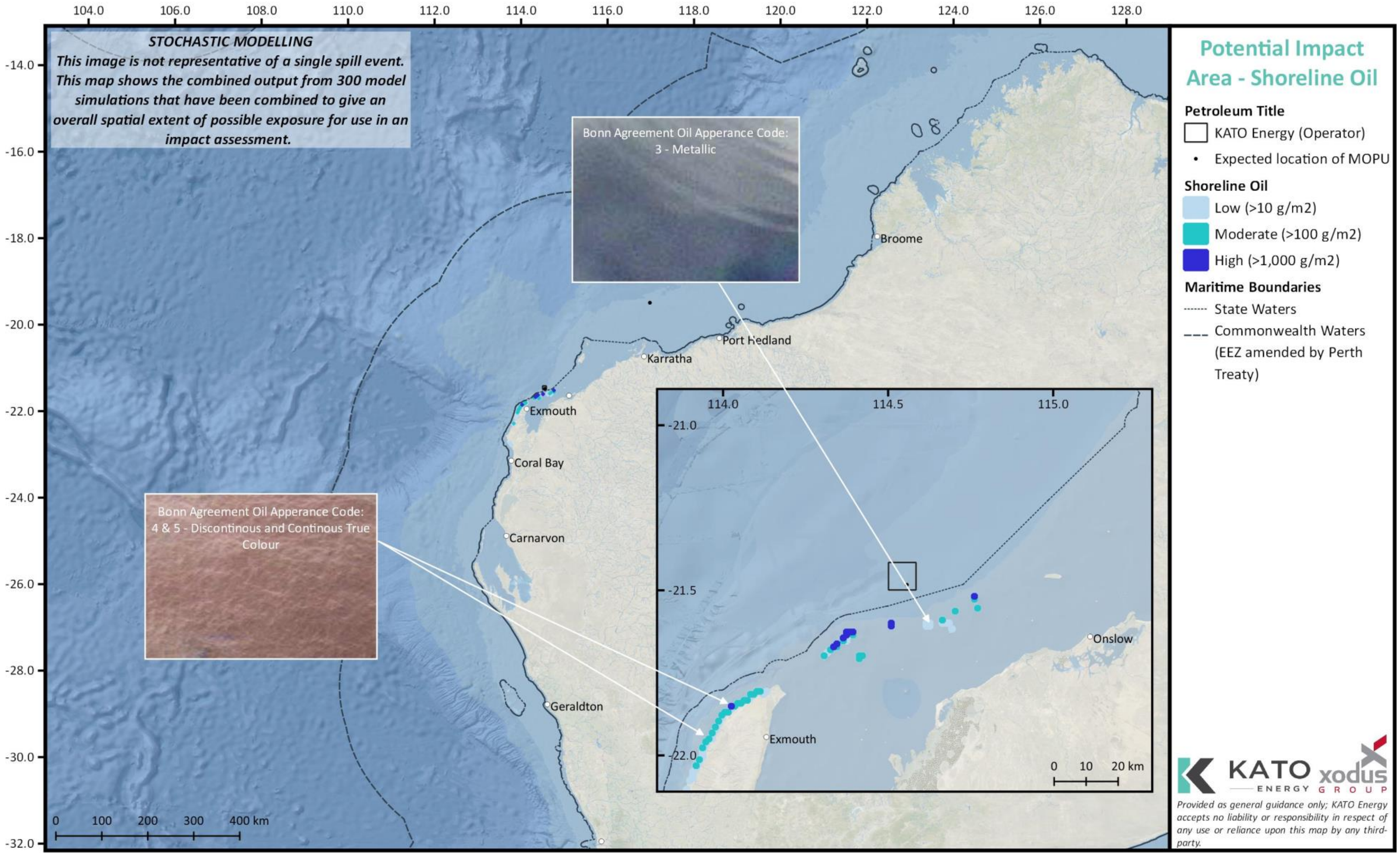


Figure 7-36 Potential Impact Area (stochastic modelling output) for Shoreline Oil from a Surface Release of MDO/MGO

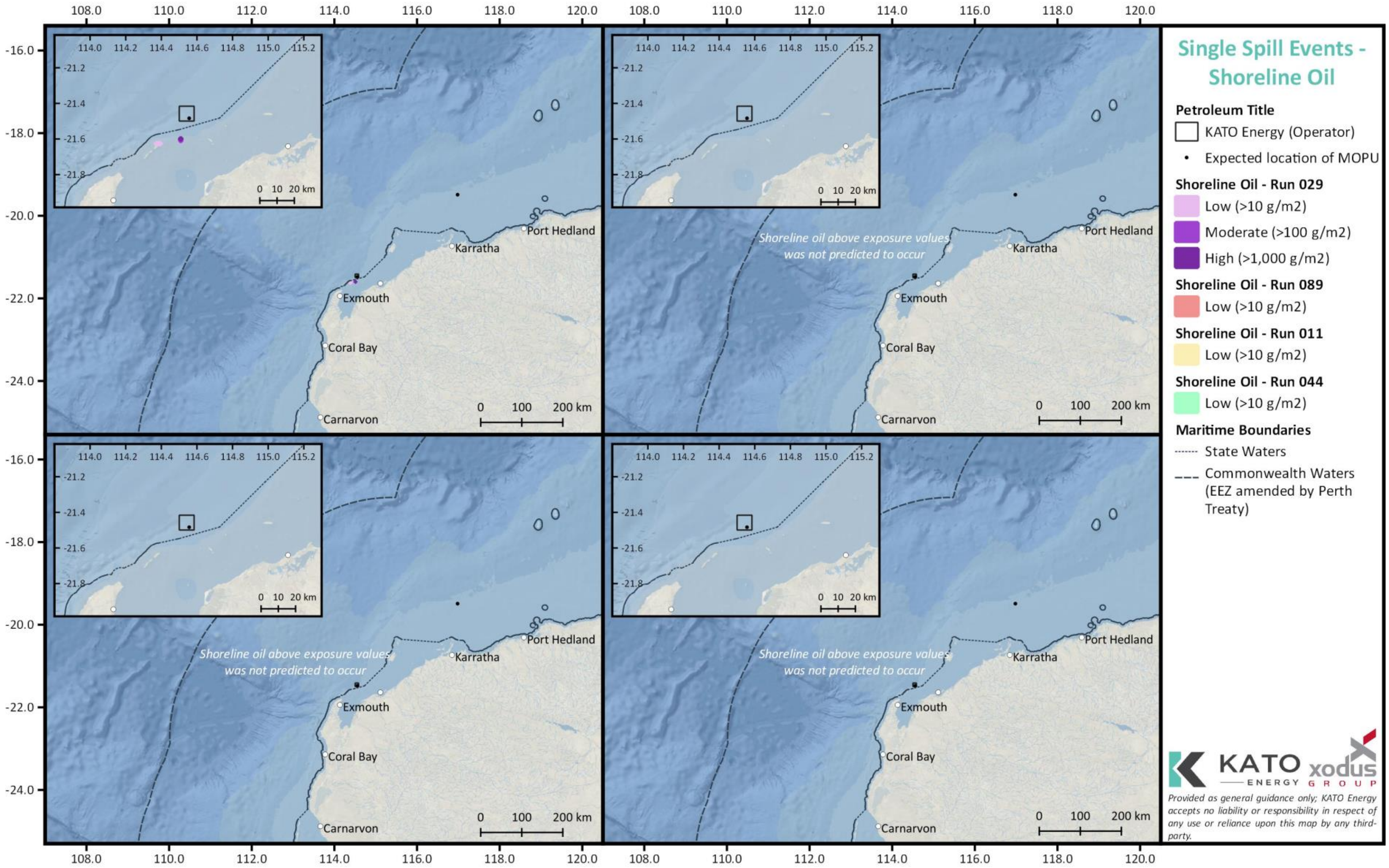


Figure 7-37 Examples of an Individual Spill Event (deterministic modelling output) for Shoreline Oil from a Surface Release of MDO/MGO

7.2.7.3 Risk Evaluation

An accidental release of MDO/MGO generated by the Corowa Development have the potential to result in these impacts:

- change in water quality
- change in sediment quality
- change in habitat.

As a result of a change in water quality, sediment and/or habitat, further impacts may occur, including:

- injury / mortality to fauna
- change in fauna behaviour
- changes to the functions, interests or activities of other users
- change in aesthetic value.

Table 7-138 identifies the potential impacts to receptors as a result of an accidental release of MDO/MGO from the Corowa Development. Receptors marked '*X*' have been determined to be subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table-7-139 provides a summary and justification for those receptors not evaluated further.

Table 7-138 Receptors Potentially Impacted by Accidental Release – MDO/MGO

Impacts	Ambient water quality	Ambient sediment quality	Plankton	Benthic habitat and communities	Coastal habitats and communities	Seabirds and shorebirds	Fish	Marine reptiles	Marine mammals	KEFs	Australian Marine Parks	State Protected Areas – Marine	State Protected Areas – Terrestrial	Heritage	Industry	Commercial Fisheries	Tourism and Recreation
Change in water quality	✓									✓	✓	✓		✓			
Change in sediment quality		X								X	X	X		X			
Change in habitat				X	✓					✓	✓	✓	X	✓			
Injury / mortality to fauna			✓	X	✓	✓	✓	✓	✓	✓	✓	✓	X	✓			
Change in fauna behaviour				X	✓	✓	✓	✓	✓	✓	✓	✓	X	✓			
Changes to the functions, interests or activities of other users											✓	✓	X	✓	✓	✓	✓
Change in aesthetic value					✓						✓	✓		✓			✓

Table-7-139 Justification for Receptors Not Evaluated Further for Accidental Release – MDO/MGO

Sediment Quality	***X***
The Corowa field is in water ~85–90 m deep and the stochastic modelling did not indicate any benthic interaction from the released MGO. For seabed within intertidal or shallow nearshore areas, exposure is typically considered possible in areas where shoreline accumulation is predicted to occur. However, the probability of shoreline accumulation above any exposure value was low (≤7%) for all modelled simulations. The MGO is also highly volatile (so once exposed to air would be expected to readily evaporate). The actual area of exposure for an individual spill event will be relatively small, and exposure is expected to be temporary given the volatility of the MGO (i.e. once exposed to air, most would be expected to readily evaporate) and very small residual component.	
Benthic Habitat and Communities	***X***
Benthic habitats and communities may be vulnerable to hydrocarbon exposure from an oil spill. The stochastic modelling undertaken for the surface release of MGO indicated that benthic habitats are not predicted to be exposed as the oil remains within surface waters. For benthic habitat present within shallow nearshore areas, exposure is typically considered possible in areas where shoreline accumulation is predicted to occur. However, the probability of shoreline accumulation above thresholds with biological impacts was very low (≤4%) for all modelled simulations. Therefore, any impact to benthic habitat and communities is considered negligible and not evaluated further.	
State Protected Areas – Terrestrial	***X***
Terrestrial protected areas (Cape Range National Park and the nature reserves associated with some of the Pilbara inshore islands) occur within the area predicted to be exposed to shoreline accumulation. Shoreline accumulation from an oil spill will typically only extend to just above the high-tide mark, so even if the management boundaries of the terrestrial protected areas extended to water limits, any impacts from hydrocarbons to the values and sensitivities of the reserves/parks will be negligible and therefore are not evaluated further.	

7.2.7.3.1 Physical Receptors

Physical receptors with the potential to be impacted from an accidental release of MDO/MGO:

- ambient water quality.

Table 7-140 provides a detailed evaluation of the impacts of an accidental release of MDO/MGO to physical receptors.

Table 7-140 Impact and Risk Assessment for Physical Receptors from Accidental Release – MDO/MGO

Ambient Water Quality	✓
Change in water quality An accidental release has the potential to result in a change in water quality. However, following a release of oil into the marine environment, weathering processes begin to immediately transform the oil (TRBNRC 2003). MGO is classified as a light persistent oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~97.3%) of volatile components and only a small (2.7%) residual component. Due to this volatility most of this oil will evaporate from the water surface; depending on wind conditions, the proportion of evaporated oil may vary between ~64–71% within several days of release (Section 7.2.7.2.3). Under moderate winds, oil will begin to entrain into the water column; again, depending on wind conditions the proportion of entrained oil may vary up to ~32% (Section 7.2.7.2.3). Entrained oil can persist for extended periods of time, however if it refloats it is subject to evaporation and is also subject to dissolution and natural degradation within the water column (noting the modelled weathering of the MGO showed slow degradation (<1% per day) rates).	

Stochastic modelling undertaken for the surface release of MGO indicated that if/when entrained oil did occur it remained in the surface layers (<10 m depth). The actual area of exposure for an individual spill event will be relatively small, with exposure shown to be transient and temporary due to the influence of waves, currents and weathering processes. Given the details above, the consequence of an accidental release of MDO/MGO causing a change in water quality has been assessed as **Minor (1)**, with the impact assessed as **Unlikely (C)** to occur, given that any change in water quality would be restricted to surface waters within a spatially restricted area, and that water quality within the EMBA is unlikely to permanently be significantly impacted.

7.2.7.3.2 Ecological Receptors

The identified ecological receptors may be impacted from:

- change in habitat
- change in fauna behaviour
- injury / mortality to fauna
- change in aesthetic value.

Table 7-141 provides a detailed evaluation of the impact of an accidental release of MDO/MGO to ecological receptors.

Table 7-141 Impact and Risk Assessment for Ecological Receptors from Accidental Release – MDO/MGO

Coastal Habitat and Communities ✓
An accidental release of MDO/MGO has the potential to result in: • change in habitat • change in fauna behaviour • injury / mortality to fauna • change in aesthetic value. Coastal habitats and communities may be vulnerable to shoreline accumulation from an oil spill. Stochastic modelling undertaken for the subsea release of MGO indicated that shoreline accumulation of oil was predicted to occur within an area extending along the western edge and around the northern tip of North West Cape, and some of the Pilbara inshore islands. No exposure was predicted at >100 g/m^2 for shorelines within Exmouth Gulf. **Shoreline habitats** Sandy beaches, rocky coasts and tidal flats are the common shoreline types within the area predicted to potentially be exposed to shoreline accumulation >100 g/m^2. Rocky coasts and sandy beaches are present on parts of the Pilbara inshore islands, while sandy beaches and tidal flats are the dominant shorelines of north-western North West Cape. These types of shorelines are known to provide foraging and/or nesting habitat for birds and turtles; these activities primarily occur above the high-tide zone. Shoreline habitats may also be inhabited by a diverse assemblage (although not always abundant) of infauna (including nematodes, copepods and polychaetes) and invertebrates (e.g. crustaceans). Oil can behave differently on these different shoreline types: • Rocky coasts – the rocky headland type features on wave-exposed coasts of the offshore islands are likely to remain unoiled, as floating/entrained oil is held back by the action of the reflected waves. • Sandy beaches – oil penetration into sandy sediments varies with particle size (i.e. greater penetration in coarser materials) and oil viscosity (the MGO has a low viscosity and therefore the fresh oil has a tendency to spread, however viscosity will increase, and this spreading tendency will reduce as the oil weathers). • Tidal flats – oil behaviour is similar to sandy beaches but with less penetration into the sediment profile due to small particle sizes. Where oil does accumulate, it is concentrated along the high-tide zone while the lower parts are often untouched (IPIECA 1995). Therefore, fauna using coastal areas above the high-tide zone are typically not

impacted unless they travel through this zone to access the upper beach (e.g. turtles). If oil does penetrate the sediment, the infauna may be exposed. Long-term depletion of sediment fauna could have an adverse effect on birds or fish that use beaches or tidal flats as feeding grounds (IPIECA 1999). However, repopulation and recovery of affected communities is expected to occur over a relatively short (~5 years) period (IPIECA 1995; IPIECA 1999). As the oil is weathered it becomes more viscous and less toxic, and may leave some residual oil on upper shores. This residue can remain as an unsightly stain for an extended period, but it is unlikely to cause ecological damage (IPIECA 1995). Whilst this unsightly stain may cause a change in the aesthetic value of the local environment, they will be temporary and due to the remote locations of coastal habitats and communities within the area, aesthetic impacts will be minor.

Vegetated habitat (Saltmarsh, Mangroves)

Coastal vegetation, including saltmarsh, mangroves and wetlands, may be vulnerable to shoreline accumulations of >1,000 g/m^2. None of these habitats are known to occur within the limited area that may be exposed to oil above this concentration.

Summary

The MGO is classified as a light persistent oil and has a high proportion (~97.3%) of volatile components and only a small (2.7%) residual component. Due to this volatility, once exposed to the atmosphere (e.g. on a shoreline) most of this oil is expected to evaporate within several days.

Given the details above, the consequence of an accidental release of MDO/MGO causing any permanent and/or significant impacts to coastal habitats and communities has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur given that exposure to hydrocarbons is expected to be short-term, and restricted to intertidal (up to high tide) zone.

Plankton ✓

Injury / mortality to fauna

Plankton may be vulnerable to hydrocarbon exposure from an oil spill. While plankton can occur throughout the water column, they are generally more abundant in the surface layers. Plankton forms the basis of the marine food web, and so any direct adverse impact may have subsequent indirect impacts further along the chain. However, a localised exposure is unlikely to affect plankton populations at the regional scale, and therefore regional indirect impacts are also not expected to occur. Surface waters of the NWS are typically low in nutrients, and so areas of vertical mixing (e.g. upwelling along the shelf edge) are likely to have a higher abundance of plankton.

Phytoplankton are typically not sensitive to the impacts of oil, though they do accumulate it rapidly (Hook et al. 2016). Oil can affect the rate of photosynthesis and inhibit growth in phytoplankton, depending on the concentration range. For example, photosynthesis is stimulated by low concentrations of fresh oil in the water column (10–30 ppb) but become progressively inhibited at concentrations >50 ppb. Conversely, photosynthesis can be stimulated at concentrations of <100 ppb for exposure to weathered oil (Volkman et al. 2004).

Zooplankton are vulnerable to hydrocarbons (Hook et al. 2016). Water column organisms may be impacted by oil via exposure through ingestion, inhalation and dermal contact (NRDA 2012), which can cause immediate mortality or declines in reproduction (Hook et al. 2016). However, reproduction by survivors or migration from unaffected areas is likely to rapidly replenish losses (Volkman et al. 2004). Entrained oil droplets are frequently in the food size spectra for zooplankton (Almeda et al. 2013). Lethal and sublethal effects, including narcosis, alterations in feeding, development, and reproduction have been observed in copepods exposed to petroleum hydrocarbons (Almeda et al. 2013). However, the effects on zooplankton can vary widely depending on intrinsic (e.g. species, life stage, size) and extrinsic (e.g. exposure value and duration) factors (Almeda et al. 2013).

MDO/MGO has higher toxicity levels when initially released due to the presence of the volatile components (Di Toro et al. 2007), and therefore plankton near the spill source may be at greater risk of impact. However, with rapid weathering expected, this toxicity also decreases. Results from the stochastic modelling also showed that the time-integrated exposures (i.e. areas consistently exposed to an exposure value for ≥96 hours) were significantly smaller than the equivalent instantaneous (i.e. areas exposed to an exposure value for 1 hour). As organisms require exposure to a toxicant over a period of time for toxic effects to occur, the majority of the area exposed to entrained and dissolved oils are expected to be representative of potential sublethal impacts only.

The actual area of exposure for an individual spill event will be relatively small, with exposure shown to be transient and temporary due to the influence of waves, currents and weathering processes. Once background water quality is re-established, plankton takes weeks to months to recover (ITOPF 2011a).

Given the details above, the consequence of an accidental release of MDO/MGO causing injury / mortality to plankton species has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur given that effects on plankton will be localised and temporary.

Seabirds and Shorebirds ✓

An accidental release of MDO/MGO has the potential to result in:

- injury / mortality to fauna
- change in fauna behaviour.

Seabirds and shorebirds may be vulnerable to hydrocarbon exposure from an oil spill. Birds at sea (e.g. foraging, resting) and onshore (e.g. roosting, nesting) have the potential to directly interact with surface oils. Seabird species most at risk include those that readily rest on the sea surface (e.g. shearwaters) and surface plunging species (e.g. terns, boobies). As seabirds are a top order predator, any impact on other marine life (e.g. krill, fish) may disrupt and limit food supply both for the maintenance of adults and the provisioning of young.

For seabirds, direct contact with hydrocarbons can foul feathers, which may subsequently result in hypothermia due to a reduction in the ability of the bird to thermo-regulate and impair waterproofing. Direct contact with surface hydrocarbons may also result in dehydration, drowning and starvation (DSEWPaC 2011b; AMSA 2013b). Increased heat loss as a result of a loss of waterproofing results in an increased metabolism of food reserves in the body, which is not countered by a corresponding increase in food intake, may lead to emaciation (DSEPWC 2011b). The greatest vulnerability in this case occurs when birds are feeding or resting at the sea surface (Peakall et al. 1987). Due to the location of their feeding habitats shorebirds are likely to be exposed to oil when it directly impacts the intertidal zone and onshore. Foraging shorebirds will be at potential risk of both direct impacts through contamination of individual birds (e.g. fouling of feathers) and indirect impacts (e.g. fouling and/or a reduction in prey items) (Clarke 2010). Oiling of birds can also suffer from damage to external tissues, including skin and eyes, as well as internal tissue irritation in their lungs and stomachs. In a review of 45 actual marine spills, there was no correlation between the numbers of bird deaths and the volume of the spill (Burger 1993).

Breeding birds (both seabirds and shorebirds) may be exposed to oil via direct contact or the contamination of the breeding habitat (e.g. shores of islands) (Clarke 2010). Bird eggs may subsequently be damaged if an oiled adult sits on the nest. Fresh crude was shown to be more toxic than weathered crude, which had a medial lethal dose of 21.3 mg/egg. Studies of contamination of duck eggs by small quantities of crude oil, mimicking the effect of oil transfer by parent birds, have been shown to result in mortality of developing embryos.

Toxic effects on birds may result where oil is ingested as the bird attempts to preen its feathers, or via consumption of oil-affected prey. Whether this toxicity ultimately results in mortality will depend on the amount consumed and other factors relating to the health and sensitivity of the particular bird species. Results from the stochastic modelling showed that the time-integrated exposures (i.e. areas consistently exposed to an exposure value for ≥96 hours) were significantly smaller than the equivalent instantaneous (i.e. areas exposed to an exposure value for 1 hour). As organisms require exposure to a toxicant over a period of time for toxic effects to occur, the majority of the area exposed to entrained and dissolved oils are expected to be representative of potential sublethal impacts only.

The MGO is classified as a light persistent oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~97.3%) of volatile components and only a small (2.79%) residual component. Due to this volatility, once on the water surface most of this oil will evaporate; depending on wind conditions, the proportion of evaporated oil may vary between ~64–71% within several days of release (Section 7.2.7.2.3). Modelling undertaken for the surface release of MGO indicated that floating oil may extend in a NE/SW and offshore direction from the spill site, and potentially up to a maximum of 50 km; shoreline accumulation of oil was predicted to occur within an area extending along north-western

North West Cape and some of the Pilbara inshore islands (the probability of shoreline accumulation above thresholds with biological impacts was very low [≤4%] for all modelled simulations).

The area potentially at risk from floating and/or shoreline exposure includes offshore islands that are known nesting habitats for migratory bird species (some with associated BIAs, such as the Wedge-tailed Shearwater). However, the actual area of exposure for an individual spill event will be relatively small, with exposure shown to be transient and temporary due to the influence of waves, currents and weathering processes.

Given the details above, the consequence of an accidental release of MDO/MGO causing injury / mortality to fauna or a change in fauna behaviour in seabirds and shorebirds has been assessed as **Moderate (2)** respectively with the impact assessed as **Very Unlikely (B)** to occur given that effects will be localised and temporary and are not expected to occur at a population level.

Fish ✓

An accidental release of MDO/MGO has the potential to result in:

- injury / mortality to fauna
- change in fauna behaviour.

Fish may be vulnerable to hydrocarbon exposure from an oil spill. Since fish do not generally break the sea surface, the risk from oil spills is more likely to occur from entrained and dissolved oil components.

Fish can be exposed to oil through a variety of pathways, including direct dermal contact (e.g. swimming through oil); ingestion (e.g. directly or via oil-affected prey/foods); and inhalation (e.g. elevated dissolved contaminant concentrations in water passing over the gills). Exposure to hydrocarbons entrained or dissolved in the water column can be toxic to fishes. Of the potential toxicants, monocyclic and polycyclic aromatic hydrocarbons (MAHs and PAHs) are generally regarded as the most toxic to fish; these toxicants form part of the dissolved oil component. Studies have shown a range of impacts including changes in abundance, decreased size, inhibited swimming ability, changes to oxygen consumption and respiration, changes to reproduction, immune system responses, DNA damage, visible skin and organ lesions, and increased parasitism. However, many fish species can metabolise toxic hydrocarbons, which reduces the risk of bioaccumulation (NRDA 2012). In addition, very few studies have demonstrated increased mortality of fish as a result of oil spills (Fodrie et al. 2014; Hjermann et al. 2007; IPIECA 1997).

Demersal fish are not expected to be impacted given the presence of entrained and dissolved oil is predicted in the surface layers only.

Pelagic free-swimming fish and sharks are unlikely to suffer long-term damage from oil spill exposure because dissolved/entrained hydrocarbons are typically insufficient to cause harm (ITOPF 2010). Pelagic species are also generally highly mobile and as such are not likely to suffer extended exposure (e.g. >40–96 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 (Volkman et al. 2004). 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 (King et al. 1996).

Fish are most vulnerable to oil during embryonic, larval and juvenile life stages. Oil exposure may result in decreased spawning success and abnormal larval development. Contact with oil droplets can mechanically damage feeding and breathing apparatus of embryos and larvae (Fodrie and Heck 2011). The toxic hydrocarbons in water can result in genetic damage, physical deformities and altered developmental timing for larvae and eggs exposed to even low concentrations over prolonged timeframes (days to weeks) (Fodrie and Heck 2011).

Marine fauna with gill-based respiratory systems, including Whale Sharks, are expected to have higher sensitivity to exposures of entrained oil. In addition, the tendency of Whale Sharks to feed close to surface waters increases the likelihood of exposure to surface slicks. A foraging BIA has been identified within the area at risk of potential exposure to surface, entrained and dissolved oils from a spill from the Corowa Development. Surface spills may also affect Whale Shark migration if attempting to travel through an area impacted by a spill. This displacement may cause stress in the animal and disrupt future migration to these areas (Taylor 2007). However, Whale Sharks do not spend all their time in surface waters—they routinely move between surface and to depths or >30 m, and in offshore regions can spend most of their time near the seafloor (DSEWPaC 2012).

Given the details above, the consequence of an accidental release of MDO/MGO causing injury / mortality to fauna or a change in fauna behaviour in fish species has been assessed as **Moderate (2)** with the impact assessed as **Very unlikely (B)** to occur given effects will be localised and temporary and are not expected to occur at a population level.

Marine Reptiles ✓

An accidental release of MDO/MGO has the potential to result in:

- injury / mortality to fauna
- change in fauna behaviour.

Marine reptiles may be vulnerable to hydrocarbon exposure from an oil spill. Marine reptiles (e.g. turtles) can be impacted by surface exposure when they surface to breathe, and by shoreline accumulation when nesting. Marine turtles can be exposed to oil externally (e.g. swimming through oil slicks) or internally (e.g. swallowing the oil, consuming oil-affected prey, or inhaling of volatile oil related compounds).

Marine turtles are vulnerable to the effects of oil at all life stages: eggs, hatchlings, juveniles, and adults. Oil exposure affects different life stages in different ways, and each life stage frequents a habitat with varied potential to be impacted during an oil spill. Effects of oil on turtles include increased egg mortality and developmental defects; direct mortality due to oiling in hatchlings, juveniles, and adults; and negative impacts to the skin, blood, digestive and immune systems, and salt glands. Several aspects of turtle biology and behaviour place them at particular risk, including a lack of avoidance (NOAA 2010b) and large pre-dive inhalations (Milton and Lutz 2003).

Experiments on physiological and clinical pathological effects of hydrocarbons on Loggerhead Turtles (~15–18 months old) showed that the major physiological systems were adversely affected by both chronic and acute exposures (96-hour exposure to a 0.05 cm layer of South Louisiana crude oil versus 0.5 cm for 48 hours) (Lutcavage et al. 1995). Recovery from the sloughing skin and mucosa took up to 21 days, increasing the turtle's susceptibility to infection or other diseases (Lutcavage et al. 1995).

Records of oiled wildlife during spills rarely include marine turtles, even from areas where they are known to be relatively abundant (Short 2011). An exception to this was the large number of marine turtles collected (613 dead and 536 live) during the Deepwater Horizon incident in the Gulf of Mexico, although many of these animals did not show any sign of oil exposure (NOAA 2011; 2013). Of the dead turtles found, 3.4% were visibly oiled and 85% of live turtles found were oiled (NOAA 2013). Of the captured animals, 88% of the live turtles were later released, suggesting that oiling does not inevitably lead to mortality.

Protected and migratory turtle species (e.g. Flatback, Green, and Hawksbill Turtles) are known to nest on the Pilbara inshore islands, within the area that may be exposed to shoreline accumulation from an oil spill from the Corowa Development. BIAs and critical habitat for nesting have also been identified for these species within the area.

The MGO is classified as a light persistent oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~97.3%) of volatile components and only a small (2.79%) residual component. Due to this volatility, once on the water surface most of this oil will evaporate; depending on wind conditions, the proportion of evaporated oil may vary between ~64–71% within several days of release (Section 7.2.7.2.3). Modelling undertaken for the surface release of MGO indicated that floating oil may extend in a NE/SW and offshore direction from the spill site, and potentially up to a maximum of 50 km; shoreline accumulation of oil was predicted to occur within an area extending along north-western North West Cape and some of the Pilbara inshore islands (the probability of shoreline accumulation above thresholds with biological impacts was very low [≤4%] for all modelled simulations).

Turtles may experience oiling impacts on nesting beaches and eggs through chemical exposures resulting in decreased survival to hatching and developmental defects in hatchlings. Adult females crossing an oiled beach could cause external oiling of the skin and carapace; most oil is deposited in the high-tide zone, and most turtles nest well above this level. Turtle hatchlings may be more vulnerable to smothering as they emerge from the nests and make their way over the intertidal area to the water (AMSA 2015b). Hatchlings that contact oil residues while crossing a beach can exhibit a range of effects including impaired movement and bodily functions (Shigenaka 2003). Hatchlings sticky with oily residues may also have more difficulty crawling and swimming, rendering them more vulnerable to predation.

Given the details above, the consequence of an accidental release of MDO/MGO causing injury / mortality to fauna or a change in fauna behaviour in marine reptile species has been assessed as **Moderate (2)** respectively with the impact assessed as **Very Unlikely (B)** to occur given effects will be localised and temporary and are not expected to occur at a population level.

Marine Mammals ✓

An accidental release of MDO/MGO has the potential to result in:

- injury / mortality to fauna
- change in fauna behaviour.

Marine mammals may be vulnerable to hydrocarbon exposure from an oil spill. Marine mammals (e.g. cetaceans, Dugongs) can be impacted by surface exposure when they surface to breathe, and by entrained/dissolved components in the water column. Marine mammals can be exposed to oil externally (e.g. swimming through surface slick or entrained oil) or internally (e.g. swallowing the oil, consuming oil-affected prey, or inhaling of volatile oil related compounds).

Direct contact with surface oil is considered to have little deleterious effect on whales, possibly due to the skin's effectiveness as a barrier to toxicity. Furthermore, effect of oil on cetacean skin is probably minor and temporary (Geraci and St Aubin 1982). French-McCay (2009) identifies that a 10–25 µm oil thickness threshold has the potential to impart a lethal dose to the species; however, also estimates a probability of 0.1% mortality to cetaceans if they encounter these thresholds based on the proportion of the time spent at surface.

The physical impacts from ingested hydrocarbons with subsequent lethal or sublethal impacts are applicable; however, the susceptibility of cetaceans 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. As highly mobile species, in general it is very unlikely that these animals will be constantly exposed to concentrations of hydrocarbons in the water column for continuous durations (e.g. >48–96 hours) that would lead to chronic effects. Note also, many marine mammals appear to have the necessary liver enzymes to metabolise hydrocarbons and excrete them as polar derivatives.

Like turtles, cetaceans appear to not exhibit avoidance behaviours. Evidence suggests that many cetacean species are unlikely to detect and avoid spilled oil (Harvey and Dahlheim 1994; Matkin et al. 2008). There are numerous examples where cetaceans have appeared to incidentally encounter oil and/or not demonstrated any obvious avoidance behaviour; e.g. following the Exxon oil spill, Matkin et al. (2008) reported Killer Whales in slicks of oil as early as 24 hours after the spill.

Some whales, particularly those with coastal migration and reproduction, display strong site fidelity to specific resting, breeding and feeding habitats, as well as to their migratory paths. Migratory BIAs identified for the Pygmy Blue Whale and Humpback Whale occur within the area that may be exposed from an oil spill from the Corowa Development. If spilled oil reaches these biologically important habitats, the oil may disrupt natural behaviours, displace animals, reduce foraging or reproductive success rates and increase mortality.

There is also Dugong BIA for foraging, breeding, nursing and calving within the Exmouth Gulf and North West Cape region. Due to the oil remaining on the surface and/or within surface waters, no impact to seagrass and foraging sources is expected. In addition, due to the volatility of the oil, predicted lengths of exposure are expected to be minimal. The probability of exposure of this Dugong BIA is also predicted to be very low: <1% floating oil, ~1–2% dissolved oil, ~7–8% entrained oil, and ~1–2% entrained time-integrated.

Organisms require exposure to a toxicant over a period of time for toxic effects to occur, therefore the majority of the area exposed to entrained and dissolved oils are expected to be representative of potential sublethal impacts only.

Given the details above, the consequence of an accidental release of MDO/MGO causing injury / mortality to fauna or a change in fauna behaviour in marine mammals has been assessed as **Moderate (2)** with the impact assessed as **Very Unlikely (B)** to occur given effects will be localised and temporary and are not expected to occur at a population level.

7.2.7.3.3 Social, Economic and Cultural Receptors

Social, economic and cultural receptors have the potential to be impacted as a result of impacts to physical or ecological receptors.

Impacts to the identified receptors include:

- change in water quality
- change in habitat
- injury / mortality to fauna
- change in fauna behaviour
- changes to the functions, interests or activities of other users
- change in aesthetic value.

Table 7-142 provides a detailed evaluation of the impact of an accidental release of MDO/MGO to social receptors.

Table 7-142 Impact and Risk Assessment for Social, Economic and Cultural Receptors from Accidental Release – MDO/MGO

Australian Marine Parks; State Protected Areas – Marine; Heritage Features ✓
An accidental hydrocarbon release of light crude oil has the potential to result in: • change in water quality • change in habitat • injury / mortality to fauna • change in fauna behaviour • changes to the functions, interests or activities of other users • change in aesthetic value. Marine protected areas (including marine parks and heritage listed places) may be vulnerable to hydrocarbon exposures from an oil spill. As the values and sensitivities of these protected places are a combination of quality, habitat, marine fauna and flora, and human use, the impact pathways are varied. Refer also to impact assessments for related receptors, including water quality, sediment quality, coastal and benthic habitats and communities and marine fauna. **Australian Marine Parks and State Protected Areas – Marine** Marine parks/reserves that may be exposed to floating oil are Ningaloo MP (State and Commonwealth), Gascoyne MP, Muiron Islands MMA (noting that the probability of exposure is low, <10%, for all modelled simulations). Floating oil can lead to temporary decrease in aesthetic values. Entrained and dissolved hydrocarbons are predicted to potentially travel a greater distance, however both the exposure value and the probability of exposure occurring reduces with distance from the spill location. However, these oil components are predicted to remain within the surface layers (<10 m depth). Therefore, impacts to pelagic values (e.g. marine fauna) are restricted to those in surface waters only. **Heritage Features** The Ningaloo Coast WHA may be exposed to floating, entrained, dissolved and shoreline oil components in the event of an MDO/MGO spill (noting that the probability of exposure is low, <10%, for all modelled simulations). Potential impacts range from a temporary decrease in aesthetic values to physical coating and/or toxicity effects associated with the values of the WHA (e.g. marine fauna, coastal habitats etc.). There are also known shipwrecks within the predicted area of entrained and dissolved oil exposure. However, both wrecks are situated in waters >2000 m. Stochastic modelling undertaken for the subsea release of the Corowa crude indicated that if/when entrained oil did occur it remained in the surface layers (predominantly within the 0–10 m depth, with some occasional and low probability of exposures to depths up to 30 m). Therefore no impact to shipwrecks is expected to occur.

Summary

Given the details above, the consequence of an accidental release of MDO/MGO causing any permanent and/or significant impacts to AMPs, State Protected Areas – Marine and/or Heritage Features has been assessed as **Moderate (2)** with the impact assessed as **Very unlikely (B)** to occur given effects will be temporary and spatially restricted.

Key Ecological Features ✓

An accidental hydrocarbon release of light crude oil has the potential to result in:

- change in water quality
- change in habitat
- injury / mortality to fauna
- change in fauna behaviour.

MGO is classified as a light oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~97.3%) of volatile components and only a small (2.7%) residual component. Due to this volatility, once on the water surface most of this oil is expected to evaporate within several days. Weathering tests predicted that after 7 days under calm conditions, ~71% would evaporate. Entrained and dissolved oil may persist for longer (compared to floating oil); however, hydrocarbons are predicted to remain within the surface layers (<10 m depth).

Therefore, KEFs associated seafloor features and/or benthic and demersal fauna and flora (e.g. ancient coastline at 125 m, continental slope demersal fish communities), are not expected to be impacted by a release of MDO/MGO.

However, for those KEFs where values include marine waters and/or pelagic fauna (e.g. Commonwealth waters adjacent to Ningaloo Reef, Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula etc.), these may be vulnerable to a spill of MGO/MDO.

The actual area of exposure for an individual spill event will be relatively small, with exposure shown to be transient and temporary due to the influence of waves, currents and weathering processes.

Refer also to impact assessments for related receptors, including water quality and marine fauna.

Given the details above, the consequence of an accidental release of MDO/MGO causing any permanent and/or significant impacts to KEFs within the EMBA has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur given that any change in water quality or habitat would be restricted to surface waters within a spatially restricted area, and similarly any change in pelagic fauna (see previous impact assessments) is not expected to occur at population levels.

Industry ✓

<u>Changes to the functions, interests or activities of other users</u>

Marine and coastal industries in the EMBA mainly comprise petroleum activities, commercial shipping and associated ports and defence activities.

Offshore petroleum activities in the region include Santos' Ningaloo Vision FPSO (~49 km), Woodside's Ngujima-Yin FPSO (~51 km), BHP's Pyrenees FPSO (~46 km) and BHP's Stybarrow Development (~75 km; note this is in cessation operations and the FPSO has left the field) and may potentially be exposed to in-water oil exposures. In the event of a large spill, an exclusion zone may be established around the spill-affected area. Any exclusion zone is likely to be localised to the source of the spill. Also, as light crude oil is subject to rapid evaporation the exclusion zone is likely to be temporary minimising the impacts to these developments.

Land-based processing hubs include Ashburton North (Wheatstone LNG), Varanus Island, Barrow Island (Gorgon LNG), and Woodside's Burrup Hub near Dampier; however, these are all beyond the predicted area of exposure of the modelled MGO release.

The largest ports adjacent to the Corowa field are the Ports of Dampier and Port Hedland; however, these are all beyond the predicted area of exposure of the modelled MGO release.

Defence practice and training areas extend offshore from Learmonth RAAF base. In-water oil exposures are not expected to adversely impact the use of these areas.

Given the details above, the consequence of an accidental release of MDO/MGO causing a change in the functions, interests or activities of other users (Marine and Coastal Industries) has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur due to being beyond the predicted area of exposure of the modelled subsea release of Corowa crude and rapid evaporation so any exclusion zone is likely to be temporary.

Commercial Fisheries ✓

Changes to the functions, interests or activities of other users

Oil spills can damage fishery and mariculture resources through physical contamination, toxic effects on stock and by disrupting business activities. The nature and extent of the impact on seafood production depends on the characteristics of the spilled oil, the circumstances of the incident and the type of fishing activity or business affected.

Tainting is a change in the characteristic smell or flavour of fish and me be due to oil being taken up by the tissues or contaminating the surface catch (McIntyre et al. 1982). Taint in seafood renders it unfit for human consumption or unsellable due to public perception. Light oils and the middle boiling range of crude distillates are the most potent sources of taint (Whittle 1978). Tainting may not be a permanent condition but will persist if the organisms are continuously exposed; when exposure is terminated, depuration will quickly occur (McIntyre et al. 1982).

A major oil spill may result in the temporary closure of part of fishery management areas. It is unlikely that a complete fishery would be closed due to their large spatial extents, but the partial closure may still displace fishing effort. Oil spills may also foul fishing equipment (e.g. traps and trawl nets) and requiring cleaning or replacement; however, due to the volatility of MDO/MGO, this is not expected to occur.

Based on historical fishing effort, the Commonwealth fisheries that may be active in the Corowa Development Areas have management areas from the 200 m isobath to the Australian Fishing Zone. Given that modelling of the Corowa crude indicates that oil at these depths is expected to occur with the surface layers of water only, impacts to Commonwealth fisheries are not expected to occur.

Historical data for State fisheries suggests that the only fishery with significant catch and fishing days around the Corowa Development is the Exmouth Gulf Prawn Managed Fishery. The modelling of the MGO release indicates that the oil does not extend into Exmouth Gulf, and therefore impacts to this fishery are not expected to occur.

Given the details above, the consequence of an accidental release of MDO/MGO causing a change in the functions, interests or activities of other users (commercial fisheries) has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur, due to the low fishing activity within the EMBA.

Tourism and Recreation ✓

An accidental hydrocarbon release of light crude oil has the potential to result in:

- changes to the functions, interests or activities of other users
- change in aesthetic value.

Tourism is a key economic driver, generating more than 97,000 jobs and injecting $10 billion into the Western Australian economy by Gross State Product (Tourism WA 2016). Coastal and marine-based tourism is a significant portion of this income due to the majority of the towns, infrastructure and sites located along the coast (DoT 2018). Charter fishing, diving, snorkelling, whale, marine turtle and dolphin watching plus cruising are the main commercial tourism activities in and adjacent to the North-west Marine Region (DEWHA 2008). Apart from offshore charter fishing, these activities are generally centred around shallow coastal waters or around areas of fauna aggregation, generally within state waters.

Any disruption to activities such as vessel activities, fishing and diving can have follow-on effects on accommodation, tourism business and other companies who gain their livelihood from tourism. Coastal areas can be affected by oil spills due to public perception and reduction in amenity. Activities that are based around marine fauna and habitats are likely to be impacted the most (e.g. diving activities on coral reefs and other marine tourist operators).

Refer also to impact assessments for related receptors, including coastal and benthic habitats and communities and marine fauna.

Given the details above, the consequence of an accidental release of MDO/MGO causing a change in the functions, interests or activities of other users (tourism and recreation) and a change in aesthetic values, has been assessed as **Minor (1)**, with the impact assessed as **Very Unlikely (B)** to occur, given that effects will be highly localised and temporary in nature.

7.2.7.4 Consequence and Acceptability Summary

The consequence of an accidental release of MDO/MGO has been evaluated as **Moderate (2)** for the worst-case potentially impacted receptors.

Vessel collisions are rare, with only 37 collisions reported from 1200 marine incidents, across all industries, in Australian waters from 2005–2012 (Australian Transport Safety Bureau 2013). Most vessel collisions involve damage to a forward tank; these tanks are generally double-lined and smaller than other tanks.

The FSO is stationary, and the only approaching vessels should be tankers and support vessels, which would approach at a slow speed (<5 knots). Non-project vessels would remain outside the PSZ. The worst-case likelihood was assessed as **Unlikely (C)** (for water quality).

The risk level for all receptors is **Low** and considered **acceptable** based on an evaluation against the criteria in Table 7-12.

Table 7-143 Demonstration of Acceptability for Accidental Release – MDO/MGO

Acceptability Criteria	Justification
To meet the principles of ESD	• MGO is classified as a light persistent oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~97.3%) of volatile components and only a small (2.7%) residual component. Due to this volatility most of this oil will evaporate from the water surface; depending on wind conditions, the proportion of evaporated oil may vary between ~64–71% within several days of release. • Weathering tests predicted that after 7 days under calmer conditions, ~71% had evaporated, ~27% of the oil remained on the sea surface, a negligible amount had entrained, and ~2% undergoing degradation. • No exposure is predicted to sediment quality and benthic habitats and communities. • Exposure above the impact threshold was predicted for rocky coasts and sandy beaches in the Pilbara inshore islands, and sandy beaches and tidal flats of the North West Cape, although no exposure is predicted in the Exmouth Gulf. • Saltmarsh, mangroves and wetlands are not known to occur within the limited area that may be exposed to oil above the impact threshold. • Plankton near the spill source may be at greater risk of impact, however, with rapid weathering expected, this toxicity also decreases therefore the majority of the area exposed to entrained and dissolved oils are expected to be representative of potential sublethal impacts only. • Shoreline accumulation above 100 g/m^2 may occur along the north-western shores of North West Cape and through the Pilbara inshore islands (from Muiron to Bessieres Island), though probability above any exposure value was low (≤7%). • Shoreline accumulation is predicted to intersect with BIAs and critical habitat for nesting for turtle species, however the probability above thresholds with biological impacts was very low (≤4%). • Offshore islands that are known nesting habitats for migratory birds (some with associated BIAs, such as the Wedge-tailed Shearwater) are potentially

Acceptability Criteria	Justification
	at risk from floating and/or shoreline exposure However, the actual area of exposure for an individual spill event will be relatively small, with exposure shown to be transient and temporary due to the influence of waves, currents and weathering processes; the probability above thresholds with biological impacts was very low (≤4%). • A foraging and migration Whale Shark BIA has been identified within the area at risk of potential exposure to surface, entrained and dissolved oils, however in-water concentrations are predicted <10m. effects will be localised and temporary and are not expected to occur at a population level. • BIAs for Dugongs, Humpback Whales and Pygmy Blue Whales are within the area at risk of potential exposure to surface and entrained hydrocarbons; however, due to the volatility of the oil, predicted lengths of exposure are expected to be minimal, and expected to be representative of potential sublethal impacts only. The probability of exposure of this Dugong BIA is also predicted to be very low (<1–8%). • Ningaloo Coast WHA may be exposed to floating, entrained, dissolved and shoreline oil components. Potential impacts range from a temporary decrease in aesthetic values to physical coating and/or toxicity affects associated with the values of the WHA (e.g. marine fauna, coastal habitats etc.); probability is low (<10%). • The Ningaloo MP (State and Commonwealth), Gascoyne MP, Muiron Islands MMA may be exposed to floating, entrained and dissolved hydrocarbons. However, these oil components are predicted to remain within the surface layers (<10 m depth). Therefore, impacts to pelagic values (e.g. marine fauna) are restricted to those in surface waters only. • KEFs where values include marine waters and/or pelagic fauna (e.g. Commonwealth waters adjacent to Ningaloo Reef, Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula etc.) may be vulnerable to a spill as Entrained and dissolved oil is predicted to remain within the surface layers (<10 m depth) and not intersect with the benthic environment. • The only State fishery with significant catch and fishing days around the Corowa Development was the Exmouth Gulf Prawn Managed Fishery; however, modelling predicts that oil does not extend into the Exmouth Gulf, and therefore impacts to this fishery are not expected to occur.
Internal context	• KATO Marine Operations Procedure (KAT-000-PO-PP-101) (KATO 2020b)
External context	• No stakeholder concerns have been raised with respect to and accidental release of MDO/MGO or potentially impacted receptors.
Other requirements	• Activities undertaken during the Corowa Development will adhere to the requirements for Oil Pollution Emergency Plans (OPEPs) under the OPGGS(E)R. • Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and the *Navigation Act 2012* implements the International Convention for the Prevention of Pollution from Ships (MARPOL). • The North-west and South-West Marine Parks Network Management Plan 2018 (DNP 2018) identifies marine pollution as a pressure, with no explicit relevant management actions. • These Conservation Advices / Recovery Plans identify pollution as a key threat: o Conservation Advice *Balaenoptera borealis* Sei Whale (TSSC 2015a) o Conservation Advice *Balaenoptera physalus* Fin Whale (TSSC 2015b)

Acceptability Criteria	Justification
	○ Recovery plan for marine turtles in Australia (CoA 2017), identified as ○ Acute chemical discharge (oil pollution) ○ Conservation Advice *Calidris ferruginea* (Curlew Sandpiper) (DoE 2015a) identified as Habitat degradation/ modification (oil pollution) ○ National recovery plan for threatened albatrosses and giant petrels 2011–2016 DSEWPaC ○ Conservation advice for *Sterna nereis nereis* (Fairy Tern) (TSSC 2011a) • These Conservation Advices / Recovery Plans identify habitats degradation/modification as threat, which may be consequence of accidental release of hydrocarbon: ○ Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Seasnake) (TSSC 2011b) ○ Approved Conservation advice for *Pristis clavata* (Dwarf Sawfish) (TSSC 2009b) ○ Approved Conservation Advice for Green Sawfish (TSSC 2008a) ○ Sawfish and River Shark Multispecies Recovery Plan (CoA 2015b) ○ Approved Conservation Advice for *Pristis pristis* (Largetooth Sawfish) (DoE 2014a) ○ Whale Shark (*Rhincodon typus*) recovery plan 2005–2010 (DEH 2005a) ○ Conservation Advice *Calidris canutus* (Red Knot) (TSSC 2016a) ○ Conservation Advice *Limosa lapponica baueri* (Bar-tailed Godwit (Western Alaskan)) (TSSC 2016b) ○ Conservation Advice *Limosa lapponica menzbieri* (Bar-tailed Godwit (Northern Siberian)) (TSSC 2016c) ○ Conservation Advice for *Numenius madagascariensis* (Eastern Curlew) (DoE 2015c) • These conservation advices and recovery plan identify the following conservation actions: ○ Minimise chemical and terrestrial discharge. ○ Ensure spill risk strategies and response programs include management for turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs. ○ Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks. ○ Ensure appropriate oil spill contingency plans are in place for the subspecies' breeding sites that are vulnerable to oil spills. ○ Implement measures to reduce adverse impacts of habitat degradation and/or modification; or ○ No explicit relevant management actions; oil pollution is recognised as a threat. • In regard to accidental release – Corowa light crude oil, activities associated with the Corowa Development will not be conducted in a manner inconsistent with: • the objectives of the respective zones of the AMPs, and the principles of the IUCN Area Categories applicable to the values of the AMPs • the management plan for, or management principles of, Australian World Heritage properties or National Heritage places • with a Recovery Plan, threat abatement plan or Conservation Advice for a listed threatened species

Acceptability Criteria	Justification
	• to the management plan for, or objectives of, State marine parks and reserves, and the principles of the marine parks and reserves zoning • protecting the values of the Commonwealth marine area for other users.

A summary of the impact analysis and evaluation, including control measures adopted and EPOs, is provided in Table 7-144.

Table 7-144 Summary of the Impact Analysis and Evaluation for Accidental Release – MDO/MGO

<table>
<tr><th>Receptor</th><th>Impacts</th><th>EPOs</th><th>Adopted Control Measures</th><th>C</th><th>L</th><th>RL</th></tr>
<tr><td>Ambient water quality</td><td>Change in water quality</td><td>EPO10: To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.
EPO13: To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.</td><td rowspan="3">CM03: Pre-start notifications will be provided to relevant stakeholders at appropriate timing.
CM29: Emergency response activities will be implemented in accordance with a vessel's valid and appropriate Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class).
CM32: NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place.
CM33: Emergency response capability will be maintained in accordance with accepted EPs and OPEPs.
CM34: NOPSEMA-accepted Well Operations Management Plan in place for all wells, in accordance with the Offshore Petroleum and Greenhouse Gas Storage Act requirements.</td><td>Minor</td><td>Unlikely</td><td>Low</td></tr>
<tr><td>Plankton</td><td>Injury / mortality to fauna</td><td rowspan="2">EPO2: To not result in the displacement of marine turtles from their nesting/internesting BIAs.
EPO3: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population.
EPO4: To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species.
EPO5: To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species.</td><td>Minor</td><td>Very unlikely</td><td>Low</td></tr>
<tr><td>Coastal habitats and communities</td><td>Change in habitat
Injury / mortality to fauna
Change in fauna behaviour
Change in aesthetic value</td><td>Minor</td><td>Very unlikely</td><td>Low</td></tr>
</table>

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
Seabirds and shorebirds	Injury / mortality to fauna Change in fauna behaviour	**EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution. **EPO14:** To not result in a change that may have an adverse effect on the protection and conservation of biodiversity, ecological processes and other natural, cultural and heritage values of marine parks and protected areas. **EPO15:** To not result in a change that may cause one or more of the World Heritage values or National	**CM35**: Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken. **CM36**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area notifications, separation distance, and vessel speed.	Moderate	Very unlikely	Low
Fish				Moderate	Very unlikely	Low
Marine reptiles				Moderate	Very unlikely	Low
Marine mammals				Moderate	Very unlikely	Low
Australian Marine Parks	Change in water quality Change in habitat Injury / mortality to fauna Change in fauna behaviour Changes to the functions, interests or activities of other users Change in aesthetic value			Moderate	Very unlikely	Low
State Protected Areas – Marine				Moderate	Very unlikely	Low
Heritage Features				Moderate	Very unlikely	Low
Key Ecological Features	Change in water quality Change in sediment quality Change in habitat Injury / mortality to fauna Change in fauna behaviour			Minor	Very unlikely	Low
Industry	Changes to the functions, interests or			Minor	Very unlikely	Low

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
	activities of other users	Heritage values of a declared World Heritage property or National Heritage place to be lost, degraded or damaged, or notably altered, modified, obscured or diminished. **EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted. **EPO17**: To not result in an impact to heritage values or social surroundings, including damage or destruction of a historic shipwreck.				
Commercial Fisheries	Changes to the functions, interests or activities of other users			Minor	Very unlikely	Low
Tourism and Recreation	Changes to the functions, interests or activities of other users Change in aesthetic value			Minor	Very unlikely	Low

C=Consequence, L=Likelihood, RL=Risk Level

8 Cumulative Impact Assessment

8.1 Introduction

The World Bank (IFC 2013), describes that effective impact and risk assessment should also assess impacts on a more holistic, whole-ecosystem level, considering the potential cumulative or combination impacts of the proposed project, and any existing and future concurrent activities, on the existing environment.

Cumulative impact assessment should determine whether the incremental impacts will have a cumulated effect along with other impacts of the activity. It should also go further to determine if the impact of a project in combination with the other impacts, may cause a significant change now or in the future to a receptor, after applying mitigation for the project (Hegmann et al. 1999).

Section 7.1 identifies and evaluates impacts related to planned activities associated with the Corowa Development. Given the low likelihood of unplanned events (e.g. accidental releases) occurring during the Corowa Development, 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 6.

8.2 Establish the Context

To establish the context of the cumulative assessment, these must be determined:

- spatial and temporal boundary of the assessment
- existing industries / projects; past, present or future
- existing environment within these boundaries
- identification of Environmental Aspects common to the Corowa Development and other actions / projects.

8.2.1 Spatial and Temporal Boundary of the Assessment

Two types of boundaries are required for the assessment of cumulative assessments: spatial (i.e. how far), and temporal (i.e. how long into the past or future).

The spatial boundary is designed to capture all possible aspect interactions (i.e. spatial extent for each aspect described in Section 7.1). The exposure areas for the Corowa Development are defined in Section 5.1.

The largest exposure area for any planned aspect is for light emissions. The Light Area for the Corowa Development has been defined as 30 km radius around the expected MODU location (Section 7.1.3), and is the worst-case extent of predicted measurable change to ambient light based on planned activities from the Corowa Development. However, after the first 9–14 months of operations, the measurable change in light will reduce to 12.6 km, staying at this level for the remainder of the operational period.

All other spatial exposure extents from planned aspects are within the Project Area (5 km radius around MOPU location). Therefore, a conservative spatial extent of 30 km has been used for purposes of cumulative impact assessment for the Corowa Development.

Temporal boundaries consider both the past and future activities and environments. Three wells have been previously drilled in the Corowa field, the most recent of which (Corowa East-1) was drilled in 2005. No other developments exist in the immediate permit areas adjacent to the Corowa Development. It is expected that the existing environment will have recovered to ambient baseline conditions following the most recent activity in the field, therefore past activities are not considered in this assessment.

The future temporal boundary should extend until all impacts from the Corowa Development have ceased and receptors have recovered to pre-disturbance conditions. Based on the environmental impact assessment undertaken, recovery could take up to one year, based upon:

- <208 days for benthic habitats and communities to recover from seabed disturbance (Dernie et al. 2003; Section 7.1.2)
- <1 year for ambient sediment quality to recovery from planned discharges of drilling cuttings and fluids. Note: Cement discharges can cause a more permanent change to the sediment; however, given the very localised nature (<60 m) of the area affected, this has not been evaluated further

On completion of the Corowa Development, all facilities and infrastructure will be removed, the wells plugged and abandoned, and the field will be depleted. No further oil and gas activity at the Corowa field is expected following the Corowa Development, and there is little interest in the area for other industries.

Therefore, the temporal boundary for the assessment has been conservatively set as one year after decommissioning of the Corowa Development. Allowing for a total project life of approximately five years, this gives a conservative temporal extent of six years.

8.2.2 Existing Industries / Projects

Existing industries / project within the temporal and spatial boundary of the assessment have been identified.

Section 5.5.5 summarises the existing industries operating within the vicinity of the Corowa Development, including:

- State- and Commonwealth-managed fisheries
- tourism and recreation
- marine and coastal industries:
  - Existing oil and gas developments – closest is BHP's Pyrenees FPSO, followed by Santos' Ningaloo Vision FPSO, at ~46 km and 49 km away from the Corowa Development respectively
  - Defence (training area)
  - Commercial shipping.

Typically, cumulative impact assessments will also consider the effect of impacts associated with future industries / projects. KATO is unaware of any projects planned that will be located in close-enough proximity to the Corowa Development to lead to cumulative impacts. Once the Corowa Development is complete, the honeybee production system will be relocated to the next field, which is likely the Amulet Development (though Amulet may be undertaken first). Amulet is >300 km from Corowa, and is subject to a separate OPP.

As the system is relocatable, the developments will be undertaken in sequence, and cannot be undertaken at the same time. Activities associated with the next development will not begin until the Corowa Development has been fully decommissioned, and the MOPU towed to the next field. Therefore, given the distance and the difference in time frame no cumulative or combination effects from the Amulet Development are expected.

8.2.3 Existing Environment within the Assessment Boundaries

A detailed description of the Existing Environment within the EMBA is provided in Section 5. Based on the spatial and temporal boundaries established, this description is sufficient to support the assessment of cumulative impacts.

8.2.4 Identification of Aspect Interactions

Aspects associated with the Corowa Development were considered in reference to the spatial and temporal boundaries of this cumulative impact assessment, to identify potential sources of cumulative impacts (Table 8-1).

Impacts resulting from planned aspects are restricted to the Project Area, comprising a 5 km buffer around the expected MOPU location, with the exception of the Light Area, which has been modelled as a 30 km radius (Section 7.1.3).

The only existing industries / projects within 5 km (i.e. spatial boundary for cumulative assessment for these aspects) are:

- fisheries
- industries (shipping and Defence training areas)

A variety of vessels will operate throughout the duration of the Corowa Development, which is expected to be approximately five years (shown in Table 3-13). This number will peak during drilling, commissioning and decommissioning at approximately ten support vessels. Throughout the operations phase (~2–4.5 years), only one to two support vessels are expected. Vessels transiting to and from the Project Area are not included in the scope of this OPP and operate under the Commonwealth *Navigation Act 2012*.

It is possible that cumulative impacts may occur within a 5 km spatial boundary from aspects related to vessel activities, including:

- Physical Presence – Interaction with Other Users (Section 8.2.4.1)
- Planned Discharges – Vessels and facilities (cooling water, brine, deck drainage, bilge, sewage, greywater, food waste) (Section 8.2.4.2)

Some aspects may result in impacts extending beyond the Project Area (5 km). The closest oil and gas development is located 49 km away, however commercial shipping and fishing vessels will likely pass close to the Corowa Development and may result in impacts becoming cumulative. Aspects that may result in cumulative impacts include:

- Emissions – Light (Section 8.2.4.3)
- Emissions – Atmospheric (Section 8.2.4.4).

Aspects identified as having the potential to result in cumulative impacts are further described in the sections below.

Table 8-1 Aspects that may lead to Cumulative Impacts

Aspect	Spatial Boundary of Corowa impacts	Existing industries / project within spatial boundary	Potential for Cumulative Impacts
Physical Presence – Interaction with Other Users	Project Area (5 km)	• Fisheries • Industries (shipping, Defence)	Interaction possible, but no cumulative impacts expected (Section 8.2.4.1)
Physical Presence – Seabed Disturbance	Project Area (5 km)	• Fisheries • Industries (shipping, Defence)	No interaction
Emissions – Light	Light Area (30 km)	• Fisheries • Industries (shipping, Defence, petroleum)	**Yes (Section 8.2.4.3)**

Aspect	Spatial Boundary of Corowa impacts	Existing industries / project within spatial boundary	Potential for Cumulative Impacts
Emissions – Atmospheric Emissions	Project Area (5 km)	• Fisheries • Industries (shipping, Defence)	Interaction possible, but no cumulative impacts expected (Section 8.2.4.4)
Emissions – Underwater Noise	Project Area (5 km)	• Fisheries • Industries (shipping, Defence)	No interaction
Planned Discharge – Drilling cuttings and Fluids	Project Area (5 km)	• Fisheries • Industries (shipping, Defence)	No interaction
Planned Discharge – Cement	Project Area (5 km)	• Fisheries • Industries (shipping, Defence)	No interaction
Planned Discharge – Commissioning Fluids	Project Area (5 km)	• Fisheries • Industries (shipping, Defence)	No interaction
Planned Discharge – Produced Formation Water	Project Area (5 km)	• Fisheries • Industries (shipping, Defence)	No interaction
Planned Discharge – Cooling Water and Brine	Project Area (5 km)	• Fisheries • Industries (shipping, Defence)	Interaction possible, but no cumulative impacts expected (Section 8.2.4.2)
Planned Discharge – Deck drainage and Bilge	Project Area (5 km)	• Fisheries • Industries (shipping, Defence)	Interaction possible, but no cumulative impacts expected (Section 8.2.4.2)
Planned Discharge – Sewage, Greywater and Food waste	Project Area (5 km)	• Fisheries • Industries (shipping, Defence)	Interaction possible, but no cumulative impacts expected (Section 8.2.4.2)

8.2.4.1 Physical Presence – Interaction with Other Users

Section 7.1.1.1 describes the direct impacts of the physical presence of the Corowa Development on other marine users, specifically a change in the functions, interests or activities of other marine users. These impacts are assessed as being **Low** and acceptable to all receptors, as the Corowa Development will generate a low volume of vessel traffic throughout the project lifecycle, and a 500 m PSZ will be established to inform other marine users of the physical presence of the Corowa Development.

Impacts from physical presence are limited to the Project Area, and the transit route of support vessels from port to the Corowa Development. Vessel traffic associated with the Corowa Development is low and therefore will not add a significant volume of marine traffic to the region. The number of vessels used for the Corowa Development will peak at up to ten support vessels, but will comprise only one to two vessels for the majority of project life (i.e. operations phase). The closest oil and gas development is ~46 km away, and it is not expected that vessels transiting to Pyrenees or the Ningaloo Vision FPSO will cross paths, other than possibly close to port.

The Corowa Development is within the Department of Defence's North West Exercise Area (NWXA); however, stakeholder engagement confirmed that the DoD have no objections to the proposed activities, but require notification prior to commencement to ensure KATO activities do not conflict with Defence training (Section 10).

Given the low vessel traffic required for the Corowa Development and the unlikely occurrence of impacts from multiple vessels impacting in combination on a receptor, no cumulative impacts from physical presence of project vessels are expected.

8.2.4.2 Planned Discharge – Project Vessels and Facilities (CW and Brine; Deck Drainage and Bilge; Sewage, Greywater and Food Waste)

Discharges from project vessels and facilities include brine and cooling water, deck drainage and bilge, food waste, and sewage and greywater.

Vessels will be required during all phases of the Corowa Development, which will peak during drilling, commissioning and decommissioning phases at up to ten support vessels. Throughout the operations phase (~2–4.5 years), only one to two support vessels are expected. Vessels transiting to and from the Project Area are not included in the scope of this OPP and operate under the Commonwealth *Navigation Act 2012*.

Vessels associated with the Corowa Development will be mostly located within the Project Area (5km). Discharges from vessels will quickly dissipate in the high-energy marine environment of the NWS, with impacts to receptors expected to remain within the Project Area.

Vessels associated with other industries / projects operating in the area will be unlikely to transit through the Project Area regularly, limiting the potential for cumulative or combination effects from vessel discharges.

Given the low vessel traffic required for the Corowa Development and the unlikely occurrence of impacts from multiple vessels impacting in combination on a receptor, no cumulative impacts from planned discharges from project vessels are expected.

8.2.4.3 Emissions – Light

There are two main sources of light emissions from the Corowa Development—navigational light from vessels and facilities, and flaring during drilling and operations. Continuous flaring will occur during the Corowa Development, which will produce the largest ‘light field’.

Corowa Development

The light intensity (illuminance) analysis undertaken in Section 7.1.3 provided the basis for defining a Potential Impact Area for light, including the worst-case extents of predicted measurable changes to ambient light based on planned activities. Due to the changing flare characteristics over the operational life of the Corowa Development, flaring will initially be the dominant source of light defining the extent of the potential area of impact. However, beyond months 10–17 (P50–P10 estimates) of operational flaring, the amount of light emitted and the predicted light intensity from the flare will have reduced to at or below the amount of light emitted and predicted light intensity from the facility lighting, for the remainder of project life.

The maximum distances of the Potential Impact Area for light emissions from the Corowa Development are:

- Flaring:
  - ~30 km during peak (17 MMscfd) operational flaring (first 7–12 months)
  - reducing to ~12.7 km for a 5 MMscfd flare rate (after 10–17 months), and continues to decrease below this, as the reservoir depletes, and flaring rates reduce further.
- Facility lighting: ~12.6 km over the life of the project.

This measurable change in light does not directly extend over any neighbouring offshore oil and gas facilities, with the closest offshore or onshore oil and gas facilities located between 46 and 52 km from the expected MOPU location:

- 46 km – BHP-operated Pyrenees FPSO
- 49 km – Santos-operated Ningaloo Vision FPSO
- 51 km – Woodside-operated Ngujima-Yin FPSO
- 52 km – Chevron-operated Wheatstone LNG (onshore south of Onslow).

Other Marine and Industrial Activities

No fixed shipping or commercial fisheries facilities occur in the offshore area. Assuming that vessels require some levels of navigational light, any vessels passing within the vicinity of the Corowa Development will result in cumulative impacts. However, these impacts will be temporary, ceasing once the vessel has moved away from the Corowa Development. Due to their intermittent and transient nature, no cumulative impacts from shipping and fishing are expected and are not discussed further in this assessment.

The closest towns to the Corowa Development are Onslow (~60 km) and Exmouth (~67 km). Some small amount of sky glow is expected from these towns. However, there are no quantifiable publicly available data on the light emissions from these towns. As the towns are relatively small, their influence on any cumulative assessment is expected to be minor and has not been considered further in this assessment.

Therefore, this cumulative assessment focuses on the other oil and gas facilities, as long-term fixed sources of light emissions.

Summary

The neighbouring oil and gas facilities generate their own light emissions, though none undertake continuous flaring. Flaring for the other facilities only occurs during upset conditions, and the timing and durations of this cannot be predicted. Therefore, during normal operations, facility lighting determines the respective light emissions from these other facilities, and this has been used for this cumulative assessment.

A literature review of publicly available information was conducted to determine whether light emissions for the neighbouring facilities had been assessed, and whether either a Visible Light Exposure Area and/or a Potential Impact Area had been defined.

An assessment of light emissions from the Ningaloo Vision FPSO predicted navigational lighting would be visible up to 20 km (Apache 2008). No lighting intensity analysis was conducted; i.e. there was no assessment of the distance that a measurable change in light from the FPSO may occur (no Potential Impact Area is available for that facility).

No publicly available assessment of light emissions was available for the Pyrenees or Ngujima-Yin FPSO’s. However, it is expected that these facilities would have a similarly lit plant process surface area and navigational lighting requirements as the Ningaloo Vision FPSO, and as such, the visible light assessment from the Ningaloo Vision is considered an appropriate analogue for these other FPSO facilities.

No visible light assessment was available for the onshore Wheatstone LNG facility. However, based on the reported height of the facility (Chevron 2010), a line of sight assessment was undertaken using the methodology in Xodus Group (2019a, Appendix B). This calculation estimated that the Visible Light Exposure Area for WHS LNG is ~41 km.

Figure 8-1 shows a comparison of the Visible Light Exposure Area for the Corowa Development and these adjacent facilities. As can be seen, there is minimal overlap between the Visible Light Exposure

Areas for the offshore FPSO facilities and the Corowa Development, and no offshore islands or other important habitat occurs within this overlap area.

The visible light overlap area for the Corowa Development and the Wheatstone LNG facility has a larger area of intersect and does include some of the offshore islands (such as Serrurier Island and Bessieres Island).

However, the visibility of an artificial light does not necessarily imply a measurable change in ambient light (and therefore a potential impact). As summarised above (and described previously in Section 7.1.3, the area corresponding to a measurable change in ambient light (the Potential Light Impact Area) for the Corowa Development varies between 30 km (during the initial 7–12 months) and 12.6 km (for the remainder of the project life). It is only during the initial months of operation, that the Corowa Development will have a measurable change in ambient light over these offshore islands (Figure 7-10, Figure 7-9).

Wheatstone LNG is the only neighbouring facility that has publicly available light intensity modelling. For routine operations (i.e. facility lighting and with pilot flare), modelling suggests that illumination above 0.001 Lux would not occur beyond ~3 km from the Ashburton North Strategic Industrial Area (SIA) (URS 2010; Chevron 2010).

The modelled Potential Impact Area for Wheatstone LNG does not overlap with the Potential Impact Area defined for the Corowa Development.

Therefore, while there is expected to be some overlap of visual light (i.e. there will be areas of water and/or island where both the Corowa Development and/or another facility can be sighted), there is not expected to be any overlap in measurable changes to ambient light from normal operations of the Corowa Development or adjacent facilities.

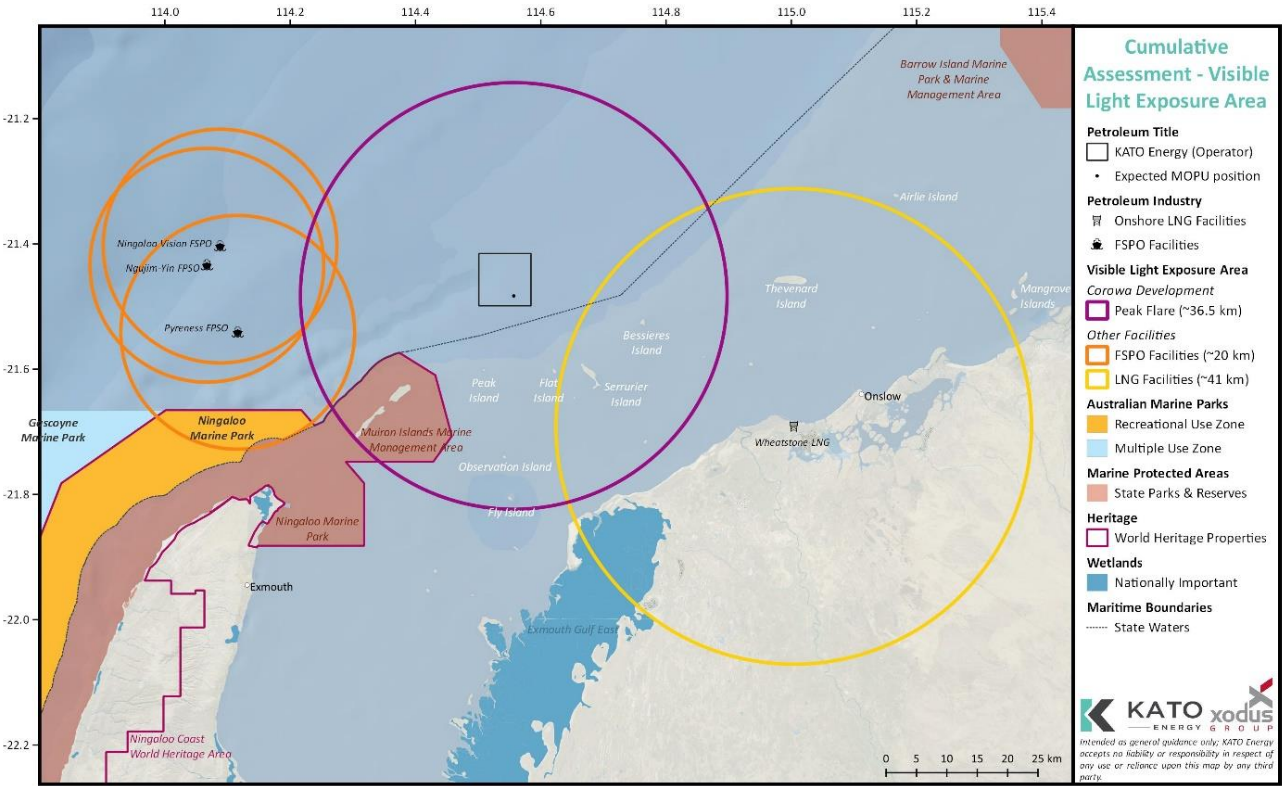


Figure 8-1 Visible Light Exposure Areas for Corowa Development and Adjacent Oil and Gas Facilities

8.2.4.4 Emissions – Atmospheric

Atmospheric emissions can be classified into two categories:

- atmospheric pollutants
- greenhouse gas (GHG) emissions.

Emissions will be generated from facilities and during flaring / venting activities. Studies indicate that atmospheric pollutant emissions could be measurable above background levels to 40 km (BP 2013), although they are likely to be below 4% NEPM criteria within 3 km. Therefore, the spatial boundary for atmospheric emissions is conservatively estimated as the Project Area (5 km).

The closest oil and gas activities are the Pyrenees FPSO (49 km away) and Ningaloo Vision FPSO (49 km away). This is outside the spatial boundary, therefore no impacts from atmospheric pollutants are expected. Vessel movements within the spatial boundary for atmospheric pollutants is expected, although vessel numbers will likely be low due to the presence of the PSZ and any impacts will be localised and temporary due to the transitory nature of vessel movements. Therefore, no cumulative impacts from atmospheric pollutants are expected.

Direct (Scope 1) GHG emissions (i.e. those generated directly as a result of Corowa Development activities) have been calculated as a total of 1.3 MT CO_2-e for the whole project life (using the conservative high P10 estimate; Section 7.1.4). The greatest contribution is from flaring, which comprises 88% of GHG emissions during the operations phase. The maximum annual direct GHG emissions from the Corowa Development only comprises 0.14% of Australia's annual GHG inventory (DoEE 2019).

Therefore, the Corowa Development does not represent a 'substantial cause' of climate change, and climate change is not considered an indirect consequence of the Corowa Development for the purposes of Section 527E of the EPBC Act (DSEWPaC 2013).

Climate change as a consequence of GHG emissions from all industries and nations is not facilitated 'to a major extent' by the Corowa Development. The proportion of GHG emissions from the Corowa Development compared to even one nation (Australia, at 0.14%) is too small for it to be considered a 'substantial cause' of a complex, global phenomena. The duration of emissions is also relatively short term (project life ~5 years).

The Ningaloo Vision FPSO was estimated to generate ~0.24 MT CO_2-e per year in Year 1 of production, with emissions expected to decrease throughout project life. Oil production at the Van Gogh field began in 2010, with an expected field life of 12–15 years.

By the time the Corowa Development is expected to start production in 2022, the Van Gough field will be in Year 12, and almost at the end of expected field life; therefore, GHG emissions are expected to be much lower.

The combination of GHG emissions from the Corowa Development and the Ningaloo Vision FPSO is not considered to be significant, with no cumulative impacts expected.

8.3 Cumulative Impact Assessment

Impact assessment is undertaken in three steps: identification, analysis and evaluation. Criteria for analysis and evaluation are described in Section 6.3.

To identify where aspects may result in cumulative impacts to receptors, the potential interactions have been considered in two ways:

- Could receptors be impacted by multiple aspects as a result of the Corowa Development?
- Could receptors be impacted by the same or multiple aspects as a result of the Corowa Development in combination with other industries operating nearby?

8.3.1 Physical Environment

The physical environment within the Project Area is likely to be impacted by planned aspects during all phases of the Corowa Development. Assessment of the potential for cumulative impacts is provided in Table 8-2.

Where cumulative impacts are possible, either from the Corowa Development or from existing industries / projects, a discussion is provided in the following subsections.

Table 8-2 Potential Cumulative Impacts to Receptors in the Physical Environment

Receptor	Physical Presence – Interaction with other users	Physical presence – Seabed disturbance	Emissions – Light	Emissions – Atmospheric	Emissions – Underwater Noise	Planned Discharge – Drilling cuttings and Fluids	Planned Discharge – Cement	Planned Discharge –Commissioning Fluids	Planned Discharge – Produced Formation Water	Planned Discharge – Cooling water and Brine	Planned Discharge – Deck drainage and Bilge	Planned Discharge – Sewage, Greywater and Food waste	Potential cumulative impacts from the Corowa Development	Potential cumulative impacts from existing industries
Water quality		✓				✓	✓	✓	✓	✓	✓	✓	✓	X
Sediment quality						✓	✓	✓	✓	✓			✓	X
Air quality				✓									X	X
Climate				✓									X	X
Ambient Light			✓										X	✓
Ambient Noise					✓								X	X

8.3.1.1 Water Quality

Impacts to water quality are likely from all phases of the Corowa Development, as discharges to the marine environment and disturbances to the seabed will vary the composition of water for the duration of the impact effect. Both surface and seabed discharges will result in changes in water quality, such as toxicity, temperature and salinity, however modelling and studies generally show that impacts are short term and localised (e.g. Shell 2010; Frick et al. 2001; Woodside 2014; Chevron 2015), and the high-energy marine environment throughout the Project Area will lead to rapid mixing and reduce the extent of any impacts.

Similarly, changes to water quality through increased sedimentation will be quick to recover, with particles settling quickly back to the seabed following disturbance events (Neff 2005; 2010).

Phases of the Corowa Development will be undertaken consecutively, and impacts are expected to be localised and temporary. Given this, the effect of changes in water quality on the ambient water quality from the Corowa Development will return to baseline levels quickly, and no cumulative impacts are expected.

8.3.1.2 Sediment Quality

Impacts to ambient sediment quality are likely from all phases of the Corowa Development. Discharges at the seabed will result in changes in sediment quality, such as toxicity or changes to the sediment composition/granulometry. Modelling and studies show that impacts from planned discharges are short term and localised (e.g. IAOGP 2016; Neff 2005; BP Azerbaijan 2013), and that sediments will quickly return to their baseline condition following discharge (Terrens et al. 1998; Neff 2010).

Phases of the Corowa Development will be undertaken consecutively, and impacts are expected to be localised and temporary. It is possible that impacts to ambient sediment quality from commissioning fluids discharges at the seabed could affect areas that have been previously impacted by drilling discharges (i.e. drilling cuttings and fluids) and that have not yet fully recovered.

However, given the small disturbance area expected from drilling discharges and the homogenous seabed found within the Project Area, recovery is expected to be rapid and no cumulative impacts are expected.

8.3.1.3 Ambient Light

Impacts to ambient light are likely to result from a combination of light generated by the Corowa Development and light generated by other marine activities, including commercial fisheries and industry (specifically oil and gas and shipping).

As described in Section 8.2.4.3, the visible light overlap area for the Corowa Development and the Wheatstone LNG facility has a larger area of intersect and does include some of the offshore islands (such as Serrurier Island and Bessieres Island).

However, the visibility of an artificial light does not necessarily imply a measurable change in ambient light (and therefore a potential impact). As summarised above (and described previously in Section 7.1.3), the area corresponding to a measurable change in ambient light (the Potential Light Impact Area) for the Corowa Development varies between 30 km (during the initial 7–12 months) and 12.6 km (for the remainder of the project life). It is only during the initial months of operation, that the Corowa Development will have a measurable change in ambient light over these offshore islands (Figure 7-10, Figure 7-9).

The modelled Potential Light Impact Area for Wheatstone LNG does not overlap with the Potential Impact Area defined for the Corowa Development.

Therefore, while there is expected to be some overlap of visual light (i.e. there will be areas of water and/or island where both the Corowa Development and/or another facility can be sighted), there is not expected to be any overlap in measurable changes to ambient light from normal operations of the Corowa Development or adjacent facilities.

8.3.1.3.1 Cumulative Impact Evaluation

Light emissions from the Corowa Development in combination with light emissions from other industries / projects may lead to this cumulative impact to ambient light:

- change in ambient light.

Table 8-3 evaluates the potential cumulative impacts to ambient light.

Table 8-3 Cumulative Impact Assessment for Ambient Light

Ambient Light	✓
Change in ambient light Estimates of maximum distances for visible light and measurable light from the Corowa Development indicate that these do not directly overlap any of the adjacent oil and gas facilities (i.e. the Corowa Development will not be visible from any of the neighbouring facilities). The intensity of light and any sky glow will decrease rapidly with distance from the source. Decreases in both intensity and glow are related to distance by an inverse square law due to the curvature of the Earth (i.e. doubling of the distance reduces light/glow to one quarter), with atmospheric absorption also further reducing these. There is overlap between the Visible Light Exposure Area from the Corowa Development and neighbouring facilities, in two key areas of overlap (Figure 8-1): • small area of overlap between Corowa, and the Pyrenees, Ngujima-Yin and Ningaloo Vision FPSOs (although only the Ningaloo Vision has published line of sight information). • large area of overlap between Corowa and Wheatstone LNG, including Serrurier Island and Bessieres Island. However, the visibility of an artificial light does not necessarily imply a measurable change in ambient light (and therefore a potential impact). As summarised above (and described previously in Section 7.1.3.2.3), the area corresponding to a measurable change in ambient light (the Light Area) for the Corowa Development varies between 30 km (during the initial 10–17 months) and 12.6 km (for the remainder of the project life). The light modelling for the onshore Wheatstone LNG facility indicated a minimal extent of measurable light intensity (~3 km from the Ashburton North SIA), which would not overlap with the Potential Impact Area defined for the Corowa Development (URS 2010; Chevron 2010). Therefore, while there is expected to be some overlap of visual light (i.e. there will be areas of water and/or island where both the Corowa Development and/or another facility can be sighted), there is not expected to be any overlap in measurable changes to ambient light from normal operations of the Corowa Development or adjacent facilities. While it is visible close to the source, in the offshore ocean environmental this does not reflect a significant change. Given the above, the consequence of any cumulative impacts has been assessed as **Minor (1).**	

8.3.2 Ecological Environment

Receptors in the ecological environment are likely to be affected by planned aspects during all phases of the Corowa Development. Assessment of the potential for cumulative impacts is provided in Table 8-4).

Where cumulative impacts are possible, either from the Corowa Development or from existing industries / projects, a discussion is provided in the following subsections.

Table 8-4 Potential Cumulative Impacts to Receptors in the Ecological Environment

Receptor	Physical Presence – Interaction with other users	Physical presence – Seabed disturbance	Emissions – Light	Emissions – Underwater Noise	Planned Discharge – Drilling cuttings and Fluids	Planned Discharge – Cement	Planned Discharge – Produced Formation Water	Planned Discharge – Commissioning Fluids	Planned Discharge – Cooling water and Brine	Planned Discharge – Deck drainage and Bilge	Planned Discharge – Sewage, Greywater and Food waste	Potential cumulative impacts from the Corowa Development	Potential cumulative impacts from existing industries
Plankton							✓		✓			✓	X
Benthic habitat and communities		✓			✓	✓						✓	X
Seabirds and shorebirds			✓									X	✓
Fish		✓	✓	✓								✓	X
Marine Mammals				✓								X	X
Marine Reptiles			✓	✓								✓	✓

8.3.2.1 Plankton

Plankton may be impacted by PFW and cooling-water and brine discharges, which will both occur within the Project Area (5km) and will occur simultaneously during Operations. Both discharge streams will result in a change in water quality, which has the potential to result in injury or mortality to plankton due to their lack of mobility and therefore greater potential to be entrained within the discharge plume.

Impact to plankton from both PFW and cooling-water discharges are shown to be limited to the immediate source of the discharge, where the change in water quality will be the highest. No significant impacts are expected from either discharge individually. Cooling water generated on board the MOPU will likely be discharged through the same subsea window as PFW, meaning that a cumulative impact on plankton from these combined discharge streams is likely to occur.

8.3.2.1.1 Cumulative Impact Assessment

Simultaneous planned discharges of PFW and cooling water may lead to this cumulative impact on plankton:

- injury / mortality to fauna.

Table 8-5 evaluates the potential cumulative impacts to plankton.

Table 8-5 Cumulative Impact Assessment for Plankton

Plankton ✓
Injury/mortality to fauna A change in water quality due to PFW discharges may cause injury or mortality to plankton species through increased toxicity levels and increased water temperatures, while a change in water quality due to CW and brine may cause injury or mortality to plankton species through increased toxicity levels, salinity levels and increased water temperatures. PFW will be rapidly mixed with receiving waters and dispersed by ocean currents, while CW and brine will quickly sink, before being mixed and dispersed in the same way. As such, any potential impacts are expected to be limited to the source of the discharge where concentrations are highest. The environmental impact assessment describes the impact to plankton from changes in water temperature and salinity, and from increased toxicity levels. Early life stages of fish (embryos, larvae) and other plankton would be most susceptible to the changes in water quality, as they are less mobile and therefore can become exposed to the plume at the outfall. Plankton have a patchy distribution linked to localised and seasonal productivity that produces sporadic bursts in populations (DEWHA 2008). The oligotrophic waters of the project area are typical of the wider offshore region supporting low phytoplankton biomass and relatively low primary productivity (Woodside 2005). Any impacts within the area would be temporary as plankton populations are able to rapidly recover once the activity ceases. Plankton species have high levels of natural mortality and a rapid replacement rates (UNEP 1985). As planktonic productivity within the spatial boundary of the cumulative assessment is low and given the relatively small area of impact as a result of PFW, CW and brine discharges, impacts to plankton are not expected to result in a significant impact with no population-level declines or reduction in ecological productivity and diversity within Commonwealth marine areas. Plankton populations are expected to rapidly recover by natural action within the affected area once activities cease. As impact to plankton species are predicted to be localised and temporary, marine fauna that rely on plankton as a prey species are also unlikely to affected (i.e. no secondary impacts are expected). Given the details above, the consequence of cumulative effects causing injury / mortality to plankton has been assessed as **Minor (1)**, given that a change in ambient water quality will be highly localised and will return to background levels after discharges cease.

8.3.2.2 Benthic Habitats and Communities

Benthic habitats and communities may be impacted at all phases of the Corowa Development, from seabed disturbance and planned discharges of drilling discharges (drilling fluids and cuttings, cement) and CW and brine.

All phases of the Corowa Development will occur consecutively (though there will be overlap between Installation, Hook-up and Commissioning, and Drilling); however, recovery of benthic habitats and communities impacted during one phase may continue into the next phase in the development. This is particularly likely between the Drilling Phase and the Installation, Commissioning and Hook-Up Phase. However, impacts from planned discharges of cement are expected to be localised to the drill site, and therefore there will be no spatial cross-over with installation impacts such as during installation of the flowline and CALM buoy array.

The assessment shows that any impacts to benthic habitats and communities will be localised and temporary, with no population effects expected. A literature review undertaken by Bakke et al. (2013) confirmed this, indicating the ecosystem and population-level effects from numerous drilling operations are not expected. The benthic assemblage within the Corowa Development is homogenous and will rapidly recover due to expected high levels of recruitment. Given the low sensitivity of benthic habitats and communities in the Project Area (5 km), any combination of effects is not expected to have a long-term or population-level impact on benthic habitats and communities, therefore no cumulative impacts are expected, and have not been evaluated further.

8.3.2.3 Seabirds and Shorebirds

Seabirds and shorebirds may be directly impacted by a change in fauna behaviour, resulting from navigational light and flaring, and potentially fauna injury/mortality from the Corowa Development. Light exposure is not listed as a threat in the Conservation Advice or Recovery Plans for any listed species found within the Light Area.

As described in Section 7.1.3, artificial light can be disorientating to birds, especially fledglings. A measurable change in light from ambient conditions may occur up to a maximum distance of 30 km from the Corowa Development during the initial period (up to 10–17 months) of peak operational flaring. This Potential Impact Area includes a change in light at some of the offshore islands (e.g. northern Muiron Island, Serrurier and Bessieres islands; Figure 7-12) at an increase comparable to between a moonless clear night sky and a quarter moon. The Potential Impact Area for light associated with the Corowa Development also intersects with breeding BIAs for the Wedge-tailed Shearwater and Lesser Crested Tern.

Vessels (fishing and shipping) passing the Project Area will use navigational lighting, however due to their intermittent and transient nature, no cumulative impacts from shipping and fishing are expected and are not discussed further in this assessment.

There is overlap between the Visible Light Exposure Area from the Corowa Development and neighbouring facilities (Figure 8-1), which shows overlap at Serrurier and Bessieres Islands. However, the visibility of an artificial light does not necessarily imply a measurable change in ambient light (and therefore a potential impact). As summarised above (and described previously in Section 7.1.3.2.3), the area corresponding to a measurable change in ambient light (the Potential Impact Area) for the Corowa Development varies between 30 km (during the initial 7–12 months) and 12.6 km (for the remainder of the project life).

Of the neighbouring facilities, only the onshore Wheatstone LNG facility has any published data on measurable change to ambient light (i.e. a Potential Light Impact area). This was predicted to extend only ~3 km from the Ashburton North SIA, and it does not intersect with the Corowa Development potential light impact area (URS 2010; Chevron 2010).

Therefore, there is no cumulative impact from measurable change to ambient light at the northern Muiron Island, Serrurier and Bessieres islands, which are known breeding locations for some species of migratory birds (e.g. Wedge-tailed Shearwater). There is not predicted to be any overlap of measurable change in ambient light from neighbouring facilities in any offshore waters, where birds may be foraging or transiting.

Therefore, while there is expected to be some overlap of visual light (i.e. there will be areas of water and/or island where both the Corowa Development and/or another facility can be sighted), there is not expected to be any overlap in measurable changes to ambient light from normal operations of the Corowa Development or adjacent facilities.

The draft National Light Pollution Guidelines (CoA 2019) requires an impact assessment to be undertaken if important habitat for listed species occurs within 20 km of the artificial light source. An important habitat is defined within the guidelines as ‘those areas necessary for an ecologically significant proportion of a listed species to undertake important activities such as foraging, breeding, roosting or dispersal’ (CoA 2019). As context for this cumulative assessment, the closest neighbouring facility to the Corowa Development is 46 km away (Pyrenees FPSO), which is greater than the 20 km buffer.

There is no interaction in spatial boundary of impacts with the Corowa Development. Therefore, cumulative impacts to seabirds and shorebirds from light emissions are not expected, and have not been evaluated further.

8.3.2.4 Fish

Fish will be impacted by disturbance and emissions associated with the Corowa Development, including light emissions, underwater sound emissions and seabed disturbance. Seabed disturbance could result in injury / mortality to fauna close to installation and decommissioning activities; however, impacts will be highly localised. Light emissions may result in attraction of fish towards the Corowa Development whilst noise emissions may result in a change in behaviour or injury / mortality to fauna, depending on the phase of the project, therefore cumulative impacts are possible.

The EPBC PMST lists one species of shark as Vulnerable (Grey Nurse Shark) and four as Vulnerable/Migratory (Dwarf Sawfish, Green Sawfish, White Shark and Whale Shark) that are likely to occur within the area. The Corowa Project Area is situated within a foraging BIA for the Whale Shark.

8.3.2.4.1 Cumulative Impact Assessment

Disturbance and emissions resulting from the Corowa Development may lead to these cumulative impacts on fish:

- Injury / mortality to fauna
- change in fauna behaviour.

Table 8-6 evaluates the potential cumulative impacts to fish.

Table 8-6 Cumulative Impact Assessment for Fish

Fish ✓
Injury / mortality to fauna
Seabed disturbance and underwater noise emissions are both predicted to result in injury / mortality to fauna. Any impacts from seabed disturbance will be localised to the Corowa Development during installation and decommissioning activities, whilst injury / mortality from underwater noise emissions is restricted to impulsive noise sources, which will only occur during survey and drilling activities.
Once the source of the impact is removed, any impacts to fish from these activities will cease. Phases of the Corowa Development will occur concurrently, therefore there will be no cumulative impacts related to dual sources of injury / mortality on fish. The presence of multiple sources of this impact occurring concurrently could result in an increase in overall impact, however given the small impact area from both seabed disturbance and underwater noise emissions and the short duration of these project phases, impacts are not expected to result in a long-term cumulative impact on fish.
Any injury / mortality to fauna resulting from cumulative impacts has been assessed as **Minor (1).**
Change in fauna behaviour
Light emissions may result in a change in fish behaviour through attraction of individuals towards the light source, which may result in individuals moving towards sources of underwater noise emissions. Light emissions and underwater noise emissions will occur through all phases of the Corowa Development, with peaks in impacts occurring when impulsive sound sources are used (Survey and Drilling phases) and during the initial phase of operations (Operations phase). It is unlikely that peak noise emissions will coincide with peak light emissions.
Light emissions are expected to result in a minor impact to fish, with no long-term or population-level impacts expected. Similarly, noise emissions from both impulsive and continuous sources will have a minor impact to fish. As the peak in impacts to fish from these two aspects will not occur concurrently, cumulative impacts are not expected to result in an increase in the impact level to fish species. Therefore, any change in behaviour resulting from cumulative impacts has been assessed as **Minor (1) .**

8.3.2.5 Marine Reptiles

Marine reptiles are sensitive to changes in their environment, including light emissions and underwater noise emissions.

Noise emissions will occur throughout the Corowa Development, with a peak during initial use of VSP. Noise emissions can lead to a change in fauna behaviour, through masking (Popper et al. 2014). Modelling shows that sound levels from both impulsive VSP and continuous MODU/MOPU operations will be below the behavioural impact threshold within 50 m.

Marine turtles use light as an orientation cue, and therefore artificial light has the potential to inhibit nesting by adult females and disrupt the orientation and sea-finding behaviour of hatchlings (CoA 2017; EPA 2010). The Potential Impact Area for light emission for the Corowa Development (the area corresponding to a measurable change in ambient light) is initially 30 km during the first 7–12 months (P10-P50), then declines to 12.6 km for the remainder of the project life (Section 7.1.3.2.3).

8.3.2.5.1 Cumulative Impact Assessment

Simultaneous noise emissions and light emissions may lead to this cumulative impact on marine reptiles:

- change in fauna behaviour.

Table 8-7 evaluates the potential cumulative impacts to marine reptiles.

Table 8-7 Cumulative Impact Assessment for Marine Reptiles

Marine Reptiles	✓
Change in fauna behaviour There will be an overlap in impacts from noise emissions and light emissions on turtles. Individuals within 50 m of the facility during drilling will likely exhibit a change in fauna behaviour due to both marking from noise emissions and disruption to orientation from light emissions. Outside this spatial boundary noise emissions will not be elevated above the behavioural threshold, and cumulative impacts will not occur. The Potential Impact Area for light emissions is predicted to be 30 km for the initial 7–12 months, then declines to 12.6 km for the remainder of project life. This only overlaps with noise within 50 m of the facility. The Corowa Development is within internesting BIAs and draft Critical Habitat for some marine turtle species. No nesting beaches are within the spatial boundary for cumulative impacts (50 m), therefore no impacts to nesting individuals are expected. Individual marine turtles' species within the spatial boundary defined for this cumulative assessment will be transitory. Impacts will cease once emissions (light or noise) are no longer detectable. Once operations at Corowa Development are completed, the noise and light sources will be removed and ambient conditions will return, with no long-term impacts to marine turtles expected. The potential cumulative impact of changes in behaviour in marine turtles from artificial lighting and underwater noise emissions have been assessed as a **Moderate (2)** due to the small impact area and the distance offshore.	

8.3.3 Social, Economic and Cultural Environment

Receptors in the Social, Economic and Cultural Environment are likely to be affected by planned aspects during all phases of the Corowa Development. Assessment of the potential for cumulative impacts is provided in Table 8-4.

Where cumulative impacts are possible, either from the Corowa Development or from existing industries / projects, a discussion is provided in the following subsections.

Table 8-8 Potential Cumulative Impacts to Receptors in the Social, Economic and Cultural Receptors

Receptor	Physical Presence – Interaction with other users	Physical presence – Seabed disturbance	Emissions – Light	Emissions – Underwater Noise	Planned Discharge – Drilling cuttings and Fluids	Planned Discharge – Cement	Planned Discharge – Produced Formation Water	Planned Discharge – Commissioning Fluids	Planned Discharge – Cooling water and Brine	Planned Discharge – Deck drainage and Bilge	Planned Discharge – Sewage, Greywater and Food waste	Potential cumulative impacts from the Corowa Development	Potential cumulative impacts from existing industries
Commercial Fisheries	✓											X	✓
Industry	✓											X	✓

The existing projects and industries within the assessment area are summarised in Section 5.5.5.

The North West Marine Region supports a range of socioeconomic activities and is of considerable importance to the local economy. Many activities are restricted to particular areas, such as shipping lanes, fishing grounds, or areas known to provide habitat for species of tourist interest or recreational value.

Impacts to socioeconomic receptors from planned activities associated with the Corowa Development are assessed in Section 7. Commonwealth- and State-managed fisheries, and Industry, may be impacted by the Physical Presence of the Corowa Development (Section 7.1.1), specifically during installation when vessel activity will increase; however, these impacts have been assessed as **Moderate (2)** and acceptable. No other impacts to socioeconomic receptors are expected, and therefore it has been assumed that cumulative impacts to socioeconomic receptors will not occur.

8.4 Risk Treatment and Acceptability

Section 6.4 described the process of risk treatment, the consideration and possible adoption of management or controls measures. Control measures are selected to reduce either the consequence of an impact or the likelihood of that impact consequence occurring and are often required by legislation or considered ‘Good Practice’ within the oil and gas industry.

Following application of controls, acceptability of the residual risk is assessed against a set of criteria (Section 6.5). These criteria are designed to demonstrate that the environmental performance is consistent with the principles of ESD and that impacts are managed to an acceptable level. Acceptable Levels of Performance have been defined for all receptors potentially impacted by the Corowa Development (Section 6.5.5).

The cumulative impact assessment has determined that cumulative impacts will occur to plankton, fish and marine reptiles. Control measures identified for direct impacts will reduce the potential consequence / likelihood of both direct and indirect impacts, lowering the impact associated with cumulative effects.

Consideration has been given to the acceptable levels of performance for plankton, fish and marine turtles (refer to Table 6-8). These levels are set by the MNES Significance guidelines for Commonwealth Marine Waters (DoEE 2013), and definitions are shown in Table 6-8.

The assessment of cumulative impacts has determined that impacts to plankton and fish will be **Minor (1)** (limited/minor impact; localised and temporary on non-threatened species or their habitat) and impacts to marine reptiles will be **Moderate (2)** (moderate impact; localised and short-term on ecosystem or threatened species).

The whole project life of the Corowa Development is relatively short, at only five years, with a conservative temporal boundary set at six years.

Analysis of light intensity showed that beyond 30 km there was no measurable change to the ambient light intensity levels. All other spatial exposure extents from planned aspects are within the Project Area (5 km radius around MOPU location). Therefore, a conservative spatial extent of 30 km has been used for purposes of cumulative impact assessment for the Corowa Development.

No long-term impacts are expected, and any changes are predicted to affect individual / limited areas only with no population-level impacts predicted. The assessment showed that lifecycle behaviours, such as breeding, are unlikely to be impacted due to the distance from sensitive habitats.

Cumulative impacts have been assessed as **Minor (1)** for plankton and fish, and **Moderate (2)** for marine reptiles, and are considered to be **acceptable** (summarised in Table 8-9). Consideration of additional control measures is not required.

EPOs defined in Section 6.5.5 are considered appropriate to ensure that the acceptable level of performance for direct and indirect impacts are achieved.

Table 8-9 Summary of Cumulative Impacts Evaluation and Risks Associated with the Corowa Development

Environment	*Phase* and Activity (source of aspect)	Receptor	Impact	Consequence
Physical Environment	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations	**Ambient light**	Change in ambient light	Minor
Ecological Environment	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations	**Plankton**	Injury / mortality to fauna	Minor
		Fish	Change in fauna behaviour	Minor
			Injury / mortality to fauna	Minor
		Marine reptiles	Change in fauna behaviour	Moderate

9 Implementation Strategy

The Corowa Development will be undertaken by KATO in accordance with this OPP and subsequent activity-specific EP/s. KATO is a standalone entity and will be accountable for the Corowa Development. The dedicated KATO team will be supported by experienced people from the shareholder companies. This section describes the implementation strategies (the systems, practices, and procedures) used to ensure emergency preparedness and environmental monitoring is applied to manage risks and impacts of the project. These will assist in achieving the project's environmental performance objectives (EPOs) as per the requirements under Section 5A of the OPGGS(E)R.

9.1 KATO Ownership Structure

WA-41-R is operated by KATO, an Australian company that was formed to combine ownership of the Corowa field, and other fields, via wholly owned subsidiaries. The shareholders of KATO are Tamarind Australia Pty Ltd (Tamarind Resources group), Aviemore Capital Pty Ltd (Burton group) and Wisdom Limited Pty Ltd (owner of the former Hydra group). Licences applicable to this OPP form part of the asset collectively referred to in the KATO ownership structure shown in Figure 9-1 as Corowa.

Tamarind is an established oil and gas operating company with operating interests in New Zealand (100% equity and operatorship of the Tui field) and Philippines (55.8% equity and operatorship of the Galoc field), as well as significant interests in a number of other Australian oil and gas companies including Triangle Energy Group. As an experienced operator Tamarind provides direct support and assistance, including secondment of relevant technical and operational personnel as well as providing access to systems and processes to support all KATO activities. Tamarind's support to KATO is highlighted in the following subsections.

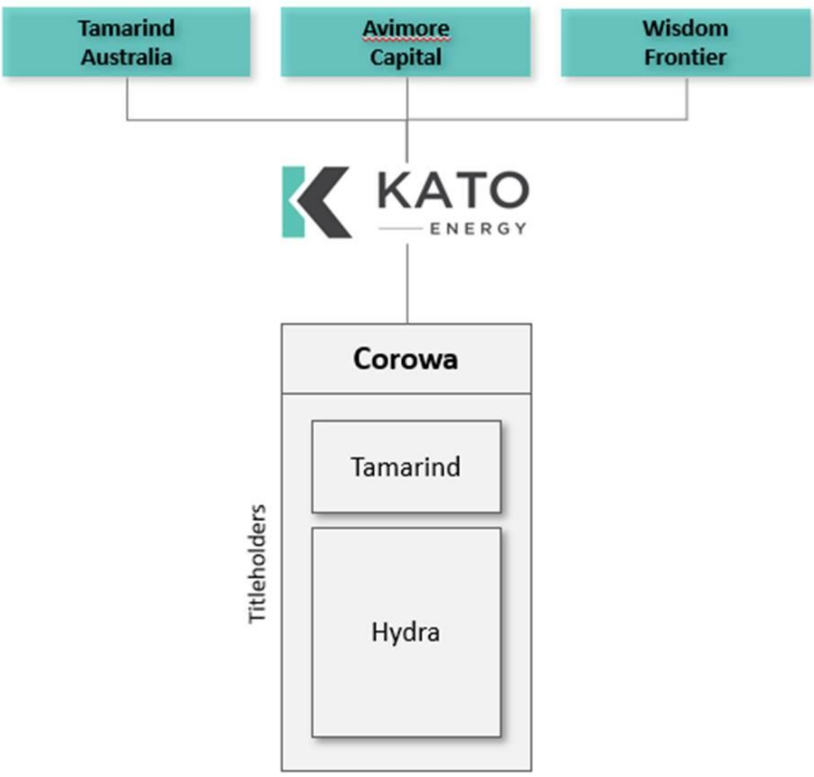


Figure 9-1 KATO Ownership Structure

9.2 KATO Integrated Management System

KATO has an Integrated Management System, referred to as the KATO IMS detailed in the KATO Integrated Management System Description (KATO 2020c). This system has been adopted and made fit-for-purpose based on Tamarind's existing Integrated Management System. It is a common framework that uses the principles of risk management to ensure that the hazards associated with all KATO activities are identified and that the associated risks to people, the environment and company assets are assessed and effectively managed. The KATO Integrated Management System Description (KATO 2020c) lays out 18 Standards, which recognise that risks are managed by controlling the activities of personnel working at every level in the organisation and across every business and technological process. The Standards also recognise the importance of establishing shared values in the development of an HSE culture with the goal of achieving a workplace that is as free from risk as reasonably practicable.

These Standards apply to all KATO operations and activities, including:

- exploration, drilling and field development activities
- production operations
- supporting logistical operations
- offices
- all other activities.

The Standards also apply to all activities where KATO has an operating responsibility and where work is carried out by contractors. In such circumstances, the Standards can be used individually or within an existing ISO based safety, risk, quality or environmental management system structure of a contractor. Review and approval to adopt a contractor's system will form part of the contractor selection process.

The Standards are mandatory for all KATO operations. All KATO Teams must have appropriate systems in place that meet the requirements of these Standards. These are typically captured within KATO Procedures, which apply throughout the organisation (as with the Standards), and Site Level procedures, site instructions and location specific training and induction (shown in Figure 9-2).

Each Operation or Site Team must be able to demonstrate the links between the elements of their HSE management systems and these HSE Management Standards.

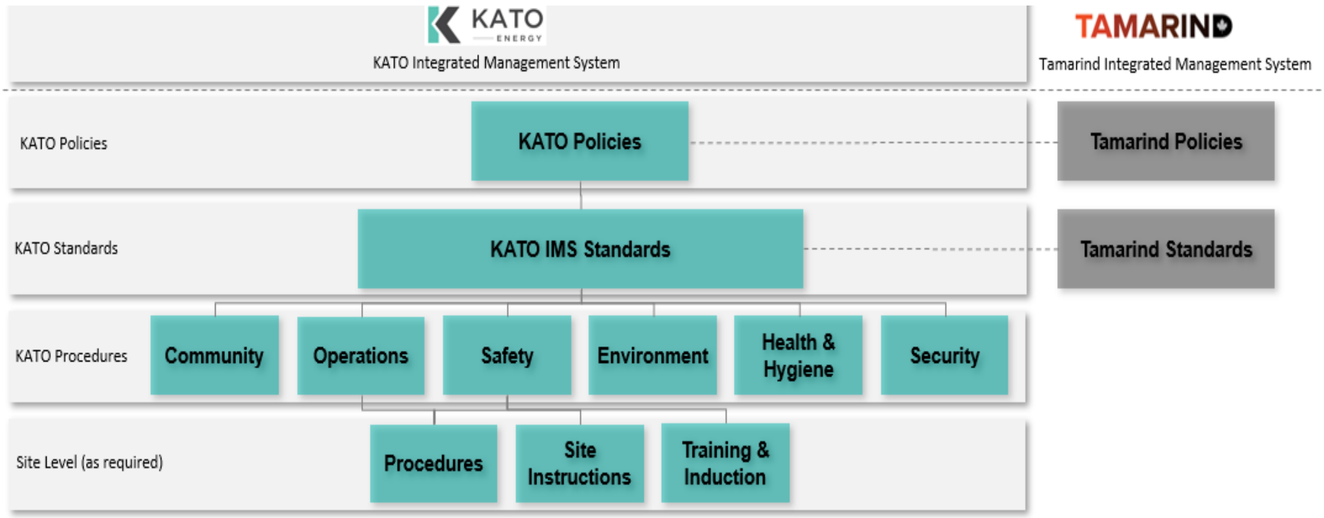


Figure 9-2 KATO Management System Overview

The IMS for this OPP is consistent with the Australian/New Zealand Standard AS/NZS ISO14001 Environmental Management Systems – Requirements for guidance with use (Figure 9-3) and these international standards:

- ISO 45001 Occupational Health and Safety Management Systems
- ISO 31000 Risk Management
- ISO 9001 Quality Management – Requirements.

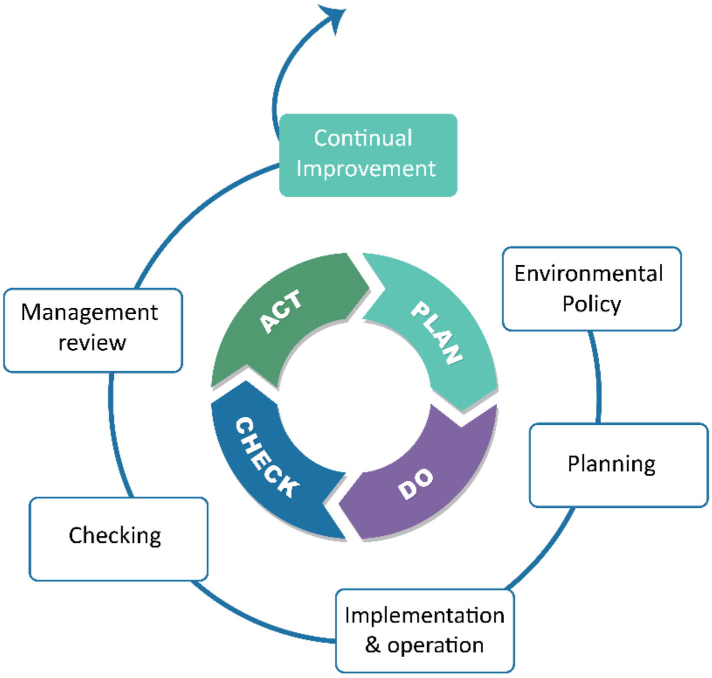


Figure 9-3 AS/NZS ISO 14001 Environmental Management Systems Model

Table 9-1 How the EMS Elements are Addressed for this Activity

EMS ELEMENT	How it is achieved	Section of this OPP
Environmental Policy	Environment Policy	Figure 9-4
Planning	Legislative requirements are identified and understood.	Section 2
	Consultation with relevant stakeholders has been undertaken	Section 10
	Environmental hazards associated with the activity have been identified and potential impacts are assessed and evaluated	Section 7
	Environmental performance outcomes to reduce impacts and risk have been identified	Section 7
Implementation and operation	Training and Awareness	Section 9.3
	Emergency Management	Section 9.3
	Management of Change	Section 9.5
	Incident Investigation	Section 9.6

EMS ELEMENT	How it is achieved	Section of this OPP
Checking	Audits and Assurance	Section 9.7
	Monitoring and Reporting	Section 9.8
Management Review	Routine Reporting	Section 9.8.2
	Incident Reporting	Section 9.8.3

9.3 Training and Awareness

KATO's IMS requires that all employees, contractors and visitors working on or in connection the Corowa Development are aware of their responsibilities with regard to the Company's HSE policy, standards and procedures. The IMS will ensure appropriate training, qualifications, experience and competency is applied to all employees, contractors and visitors throughout the Corowa Development. This will include emergency response and crisis management situations.

Contractor management and competency management is part of the KATO Integrated Management System Description.

Training requirements will be developed for the Corowa Development, which will ensure a centralised method for personnel records ensuring up to date personnel qualifications.

9.4 Emergency Management

KATO's Emergency Management Procedure (KATO 2020d) forms part of the KATO IMS, and provides organisational structures, management processes, and the tools necessary to respond to emergencies and to prevent or mitigate emergency and crisis situations, and to respond to incidents in a safe, rapid, and effective manner.

The Emergency Management Procedure will define specific procedural guidance for emergency and unplanned events including hydrocarbon spills, plus detail reporting relationships for command, control and communications. This will include specialist emergency response groups, statutory authorities and other relevant external bodies.

Any future EPs for the Corowa Development are required to detail an Oil Pollution Emergency Plan (OPEP) as per Section 14(8) of the OPGGS(E)R. Regulation 14(8AA) provides a framework for the control measures and arrangements for responding to and monitoring of oil pollution.

The ERP and OPEP will prioritise the safety of all personnel and subsequently the protection of the environment and property. All employees, contractors and visitors and required to comply with the ERP and OPEP throughout the duration of the Corowa Development.

9.5 Management of Change

KATO's Risk and Change Management Procedure (KATO 2020a) manages changes to facilities, operations, products, and the organisation so as to prevent incidents, support reliable and efficient operations, and keep unacceptable risks from being introduced.

Hazards and risks arising as a result of proposed changes to the approved plan, procedure or program will be assessed using the KATO Risk Assessment Matrix (Figure 6-2) to determine if there is potential for new or increased environmental impact or risk not already provided for in this OPP.

If the identified changes do not trigger a requirement for revision, under Regulation 17 of the OPGGS (Environment) Regulations the Plan can be revised and changes recorded within it without resubmission to the Regulator.

KATO ENERGY

Health, Safety and Environment Policy

KATO is committed to protecting the health and safety of all employees and contractors, and to conducting our business in an environmentally aware and responsible manner. We seek the co-operation of our employees and business partners in ensuring our organisational practices are conducted with minimal environmental impact.

Our vision is that while undertaking our activities, we will cause 'no harm', and that:

- All accidents/injuries are preventable
- Minimise impact on the environment
- Protect and promote the health and safety of its work-force and third parties.
- Ensure the personal security of the workforce and third parties and the security of property.
- Maintain internationally acceptable HSE standards.

Our top priority is to provide an environment that safeguards employees, contractors, stakeholders, the public and the environment and communities in which we work. We take all necessary steps to minimize risks, while meeting or exceeding regulatory laws and standards. This includes:

- Create a HSE culture where every worker is empowered to stop work if they believe their personal safety, the safety of others, or the protection of the environment is compromised
- Identify, assess and mitigate HSE hazards and risks, to as low as reasonably practicable
- Providing ongoing employee training, equipment and facilities necessary to maintain a safe and healthy worksite
- Continually strive to improve HSE performance by establishing clear and measurable objectives and targets, auditing, reviewing and reporting performance
- Operate in a sustainable manner by conserving natural resources, reducing waste, and recycling and re-using materials where possible
- Comply with all applicable HSE legislation, regulations and industry standards.

16th April 2019

Joseph Graham — Date

KATO Director

KATO HSE Policy KAT-000-HS-PP-001 — Revision 0 2019

Figure 9-4 KATO HSE Policy

9.6 Incident Investigation

KATO's Incident Management Procedure (KATO 2020e) is designed to ensure that all incidents and near misses are promptly and thoroughly investigated. Investigation procedures are designed to identify the root cause of the incident or near miss and introduce corrective actions to prevent a recurrence and continuously improve HSE performance. All near misses and incidents will be recorded to enable performance tracking and corrective action implementation.

For reporting of incidents as required by Regulatory authorities see Section 9.8.3.

9.7 Audits and Assurance

KATO's Integrated Management System Description ensures a process is in place to enable conformance with applicable legal and company requirements, verify necessary safeguards are in place and functioning, and non-compliances are reported and tracked to closure.

Environmental performance of the activities will be audited and reviewed. These reviews are undertaken to ensure that:

- environmental performance standards to achieve the EPOs are being implemented, reviewed and where necessary amended
- potential non-compliances and opportunities for continuous improvement are identified
- all environmental monitoring requirements are being met.

Further details including the schedule for environmental performance auditing will be provided in future EPs for petroleum activities. However, these will include both monthly recordable incident reports and an annual environmental performance report to NOPSEMA (See Sections 9.8.2 and 9.8.3). These will assess the effectiveness of the implementation strategy, during the in-force period. Any opportunities for improvement or non-compliances noted will be communicated to all relevant personnel at the time of the audit to ensure adequate time to implement corrective actions. The findings and recommendations of inspections and audits will be documented and distributed to relevant personnel for comments, and any actions tracked until closed out.

9.8 Monitoring and Reporting

9.8.1 Monitoring

Monitoring will be undertaken to demonstrate that KATO Energy complies with regulatory requirements as specified in this OPP and future EPs. The goals of future monitoring activities are to:

- monitor discharges and emissions
- identify changes to the environmental due to Corowa Development activities
- provide continuous review of procedures and activities.

Monitoring programs will be described in detail in future EPs designed for the specific activities and will identify all monitoring, auditing reporting and corrective action requirements.

9.8.2 Routine Reporting

Regulation 26 of the OPGGS(E)R requires the reporting of environmental performance for future EPs (Table 9-2).

Table 9-2: Routine External Reporting Requirements

Reporting Requirement	Description	Reporting to	Timing
Environmental Performance Report	Report includes: • summary of activities undertaken throughout the reporting period • compliance with EPOs outlined in any future EPs • compliance with controls and standards outlined in any future EPs.	NOPSEMA	Annually
Recordable incident report	Report includes: • recordable incidents	NOPSEMA	Monthly

9.8.3 Incident Reporting

Regulation 26A (4) of the OPGGS(E)R requires the reporting of incidents for future EPs. KATO's Incident Management Procedure (KATO 2020e) describes the process for incident classification, investigation and reporting.

The legislative definition of a 'recordable incident' is:

> *'a breach of an environmental performance outcome or environmental performance standard, in the environment plan that applies to the activity, that is not a reportable incident'*

Recordable incidents are breaches of environmental performance objectives and standards described in Section 9.8.

The legislative definition of a 'reportable incident' is:

> *'an incident relating to an activity that has caused, or has the potential to cause an adverse environmental impact; and under the environmental risk assessment process the environmental impact is categorised as moderate or more serious than moderate.'*

NOPSEMA will be notified of all reportable incidents, as per the requirements of Regulations 26, 26A and 26AA of the OPGGS(E)R:

- must verbally be reported as soon as practicable, and in any case not later than 2 hours after:
    - the first occurrence of the reportable incident; or
    - if the reportable incident was not detected by the titleholder at the time of the first occurrence—the time the titleholder becomes aware of the reportable incident
- must provide a written record of the incident as soon as practicable to NOPSEMA, the National Offshore Petroleum Titles Administrator (NOPTA) and the Department of the responsible State Minister (DMIRS)
- must complete a written report to NOPSEMA (Form FM0929) – Reportable Environment Incident within three days of the incident or of its detection
- must provide a written copy of the report to NOPTA and DMIRS within seven days of the written report being provided to NOPSEMA.

9.9 Implementing Requirements of the OPP in Future EPs

NOPSEMA's Offshore Project Proposal Content Requirements (NOPSEMA 2019) states that:

> *'appropriate environmental performance outcomes that are consistent with the principles of ecologically sustainable development; and demonstrate that the environmental impacts and risks of the project will be managed to an acceptable level.'*

As described in Section 6.5.5, 18 EPOs were developed to align with definition of significant impact guidance. Table 9-3 and Table 9-4 summarises the impacts, risks, EPOs and adopted control measures for the Corowa Development for planned and unplanned aspects respectively.

Table 9-3 Summary of Environmental Impacts and Risks Associated with the Corowa Project – Planned Aspects

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
Physical Presence-Interaction with Other Users	*Installation, Hook-up and Commissioning* MOPU; CALM buoy and mooring arrangements; flowlines; FSO *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations	**Commercial Fisheries**	Changes to the functions, interests or activities of other users	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.	**CM01**: Vessels to adhere to the navigation safety requirements including the Commonwealth *Navigation Act 2012* and any subsequent Marine Orders. **CM02**: Notify Australian Hydrographic Office (AHO) of activities and movements prior to activity commencing. **CM03**: Pre-start notifications will be provided to relevant stakeholders at appropriate timing, including presence of exclusion and cautionary zones.	Minor
		Industry				Minor
Physical Presence – Seabed Disturbance	*Survey* geotechnical survey *Drilling* MODU positioning; top-hole drilling *Installation, Hook-up and commissioning* MOPU; CALM buoy and mooring arrangements; flowlines	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM04**: Mooring analysis will be undertaken, which will include an environmental sensitivity and seabed topography analysis. **CM05**: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below seabed and removed.	Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
	Operations maintenance and repair; well intervention *Decommissioning* well P&A; removal of subsea infrastructure; disconnection of FSO and MOPU *Support Activities (all phases)* vessel operations	**Benthic habitat and communities**	Change in habitat	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor
		Fish	Injury / mortality to fauna			Minor
Emissions – Light	*Drilling* well clean-up and flowback *Operations* hydrocarbon processing, storage	**Ambient light**	Change in ambient light	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM06**: Lighting will be sufficient for navigational, safety and emergency requirements (e.g. requirements contained in AMSA Marine Order Part 30 and Facility Safety Cases). **CM07**: Best practice design of the flare will be investigated in FEED to reduce flare height.	Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
	and offloading (flaring) *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Seabirds and shorebirds**	Change in fauna behaviour	**EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	**CM08:** An Artificial Light Management Plan will be developed in alignment with the Draft National Light Pollution Guidelines (DoEE 2019).	Moderate
		Fish				Minor
		Marine reptiles				Moderate

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
		State Protected Areas	Change in ambient light Change in fauna behaviour Changes to the functions, interests or activities of other users Change in aesthetic value	**EPO14:** To not result in a change that may have an adverse effect on the protection and conservation of biodiversity, ecological processes and other natural, cultural and heritage values of marine parks and protected areas. **EPO15:** To not result in a change that may cause one or more of the World Heritage values or National Heritage values of a declared World Heritage property or National Heritage place to be lost, degraded or damaged, or notably altered, modified, obscured or diminished.		Moderate
		Heritage features				Moderate
Emissions – Atmospheric	*Drilling* well clean-up and flowback *Installation, Hook-up and Commissioning* MOPU *Operations* hydrocarbon processing, storage and offloading *Support Activities (all phases)* MODU operations; MOPU operations;	**Ambient air quality**	Change in air quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO18**: To not significantly contribute to Australia's annual greenhouse gas emissions.	**CM09**: Compliance with AMSA Marine Order 97 (Marine pollution prevention — air pollution). **CM10**: Restrictions on import and use of Ozone Depleting Substances (ODS) for refrigeration and air conditioning systems as per the Commonwealth *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*. **CM11**: Use of associated gas as fuel gas during operations is optimised to enable the safe and economically efficient operation of the facility. **CM12**: Reporting of GHG emissions are required as per the National Greenhouse and Energy Reporting (NGER) Scheme.	Minor
		Climate	Climate change			Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
	FSO operations; vessel operations				**CM13**: Operations designed to be optimised to enable the safe and economically efficient operation of the facility.	
Emissions – Underwater Noise	*Survey* geophysical survey (sonar) *Drilling* top-hole drilling; bottom-hole drilling; completions *Operations* well intervention *Decommissioning* Well P&A *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations	**Ambient noise**	Change in ambient noise	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM14**: Vessels will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the project area. **CM15**: Vertical seismic profiling (VSP) operations will adhere to the EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines. **CM16**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements.	Minor
		Fish	Injury / mortality to fauna	**EPO1:** Noise emissions are managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging BIA. **EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species.		Minor
			Change in fauna behaviour			Minor
		Marine mammals	Injury / mortality to fauna			Moderate

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
			Change in fauna behaviour	**EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		Moderate
		Marine reptiles	Change in fauna behaviour			Moderate
Planned Discharge – Drilling Cuttings and Fluids	*Drilling* top-hole drilling; bottom-hole drilling; completions; well clean-up and flowback *Installation, Hook-up and Commissioning* CALM buoy and mooring installation *Operations* well intervention *Decommissioning* well P&A	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM18**: Solid removal and treatment equipment will be used to reduce and minimise the amount of residual fluid contained in drilled cuttings prior to discharge to the marine environment. **CM19**: Drilling and cementing procedures to standard industry practices will be developed that will describe specific well locations, design and fluid volumes.	Minor
		Ambient sediment quality	Change in sediment quality			Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
Planned Discharge – Cement	*Drilling* top-hole drilling; bottom-hole drilling *Installation, Hook-up and Commissioning* CALM buoy and mooring installation *Operations* well intervention *Decommissioning* well P&A	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM19**: Drilling and cementing procedures to standard industry practices will be developed that will describe specific well locations, design and fluid volumes.	Minor
		Ambient sediment quality	Change in sediment quality			Minor
		Benthic habitats and communities	Injury / mortality to fauna	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor
Planned Discharge – Commissioning Fluids	*Installation, Hook-up and commissioning* flowlines; FSO; MOPU *Decommissioning* disconnection of FSO and MOPU	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness.	Minor
		Ambient sediment quality	Change in sediment quality			Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
Planned Discharge – Produced Formation Water	*Operations* hydrocarbon processing, storage and offloading	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM20**: A management framework for produced formation water discharges will be developed.	Moderate
		Ambient sediment quality	Change in sediment quality			Minor
		Plankton	Injury / mortality to fauna	**EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Moderate
Planned Discharge – Cooling Water and Brine	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM16**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness.	Minor
		Plankton	Injury / mortality to fauna	**EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor
Planned Discharge – Deck drainage and Bilge	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM16**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness.	Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
					CM21: Compliance with AMSA Marine Order Part 91 (Marine Pollution Prevention – Oil) (MARPOL Annex I. MARPOL International Convention for the Prevention of Pollution from Ships) to prevent accidental pollution and pollution from routine operations.	
Planned Discharge – Sewage, greywater and food waste	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM16**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM22:** Compliance with Marine Order 96 (Marine pollution prevention – Sewage) 2013. **CM23:** Compliance with Marine Order 95 (Marine pollution prevention – Garbage) 2013.	Minor

Table 9-4 Summary of Environmental Impacts and Risks Associated with the Corowa Development – Unplanned Aspects

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
Unplanned Introduction of IMS	*Drilling* MODU positioning *Installation, Hook-up and Commissioning* MOPU; FSO; CALM buoy and mooring arrangements *Decommissioning* inspection and cleaning *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Benthic habitats and communities**	Change in ecosystem dynamics	**EPO7:** To not result in an introduced marine species becoming established in the marine environment. **EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution.	**CM24**: Requirements of the Australian Ballast Water Management Requirements Version 7 to be met. **CM25**: Requirements of the National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry to be met. **CM26**: Inspection and in-water cleaning of marine growth as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015) on relocatable subsea infrastructure and MOPU and FSO wetsides before demobilisation from Project Area, including methods to ensure minimal release of biological material into the water. **CM27**: A Biofouling Management Plan will be developed as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015).	Serious	Unlikely	Medium
		Coastal habitats and communities				Serious	Very unlikely	Medium
		Commercial Fisheries	Changes to the functions, interests or activities of other users	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Moderate	Very unlikely	Low
		Industry				Moderate	Very unlikely	Low

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
Physical Presence – Interaction with Marine Fauna	*Survey* geophysical survey; geotechnical survey *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations	**Fish**	Injury / mortality to fauna	**EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO3:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	**CM14**: Vessels will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the Project Area.	Minor	Unlikely	Low
		Marine mammals				Minor	Unlikely	Low
		Marine Reptiles				Minor	Unlikely	Low
Physical Presence – Unplanned Seabed Disturbance	*Installation, Hook-up and commissioning* MOPU; CALM buoy and mooring arrangements; flowlines *Decommissioning* Inspection and cleaning; well P&A; Removal of subsea infrastructure; disconnection of MOPU/FSO *Support Activities (all phases)*	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM04**: Mooring analysis will be undertaken, which will include an environmental sensitivity and seabed topography analysis. **CM05**: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below the mudline and removed. **CM26**: Inspection and in-water cleaning of marine growth will be undertaken as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015) on relocatable subsea infrastructure and MOPU and FSO	Minor	Unlikely	Low
		Benthic habitats and communities	Change in habitat Injury / mortality to fauna	**EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a		Minor	Unlikely	Low

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
	MODO operations; MOPU operations; FSO operations; vessel operations; ROV operations			Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution.	wetsides before demobilisation from Project Area, including methods to ensure minimal release of biological material into the water.			
Unplanned Discharge – Solid Waste	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users.	**CM23**: Compliance with Marine Order 95 (Marine Pollution Prevention – Garbage). **CM28**: Compliance with API Recommended Practice 14G: Recommended Practice for Fire Prevention and Control on Open Type Offshore Production Platforms.	Minor	Very Unlikely	Low
		Seabirds and Shorebirds	Injury / mortality to fauna	**EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or		Minor	Very Unlikely	Low
		Fish				Minor	Very Unlikely	Low
		Marine mammals				Minor	Very Unlikely	Low

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
		Marine reptiles		resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution.		Minor	Very Unlikely	Low
Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons)	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; ROV operations; helicopter operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO13**: To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	**CM17**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM28**: Compliance with API Recommended Practice 14G: Recommended Practice for Fire Prevention and Control on Open Type Offshore Production Platform. **CM29**: Emergency response activities will be implemented in accordance with a vessel's valid and appropriate Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class). **CM30**: Spill response equipment will be present and maintained. **CM31**: Bunkering procedures will be implemented to prevent minor loss of containment.	Minor	Very unlikely	Low

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
Accidental Release – Corowa Light Crude Oil	*Drilling* top-hole drilling; bottom-hole drilling; completions; well clean-up and flowback *Operations* hydrocarbon extraction; hydrocarbon processing, storage and offloading; inspections; maintenance and repair; well intervention *Decommissioning* well P&A; removal of subsea infrastructure *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO13**: To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	**CM03**: Pre-start notifications will be provided to relevant stakeholders at appropriate timing. **CM29**: Emergency response activities will be implemented in accordance with a vessel's valid and appropriate Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class). **CM32:** NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place. **CM33:** Emergency response capability will be maintained in accordance with accepted EPs and OPEPs. **CM34:** NOPSEMA-accepted Well Operations Management Plan in place for all wells, in accordance with the OPGGS Act requirements. **CM35**: Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken. **CM36**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area,	Minor	Unlikely	Low
		Ambient sediment quality	Change in sediment quality			Minor	Unlikely	Low
		Plankton	Injury / mortality to fauna	**EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO3**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species.		Minor	Very unlikely	Low
		Benthic habitat and communities	Change in habitat Injury / mortality to fauna Change in fauna behaviour			Moderate	Very unlikely	Low
		Coastal habitats and communities	Change in habitat			Moderate	Very unlikely	Low

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
			Injury / mortality to fauna Change in fauna behaviour Change in aesthetic value	**EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO8:** To not result in a change that may modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding,	notifications, separation distance, and vessel speed. **CM37**: If an infill drilling campaign is required, a simultaneous production and drilling (SIMOPS) workshop will be completed, and a procedure developed to manage and mitigate any additional risks due to concurrent activities. At a minimum, this will include shut-in of production and isolation of the reservoir during: • MODU approach and disconnection • handling of the BOP over existing wells • any drilling clash potential due to new wellbore proximity to an existing production wellbore.			
		Seabirds and shorebirds	Injury / mortality to fauna Change in fauna behaviour			Moderate	Very unlikely	Low
		Fish				Moderate	Very unlikely	Low
		Marine reptiles				Moderate	Very unlikely	Low
		Marine mammals				Moderate	Very unlikely	Low
		Australia Marine Parks	Change in water quality Change in sediment quality			Moderate	Very unlikely	Low

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
		State protected areas – marine	Change in habitat Injury / mortality to fauna Change in fauna behaviour	migration behaviour, life expectancy) and spatial distribution. **EPO14:** To not result in a change that may have an adverse effect on the protection and conservation of biodiversity, ecological processes and other natural, cultural and heritage values of marine parks and protected areas. **EPO15:** To not result in a change that may cause one or more of the World Heritage values or National Heritage values of a declared World Heritage property or National Heritage place to be lost, degraded or damaged, or notably altered, modified, obscured or diminished. **EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted. **EPO117**: To not result in an impact to heritage values or social surroundings, including damage or destruction of a historic shipwreck.		Moderate	Very unlikely	Low
		Heritage and cultural features	Changes to the functions, interests or activities of other users Change in aesthetic value			Moderate	Very unlikely	Low
		Key ecological features	Change in water quality Change in sediment quality Change in habitat Injury / mortality to fauna Change in fauna behaviour			Minor	Very unlikely	Low
		Industry	Changes to the			Minor	Very unlikely	Low

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
			functions, interests or activities of other users					Low
		Commercial Fisheries	Changes to the functions, interests or activities of other users			Minor	Very unlikely	Low
		Tourism and recreation	Changes to the functions, interests or activities of other users Change in aesthetic value			Minor	Very unlikely	Low
Accidental Release – Marine Diesel/Gas Oil	*Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Ambient water quality**	Change in water quality	**EPO10:** To not result in a change in water quality, sediment quality, air quality, ambient noise or ambient light, which may adversely impact on biodiversity, ecological integrity, social amenity, human health or other marine users. **EPO13**: To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the	**CM03**: Pre-start notifications will be provided to relevant stakeholders at appropriate timing. **CM29**: Emergency response activities will be implemented in accordance with a vessel's valid and appropriate Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine	Minor	Very unlikely	Low

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
				marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	Pollution Emergency Plan (SMPEP) (or equivalent, according to class). **CM32:** NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place. **CM33:** Emergency response capability will be maintained in accordance with accepted EPs and OPEPs. **CM34:** NOPSEMA-accepted Well Operations Management Plan in place for all wells, in accordance with the OPGGS Act requirements. **CM35**: Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken. **CM36**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area notifications, separation distance, and vessel speed.			
		Plankton	Injury / mortality to fauna	. **EPO2:** To not result in the displacement of marine turtles from their nesting/internesting BIAs. **EPO2**: To not lead to a decrease in the size of a population or area of occupancy of a listed threatened species, or fragment an existing population. **EPO4:** To not result in a change that may have an adverse effect on habitat critical to the survival of a listed threatened species. **EPO5:** To not result in a change that may disrupt the breeding cycle of a population or interfere with the recovery of a listed threatened species. **EPO6:** To not result in a change that may modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the listed threatened species is likely to decline. **EPO8:** To not result in a change that may modify, destroy or isolate		Minor	Very unlikely	Low
		Coastal habitats and communities	Change in habitat Injury / mortality to fauna Change in fauna behaviour Change in aesthetic value			Minor	Very unlikely	Low
		Seabirds and shorebirds	Injury / mortality to fauna Change in fauna behaviour			Moderate	Very unlikely	Low
		Fish				Moderate	Very unlikely	Low
		Marine reptiles				Moderate	Very unlikely	Low
		Marine mammals				Moderate	Very unlikely	Low

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
		Australian Marine Parks	Change in water quality Change in habitat Injury / mortality to fauna Change in fauna behaviour Changes to the functions, interests or activities of other users Change in aesthetic value	an area of important habitat for a migratory species. **EPO9:** To not result in a change that may disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO11:** To not result in a change that may modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth or State marine area results. **EPO12:** To not result in a change that may have an adverse effect on a population of a non-listed marine species including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution. **EPO14:** To not result in a change that may have an adverse effect on the protection and conservation of biodiversity, ecological processes and other natural, cultural and heritage values of marine parks and protected areas.		Moderate	Very unlikely	Low
		State Protected Areas – marine				Moderate	Very unlikely	Low
		Heritage features				Moderate	Very unlikely	Low
		Key ecological features	Change in water quality Change in sediment quality Change in habitat Injury / mortality to fauna			Minor	Very unlikely	Low

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
			Change in fauna behaviour	**EPO15:** To not result in a change that may cause one or more of the World Heritage values or National Heritage values of a declared World Heritage property or National Heritage place to be lost, degraded or damaged, or notably altered, modified, obscured or diminished. **EPO16:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted. **EPO17**: To not result in an impact to heritage values or social surroundings, including damage or destruction of a historic shipwreck.				
		Industry	Changes to the functions, interests or activities of other users			Minor	Very unlikely	Low
		Commercial Fisheries	Changes to the functions, interests or activities of other users			Minor	Very unlikely	Low
		Tourism and Recreation	Changes to the functions, interests or activities of other users Change in aesthetic value			Minor	Very unlikely	Low

C=Consequence, L=Likelihood, RL=Risk Level

10 Stakeholder Consultation

The principal objectives of KATO's consultation strategy is to:

- identify stakeholders
- initiate and maintain open communications between stakeholders and KATO relevant to their interests
- proactively work with stakeholders on recommended strategies to minimise impacts.

Consultation will be planned, outcomes tracked, and ongoing actions recorded in the KATO Stakeholder Communications Register (KATO 2020f).

Consultation with stakeholders began before submission of the OPP, and will continue throughout the life of the Corowa Development.

The OPP process includes a period of public consultation, for a minimum of four weeks. The OPP will be made publicly available, and the public has the opportunity to provide comment to NOPSEMA. Following the public comment period, KATO must demonstrate an assessment of merits of the comments, and how they have been addressed.

10.1 Stakeholder Identification

Stakeholders were identified based on experience with similar projects in the region. Table 10-1 gives a summary of the key stakeholders, arranged by group. The proposed timing of engagement with each stakeholder is shown. Stakeholders who could potentially require known project information (e.g. exact location, timing, duration, exclusion/cautionary zones) will be consulted at the EP development phase, when this level of information is certain.

An initial assessment of stakeholders' functions, interests and activities has been undertaken, based on KATO's understanding of their and the preliminary impact assessment conducted for the project.

Functions, interests and activities of stakeholder groups have been mapped to the receptors and potential environmental impacts, identified in Section 7, shown in Table 10-2.

Table 10-1 Stakeholders Relevant to the Corowa Development

Stakeholder Group	Stakeholder	Pre-OPP submission	Pre-public comment	Pre-EP submission
Commonwealth Government	Department of Defence (DoD)	✓		✓
	Australian Fisheries Management Authority (AFMA)	✓		✓
	Australian Hydrographers Office (GA)	✓		✓
	Australian Maritime Safety Authority (AMSA)	✓		✓
	Department of Agriculture (DoA)	✓		✓
	Director of National Parks (DoEE)	✓		✓
	Department of the Environment and Energy (DoEE)	✓		✓
	Department of Industry, Innovation and Science (DoIIS)			✓
	Geoscience Australia	✓		✓
	NOPSEMA	✓		✓
	NOPTA	✓		✓

Stakeholder Group	Stakeholder	Pre-OPP submission	Pre-public comment	Pre-EP submission
WA Government	Shire of Ashburton	✓		✓
	Shire of Exmouth			✓
	Department of Biodiversity, Conservation and Attractions (DBCA)	✓		✓
	Department of Mines, Industry regulation and Safety (DMIRS)	✓		✓
	Department of Transport (DoT)	✓		✓
	Department of Water and Environment Regulation (DWER)	✓		
	Department of Primary Industries and Regional Development (DPIRD): Fisheries	✓		✓
	Local governments			✓
Fisheries	Commonwealth Fisheries Association			✓
	Recreational fishing groups			✓
	Northern Prawn Fishing Industry Organisation			✓
	Western Australia Fishing Industry Council (WAFIC)		✓	✓
	Pilbara Pearl Producers Association			✓
	Western Australian Northern Trawl Owners Association			✓
	State-managed Fisheries			✓
	Commonwealth-managed Fisheries			✓
Tourism and Recreation	Fishing tour operators			✓
	Ningaloo tourism operators			✓
	Tourism operators			✓
	Recreational fishing groups			✓
	RecFishWest			✓
Industry	Pilbara Port Authority (PPA)	✓		✓
	Other oil and gas operators			✓
	Dampier Salt			✓
Non-Government Organisations / Community Groups	Buurabalayji Thalanyji Aboriginal Corporation			✓
	Cape Conservation Group			✓
	Protect Ningaloo			✓

Table 10-2 Relevance of Receptor and Environmental Impact to Stakeholder Groups

Receptor		Potential Impact	Cth Govt	WA Govt	Fisheries	Tourism / Recreation	Industry	NGOs / Community Groups
Physical	Water quality	Change in water quality	✓	✓				✓
	Sediment quality	Change in sediment quality	✓	✓				✓
	Air quality	Change in air quality	✓	✓				✓
	Climate	Change in climate	✓	✓				✓
	Ambient light	Change in ambient light	✓	✓				
	Ambient noise	Change in ambient noise	✓	✓				
Ecological	Benthic habitats and communities	Change in habitat	✓	✓				✓
		Change in fauna behaviour	✓	✓				✓
		Injury / mortality to fauna	✓	✓				✓
	Coastal habitats and communities	Change in habitat	✓	✓				✓
		Change in ecosystem dynamics	✓	✓				✓
	Plankton	Change in fauna behaviour	✓	✓				✓
		Injury / mortality to fauna	✓	✓				✓
	Seabirds and Shorebirds	Change in fauna behaviour	✓	✓				✓
		Injury / mortality to fauna	✓	✓				✓
	Fish	Change in fauna behaviour	✓	✓	✓			✓
		Injury / mortality to fauna	✓	✓	✓			✓
	Marine mammals	Change in fauna behaviour	✓	✓				✓
		Injury / mortality to fauna	✓	✓				✓
	Marine reptiles	Change in fauna behaviour	✓	✓				✓

Receptor		Potential Impact	Cth Govt	WA Govt	Fisheries	Tourism / Recreation	Industry	NGOs / Community Groups
		Injury / mortality to fauna	✓	✓				✓
Social, economic and cultural	CMA – KEFs	Changes to the functions, interests or activities of other users	✓	✓				✓
		Change in water quality	✓	✓				✓
		Change in habitat	✓	✓				✓
		Injury / mortality to fauna	✓	✓				✓
		Change in fauna behaviour	✓	✓				✓
	CMA – AMPs	Changes to the functions, interests or activities of other users	✓	✓		✓		✓
		Change in water quality	✓	✓				✓
		Change in habitat	✓	✓				✓
		Injury / mortality to fauna	✓	✓				✓
		Change in fauna behaviour	✓	✓				✓
		Change in aesthetic value	✓	✓		✓		✓
	Commonwealth-managed Fisheries	Changes to the functions, interests or activities of other users	✓	✓	✓			✓
	State-managed Fisheries	Changes to the functions, interests or activities of other users	✓	✓	✓			✓
	Marine Tourism and Recreation	Changes to the functions, interests or activities of other users	✓	✓		✓	✓	✓
		Change in aesthetic value	✓	✓		✓	✓	✓

Receptor		Potential Impact	Cth Govt	WA Govt	Fisheries	Tourism / Recreation	Industry	NGOs / Community Groups
	State Protected Areas – Marine	Changes to the functions, interests or activities of other users	✓	✓		✓		✓
		Change in water quality	✓	✓				✓
		Change in sediment quality	✓	✓				✓
		Change in habitat	✓	✓				✓
		Injury / mortality to fauna	✓	✓				✓
		Change in aesthetic value	✓	✓		✓		✓
	State Protected Areas – Terrestrial	Changes to the functions, interests or activities of other users	✓	✓		✓		✓
	Marine and Coastal Industries	Changes to the functions, interests or activities of other users	✓	✓		✓	✓	✓
	Cth Land Area – Defence	Changes to the functions, interests or activities of other users	✓	✓			✓	
	Heritage	Changes to the functions, interests or activities of other users	✓	✓		✓	✓	✓
		Change in water quality	✓	✓				✓
		Change in sediment quality	✓	✓				✓
		Change in habitat	✓	✓				✓
		Injury / mortality to fauna	✓	✓				✓
		Change in fauna behaviour	✓	✓				✓
		Change in aesthetic value	✓	✓		✓		✓

Table 10-3 shows the mapping of stakeholder interests to the planned and unplanned environmental aspects. This mapping will be updated as per Section 10.3, as consultation progresses.

Table 10-3 Relevance of Aspect to Stakeholder Groups

Aspect		Cth Govt	WA Govt	Fisheries	Tourism/ Recreation	Industry	NGOs / Community Groups
Planned	Physical Presence – Interaction with Other Users	✓	✓	✓	✓	✓	✓
	Physical presence – Seabed disturbance	✓	✓				✓
	Emissions – Light	✓	✓		✓		✓
	Emissions – Atmospheric	✓	✓	✓		✓	✓
	Emissions – Underwater Sound	✓	✓	✓			
	Planned Discharge – Drilling cuttings and Fluids	✓	✓				
	Planned Discharge – Cement	✓	✓				
	Planned Discharge – Commissioning Fluids	✓	✓				
	Planned Discharge – PFW	✓	✓				
	Planned Discharge – Project Vessels and Facilities (Cooling Water and Brine)	✓	✓				
	Planned Discharge – Project Vessels and Facilities (Deck Drainage and Bilge)	✓	✓				
	Planned Discharge – Project Vessels and Facilities (Sewage, greywater and food waste)	✓	✓				
Unplanned	Introduction of Invasive Marine Species	✓	✓	✓	✓	✓	✓
	Physical Presence – Interaction with Marine Fauna	✓	✓				✓
	Physical Presence (Unplanned) – Seabed disturbance	✓	✓				
	Unplanned Discharge – Solid Waste	✓	✓				
	Minor LOC – Chemicals and Hydrocarbons	✓	✓				
	Accidental Release – Corowa Light Crude Oil	✓	✓	✓	✓	✓	✓
	Accidental Release – Marine Diesel/Gas Oil	✓	✓	✓	✓	✓	✓

10.2 Summary of Consultation

KATO's consultation strategy identified that there were locality specific stakeholders and regulators that needed to be engaged as soon as possible. The remaining stakeholders could then be engaged prior to the public consultation period of the OPP.

These timings were:

- prior to submission of the OPP to NOPSEMA
- prior to public consultation.

This is based on KATO's understanding of the needs and concerns of these stakeholders, and discussion with NOPSEMA.

Therefore, KATO has proactively engaged key government stakeholders prior to submission of the OPP to NOPSEMA, summarised in Table 10-4. The initial round of consultation focused on State and Commonwealth government agencies and regulators.

Stakeholders were provided with a fact sheet on 1 July 2019, along with a phone call and/or meeting. Any comments received, and KATO's responses are summarised in Table 10-4.

Table 10-4 Summary of Stakeholder Consultation

Stakeholder	Date	Summary of Response
AFMA	1 July 2019	No response.
Australia Hydrographic Office	1 July 2019	Confirmed the supplied data will be registered, assessed, prioritised and validated in preparation for updating Navigational Charts.
AMSA	1 July 2019	Confirmed notification requirements: • JRCC for promulgation of radio-navigation warnings at least 24–48 hours before operations commence. • Australian Hydrographic Office no less than four working weeks before operations, who govern Notice to Mariners.
AMSA – Joint Rescue Coordination Centre (JRCC) Australia	1 July 2019	JRCC advised requirements to formally request an AUSCOAST Warning, including information required, and commencement of operations confirmation.
AMSA Connect	1 July 2019	Allocation of case number by AMSA.
DoA – Marine & Aquatic Biosecurity Branch	1 July 2019	DoA requested clarification that introduction of NIS is also relevant for installations, not only support vessels.
DoA – Conveyances and Ports	1 July 2019	Provided the Department of Agriculture's Offshore Installation – biosecurity guide for initial reference.
Department of Defence (DoD)	1 July 2019	Confirmed the permit is within the North West Exercise Area (NWXA); however, DoD have no objections to the proposed activities. DoD advised that unexploded ordnance (UXO) may be present on and in the sea floor within the NWXA, and KATO must inform itself as to the risks associated with conducting activities in the area (i.e. detonation). DoD require notification >5 weeks prior to commencement to ensure KATO activities do not conflict with Defence training. Reiterated to notify AHO >3 weeks prior to reduce negative impacts on other maritime users.

Stakeholder	Date	Summary of Response
DBCA	1 July 2019	DBCA confirmed they currently have no comments in relation to its responsibilities under the *Biodiversity Conservation Act 2016* (WA) and the *Conservation and Land Management Act 1984* (WA). Provided contact email for any future notifications/ consultation.
Director of National Parks (DNP; DoEE)	1 July 2019	Requested confirmation of GPS coordinates for the Amulet Development. Acknowledgement there is no authorisation requirement from the DNP. Provide links to consultation guidance note and marine mark management plans. Confirmation that DNP should be notified in the event of an oil spill that may impact a marine park.
DoT – Maritime Environmental Emergency Response (MEER) Unit	1 July 2019	Confirmed DoT intend to provide comment on the OPP. Directed KATO to DoT's Petroleum Industry Guidance Note.
DWER	1 July 2019	No response.
DoF (DPIRD)	1 July 2019	No response.
DoEE (EPBC)	1 July 2019	No response.
DoEE (National Inventory Systems and International Reporting Branch)	30 July 2019	Discussion on KATO's proposed gas strategy, comparative assessment of alternatives and estimated greenhouse gas emissions.
DMIRS	1 July 2019	No response.
Geoscience Australia	1 July 2019	No response.
Pilbara Port Authority	1 July 2019	PPA confirmed they wish to be on an 'interested stakeholder list' for future engagement.
NOPTA	24 July 2019	No response.
NOPSEMA	May to November 2019	Meetings held pre-OPP submission on scope, methodology, and key alternatives analysis. Meeting held post-submission on NOPSEMA comments and KATO's proposed responses.
Shire of Ashburton	1 July 2019	No response.
WAFIC	28 November 2019	Meeting with WAFIC on Corowa and Amulet Developments activity and location, and consultation strategy. WAFIC does not require consultation directly with fisheries at the early OPP stage. Recommend consulting with fisheries when project information is known, during development of the EP/s; i.e. project timing, location and exact exclusion/cautionary zones.

10.3 Ongoing Consultation

As the Corowa Development has a short life span (~5 years), ongoing consultation will be undertaken during the development of the EP/s, with groups identified in Table 10-1.

If stakeholders have made their preferred frequency, triggers and interests known, that preference will be implemented.

These consultations will be tracked and recorded, and any claims or objections raised will be dealt with as per KATO Stakeholder Communications Register (KAT-000-GN-RE-001) (KATO 2020f).

11 Acronyms and Units

Table 11-1 Acronyms

Acronyms	Description
ACAP	Agreement on the Conservation of Albatrosses and Petrels
AFFF	Aqueous Film Forming Foam
AFS	antifouling system
AHT	anchor handling tug
AIMS	Australian Institute of Marine Science
ALARP	as low as reasonably practicable
AMPs	Australian Marine Parks
AMSA	Australian Maritime Safety Authority
APPEA	Australian Petroleum Production and Exploration Association
AQIS	Australian Quarantine Inspection Service
BIA	biologically important areas
BOD	biological oxygen demand
BOP	blowout preventer
BPMF	Broome Prawn Managed Fishery
BTEX	benzene, toluene, ethylbenzene and xylenes
CALM	catenary anchor leg mooring
CAMBA	China Australia Migratory Bird Agreement
CCR	central control room
CHARM	Chemical Hazard Assessment and Risk Management
CITES	International Convention on International Trade in Endangered Species of Wild Fauna and Flora
CNG	compressed natural gas
CO_2	Carbon dioxide
COLREGS	Convention on the International Regulations for Preventing Collisions at Sea 1972
CSV	construction support vessel
CTE	critical technology elements
CW	cooling water
DBCA	Department of Biodiversity, Conservation and Attractions
DEWHA	Department of the Environment, Heritage, Water and the Arts
DGV	default guideline model
DITCRD	Department of Infrastructure, Transport, Cities and Regional Development
DMA	dead man's anchor
DMIRS	Department of Mines, Industry Regulation and Safety
DNP	Director of National Parks

Acronyms	Description
DoA	Department of Agriculture
DoEE	Department of the Environment and Energy
DoEE	Department of the Environment and Energy
DoF	Department of Fisheries
DoIIS	Department of Industry, Innovation and Science
DoT	Department of Transport
DotE	Department of the Environment (now DoEE)
DP	dynamic positioning
DPaW	Department of Parks and Wildlife
DPIRD	Department of Primary Industries and Regional Development
DWER	Department of Water and Environmental Regulation
EEZ	Exclusive Economic Zone
EGPMF	Exmouth Gulf Prawn Managed Fishery
EHS	Environmental Health and Safety
EMBA	environment that may be affected
EP	environmental plan
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EPO	environment protection order
EPO	environmental performance outcomes
ESD	ecologically sustainable development
FEED	Front-end engineering design
FLET	Flowline End Termination
FPSO	floating production storage and offloading
FSO	floating storage and offloading
FTU	Formazin Turbidity Units
GHG	greenhouse gas
GOR	gas-oil-ratio
HF	high frequency
HFC	hydrofluorocarbons
HMCS	OSPAR Harmonised Mandatory Control Scheme
IAOGP	International Association of Oil & Gas Producers
IFC	International Finance Corporation
IHC	Installation, Hook-up and commissioning
IMO	International Maritime Organisation
IMS	invasive marine species
IOT	Indian Ocean Territory

Acronyms	Description
ISV	Subsea installation vessel
JAMBA	Japan Australia Migratory Bird Agreement
JPDA	Joint Petroleum Development Area
KEF	Key Ecological Features
KPMF	Kimberley Prawn Managed Fishery
LBL	long baseline
LE	equivalent sound level
LF	low frequency
LNG	liquified natural gas
LOR	lowest observable reading
LOWC	loss of well control
Lp	sound pressure level
Lpk	peak sound pressure level
MAFMF	Marine Aquarium Fish Managed Fishery
MARPOL	International Convention for the Prevention of Pollution from Ships
MBES	multi-beam echo sounder
MDO	marine diesel oil
MEG	Monoethylene Glycol
MeOH	Methanol
MF	medium frequency
MLOC	Minor los of containment
MMA	marine management area
MMF	Mackerel Managed Fishery
MNES	matters of national environmental significance
MODIS	Moderate Resolution Imaging Spectroradiometer
MODPU	mobile offshore drilling and production unit
MODU	mobile offshore drilling unit
MOPU	mobile offshore production unit
NBPMF	Nickol Bay Prawn Managed Fishery
NEPM	National Environment Protection Matters
NES	national environmental significance
NGER	National Greenhouse and Energy Reporting
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
NT	Northern Territory
NWMR	North-west Marine Region

Acronyms	Description
NWS	North West Shelf
NWSP	Northwest Shelf Province
NWSTF	North West Slope Trawl Fishery
OBF	oil-based drilling fluids
OCNS	Offshore Chemical Notification Scheme
OCS	Offshore Constitutional Settlement
ODS	ozone depleting substances
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*
OPMF	Onslow Prawn Managed Fishery
OPP	Offshore Project Proposal
OSMP	Operational and Scientific Monitoring Plan
PAE	projected-area-entrainment hypothesis
PAH	Polycyclic Aromatic Hydrocarbons
PCPT	Piezocone Penetration Test
PDSF	Pilbara Demersal Scale Fisheries
PFW	produced formation water
PK	peak sound level
PLF	Pilbara Line Fishery
PMST	principle matters search tool
PNEC	predicted no effect concentration
POB	persons on board
PPA	Pilbara Ports Authority
PSZ	petroleum safety zone
PTMF	Pilbara Trap Managed Fishery
PTS	permanent hearing loss
PUQ	Production, Utilities and Quarters
RMS	root mean square
RO	reverse osmosis
ROKAMBA	The Republic of Korea Migratory Birds Agreement
ROV	remotely operated vehicle
SBL	sub-bottom profiler
SBM	synthetic-based muds
SBTF	Southern Bluefin Tuna Fishery

Acronyms	Description
SCF	Western Australian Sea Cucumber Fishery
SEA-ME-WE3	South-East Asia–Middle East–Western Europe 3 cable
SEL	sound exposure level
SELcum	sound exposure level cumulative
SMPEP	shipboard marine pollution emergency plan
SOLAS	safety of life at sea
SPL	sound pressure level
SSMF	Specimen Shell Managed Fishery
SSS	side-scan sonar
STOIIP	Standard Tank Oil In Place
SWMR	South-west Marine Region
TEC	threatened ecological community
TPH	total petroleum hydrocarbons
TRL	technology readiness level
TTS	temporary hearing threshold shift
UM3	three-dimensional Updated Merge model
UNCLOS	United Nations Convention on the Law of the Sea 1982
US EPA	United States Environment Protection Agency
USBL	ultra-short baseline
VSP	vertical seismic profiling
WA	Western Australia
WAFIC	Western Australia Fishing Industries Council
WBM	water-based muds
WCDSC	West Coast Deep Sea Crustacean Managed Fishery
WDTF	Western Deepwater Trawl Fishery
WHP	wellhead platform
WOMP	Well Operations Management Plan
WSTF	Western Skipjack Tuna Fishery
WTBF	Western Tuna and Billfish Fishery

Table 11-2 Units of Measurement

Unit	Description
~	approximately
"	Inch
°API	American Petroleum Institute gravity
°C	degrees Celsius
µg/L	micrograms per litre
bbl	barrels
bbl/day	barrels per day
BOPD	barrels of oil per day
BWPD	barrels of Water Per Day
cui	cubic inches
dB	decibel
dB re 1 µPa RMS @ 1 m	dB level/micropascal/ root mean squared at 1 m.
DWT	deadweight tonnage
FTU	Formazin turbidity unit
ha	hectare
Hz	hertz
kg	kilogram
kHz	kilo hertz
km	kilometre
kt	kilotonne
kW	kilowatt
L	litre
Lumen/m^2	Lumen metre squared
Lux	unit of illuminance
m	metre
m/s	metre per second
m^2	metres squared
m^3	cubic metre
m^3/d	cubic metre per day
m^3/day	cubic metres per days
mg/l	milligram/litre
mg/L	milligram per litre
mg/m^2	milligram per metre squared
mm	millimetre

Unit	Description
MMscf	millions of standard cubic feet
MMstb	million stock tank barrels
mol	mole
MV	megawatt
nm	nautical miles
pH	hydrogen ion concentration
ppm	parts per million
R_{max}	maximum value of a vector
scf/stb	standard cubic feet/standard barrels
sm^3	standard cubic metre
t	tonne
wt%	weight percentage
µPa	micropascal

12 References

Abarnou A., and Miossec L. 1992. *Chlorinated waters discharged to the marine environment chemistry and environmental impact. An overview*. The Science of the Total Environment, 126, 173–197

ABP Research 1999. *Good practice guidelines for ports and harbours operating within or near UK European marine sites.* English Nature, UK Marine SACs Project. pp 120. Accessed on 24 May 2018 at <https://webarchive.nationalarchives.gov.uk/+/http:/www.dft.gov.uk/pgr/shippingports/ports/environment/advice/practiceguidelinesukmari4926.pdf>

Aereon. 2020. *MACH-1 Sonic Flares Product Specifications*. Accessed on 6 January 2020 at <http://www.aereon.com/sites/default/files/flare_systems_MACH-1%20SONIC%20FLARES%20Product%20Sheet%20FINAL.pdf>

Almeda R., Wambaugh Z., Chai C., Wang Z, Liu Z., Buskey E.J. 2013. *Effects of Crude Oil Exposure on Bioaccumulation of Polycyclic Aromatic Hydrocarbons and Survival of Adult and Larval Stages of Gelatinous Zooplankton*. PLoS ONE 8(10): e74476. Access at <https://doi.org/10.1371/journal.pone.0074476>

American Petroleum Institute (2009) *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry*. American Petroleum Institute, Washington, United States of America.

AMSA 2015. *Technical guidelines for preparing contingency plans for marine and coastal facilities*. Australian Maritime Safety Authority.

AMSA 2018. The effects of maritime oil spills on wildlife including non-avian marine life. Australian Maritime Safety Authority, Australian Government. Accessed on August 2019 at <https://www.amsa.gov.au/audiences/teacher-or-student>

AMSA 2019. *Vessel tracking data*. Australian Maritime Safety Authority (AMSA). Accessed at: <https://www.operations.amsa.gov.au/Spatial/DataServices/DigitalData>

ANZECC and ARMCANZ 2000. *Australian & New Zealand guidelines for fresh & marine water quality*. Australia Government Initiative.

ANZG 2018. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at <www.waterquality.gov.au/anzguidelines>

Apache 2008*. Van Gogh Oil Field Development, Draft Public Environment Report (PER).* EPBC Referral 2007/3213. Document no: EA-00-RI-166.01

Aubé M., Roby J., Kocifaj M. 2013. *Evaluating Potential Spectral Impacts of Various Artificial Lights on Melatonin* Suppression, Photosynthesis, and Star Visibility. PLOS ONE. 8 (7).

Australian Transport Safety Bureau 2013. *Australian Shipping Occurrence Statistics 2005 to 2012*. Accessed at: <http://www.atsb.gov.au/media/4119146/mr-2013-002_final.pdf>

Azis P.K.A., Al-Tisan I.A., Daili M.A, Green, T.N., Dalvi, A.G.I., Javeed, M.A. 2003. *Chlorophyll and plankton of the Gulf coastal waters of Saudi Arabia bordering a desalination plant*. Desalination 154: pp291–302

Balcom B.J., Graham B.D., Hart A.D., Bestall G.P. 2012. *Benthic impacts resulting from the discharge of drill cuttings and adhering synthetic based drilling fluid in deep water,* in: International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production. Presented at the International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Society of Petroleum Engineers, Perth, p. SPE-157325-MS

Baldwin, R., G. Hughes and R. Prince. 2003. *Loggerhead turtles in the Indian Ocean*. In: Bolten, A. and B. Witherington, eds. Loggerhead sea turtles. Washington: Smithsonian Books.

Barron M.G., Podrabsky T., Ogle S. and Ricker R.W. 1999. *Are aromatic hydrocarbons the primary determinant of petroleum toxicity to aquatic organisms?* Aquatic Toxicology 46:253–268.

Bartol S.M. and J.A. Musick. 2003. *Sensory biology of sea turtles*. Pages 79–102 in P.L. Lutz, J.A. Music, and J. Wyneken. *The biology of sea turtles*, Volume II. CRC Press Boca Raton, Florida.

Bax N.W., Aguero, M., Gonzalez P., Geeves, W. 2003. *Marine Invasive Alien Species: A Threat to Global Biodiversity*. Marine Policy. 27. 313–323. 10.1016/S0308-597X(03)00041-1.

Beckley L.E., Muhling B.A. and Gaughan D.J. 2009. *Influence of the Leeuwin Current on larval fishes off* Western Australia. Proceedings of the Royal Society of Western Australia (this volume).

Belkin N., Rahav E., Elifantz H., Kress N., Berman-Frank I. 2017. *The effect of coagulants and antiscalants discharged with seawater desalination brines on coastal microbial communities*: A laboratory and in situ study from the southeastern Mediterranean. Water Res. 2017, 110, 321–331.

BFS 2019. *ROV inspection summary of the Ocean Monarch*. A report for the EPA Tasmania by Biofouling Solutions, Tasmania. Accessed on 19 July at: <https://epa.tas.gov.au/Documents/BFS1573%20Ocean%20Monarch%20ROV%20Inspection%20Report%20V2.0_Redacted11Jan2019.pdf>

BHP Billiton. 2011. *Marine Turtle Management* Plan. pp 27. Accessed at: <https://www.bhp.com/-/media/bhp/regulatory-information-media/iron-ore/western-australia-iron-ore/0000/appendices-a1--a7-management-plans/perappendixa1marineturtlemanagementplan.pdf>

Birch R., Glaholt, R and Lemon, D. 2000. *Noise Measurements near an underwater gas pipeline at Secret Cove, British Columbia*. Prepared for Georgia Straight Crossing Pipeline Limited. Prepared by ASL Environmental Sciences, Inc., Sidney BC, Canada and TERA Environmental Consultants (Alta.) Ltd., Calgary Canada. Cited in 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. Perth. Accessed at: <https://www.inpex.com.au/media/1738/draft-eis-technical-appendices-appendix-15-review-of-literature-on-sound-in-the-ocean-and-on-the-effects-of-noise-on-marine-fauna.pdf>

BoM 2014. Climate Data Online. Accessed in June 2014 at: <http://www.bom.gov.au/climate/averages/tables/cw_015590.shtml>

BP 2013*. Shah Deniz Stage 2 (SD2) Project, Environmental and Social Impact Assessment*. Accessed at: <https://www.bp.com/en_az/caspian/sustainability/environment/env-and-social-documentation/ShahdenizESIAs/ESIA.html>

BP 2013. *Shah Deniz Stage 2 (SD2) Project, Environmental and Social Impact Assessment*. British Petroleum, London, United Kingdom. Accessed at: <https://www.bp.com/en_az/caspian/sustainability/environment/env-and-social-documentation/ShahdenizESIAs/ESIA.html>

Bretherton L., Williams A., Genzer J., Hillhouse J., Kamalanathan M., Finkel Z.V., Quigg A. 2018. *Physiological response of 10 phytoplankton species exposed to Macondo oil and the dispersant*. Corexit. J. Phycol. 54 (3), 317–328. https://doi.org/ 10.1111/jpy.12625.

Brewer, DT, Lyne, V, Skewes, TD and Rothlisberg, P. 2007. *Trophic systems of the north west marine region*. Report to the Department of the Environment, Water, Heritage and the Arts, CSIRO, Cleveland. Accessed at: <https://www.environment.gov.au/system/files/resources/492fa28c-15e4-488a-8cde-d14aa1321277/files/nw-trophic-systems-1-3.pdf>

Bridgwood S., Muñoz J., McDonald J.I. 2014. *Catch me if you can! The story of a colonial ascidian's takeover bid in Western Australia*. BioInvasions Records 3: 217–223, https://doi.org/10. 3391/bir.2014.3.4.02 in Wells F. 2018. *A low number of invasive marine species in the tropics: a case study from Pilbara (Western Australia)*. Management of Biological Invasions (2018) Volume 9, Issue 3: 227–237. Accessed at: <https://www.reabic.net/journals/mbi/2018/3/MBI_2018_Wells.pdf>

BRS 2007. Designated Exchange Areas Project – *Providing Informed Decision on the Discharge of Ballast Water in Australia (Phase II)* Ed. Knight, E., Barry, S., Summerson, R., Cameron S., Darbyshire R. report for the Bureau of Rural sciences.

Burger AE.1993. *Estimating the mortality of seabirds following oil spills: effects of spill volume*. Mar Pollut Bull.26:140–143. doi: 10.1016/0025-326X(93)90123-2

CALM 1990. *Dampier Archipelago Nature Reserves Management Plan 1990–2000.* Department of Conservation and Land Management.

CALM 1999. *Jurabi and Bundegi Coastal Parks, and Muiron Islands Management Plan 1999–2009*. Department of Conservation and Land Management.

CALM 2005. *Management Plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area 2005–2015*. Department of Conservation and Land Management.

Cannell, B., Hamilton, S. and Driessen, J. 2019. *Wedge-tailed shearwater foraging behaviour in the Exmouth region*. Report for Woodside Energy Ltd by University of Western Australia and Birdlife Australia.

Capuzzo J.M., Davidson J. A., Lawrence, S.A., Libni M. 1977. *The differential effects of fine and 4 combined chlorine on juvenile marine fish*. Estuarine Coastal Mar. Sci. 5: 733–741.

Cheremisinoff, N. 2016. *Pollution Control Handbook for Oil and Gas Engineering*. John Wiley and Sons, New Jersey, United States of America.

Chevron 2010. *Wheatstone Draft Environmental Impact Statement/ Environment Review and Management Programme for the Proposed Wheatstone Project.* Chevron, Perth, Western Australia.

Chevron 2014. *Wheatstone Project Trunkline Installation Environmental monitoring and Management plan.* Chevron, Perth, Western Australia. Cited in: ConocoPhillips 2018. *Barossa Area Development Offshore Project proposal*. ConocoPhillips, Perth, Western Australia.

Chevron 2015. *Gorgon Gas Development and Jansz Feed Gas Pipeline: Reverse Osmosis Brine Disposal via Ocean Outfall Environmental Management and Monitoring Plan.* Accessed at: <https://australia.chevron.com/-/media/australia/our-businesses/documents/gorgon-emp-reverse-osmosis-brine-disposal-via-ocean-outfall-environmental-plan.pdf>

Chevron. 2016. *Gorgon and Jansz Feed Gas Pipeline and Wells Operations Environment Plan Summary: Commonwealth Waters*. Accessed at: <https://docs.nopsema.gov.au/A680619>

Choi K.H., Kim Y.O., Lee J.B., Wang, S.Y., Lee, M.W., Lee, P.G., Ahn D.S., Hong J.S., Soh H.Y. 2012. *Thermal impacts of a coal power plant on the plankton in an open coastal water environment*. Journal of Marine Science and Technology. 20.

CIN 2005. *Chemical Hazard Assessment and Risk Management, for the use and discharge of chemicals used offshore. User Guide version 1.4.* CHARM Implementation Network (CIN).

Clark J.R., Bragin G.E., Febbo E.J., and Letinski D.J. 2001. *Toxicity of physically and chemically dispersed oils under continuous and environmentally realistic exposure conditions: applicability to dispersant use decisions in spill response planning.* International Oil Spill Conference Proceedings: March 2001, Vol. 2001, No. 2, pp. 1249–1255.

Clarke R.H. 2010. *The Status of Seabirds and Shorebirds at Ashmore Reef and Cartier and Browse Islands: monitoring program for the Montara Well release—pre-impact assessment and first post- impact field survey.* Prepared on behalf of PTTEP Australasia and the Department of the Environment, Water, Heritage and the Arts, Australia (now the Department of Sustainability, Environment, Water, Population and Communities).

Coles S.L., Eldredge L.G. 2002. *Nonindigenous species introduced on coral reefs: A need for information.* Pacific Science 56: 191– 209, https://doi.org/10.1353/psc.2002.0010. Cited in Wells 2018. *A low number of invasive marine species in the tropics: a case study from Pilbara (Western Australia).* Management of Biological Invasions (2018) Volume 9, Issue 3: 227–237.

Conservation Commission. 2009. *Status Performance Assessment: Biodiversity Conservation on Western Australian Islands*. Conservation Commission of Western Australia.

Commonwealth of Australia 2015a. *Conservation Management Plan for the Blue Whale—A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999,* Commonwealth of Australia 2019. Accessed at: <https://www.environment.gov.au/system/files/resources/9c058c02-afd1-4e5d-abff-11cac2ebc486/files/blue-whale-conservation-management-plan.pdf>

Commonwealth of Australia 2015b. *Sawfish and river shark multispecies recovery plan*. Commonwealth of Australia. Accessed at : <http://www.environment.gov.au/system/files/resources/062794ac-ef99-4fc8-8c18-6c3cd5f6fca2/files/sawfish-river-sharks-multispecies-recovery-plan.pdf>

Commonwealth of Australia. 2016*. Draft National Strategy for Mitigating Vessel Strike of Marine Mega-fauna 2016.* Department of the Environment and Energy, Commonwealth of Australia.

Commonwealth of Australia 2017. *Recovery Plan for Marine Turtles in Australia*. Department of the Environment and Energy, Commonwealth of Australia. Accessed on 25 June 2019 at: <https://www.environment.gov.au/system/files/resources/46eedcfc-204b-43de-99c5-4d6f6e72704f/files/recovery-plan-marine-turtles-2017.pdf>

Commonwealth of Australia 2019. *DRAFT National Light Pollution Guidelines for Wildlife including marine turtles, seabirds and migratory shorebirds*. Department of the Environment and Energy, Commonwealth of Australia.

Correa I.C.S, Toldo E.E. Jr. and Toledo F.A.L. 2010. *Impacts on seafloor geology of drilling disturbance in shallow waters.* Environ. Monit. Assess. 167: 79–16. Cited in: IAOPG 2016. Environmental fates and Effects of Ocean Discharge of Drilling Cuttings and Associated Drilling Fluids from Offshore Oil and Gas Operations. Prepared by Sanzone, D.M., Neff, J.M., Lewis, D., Vinhateriom, N., Blake, J. for International Association of Oil Gas Producers.

CSA (Continental Shelf Associates, Inc.). 2004 *Gulf of Mexico Comprehensive Synthetic Based Drilling Muds Monitoring Program.* Final Report submitted to SBM Research Group. Volumes I-II, Technical Results; Volume III Appendices. Cited in: IAOPG 2016. Environmental fates and Effects of Ocean Discharge of Drilling Cuttings and Associated Drilling Fluids from Offshore Oil and Gas Operations. Prepared by Sanzone, D.M., Neff, J.M., Lewis, D., Vinhateriom, N., Blake, J. for International Association of Oil Gas Producers.

CSA (Continental Shelf Associates, Inc.). 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. Cited in: IAOPG 2016. *Environmental fates and Effects of Ocean Discharge of Drilling Cuttings and Associated Drilling Fluids from Offshore Oil and Gas Operations*. Prepared by Sanzone, D.M., Neff, J.M., Lewis, D., Vinhateriom, N., Blake, J. for International Association of Oil Gas Producers.

CSIRO. 2011. *Regional Climate Vulnerability Assessment: The Pilbara*. CSIRO Report EP114812, CSIRO, Western Australia.

DAFF 2003. *Domestic vessel movements and the spread of marine pests. Risks and management approaches.* Report for Department of Agriculture, Fisheries and Forestry. Accessed at: <http://www.environment.gov.au/system/files/resources/a746d310-92d6-4287-b689-fb12eae8318c/files/domestic-vessel-imp-risks.pdf>

DAFF 2009. *The National Biofouling Management Guidance for the Petroleum Production and Exploration Industry*. Department of Agriculture, Fisheries and Forestry. Accessed on 27 May 2019 at <www.marinepests.gov.au.>

DAWR 2019. *Marine Pests, Research and Development.* Department of Agriculture and Water Resources. Accessed on 27 May 2019 at <https://www.marinepests.gov.au/what-we-do/research>

DBCA 2017. *Pilbara Inshore Islands Nature Reserves. Parks and Wildlife Service*, Department of Biodiversity, Conservation and Attractions. Government of Western Australia. Accessed on August 2019 at: <https://parks.dpaw.wa.gov.au/park/pilbara-inshore-islands>

DBCA 2019. *Proposed Niiwalarra Islands National Park and Lesueur Island Nature Reserve; Draft joint management plan 2019*. Department of Biodiversity, Conservation and Attractions, Conservation and Parks Commission, Government of Western Australia.

de Campos L.F., Paiva P.M., Rodrigues P.P.G.W., Ferreira M.I.P., Lugon Junior J. 2017. *Disposal of waste from cementing operation from offshore oil and gas wells building*. Ciência e Natura. v.39 n.2. 413–422. Accessed at: <https://pdfs.semanticscholar.org/15f8/5dd7aab34c3700f8580345ed9d9eb41e18bd.pdf>

DEC 2006. *Management Plan for The Montebello/Barrow Islands Marine Conservation Reserves 2007–2017*. Department of Environment and Conservation.

DEC 2006a. *Background quality of the marine sediments of the Pilbara coast*. Department of Environment and Conservation, Marine Technical Report Series, No. MTR 1.

DEC 2010. *Cape Range National Park Management Plan No 65 2010*. Department of Environment and Conservation.

DEE 2015. *National Conservation Values Atlas*. Department of Environment and Energy. Australian Government. Available from: http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf

DEH 2005a. *Whale Shark (Rhincodon typus) Recovery Plan 2005–2010*. Department of Environment and Heritage, Canberra, Australian Capital Territory. Accessed at: <https://www.legislation.gov.au/Details/F2005L01890>

DEH 2005b. *Humpback Whale Recovery Plan 2005–2010*. Department of Environment and Heritage. Accessed at: <https://www.legislation.gov.au/Details/F2005L01890>

DEHP 2016. *Operational Policy, Environmental Management of Firefighting Foam*. Department of Environment and Heritage Protection. Queensland Government. Accessed on 27 May 2019 at: <https://environment.des.qld.gov.au/assets/documents/regulation/firefighting-foam-policy.pdf>

Del-Pilar-Ruso, Y., de-la-Ossa-Carretero, J.A., Giménez-Casalduero, F., Sánchez-Lizaso, J.L. 2018. *Effects of a brine discharge over soft bottom polychaeta assemblage*. Environ. Pollut. 2008, 156, 240–250.

Dernie K.M., Kaiser M., Richardson E., Warwick R. 2003. *Recovery of soft sediment communities and habitat following physical disturbance*. Journal of Experimental Marine Biology and Ecology. 285–286. 415–434. 10.1016/S0022-0981(02)00541-5.

DEWHA 2007. *Characterisation of the Marine Environment of the North-west Marine Region. A summary of an expert workshop convened in Perth*, Western Australia, 5–6 September 2007. Prepared by the North-west Marine Bioregional Planning section, Marine and Biodiversity Division, Department of the Environment, Water, Heritage and the Arts. Accessed at: https://www.environment.gov.au/system/files/resources/b1760d66-98f5-414f-9abf-3a9b05edc5ed/files/nw-characterisation.pdf

DEWHA 2008. *The North-west Marine Bioregional Plan, Bioregional Profile. A Description of the Ecosystems, Conservation Values and Uses of the North-west Marine Region.* Department of Environment, Water, Heritage and the Arts. Commonwealth of Australia.

DEWHA 2008a. Species group report card – seabirds and migratory shorebirds Supporting the marine bioregional plan for the North-west Marine Region. Department of Environment, Water, Heritage and the Arts. Commonwealth of Australia. Accessed at: <https://www.environment.gov.au/system/files/pages/1670366b-988b-4201-94a1-1f29175a4d65/files/north-west-report-card-seabirds.pdf>

DEWHA 2008b. Species group report card – sharks and sawfishes Supporting the marine bioregional plan for the North-west Marine Region Department of Environment, Water, Heritage and the Arts. Commonwealth of Australia. Accessed at: https://www.environment.gov.au/system/files/pages/1670366b-988b-4201-94a1-1f29175a4d65/files/north-west-report-card-sharks-sawfishes.pdf

DEWHA 2008c. Species group report card – cetaceans Supporting the marine bioregional plan for the North-west Marine Region. Department of Environment, Water, Heritage and the Arts. Commonwealth of Australia. Accessed at: https://www.environment.gov.au/system/files/pages/1670366b-988b-4201-94a1-1f29175a4d65/files/north-west-report-card-cetaceans.pdf

DEWHA 2008d. Species group report card – dugongs Supporting the marine bioregional plan for the North-west Marine Region. Department of Environment, Water, Heritage and the Arts. Commonwealth of Australia. Accessed at: https://www.environment.gov.au/system/files/pages/1670366b-988b-4201-94a1-1f29175a4d65/files/north-west-report-card-dugongs.pdf

DEWHA 2008e. *The South-west Marine Bioregional Plan, Bioregional Profile. A Description of the Ecosystems, Conservation Values and Uses of the South-west Marine Region.* Department of Environment, Water, Heritage and the Arts. Commonwealth of Australia.

Di Toro D.M., McGrath J.A., Stubblefield W.A. 2007. *Predicting the toxicity of neat and weathered crude oil: toxic potential and the toxicity of saturated mixtures*. Environmental Toxicology and Chemistry 26, 24–36. doi:10.1897/06174R.1

DITCRD 2019. *Christmas Island – Environment and Heritage*. Department of Infrastructure, Transport, Cities and Regional Development. Australian Government. Accessed at: <https://www.regional.gov.au/territories/christmas/enviro_herritage.aspx>

DNP 2018. *North-west Marine Parks Network Management Plan 2018*. Director of National Parks, Canberra.

DNP. 2018a. North-west Marine Parks Network Management Plan 2018, Director of National Parks, Canberra.

DNP. 2018b. South-west Marine Parks Network Management Plan 2018, Director of National Parks, Canberra.

DoA 2015. *Antifouling and in-water cleaning guidelines*. Department of Agriculture. Accessed at: < http://www.agriculture.gov.au/biosecurity/avm/vessels/biofouling/anti-fouling-and-inwater-cleaning-guidelines>

DoA 2019a. *Marine Pests*. Department of Agriculture, Canberra. Accessed on 1 July 2019 at: <http://www.agriculture.gov.au/pests-diseases-weeds/marine-pests>

DoA 2019b. *Map of marine pests in Australia*. Department of Agriculture. Accessed on 2 July 2019 at: <http://www.marinepests.gov.au/pests/map>

DoE 2004. *Pilbara Air Quality Study – Summary Report*. Department of Environment, Technical Series No. 120. Accessed at: https://www.der.wa.gov.au/images/documents/your-environment/air/publications/pilbara-air-quality-report-2004.pdf

DoE 2013. *Matters of National Environmental Significance. Significant impact guidelines 1.1* Environment Protection and Biodiversity Conservation Act 1999

DoE 2014a. *Approved Conservation Advice for Pristis pristis (largetooth sawfish).* Canberra: Department of the Environment. Available from: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/60756-conservation-advice.pdf>

DoE 2014b. *Recovery Plan for the Grey Nurse Shark (Carcharias taurus).* Department of the Environment. Accessed at: < https://www.environment.gov.au/system/files/resources/91e141d0-47aa-48c5-8a0f-992b9df960fe/files/recovery-plan-grey-nurse-shark-carcharias-taurus.pdf>

DoE 2015a. *Conservation Advice Calidris ferruginea curlew sandpiper*. Canberra: Department of the Environment. Available from: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/856-conservation-advice.pdf>

DoE 2015b. *Conservation Management Plan for the Blue Whale*—A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999, Commonwealth of Australia.

DoE 2015c. *Conservation Advice Numenius madagascariensis eastern curlew*. Canberra: Department of the Environment. Available from: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/847-conservation-advice.pdf>

DoE. 2019a. *Natator depressus in Species Profile and Threats Database*, Department of the Environment, Canberra. Available from: <http://www.environment.gov.au/sprat>

DoE. 2019b. *Chelonia mydas in Species Profile and Threats Database*, Department of the Environment, Canberra. Available from: <http://www.environment.gov.au/sprat>

DoE. 2019c. *Eretmochelys imbricata in Species Profile and Threats Database*, Department of the Environment, Canberra. Available from: <http://www.environment.gov.au/sprat>

DoEE 2015. *Wildlife Conservation Plan for Migratory Shorebirds*, Commonwealth of Australia 2015 Accessed at: < https://www.environment.gov.au/system/files/resources/9995c620-45c9-4574-af8e-a7cfb9571deb/files/widlife-conservation-plan-migratory-shorebirds.pdf>

DoEE 2017b. *Australian National Guidelines for Whale and Dolphin Watching 2017*. Department of Environment and Energy. Commonwealth of Australia 2017. Accessed at 25 June at: <https://www.environment.gov.au/marine/publications/australian-national-guidelines-whale-and-dolphin-watching-2017>

DoEE 2018a. *Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (2018).* Department of the Environment and Energy. Accessed at: < https://www.environment.gov.au/biodiversity/threatened/publications/tap/marine-debris-2018>

DoEE 2019a. *Australian Wetlands Database*. Department of the Environment and Energy, Australian Government. Available online: http://www.environment.gov.au/node/25066. Accessed at: August 2019.

DoEE 2019b. *Species Profile and Threats Database*. Department of the Environment and Energy, Australian Government. Accessed at: <https://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl>

DoEE 2019c. *National Inventory Report 2017*. Department of the Environment and Energy. Government of Australia, Canberra, Australia.

DoEE 2019d. *Indigenous Protected Areas*. Department of the Environment and Energy, Australian Government. Accessed at: <https://www.environment.gov.au/land/indigenous-protected-areas>

DoEE 2019e. *Australian Heritage Database*. Department of the Environment and Energy, Australian Government. Accessed at: <http://www.environment.gov.au/cgi-bin/ahdb/search.pl.> Accessed: August 2019

DoEE 2018f. *Australian Petroleum Statistics Issue 258*, January 2018, Department of the Environment and Energy, Australian Government.

DoEE 2018g. *National Greenhouse Accounts Factors, Australian National Greenhouse Accounts July 2018,* Department of the Environment and Energy. Canberra, Australia.

DoEE 2019h*. National Inventory Report 2017*. Department of the Environment and Government of Australia, Canberra, Australia.

DoF 2014a. *Western Australian Prevention List for Introduced Marine Pests*. Department of Fisheries, Perth, WA. Accessed on 2 July 2019 at: <http://www.fish.wa.gov.au>

DoF 2014b. *Potential Eradication and Control Methods for the Management of the Ascidian Didemnum perlucidum in Western Australia*. Fisheries Research Report No. 252, 2014. Accessed at: <https://www.fish.wa.gov.au/Documents/research_reports/frr252.pdf>

DoF 2019. *Biofouling Management Tools and Guidelines*. WA Department of Fisheries. Accessed 19 July 2019 at: <https://www.fish.wa.gov.au/Sustainability-and-Environment/Aquatic-Biosecurity/Vessels-And-Ports/Pages/Biofouling-management-tools-and-guidelines.aspx>

Dorn P.B., Rhodes I.A., Wong D.C.L., Van Compernolle R., Farmayan W.F., Ray J.P., James B., Hii K.K. 2007. *Assessment of the Fate and Ecological Risk of Synthetic Paraffin Based Drilling Mud Discharges Offshore Sarawak and Sabah (Malaysia).* 10.2118/108653-MS. Cited in: IAOPG 2016. *Environmental fates and Effects of Ocean Discharge of Drilling Cuttings and Associated Drilling Fluids from Offshore Oil and Gas Operations.* Prepared by Sanzone D.M., Neff J.M., Lewis D., Vinhateriom N., Blake J. for International Association of Oil Gas Producers.

DOT 2018. *DOT307215 Provision of Western Australian Marine Oil Pollution Risk Assessment – Protection Priorities*. Assessment for Zone 5 & 6: South West and South Coast – Final Report. Accessed at: <https://www.transport.wa.gov.au/mediaFiles/marine/MAC_P_DOT307215_SouthWestSouthCoastProtectionPriorities.pdf>

Double M.C., Gales N., Jenner K.C.S., Jenner M.N. 2010. *Satellite tracking of south-bound female Humpback Whales in the Kimberley region of Western Australia Final Report* Australian Marine Mammal Centre, Australian Antarctic Division, 203 Channel Highway, Kingston, Tasmania 7150. 2 Centre for Whale Research (Western Australia) Inc., PO Box 1622, Fremantle WA 6959. Accessed at: <https://www.wamsi.org.au/sites/wamsi.org.au/files/Final%20report%20-%20Kimberley%20satellite%20tracking%20humpback%20whales%206%209%2010.pdf>

DPAW 2015. *Barrow Group Nature Reserves Management Plan 82 2015*. Department of Parks and Wildlife.

DPIRD 2018. *Fisheries, Management of Marine Protected Areas. Department of Primary Industries and Regional Development.* Government of Western Australia. Accessed at: <http://www.fish.wa.gov.au/Sustainability-and-Environment/Aquatic-Biodiversity/Marine-Protected-Areas/Pages/default.aspx>

DPIRD 2019. Catch and effort data obtained on 06/May/2019 for 60 nm cube 21140 from the Department of Primary Industries and Regional Development, Western Australia.

DSEWPaC 2011. *National recovery plan for threatened albatrosses and giant petrels 2011–2016*. Department of Sustainability, Environment, Water, Population and Communities (2011)

DSEWPaC 2012a. *Marine bioregional plan for the North-west Marine Region* prepared under the Environment Protection and Biodiversity Conservation Act 1999. Department of Sustainability, Environment, Water, Population and Communities. Canberra.

DSEWPaC 2012b. *Marine bioregional plan for the South-west Marine Region* prepared under the Environment Protection and Biodiversity Conservation Act 1999. Department of Sustainability, Environment, Water, Population and Communities. Canberra.

DSEWPaC 2013. *Indirect consequences of an action: Section 527E of the EPBC Act*. Environment Protection and Biodiversity Conservation Act 1999 (Cth).

DSEWPaC 2011. *Approved Conservation Advice for Aipysurus apraefrontalis (Short-nosed Sea Snake)*. Canberra, ACT: Department of Sustainability, Environment, Water, Population and Communities. Accessed at: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/1115-conservation-advice.pdf.>

DSEWPaC 2011a. *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.

DSEWPaC 2012a. *Conservation Management Plan for the Southern Right* Whale 2011–2021. A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999. Department of Sustainability, Environment, Water, Population and Communities. Canberra.

DSEWPaC 2012b*. Species Profile and Threats Database*. *Rhincodon typus* — Whale Shark. Accessed at: <http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=66680>

DSEWPaC 2013a. *Recovery plan for the White Shark (Carcharodon carcharias).* Canberra, ACT: Department of Sustainability, Environment, Water, Population and Communities. Accessed at: < https://www.environment.gov.au/system/files/resources/ce979f1b-dcaf-4f16-9e13-010d1f62a4a3/files/white-shark.pdf>

Dufois, F., Lowe, R. J., Branson, P., and Fearns, P. 2017. *Tropical cyclone-driven sediment dynamics over the Australian North West Shelf*. Journal of Geophysical Research: Oceans, 122, 10,225–10,244. Accessed at: < https://www.wamsi.org.au/sites/wamsi.org.au/files/files/2017JC013518.pdf>

Ekins P., Vanner R., Firebrace J. 2005. *Management of produced water on offshore oil installations: a comparative assessment using flow analysis (Final Report)*. Policy Studies Institute, London, United Kingdom.

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. Accessed at: <https://doi.org/10.3390/en9010014>

EMSA 2016. *The Management of Ship-Generated Waste On-board Ships*. Report by Delft., C.E. for the European Maritime Safety Agency. EMSA/OP/02/2016. Accessed on 28 May 2019 at <http://www.emsa.europa.eu/news-a-press-centre/external-news/item/2925-the-management-of-ship-generated-waste-on-board-ships.html>

ENVIRON 2014. *South Hedland Power Station Air Quality Assessment*. ENVIRON Australia Pty Ltd, Perth, Australia. Accessed at: <https://consultation.epa.wa.gov.au/seven-day-comment-on-referrals/copy-of-albany-port-maintenance-dredging-1/supporting_documents/Appendix%201%20%20Air%20Quality%20Assessment.pdf>

Environment Australia 2002. *Australian IUCN Reserve Management Principles for Commonwealth Marine Protected Areas*; ISBN 0 642 54853 6.

EOSCA 2004. *CHARM Chemical Hazard Assessment and Risk Management. A user guide for the evaluation of Chemicals used and discharged offshore*. European Oilfield Specialty Chemicals Association (EOSCA). Aberdeen. UK. Accessed on 27 May 2019 at <http://www.eosca.eu/wp-content/uploads/CHARM-User-Guide-Version-1.4.pdf>

EPA 2001. *Protection of Tropical Arid Zone Mangroves Along the Pilbara Coastline*. Guidance Statement No. 1. Environmental Protection Authority, Western Australia.

EPA 2010. *Environmental Assessment Guidelines. No.5 Environmental Assessment Guideline for Protecting Marine Turtles from Light Impacts*. Environmental Protection Authority, Western Australia.

EPA 2019. *Inspection Summary for Ocean Monarch Drilling Unit*. A report prepared by Biofouling Solutions for the Environment Protection Authority Tasmania. Accessed at: <https://epa.tas.gov.au/Documents/BFS1573%20Ocean%20Monarch%20ROV%20Inspection%20Report%20V2.0_Redacted.pdf>

ERM 2010. *Browse Upstream LNG Development*: Light Impact Assessment, Environmental Resources Management. Perth, Western Australia.

European Commission *(2014) EU Bulk Assessment Inputs Data Sheet – Communication and Information Resource Centre for Administrations, Businesses and Citizens*. European Commission Communication and Information Resource Centre for Administrations, Businesses and Citizens, Brussels, Belgium

Ferguson R. 2000. *The Effectiveness of Australia's Response to the Black Striped Mussel Incursion in Darwin, Australia*. A Report of the Marine Pest Incursion Management Workshop – 27–28 August 1999. The Department of Environment and Heritage, Canberra, ACT.

Fernández-Torquemada, Y., Sánchez-Lizaso, J.L. 2005. *Effects of salinity on leaf growth and survival of the Mediterranean seagrass Posidonia oceanica (L.)* Delile. J. Exp. Mar. Biol. Ecol. 2005, 320, 57–63. [CrossRef]

Fingas M. and Fieldhouse B. 2004. *Formation of water-in-oil emulsions and application to oil spill modelling*. Journal of Hazardous Materials 107 (2004) 37–50

Fisher D. 2017. *Earth Engine Users Summit: Characterising Gas Flares from Single Channel SWIR Observations.* Kings College London, London

Fodrie F.J. and Heck Jr K.L. 2011. *Response of coastal fishes to the Gulf of Mexico oil disaster*. PLOS ONE 6(7):1–8. Doi:10.1371/journal.pone.0021609.

Fodrie F.J., Able K.W., Galvez F., Heck K.L., Jensen O.P., López-Duarte P.C., Martin C.W., Turner R.E., Whitehead A. 2014. *Integrating Organismal and Population Responses of Estuarine Fishes* in Macondo Spill Research, BioScience, Volume 64, Issue 9, September 2014, Pages 778–788. Acessed at: <https://doi.org/10.1093/biosci/biu123>

Forbes. 2017. *Seven Years After Deepwater Horizon, Offshore Oil Has Flourished Amid Tighter Regulation.* Accessed 6 November 2019 at < https://www.forbes.com/sites/ucenergy/2017/04/17/seven-years-after-deepwater-horizon-industry-has-flourished-amid-tighter-regulation/#383a00f328b6>

Frank, H., Rahav, E., Bar-Zeev, E. 2017. *Short-term effects of SWRO desalination brine on benthic heterotrophic microbial communities.* Desalination 2017, 417, 52–59. [CrossRef] Water 2019, 11, 208 19 of 21

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*, Volume 78, 2017, Pages 229–242

Freestone A.L., Osman R.W., Ruiz G.M., Torchin M.E., 2011 *Stronger predation in the tropics shapes species richness patterns in marine communities.* Ecology 92: 983–993, https://doi.org/10.1890/09-2379.1 Cited in Wells, 2018. *A low number of invasive marine species in the tropics: a case study from Pilbara (Western Australia).* Management of Biological Invasions (2018) Volume 9, Issue 3: 227–237.

French D.S. 2000. Probabilities of Oil Exceeding Thresholds of Concern: Examples from an Evaluation for Florida Power and Light. Environment Canada's Proceedings of the Twenty Second Arctic and Marine Oil Spill Program (AMOP) Technical Seminar. Alberta, Canada.

French-McCay D. 2016. Potential Effects Thresholds for Oil Spill Risk Assessments. RPS Ocean Science, Rhode Island. 1

French-McCay D. 2018. Aquatic Toxicity Thresholds for Oil Spill Risk Assessments. RPS Ocean Science, Rhode Island.

French-McCay, D.P. 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.

Frick W.E., Roberts P.J.W., Davis L.R., Keyes J., Baumgartner D.J., George K.P. 2001. *Dilution Models for Effluent Discharges*. 4th Edition (Visual Plumes) – DRAFT. U.S. EPA Environmental Standards Division.

Frisby J.P. 1980. *Seeing: Illusion, Brain and Mind*. Oxford University Press.

Fucik, K.W., Carr, K.A., Balcom, B.J. 1995. *Toxicity of oil and dispersed oil to the eggs and larvae of seven marine fish and invertebrates from the Gulf of Mexico*, in: Lane, P. (Ed.), *The Use of Chemicals in Oil Spill Response,* American Society for Testing and Materials: ASTM Special Technical Publication. ASTM International.

Gales R.S. 1982. *Effects of Noise of Offshore Oil and Gas Operations on Marine Mammals* – Introductory Assessment. Technical Report 884(1). Prepared for the Bureau of Land Management, Department of Interior. Naval Ocean Systems Center. San Diego, California.

Galindo-Romero, M., Gavrilov, A., Duncan, A. (2013). *Spatial decay of the peak pressure of an air gun array signal in a range dependent environment off Cape Leeuwin, Western Australia*, Proceedings of 1st International Conference and Exhibition on Underwater Acoustics Corfu, Greece pp. 1571–1576. June 2013.

Gas Processors Suppliers Association (1998). *Gas Processors Suppliers Association Engineering Data Book*. GPSA, Tulsa, United States of America.

Gaughan D.J. and Santoro K. (eds), 2018. *Status Reports of the Fisheries and Aquatic Resources of Western Australia 2016/17*: The State of the Fisheries. Department of Primary Industries and Regional Development, Western Australia.

Gauthreaux, S.A. and Belser, C.G. 2006. *Effects of artificial night lighting on migrating birds*. In: Ecological Consequences of Artificial Night Lighting, Rich C and Longcore T, Editors. Island Press: Washington, D.C., USA, p:67–93.

Geoscience Australia 2019a. *Petroleum Wells*. Accessed 22 July 2019 at: <http://dbforms.ga.gov.au/www/npm.well.search>

Geoscience Australia 2019b. *Sidescan sonar, Applying geoscience to Australia's most important challenges.* Geoscience Australia. Accessed on 5 June 2019 at <https://www.ga.gov.au/scientific-topics/marine/survey-techniques/sonar/sidescan-sonar>

Geoscience Australia 2019c. *Christmas Island.* Geoscience Australia. Accessed at: <https://www.ga.gov.au/scientific-topics/national-location-information/dimensions/remote-offshore-territories/christmas-island>

Geraci J.R., St. Aubin O.J. 1982. *Study of the effects of oil on cetaceans*. Final Report. U.S. Dept. of the Interior, Bureau of Land Management, Contract No. AA 551- CT-29 Un of Guelph, Guelph, Ontario, Canada.

Gleiss A., Wright S., Liebsch N. and Wilson R. 2013. *Contrasting diel patterns in vertical movement and locomotor activity of Whale Sharks at Ningaloo Reef*. Marine Biology 160(11): pp2981–2992.

Gohlke J.M, Doke, Dzigobodi, Tipre M., Leder, M., Fitzgerald T.P. 2011. *A Review of seafood safety after the Deepwater Horizon blowout*. Environmental Health Perspectives 119(8):1062–9 May 2011.

Gratwicke B., and Speight M. 2005. *The relationship between fish species richness, abundance and habitat complexity in a range of shallow tropical marine habitats*. Journal of Fish Biology, 66, 650-

Groom R.A., Lawler I.R. and Marsh H. 2004. *The risk to dugongs of vessel strike in the Southern Bay Islands area of Moreton Bay*. Report to Queensland Parks and Wildlife Service. School of Tropical Environment Studies and Geography. James Cook University.

Gulec I. and Holdway D.A. 2000. *Toxicity of crude oil and dispersed crude oil to ghost shrimp Palaemon serenus and larvae of Australian bass Macquaria novemaculeata*. Journal Article 2000, Environmental Toxicology. 15(2), 91–98.

Gulec I.L., Leonard B. and Holdway D.A. 1997. *Oil and Dispersed oil toxicity to amphipods and snails.* Spill Science and Technology Bulletin, 4(1), 1–6.

Gunter G., B. S. Ballard and A. Venkataramiah. 1974. *A Review of Salinity Problems of Organisms in United States Coastal Areas Subject to the Effects of Engineering Works*. Gulf Research Reports 4 (3): 380–475. Accessed at: <http://aquila.usm.edu/gcr/vol4/iss3/5>

Gust N., Coutts, A., Lewis P., Tigges, R., Prout J., Carter S. 2019. *Biofouling risk management for the importation of a floating production, storage and offloading (FPSO) facility and the central processing facility (CPF); the world's largest semi-submersible platform* The APPEA Journal 2019, 59, 596–600

Halvorsen M.B., Casper B.C., Matthews F., Carlson T.J., Popper A.N. 2012c. *Effects of exposure to pile driving sounds on the lake sturgeon, Nile tilapia, and hogchoker*. Proc Roy Soc B 279:4705–4714.

Hannay D.E., MacGillivray A.O., Laurinolli M., Racca R. 2004. *Sakhalin Energy: source level measurements from 2004 acoustics program,* Ver. 1.5. Technical report by JASCO Research, Victoria, BC, for Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk

Hanson C., Waite A., Thompson P. A., and Pattiaratchi C. 2007. *Phytoplankton community structure and nitrogen nutrition in Leeuwin Current and coastal waters off the Gascoyne region of Western Australia*. Deep Sea Research Part II: Topical Studies in Oceanography, 54(8–10), 902–924. Accessed at: <https://doi.org/10.1016/j.dsr2.2006.10.002>

Harding S.B., Wilson J.R and Geering D.W. 2007. *Threats to shorebirds and conservation actions*. In: Geering, A., L. Agnew and S. Harding, eds. Shorebirds of Australia. Page(s) 197–213. Melbourne, Victoria: CSIRO Publishing.

Harrison P.L. 1994. *The effects of oil pollutants on fertilization and larval settlement in the scleractinian reef coral Acropora tenuis.* In Proceed of Joint Scientific Conf Sci management and Sustainability of Marine Habitats in the 21st century. Townsville, Australia.

Harrison P.L. 1999. *Oil pollutants inhibit fertilization and larval settlement in the scleractinian reef coral Acropora tenuis from the Great Barrier Reef, Australia.* Sources, Fates and Consequences of Pollutants in the Great Barrier Reef and Torres Strait, GBRMPA: 11–12

Harvey J.T., Dahlheim M.E. 1994. *Cetaceans in oil*. In: Loughlin TR (ed) Marine mammals and the 'Exxon Valdez'. Academic Press, San Diego, CA, p257–264

Hassel A, Knutsen T., Dalen J. 2004. *Influence of seismic shooting on the lesser sand eel* (*Ammodytes marinus*). J Marine Sci 61:1165–1173. Cited in Popper Worcester T. 2006. *Effects of Seismic Energy on Fish: A Literature Review,* Canadian Science Advisory Secretariat (2006). Accessed at: <http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_092_e.pdf>

Hazel J and Gyuris E. 2006. *Vessel-related mortality of sea turtles in Queensland*, Australia. Wildlife Research 33: 149–154. 98.

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, pp105–113.

Hegmann, G, Cocklin, C., Creasey, R., Dupuis, S, Kennedy, A., Ross, W.A., Spaling, H., Stalker, D. 1999. *Cumulative Effects Assessment: a practitioners' guide*. Prepared by Axys Environmental Consulting Ltd and the CEA Working Group for he Canadian Environmental Assessment Agency, Hull, Quebec

Hewitt C.L. 2002. *The distribution and diversity of tropical Australian marine bioinvasions*. Pacific Science 56: 213–222. Accessed at: <https://doi.org/10.1353/psc.2002.0016>

Hewitt C.L., Campbell M.L., Thresher R.E. and Martin R.B. 1999, *Marine Biological Invasions of Port Phillip Bay, Victoria.* Centre for Research on Introduced Marine Pests, Technical report no. 20, CSIRO Marine Research Hobart, Australia.

Hewitt C.L., Campbell M.L., Thresher R.E., Martin R.B., Boyd S., Cohen B.F., Currie D.R., Gomon M.F., Keogh M.J., Lewis J.A., Lockett M.M., Mays N., McArthur M.A., O'Hara T.D., Poore G.C.B., Ross D.J., Storey M.J., Watson J.E. and Wilson R.S. 2004a, '*Introduced and cryptogenic species in Port Phillip Bay, Victoria, Australia*', Marine Biology, vol. 144, pp. 182–202.

Heyward A., Jones R., Meeuwig J., Burns K., Radford B., Colquhoun J., Cappo M., Case M. O'Leary R., Fisher R., Meekan M. and Stowar M. 2012. *Monitoring Study S5 banks and Sholas, Montara 2011 Offshore banks Assessment Survey*. Report for PTTEP Australasia (Ashmore Cartier) Pty. Ltd. Australian Institute of Marine Science. Townsville.

Heyward A., Moore C., Radford B. and Colquhoun J. 2010. *Monitoring Program for the Montara Well Release Timor Sea:* Final Report on the Nature of Barracouta and Vulcan Shoals. Report for PTTEP AA Australasia (Ashmore Cartier) Pty. Ltd. Australian Institute of Marine Science, Townsville, Queensland.

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* WA-271-P. AIMS. 52 p.

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 unpub. report.

Hinwood J., Potts A.E., Dennis L.R., Carey J., Houridis, H., Bell R.J., Thomson J.R., Boudreau P., Ayling A.M. 1994. *Environmental implications of offshore oil and gas development in Australia – Drilling activities*. In book: *Environmental implications of offshore oil and gas development in Australia.,* Publisher: Australian Petroleum Exploration Association, Sydney., Editors: J.M. Swan, J.M. Neff, P.C. Young, pp.123–209

Hirayama K. and Hirano, R. 1970. *Influence of high temperature and residual chlorine on marine phytoplankton*. Marine Biology. November 1970, Volume 7, Issue 3, pp205–213. <https://doi.org/10.1007/BF00367490>

Hjermann D.Ø., Melsom A., Dingsør G.E., Durant J.M., Eikeset A.M., Roed L.P., Ottersen G., Storvik G., Stenseth N. 2007. *Fish and oil in the Lofoten-Barents Sea system: synoptic review of the effect of oil spills on fish populations* Mar. Ecol. Prog. Ser., 339 (2007), pp. 283–299

Hodgson A.J. 2004. *Dugong behaviour and responses to human influences*. PhD Thesis submission. James Cook University.

Honeywell. 2020. *Totally Enclosed Ground Flares*. Accessed 6 January 2020 at: <https://www.uop.com/equipment/totally-enclosed-ground/>

Hook S., Batley G., Holloway M., Irving P. and Ross A. (eds). 2016. *Oil Spill Monitoring Handbook*. CSIRO Publishing, Australia.

Hosche A.M. and Whisson G.J. 2016. *First aggregation of grey nurse sharks (Carcharias Taurus*) confirmed in Western Australia. Marine Biodiversity Records 9:17.

Huisman J.M. 2000. *Marine Plants of Australia*. University of Western Australia Press. ix + 300pp.

Huisman J.M., Jones D.S., Wells F.E., Burton T. 2008. *Introduced marine biota in Western Australian waters.* Records of the Western Australian Museum 25: 1–44, https://doi.org/10.18195/issn. 0312-3162.25(1).2008.001-044. Cited in Wells 2018. *A low number of invasive marine species in the tropics: a case study from Pilbara (Western Australia*). Management of Biological Invasions (2018) Volume 9, Issue 3: 227–237.

Hydra 2015. *Corowa Development Offshore Project Proposal*. Offshore Project Proposal. Hydra Energy, Perth. Document Number. HEH-COR-ENV-RNO-0-001

Hydra 2015: *Offloading System Costing and Installation Study* Document Ref. No: HYD-A-RP-0001. Unpublished report.

IAOPG 2016. *Environmental fates and Effects of Ocean Discharge of Drilling Cuttings and Associated Drilling Fluids from Offshore Oil and Gas Operations*. Prepared by Sanzone, D.M., Neff, J.M., Lewis, D., Vinhateriom, N., Blake, J. for International Association of Oil Gas Producers.

IECA 1997. *IPIECA Biological Impacts of Oil Pollution*: Fisheries International Petroleum Industry Environmental Conservation Association (1997).

IFC 2015. *Environmental, Health and Safety (EHS) General Guidelines*. International Finance Corporation. Prepared by the International Finance Corporation World Group Bank. Accessed at: < https://www.ifc.org/wps/wcm/connect/e2a72e1b-4427-4155-aa8f-c660ce3f2cd5/FINAL_Jun+2015_Offshore+Oil+and+Gas_EHS+Guideline.pdf?MOD=AJPERES&CVID=kU7RMJ6>

IFC. 2013. *Guidance Notes to IFC Performance Standards on Environmental and Social Sustainability* (includes "Guidance Note 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources"). Washington: International Finance Corporation.

Illingworth and Rodkin. 2014. *Cook Inlet Exploratory Drilling Program – underwater sound source verification assessment, Cook Inlet, Alaska*. Prepared for BlueCrest Energy, Inc. by Illingworth & Rodkin, Inc., Petaluma, California.

Imber M. 1975. *Behaviour of petrels in relation to the moon and artificial lights*. Notornis 22: 302- 306.

Imbricata Environmental 2018. *Narrabri Gas Project: Gas Flare Light Assessment*. Imbricatta Pty Ltd, Northbridge, Australia

IMO 2017. *International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM).* International Maritime Organisation.

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. Perth Accessed at <https://www.inpex.com.au/media/1738/draft-eis-technical-appendices-appendix-15-review-of-literature-on-sound-in-the-ocean-and-on-the-effects-of-noise-on-marine-fauna.pdf>

INPEX 2018*. Ichthys Gas Field Development. Draft-environmental-impact-statement-07-chapter-5-emissions-discharges-and-wastes*. INPEX. Accessed at: <https://www.inpex.com.au/media/2409/draft-environmental-impact-statement-07-chapter-5-emissions-discharges-and-wastes.pdf>

IPIECA 1995. *Biological Impacts of Oil Pollution: Rocky Shores*, Volume 7. International Petroleum Industry Environmental Conservation Association, London.

IPIECA 1999. *IPIECA Report Series*. Volume Nine. Biological impacts of oil pollution: Sedimentary shores. International Petroleum Industry Environmental Conservation Association. London.

IRC 2011. *Review of Diesel Toxicity to the Marine Environment*. Commissioned by Apache Energy.

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, 34:294–310

Isichei, A. and Sanford, W. 1976. *The Effect of Waste Gas Flares on the Surrounding Vegetation in South-Eastern Nigeria*. Journal of Applied Ecology 13(1):177.

ITOPF 2011. *Fate of marine oil spills, Technical Information Paper*. International Tanker Owners Pollution Federation.

ITOPF 2014. *Effects of oil pollution on the marine environment*. Technical Information Paper No. 13. The International Tanker Owners Pollution Federation Limited. London, United Kingdom.

ITOPF. 2018. *Technical Information Papers. Retrieved from Tip 2: Fate of marine oil spills*. Accessed at: <http://www.itopf.com/knowledge-resources/documents-guides/document/tip-2-fate-of-marine-oil-spills/>

Jahagirdar, S. 2013. *Air Pollution Control*. Accessed 6 January 2020 at: <https://www.slideshare.net/jshrikant/l-34-and-35-final>

John Zink Hamworthy Combustion. 2020. *Flares*. Accessed 6 January 2020 at <https://www.johnzinkhamworthy.com/products-applications/flares/>

Jenkins G.P., McKinnon L. 2006. *Channel Deeping Supplementary Environment Effects Statement – Aquaculture and Fisheries.* Primary Industries Research, Victoria.

Jenner C. and Jenner M. 2005. *Distribution and abundance of Humpback Whales and other mega-fauna in Exmouth Gulf, Western Australia, during 2004/2005*. Unpublished report to Straits Resources.

Jenner K, Jenner N.M., McCabe, K. 2001. *Geographical and temporal movements of Humpback Whales in Western Australian waters*. APPEA Journal. 2001. 10.1071/AJ00044.

Jensen A.S. and Silber G.K. 2004. *Large whale ship strike database*. NOAA Technical Memorandum NMFS-OPR.

Jiang Z., Huang Y., Xu X, Liao Y, Shou L,. 2010. *Advance in the toxic effects of petroleum water accommodated fraction on marine plankton*. Acta Ecol Sin 30: 8–15

Kastelein R.A., Jennings N., and Van de Voord S. 2018. *Swimming Speed of a Harbor Porpoise (Phocoena phocoena) During Playbacks of Offshore Pile Driving Sounds*. Aquatic Mammals 44(1): 92–99.

KATO 2020a. *Risk and Change Management Procedure* (KAT-000-GN-PP-002). KATO Energy Pty Ltd, Perth

KATO 2020b. *Marine Operations Procedure* (KAT-000-PO-PP-101). KATO Energy Pty Ltd, Perth

KATO 2020c. *Integrated Management System Description* (KAT-000-GN-PP-001). KATO Energy Pty Ltd, Perth

KATO 2020d. *Emergency Management Procedure* (KAT-000-HS-PP-002). KATO Energy Pty Ltd, Perth

KATO 2020e. *Incident Management Procedure* (KAT-000-GN-PP-003). KATO Energy Pty Ltd, Perth

KATO 2020f. *Stakeholder Communications Register* (KAT-000-GN-RE-001). KATO Energy Pty Ltd, Perth

KATO 2020g. *Artificial Light Management Plan* KAT-000-PO-PP-102. KATO Energy Pty Ltd, Perth

KATO 2020h. *Chemical Management Procedure* (KAT-000-EN-PP-001). KATO Energy Pty Ltd, Perth

KATO 2020i. *Introduced Marine Pest Management* (KAT-000-EN-PP-002). KATO Energy Pty Ltd, Perth

Kilminster K., Hovey R., Waycott M. and Kendrick G. 2018. *Seagrasses of Southern and South-Western Australia*. in A Larkum, G Kendrick and P Ralph (eds), Seagrasses of Australia: Structure, Ecology and Conservation. Springer, Netherlands, pp. 61–89.

King D.J., Lyne R.L., Girling A., Peterson D.R., Stephenson R., Short D. 1996. Environmental risk assessment of petroleum substances: the hydrocarbon block method. Prepared by members of CONCAWE's Petroleum Products Ecology Group. Report 95/62. Accessed at :< https://www.concawe.eu/wp-content/uploads/2017/01/rpt_96-52-2004-01719-01-e-2.pdf>

King G.E. and Valencia R.L. 2014. *Environmental Risk and Well Integrity of Plugged and Abandoned Wells*. Society of Petroleum Engineers. doi:10.2118/170949-MS

Kirkman H. 1997. *Seagrasses of Australia, Australia: State of the Environment*, Technical Paper Series (Estuaries and the Sea). Environment Australia, Commonwealth of Australia.

KLC. 2019. Indigenous Protected Areas. Kimberley Land Council. Kimberley Land Council. Accessed at: <https://www.klc.org.au/indigenous-protected-areas>

Knap A.H, Wyers S.C, Dodge R.E, Sleeter T.D, Frith H.R, Smith S.R, Cook C.B. 1985. *The effects of chemically and physically dispersed oil on the brain coral Diploria strigosa*. 1985 Oil Spill Conf, Publ 4385. Am Petroleum Inst, Washington, DC: 547–551.

Koops W., Jak R.G. and van der Veen D.P.C. 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.

Kukert H. 1991. *In situ experiments on the response of deep sea macrofauna to burial disturbance.* Pacific Science 45, 95 only.

Kültz D. 2015. *Physiological mechanisms used by fish to cope with salinity stress*. J Exp Biol 218(Pt 12):1907–1914.

L J McCook, D W Klumpp and A D McKinnon 1995. Seagrass communities in Exmouth Gulf, Western Australia: A preliminary survey. Journal of the Royal Society of Western Australia. 78:81–87

Laist D.W., Knowlton A.R., Mead J.G., Collet A.S., Podesta M. 2001. *Collisions between ships and whales*. Marine Mammal Science 17: pp35–75.

Lane A. and Harrison P.L. 2000. *Effects of oil contaminants on survivorship of larvae of the scleractinian reef corals Acropora tenuis,* Goniastrea aspera and Platygyra sinensis from the Great Barrier Reef. In: Proceedings of the 9th International Coral Reef Symposium, Vol. 1, pp. 403–408.

Langford T.E., Hawkins S.J., Bray S., Hill C., Wels N. and Yang, Z. 1998. *Pembroke Power Station: impact of cooling-water discharge on the marine biology of Milford Haven*. Report No. UC285 by the Aquatic and Coastal Ecology Group, GeoData Institute, University of Southampton for the Countryside Council for Wales

Larcombe P., Peter R., Prytz A and Wilson B. 1995. *Factors Controlling Suspended Sediment on the Inner-Shelf Coral Reefs*. Coral Reefs. 14. 163–171. 10.1007/BF00367235.

Lavender A., Bartol S., Bartol I. 2012. *Hearing Capabilities of Loggerhead Sea Turtles (Caretta caretta)* Throughout Ontogeny. Advances in experimental medicine and biology. 730. 89–92. 10.1007/978-1-4419-7311-5_19.

Lewis M. and Pryor R. 2013. *Toxicities of oils, dispersants and dispersed oils to algae and aquatic plants: Review and database value to resource sustainability*. Environmental Pollution 180:345–367.

Limpus C. and Kamrowski R.L. 2013. *Ocean-finding in marine turtles: the importance of low horizon elevation as an orientation cue*. Behaviour 150: 863–893

Limpus C. J. 1971. *Sea turtle ocean finding behaviour*. Search 2(10) 385–387.

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 25–27 August 2014, Whiting SD and Tucker A, Eds. Science Division, Department of Parks and Wildlife, Perth, Western Australia. pp 56.

Loehr L. C., Beegle-Krause C.-J., George K., McGee C. D., Mearns A. J., Atkinson M. J. 2006. *The significance of dilution in evaluating possible impacts of wastewater discharges from large cruise ships.* Marine Pollution Bulletin, Vol 52, pp 681–688.

Lohmann, K.J. and Lohmann, C.M.F. 1992. *Orientation to oceanic waves by Green Turtle hatchlings*. Journal Experimental Biology, Vol. 171, pp. 1–13.

Lohmann K.J., Witherington B.E., Lohmann C.M. and Salmon M. 1997. *Orientation, navigation and natal beach homing in sea turtles.* in Lutz, P. L. and Musick, J. A. (eds) *The Biology of Sea Turtles*. CRC Press, Boca Raton, Florida.

Lucke K., Siebert U., Lepper P.A., Blanchet M.A. 2009. *Temporary shift in masked hearing thresholds in a harbor porpoise (Phocoena phocoena) after exposure to seismic airgun stimuli*. J Acoust Soc Am.2009 Jun; 125(6): 4600–70.

Luginbuhl C., Boley P., Davis D. 2014. *The impact of light source spectral power distribution on sky glow*. Journal of Quantitative Spectroscopy and Radiative Transfer. 139: 21–26.

Lutcavage M.E., Lutz P.L., Bossart G.D. and Hudson D.M. 1995. *Physiologic and clinicopathologic effects of crude oil on Loggerhead sea turtles.* Archives of Environmental Contamination and Toxicology 28: 417–422.

MacGillivray A.O, Racca R. and Li Z. 2013. *Marine Mammal Audibility of Selected Shallow-water Survey Sources*. J. Acoust. Soc. Am. 135 (1), January 2014. Accessed at <https://asa.scitation.org/doi/pdf/10.1121/1.4838296>

Mann D.A., Higgs D.M., Tavolga W.N., Souza M.J., Popper A.N. 2001. *Ultrasound detection by clupeiform fishes*. J Acoust Soc Am 109:3048–3054. Cited in Popper A.N., Hawkins A.D., Fay R.R., Mann D., Bartol S., Carlson T., Coombs S., Ellison W.T., Gentry R., Halvorsen M.B., Løkkeborg S., Rogers P., Southall B.L, Zeddies D. and Tavolga W.N. 2014. *Sound Exposure Guidelines for Fishes and Sea Turtles*: A Technical Report, ASA S3/SC1.4 TR-201.4 prepared by ANSI Accredited Standards Committee Rationale and Background Information (Chapter 8).

Marchant, S., and Higgins, P. 1990. *Handbook of Australian, New Zealand and Antarctic Birds. Volume One – Ratites to Ducks*. Melbourne, Victoria: Oxford University Press

Marine Pest Sectoral Committee 2018, *National biofouling management guidelines for non-trading vessels,* Department of Agriculture and Water Resources, Canberra, November. CC BY 4.0. Document modified in 2018 to meet accessibility requirements.

Marquenie J., Donners M., Poot H., Steckel W. and de Wit B. (no date). *Adapting the spectral composition of artificial lighting to safeguard the environment*. NAM, The Netherlands. Accessed at: <http://www.opc.ca.gov/webmaster/_media_library/2016/01/Marquenie-et-al-2008-Adapting-Spectral-Composition-Artificial-Lighting.pdf>

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. Accessed at: <https://www.researchgate.net/publication/260626775_Bird-Friendly_Light_Sources_Adapting_the_Spectral_Composition_of_Artificial_Lighting>

Marsh, H., Penrose, C., Eros, C., and Hugue, J. 2002. *Dugong Status Report and Action Plans for Countries and Territories.* Nairobi: United Nations Environment Programme

Matkin, C.O., Saulitis, E.L., Ellis, G.M., Olesiuk, P., Rice, S.D. 2008. *Ongoing population-level impacts on killer whales Orcinus orca following the 'Exxon Valdez' oil spill in Prince William Sound, Alaska*. Mar Ecol Prog Ser 356, 269–281

Matthews M.N.R. 2012. *Underwater Sound Propagation from an Airgun Array in Baffin Bay:* Shell 2012 Seismic Surveys in Baffin Bay Blocks 5. Version 3.0. Jasco Applied Sciences

McCauley R. D. 1994. *The environmental implications of offshore oil and gas development in Australia – seismic surveys*. In J. M. Swan, J. M. Neff, and P. C. Young, *Environmental Implications of Offshore Oil and Gas Development in Australia.* Perth: APPEA.

McCauley R.D. and Jenner K 2010. Migratory patterns and estimated population size of pygmy blue whales (Balaenoptera musculus brevicauda) traversing the Western Australian coast based on passive acoustics. Paper submitted for consideration by the IWC Scientific Committee. SC/62/SH26.

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.

McCauley. R., A. J. Duncan., A. N. Gavrilov, D. H. Cato. 2016. *Transmission of marine seismic survey, air gun array signals in Australian waters.* Proceedings of ACOUSTICS 2016. 9–11 November 2016, Brisbane, Australia.

McCauley R.D. and Kent C 2008. *Sea Noise Logger Deployment 2006–2008 Scott Reef – Whales, Fish and Seismic Surveys. Report for URS/Woodside Energy by Centre for Marine Science and Technology (CMST).* Perth: Woodside.

McCauley R.D., Day R.D., Swadling K.M., Fitzgibbon Q.P., Watson R.A., Semmens M.J. 2017. *Widely used marine seismic survey air gun operations negatively impact zooplankton*. Centre for Marine Science and Technology, Curtin University.

McCauley R.D., Fewtrell J., Duncan A.J., Jenner C., Jenner M-N., Penrose J.D., Prince R.I.T., Adhitya A., Murdoch J. McCabe K. 2000. *Marine seismic surveys— a study of environmental implications.* The APPEA Journal 40, 692–708.

McClatchie S, Middleton J, Pattiaratchi C, Currie D, Kendrick G. 2006. *The South-west Marine Region: Ecosystems and Key Species Groups*. Department of the Environment and Water Resources

McClatchie S., Middleton J., Pattiaratchi C., Currie, D. and Kendrick, G. 2006. *The South-west Marine Region: Ecosystems and Key Species Groups*. Department of the Environment and Water Resources. Australian Government.

McCook L.J., Klumpp D.W. and McKinnon A.D. 1995. *Seagrass communities in Exmouth Gulf, Western Australia: A preliminary survey*. Journal of the Royal Society of Western Australia, 78:81–87.

Mccrea-Strub, A., Kleisner, K., Sumaila, U. R., Swartz, W., Watson, R., Zeller, D., and Pauly, D. 2011. *Potential Impact of the Deepwater Horizon Oil Spill on Commercial Fisheries in the Gulf of Mexico*. Fisheries, 36(7), 332–336.

McDonald S. F., Hamilton S. J., Buhl K. J. and Heisinger J. F. 1996. *Acute toxicity of fire control chemicals to Daphnia magna (Staus) and Senastrum capricornutum (Printz).* Ecotoxicology and Environmental Safety 33: 62–72.

Meekan. M., Bradshaw, C.J.., Wilson, S., Stevens, Polovina, J. and Stewart, B. 2008. *The ecology of the world's largest fish, Rhincodon typus.* Wildlife Conservation Notice 2008(2). McIntyre A., Baker J., Southward A., Bourne W., Hawkins S., and Gray J. 1982. *Oil Pollution and Fisheries [and Discussion].* Philosophical

Transactions of the Royal Society of London. Series B, Biological Sciences, 297(1087), 401–411. Accessed at: <http://www.jstor.org/stable/2396583>

McKenna M.F., Calambokidis J., Oleson E.M., Laist D.W. and Goldbogen J.A. 2015. *Simultaneous tracking of blue whales and large ships demonstrates limited behavioural responses for avoiding collision*. Endangered species Research 27: pp219–232.

McLeay L.J., Sorokin S.J., Rogers P.J. and Ward T.M. 2003. *Benthic Protection Zone of the Great Australian Bight Marine Park: Literature Review. South Australia Marine Research and Development Institute (Aquatic Sciences)*, Commonwealth Department of Environment and Heritage.

McMahon K.M, Evans R.D., Dijk K., Hernawan U., Kendrick G., Lavery P.S., Lowe R., Puotinen M. and Waycott M. 2017. *Disturbance is an important driver of clonal richness in tropical seagrasses*. Front. Plant Sci. 8:2026. doi: 10.3389/fpls.2017.02026

Meekan, M. G. , Wilson , S. G., Halford , A. and Retzel, A. 2001. *A comparison of catches of fishes and invertebrates by two light trap designs, in tropical NW Australia*. Marine Biology. Vol. 139, pp. 373–381

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*. International Oil and Gas Conference, Rio, Brazil; 13–19 October 2000.

Milicich, M. J., Meekan, M. G. and Doherty, P. J. 1992*. Larval supply: a good predictor of recruitment in three species of reef fish (Pomacentridae).* Mar Ecol Prog Ser. Vol. 86, pp. 153–166.

Milton S.L. and Lutz P. 2003. *Physiological and Genetic response to Environmental Stress*. The Biology of Sea Turtles 2. CRC Press, Boca Raton. pp163.

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, Vol. 151, pp. 1299–1307.

Minton S.A. and Heatwole H. 1975. *Sea Snakes from Reefs of the Sahul Shelf*. In *The Biology of Sea Snakes* (ed WA Dunson). University Park Press, Baltimore. Cited in Approved Conservation Advice for Aipysurus apraefrontalis (Short-nosed Sea Snake). Department of the Environment and Energy, 2011. Accessed at: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/1115-conservation-advice.pdf>

Montevecchi W. A. 2006 *Influences of artificial light on marine birds.* Chapter 5 in C. Rich and T. Longcore, eds. *Ecological consequences of artificial night lighting*. Washington, D.C.: Island Press.

Mooney A.T., Yamato M., Branstetter B.K. 2012. *Hearing in Cetaceans: From Natural History to Experimental Biology. Biology Department*, Woods Hole Oceanographic Institution, CA.

Myrberg A.A. 2001. *The acoustical biology of elasmobranchs.* Environmental Biology of FISHES, 60, 31–46. Accessed at < http://foodweb.uhh.hawaii.edu/MARE%20594/Myberg%202001.pdf>.

Nedwed T., Smith J. P., and Melton R. 2006. *Fate of Nonaqueous Drilling Fluid Cuttings Discharged from a Deepwater Exploration Well.* Presented at the SPE International Health Safety & Environment Conference. Abu Dhabi, UAE, 2–4 April 2006. SPE98612.

Neff J., Lee K. and DeBlois E.M. 2011. *Produced water: overview of composition, fates, and effects,* in: Lee, K., Neff, J. (Eds.), Produced Water. Springer, New York, pp. 3–54.

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

Negri A.P, 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

NERA 2017. *Environment Plan Reference Case, Planned discharge of sewage, putrescible waste and grey water*. National Energy Resources Australia (NERA), Kensington, WA. Accessed on 28 May 2019 at: <https://referencecases.nopsema.gov.au/assets/reference-case-project/2017-1001-Sewage-grey-water-and-putrescible-waste-discharges.pdf>

NERA 2018*. Environment Plan Reference Case Consequence analysis of an accidental release of diesel.* National Energy Resources Australia. Accessed at*:* <https://referencecases.nera.org.au/Article?Action=View&Article_id=130>

Neuparth T., Costa F.O. and Costa M.H. 2002. *Effects of Temperature and Salinity on Life History of the Marine Amphipod Cammarus locusta*. Implications for Ecotoxicological Testing. Ecotoxicology 11: pp61–73.

Newell R.C., Seiderer L.J., Simpson N.M. and Robinson J.E. 2004. Impacts of Marine Aggregate Dredging on Benthic Macrofauna off the South Coast of the United Kingdom. Journal of Coastal Research: Volume 20, Issue 1: pp. 115–125.

NIMPCG 2009a. *Marine pests monitoring manual*: Version 1c. National Introduced Marine Pests Coordination Group, Department of Agriculture, Fisheries and Forestry, Canberra, 142 pp

NIMPCG 2009b. *Australian marine pests monitoring guidelines*: Version 1c. National Introduced Marine Pests Coordination Group, Department of Agriculture, Fisheries and Forestry, Canberra, 55 pp

NMFS 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.* National Marine Fisheries Service. U.S. Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59. 167 pp.

NOAA 2001. *Toxicity of oil to Reef-Building Corals: A Spill Response Perspective.* Washington: National Oceanic and Atmospheric Administration

NOAA 2010a. *Oil Spills in Coral Reefs planning & response considerations*. National Oceanic and Atmospheric Administration National Ocean Service Office of Response and Restoration.

NOAA 2010b. *Oil and Sea Turtles*: *Biology, Planning, and Response*. National Oceanic and Atmospheric Administration National Ocean Service Office of Response and Restoration. Accessed at: <https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/resources/oil-and-sea-turtles.html>

NOAA 2013a. *Deepwater Horizon Oil Spill: Assessment of Potential Impacts on the Deep Softbottom Benthos. Interim data summary report.* NOAA Technical Memorandum NOS NCCOS166. National Oceanic and Atmospheric Administration. Washington

NOAA 2013b. *Screening level risk assessment package Gulf state*, Office of National Marine Sanctuaries & Office of Response and Restoration, National Oceanic and Atmospheric Administration, Washington DC.

NOAA 2014. *Oil Spills in Mangroves planning & response considerations*. National Oceanic and Atmospheric Administration National Ocean Service Office of Response and Restoration.

NOAA 2016. *Marine Mammal Acoustic Thresholds*. NOAA Fisheries, Wes Coast Region. Accessed at: <https://www.westcoast.fisheries.noaa.gov/protected_species/marine_mammals/threshold_guidance.html>

NOAA Colorado School of Mines 2018. *Flaring intensity – top 30 flaring countries (2014–18)* Ranked by 2018 flaring volumes. Accessed at: <http://pubdocs.worldbank.org/en/765161560185685003/pdf/Flaring-intensity-Top-30-flaring-countries-2014-2018.pdf>

NOPSEMA 2019. *Oil spill modelling*. NOPSEMA Bulletin #1. Accessed at: <
https://www.nopsema.gov.au/assets/Bulletins/A652993.pdf>

NRC 2003. *Ocean Noise and Marine Mammals*. Summary Review for the National Academies National Research Council.

NRDA 2012. *April 2012 Status Update for the Deepwater Horizon Oil Spill*. A WWW publication accessed at: http://www.gulfspillrestoration.noaa.gov. Natural Resource Damage Assessment.

NRDA. 2012. *April 2012 Status Update for the Deepwater Horizon Oil Spill.* A WWW publication. Accessed at: <http://www.gulfspillrestoration.noaa.gov>

Nwaobi, G. 2005. *Oil Policy in Nigeria: A Critical Assessment (1958–1992).* Quantitative Economic Research Bureau, Abuja, Nigeria.

O'Hara J. 1990. *Avoidance responses of Loggerhead Turtles (Caretta caretta) to low frequency sound*. Copeia 1990 (2), 564–7.

O'Brien P.Y. and Dixon P.S. 1976. *The Effects of Oil and Oil Components on Algae*: A review. British Phycological Journal 11:115–142.

Oceansubsea 2019. *Ultra-Heavy Duty Work Class ROV*. Oceansubsea, Aberdeen. Accessed at: <http://www.oceanasubsea.com/media/1099/oceana-subsea-datasheet-xlx-ultra-heavy-duty-work-class-rov.pdf>

Oceanwise 2019. *Exmouth Gulf, North western Australia. A review of environmental and economic values and baseline scientific survey of the south west region*. Accessed at: https://www.oceanwise.com.au/exmouth-gulf

Offshore Energy 2017. *Small scale FLNG to unlock hundreds of small gas fields?* Accessed at: <https://www.offshoreenergytoday.com/small-scale-flng-to-unlock-hundreds-of-small-gas-fields/>

Oil Spill Commission. 2011. *Rebuilding an Appetite for Gulf seafood after Deepwater Horizon*, Staff Working Paper No. 16. Washington D.C: National Commission on the Deepwater Horizon Oil Spill and Oil Drilling.

OGP 2005. *Fate and effects of naturally occurring substances in produced water on the marine environment.* Report No. 364. International Association of Oil & Gas Producers.

OSPAR 2012a. *OSPAR Recommendation 2012/5 for a risk-based approach to the Management of Produced Water Discharges from Offshore Installations*. OSPAR Commission, Recommendation 2012/5. United Kingdom

OSPAR 2012b. *OSPAR Guidelines in support of Recommendation 2012/5 for a Risk-based Approach to the Management of Produced Water Discharges from Offshore Installations*. OSPAR Commission, Agreement 2012–7. United Kingdom.

OSPAR 2014. *Establishment of a list of Predicted No Effect Concentrations (PNECs) for naturally occurring substances in produced water*. OSPAR Commission. OSPAR Agreement: 2014–05

Özhan K., Miles S.M., Gao H., Bargu S. 2014a. *Relative Phytoplankton growth responses to physically and chemically dispersed South Louisiana sweet crude oil*. Environ. Monit. Assess. 186, 3941–3956. Accessed at: <https://doi.org/10.1007/s10661-014- 3670-4>

Park G.S.; Yoon S.-M.; Park K.-S. 2011. *Impact of desalination byproducts on marine organisms: A case study at Chuja Island Desalination Plant in Korea*. Desalin. Water Treat. 2011, 33, 267–272. Accessed at: <https://www.mdpi.com/2073-4441/11/2/208/pdf>

Patterson H., Georgeson L., Noriega R., Curotti R., Helidoniotis F., Larcombe J., Nicol S and Williams A. 2018. *Fishery Status Reports 2018. Australian Bureau of Agricultural and Resource Economics and Sciences*, Department of Agriculture and Water Resources, Commonwealth of Australia.

Pattiaratchi, C., Bahmanpour, H., Wijeratne, E., Steinberg, C. and D'Adamo, N. 2014. *The Holloway Current along North-West Australia*. Conference Proceedings. 10.13140/2.1.1928.2889.

Peakall D.B., Wells P.G., Mackay D. 1987. *A hazard assessment of chemically dispersed oil spills and seabirds.* Mar Environ Res 22:91–106.

Pearce A., Buchan S., Chiffings T., D'Adamo N., Fandry C., Fearns P., Mills D., Phillips R. and Simpson C. 2003. *A review of the oceanography of the Dampier Archipelago,* Western Australia. IN: F.E. Wells, D.I. Walker and D.S. Jones (eds) 2003. The Marine Flora and Fauna of Dampier, Western Australia, Western Australian Museum, Perth.

Pearson W.H., Skalski J.R. and Malme C.I. 1992—*Effects of sounds from a geophysical survey device on behaviour of captive rockfish (Sebastes spp.).* Canadian Journal of Fisheries and Aquatic Sciences. 49 (7),1343–56. Cited in McCauley R.D., Fewtrell J., Duncan A.J., Jenner C., Jenner M-N., Penrose J.D., Prince R.I.T., Adhitya A., Murdoch J. McCabe K., (2000) *Marine seismic surveys— a study of environmental implications.* The APPEA Journal 40, 692–708.

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. 10.3389/fmars.2018.00069.

Peel D., Smith J.N., Childerhouse S. 2016. *Historical data on Australian Whale Vessel Strikes. International Whaling Commission*. SC/66b/HIM/05.

Pendoley Environmental. 2005. *Proposed Gorgon Gas Development Barrow Island – Sea Turtle Light Orientation Arena Experiments*. Technical Appendix to Environmental Impact Statement / Environmental Review and Management Programme for the Proposed Gorgon Gas Development. Perth.

Pendoley K. 1999. *The Influence of Gas Flares on the Orientation of Green Turtle Hatchlings at Thevenard Island, Western Australia*. Accessed 15 December 2019 at: <http://www.seaturtle.org/PDF/PendoleyK_2000_InSecondASEANSymposiumandWorkshoponSe_p130-142.pdf>

Pendoley K. 2005. *Seas turtles and the environmental management of industrial activities in the north west Western Australia.* PhD thesis, Murdoch University. Accessed 15 December 2019 at: <https://researchrepository.murdoch.edu.au/id/eprint/254/2/02Whole.pdf>

Peters, E.C. 1981. *Bioaccumulation and histopathological effects of oil on a stony coral*. Marine Pollution Bulletin 12(10):333–339

Petersen K.L., Frank H., Paytan A., Bar-Zeev E. 2018. *Impacts of seawater desalination on coastal environments.* In Sustainable Desalination Handbook, 1st ed.; Gude, V.G., Ed.; Butterworth-Heinemann: Oxford, UK 2018; pp. 437–463.

Pineda M.C., Duckworth A., Webster N. 2016. *Appearance matters: sedimentation effects on different sponge morphologies.* Journal of the Marine Biological Association of the United Kingdom 96, 481–492.

Plank M. 1914. *The Theory of Heat Radiation*. P. Blakiston's Son & Co. Philadelphia, United States of America.

Popper A.N., Hawkins A.D., Fay R.R., Mann D., Bartol S., Carlson T., Coombs S., Ellison W.T., Gentry R., Halvorsen M.B., Løkkeborg S., Rogers P., Southall B.L, Zeddies D. and Tavolga W.N. 2014. *Sound Exposure Guidelines for Fishes and Sea Turtles*: A Technical Report, ASA S3/SC1.4 TR-201.4 prepared by ANSI Accredited Standards Committee Rationale and Background Information (Chapter 8).

Prince, R.I.T. 1998. *North West Cape and Muiron Islands Marine Turtle Nesting Population Study: Report on the 1997/98 seasonal work program, a focal marine wildlife management program segment being part of the Western Australian marine turtle program.* DBCA.

Purkinje J.E. 1825. *Neue Beiträge zur Kenntniss des Sehens in Subjectiver Hinsicht*. Reimer: Berlin. pp. 109–110.

Quadrant Energy Australia Limited. 2018. Quadrant environmental monitoring program- Varanus and Airlie Islands Shearwater monitoring annual report, 2017/18.

Richardson A.J., Matear R.J. and Lenton, A. 2017. *Potential impacts on zooplankton of seismic surveys*. CSIRO Oceans and Atmosphere. APPEA. Australia. 34pp.

Richardson W.J., Greene C.R., Maime C.I. and Thomson D. H. 1995. *Marine Mammals and Noise*. Academic Press, San Diego, California. Cited in Wyatt. R. 2008. Joint Industry Programme on Sound and Marine Life. Review of Existing Data on Underwater Sounds Produced by the Oil and Gas Industry, Issue 1. Seiche Measurements Ltd., Great Torrington. Accessed at <https://gisserver.intertek.com/JIP/DMS/ProjectReports/Cat1/JIP-Proj1.4_Soundsinventory_Seiche_2008.pdf>

Roberts D.E., Davis A.R., Cummins S.P. 2006. *Experimental manipulation of shade, silt, nutrients and salinity on the temperate reef sponge Cymbastela concentrica*. Marine Ecology Progress Series, 307, 143–154

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.

Rodríguez A., Arcos J.M., Bretagnolle V., Dias M.P., Holmes N.D., Louzao M., Provencher J., Raine André F., Ramírez F., Rodríguez B., Ronconi R.A., Taylor R.S., Bonnaud E., Borrelle S.B., Cortés V., Descamps S., Friesen V.L., Genovart M., Hedd A., Hodum P., Humphries G.R.W., Le Corre M., Lebarbenchon C., Martin R., Melvin E.F., Montevecchi W.A., Pinet P., Pollet I.L., Ramos R., Russell J.C., Ryan P.G., Sanz-A.A, Spatz D.R., Travers M., Votier S.C., Wanless R.M., Woehler E., Chiaradia A. 2006. Future Directions in Conservation Research on Petrels and Shearwaters. Frontiers in Marine Science 6, 2019. P94. Accessed at: <https://www.frontiersin.org/article/10.3389/fmars.2019.00094DOI=10.3389/fmars.2019.00094ISSN=2296-7745>

Röthig T., Ochsenkühn M.A., Roik A., van der Merwe R., Voolstra C.R. 2016. *Long-term salinity tolerance is accompanied by major restructuring of the coral bacterial microbiome*. Mol. Ecol. 2016, 25, 1308–1323. [CrossRef]

RPS 2009. *Effects of a Desalination Plant Discharge on the Marine Environment of Barrow Island, Unpublished report for Chevron Australia*, RPS, Perth, Western Australia.

RPS 2012. *Sediment quality surveys March-April 2011. Greater Western Flank Marine Environmental Baseline Studies.* Perth: RPS Environment and Planning Pty Ltd. Cited in Hydra, 2015. *Corowa Development Offshore Project Proposal*, Hydra Energy, West Perth.

RPS 2014. Competent persons report on the assets of Hydra Energy Pty Ltd located in the Carnarvon Basin. Report No: ACI05881. RPS, Perth.

RPS 2017. Appendix 1: *ConocoPhillips Barossa Project Cooling Water Dispersion Modelling*. Prepared by RPS for Conocophillips Australia. Report Number: MAQ0540J.000, 7 March 2017.

RPS 2019. Kato Oil Quantitative Spill Risk Assessment, Corowa Field – Subsurface Corowa Light Crude and Surface Marine Gas Oil Spills. Report No. MAW0843J.000, Rev 2. RPS Group, Perth.

Runcie J., Macinnis-Ng C., Ralph P. 2019. *The toxic effects of petrochemicals on seagrasses. Literature review.* Accessed at: <https://www.researchgate.net/publication/252133825_The_toxic_effects_of_petrochemicals_on_seagrasses_Literature_review>

Salmon M., Wyneken, J., Fritz, E. and Lucas, M. 1992. *Seafinding by hatchling sea turtles: role of brightness, silhouette and beach slope as orientation cues*. Behaviour 122 56–77.

Sanderson J.C. 1997. *Subtidal Macroalgal Assemblages in Temperate Australian Coastal Waters*. State of the Environment Technical Paper Series. Estuaries and the Sea. Department of Environment. Canberra.

Schlumberger 2019. *Oilfield Glossary, drilling*. Accessed at: <https://www.glossary.oilfield.slb.com/en/Terms/w/well_control.aspx>

Schmeichel 2017*. Effects of produced water and production chemical additives on marine environments: a toxicological review (Master of Environmental Assessment).* North Carolina State University, Raleigh.

Shapiro & Associates 2004. *George Straight Crossing Project: Final Supplemental environmental Impact Statement*. Prepared for Washington Department of Ecology. Cited in: 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. Perth Accessed at <https://www.inpex.com.au/media/1738/draft-eis-technical-appendices-appendix-15-review-of-literature-on-sound-in-the-ocean-and-on-the-effects-of-noise-on-marine-fauna.pdf>

Shell 2010. *Prelude Floating LNG Project EIS Supplement-Response to Submissions*. Shell Development (Australia) Proprietary Limited EPBC 2008/4146.

Shell 2018. *Crux Project, Offshore Project Proposal.* Shell Australia Pty Ltd, Perth, Western Australia.

Shingenaka G., Milton G., Lutz P. 2003. *Oil and Sea turtles: Biology, planning and response*. U.S. Department of Commerce, national Oceanic and Atmospheric Administration Office of Response and Restoration.

Shojaeddini E., Naimoli S., Ladislaw S. and Bazilian M. 2019. *Oil and gas company strategies regarding the energy transition*. Progress in Energy, 1, 2019. Accessed at: <https://iopscience.iop.org/article/10.1088/2516-1083/ab2503/pdf>

Short M. 2011. *Michael Short Oiled Wildlife Repsonse Training Module*. Accessed at: <https://www.dpaw.wa.gov.au/images/documents/conservation-management/marine/wildlife/West_Australian_Oiled_Wildlife_Response_Plan_V1.1.pdf>

SINTEF 2017. *SINTEF Offshore Blowout Database*. Accessed on 1 August 2019 at: <https://www.sintef.no/en/projects/sintef-offshore-blowout-database/>

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.

SLR 2017. *Deepwater Exploration Well Drilling Underwater Noise Impact Assessment*. SLR Consulting (Cape Town office) Shell Namibia. Accessed at: <https://slrconsulting.com/media/files/documents/Appendix_4_2-Noise_Assessment.pdf>

Smit M.G.D., R.K. Bechman A.J. Hendriks S. Bamber, A. Skadsheim, B.K. Larssen, T. Baussant, S.Sanni 2009. *Relating biomarkers to whole organism effects using species sensitivity distributions: a pilot study for marine species exposed to oil*. Environmental Toxicology and Chemistry. 28:1004–1009.

Sonardyne 2019a. *Construction Survey Positioning Systems Wideband™ Fusion LBL and USBL.* Sonardyne, Hampshire. Accessed 5 June 2019 at: <https://seatronics-group.com/files/1914/1890/7939/Sonardyne_Data_Fusion_Engine_-_Datasheet.pdf>

Sonardyne 2019b. *Dunker 6 LBL and telemetry transceiver. Sonardyne,* Hampshire. Accessed 5 June 2019 at: <https://www.sonardyne.com/product/dunker-6-lbl-and-telemetry-transceiver/>

Sonardyne 2019c. *ROVNav 6 LBL Transceiver and USBL Responder. Sonardyne*, Hampshire. Accessed 5 June 2019 at: <https://www.sonardyne.com/app/uploads/2016/06/Sonardyne_8310_rovnav6-2.pdf>

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.

Sudmeyer, R. 2016. *Climate in the Pilbara.* Bulletin 4873, Department of Agriculture and Food, Western Australia, Perth.

Surman, C.A. and Nicholson, L.W. 2015. *Exmouth Sub-basin Marine Avifauna Monitoring Program: Final Report*. Unpublished report prepared for Apache Energy Ltd by Halfmoon Sciences.

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.* Vol 159(3), 867-877.

Taylor B.L., Chivers S.J., Larese J. and Perrin W.F. 2007. *Generation length and percent mature estimates for IUCN assessments of Cetacean*s. Southwest Fisheries Science Centre.

TCD-Italia. 2020. *Burn pit*. Accessed 6 January 2020 at: <http://tcd-italia.com/index.php/products/10-flare-system-oil-gas-division/13-burn-pit>

Terrens G.W., Gwyther D., Keogh M.J. 1998. *Environmental Assessment of Synthetic-based Drilling Mud Discharges to Bass Strait*, *Australia*. APPEA Journal. V38: Part 1. Proceedings of the APPEA Conference, Canberra, 8–11 March 1998.

Thales 2001. *Corowa-1 Site Survey Report.* Balcatta: Unpublished report for Santos.

Thomsen M.S., Wernberg T., Engelen A.H., Tuya F., Vanderklift M.A., Holmer M., et al. 2012. *A Meta-Analysis of Seaweed Impacts on Seagrasses: Generalities and Knowledge Gaps.* PLoS ONE 7(1): e28595. Accessed at: <https://doi.org/10.1371/journal.pone.0028595>

Thursby G.B. and Steele R. L. 2003. *Toxicity of arsenite and arsenate to the marine macroalga Champia parvula (rhodophyta)*. Environmental Toxicology and Chemistry. 3(3):391–397.

Tian, T., Merico, A., Su, J., Staneva, J., Wiltshire, K., and Wirtz, K. 2009. *Importance of resuspended sediment dynamics for the phytoplankton spring bloom in a coastal marine ecosystem. Journal of Sea Research,* 62(4), 214–228. Accessed at: <https://doi.org/10.1016/j.seares.2009.04.001>

Tourism WA 2016. *Tourism WA Corporate Plan 2015–17*. Accessed from <https://www.tourism.wa.gov.au/Publications%20Library/About%20Us/Final%202015-16%20Corporate%20Plan%205-8-15.pdf>

TRBNRC. 2003. *Oil in the Sea III: Inputs, Fates, and Effects*. Transportation Research Board and National Research Council Washington, DC: The National Academies Press. Accessed at: <https://doi.org/10.17226/10388>

Tritech 2019. *Tritech Knowledge Base, learn More about Side Scan Sonars*. Tritech, Aberdeen. Accessed 5 June 2019 at: <https://www.tritech.co.uk/uploaded_files/Side%20Scan%20Sonars.pdf>

TSSC 2001. *Commonwealth Listing Advice on Rhincodon typus (Whale shark). Threatened Species Scientific Committee*. Accessed at: <http://www.environment.gov.au/biodiversity/threatened/species/r-typus.html. In effect under the EPBC Act from 16-Oct-2001>

TSSC 2008a. *Listing Advice for Pristis zijsron (Green Sawfish*). Threatened Species Scientific Committee. Accessed at: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/68442-listing-advice.pdf. In effect under the EPBC Act from 07-Mar-2008.>

TSSC 2009a. *Approved Conservation Advice for Dermochelys coriacea (Leatherback Turtle).* Canberra: Department of the Environment, Water, Heritage and the Arts. Accessed at: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/1768-conservation-advice.pdf.>

TSSC 2009b. *Commonwealth Listing Advice on Pristis clavata (Dwarf Sawfish).* Threatened Species Scientific Committee. Department of the Environment, Water, Heritage and the Arts. Canberra, ACT: Department of the Environment, Water, Heritage and the Arts. Accessed at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/68447-listing-advice.pdf.

TSSC 2011a. *Commonwealth Listing Advice on Aipysurus apraefrontalis (Short-nosed Seasnake).* Threatened Species Scientific Committee. Department of Sustainability, Environment, Water, Population and Communities. Canberra, ACT: Accessed at: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/1115-listing-advice.pdf>

TSSC 2011b. *Commonwealth Listing Advice on Sternula nereis nereis (Fairy Tern).* Threatened Species Scientific Committee. Department of Sustainability, Environment, Water, Population and Communities. Canberra, ACT. Accessed at: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/82950-listing-advice.pdf. In effect under the EPBC Act from 03-Mar-2011>

TSSC 2015a. *Conservation Advice Balaenoptera borealis Sei Whale*. Threatened Species Scientific Committee. Canberra: Department of the Environment, Threatened Species Scientific Committee. Accessed at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/34-conservation-advice-01102015.pdf.

TSSC 2015b. *Approved Conservation Advice for Balaenoptera physalus (Fin Whale)*. Threatened Species Scientific Committee. Department of the Environment. Accessed at: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/37-conservationadvice-01102015.pdf.>

TSSC 2015c. *Approved Conservation Advice for Megaptera novaeangliae (Humpback Whale).* Threatened Species Scientific Committee. Department of the Environment. Accessed at: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/38-conservationadvice-10102015.pdf.>

TSSC 2016a. *Conservation Advice Calidris canutus Red knot*. Threatened Species Scientific Committee Canberra: Department of the Environment. Accessed at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/855-conservation-advice-05052016.pdf.

TSSC 2016b. *Conservation Advice Limosa lapponica baueri Bar-tailed Godwit (Western Alaskan).* Threatened Species Scientific Committee. Canberra: Department of the Environment. Accessed at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/86380-conservation-advice-05052016.pdf

TSSC 2016c. *Conservation Advice Limosa lapponica menzbieri Bar-tailed Godwit (Northern Siberian).* Threatened Species Scientific Committee. Canberra: Department of the Environment. Acesed at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/86432-conservation-advice-05052016.pdf

Tzioumis V and Keable S (Eds) 2007. *Description of key species groups in the East Marine Region*, final report to the Australian Government Department of the Environment, Water, Heritage and the Arts, Australian Museum, Sydney.

UK Marine SCA 2019. *Thermal discharges*. UK Marine Special Area Project. Accessed at: <http://www.ukmarinesac.org.uk/activities/water-quality/wq9_8.htm>

UN Environment 2018. *Emissions Gap Report 2018*. Accessed at: <https://www.ipcc.ch/site/assets/uploads/2018/12/UNEP-1.pdf>

UNEP 1985. *GESMAP: Thermal discharges in the marine environment*. United Nations Environment Program (UNEP) Regional Seas Report and Studies No.45.

UNESCO 2019. *Ningaloo Coast*. United Nations Educational, Scientific and Cultural Organisation. Available: <http://whc.unesco.org/en/list/1369. Accessed: August 2019.>

URS 2010. *Wheatstone Project Lighting Emissions Study*. URS Australia, Perth, Australia.

US Energy Information Administration 2019. *Short-term energy outlook*. Accessed at: <https://www.eia.gov/outlooks/steo/report/global_oil.php>

US EPA. 2002. *EPA Air Pollution Control Cost Manual – Sixth Edition*. United States Environmental Protection Authority Agency Office of Air Quality Planning and Standards Research. North Carolina, United States of America.

US EPA. 2002. *Region 9: Total Maximum Daily Loads (TMDLs) for Toxic Pollutants*, San Diego, Creek and Newport Bay. U.S. Environmental Protection Agency.

US EPA. 2016. *The Fate of Spilled Oil. US Environmental Protection Agency*. Accessed at: <https://archive.epa.gov/emergencies/content/learning/web/html/oilfate.html>

van der Oost R., Beyer, J. and Vermeulen, N.P.E. 2003. *Fish bioaccumulation and biomarkers in environmental risk assessment*: A review. Environmental Toxicology and Pharmacology, 13, 57–149. doi:10.1016/S1382-6689(02)00126-6

Vanderlaan A.S.M. and Taggart C.T. 2007. *Vessel collisions with whales: the probability of lethal injury based on vessel speed*. Marine Mammal Science 23: pp144–156.

Vijverberg J. 1980. *Effect of temperature in laboratory studies on development and growth of Cladocera and Copepoda from Tjeukemeer, the Netherlands*. Freshwater Biology 10. pp 317–340. Accessed at: <http://cdn.waleedzubari.com/envi%20impact%20of%20desalination/Desalination%20Plants.pdf>

Volkman J.K., Miller, G.J., Revill, A.T. and Connell, D.W. 2004. *Oil spill in Environmental Implications of offshore oil and gas development in Australia – the findings of an independent scientific review*. Edited by Swan, J.M., Neff, J.M. and Young, P.C. Australian Petroleum Exploration Association. Sydney.

Vrålstad T., Saasen A., Fjær E., Øia T., Ytrehus J.D., Khalifeh M. 2019. *Plug & abandonment of offshore wells: Ensuring long-term well integrity and cost-efficiency,* Journal of Petroleum Science and Engineering, Volume 173, 2019, Pages 478–491, ISSN 0920-4105. Accessed at: <https://doi.org/10.1016/j.petrol.2018.10.049>

WA Fisheries 2014. *Potential Eradication and Control Methods for the Management of the Ascidian Didemnum perlucidum in Western Australia.* Fisheries Research Report No. 252, 2014. Accessed at: <http://www.fish.wa.gov.au/Documents/research_reports/frr252.pdf>

WAFIC 2019. *Fisheries*. Western Australian Fishing Industry Council Inc. Accessed at: <http://www.wafic.org.au/fishery/>

Wardrop J.A., Butler A.J. and Johnson J.E. 1987. *Field study of the toxicity of two oils and a dispersant to the mangrove Avicennia Marina*, Marine Biology, 96(1): 151–156.

Water Corporation 2017. *Southern Seawater Desalination Plant Marine Environment Monitoring Annual Report 17 January 2016 to 16 January 2017*.

WDCS 2004. Oceans of Noise: *A WDCS Science report*. Editors: Mark Simmonds, Sarah Dolman and Lindy Weilgart. The Whale and Dolphin Conservation Society, Wiltshire P168. Accessed at <https://us.whales.org/wp-content/uploads/sites/2/2018/08/Oceans-of-Noise.pdf>

Wells F. 2018. *A low number of invasive marine species in the tropics: a case study from Pilbara (Western Australia).* Management of Biological Invasions (2018) Volume 9, Issue 3: 227–237. Accessed at: <https://www.reabic.net/journals/mbi/2018/3/MBI_2018_Wells.pdf>

Wenziker K. McAlpine K. Apte S. Masini R. 2006. B*ackground quality for coastal marine waters of the North West Shelf*, Western Australia. NWSJEMS Technical Report. Accessed at: <http://www.epa.wa.gov.au/sites/default/files/Policies_and_Guidance/NWSJEMS%20Technical%20Report-NWS%20BG%20WaterQual.pdf>

Whinney J.C. 2007. *Physical conditions on marginal coral reefs*. PhD, James Cook University, Thesis (unpublished).

Whittle K.J. 1978. *Tainting in marine fish and shellfish with reference to the Mediterranean Sea*. In Data profiles for chemicals for the evaluation of their hazards to the environment of the Mediterranean Sea, vol. 3, pp.89–108. Geneva: U.N.E.P.

Wiese F., Montevecchi W.A., Davoren G.K, Huettmann F., Diamond A.W., Linke J. 2001. *Seabirds at risk around offshore oil platforms in the north-west Atlantic.* Marine Pollution Bulletin, Volume 42, Issue 12, 2001, Pages 1285–1290, ISSN 0025-326X, https://doi.org/10.1016/S0025-326X(01)00096-0.

Wilson S.G., Polovina J.J., Stewart B.S. and Meekan M.G. 2006. *Movements of Whale Sharks (Rhincodon typus) tagged at Ningaloo Reef, Western Australia.* Marine Biology 148: pp11

Wood Mackenzie. 2019a. *Global FLNG Overview 2019*. Accessed at: <www.woodmac.com>

Wood Mackenzie. 2019b. *GoFLNG – Cameroon GoFLNG Commercial Overview*. Accessed at: <www.woodmac.com>

Woodside. 2003. *WA-271-P Field Development: Environmental Impact Statement.* Perth: Woodside Energy Limited.

Woodside 2005. *The Vincent Development – Draft Environmental Impact Statement (EPBC Referral 2005/2110).* Perth, Western Australia: Woodside Energy Ltd. Cited in Hydra, 2015. *Corowa Development Offshore Project Proposal*. Hydra Energy, West Perth.

Woodside 2008. *Torosa South – 1 (TS-1) Pilot Appraisal well, Environmental Monitoring Program – Development of Methodologies Part 1 (p51).* Report produced by Environmental Resources Management and SKM.

Woodside 2014. *Browse FLNG Development, Draft Environmental Impact Statement*. EPBC 2013/7079. November 2014. Woodside Energy, Perth WA

Woodside 2019. *Scarborough Offshore Project Proposal. Development Division Revision 2, Submission* June 2019. Woodside Energy, Perth

World Bank 2015. *CNG for commercialization of small volumes of associated gas*. Accessed at: <http://documents.worldbank.org/curated/en/210571472125529218/text/104200-V2-WP-CNG-commercialization-PUBLIC-Main-report-REPLACEMENT.txt>

Xodus Group 2019a. *Corowa Development Facility and Flare Light Assessment.* Document Number: P-100092-S00-TECH-001. Unpublished report prepared for KATO Energy.

Xodus Group 2019b. *Corowa Development Greenhouse Gas Report.* Document Number: P-100092-S00-TECH-001. Unpublished report prepared for KATO Energy.

Xodus Group 2019c. *Corowa Development Produced Formation Water and Cooling Water Discharge Modelling*. Document Number: P-100092-S00-REPT-001. Unpublished report prepared for KATO Energy

Young A. 2003. *Distance to the Horizon*. San Diego State University Department of Astronomy. San Diego, United States of America. Accessed at: <https://aty.sdsu.edu/explain/atmos_refr/horizon.html>

Young, J.W., Skewes, T.D., Lyne, T.E. Hook, S.E. Revill, A.T., Condie, S.A., Newman, S.J., Wakefield C.B., and Molony, B.W.. 2011. A Review of the fisheries potentially affected by the Montara Oil Spill off Northwest Australia and Potential Toxicological Effects. Montara Well Release Scientific Monitoring Program Study S4B. Report to PTTEP Australasia and SEWPAC. Accessed 6 November 2019 at <https://www.researchgate.net/publication/258821367_A_Review_of_the_Fisheries_Potentially_Affected_by_the_Montara_Oil_Spill_off_Northwest_Australia_and_Potential_Toxicological_Effects>

Zeeco. 2020. *Air-Assisted Flares*. Accessed 6 January 2020 at <https://www.zeeco.com/flares/flares-air-assisted-af.php>

Zieman J.C., Orth R., Phillips R.C., Thayer G.W., Thorhaug A. 1984. *The effects of oil on seagrass ecosystems*. In: Cairns J, Buikema AL (eds) Restoration of habitats impacted by oil spills. Butterworth-Heinemann, Boston, MA, p37–64

Appendix A: EPBC Act Protected Matters Reports

(Source: PMST; DoEE 2019)

Australian Government
Department of the Environment and Energy

EMBA

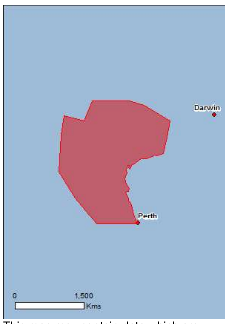
EPBC Act Protected Matters Report

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.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 29/07/19 16:50:25



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 10.0Km

Summary

Matters of National Environmental 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:	4
National Heritage Places:	8
Wetlands of International Importance:	2
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	3
Listed Threatened Species:	132
Listed Migratory Species:	104

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 http://www.environment.gov.au/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 Land:	20
Commonwealth Heritage Places:	10
Listed Marine Species:	191
Whales and Other Cetaceans:	41
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	28

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	100
Regional Forest Agreements:	None
Invasive Species:	54
Nationally Important Wetlands:	18
Key Ecological Features (Marine)	16

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Status
Australian Convict Sites (Fremantle Prison Buffer Zone)	WA	Buffer zone
Australian Convict Sites (Fremantle Prison)	WA	Declared property
Shark Bay, Western Australia	WA	Declared property
The Ningaloo Coast	WA	Declared property

National Heritage Properties [Resource Information]

Name	State	Status
Natural		
Lesueur National Park	WA	Listed place
Shark Bay, Western Australia	WA	Listed place
The Ningaloo Coast	WA	Listed place
Indigenous		
Dampier Archipelago (including Burrup Peninsula)	WA	Listed place
Historic		
Batavia Shipwreck Site and Survivor Camps Area 1629 - Houtman Abrolhos	WA	Listed place
Dirk Hartog Landing Site 1616 - Cape Inscription Area	WA	Listed place
Fremantle Prison (former)	WA	Listed place
HMAS Sydney II and HSK Kormoran Shipwreck Sites	EXT	Listed place

Wetlands of International Importance (Ramsar) [Resource Information]

Name	Proximity
Eighty-mile beach	Within Ramsar site
Forrestdale and thomsons lakes	Within 10km of Ramsar

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 the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea
Extended Continental Shelf

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west
South-west

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, 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.

Name	Status	Type of Presence
Banksia Woodlands of the Swan Coastal Plain ecological community	Endangered	Community likely to occur within area
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area
Tuart (Eucalyptus gomphocephala) Woodlands and Forests of the Swan Coastal Plain ecological community	Critically Endangered	Community may occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Botaurus poiciloptilus Australasian Bittern [1001]	Endangered	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	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 tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Calyptorhynchus banksii naso Forest Red-tailed Black-Cockatoo, Karrak [67034]	Vulnerable	Species or species habitat known to occur within area
Calyptorhynchus latirostris Carnaby's Cockatoo, Short-billed Black-Cockatoo [59523]	Endangered	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat may occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat known to occur within area

Name	Status	Type of Presence
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	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
Malurus leucopterus leucopterus White-winged Fairy-wren (Dirk Hartog Island), Dirk Hartog Black-and-White Fairy-wren [26004]	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
Pachyptila turtur subantarctica Fairy Prion (southern) [64445]	Vulnerable	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat likely to occur within area
Pezoporus occidentalis Night Parrot [59350]	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
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Rostratula australis Australian Painted-snipe, 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	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta cauta Shy Albatross, Tasmanian Shy Albatross [82345]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche cauta steadi White-capped Albatross [82344]	Vulnerable	Foraging, feeding or related behaviour likely to 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
Turnix varius scintillans Painted Button-quail (Houtman Abrolhos) [82451]	Vulnerable	Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Fish		
Milyeringa veritas Blind Gudgeon [66676]	Vulnerable	Species or species habitat known to occur within area
Nannatherina balstoni Balston's Pygmy Perch [66698]	Vulnerable	Species or species habitat likely to occur within area
Ophisternon candidum Blind Cave Eel [66678]	Vulnerable	Species or species habitat known to occur within area
Insects		
Hesperocolletes douglasi Douglas' Broad-headed Bee, Rottnest Bee [66734]	Critically Endangered	Species or species habitat may occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Foraging, feeding or related behaviour 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
Bettongia lesueur lesueur Burrowing Bettong (Shark Bay), Boodie [66659]	Vulnerable	Species or species habitat known to occur within area
Bettongia penicillata ogilbyi Woylie [66844]	Endangered	Species or species habitat known to occur within area
Dasyurus geoffroii Chuditch, Western Quoll [330]	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	Breeding known to occur within area
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
Lagorchestes hirsutus bernieri Rufous Hare-wallaby (Bernier Island) [66662]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
Lagorchestes hirsutus dorreae Rufous Hare-wallaby (Dorre Island) [66663]	Vulnerable	Species or species habitat known to occur within area
Lagostrophus fasciatus fasciatus Banded Hare-wallaby, Merrnine, Marnine, Munning [66664]	Vulnerable	Species or species habitat known to occur within area
Leporillus conditor Wopilkara, Greater Stick-nest Rat [137]	Vulnerable	Translocated population known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat known to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Vulnerable	Breeding known to occur within area
Osphranter robustus isabellinus Barrow Island Wallaroo, Barrow Island Euro [89262]	Vulnerable	Species or species habitat likely to occur within area
Parantechinus apicalis Dibbler [313]	Endangered	Species or species habitat known to occur within area
Perameles bougainville bougainville Western Barred Bandicoot (Shark Bay) [66631]	Endangered	Species or species habitat known 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
Pseudocheirus occidentalis Western Ringtail Possum, Ngwayir, Womp, Woder, Ngoor, Ngoolangit [25911]	Critically Endangered	Species or species habitat likely to occur within area
Pseudomys fieldi Shark Bay Mouse, Djoongari, Alice Springs Mouse [113]	Vulnerable	Species or species habitat likely to occur within area
Rhinonicteris aurantia (Pilbara form) Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat known to occur within area
Setonix brachyurus Quokka [229]	Vulnerable	Species or species habitat known to occur within area
Other		
Idiosoma nigrum Shield-backed Trapdoor Spider, Black Rugose Trapdoor Spider [66798]	Vulnerable	Species or species habitat known to occur within area
Kumonga exleyi Cape Range Remipede [86875]	Vulnerable	Species or species habitat known to occur within area
Plants		
Andersonia gracilis Slender Andersonia [14470]	Endangered	Species or species habitat may occur within area

Name	Status	Type of Presence
Androcalva bivillosa Straggling Androcalva [87807]	Critically Endangered	Species or species habitat likely to occur within area
Anigozanthos viridis subsp. terraspectans Dwarf Green Kangaroo Paw [3435]	Vulnerable	Species or species habitat likely to occur within area
Beyeria lepidopetala Small-petalled Beyeria, Short-petalled Beyeria [18362]	Endangered	Species or species habitat likely to occur within area
Caladenia barbarella Small Dragon Orchid, Common Dragon Orchid [68686]	Endangered	Species or species habitat may occur within area
Caladenia bryceana subsp. cracens Northern Dwarf Spider-orchid [64556]	Vulnerable	Species or species habitat known to occur within area
Caladenia elegans Elegant Spider-orchid [56775]	Endangered	Species or species habitat known to occur within area
Caladenia hoffmanii Hoffman's Spider-orchid [56719]	Endangered	Species or species habitat known to occur within area
Caladenia huegelii King Spider-orchid, Grand Spider-orchid, Rusty Spider-orchid [7309]	Endangered	Species or species habitat known to occur within area
Chorizema varium Limestone Pea [16981]	Endangered	Species or species habitat known to occur within area
Conostylis micrantha Small-flowered Conostylis [17635]	Endangered	Species or species habitat may occur within area
Diuris micrantha Dwarf Bee-orchid [55082]	Vulnerable	Species or species habitat likely to occur within area
Diuris purdiei Purdie's Donkey-orchid [12950]	Endangered	Species or species habitat likely to occur within area
Drakaea concolor Kneeling Hammer-orchid [56777]	Vulnerable	Species or species habitat known to occur within area
Drakaea elastica Glossy-leafed Hammer Orchid, Glossy-leaved Hammer Orchid, Warty Hammer Orchid [16753]	Endangered	Species or species habitat likely to occur within area
Drakaea micrantha Dwarf Hammer-orchid [56755]	Vulnerable	Species or species habitat likely to occur within area
Drummondita ericoides Morseby Range Drummondita [9193]	Endangered	Species or species habitat known to occur within area
Eleocharis keigheryi Keighery's Eleocharis [64893]	Vulnerable	Species or species habitat may occur within area
Eucalyptus argutifolia Yanchep Mallee, Wabling Hill Mallee [24263]	Vulnerable	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Eucalyptus beardiana Beard's Mallee [18933]	Vulnerable	Species or species habitat known to occur within area
Eucalyptus cuprea Mallee Box [56773]	Endangered	Species or species habitat known to occur within area
Grevillea batrachioides Mt Lesueur Grevillea [21735]	Endangered	Species or species habitat may occur within area
Grevillea bracteosa subsp. howatharra [85002]	Critically Endangered	Species or species habitat likely to occur within area
Grevillea humifusa Spreading Grevillea [61182]	Endangered	Species or species habitat may occur within area
Hemiandra gardneri Red Snakebush [7945]	Endangered	Species or species habitat likely to occur within area
Hypocalymma longifolium Long-leaved Myrtle [8081]	Vulnerable	Species or species habitat likely to occur within area
Lechenaultia chlorantha Kalbarri Leschenaultia [16763]	Vulnerable	Species or species habitat likely to occur within area
Lepidosperma rostratum Beaked Lepidosperma [14152]	Endangered	Species or species habitat likely to occur within area
Leucopogon marginatus Thick-margined Leucopogon [12527]	Endangered	Species or species habitat likely to occur within area
Leucopogon obtectus Hidden Beard-heath [19614]	Endangered	Species or species habitat may occur within area
Macarthuria keigheryi Keighery's Macarthuria [64930]	Endangered	Species or species habitat likely to occur within area
Marianthus paralius [83925]	Endangered	Species or species habitat known to occur within area
Paracaleana dixonii Sandplain Duck Orchid [86882]	Endangered	Species or species habitat likely to occur within area
Pityrodia augustensis Mt Augustus Foxglove [4962]	Vulnerable	Species or species habitat likely to occur within area
Pterostylis sinuata Northampton Midget Greenhood, Western Swan Grrenhood [84991]	Endangered	Species or species habitat known to occur within area
Stachystemon nematophorus Three-flowered Stachystemon [81447]	Vulnerable	Species or species habitat known to occur within area
Synaphea sp. Fairbridge Farm (D. Papenfus 696) Selena's Synaphea [82881]	Critically Endangered	Species or species habitat may occur within area

Name	Status	Type of Presence
Tetratheca nephelioides [83217]	Critically Endangered	Species or species habitat may occur within area
Thelymitra stellata Star Sun-orchid [7060]	Endangered	Species or species habitat likely to occur within area
Wurmbea tubulosa Long-flowered Nancy [12739]	Endangered	Species or species habitat known to occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	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
Ctenotus lancelini Lancelin Island Skink [1482]	Vulnerable	Species or species habitat 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
Egernia stokesii badia Western Spiny-tailed Skink, Baudin Island Spiny-tailed Skink [64483]	Endangered	Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Lerista nevinae Nevin's Slider [85296]	Endangered	Species or species habitat known to occur within area
Liasis olivaceus barroni Olive Python (Pilbara subspecies) [66699]	Vulnerable	Species or species habitat known to occur within area
Liopholis pulchra longicauda Jurien Bay Skink, Jurien Bay Rock-skink [83162]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Glyphis garricki Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within

Name	Status	Type of Presence
		area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
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]		Foraging, feeding or related behaviour 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 known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat may occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding 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

Name	Threatened	Type of Presence
		within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	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]		Breeding likely to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta Tasmanian Shy Albatross [89224]	Vulnerable*	Foraging, feeding or related behaviour likely to 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*	Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	Breeding known to 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

Name	Threatened	Type of Presence
		habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour 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
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely 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
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding 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
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat likely to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat known to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area

Name	Threatened	Type of Presence
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Foraging, feeding or related behaviour known to occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		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		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to 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 known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area

Name	Threatened	Type of Presence
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 known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius dubius Little Ringed Plover [896]		Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area

Name	Threatened	Type of Presence
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [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.

Name
Commonwealth Land -
Defence - ARTILLERY BARRACKS - FREMANTLE
Defence - CAMPBELL BARRACKS - SWANBOURNE
Defence - CARNARVON TRAINING DEPOT
Defence - EAST FREMANTLE SMALL CRAFT BASE
Defence - EXMOUTH ADMIN & HF TRANSMITTING
Defence - EXMOUTH VLF TRANSMITTER STATION
Defence - GERALDTON TRAINING DEPOT "A" Company 16th Battalion
Defence - GREENOUGH RIFLE RANGE
Defence - IRWIN BARRACKS - KARRAKATTA
Defence - KARRATHA TRAINING DEPOT
Defence - LANCELIN TRAINING AREA
Defence - LEARMONTH - AIR WEAPONS RANGE
Defence - LEARMONTH - RAAF BASE
Defence - LEARMONTH RADAR SITE - TWIN TANKS EXMOUTH
Defence - LEARMONTH RADAR SITE - VLAMING HEAD EXMOUTH
Defence - LEARMONTH TRANSMITTING STATION
Defence - LEEUWIN BARRACKS - EAST FREMANTLE
Defence - PRESTON POINT TRAINING DEPOT
Defence - SWANBOURNE RIFLE RANGE

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Lancelin Defence Training Area	WA	Listed place
Learmonth Air Weapons Range Facility	WA	Listed place
Mermaid Reef - Rowley Shoals	WA	Listed place
Ningaloo Marine Area - Commonwealth Waters	WA	Listed place
Scott Reef and Surrounds - Commonwealth Area	EXT	Listed place

Name	State	Status
Historic		
Army Magazine Buildings Irwin Barracks	WA	Listed place
Artillery Barracks	WA	Listed place
Claremont Post Office	WA	Listed place
Geraldton Drill Hall Complex	WA	Listed place
HMAS Sydney II and HSK Kormoran Shipwreck Sites	EXT	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
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
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Breeding known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	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 known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Catharacta skua Great Skua [59472]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius dubius Little Ringed Plover [896]		Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered	Species or species habitat may occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eudyptula minor Little Penguin [1085]		Breeding known to occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Foraging, feeding or related behaviour known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Breeding known to occur within area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Heteroscelus brevipes Grey-tailed Tattler [59311]		Roosting known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area
Hirundo daurica Red-rumped Swallow [59480]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Larus novaehollandiae Silver Gull [810]		Breeding known to occur within area
Larus pacificus Pacific Gull [811]		Breeding known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		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 known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pachyptila turtur Fairy Prion [1066]		Species or species habitat 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 likely to occur

Name	Threatened	Type of Presence
		within area
Pelagodroma marina White-faced Storm-Petrel [1016]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding likely to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Species or species habitat may occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Phalacrocorax fuscescens Black-faced Cormorant [59660]		Breeding likely to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Pterodroma macroptera Great-winged Petrel [1035]		Foraging, feeding or related behaviour known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Puffinus assimilis Little Shearwater [59363]		Breeding known to occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Foraging, feeding or related behaviour likely to occur within area
Puffinus huttoni Hutton's Shearwater [1025]		Foraging, feeding or related behaviour known to occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding known to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Sterna albifrons Little Tern [813]		Breeding known to occur within area
Sterna anaethetus Bridled Tern [814]		Breeding known to occur within area
Sterna bengalensis Lesser Crested Tern [815]		Breeding known to occur within area

Name	Threatened	Type of Presence
Sterna bergii Crested Tern [816]		Breeding known to occur within area
Sterna caspia Caspian Tern [59467]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sterna fuscata Sooty Tern [794]		Breeding known to occur within area
Sterna nereis Fairy Tern [796]		Breeding known to occur within area
Stiltia isabella Australian Pratincole [818]		Roosting known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta Tasmanian Shy Albatross [89224]	Vulnerable*	Foraging, feeding or related behaviour likely to 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*	Foraging, feeding or related behaviour likely to occur within area
Thinornis rubricollis Hooded Plover [59510]		Breeding known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area
Fish		
Acentronura australe Southern Pygmy Pipehorse [66185]		Species or species habitat may occur within area
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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
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

Name	Threatened	Type of Presence
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
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
Heraldia nocturna Upside-down Pipefish, Eastern Upside-down Pipefish, Eastern Upside-down Pipefish [66227]		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 breviceps Short-head Seahorse, Short-snouted Seahorse [66235]		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 subelongatus West Australian Seahorse [66722]		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
Histiogamphelus cristatus Rhino Pipefish, Macleay's Crested Pipefish, Ring-back Pipefish [66243]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Lissocampus caudalis Australian Smooth Pipefish, Smooth Pipefish [66249]		Species or species habitat may occur within area
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Lissocampus runa Javelin Pipefish [66251]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Mitotichthys meraculus Western Crested Pipefish [66259]		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
Phycodurus eques Leafy Seadragon [66267]		Species or species habitat may occur within area
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area
Pugnaso curtirostris Pugnose Pipefish, Pug-nosed Pipefish [66269]		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
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		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

Name	Threatened	Type of Presence
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Vanacampus phillipi Port Phillip Pipefish [66284]		Species or species habitat may occur within area
Vanacampus poecilolaemus Longsnout Pipefish, Australian Long-snout Pipefish, Long-snouted Pipefish [66285]		Species or species habitat may occur within area
Mammals		
Arctocephalus forsteri Long-nosed Fur-seal, New Zealand Fur-seal [20]		Species or species habitat may occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Vulnerable	Breeding known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus fuscus Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus pooleorum Shark Bay Seasnake [66061]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		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

Name	Threatened	Type of Presence
		within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
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	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour may occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Breeding known 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
Globicephala melas Long-finned Pilot Whale [59282]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Hyperoodon planifrons Southern Bottlenose Whale [71]		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 simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Lissodelphis peronii Southern Right Whale Dolphin [44]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Mesoplodon bowdoini Andrew's Beaked Whale [73]		Species or species habitat may 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
Mesoplodon grayi Gray's Beaked Whale, Scamperdown Whale [75]		Species or species habitat may occur within area
Mesoplodon layardii Strap-toothed Beaked Whale, Strap-toothed Whale, Layard's Beaked Whale [25556]		Species or species habitat may occur within area
Mesoplodon mirus True's Beaked Whale [54]		Species or species habitat may occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat may 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]		Foraging, feeding or related behaviour known to occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		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

Name	Status	Type of Presence
Tursiops aduncus		
Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely 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
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]

Name	Label
Abrolhos	Habitat Protection Zone (IUCN IV)
Abrolhos	Multiple Use Zone (IUCN VI)
Abrolhos	National Park Zone (IUCN II)
Abrolhos	Special Purpose Zone (IUCN VI)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	National Park Zone (IUCN II)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)
Carnarvon Canyon	Habitat Protection Zone (IUCN IV)
Dampier	Habitat Protection Zone (IUCN IV)
Dampier	Multiple Use Zone (IUCN VI)
Dampier	National Park Zone (IUCN II)
Eighty Mile Beach	Multiple Use Zone (IUCN VI)
Gascoyne	Habitat Protection Zone (IUCN IV)
Gascoyne	Multiple Use Zone (IUCN VI)
Gascoyne	National Park Zone (IUCN II)
Jurien	National Park Zone (IUCN II)
Jurien	Special Purpose Zone (IUCN VI)
Kimberley	Multiple Use Zone (IUCN VI)
Mermaid Reef	National Park Zone (IUCN II)
Montebello	Multiple Use Zone (IUCN VI)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)
Perth Canyon	Habitat Protection Zone (IUCN IV)
Perth Canyon	Multiple Use Zone (IUCN VI)
Perth Canyon	National Park Zone (IUCN II)
Shark Bay	Multiple Use Zone (IUCN VI)
Two Rocks	Multiple Use Zone (IUCN VI)
Two Rocks	National Park Zone (IUCN II)

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Airlie Island	WA
Alfred Cove	WA
Barrow Island	WA
Bedout Island	WA
Beekeepers	WA
Bernier And Dorre Islands	WA
Bessieres Island	WA
Boodie, Double Middle Islands	WA
Boullanger, Whitlock, Favourite, Tern And Osprey Islands	WA
Bundegi Coastal Park	WA
Burnside And Simpson Island	WA
Cape Range	WA
Carnac Island	WA
Chinamans Pool	WA
Dirk Hartog Island	WA
Dongara	WA
Drovers Cave	WA
Escape Island	WA
Faure Island	WA
Francois Peron	WA
Freycinet, Double Islands etc	WA
Giralia	WA
Gnandaroo Island	WA
Hamelin Station	WA
Jurabi Coastal Park	WA
Kalbarri	WA
Keanes Point Reserve	WA
Koks Island	WA
Lancelin And Edwards Islands	WA
Lesueur	WA
Little Rocky Island	WA
Locker Island	WA
Lowendal Islands	WA
Matilda Bay Reserve	WA
Monkey Mia Reserve	WA
Montebello Islands	WA
Muiron Islands	WA
Murujuga	WA
Nambung	WA
Nanga Station	WA
Nilgen	WA
North Sandy Island	WA
North Turtle Island	WA
Nyangumarta Warrarn	WA
One Tree Point	WA
Part Murchison house	WA
Port Gregory	WA
Rocky Island	WA
Round Island	WA
Serrurier Island	WA
Shell Beach	WA
Southern Beekeepers	WA
Tamala Pastoral Lease (Part)	WA
Tent Island	WA
Unnamed WA11883	WA
Unnamed WA26400	WA
Unnamed WA31906	WA
Unnamed WA33287	WA
Unnamed WA33799	WA
Unnamed WA34039	WA
Unnamed WA36907	WA
Unnamed WA36909	WA
Unnamed WA36910	WA
Unnamed WA36913	WA
Unnamed WA36915	WA
Unnamed WA37338	WA
Unnamed WA37383	WA
Unnamed WA37500	WA
Unnamed WA38287	WA
Unnamed WA40322	WA
Unnamed WA40828	WA
Unnamed WA40877	WA
Unnamed WA41080	WA
Unnamed WA42030	WA
Unnamed WA42469	WA
Unnamed WA44414	WA
Unnamed WA44665	WA
Unnamed WA44667	WA
Unnamed WA44672	WA
Unnamed WA44682	WA
Unnamed WA44688	WA
Unnamed WA45772	WA
Unnamed WA45773	WA
Unnamed WA46982	WA
Unnamed WA46983	WA
Unnamed WA46984	WA
Unnamed WA48205	WA
Unnamed WA48717	WA
Unnamed WA49144	WA
Unnamed WA49220	WA
Unnamed WA49994	WA
Utcha Well	WA
Victor Island	WA
Wanagarren	WA
Wedge Island	WA
Weld Island	WA
Whitmore,Roberts,Doole Islands And Sandalwood Landing	WA
Y Island	WA
Yaringga	WA
Zuytdorp	WA

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Acridotheres tristis		
Common Myna, Indian Myna [387]		Species or species habitat likely to occur within area
Anas platyrhynchos		
Mallard [974]		Species or species habitat likely to occur within area
Carduelis carduelis		
European Goldfinch [403]		Species or species habitat likely to occur within area
Columba livia		
Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus		
House Sparrow [405]		Species or species habitat likely to occur within area
Passer montanus		
Eurasian Tree Sparrow [406]		Species or species habitat likely to occur within area
Pavo cristatus		
Indian Peafowl, Peacock [919]		Species or species habitat likely to occur within area
Phasianus colchicus		
Common Pheasant [920]		Species or species habitat likely to occur within area
Streptopelia chinensis		
Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Streptopelia senegalensis		
Laughing Turtle-dove, Laughing Dove [781]		Species or species habitat likely to occur within area
Sturnus vulgaris		
Common Starling [389]		Species or species habitat likely to occur within area
Turdus merula		
Common Blackbird, Eurasian Blackbird [596]		Species or species habitat likely to occur within area
Mammals		
Bos taurus		
Domestic Cattle [16]		Species or species habitat likely to occur within area
Camelus dromedarius		
Dromedary, Camel [7]		Species or species habitat likely to occur within area
Canis lupus familiaris		
Domestic Dog [82654]		Species or species habitat likely to occur within area
Capra hircus		
Goat [2]		Species or species habitat likely to occur within area
Equus asinus		
Donkey, Ass [4]		Species or species habitat likely to occur within area
Equus caballus		
Horse [5]		Species or species habitat likely to occur within area
Felis catus		
Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Feral deer		
Feral deer species in Australia [85733]		Species or species habitat likely to occur within area
Funambulus pennantii		
Northern Palm Squirrel, Five-striped Palm Squirrel [129]		Species or species habitat likely to occur within area
Mus musculus		
House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus		
Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus norvegicus		
Brown Rat, Norway Rat [83]		Species or species habitat likely to occur within area
Rattus rattus		
Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa		
Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes		
Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Andropogon gayanus		
Gamba Grass [66895]		Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Anredera cordifolia Madeira Vine, Jalap, Lamb's-tail, Mignonette Vine, Anredera, Gulf Madeiravine, Heartleaf Madeiravine, Potato Vine [2643]		Species or species habitat likely to occur within area
Asparagus aethiopicus Asparagus Fern, Ground Asparagus, Basket Fern, Sprengi's Fern, Bushy Asparagus, Emerald Asparagus [62425]		Species or species habitat likely to occur within area
Asparagus asparagoides Bridal Creeper, Bridal Veil Creeper, Smilax, Florist's Smilax, Smilax Asparagus [22473]		Species or species habitat likely to occur within area
Asparagus declinatus Bridal Veil, Bridal Veil Creeper, Pale Berry Asparagus Fern, Asparagus Fern, South African Creeper [66908]		Species or species habitat likely to occur within area
Asparagus plumosus Climbing Asparagus-fern [48993]		Species or species habitat likely to occur within area
Brachiaria mutica Para Grass [5879]		Species or species habitat may occur within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Chrysanthemoides monilifera Bitou Bush, Boneseed [18983]		Species or species habitat may occur within area
Chrysanthemoides monilifera subsp. monilifera Boneseed [16905]		Species or species habitat likely to occur within area
Cylindropuntia spp. Prickly Pears [85131]		Species or species habitat likely to occur within area
Genista sp. X Genista monspessulana Broom [67538]		Species or species habitat may occur within area
Jatropha gossypifolia Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Lycium ferocissimum African Boxthorn, Boxthorn [19235]		Species or species habitat likely to occur within area
Olea europaea Olive, Common Olive [9160]		Species or species habitat may occur within area
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Pinus radiata Radiata Pine Monterey Pine, Insignis Pine, Wilding Pine [20780]		Species or species habitat may occur within

Name	Region
Mermaid Reef and Commonwealth waters	North-west
Seringapatam Reef and Commonwealth waters in	North-west
Wallaby Saddle	North-west
Ancient coastline at 90-120m depth	South-west
Commonwealth marine environment surrounding	South-west
Commonwealth marine environment within and	South-west
Perth Canyon and adjacent shelf break, and other	South-west
Western demersal slope and associated fish	South-west
Western rock lobster	South-west

Name	Status	Type of Presence
		area
Prosopis spp. Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Rubus fruticosus aggregate Blackberry, European Blackberry [68406]		Species or species habitat likely to occur within area
Sagittaria platyphylla Delta Arrowhead, Arrowhead, Slender Arrowhead [68483]		Species or species habitat likely to occur within area
Salix spp. except S.babylonica, S.x calodendron & S.x reichardtii Willows except Weeping Willow, Pussy Willow and Sterile Pussy Willow [68497]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Tamarix aphylla Athel Pine, Athel Tree, Tamarisk, Athel Tamarisk, Athel Tamarix, Desert Tamarisk, Flowering Cypress, Salt Cedar [16018]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species habitat likely to occur within area
Ramphotyphlops braminus Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat known to occur within area

Nationally Important Wetlands

[Resource Information]

Name	State
Booragoon Swamp	WA
Bundera Sinkhole	WA
Cape Range Subterranean Waterways	WA
De Grey River	WA
Eighty Mile Beach System	WA
Exmouth Gulf East	WA
Hamelin Pool	WA
Herdsman Lake	WA
Hutt Lagoon System	WA
Lake MacLeod	WA
Lake Thetis	WA
Learmonth Air Weapons Range - Saline Coastal Flats	WA
Leslie (Port Hedland) Saltfields System	WA
Mermaid Reef	EXT
Murchison River (Lower Reaches)	WA
Rottnest Island Lakes	WA
Shark Bay East	WA
Swan-Canning Estuary	WA

Key Ecological Features (Marine)

[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 Argo Abyssal Plain with the	North-west
Canyons linking the Cuvier Abyssal Plain and the	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

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, 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 distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for 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 reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-32.055 115.769,-32.055 107.83,-27.65 103.715,-23.061 100.497,-16.308 100.945,-12.563 101.552,-13.644 105.482,-9.74 107.012,-9.767 114.266,-10.637 117.115,-13.591 122.179,-19.637 120.947,-20.061 119.597,-19.967 119.123,-20.305 118.8,-20.369 118.154,-20.649 117.752,-20.707 116.739,-20.951 116.179,-21.59 115.174,-21.856 114.635,-22.495 114.355,-22.208 114.09,-21.806 114.183,-21.892 113.975,-22.595 113.666,-23.127 113.767,-24.218 113.343,-25.116 113.702,-25.898 114.248,-26.473 114.104,-26.624 113.566,-27.686 114.14,-28.139 114.154,-28.318 114.377,-28.849 114.628,-29.129 114.872,-30.084 114.951,-30.81 115.181,-32.055 115.769

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 the Environment
GPO Box 787
Canberra ACT 2601 Australia
+61 2 6274 1111

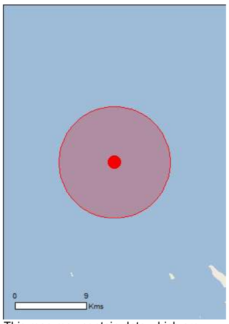
EPBC Act Protected Matters Report

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.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 01/08/19 12:20:09



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 7.0Km

Summary

Matters of National Environmental 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:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	21
Listed Migratory Species:	32

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 http://www.environment.gov.au/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 Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	60
Whales and Other Cetaceans:	24
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	1

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 the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	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
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species

Name	Status	Type of Presence
		habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Reptiles		
Aipysurus apraefrontalis 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 known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat may 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 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

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
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
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

Name	Threatened	Type of Presence
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within area
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	Species or species habitat may 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 may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	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
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 known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat known to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation 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
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area

Name	Threatened	Type of Presence
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
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to 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]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
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
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
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]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may 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 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
Pandion haliaetus Osprey [952]		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
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		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

Name	Threatened	Type of Presence
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
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 trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
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

Name	Threatened	Type of Presence
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat may occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		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 known to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area

Name	Threatened	Type of Presence
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may 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 may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	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 simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	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

Name	Status	Type of Presence
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
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

Extra Information

Key Ecological Features (Marine) [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

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, 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 distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for 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 reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-21.48306 114.55722

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 the Environment
GPO Box 787
Canberra ACT 2601 Australia
+61 2 6274 1111

Australian Government
Department of the Environment and Energy

LIGHT AREA

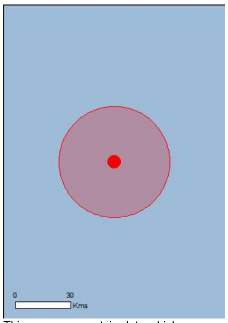
EPBC Act Protected Matters Report

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.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 27/10/19 20:14:52



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 30.0Km

Summary

Matters of National Environmental 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:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	22
Listed Migratory Species:	43

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 http://www.environment.gov.au/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 Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	75
Whales and Other Cetaceans:	26
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	5
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	3

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Status
The Ningaloo Coast	WA	Declared property

National Heritage Properties [Resource Information]

Name	State	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 the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	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
Rostratula australis Australian Painted-snipe, Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Species or species habitat known to occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	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 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

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		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 likely to occur within area
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
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	Species or species habitat may 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	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat likely to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour 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
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat known to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour 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
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known 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 chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat likely 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 may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
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
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
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
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
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
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

Name	Threatened	Type of Presence
		within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Larus novaehollandiae Silver Gull [810]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	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
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat may occur within area
Sterna anaethetus Bridled Tern [814]		Breeding known to occur within area
Sterna bengalensis Lesser Crested Tern [815]		Breeding known to occur within area
Sterna bergii Crested Tern [816]		Breeding known to occur within area
Sterna fuscata Sooty Tern [794]		Breeding known to occur within area
Sterna nereis Fairy Tern [796]		Breeding known to 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

Name	Threatened	Type of Presence
		habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		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 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 trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
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
Mammals		
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species

Name	Threatened	Type of Presence
		habitat known to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans

[Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may 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	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within

Extra Information

State and Territory Reserves

[Resource Information]

Name	State
Bessieres Island	WA
Muiron Islands	WA
Round Island	WA
Serrurier Island	WA
Unnamed WA44665	WA

Key Ecological Features (Marine)

[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	North-west
Continental Slope Demersal Fish Communities	North-west

Name	Status	Type of Presence
		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 simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation 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 chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat likely 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
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

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, 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 distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for 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 reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-21.48306 114.55722

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 the Environment
GPO Box 787
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.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 01/08/19 12:57:10

This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 1.0Km

Summary

Matters of National Environmental 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:	2
National Heritage Places:	3
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	2
Listed Threatened Species:	60
Listed Migratory Species:	85

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 http://www.environment.gov.au/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 Land:	4
Commonwealth Heritage Places:	3
Listed Marine Species:	164
Whales and Other Cetaceans:	39
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	19

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	20
Regional Forest Agreements:	None
Invasive Species:	20
Nationally Important Wetlands:	3
Key Ecological Features (Marine)	13

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Status
Shark Bay, Western Australia	WA	Declared property
The Ningaloo Coast	WA	Declared property

National Heritage Properties [Resource Information]

Name	State	Status
Natural		
Shark Bay, Western Australia	WA	Listed place
The Ningaloo Coast	WA	Listed place
Historic		
HMAS Sydney II and HSK Kormoran Shipwreck Sites	EXT	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 the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea
Extended Continental Shelf

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west
South-west

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, 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.

Name	Status	Type of Presence
Banksia Woodlands of the Swan Coastal Plain ecological community	Endangered	Community may occur within area
Tuart (Eucalyptus gomphocephala) Woodlands and Forests of the Swan Coastal Plain ecological community	Critically Endangered	Community may occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Botaurus poiciloptilus Australasian Bittern [1001]	Endangered	Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area

Name	Status	Type of Presence
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	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
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	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
Pachyptila turtur subantarctica Fairy Prion (southern) [64445]	Vulnerable	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
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area

Name	Status	Type of Presence
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known 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	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta cauta Shy Albatross, Tasmanian Shy Albatross [82345]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche cauta steadi White-capped Albatross [82344]	Vulnerable	Foraging, feeding or related behaviour likely to 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
Fish		
Milyeringa veritas 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
Insects		
Hesperocolletes douglasi Douglas' Broad-headed Bee, Rottnest Bee [66734]	Critically Endangered	Species or species habitat may occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Foraging, feeding or related behaviour 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 likely to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Breeding known to occur within area
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

Name	Status	Type of Presence
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Vulnerable	Breeding known 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
Setonix brachyurus Quokka [229]	Vulnerable	Species or species habitat known to occur within area
Other		
Kumonga exleyi Cape Range Remipede [86875]	Vulnerable	Species or species habitat likely to occur within area
Plants		
Diuris micrantha Dwarf Bee-orchid [55082]	Vulnerable	Species or species habitat may occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	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
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
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
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

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
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]		Foraging, feeding or related behaviour 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
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour 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
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur

Name	Threatened	Type of Presence
		within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta Tasmanian Shy Albatross [89224]	Vulnerable*	Foraging, feeding or related behaviour likely to 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*	Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	Breeding known to 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	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Foraging, feeding or related behaviour 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

Name	Threatened	Type of Presence
		to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding 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
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat known to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Foraging, feeding or related behaviour known to occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known 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 chinensis Indo-Pacific Humpback Dolphin [50]		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 known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species

Name	Threatened	Type of Presence
		habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	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 known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area

Name	Threatened	Type of Presence
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [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.

Name
Commonwealth Land -
Defence - EXMOUTH ADMIN & HF TRANSMITTING
Defence - EXMOUTH VLF TRANSMITTER STATION
Defence - LEARMONTH - AIR WEAPONS RANGE

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
Historic		
HMAS Sydney II and HSK Kormoran Shipwreck Sites	EXT	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
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
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur

Name	Threatened	Type of Presence
		within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Breeding known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	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 known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Catharacta skua Great Skua [59472]		Species or species habitat may occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour 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
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area
Heteroscelus brevipes Grey-tailed Tattler [59311]		Roosting known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Larus novaehollandiae Silver Gull [810]		Breeding known to occur within area
Larus pacificus Pacific Gull [811]		Breeding known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pachyptila turtur Fairy Prion [1066]		Species or species habitat 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
Pelagodroma marina White-faced Storm-Petrel [1016]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Phalacrocorax fuscescens Black-faced Cormorant [59660]		Breeding likely to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Pterodroma macroptera Great-winged Petrel [1035]		Foraging, feeding or related behaviour known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Puffinus assimilis Little Shearwater [59363]		Breeding known to occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Foraging, feeding or related behaviour likely to occur within area
Puffinus huttoni Hutton's Shearwater [1025]		Foraging, feeding or related behaviour known to occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding known to occur within area

Name	Threatened	Type of Presence
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area
Sterna anaethetus Bridled Tern [814]		Breeding known to occur within area
Sterna bengalensis Lesser Crested Tern [815]		Breeding known to occur within area
Sterna bergii Crested Tern [816]		Breeding known to occur within area
Sterna caspia Caspian Tern [59467]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sterna fuscata Sooty Tern [794]		Breeding known to occur within area
Sterna nereis Fairy Tern [796]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta Tasmanian Shy Albatross [89224]	Vulnerable*	Foraging, feeding or related behaviour likely to 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*	Foraging, feeding or related behaviour likely to occur within area
Thinornis rubricollis Hooded Plover [59510]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area
Fish		
Acentronura australe Southern Pygmy Pipehorse [66185]		Species or species habitat may occur within area
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish		Species or species

Name	Threatened	Type of Presence
[66189]		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 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
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

Name	Threatened	Type of Presence
		area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Heraldia nocturna Upside-down Pipefish, Eastern Upside-down Pipefish, Eastern Upside-down Pipefish [66227]		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 breviceps Short-head Seahorse, Short-snouted Seahorse [66235]		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 subelongatus West Australian Seahorse [66722]		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
Histiogamphelus cristatus Rhino Pipefish, Macleay's Crested Pipefish, Ring-back Pipefish [66243]		Species or species habitat may occur within area
Lissocampus caudalis Australian Smooth Pipefish, Smooth Pipefish [66249]		Species or species habitat may occur within area
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Lissocampus runa Javelin Pipefish [66251]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Mitotichthys meraculus Western Crested Pipefish [66259]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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
Phycodurus eques Leafy Seadragon [66267]		Species or species habitat may occur within area
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area
Pugnaso curtirostris Pugnose Pipefish, Pug-nosed Pipefish [66269]		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
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		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
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Vanacampus phillipi Port Phillip Pipefish [66284]		Species or species habitat may occur within area
Vanacampus poecilolaemus Longsnout Pipefish, Australian Long-snout Pipefish, Long-snouted Pipefish [66285]		Species or species habitat may occur within area
Mammals		
Arctocephalus forsteri Long-nosed Fur-seal, New Zealand Fur-seal [20]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Dugong dugon Dugong [28]		Breeding known to occur within area
Neophoca cinerea Australian Sea-lion, Australian Sea Lion [22]	Vulnerable	Breeding known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus pooleorum Shark Bay Seasnake [66061]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		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
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
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	Foraging, feeding or related behaviour known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour may occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Breeding known 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
Globicephala melas Long-finned Pilot Whale [59282]		Species or species habitat may occur within area

Name	Status	Type of Presence
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Hyperoodon planifrons Southern Bottlenose Whale [71]		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 simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Lissodelphis peronii Southern Right Whale Dolphin [44]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Mesoplodon bowdoini Andrew's Beaked Whale [73]		Species or species habitat may 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
Mesoplodon grayi Gray's Beaked Whale, Scamperdown Whale [75]		Species or species habitat may occur within area
Mesoplodon layardii Strap-toothed Beaked Whale, Strap-toothed Whale, Layard's Beaked Whale [25556]		Species or species habitat may occur within area
Mesoplodon mirus True's Beaked Whale [54]		Species or species habitat may 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]		Foraging, feeding or related behaviour known to occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		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
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]

Name	Label
Abrolhos	Habitat Protection Zone (IUCN IV)
Abrolhos	Multiple Use Zone (IUCN VI)
Abrolhos	National Park Zone (IUCN II)
Abrolhos	Special Purpose Zone (IUCN VI)
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	National Park Zone (IUCN II)
Carnarvon Canyon	Habitat Protection Zone (IUCN IV)
Gascoyne	Habitat Protection Zone (IUCN IV)
Gascoyne	Multiple Use Zone (IUCN VI)
Gascoyne	National Park Zone (IUCN II)
Jurien	National Park Zone (IUCN II)
Jurien	Special Purpose Zone (IUCN VI)
Montebello	Multiple Use Zone (IUCN VI)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)
Perth Canyon	Habitat Protection Zone (IUCN IV)
Perth Canyon	Multiple Use Zone (IUCN VI)
Perth Canyon	National Park Zone (IUCN II)
Shark Bay	Multiple Use Zone (IUCN VI)

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Airlie Island	WA
Barrow Island	WA
Bessieres Island	WA
Boodie, Double Middle Islands	WA
Bundegi Coastal Park	WA
Cape Range	WA
Jurabi Coastal Park	WA
Locker Island	WA
Lowendal Islands	WA
Montebello Islands	WA
Muiron Islands	WA
Rocky Island	WA
Round Island	WA
Serrurier Island	WA
Unnamed WA37500	WA
Unnamed WA40322	WA
Unnamed WA41080	WA
Unnamed WA44665	WA
Victor Island	WA
Y Island	WA

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Pavo cristatus Indian Peafowl, Peacock [919]		Species or species habitat likely to occur within area
Phasianus colchicus Common Pheasant [920]		Species or species habitat likely to occur within area
Streptopelia senegalensis Laughing Turtle-dove, Laughing Dove [781]		Species or species habitat likely to occur within area
Mammals		
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Capra hircus Goat [2]		Species or species habitat likely to occur within area
Equus asinus Donkey, Ass [4]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Lycium ferocissimum African Boxthorn, Boxthorn [19235]		Species or species habitat likely to occur within area
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Prosopis spp. Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species habitat likely to occur within area
Ramphotyphlops braminus Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat may occur within area

Nationally Important Wetlands

[Resource Information]

Name	State
Cape Range Subterranean Waterways	WA
Exmouth Gulf East	WA
Rottnest Island Lakes	WA

Key Ecological Features (Marine)

[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	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
Wallaby Saddle	North-west
Ancient coastline at 90-120m depth	South-west
Commonwealth marine environment surrounding	South-west
Commonwealth marine environment within and	South-west
Perth Canyon and adjacent shelf break, and other	South-west
Western demersal slope and associated fish	South-west
Western rock lobster	South-west

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 the Environment
GPO Box 787
Canberra ACT 2601 Australia
+61 2 6274 1111

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, 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 distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for 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 reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-21.24 115.355,-21.663 114.949,-21.836 114.654,-22.094 114.249,-21.967 114.131,-21.869 114.156,-21.812 114.19,-21.781 114.162,-21.818 114.07,-21.875 113.997,-22.003 113.924,-22.354 113.794,-22.385 113.765,-22.417 113.747,-22.496 113.72,-22.544 113.689,-22.551 113.66,-22.585 113.657,-22.594 113.67,-22.685 113.678,-22.702 113.67,-22.723 113.674,-22.717 113.696,-22.73 113.726,-22.768 113.759,-22.812 113.779,-22.894 113.804,-22.988 113.828,-23.05 113.826,-23.092 113.81,-23.115 113.781,-23.171 113.744,-23.391 113.749,-23.526 113.685,-23.712 113.556,-23.887 113.481,-24.462 113.207,-25.041 112.978,-25.548 112.852,-26.007 112.972,-26.737 113.089,-28.298 113.47,-28.681 113.85,-29.385 114.32,-30.697 115.035,-31.14 114.715,-31.443 114.212,-31.879 114.346,-31.889 115.634,-32.013 115.686,-31.97 113.513,-31.343 113.839,-31.271 114.413,-30.601 114.442,-30.208 113.8,-29.873 113.274,-29.734 112.326,-28.595 111.703,-28.94 111.086,-28.901 110.344,-29.529 110.133,-30.381 109.635,-30.046 109.243,-28.806 108.979,-28.289 109.999,-27.91 110.377,-27.652 110.344,-27.762 109.755,-27.25 109.195,-26.747 109.238,-26.383 109.726,-26.287 109.989,-25.507 109.841,-25.215 109.281,-24.741 109.161,-24.535 108.199,-24.171 107.672,-23.492 107.122,-23.314 107.897,-24.028 108.448,-23.458 108.606,-22.276 108.457,-22.319 107.806,-22.247 107.701,-21.62 107.318,-20.538 107.088,-20.418 107.399,-19.326 107.356,-18.225 107.586,-17.651 106.791,-16.99 107.055,-16.655 107.735,-16.516 108.118,-16.722 109.492,-17.761 110.004,-17.163 111.296,-16.684 111.952,-15.774 112.512,-15.272 112.311,-15.291 114.834,-15.865 115.749,-13.658 116.773,-16.071 116.721,-15.066 117.961,-17.622 117.554,-18.149 116.692,-18.68 117.552,-18.788 118.467,-19.073 118.237,-19.439 117.584,-19.665 116.972,-19.887 117.3,-19.992 116.466,-20.37 115.518,-20.46 115.493,-20.614 115.572,-21.24 115.355

Appendix B: Corowa Development – Facility and Flare Light Assessment

Corowa Development

Facility and Flare Light Assessment

KATO Energy

Assignment Number: P100092-S00
Document Number: P-100092-S00-TECH-001

Xodus Group
Level 5, 1 William Street
Perth, Australia, WA 6000

T +61 (8) 6555 5600
E info@xodusgroup.com
www.xodusgroup.com

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Project Overview

The Corowa Development will be centred on the Corowa oil field, located within petroleum permit WA-41-R in the Carnarvon Basin, approximately 60 km offshore from Onslow in Western Australia. The field is in Commonwealth waters in approximately 85–90 m water depth.

KATO Energy Pty Ltd (KATO) plan to develop the Corowa field using a re-locatable ‘honeybee production system’ which includes the following key facilities and support:

- mobile offshore production unit (MOPU)
- mobile offshore drilling unit/s (MODU)
- floating storage and offloading (FSO)
- support vessels.

1.2 Objective

The purpose of this Technical Note is present the outcomes of the assessment undertaken to estimate the artificial light emissions from the Corowa Development.

1.3 Scope

The operations of vessels and facilities associated with the Corowa Development will generate artificial light emissions. The source of these emissions includes

- external facility lighting on vessels and facilities for safe navigation and working conditions
- continuous flaring of excess gas will be required to allow for hydrocarbon production and processing during the operations phase.

Both sources of light emissions are quantified and discussed in this Technical Note.

The assessment included two types of quantification based on the expected light emissions from the MOPU and MODU:

- light intensity modelling using published modelled and measured data as analogues
- line of sight estimates.

Light intensity modelling has been used as an indication of the measurable change in ambient light conditions, while line of sight estimates have been used as an indication of the distance that light may be visible.

Artificial light emissions from other facilities (e.g. FSO) or vessels associated with the Corowa Development were not been included in the assessment due to their smaller scale and/or temporary and transient nature. The MOPU and MODU are the tallest and most lit structures on the Corowa Development and therefore the light will be visible and measurable for the greatest distance and have therefore been used for the purposes of worst-case assessment.

2 LIGHT

Light can be described in terms of luminous flux, luminous intensity and illuminance:

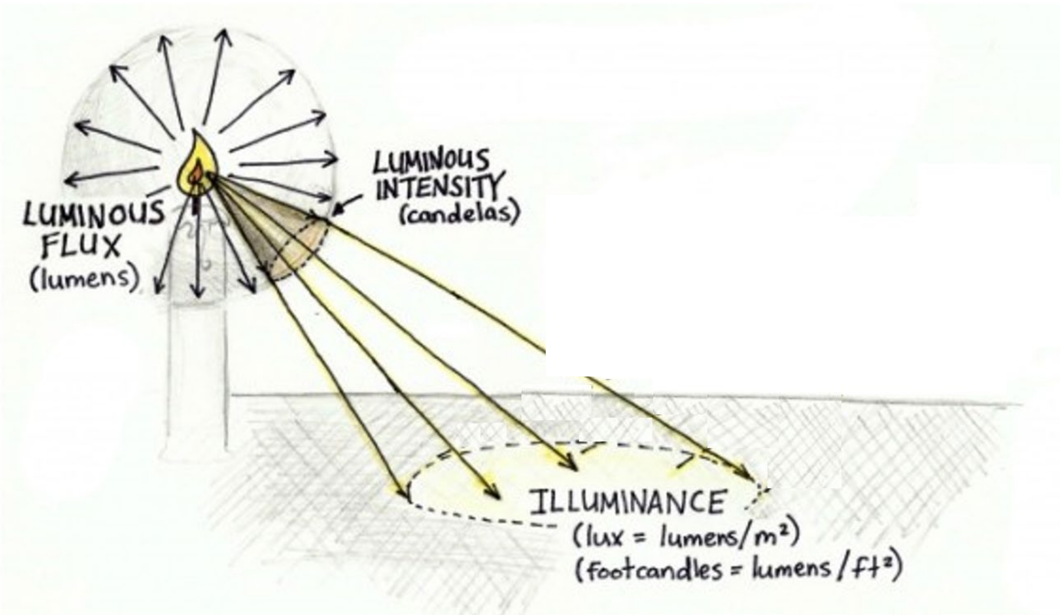
> luminous flux is a measure of the amount of light from a source emitted in total regardless of direction (unit of measurement: lumens)

> luminous intensity is the amount of light emitted in a particular direction; the direction is typically stated in steradians (unit of measurement: candelas)

> illuminance is the amount of light reaching an area (unit of measurement: lux; where 1 lux is equivalent to 1 lumen/m^2).

These terms are graphically depicted in Figure 2.1.

Illuminance (also referred to as light intensity) is the term of interest for environmental impact assessment for the KATO Corowa Development.



(Source: adapted from Sigma Safety Corp 2016)

Figure 2.1 Light terminology

Typical light illuminance values from natural light sources are described in Table 2-1 and these are considered representative of ambient light levels in the vicinity of the Corowa Development and wider North West Shelf, Western Australia region.

The minimum threshold used to describe a change in ambient light conditions within this light assessment is an illuminance equivalent to a moonless clear night sky (0.001 lux), beyond this threshold no impact to light sensitive fauna is assumed.

Table 2-1 Summary of natural light illuminance

Natural Light Source	Light Illuminance (lux)
Direct sunlight	100,00–130,000
Full daylight, indirect sunlight	10,000–20,000
Overcast day	1,000
Very dark day	100
Twilight	10
Deep twilight	1
Full moon	0.1
Quarter moon	0.01
Moonless clear night sky[1]	0.001
Moonless overcast night sky	0.0001

(Source: ERM 2010)

[1] Impact threshold utilised in this report is 0.001 lux, beyond this threshold no impact to light sensitive fauna is assumed.

3 LIGHT INTENSITY MODELLING

The two sources of artificial lighting (facility and flaring) for the Corowa Development were assessed separately, using published modelled and measured data as analogues.

3.1 Facility Lighting

It is expected that the MOPU and MODU for the Corowa Development will have a similar lit surface area as the Woodside-operated Torosa platform and drill rig in the North-West Shelf, with similar lighting required for safe operations of the facilities. Therefore, it is expected that the MOPU and MODU facility light emissions would also be comparable to that of the Torosa facilities used during a previous light intensity modelling completed by ERM (2010). The ERM (2010) modelling assessment predicted the following:

- light intensity levels greater than 0.1 Lux up to 800 m from the rig, comparable to ambient light levels during full moon to twilight
- between 800 m and 1.2 km from the drill rig, the model predicted light intensity levels comparable to ambient light levels during a quarter moon to full moon night sky (0.01 Lux to 0.1 Lux)
- between 1.2 km and 12.6 km, light intensity levels were predicted to be between 0.01 Lux and 0.001 Lux, which is comparable to ambient light intensity levels between a moonless clear night sky and a quarter moon
- beyond 12.6 km there was no measurable change to the ambient light intensity levels (less than 0.001 Lux) and therefore no impact to light sensitive fauna.

These light intensity values for facility lighting have been adopted for the Corowa Development and are shown in Figure 3.6.

3.2 Flare Lighting

The proposed Corowa Development will require a gas flare to dispose of the associated gas generated from the oil production system during operations. The flare disposal system includes a cantilevered flare boom set at an angle between 45° to 60° to the horizontal; with expected flare tip height approximately 80 m above sea level.

Flaring will be continuous during operation of the facility and is expected to peak at 15–17 MMscfd (P50–P10 estimates of reservoir outcomes respectively) during the initial 7–12 months (P50–P10) of operation, and then decline as the reservoir depletes to end of field life (Figure 3.1). P10 has been used to identify the flaring durations, as the most conservative measure.

To inform the environmental impact assessment for Corowa Development environmental approvals, light intensity from two flare flow rates were modelled, representing peak and post-peak flaring:

- 17 MMscfd representing peak flaring from start-up of the facility to month 10–17 of operations
- 5 MMscfd representing post peak flaring after month 10–17 (P50–P10 reservoir outcomes).

Using the Gas Processors Suppliers Association Engineering Data Book (1998), it has been calculated that this expected peak rate of flaring during operations will result in a flare flame height of approximately 20–25 m above the MOPU flare tower tip in calm conditions.

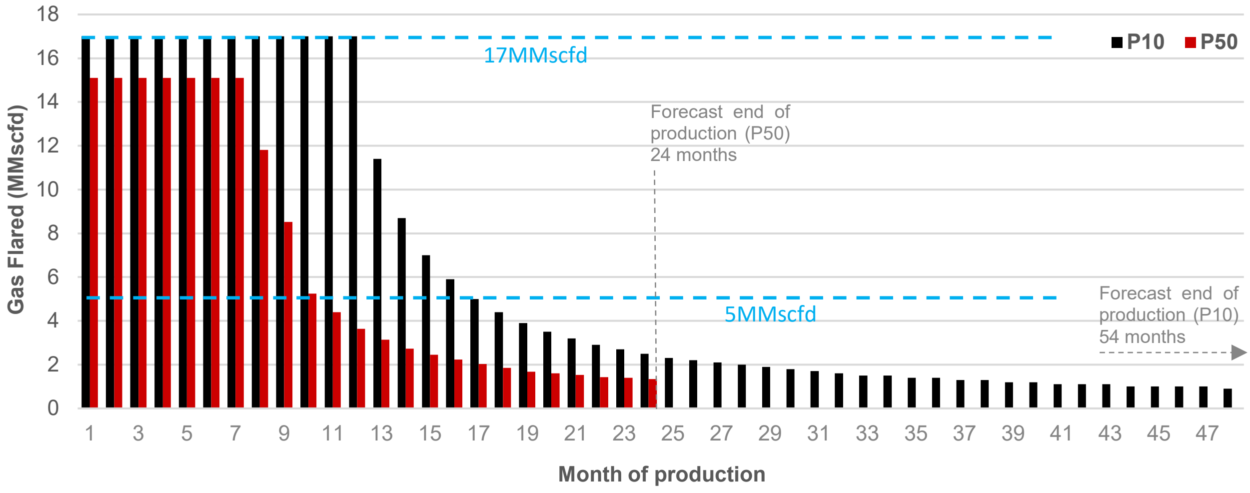


Figure 3.1 **Corowa expected gas flaring profiles (P10 & P50) and the two modelled flaring rates**

3.2.1 Method

3.2.1.1 Inverse Law

The light modelling used the inverse square law of illuminance which states that *a doubling of distance results in a reduction in illuminance by four times*, i.e. as a surface that is illuminated by a light source moves away from the light source, the surface appears dimmer. Light emitted becomes dimmer in an inverse square relationship to distance as represented in Figure 3.2 and in the mathematical equation below:

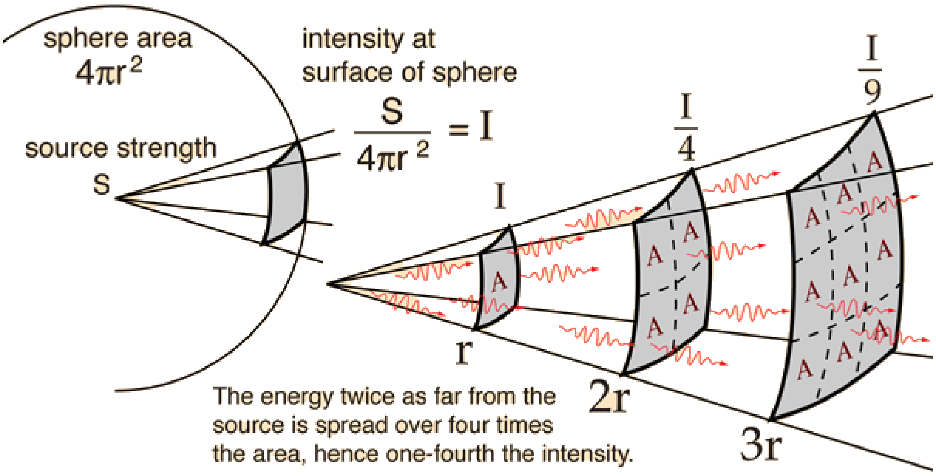
$$E = \frac{I}{D^2}$$

Where:

> E = illuminance (in lux

> I = intensity in candela

> D = the distance from the light source in meters.



(Source: Georgia State University, 2016)

Figure 3.2 Inverse square law

Therefore, it is possible to calculate luminance intensity if the illuminance and the distance from the source is known (and vice versa).

3.2.1.2 Analogues

As flares are not designed to be luminaries (light emitting devices) there is some uncertainty in calculating luminance intensity from a flare. As the Corowa Development is currently in pre-FID, no actual measurements of flare intensity are possible, therefore the flare light intensity modelling undertaken during this assessment incorporates data from analogues within publicly available literature on light emissions from flares.

The following analogues for gas flares were identified and are detailed in Table 3-1:

> Galoc Oil FPSO – Philippines
> Obigbo Oil Production facility – Nigeria
> Narrabri Gas Project safety flare – New South Wales
> Wheatstone LNG facility flare – Western Australia.

Table 3-1 Details of potential analogue natural gas flares

Analogue Site	Facility Type	Flare Rate	Luminance Intensity	Illuminance Method	Reference
Galoc FPSO – Philippines	Tamarind operated FPSO oil facility continuous gas flare	~15 MMscfd 18–20 m high flame	Not specified	N/A (Flame height provided only)	Tamarind 2019
Wheatstone LNG Plant – Onslow, WA	Chevron-operated onshore LNG facility: Safety flare	Not specified	Not specified	Modelled Illuminance (lux)	URS 2010
Narrabri Gas Project – Bibblewindi, NSW	Proposed Santos-operated onshore gas production facility: Safety flare	244 MMscfd 30 m high flame	Not specified	Modelled Illuminance (lux) based on measured and calculated source data	Imbricata 2018

Analogue Site	Facility Type	Flare Rate	Luminance Intensity	Illuminance Method	Reference
Obigbo North – Nigeria	Shell-operated oil production facility: Continuous flaring of associated gas	30 MMscfd	~1,805,000 candelas	Measured Illuminance (lux)	Isichei et al 1976 Nwaob 2005 European Commission 2014

The four analogues were compared to the expected flare characteristics (rates, flame heights) for the Corowa Development to determine if they were appropriate for use in this light emissions assessment.

The Galoc FPSO has a continuous flare that is of similar service and flare rate to the peak 15–17 MMscfd (P50–P10) rate expected for the Corowa Development. However, the Galoc FPSO has not had light intensity levels or illuminance levels measured or modelled, and is therefore not considered further within this light intensity assessment (it has been used for an analogue of flame height within the line of sight assessment (Section 4).

The Wheatstone LNG flare has modelled illuminance information, but no details on flare rate or height are publicly available. As an unknown, the Wheatstone LNG flare was carried through to the next stage of assessment as a potential analogue.

Despite the similar flame height (30 m for Narrabri compared to the 20–25 m from Corowa Development), the Narrabri gas flare rate is >200 MMscfd, which is an order of magnitude higher than that for the Corowa Development and as such was not considered an appropriate analogue and is not discussed further in this assessment.

The Obigbo facility has a continuous flare that is of similar service and has a flare rate in same order of magnitude to the peak rate expected for the Corowa Development. For these reasons the Obigbo oil production facility was considered an appropriate analogue for the Corowa Development

A detailed study describing lux levels at varying distances from the operational flare was also available for the Obigbo oil production facility (Isichei et al. 1976). The detail provided in that study, as well as Nwaob (2005) and European Commission (2014) allows for the characteristics of the Obigbo flare to be scaled and allow for characterisation of other flares. This data provides the basis for the following flare light intensity modelling.

3.2.1.3 Model

The light model was built in Microsoft Excel utilising the inverse law of illumination (Section 3.2.1.1). The following assumptions were made.

> Obigbo North flare characteristics as stated in Table 3-1.

> Combustion characteristics of the Corowa flare are similar to Obigbo (both open pipe flares).

> No allowance was made for atmospheric or topographic interactions including shadowing, absorption or scattering as such the model is conservative and likely to overestimate illuminance at distance.

> Luminance intensity is calculated directly proportional to flare flow rate.

> Fuel gas usage of ~0.5 -1 MMscfd assumed for Corowa post peak flaring scenario.

Illuminance was calculated every 100m from the flare source in Lux, and results overlaid in GIS to identify geospatial Lux contours.

A verification exercise of the Xodus Group light decay model (Xodus model) was conducted using the light decay model developed by Jacobs–SKM for the Browse FLNG Draft Environmental Impact Statement (Jacobs–SKM 2014). The verification exercise for the Xodus model plotted the Xodus Group light model expected illuminance for the Browse Development against the Jacobs–SKM modelled illuminance for the Browse Development. The Xodus model predicted illumination levels aligned with the Jacobs - SKM model verifying the Xodus model outcomes.

3.2.2 Results

The results of the light intensity modelling are summarised in Table 3-2 for all scenarios and also shown graphically for the Corowa Development in Figure 3.3 and Figure 3.4.

Table 3-2 Detailed comparison of potential analogue natural gas flares

Site/Scenario	Flare Luminance Intensity (candela)	Light Illuminance (Lux)						
		Distance from Facility (km)						
		0.5 km	1 km	5 km	8 km	10 km	20 km	30 km
Base Case								
Obigbo North – Nigeria	~1,805,000	7.2	1.8	0.072	0.028	0.018	0.004	0.002
Modelled Cases								
Corowa Development Peak flaring (17 MMscfd)	1,022,823	4.1	1.00	0.040	0.016	0.010	0.0026	0.001
Corowa Development: Post-peak flaring (5 MMscfd)	300,833	1.0	0.24	0.010	0.004	0.002	0.000	0.000
Wheatstone LNG	~2,160,000	8.6	2.5	0.09	0.04	0.030	0.007	0.001

The modelled luminance intensity level for the Wheatstone LNG flare is over twice that modelled for the peak Corowa Development flare; as such the Wheatstone LNG facility is not discussed further in this assessment as an analogue for flaring light intensity.

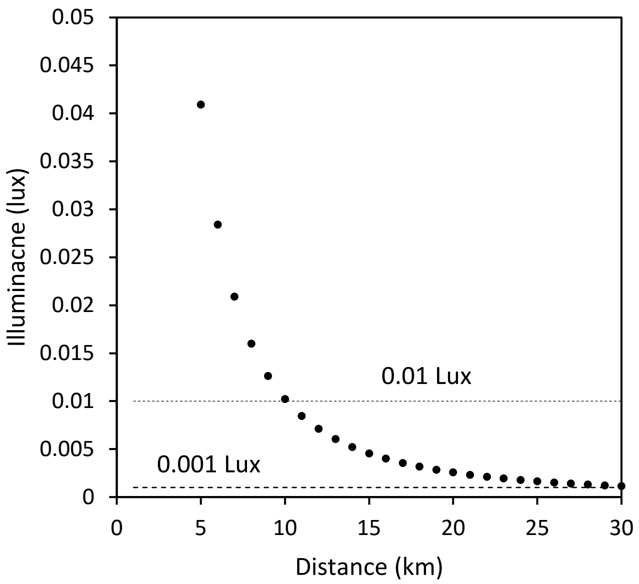


Figure 3.3 Flare illuminance peak flaring (17 MMscfd)

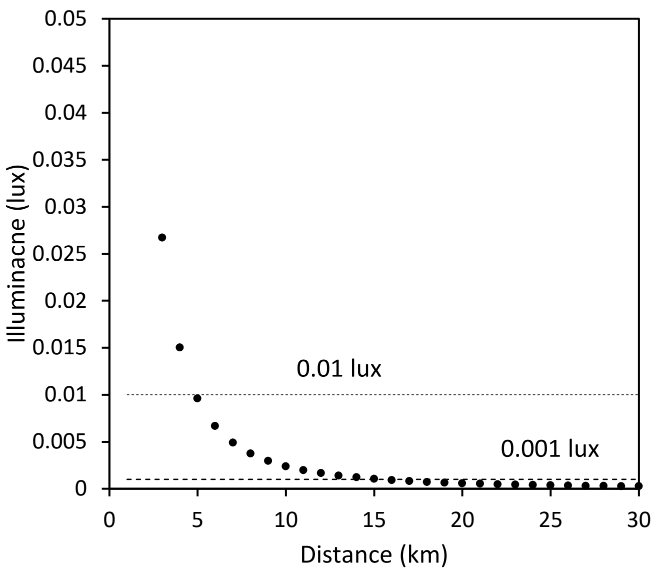


Figure 3.4 Flare illuminance post-peak flaring (5 MMscfd)

For the Corowa Development, the model predicted the following for peak flaring rate of 17 MMscfd during operations (Figure 3.6):

- Light intensity levels greater than 0.1 Lux up to 3.2 m from the MOPU, comparable to ambient light levels during full moon to twilight
- Between 3.2 km and 10 km from the MOPU, the model predicted light intensity levels comparable to ambient light levels during a quarter moon to full moon night sky (0.01 Lux to 0.1 Lux)
- Between 10 km and 30 km, light intensity levels were predicted to be between 0.01 Lux and 0.001 Lux, which is comparable to ambient light intensity levels between a moonless clear night sky and a quarter moon
- Beyond 30 km there was no measurable change to the ambient light intensity levels.

The model predicted the following for Corowa Development for post-peak flaring (5 MMscfd) during operations:

- Light intensity levels greater than 0.1 Lux up to 1.5 km from the MOPU, comparable to ambient light levels during full moon to twilight
- Between 1.5 km and 4.9 km from the MOPU, the model predicted light intensity levels comparable to ambient light levels during a quarter moon to full moon night sky (0.01 Lux to 0.1 Lux)
- Between 4.9 km and 12.7 km, light intensity levels were predicted to between 0.01 Lux and 0.001 Lux, which is comparable to ambient light intensity levels between a moonless clear night sky and a quarter moon
- Beyond 12.7 km there was no measurable change to the ambient light intensity levels.

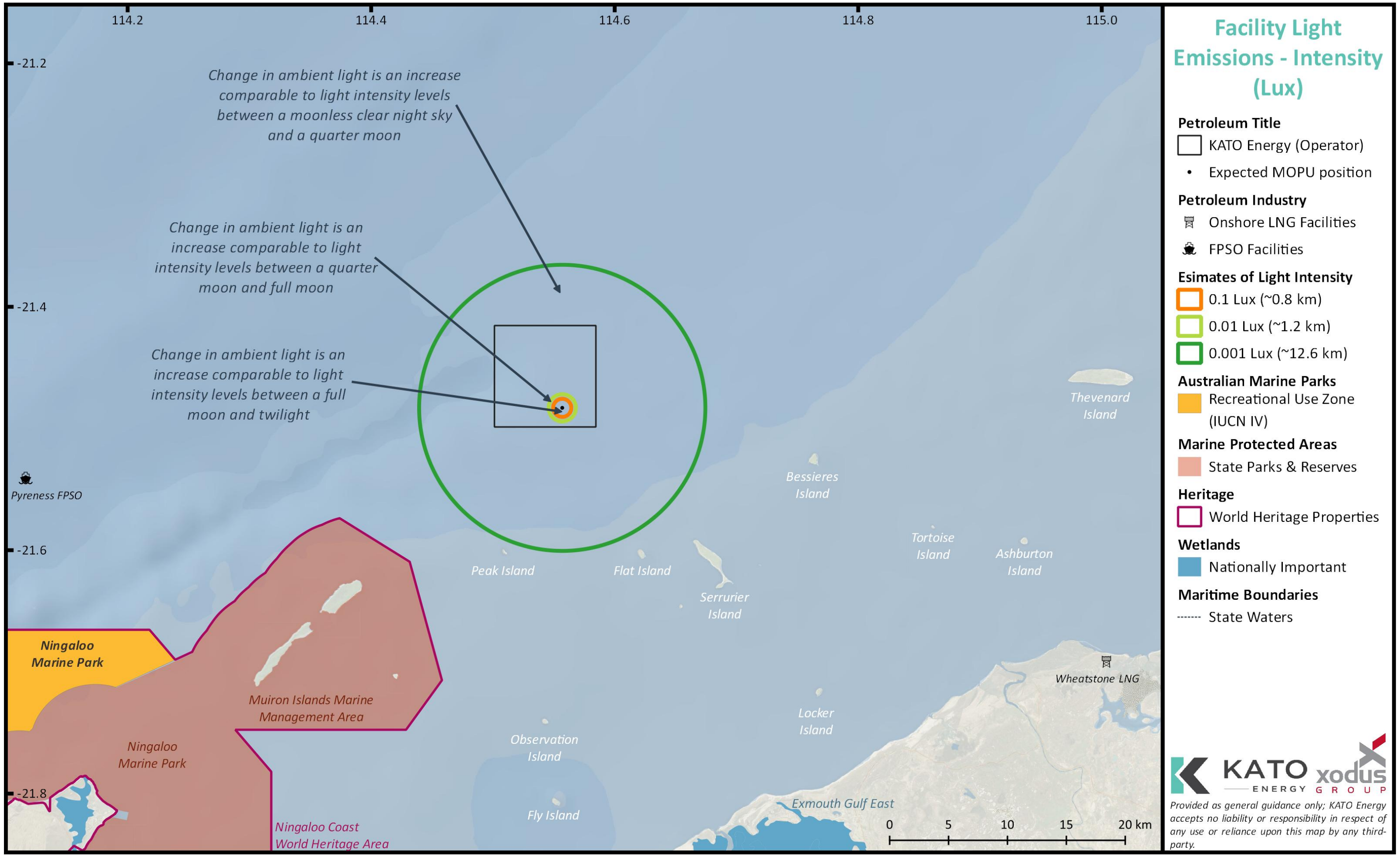


Figure 3.5 Expected light intensity levels from the facility lighting of the MOPU and MODU

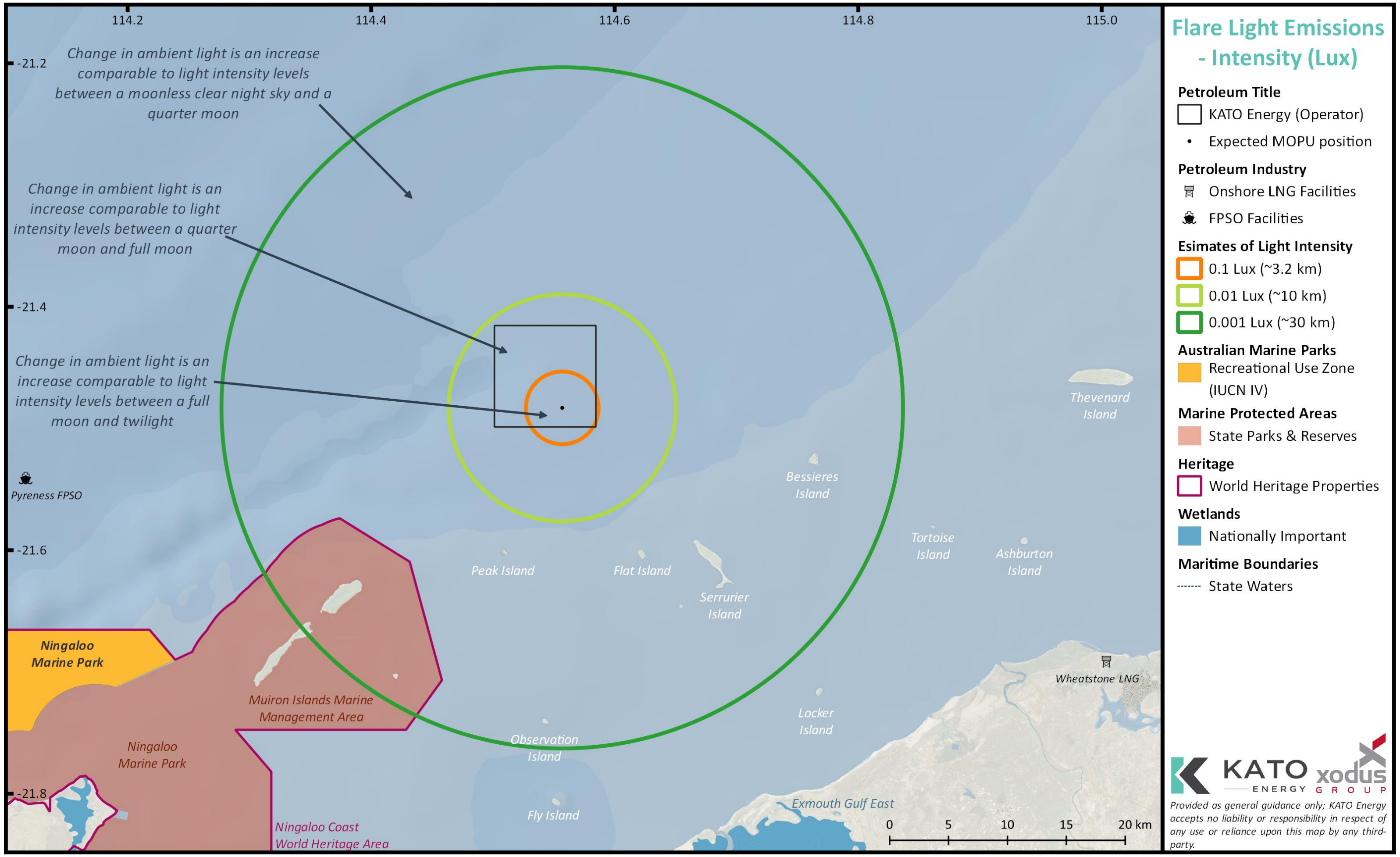


Figure 3.6 Expected light intensity levels from flare lighting on the MOPU during peak flaring (17 MMscfd)

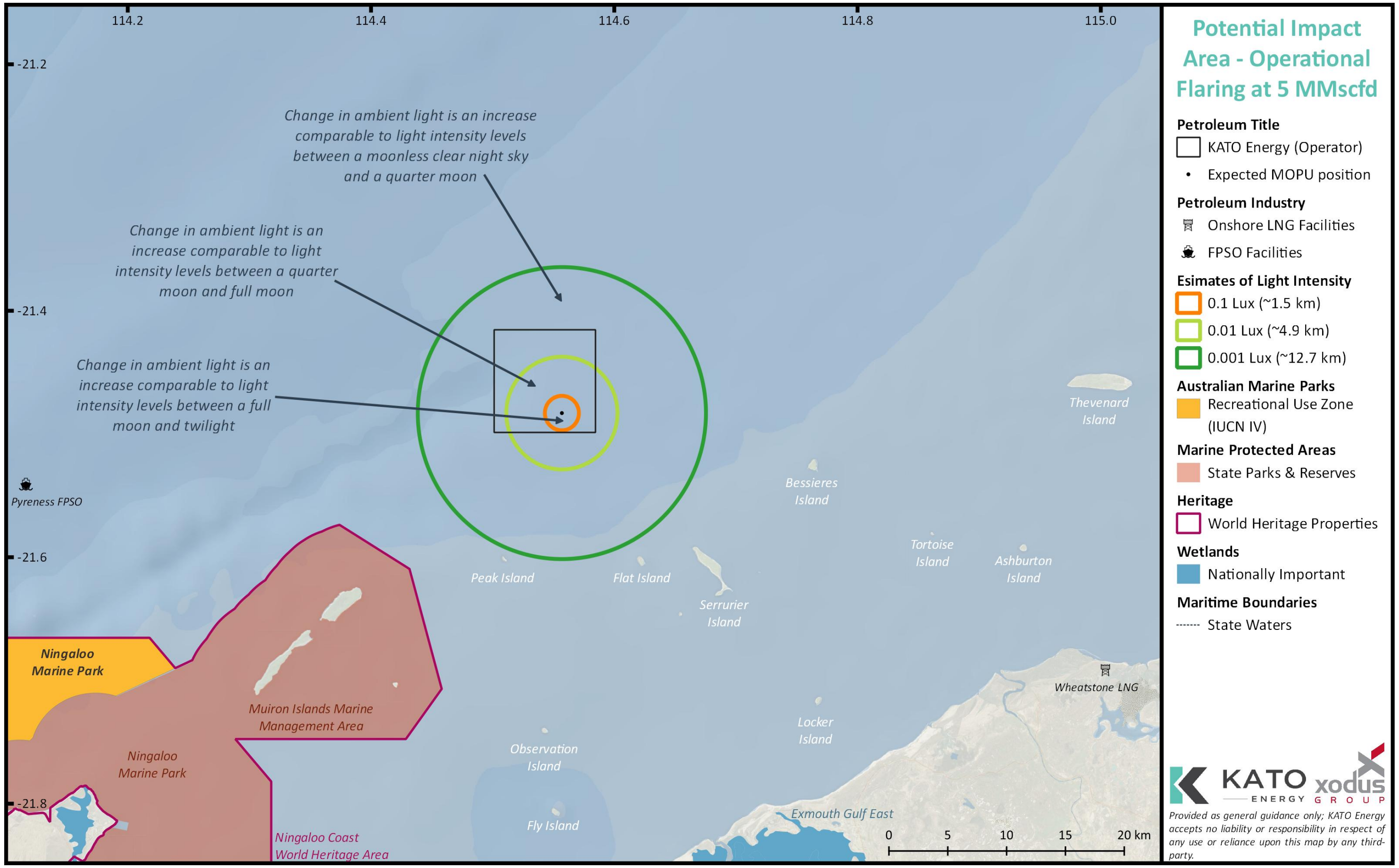


Figure 3.7 Expected light intensity levels from flare lighting on the MOPU post peak flaring (5 MMscfd)

4 LINE OF SIGHT ASSESSMENT

4.1 Method

A line of sight analysis was conducted using the methodology described in Young (2003) for the MOPU and MODU to determine the potential extent of visible light. Line of sight and viewshed analysis is typically used in environmental impact assessment for the assessment of impact to visual amenity where an impact may alter a perceived sense of place or inherent value. The visibility of an artificial light does not necessarily imply a measurable change in ambient light (and therefore a potential environmental impact), this is estimated though change to illuminance as discussed in Section 3.

Line of sight calculations utilised the following method:

$$d_l = (2Rh)^{0.5}$$

Where:

- h = height of object
- R = radius of earth
- dl = total line of sight

The analysis was completed using assumed heights of the MOPU and MODU for the Corowa Development, with final designs being confirmed during FEED (Table 4-1). Note that as the Corowa flare height reduces over time during production as the field is depleted, therefore this maximum height of the flame tip will drop towards 80 m, the height of the flare tower tip.

Table 4-1 Corowa Development Facility Infrastructure Heights

Corowa Facility infrastructure	Height of Facility / Lighting / Flare
Main deck lights	32 m
Process module lights	50 m
Lighting on the flare tower/drill rig	80 m
Derrick (navigation lights)	99 m
5 m high flame from the flare tower	85 m
25 m high flame from the flare (maximum)	105 m

4.2 Results

The Corowa Development line of sight assessment showed that the maximum distances light may be visible extends up to approximately 36.5 km for a 25 m high flame from the flare (Table 4-2). Note that as the flare height reduces over time as the field is depleted, this maximum distance of 36.5 km will drop towards 31.9 km, that is associated with the height of the flare tower tip.

The line of sight assessment indicates that the Corowa Development will likely be visible as a small object or light on the horizon from some of the neighbouring offshore islands, including the Muiron Islands and Serrurier Island (Figure 5.1). This is not dissimilar to the manner that the FPSO facilities off Exmouth are visible from the North West Cape, Western Australia.

Table 4-2 Corowa Facility Visual Impact Line of Sight Distances

Facility infrastructure	Visible radius – line of sight analysis
Main deck lights	20.2 km
Process module lights	25.2 km
Lighting on the flare tower/drill rig	31.9 km
Derrick (navigation lights)	35.5 km
5 m high flame from the flare tower	32.9 km
25 m high flame from the flare	36.5 km

5 CUMULATIVE IMPACT ASSESSMENT

The offshore Woodside-operated Ngujima-Yin FPSO and onshore Chevron-operated Wheatstone LNG facility are located in the same region as the Corowa Development, and therefore there is the potential for cumulative impacts. While infrastructure heights were provided in the EIA (Chevron 2010) or Environment Plan Summary (Woodside 2018), line of sight analysis were not detailed.

Therefore, line of sight calculations were completed for the two facilities based on details in Table 5-1. Typically, LNG environmental impact assessments assume that non-routine flaring occurs approximately 5% of the time, this is relevant to the impact assessment for the Wheatstone LNG facility.

Table 5-1 Height of Neighbouring Facility Infrastructure

Facility	Height of Facility / Lighting / Flare
Wheatstone LNG (Routine operations)	~130 m
Wheatstone LNG (Non-routine Flaring)	~150 m
Ngujima-Yin FPSO (Routine operations)	~95m

(Source: Chevron 2010, Woodside 2018)

5.1 Cumulative Impact Assessment Results

The Wheatstone LNG flare line of sight assessment showed that the maximum distances light may be visible extends up to approximately 43 km and 40 km for a 25 m high flame (non-routine flaring) and a 5 m high flame (routine flaring) respectively.

The Ngujima-Yin flare line of sight assessment showed that the maximum distances light may be visible extends up to approximately 34.8 km for a 5 m high flame (routine operations).

Table 5-2 summarises the line of sight assessment for the oil and gas facilities neighbouring the Corowa Development.

Figure 5.1 shows the line of sight assessment for the Corowa Development and the neighbouring facilities.

Table 5-2 Visual Impact Line of Sight Distances for Neighbouring Facilities

Facility	Visible radius – line of sight analysis
Wheatstone LNG (Routine operations)	~40.7 km
Wheatstone LNG (Non-routine Flaring)	~43.6 km
Ngujima-Yin FPSO (Routine operations)	~34.8 km

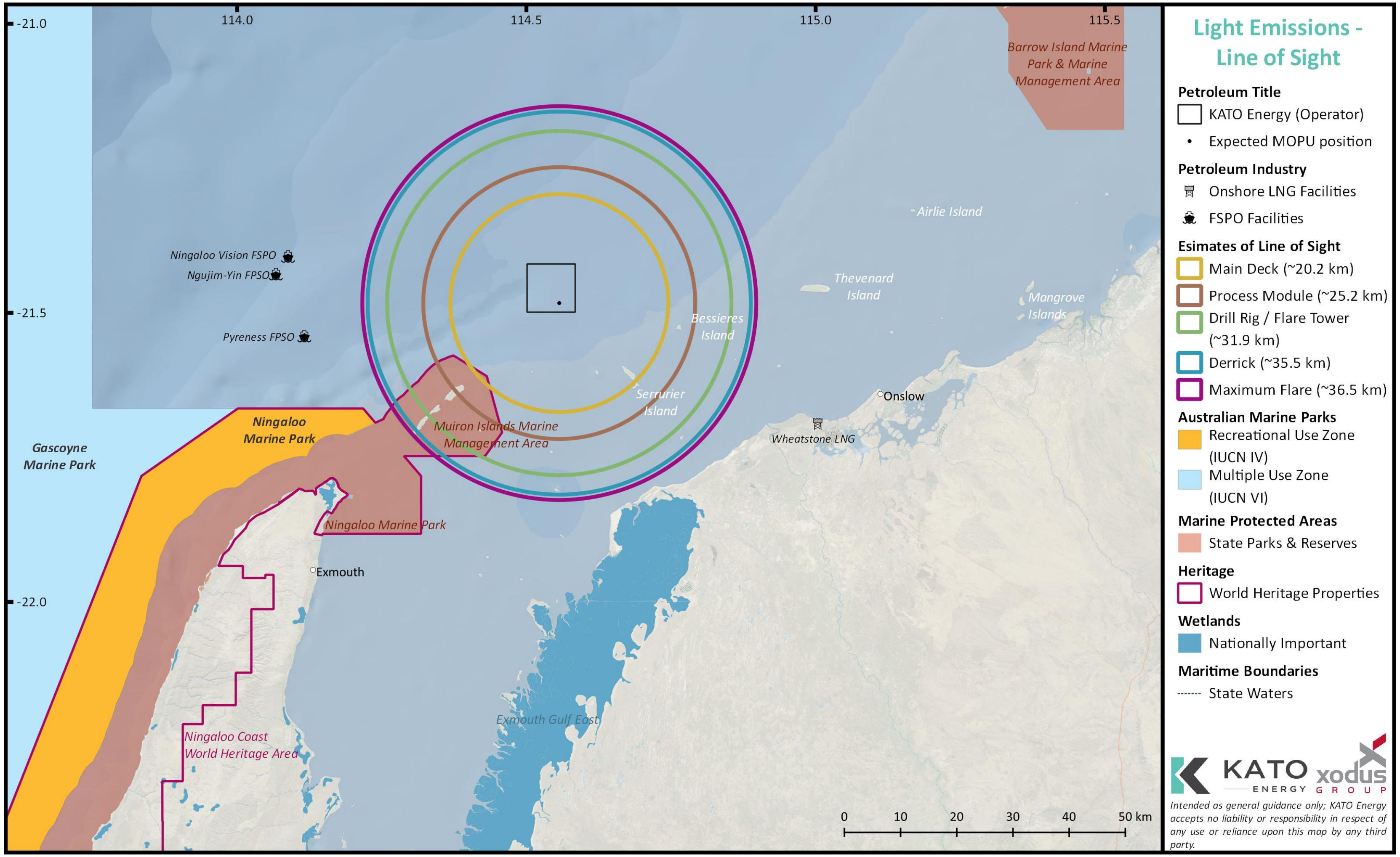


Figure 5.1 Line of Sight Assessment

6 ABBREVIATIONS

Acronym	Description
EIA	environmental impact assessment
FID	final investment decision
FPSO	floating production storage and offtake facility
km	kilometre (unit of measurement for distance)
LNG	liquefied natural gas
m	metre (unit of measurement for distance)
MMscfd	million standard cubic feet per day (unit of measurement for gas)
MODU	mobile offshore drilling unit
MOPU	mobile offshore production unit

7 REFERENCES

Chevron 2010. *Wheatstone Draft Environmental Impact Statement/ Environment Review and Management Programme for the Proposed Wheatstone Project.* Chevron, Perth, Western Australia.

European Commission. 2014. *EU Bulk Assessment Inputs Data Sheet – Communication and Information Resource Centre for Administrations, Businesses and Citizens*. European Commission Communication and Information Resource Centre for Administrations, Businesses and Citizens, Brussels, Belgium

ERM. 2010. *Browse Upstream LNG Development: Light Impact Assessment*. Environmental Resources Management. Perth, Western Australia.

Gas Processors Suppliers Association (1998). *Gas Processors Suppliers Association Engineering Data Book*. GPSA, Tulsa, United States of America.

Georgia State University. 2016. *Hyperphysics*. Department of Physics and Astronomy, Georgia State University, Atalanta, United States of America. Accessed online: http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html

Imbricata Environmental. 2018. *Narrabri Gas Project: Gas Flare Light Assessment*. Imbricatta Pty Ltd, Northbridge, Australia

Isichei, A. & Sanford,7 W. 1976. The Effect of Waste Gas Flares on the Surrounding Vegetation in South-Eastern Nigeria. *Journal of Applied Ecology* 13(1):177.

Nwaobi, G. 2005. *Oil Policy in Nigeria: A Critical Assessment (1958-1992).* Quantitative Economic Research Bureau, Abuja, Nigeria

Jacobs–SKM. 2014. *Light Modelling Study Final Report. Browse FLNG Development Draft Environmental Impact Statement.* Woodside Energy Ltd, Perth Australia.

Sigma Safety Corp. 2016. *Lumens and Lux and Candela*. Sigma Safety Corp. Langley, Canada. Viewed online: https://sigmasafety.ca/2016/07/25/lumens-and-lux-and-candela-oh-my/

Tamarind 2019. Per Comm Brett MacRae 7th October 2019. *Email: Galoc flare flame height estimates*

URS. 2010. *Wheatstone Project Lighting Emissions Study*. URS Australia, Perth, Australia.

Woodside. 2018. *Ngujima-Yin (NY) Facility Operations Environment Plan Summary*. Woodside, Perth Australia. Accessed at https://docs.nopsema.gov.au/A680725

Young A. 2003. *Distance to the Horizon*. San Diego State University Department of Astronomy. San Diego, United States of America. https://aty.sdsu.edu/explain/atmos_refr/horizon.html

Appendix C: Corowa Development – Greenhouse Gas Assessment

>

Corowa Development

Greenhouse Gas Assessment

KATO Energy

Assignment Number: P100092-S00
Document Number: P-100092-S00-REPT-001

Xodus Group
Level 5, 1 William Street
Perth, Australia, WA 6000

T +61 (0)86555 5600
E info@xodusgroup.com
www.xodusgroup.com

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Project Overview

The Corowa Development will be centred on the Corowa oil field, located within petroleum permit WA-41-R in the Carnarvon Basin, approximately 60 km offshore from Onslow in Western Australia. The field is in Commonwealth waters in approximately 85–90 m water depth.

KATO Energy Pty Ltd (KATO) plan to develop the Corowa field using a re-locatable 'honeybee production system' which includes the following key facilities and support:

- mobile offshore production unit (MOPU)
- mobile offshore drilling unit/s (MODU)
- floating storage and offloading (FSO)
- support vessels.

1.2 Objective

The purpose of this Technical Note is present the method and results of the estimation of greenhouse gas (GHG) emissions for the Corowa Development for the purpose of environmental impact assessment in the Offshore Project Proposal required under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* and *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009* [OPGGS(E)R].

1.3 Scope

The Department of Environment and Energy (DoEE) have provided advice for primary approvals that are assessed under the Environment Protection and Biodiversity (EPBC) Act; rather than OPGGS(E)R, such as the Corowa Development. This Commonwealth guidance has been used as the basis for the calculation of GHG emissions from the Corowa Development; to estimate maximum emissions, from the Project Area and, to the extent it can be predicted, from elsewhere as it is transported and combusted, in Australia or overseas.

The relevant Commonwealth legislation relating to reporting of greenhouse gas emissions is the *National Greenhouse and Energy Reporting Act 2007 (NGER).* NGER provides for the reporting information related to GHG emissions energy production and energy consumption. As both KATO as a corporate entity and Corowa as a project are likely to exceed the threshold for reporting under NGER they will be required to report emissions annually.

2 GREENHOUSE GAS ASSESSMENT

GHG emissions are measured as tonnes of carbon dioxide equivalence (CO_2-e). This means that the amount of a GHG that a business emits is measured as an equivalent amount of CO_2 which has a global warming potential of one.

The direct and indirect (or Scope 1, 2 and 3) GHG emissions have been calculated for all phases identified in section 1 for the Corowa Development. The boundary of the assessment is shown in Figure 2-1. The definition of scope 1, 2 and 3 emissions are discussed below.

Scope 1 GHG emissions are those released to the atmosphere as a direct result of an activity, or series of activities at a facility level, sometimes referred to as direct emissions. Examples include emissions produced from power generation on the mobile offshore production unit (MOPU) and from burning diesel fuel in support vessels.

Scope 2 emissions are those released to the atmosphere from the indirect consumption of an energy commodity. For example, 'indirect emissions' come from the use of electricity produced by the burning of coal at another facility.

There are no indirect scope 2 emissions associated with the Corowa Development, as KATO will not purchase power from an external provider and generates all its own power requirements directly.

Scope 3 emissions are indirect GHG emissions, other than scope 2 emissions, that are generated in the wider economy. They occur because of the activities of a facility, but from sources not owned or controlled by that facility's business. Relevant to Corowa, this is the transportation of exported oil, and the subsequent burning of that oil for energy by the customer. Scope 3 greenhouse gas emissions are not reported under the NGER Scheme but have been estimated using Australia's National Greenhouse Accounts. For the Corowa Development, oil will most likely be exported to international markets.

2.1 Significant GHG Emissions Sources

The significant GHG emission sources from the Corowa Development are expected to be:

> Exhaust from construction and support vessels
> Exhaust from power generation facilities on the MOPU and MODU
> Exhaust from process heat generation facilities on the MOPU
> Combustion emissions from associated gas flaring (main source of emissions)
> Fugitive emissions from the extraction, processing, storage and export of crude oil
> Emissions from transport and refining of crude oil and its products
> Combustion emissions of the exported crude oil by final customers.

The emissions sources in Table 2-1 have been excluded from the GHG assessment as activity data is not readily available or GHG emissions are considered minor and not material compared to the emission associated with installation, operations, decommissioning and use the oil produced by Corowa.

Further information regarding emission sources is provided in Section 3.2.

Table 2-1 Data Exclusions

Emissions Source	Scope	Description
Facility construction	Scope 3	Emissions associated with the original construction of the MOPU, MODU and FPSO.
Facility materials	Scope 3	Embodied emissions in the materials of construction of the facility
Wastewater	Scope 1	Methane emissions associated with treatment of wastewater
Industrial processes	Scope 1	Sulphur hexafluoride (high voltage switch gear)
Solid waste	Scope 1	Solid waste to landfills
Business and employee travel	Scope 3	Employees travelling for business or to and from work

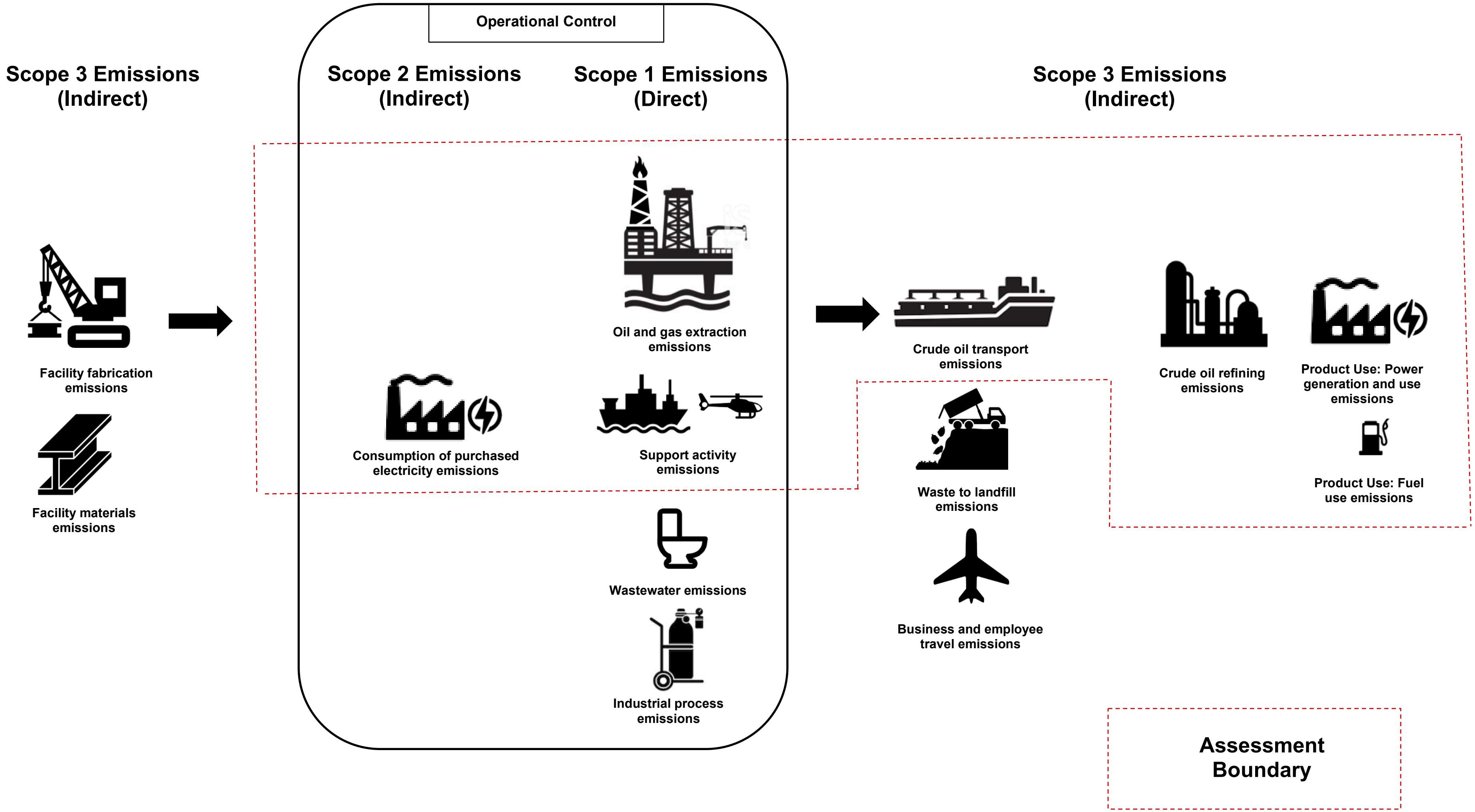


Figure 2-1: Corowa Greenhouse Gas Emissions Assessment Boundary

3 METHODS

3.1 Emissions factors and calculation methodology

The Corowa project is in an early design phase. As such specific details of greenhouse emissions from equipment is not available. As such methodologies selected align with those described in the *National Greenhouse and Energy Reporting (Measurement) Determination 2008 as* method 1 (known as the default method). These are derived from the National Greenhouse Accounts methods and is based on national average estimates. The methods align with Australian Government requirements and are considered representative of Corowa facility and are appropriate for the purpose of environmental impact assessment for the Corowa OPP.

3.1.1 Combustion emission for stationary power generation or transport

Emissions calculation methodology of carbon dioxide, methane and nitrous oxide form the combustion of liquid of gaseous fuels for power generation or transport is taken from Section 2.20 of *National Greenhouse and Energy Reporting (Measurement) Determination 2008.*

$$E_{ij} = (Q_i \text{ x } EC_i \text{ x } EF_{ijoxec}) / 1000$$

Where:

- E_{ij} is the emissions of gas type (j), being carbon dioxide, methane or nitrous oxide, from each gaseous fuel type (i) released from the operation of the facility during the year measured in CO2-e tonnes.
- Q_i is the quantity of fuel type (i) combusted, whether for stationary energy purposes or transport energy purposes, from the operation of the facility during the year measured in cubic metres or gigajoules.
- EC_i is the energy content factor of fuel type (i) estimated (Table 3-1).
- EF_{ijoxec} is the emission factor for each gas type (j) released during the year (which includes the effect of an oxidation factor) measured in kilograms $CO_{2\text{-}e}$ per gigajoule of fuel type (Table 3-1).

3.1.2 Flaring

Crude oil production (flared) emissions calculation methodology from Section 3.52 of *National Greenhouse and Energy Reporting (Measurement) Determination 2008.*

$$E_{ij} = Q_i \text{ x } EF_{ij}$$

Where:

- E_{ij} is the emissions of gas type (j) measured in $CO_{2\text{-}e}$ tonnes from a fuel type (i) flared in crude oil production during the year.
- Q_i is the quantity of fuel type (i) measured in tonnes flared in crude oil production during the year.
- EF_{ij} is the emission factor for gas type (j) measured in tonnes of $CO_{2\text{-}e}$ emissions per tonne of the fuel type (i) flared. Emission factors are listed in Table 3-2.

3.1.3 Crude oil production fugitive emissions

The estimation methodology is taken from Section 6.1.1 of the Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry [American Petroleum Institute (API) 2009].

$$E_{ij} = Q_i \text{ x } E_{ij} \text{ x } GHP_{CH4}$$

Where:

- E_{ij} is the fugitive emissions of methane (j) from fuel type (i) being crude oil produced from the offshore facility during the year measured in $CO_{2\text{-}e}$ tonnes.
- Q_i is the quantity of crude oil (i) produced from the offshore facility measured in m^3.
- EF_{ij} is the emission factor for methane (j) being 7.66 x10^{-5} T_{CH4}/ bbl crude oil produced.
- Note: The emissions factor 9.386x10^{-5} T_{CH4}/bbl is taken from Table 6-2 Offshore oil production the reference methane composition and was corrected to 7.66x10^{-5} T_{CH4}/bbl corrected for composition for Corowa gas composition (64.3mol% methane).
- GHP_{CH4} is the greenhouse gas potential of methane which is 25 (DoEE 2017).

3.1.4 Crude storage fugitive emissions

Crude oil storage fugitive emissions calculation for crude oil is taken from Section 3.63 of *National Greenhouse and Energy Reporting (Measurement) Determination 2008.*

$$E_{ij} = Q_i \text{ x } E_{ij}$$

Where:

- E_{ij} is the fugitive emissions of methane (j) from fuel type (i) being crude oil stored in tanks during the year measured in $CO2_{\text{-}e}$ tonnes.
- Q_i is the quantity of crude oil (i) stored in tanks during the year measured in tonnes.
- EF_{ij} is the emission factor for methane (j) being 1.5 x 10^{-4} tonnes $CO2_{\text{-}e}$ per tonne of crude oil
- stored in tanks.

3.1.5 Crude refining and transport fugitive emissions

Crude oil refining and transport calculation mythology for crude oil is taken from Section 3.63 and 3.59 of *National Greenhouse and Energy Reporting (Measurement) Determination 2008* (DoEE 2017).

$$E_{ij} = \Sigma_i \, Q_i \text{ x } E_{ij}$$

Where:

- E_{ij} is the fugitive emissions of methane (j) from fuel type (i) being crude oil
- refined during the year measured in CO2-e tonnes.
- Σ_I is the sum of emissions of methane (j) released during refining and transportation.

- Q_i is the quantity of crude oil (i) refined or transported during the year measured in tonnes.
- EF_{ij} is the emission factor for methane (j) being 8.5 x 10^{-4} tonnes $CO2_{-e}$ per tonne of crude oil refined or 8.7 x 10^{-4} tonnes $CO2_{-e}$ per tonne of crude oil transported during the year.

3.1.6 Product use

It is assumed that all crude oil and its products are burnt by consumers. The Emissions calculation methodology of carbon dioxide, methane and nitrous oxide form the combustion of final products is taken from Section 2.20 of *National Greenhouse and Energy Reporting (Measurement) Determination 2008* (DoEE 2017).

$$E_{ij} = (Q_i \times EC_i \times EF_{ijoxec}) / 1000$$

Where:

- E_{ij} is the emissions of gas type (j), being carbon dioxide, methane or nitrous oxide, from each gaseous fuel type (i) released from the combustion of the product measured in CO2-e tonnes.
- Q_i is the quantity of product (i) combusted measured in cubic metres or gigajoules.
- EC_i is the energy content factor of the product type (i) estimated (Table 3-1).
- EF_{ijoxec} is the emission factor for each gas type (j) released during the year (which includes the effect of an oxidation factor) measured in kilograms $CO_{2\text{-e}}$ per gigajoule of fuel type (Table 3-1).

Table 3-1 Emissions Factors for Gaseous and Liquid Fuels

		Emission Factor				
		EF CO_2 $kgCO_{2\text{-e}}/GJ$	EF CH_4 $kgCO_{2\text{-e}}/GJ$	EF N_2O $kgCO_{2\text{-e}}/GJ$	EF $CO_{2\text{-e}}$ $kgCO_{2\text{-e}}/GJ$	Energy Content
Activity	**Purpose**					
Natural Gas Consumption	Stationary Energy Generation	51.4	0.1	0.03	51.53	3.93E-02 GJ/m3
Diesel Consumption	Stationary Energy Generation	69.9	0.1	0.2	70.2	38.6 GJ/kl
Fuel Oil Consumption	Transport Fuel Emission	73.6	0.07	0.6	74.27	39.7 GJ/kl
Crude Oil Including Crude Condensates	Stationary Energy Generation	69.6	0.1	0.2	69.9	45.3 GJ/t
Kerosene Consumption	Transport Fuel Emission	69.6	0.01	0.6	70.21	36.8 GJ/kl

Note: All emission factors sourced from NGER (Measurement) Determination 2008, Compilation 11, Schedule 1 Emissions Factor (Items 21, 40, 57 & 56)

Table 3-2 Emissions Factors for Crude Oil Production

		Emission Factor			
		EF CO_2 tCO_{2-e}/t flared gas	**EF CH_4 tCO_{2-e}/t flared gas**	**EF N_2O tCO_{2-e}/t flared gas**	**EF CO_{2-e} tCO_{2-e}/t flared gas**
Activity	**Purpose**				
Unprocessed Gas Flared	Crude oil production (flared) emissions	2.8	0.8	0.03	3.63

3.2 Input Data

The following input data was entered into an excel based emissions inventory calculation tool with the above methodologies and emissions factors to generate the projects emissions profile.

Calculations were made for each line detailed in Table 3-3.

Table 3-3 Emissions Calculation Inputs

Phase	Activity	Detail	Fuel Type
Construction	MOPU Transit from SE Asia 1,500nm	20 days, two towing AHTs burning 40 m^3/day per vessel	Fuel Oil
	MODU Transit from SE Asia 1,500nm	SE Asia (1,500nm) up to 20 days, two towing AHTs burning 40 m^3/day per vessel	Fuel Oil
	MOPU Installation (after tow)	Three AHTs burning 25m3/day per vessel for 4 days	Fuel Oil
		MOPU Power Generation 6 MW (jacking) for 12 hours	Diesel
	MODU Installation (after tow)	Assume three positioning AHTs burning 25 m^3/day for 4 days	Fuel Oil
		MODU Power Generation 6 MW (jacking) for 12 hours.	Diesel
	CALM & Mooring Installation	ISV MOB/DEMOB 5 days at 40 T/day	Fuel Oil
		ISV DP Mode 7 days 13 T/day	Fuel Oil
		One AHTS: burning 11 T/day for 21 days	Fuel Oil
	Flowline Installation	One ISV: DP Mode 13 T/day for 14 days	Fuel Oil
	MODU in Drilling Mode	Drilling power consumption 4 MW for duration (all diesel)	Diesel
		Two supply vessels burning average 15 MT/day each	Fuel Oil
		Eight S76 Helicopter round trips per week (to/from Exmouth)	Kerosene for Aviation
	MODU Removal (after tow)	Three positioning AHTS burning 30 T/day for 2 days.	Fuel Oil
	FSO Transit from SE Asia 1,500nm & Hook-Up	14 days self-propelled, burning 35 MT/day	Fuel Oil
Commissioning	MOPU in Commissioning/Workover/Prep for Removal and P&A (assume one of each)	Assume duration 21 days each event: • Commissioning • Workover • preparation for removal and well P&A	NA
		30 dedicated POB for additional operations + 20 allowance for Ops	NA
		Assume MOPU power consumption 2MW for duration (all diesel)	Diesel

Phase	Activity	Detail	Fuel Type
		One supply boat burning 12 MT/day each	Fuel Oil
		Four S76 Helicopter round trips per week	Kerosene for aviation
	Well Clean-up	Flaring	Natural Gas
Operations	MOPU in Production Mode	P10 production duration	NA
		MOPU power consumption for process 2 MW for duration	Diesel
		Process heating medium heater 1.5 MW	Natural Gas
		MOPU Process fugitive emissions	NA
		One supply vessel burning average 12 T/day	Fuel Oil
		Two S76 Helicopter round trips per week	Kerosene for aviation
	FSO in Operation	17 marine POB	NA
		1MW power consumption whilst connected	Diesel
		Four cyclone avoidance events up to 5 days self-propelled burning 35 MT/day and 5 days low speed 10 MT/day	Fuel Oil
	FSO Oil Storage	P10 throughput	NA
	FSO in Export	1 tailing tug burning 8 MT/day for 3 days each offload	Fuel Oil
	Flaring	Production flaring or associated gas P10 throughput	Natural Gas
Decommissioning	Flowline Recovery	One ISV: MOB/DEMOB 5 days at 40 T/day	Fuel Oil
		DP Mode 7 days at 13 T/day	Fuel Oil
	CALM & Mooring Recovery	One AHTS burning 30 T/day for 21 days	Fuel Oil
		One ISV DP Mode 7 days burning 13 MT/day	Fuel Oil
	MOPU Removal (after P&A)	3 positioning AHTS burning 30 T/day for 4 days.	Fuel Oil

4 RESULTS

4.1 Direct (Scope 1) Emissions Calculation

The calculated direct (Scope 1) emissions from the Corowa Development total 1.3 MT CO_2-e for the total field life of all phases of the project, with the most optimistic reservoir outcome (P10) assuming four years of operation (Table 4-1). This figure has been used for the purposes of impact assessment, as the most conservative estimate.

Operations phase presents the largest source of GHG emissions (1.28 MT CO_2-e). Figure 4-2 shows the breakdown of emissions in operations phase by source or activity. The greatest contributor is from flaring, which comprises 88% of GHG emissions during the operations phase (1.1 MT CO_2-e).

Table 4-1 Corowa Development Greenhouse Gas Estimates

Emissions Source	Calculation			GHG Emissions for Project Life ($T CO_2$-e)			
Activity	**Estimation Methodology**	**Inputs**	**Emission Factor Used**	**CO_2**	**CH_4**	**N_2O**	**Total**
Vessel operations (all phases)	NGER (Measurement) Determination 2008: Transport fuel emissions	Activity type, vessel type and numbers as per section 3, daily fuel consumption and duration	Fuel oil and diesel oil	90,049	86	734	90,869
Helicopter operations (all phases)	NGER (Measurement) Determination 2008: Transport fuel emissions	Helicopter type, fuel consumption, flight distance, flight speed	Kerosene for use in an aircraft	1,220	0	11	1,231
Flaring (all phases)	NGER (Measurement) Determination 2008: Crude oil production (flared emissions)	Oil and gas production rate, duration of flaring, gas composition (molecular weight)	Gas Flared	848,441	242,412	9,090	1,106,528
Electrical Power Generation MOPU, MODU and FSO (all phases)	NGER (Measurement) Determination 2008: Stationary energy emission	Power generation method, fuel type, gas composition (molecular weight), fuel energy content, energy efficiency	Unprocessed natural gas and diesel oil	86,346	114	247	86,716
Process Heating (all phases)	NGER (Measurement) Determination 2008: Stationary energy emission	Heat generation method, fuel type, gas composition (molecular weight), fuel energy content, energy efficiency	Unprocessed natural gas	27,788	54	16	27,858
Fugitive Emissions (All phases)	NGER (Measurement) Determination 2008: Crude oil production (non-flared) – fugitive leaks emissions of methane API Compendium of GHG Emissions Methodologies: Facility-Level Average Emission Factors Approach	Oil Throughput	Fixed Roof Tank Offshore Oil Production	-	23,757	-	23,757

Approximate Total Direct Emissions	1,300,000 (1.3 MT CO_2-e)
Assumptions: • *Assumed four years of production for P10 outcome.* • *Flaring emissions assumed to be P10 reservoir outcome.* • *All emissions factors and energy content figures sourced from NGER (Measurement)Determination 2008 Schedule 1* • *Helicopter characteristics from a representative helicopter (https://www.polarisaviation.com/wp-content/uploads/2015/06/S76-C-Specs-Sheet.pdf)* • *Internal combustion power generation assumed to be 35% thermal efficiency.* • *Turbine power generation assumed to be 35% thermal efficiency.* • *Vessel fuel burn data sourced from 2018 data from well construction activities in Australian waters using MODU and AHTSs.* • *ISV fuel burn from a representative vessel (http://www.dofman.no/Files/System/dof2008/pdf/csv/Skandi_Hercules.pdf)*	

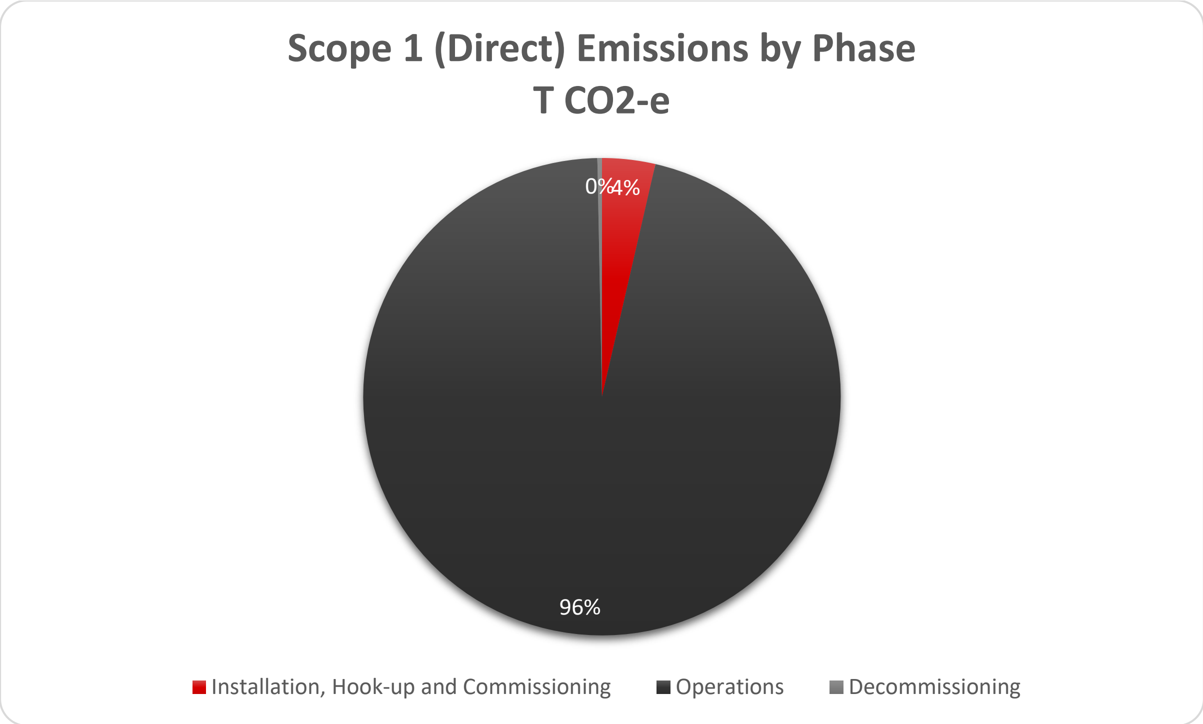


Figure 4-1 Corowa Development GHG Emissions by Phase

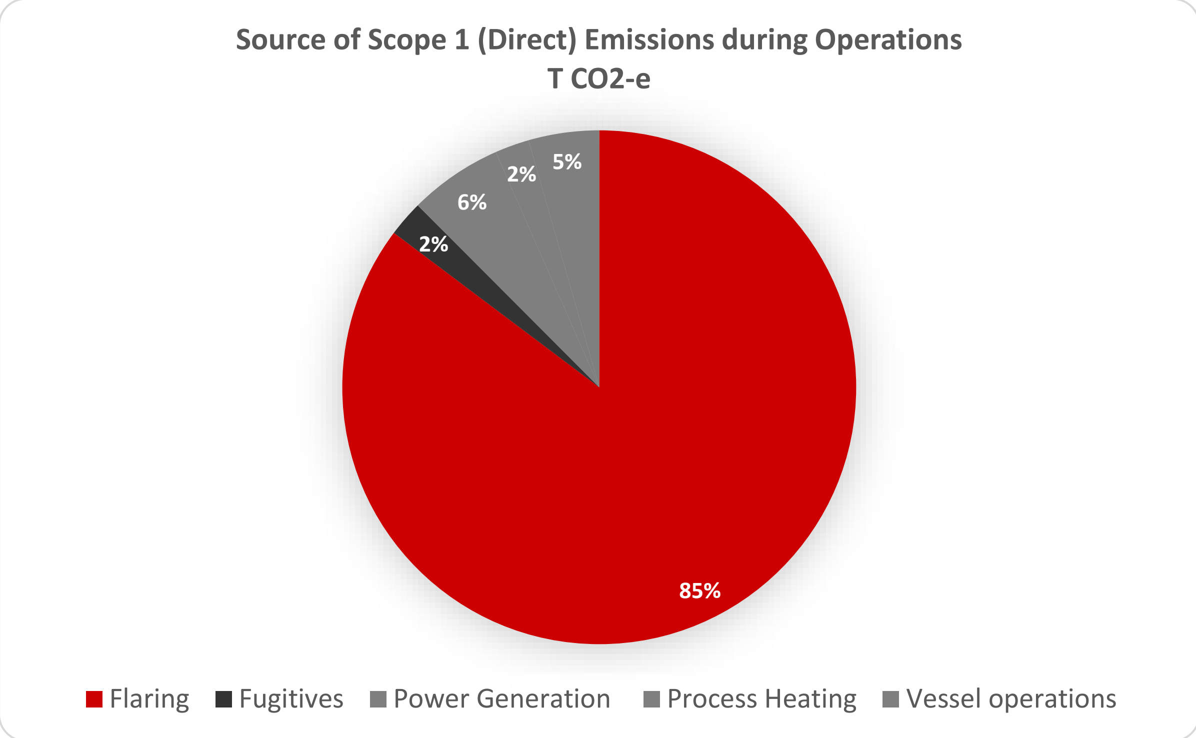


Figure 4-2 Corowa Development Operations Phase - GHG emissions by activity

The National Inventory Report 2017 Volume 1 (DoEE 2019) provides an emissions inventory for the States and Australia, which is submitted under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Table 4-2 provides a comparison between Corowa Development direct (Scope 1) emissions against the total GHG inventory for WA and Australia.

Table 4-2 Comparison of Corowa Emissions to WA and Australian GHG emissions

Source of Emissions - Operations	% of Australia's Annual GHG Emissions^	% of WA's Annual GHG Emissions^
Maximum annual emissions of the Corowa Development*	0.14%	0.91%
Maximum emissions of total field life of Corowa Development#	0.24%	1.55%
Assumptions: • ** Using first year of high estimate (P10 profile)* • *# <4.5 years for high estimate (P10 profile)* • *^ Source: National Inventory Report 2017 Volume 1 (DoEE 2019)*		

4.2 Indirect (Scope 3) Emissions Calculation

Table 4-3 provides the calculation of indirect GHG emissions (Scope 3) for the life of the Corowa Development. Indirect emissions associated with delivering the crude oil, refining the oil into end products and the consumption of these products by the end customer are calculated as 4.57 MT CO_2e.

Table 4-3 Corowa Development Scope 3 Emissions Estimate

Emissions Source	Calculation			GHG Emissions for Project Life
Activity	**Estimation Methodology**	**Inputs**	**Emission Factor Used**	**Total (T CO_2-e)**
Oil Transport	NGER (Measurement) Determination 2008: Crude oil transport	Oil Throughput	Crude oil transport	1,255
Oil Refining	NGER (Measurement) Determination 2008: Crude oil refining	Oil Throughput	Crude oil refining	1,226
Oil Storage	NGER (Measurement) Determination 2008: Crude oil refining	Oil Throughput	Fixed roof tank	216
Consumer Use	NGER (Measurement) Determination 2008: Appendix 4 Scope 3 emission factors	Oil Throughput	Crude oil including crude oil condensates	4,568,895
TOTAL Indirect (Scope 3) Emissions				**4,571,593 (4.57 MT CO_2-e)**

Assumptions:

- *All emissions factors and energy content figures sourced from NGER (Measurement)Determination 2008 Schedule 1*
- *Conservatively assumes all oil produced is used as fuel rather than manufactured into secondary products (plastics, chemicals etc).*

5 REFERENCES

API - American Petroleum Institute (2009). *Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry*. American Petroleum Institute, Washington DC, United States of America.

DoEE. 2017. *National Greenhouse Accounts Factors Australian National Greenhouse Accounts*. Australian Government, Canberra, Australia.

DoEE 2019. *National Inventory Report 2017*. Department of the Environment and Government of Australia, Canberra, Australia

Appendix D: Corowa Development – Produced Formation Water and Cooling Water Discharge Modelling

Corowa Development

Produced Formation Water and Cooling Water Discharge Modelling

KATO Energy

Assignment Number: P100092-S00
Document Number: P-100092-S00-REPT-001

Xodus Group
Level 5, 1 William Street
Perth, Australia, WA 6000

T +61 (0)86555 5600
E info@xodusgroup.com
www.xodusgroup.com

CONTENTS

LIST OF TABLES

1 INTRODUCTION

1.1 Project Overview

The Corowa Development will be centred on the Corowa oil field, located within petroleum permit WA-41-R in the Carnarvon Basin, approximately 60 km offshore from Onslow in Western Australia. The field is in Commonwealth waters in approximately 85–90 m water depth.

KATO Energy (KATO) plan to develop the Corowa field using a re-locatable ‘honeybee production system’ which includes the following key facilities and support:

- mobile offshore production unit (MOPU)
- mobile offshore drilling unit/s (MODU)
- floating storage and offloading (FSO)
- support vessels.

1.2 Objective

The purpose of this report is to present the outcomes of the discharge modelling undertaken for the produced formation water (PFW) and cooling water (CW) discharges from the Corowa Development.

1.3 Scope

During operations for the Corowa Development, hydrocarbons from the wells will be processed onboard the MOPU where PFW will be separated from the crude oil and gas. The PFW, which may contain residual amounts of hydrocarbon and other components, is then discharged into the marine environment from the MOPU. The discharge point will be at or below the lowest anticipated sea level, from a pipe within one of the legs of the MOPU.

The processing facilities and the machinery onboard the MODU, MOPU, FSO and vessels throughout all phases of the Corowa Development will 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 discharge point for the MODU and MOPU will be below the lowest anticipated sea level, from a pipe within one of the support legs.

An assessment of near-field and far-field mixing behaviour of each of the PFW and CW discharge streams was undertaken to support an environmental risk assessment.

2 MODEL

2.1 Overview

Visual Plumes (VPLUMES) is a set of mixing zone models developed by the United States Environment Protection Agency (US EPA) that can simulate single and merging submerged plume behaviour (Frick et al. 2003). The following two models, available within the VPLUMES package, were used to model various scenarios of PFW and CW discharges from the MOPU to quantify the spatial extent of the discharge plume:

- The three-dimensional Updated Merge (UM3) model, which is a Lagrangian initial dilution model that incorporates the projected-area-entrainment (PAE) hypothesis. The UM3 model was used to simulate mixing of the PFW and CW discharges from the MOPU within the near-field.
- The Brooks algorithm, which is a simple dispersion calculation that is a function of travel time and initial plume width. The Brooks algorithm was used to predict centreline dilution and plume width of the PFW and CW discharges within the far-field.

It is acknowledged that the Brooks algorithm is a simplified approach to far-field modelling, however given that external processes (e.g. waves) that would enhance mixing are not taken into account, it is considered to provide a conservative estimate and is therefore appropriate for use in impact analysis.

Initial dilution refers to the phase occurring from the point of discharge to a point of maximum rise or fall (e.g. reaching the surface of the water body) of the plume. Mixing during this phase is primarily density driven.

For this study, the UM3 model was configured to run this initial dilution phase to the '*2nd max rise or fall*' point. This option is important when a discharged plume still has great potential for rising or falling upon reaching the first extremum (Frick et al. 2003). For example, a discharge plume may not complete the initial dilution process at the first maximum rise, as it will reverse direction and accelerate again in the opposite direction.

Trapping effects can occur when the discharged plume reaches an equilibrium density with ambient conditions at some in-water depth before meeting the surface. This is common if the ambient and discharge densities are similar.

2.2 Exposure values

2.2.1 Produced Formation Water

For the PFW discharge, the critical parameters that have the potential to impact the marine environment are the temperature differential and the residual hydrocarbons. The following environmental exposure values have been used within the discharge modelling to support exposure and mixing zone assessments:

- Hydrocarbon: A Predicted No Effect Concentration (PNEC) for dispersed oil in PFW has been defined at 70.5 µg/L (OSPAR 2014). This PNEC was developed from toxicity data from marine species from five taxonomic groups (OSPAR 2014, Smit et al. 2009). The PNEC values for naturally occurring substances within PFW were compiled in support of OSPAR Recommendation 2012/5 and Guidelines 2012/7 (OSPAR 2012a, 2012b).
- Temperature: The World Bank Group's Environmental Health and Safety (EHS) Guidelines for Offshore Oil and Gas Development (IFC 2015) define a guideline for cooling water discharges as:

  > '*The effluent should result in a temperature increase of no more than 3 °C at edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 m from point of discharge*.'

  These EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice. The EHS Guidelines do not specify a temperature guideline for PFW discharges, and so this cooling water discharge guideline has been adopted as also being appropriate for PFW discharges.

2.2.2 Cooling Water

For CW, the critical parameters that have the potential to impact the marine environment are the temperature differential (i.e. heat) and the residual chlorine (from treatment to prevent biofouling of pipework). The following environmental exposure values have been used within the discharge modelling to support exposure and mixing zone assessments:

- Chlorine: The default guideline value (DGV) for chlorine in marine waters is defined at 3 ppb within the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018). This DGV is noted as being a 'low reliability' value; classification is mainly based on the number and type (e.g. chronic, acute or both) of data used to derive the DGV, as well as the fit of the statistical (SSD) model to the data (ANZG 2018).
- Temperature: The World Bank Group's EHS Guidelines for Offshore Oil and Gas Development (IFC 2015) define a guideline for CW discharges as: '*The effluent should result in a temperature increase of no more than 3 °C at edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 m from point of discharge*." These EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice.

2.3 Ambient conditions

Ambient environmental conditions are defined in the model and can affect the buoyancy of a plume (ambient temperature and salinity) and the intensity and movement of initial mixing (ambient currents).

2.3.1 Temperature and salinity

Temperature and salinity data were sourced from the World Ocean Atlas 2018 (NOAA 2018). Average annual temperature and salinity profiles (from data over the 2005–2017 period) for a location in close proximity to the MOPU are provided in Table 2-1 and have been used in the model scenarios.

Table 2-1 Ambient temperature and salinity conditions

Depth (m)	Temperature (°C)	Salinity
0	28.0	35.1
15	27.9	35.1
20	27.7	35.2
60	27.6	35.2
70	27.4	35.2
80	26.8	35.2
90	26.1	35.0

2.3.2 Currents

Three current speeds were across a typical expected range were used in the model scenarios (0.05 m/s, 0.2 m/s and 0.5 m/s). A consistent current direction (southwest) was applied to all scenarios.

3 PRODUCED FORMATION WATER DISCHARGE

3.1 Scenarios

Multiple scenarios (Table 3-1) were modelled, including variations in both discharge characteristics (temperature, volume and discharge depth) and ambient conditions (current velocity) to evaluate the differences in plume mixing behaviour and spatial extent to reach environmental thresholds. Final configuration of the PFW discharge from the MOPU will occur during FEED.

Table 3-1 Modelling parameters (and variations) for PFW Discharge

Parameter	Description / Value				
Outlet characteristics					
Number of ports	1				
Port orientation	Vertical down				
Port diameter	0.15 m				
Port depth	75 m	50 m	30 m	10 m	0 m
Water depth	90 m				
Discharge characteristics					
Flow type	Continuous				
Flow rate	178 m^3/hr (0.05 m^3/s)				
Temperature	45 °C	65 °C			
Salinity	37				
Hydrocarbon concentration (Oil in Water [OIW])	29 mg/L				
Ambient characteristics^					
Temperature	Profile as per Table 2-1				
Salinity	Profile as per Table 2-1				
Current^	0.05 m/s	0.2 m/s	0.5 m/s		

^ Far-field dilution simulations used the same ambient characteristics and a default conservative value of a diffusion coefficient of 0.0003 $m^{2/3}/s^2$ (Frick et al. 2003).

3.2 Results

3.2.1 Hydrocarbon

3.2.1.1 PFW discharge at 45 °C

The following series of tables show the results of the modelling simulations and the mixing behaviour to reach the hydrocarbon exposure values. Screen grabs from model outputs are also shown in Appendix A.

Table 3-2 Dilution estimates for PFW from different discharge depths under a southwest current at low (0.05 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	71	187	431	1,423	175
Approx. horizontal distance between discharge point and edge of near-field mixing zone	8 m	15 m	31 m	89 m	20 m
Near-field vertical mixing	Surface	Surface	Trap (20 m)	Trap (32 m)	Trap (75 m)

Discharge Depth (m)	0	10	30	50	75
Approx. horizontal distance from discharge point required to reach 411 dilutions	250 m	140 m	<31 m	<89 m	160 m
Approx. width of plume at this distance	61 m	40 m	<22 m	<42 m	44 m
Type of mixing required for OIW to dilute to threshold concentration	NF + FF	NF + FF	NF	NF	NF + FF

NF = Near field; FF = Far field

Table 3-3 Dilution estimates for PFW from different discharge depths under a southwest current at low (0.2 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	127	633	2,361	2,406	377
Approx. horizontal distance between discharge point and edge of near-field mixing zone	28 m	87 m	313 m	359 m	82 m
Near-field vertical mixing	Surface	Surface	Trap (23 m)	Trap (43 m)	Trap (76 m)
Approx. horizontal distance from discharge point required to reach 411 dilutions	520 m	<87 m	<313 m	<359 m	190 m
Approx. width of plume at this distance	29 m	<14 m	<27 m	<28 m	16 m
Type of mixing required for OIW to dilute to threshold concentration	NF + FF	NF	NF	NF	NF + FF

NF = Near field; FF = Far field

Table 3-4 Dilution estimates for PFW from different discharge depths under a southwest current at low (0.5 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	154	1,211	3,194	3,258	506
Approx. horizontal distance between discharge point and edge of near-field mixing zone	63 m	314 m	884 m	896 m	201 m
Near-field vertical mixing	Surface	Surface	Trap (25 m)	Trap (45 m)	Trap (76 m)
Approx. horizontal distance from discharge point required to reach 411 dilutions	840 m	<314 m	<884 m	<896 m	<201 m
Approx. width of plume at this distance	16 m	<12 m	<20 m	<20 m	<8 m
Type of mixing required for OIW to dilute to threshold concentration	NF + FF	NF	NF	NF	NF

NF = Near field; FF = Far field

3.2.1.2 *PFW discharge at 65 °C*

The following series of tables show the results of the modelling simulations and the mixing behaviour to reach the hydrocarbon exposure values. Screen grabs from model outputs are also shown in Appendix A.

Table 3-5 Dilution estimates for PFW from different discharge depths under a southwest current at low (0.05 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	33	111	329	770	404
Approx. horizontal distance between discharge point and edge of near-field mixing zone	3 m	7 m	22 m	31 m	30 m
Approx. horizontal distance from discharge point required to reach 411 dilutions	295 m	170 m	80 m	<31 m	55 m
Approx. width of plume at this distance	67 m	40 m	30 m	<26 m	27 m
Type of mixing required for OIW to dilute to threshold concentration	NF + FF	NF + FF	NF + FF	NF	NF + FF

NF = Near field; FF = Far field

Table 3-6 Dilution estimates for PFW from different discharge depths under a southwest current at low (0.2 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	67	476	1,871	4,325	556
Approx. horizontal distance between discharge point and edge of near-field mixing zone	11 m	40 m	124 m	348 m	75 m
Approx. horizontal distance from discharge point required to reach 411 dilutions	740 m	<40 m	<124 m	<348 m	<75 m
Approx. width of plume at this distance	39 m	<12 m	<24 m	<37 m	<13 m
Type of mixing required for OIW to dilute to threshold concentration	NF + FF	NF	NF	NF	NF

NF = Near field; FF = Far field

Table 3-7 Dilution estimates for PFW from different discharge depths under a southwest current at low (0.5 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	83	966	3,389	5,854	744
Approx. horizontal distance between discharge point and edge of near-field mixing zone	25 m	135 m	388 m	871 m	187 m
Approx. horizontal distance from discharge point required to reach 411 dilutions	1,220 m	<135 m	<388 m	<871 m	<187 m
Approx. width of plume at this distance	22 m	<11 m	<21 m	<27 m	<10 m
Type of mixing required for OIW to dilute to threshold concentration	NF + FF	NF	NF	NF	NF

NF = Near field; FF = Far field

3.2.2 Temperature

3.2.2.1 PFW discharge at 45 °C

The following series of tables show the results of the modelling simulations and the mixing behaviour to reach the temperature exposure values. Screen grabs from model outputs are also shown in Appendix A.

Table 3.8: Dilution estimates for PFW from different discharge depths under a southwest current at low (0.05 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	71	187	431	1,423	175
Approx. horizontal distance between discharge point and edge of near-field mixing zone	8 m	15 m	31 m	89 m	20 m
Near-field vertical mixing	Surface	Surface	Trap (20 m)	Trap (32 m)	Trap (75 m)
Plume temperature at the edge of near-field mixing zone	28.2 °C	28.0 °C	27.7 °C	27.7 °C	27.1 °C
Criteria of Δ3°C variation from ambient conditions met?	Yes	Yes	Yes	Yes	Yes

Table 3.9: Dilution estimates for PFW from different discharge depths under a southwest current at moderate (0.2 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	127	633	2,361	2,406	377
Approx. horizontal distance between discharge point and edge of near-field mixing zone	28 m	87 m	313 m	359 m	82 m
Near-field vertical mixing	Surface	Surface	Trap (23 m)	Trap (43 m)	Trap (76 m)
Plume temperature at the edge of near-field mixing zone	28.1 °C	28.0 °C	27.7 °C	27.7 °C	27.0 °C
Criteria of Δ3°C variation from ambient conditions met?	Yes	Yes	Yes	Yes	Yes

Table 3.10: Dilution estimates for PFW from different discharge depths under a southwest current at high (0.5 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	154	1,211	3,194	3,258	506
Approx. horizontal distance between discharge point and edge of near-field mixing zone	63 m	314 m	884 m	896 m	201 m
Near-field vertical mixing	Surface	Surface	Trap (25 m)	Trap (45 m)	Trap (76 m)
Plume temperature at the edge of near-field mixing zone	28.1 °C	27.9 °C	27.7 °C	27.6 °C	27.1 °C
Criteria of Δ3°C variation from ambient conditions met?	Yes	Yes	Yes	Yes	Yes

3.2.2.2 *PFW discharge at 65 °C*

The following series of tables show the results of the modelling simulations and the mixing behaviour to reach the temperature exposure values. Screen grabs from model outputs are also shown in Appendix A.

Table 3.11: Dilution estimates for PFW from different discharge depths under a southwest current at low (0.05 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	33	111	329	770	404
Approx. horizontal distance between discharge point and edge of near-field mixing zone	3 m	7 m	22 m	31 m	30 m
Plume temperature at the edge of near-field mixing zone	29.1 °C	28.3 °C	27.9 °C	27.7 °C	27.6 °C
Criteria of Δ3°C variation from ambient conditions met?	Yes	Yes	Yes	Yes	Yes

Table 3.12: Dilution estimates for PFW from different discharge depths under a southwest current at moderate (0.2 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	67	476	1,871	4,325	556
Approx. horizontal distance between discharge point and edge of near-field mixing zone	11 m	40 m	124 m	348 m	75 m
Plume temperature at the edge of near-field mixing zone	28.5 °C	28.0 °C	27.7 °C	27.7 °C	27.2 °C
Criteria of Δ3°C variation from ambient conditions met?	Yes	Yes	Yes	Yes	Yes

Table 3.13: Dilution estimates for PFW from different discharge depths under a southwest current at high (0.5 m/s) speed

Discharge Depth (m)	0	10	30	50	75
Dilution achieved under near-field mixing only	83	966	3,389	5,854	744
Approx. horizontal distance between discharge point and edge of near-field mixing zone	25 m	135 m	388 m	871 m	187 m
Plume temperature at the edge of near-field mixing zone	28.4 °C	28.0 °C	27.7 °C	27.7 °C	27.2 °C
Criteria of Δ3°C variation from ambient conditions met?	Yes	Yes	Yes	Yes	Yes

3.3 Summary

The discharge modelling showed the following mixing behaviours for PFW from the MOPU:

> Both discharges are initially buoyant compared to ambient seawater (the 65 °C more than the 45 °C discharge), but for discharges at depths (typically ≥30 m) the discharged PFW plume is not predicted to reach the surface during the initial dilution phase (i.e. where mixing is due to density differences) as it will have reached an equilibrium density to ambient conditions at some depth in the water column

> The PFW discharge plume is never predicted to interact with the seabed, even from the deepest modelled discharge (i.e. 75 m depth or 15 m above seabed)

> Mixing required to meet the hydrocarbon threshold varies between 31 m and 896 m for the 45 °C discharge, and 31 m and 1,220 m for the 65 °C discharge. The hydrocarbon threshold is met under either near-field or far-field mixing depending on the combination of discharge and ambient conditions.

> The temperature threshold is met within the near-field mixing zone for all scenarios. The near-field mixing zone varies between 8 m and 896 m for the 45 °C discharge, and 3 m and 871 m for the 65 °C discharge

Therefore, the maximum horizontal distance predicted to be needed to reach the hydrocarbon and temperature thresholds is 1,220 m and 896 m from the MOPU respectively.

4 COOLING WATER DISCHARGE

4.1 Scenarios

Multiple scenarios (Table 4-1) were modelled, including variations in both discharge characteristics (temperature, volume and discharge depth) and ambient conditions (current velocity) to evaluate the differences in plume mixing behaviour and spatial extent to reach environmental thresholds. Final configuration of the CW discharge from the MOPU will occur during FEED.

Table 4-1 Modelling parameters (and variations) for CW discharge

Parameter	Description / Value				
Outlet characteristics					
Number of ports	1				
Port orientation	Vertical down				
Port diameter	0.254 m				
Port depth	75 m	50 m	30 m	10 m	2 m
Water depth	90 m				
Discharge characteristics					
Flow type	Continuous				
Flow rate	440 m^3/hr (0.12 m^3/s)	80 m^3/hr (0.0285 m^3/s)			
Temperature	45 °C	65 °C			
Salinity	35				
Residual chlorine	2,000 ppb				
Ambient characteristics^					
Temperature	Profile as per Table 2-1				
Salinity	Profile as per Table 2-1				
Current	0.05 m/s	0.2 m/s	0.5 m/s		

^ Far-field dilution simulations used the same ambient characteristics and a default conservative value of a diffusion coefficient of 0.0003 $m^{2/3}/s^2$ (Frick et al. 2003).

4.2 Results

4.2.1 Chlorine

4.2.1.1 CW discharge at 45 °C

The following series of tables show the results of the modelling simulations and the mixing behaviour to reach the chlorine exposure values. Screen grabs from model outputs are also shown in Appendix B.

Table 4.2: Dilution estimates for CW from different discharge depths under a southwest current at low (0.05 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	38	74	181	350	169
Approx. horizontal distance between discharge point and edge of near-field mixing zone	6 m	9 m	23 m	27 m	27 m
Near-field vertical mixing	Surface	Surface	Trap (18 m)	Surface	Trap (68 m)

Discharge Depth (m)	2	10	30	50	75
Approx. horizontal distance from discharge point required to reach 667 dilutions	555 m	435 m	315 m	220 m	360 m
Approx. width of plume at this distance	164 m	126 m	97 m	86 m	114 m
Type of mixing required for Residual Chlorine to dilute to threshold concentration	NF + FF	NF + FF	NF + FF	NF + FF	NF + FF

NF = Near field; FF = Far field

Table 4.3: Dilution estimates for CW from different discharge depths under a southwest current at moderate (0.2 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	91	275	1,018	2,177	300
Approx. horizontal distance between discharge point and edge of near-field mixing zone	23m	47 m	135 m	354 m	78 m
Near-field vertical mixing	Surface	Surface	Trap (20 m)	Trap (36 m)	Trap (75 m)
Approx. horizontal distance from discharge point required to reach 667 dilutions	1,280 m	550 m	<135 m	<354 m	645 m
Approx. width of plume at this distance	84 m	48 m	<28 m	<41 m	46 m
Type of mixing required for Residual Chlorine to dilute to threshold concentration	NF + FF	NF + FF	NF	NF	NF + FF

NF = Near field; FF = Far field

Table 4.4: Dilution estimates for CW from different discharge depths under a southwest current at high (0.5 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	130	520	1,783	2,914	407
Approx. horizontal distance between discharge point and edge of near-field mixing zone	58 m	150 m	415 m	877 m	195 m
Near-field vertical mixing	Surface	Surface	Trap (20 m)	Trap (40 m)	Trap (75 m)
Approx. horizontal distance from discharge point required to reach 667 dilutions	1,975 m	650 m	<415 m	<877 m	940 m
Approx. width of plume at this distance	45 m	22 m	<23 m	<30 m	25 m
Type of mixing required for Residual Chlorine to dilute to threshold concentration	NF + FF	NF + FF	NF	NF	NF + FF

NF = Near field; FF = Far field

4.2.1.2 CW discharge at 65 °C

The following series of tables show the results of the modelling simulations and the mixing behaviour to reach the chlorine exposure values. Screen grabs from model outputs are also shown in Appendix B.

Table 4.5: Dilution estimates for CW from different discharge depths under a southwest current at low (0.05 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	9	73	480	1,128	2,309
Approx. horizontal distance between discharge point and edge of near-field mixing zone	1 m	3 m	22 m	29 m	82 m
Near-field vertical mixing	Surface	Surface	Trap (16 m)	Trap (19 m)	Trap (47 m)
Approx. horizontal distance from discharge point required to reach 667 dilutions	480 m	250 m	90 m	<29 m	<82 m
Approx. width of plume at this distance	118 m	55 m	29 m	<23 m	<36 m
Type of mixing required for Residual Chlorine to dilute to threshold concentration	NF + FF	NF + FF	NF + FF	NF	NF

NF = Near field; FF = Far field

Table 4.6: Dilution estimates for CW from different discharge depths under a southwest current at moderate (0.2 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	32	492	2102	6128	961
Approx. horizontal distance between discharge point and edge of near-field mixing zone	3 m	27 m	100 m	340 m	102 m
Near-field vertical mixing	Surface	Surface	Trap (20m)	Trap (34 m)	Trap (70 m)
Approx. horizontal distance from discharge point required to reach 667 dilutions	1,150 m	200 m	<100 m	<340 m	<102 m
Approx. width of plume at this distance	60 m	15 m	<17 m	<29 m	<12 m
Type of mixing required for Residual Chlorine to dilute to threshold concentration	NF + FF	NF + FF	NF	NF	NF

NF = Near field; FF = Far field

Table 4.7: Dilution estimates for CW from different discharge depths under a southwest current at high (0.5 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	85	1281	4518	8379	1025
Approx. horizontal distance between discharge point and edge of near-field mixing zone	15 m	116 m	354 m	859 m	177 m
Near-field vertical mixing	Surface	Surface	Trap (20 m)	Trap (39 m)	Trap (72 m)

Discharge Depth (m)	2	10	30	50	75
Approx. horizontal distance from discharge point required to reach 667 dilutions	1390	<116 m	<354 m	<859 m	<177 m)
Approx. width of plume at this distance	24	<8 m	<16 m	<22 m	<8m
Type of mixing required for Residual Chlorine to dilute to threshold concentration	NF + FF	NF	NF	NF	NF

NF = Near field; FF = Far field

4.2.2 Temperature

4.2.2.1 CW discharge at 45 °C

The following series of tables show the results of the modelling simulations and the mixing behaviour to reach the temperature exposure values. Screen grabs from model outputs are also shown in Appendix B.

Table 4.8: Dilution estimates for CW from different discharge depths under a southwest current at low (0.05 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	38	74	181	350	169
Approx. horizontal distance between discharge point and edge of near-field mixing zone	6 m	9 m	23 m	27 m	27 m
Near-field vertical mixing	Surface	Surface	Trap (18 m)	Surface	Trap (68 m)
Plume temperature at the edge of near-field mixing zone	28.4 °C	28.2 °C	27.9 °C	27.7 °C	27.4 °C
Criteria of Δ3°C variation from ambient conditions met?	Yes	Yes	Yes	Yes	Yes

Table 4.9: Dilution estimates for CW from different discharge depths under a southwest current at moderate (0.2 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	91	275	1,018	2,177	300
Approx. horizontal distance between discharge point and edge of near-field mixing zone	23m	47 m	135 m	354 m	78 m
Near-field vertical mixing	Surface	Surface	Trap (20 m)	Trap (36 m)	Trap (75 m)
Plume temperature at the edge of near-field mixing zone	28.2 °C	28.0 °C	27.7 °C	27.7 °C	27.1 °C
Criteria of Δ3°C variation from ambient conditions met?	Yes	Yes	Yes	Yes	Yes

Table 4.10: Dilution estimates for CW from different discharge depths under a southwest current at high (0.5 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	130	520	1,783	2,914	407
Approx. horizontal distance between discharge point and edge of near-field mixing zone	58 m	150 m	415 m	877 m	195 m
Near-field vertical mixing	Surface	Surface	Trap (20 m)	Trap (40 m)	Trap (75 m)
Plume temperature at the edge of near-field mixing zone	28.1 °C	28.0 °C	27.7 °C	27.7 °C	27.1 °C
Criteria of Δ3°C variation from ambient conditions met?	Yes	Yes	Yes	Yes	Yes

4.2.2.2 *CW discharge at 65 °C*

The following series of tables show the results of the modelling simulations and the mixing behaviour to reach the temperature exposure values. Screen grabs from model outputs are also shown in Appendix B.

Table 4.11: Dilution estimates for CW from different discharge depths under a southwest current at low (0.05 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	9	73	480	1,128	2,309
Approx. horizontal distance between discharge point and edge of near-field mixing zone	1 m	3 m	22 m	29 m	82 m
Near-field vertical mixing	Surface	Surface	Trap (16 m)	Trap (19 m)	Trap (47 m)
Plume temperature at the edge of near-field mixing zone	32.1	28.5 °C	27.9 °C	27.7 °C	27.6 °C
Criteria of Δ3°C variation from ambient conditions met?	No	Yes	Yes	Yes	Yes
Dilutions at 100 m	80	N/A	N/A	N/A	N/A
Criteria of Δ3°C variation from ambient conditions met at 100 m?	Yes	N/A	N/A	N/A	N/A

Table 4.12: Dilution estimates for CW from different discharge depths under a southwest current at moderate (0.2 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	32	492	2102	6128	961
Approx. horizontal distance between discharge point and edge of near-field mixing zone	3 m	27 m	100 m	340 m	102 m
Near-field vertical mixing	Surface	Surface	Trap (20m)	Trap (34 m)	Trap (70 m)
Plume temperature at the edge of near-field mixing zone	29.1 °C	28.0 °C	27.7 °C	27.7 °C	27.4 °C
Criteria of Δ3°C variation from ambient conditions met?	Yes	Yes	Yes	Yes	Yes

Table 4.13: Dilution estimates for CW from different discharge depths under a southwest current at high (0.5 m/s) speed

Discharge Depth (m)	2	10	30	50	75
Dilution achieved under near-field mixing only	85	1281	4518	8379	1025
Approx. horizontal distance between discharge point and edge of near-field mixing zone	15 m	116 m	354 m	859 m	177 m
Near-field vertical mixing	Surface	Surface	Trap (20 m)	Trap (39 m)	Trap (72 m)
Plume temperature at the edge of near-field mixing zone	28.4 °C	28.0 °C	27.7 °C	27.7 °C	27.3 °C
Criteria of Δ3°C variation from ambient conditions met?	Yes	Yes	Yes	Yes	Yes

4.3 Summary

The discharge modelling showed the following mixing behaviours for CW from the MOPU:

- The larger volume (440 m^3/day) has a greater port exit velocity and Froude number compared to the lower volume (80 m^3/day), and therefore momentum (and not just buoyancy) has an effect on mixing with the near-field
- Both discharges are initially buoyant compared to ambient seawater (the 65 °C more than the 45 °C discharge), but for discharges at depths (typically ≥30 m) the discharged CW plume is not predicted to reach the surface during the initial dilution phase (i.e. where mixing is due to density differences) as it will have reached an equilibrium density to ambient conditions at some depth in the water column
- The CW discharge plume is never predicted to interact with the seabed, even from the deepest modelled discharge (i.e. 75 m depth or 15 m above seabed)
- The size of the near-field mixing zone (i.e. the initial dilution phase) varies between 6 m and 877 m for the 440 m^3/day at 45 °C discharge, and 1 m and 859 m for the 80 m^3/day at 65 °C discharge.
- Mixing required to meet the chlorine threshold varies between 135 m and 1,975 m for the 440 m^3/day at 45 °C discharge, and 30 m and 1,390 m for the 80 m^3/day at 65 °C discharge. The chlorine threshold is met under either near-field or far-field mixing depending on the combination of discharge and ambient conditions.
- The temperature threshold is met within the near-field mixing zone for all scenarios, with the exception of the 80 m^3/day at 65 °C near-surface discharge under low ambient currents.
- Mixing required to meet the temperature threshold varies between 135 m and 1,975 m for the 440 m^3/day at 45 °C discharge, and 30 m and 1,390 m for the 80 m^3/day at 65 °C discharge. However, for this scenario the temperature threshold would be met within 20 m of the discharge outlet (as predicted from far-field modelling). This is well below the 100 m distance referred to in the EHS Guidelines (IFC 2015) for cases where the initial mixing zone is not defined. This secondary part of the guideline is considered appropriate for this particular scenario given the conditions (i.e. near-surface discharge, low port exit velocity and low Froude number, and low ambient current) are not conducive for initial mixing to occur.

Therefore, the maximum horizontal distance predicted to be needed to reach the chlorine and temperature thresholds is 1,975 m and 877 m from the MOPU respectively.

5 ABBREVIATIONS

Term	Description
CW	Cooling water
DGV	Default guideline value
EHS	Environmental, health and safety
FEED	Front end engineering design
FSO	Floating storage and offloading
KATO	KATO Energy
km	kilometre
m	metre
MODU	Mobile offshore drilling unit
MOPU	Mobile offshore production unit
OIW	Oil in Water
PAE	Projected area entrainment
PFW	Produced formation water
PNEC	Predicted No Effect Concentration
SSD	Species sensitivity distribution
UM3	Updated Merge 3
US EPA	United States Environment Protection Agency
VPLUMES	Visual Plumes

6 REFERENCES

ANZG. 2018. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia.

Frick W.E., Roberts P.J.W., Davis L.R., Keyes J., Baumgartner D.J., George K.P. 2001. *Dilution Models for Effluent Discharges*. 4th Edition (Visual Plumes) – DRAFT. U.S. EPA Environmental Standards Division.

IFC. 2015. *Environmental, Health and Safety (EHS) General Guidelines*. International Finance Corporation. Prepared by the International Finance Corporation, World Group Bank.

NOAA. 2018. *World Ocean Atlas 2018*. National Oceanic and Atmospheric Administration.

OSPAR 2012a. *OSPAR Recommendation 2012/5 for a risk-based approach to the Management of Produced Water Discharges from Offshore Installations*. OSPAR Commission, Recommendation 2012/5. United Kingdom.

OSPAR. 2012b. *OSPAR Guidelines in support of Recommendation 2012/5 for a Risk-based Approach to the Management of Produced Water Discharges from Offshore Installations*. OSPAR Commission, Agreement 2012-7. United Kingdom.

OSPAR. 2014. *Establishment of a list of Predicted No Effect Concentrations (PNECs) for naturally occurring substances in produced water*. OSPAR Commission. OSPAR Agreement: 2014–05.

Smit M.G.D., R.K. Bechman A.J. Hendriks S. Bamber, A. Skadsheim, B.K. Larssen, T. Baussant, S.Sanni 2009. *Relating biomarkers to whole organism effects using species sensitivity distributions: a pilot study for marine species exposed to oil. Environmental Toxicology and Chemistry*. 28:1004-1009.

APPENDIX A VPLUMES RESULTS FOR PRODUCED FORMATION WATER MODELLING

Appendix A.1 Discharge at 45 °C and 0.05 m/s ambient current

Port Depth = 0 m

```
/ UM3. 7/3/2019 11:22:08 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: ----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0      0.05    -135.0      35.1      28.0       0.0       0.0      0.05     225.0    0.0003     22.49
.....
      90.0      0.05    -135.0      35.0      26.1       0.0       0.0      0.05     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    90.0   -90.0   225.0     1.0   100.0  5000.0     0.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:      32.53; effleunt density (sigma-T)     17.26; effleunt velocity     2.829(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0      0.0     0.05     0.15     37.0     45.0     28.0     28.0      1.0      0.0      0.0;
   8   0.0634     0.05    0.174    36.72    42.51     23.9     23.9    1.171-7.656E-5-7.656E-5; matched energy radia
 100    2.313     0.05    1.098    35.36    30.34    3.865    3.865    7.212   -0.094   -0.094;
 164    6.093     0.05    4.015    35.18    28.72    1.229    1.229    22.68   -0.888   -0.888; begin overlap;
 200    6.929     0.05    5.467    35.17    28.57    0.981    0.981     28.4   -1.434   -1.434;
 264     7.34     0.05    6.361    35.16    28.52    0.906    0.906    30.76   -2.271   -2.271; local maximum rise o
 300    7.211     0.05    6.186    35.16    28.52    0.899    0.899     31.0   -2.732   -2.732;
 338    6.497     0.05    5.777    35.16    28.47     0.82     0.82    33.96   -3.489   -3.489; end overlap;
 379    2.316     0.05     7.58    35.13    28.21    0.393    0.393    70.88   -5.988   -5.988; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of      7.58 m
   conc  dilutn    width distnce    time
  (ppm)              (m)     (m)   (hrs)   (ppm)   (s-1)   (m/s)(m0.67/s2)
 0.17385   160.7   23.71   100.0   0.509     0.0     0.0    0.05 3.00E-4
 8.76E-2   319.1   47.15   200.0   1.064     0.0     0.0    0.05 3.00E-4
 5.48E-2   510.3   75.43   300.0    1.62     0.0     0.0    0.05 3.00E-4
 3.84E-2   729.3   107.8   400.0   2.175     0.0     0.0    0.05 3.00E-4
 .....
 7.74E-3  3616.3   534.4  1300.0   7.175     0.0     0.0    0.05 3.00E-4
 6.97E-3  4018.8   593.9  1400.0   7.731     0.0     0.0    0.05 3.00E-4
 6.31E-3  4435.2   655.4  1500.0   8.286     0.0     0.0    0.05 3.00E-4
 5.75E-3  4865.1   718.9  1600.0   8.842     0.0     0.0    0.05 3.00E-4
 5.27E-3  5308.0   784.4  1700.0   9.397     0.0     0.0    0.05 3.00E-4
```

Port Depth = 10 m

```
/ UM3. 7/3/2019 11:46:56 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0      0.05    -135.0      35.1      28.0       0.0       0.0      0.05     225.0    0.0003     22.49
.....
      90.0      0.05    -135.0      35.0      26.1       0.0       0.0      0.05     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    80.0   -90.0   225.0     1.0   100.0  5000.0    10.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:       32.47; effleunt density (sigma-T)      17.26; effleunt velocity       2.829(m/s);
        Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step      (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0     10.0     0.05      0.15     37.0     45.0     28.0     28.0      1.0       0.0       0.0;
 100    12.31     0.05     1.098    35.36    30.28    3.865    3.865    7.212    -0.094    -0.094;
 163    16.03     0.05     3.953    35.19    28.67    1.251    1.251    22.28    -0.863    -0.863; begin overlap;
.....
 436    5.281     0.05     13.49    35.11    28.02    0.152    0.152    182.9    -10.26    -10.26; matched energy radia
 437     5.13     0.05     13.65    35.11    28.02    0.149    0.149    186.6     -10.4     -10.4; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       13.65 m
    conc   dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 0.14919    186.7    14.57    20.0   0.0294     0.0      0.0     0.05 3.00E-4
 0.14797    188.3    16.37    30.0    0.085     0.0      0.0     0.05 3.00E-4
.....
 7.02E-2    398.0    40.16   140.0    0.696     0.0      0.0     0.05 3.00E-4
 6.61E-2    422.5    42.65   150.0    0.752     0.0      0.0     0.05 3.00E-4
.....
 7.05E-3   3973.3    401.7  1030.0    5.641     0.0      0.0     0.05 3.00E-4
 6.95E-3   4026.0    407.1  1040.0    5.696     0.0      0.0     0.05 3.00E-4
 6.86E-3   4078.8    412.4  1050.0    5.752     0.0      0.0     0.05 3.00E-4
 6.77E-3   4132.0    417.8  1060.0    5.807     0.0      0.0     0.05 3.00E-4
 6.69E-3   4185.3    423.2  1070.0    5.863     0.0      0.0     0.05 3.00E-4
 6.60E-3   4238.9    428.6  1080.0    5.918     0.0      0.0     0.05 3.00E-4
 6.52E-3   4292.7    434.0  1090.0    5.974     0.0      0.0     0.05 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 7/3/2019 11:35:06 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0      0.05    -135.0      35.1      28.0       0.0       0.0      0.05     225.0    0.0003     22.49
.....
      90.0      0.05    -135.0      35.0      26.1       0.0       0.0      0.05     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    60.0   -90.0   225.0     1.0   100.0  5000.0    30.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:       31.99; effleunt density (sigma-T)      17.26; effleunt velocity       2.829(m/s);
        Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step      (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0     30.0     0.05      0.15     37.0     45.0     28.0     28.0      1.0       0.0       0.0;
 100    32.31     0.05     1.099    35.45    30.06    3.865    3.865    7.211   -0.0942   -0.0942;
.....
 500    17.55     0.05     21.62     35.2    27.74   0.0743   0.0743    375.0    -17.32    -17.32;
 521    17.46     0.05     21.93     35.2    27.74   0.0739   0.0739    376.7    -17.98    -17.98; local maximum rise o
 582    19.21     0.05     20.62     35.2    27.74   0.0697   0.0697    399.6    -20.96    -20.96; end overlap;
 586    20.24     0.05     21.38     35.2    27.74   0.0646   0.0646    431.0    -22.05    -22.05; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       21.38 m
    conc   dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 6.46E-2    431.2    23.16    40.0    0.049     0.0      0.0     0.05 3.00E-4
 6.42E-2    433.5    25.25    50.0    0.105     0.0      0.0     0.05 3.00E-4
 6.27E-2    444.6    27.39    60.0     0.16     0.0      0.0     0.05 3.00E-4
.....
 7.00E-3   3998.6    274.2   750.0    3.993     0.0      0.0     0.05 3.00E-4
 6.88E-3   4067.0    278.9   760.0    4.049     0.0      0.0     0.05 3.00E-4
 6.77E-3   4135.7    283.6   770.0    4.105     0.0      0.0     0.05 3.00E-4
 6.66E-3   4204.9    288.3   780.0     4.16     0.0      0.0     0.05 3.00E-4
 6.55E-3   4274.4    293.1   790.0    4.216     0.0      0.0     0.05 3.00E-4
 6.44E-3   4344.3    297.9   800.0    4.271     0.0      0.0     0.05 3.00E-4
 6.34E-3   4414.6    302.7   810.0    4.327     0.0      0.0     0.05 3.00E-4
 6.24E-3   4485.3    307.6   820.0    4.382     0.0      0.0     0.05 3.00E-4
```

Port Depth = 50 m

```
/ UM3. 7/3/2019 11:54:28 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0      0.05    -135.0      35.1      28.0       0.0       0.0      0.05     225.0    0.0003     22.49
      15.0      0.05    -135.0      35.1      27.9       0.0       0.0      0.05     225.0    0.0003     22.53
      20.0      0.05    -135.0      35.2      27.7       0.0       0.0      0.05     225.0    0.0003     22.67
      60.0      0.05    -135.0      35.2      27.6       0.0       0.0      0.05     225.0    0.0003      22.7
      70.0      0.05    -135.0      35.2      27.4       0.0       0.0      0.05     225.0    0.0003     22.76
      80.0      0.05    -135.0      35.2      26.8       0.0       0.0      0.05     225.0    0.0003     22.96
      90.0      0.05    -135.0      35.0      26.1       0.0       0.0      0.05     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)       ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    40.0   -90.0   225.0      1.0   100.0  5000.0    50.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:       31.94; effluent density (sigma-T)     17.26; effluent velocity      2.829(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     50.0     0.05     0.15     37.0     45.0     28.0     28.0      1.0      0.0      0.0;
 100    52.31     0.05    1.099    35.45    30.02    3.865    3.865    7.211  -0.0942  -0.0942;
 .....
 400     49.4     0.05    9.312    35.22    27.78    0.265    0.265    105.2   -7.527   -7.527;
 488    32.78     0.05    26.12     35.2    27.67   0.0463   0.0463    600.9   -22.24   -22.24; trap level;
 500    30.15     0.05    30.11     35.2    27.67   0.0366   0.0366    761.4   -26.57   -26.57;
 536    26.44     0.05    37.24     35.2    27.67   0.0256   0.0256   1088.2   -41.92   -41.92; local maximum rise o
 566    31.59     0.05     42.0     35.2    27.68   0.0196   0.0196   1423.0   -62.83   -62.83; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       42.00 m
    conc   dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 1.95E-2   1427.6    42.29    90.0 0.00638      0.0      0.0     0.05 3.00E-4
 1.96E-2   1423.9    44.82   100.0  0.0619      0.0      0.0     0.05 3.00E-4
 .....
 7.14E-3   3915.1    159.6   450.0   2.006      0.0      0.0     0.05 3.00E-4
 6.97E-3   4010.9    163.5   460.0   2.062      0.0      0.0     0.05 3.00E-4
 6.80E-3   4107.5    167.4   470.0   2.117      0.0      0.0     0.05 3.00E-4
 6.65E-3   4205.0    171.4   480.0   2.173      0.0      0.0     0.05 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 7/3/2019 11:29:15 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0      0.05    -135.0      35.1      28.0       0.0       0.0      0.05     225.0    0.0003     22.49
.....
      90.0      0.05    -135.0      35.0      26.1       0.0       0.0      0.05     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)       ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    15.0   -90.0   225.0      1.0   100.0  5000.0    75.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:       31.45; effluent density (sigma-T)     17.26; effluent velocity      2.829(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     75.0     0.05     0.15     37.0     45.0     28.0     28.0      1.0      0.0      0.0;
 100    77.31     0.05      1.1    35.45    29.51    3.865    3.865    7.209  -0.0943  -0.0943;
 .....
 482    72.46     0.05    13.24    35.21    27.13    0.204    0.204    136.6    -9.98    -9.98; local maximum rise o
 500    72.56     0.05    13.16    35.21    27.13    0.203    0.203    137.1   -10.71   -10.71;
 528    73.37     0.05    12.95    35.21    27.14    0.192    0.192    145.0    -12.3    -12.3; end overlap;
 540     74.9     0.05    14.04    35.21    27.14    0.159    0.159    175.5   -14.27   -14.27; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       14.04 m
    conc   dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 0.15855    175.6    15.78    30.0  0.0545      0.0      0.0     0.05 3.00E-4
 0.15516    179.5    17.62    40.0    0.11      0.0      0.0     0.05 3.00E-4
 .....
 7.37E-2    379.1    41.84   150.0   0.721      0.0      0.0     0.05 3.00E-4
 6.95E-2    401.8    44.36   160.0   0.777      0.0      0.0     0.05 3.00E-4
 6.57E-2    425.0    46.93   170.0   0.832      0.0      0.0     0.05 3.00E-4
 6.23E-2    448.6    49.55   180.0   0.888      0.0      0.0     0.05 3.00E-4
 .....
 7.07E-3   3958.6    437.7  1100.0   5.999      0.0      0.0     0.05 3.00E-4
 6.98E-3   4008.2    443.2  1110.0   6.055      0.0      0.0     0.05 3.00E-4
 6.90E-3   4057.9    448.7  1120.0    6.11      0.0      0.0     0.05 3.00E-4
 6.81E-3   4107.9    454.2  1130.0   6.166      0.0      0.0     0.05 3.00E-4
```

Appendix A.2 Discharge at 45 °C and 0.2 m/s ambient current

Port Depth = 0 m

```
/ UM3. 7/4/2019 10:42:09 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: ------------------------------------

Ambient Table:
    Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir   Disprsn    Density
        m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg  m0.67/s2    sigma-T
      0.0        0.2     -135.0       35.1       28.0        0.0        0.0        0.2      225.0    0.0003      22.49
     15.0        0.2     -135.0       35.1       27.9        0.0        0.0        0.2      225.0    0.0003      22.53
     20.0        0.2     -135.0       35.2       27.7        0.0        0.0        0.2      225.0    0.0003      22.67
     60.0        0.2     -135.0       35.2       27.6        0.0        0.0        0.2      225.0    0.0003       22.7
     70.0        0.2     -135.0       35.2       27.4        0.0        0.0        0.2      225.0    0.0003      22.76
     80.0        0.2     -135.0       35.2       26.8        0.0        0.0        0.2      225.0    0.0003      22.96
     90.0        0.2     -135.0       35.0       26.1        0.0        0.0        0.2      225.0    0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    90.0   -90.0   225.0     1.0   100.0  6000.0     0.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:      32.53; effleunt density (sigma-T)     17.26; effleunt velocity     2.829(m/s);
           Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step         (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0         0.0      0.2     0.15     37.0     45.0     28.0     28.0      1.0      0.0      0.0;
   8      0.0634      0.2    0.174    36.72    42.51     23.9     23.9    1.171-0.000306-0.000306; matched energy radia
 100       1.594      0.2    1.042    35.36    30.34    3.865    3.865    7.212   -0.216   -0.216;
 200       3.618      0.2    3.832    35.14    28.35    0.603    0.603    46.24   -2.788   -2.788;
 229       4.343      0.2    5.041    35.12    28.19    0.353    0.353    78.82   -9.768   -9.768; local maximum rise or
 256       3.114      0.2    6.372    35.11    28.11    0.219    0.219    127.5    -20.1    -20.1; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of        6.37 m
    conc  dilutn    width distnce    time
   (ppm)               (m)     (m)   (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
  0.2179   127.8     6.424    30.0 0.00218     0.0      0.0      0.2 3.00E-4
 ....
 6.90E-2   405.2     27.98   510.0   0.669     0.0      0.0      0.2 3.00E-4
 6.77E-2   413.1     28.52   520.0   0.683     0.0      0.0      0.2 3.00E-4
 6.64E-2   421.1     29.08   530.0   0.697     0.0      0.0      0.2 3.00E-4
 .....
 7.02E-3  3987.8     275.5  3270.0   4.502     0.0      0.0      0.2 3.00E-4
 6.99E-3  4004.7     276.6  3280.0   4.516     0.0      0.0      0.2 3.00E-4
 6.96E-3  4021.7     277.8  3290.0    4.53     0.0      0.0      0.2 3.00E-4
```

Port Depth = 10 m

```
/ UM3. 7/4/2019 10:44:51 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: ------------------------------------

Ambient Table:
    Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir   Disprsn    Density
        m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg  m0.67/s2    sigma-T
      0.0        0.2     -135.0       35.1       28.0        0.0        0.0        0.2      225.0    0.0003      22.49
     15.0        0.2     -135.0       35.1       27.9        0.0        0.0        0.2      225.0    0.0003      22.53
     20.0        0.2     -135.0       35.2       27.7        0.0        0.0        0.2      225.0    0.0003      22.67
     60.0        0.2     -135.0       35.2       27.6        0.0        0.0        0.2      225.0    0.0003       22.7
     70.0        0.2     -135.0       35.2       27.4        0.0        0.0        0.2      225.0    0.0003      22.76
     80.0        0.2     -135.0       35.2       26.8        0.0        0.0        0.2      225.0    0.0003      22.96
     90.0        0.2     -135.0       35.0       26.1        0.0        0.0        0.2      225.0    0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    80.0   -90.0   225.0     1.0   100.0  6000.0    10.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:      32.47; effleunt density (sigma-T)     17.26; effleunt velocity     2.829(m/s);
           Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step         (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0        10.0      0.2     0.15     37.0     45.0     28.0     28.0      1.0      0.0      0.0;
 100       11.59      0.2    1.042    35.36    30.28    3.865    3.865    7.212   -0.216   -0.216;
 200       13.62      0.2    3.832    35.14    28.28    0.603    0.603    46.22   -2.788   -2.788;
 229       14.34      0.2    5.036    35.12    28.13    0.354    0.354    78.67   -9.778   -9.778; local maximum rise or
 300       10.34      0.2    9.828    35.11    27.97   0.0915   0.0915    304.4   -35.89   -35.89;
 335       7.194      0.2    13.91     35.1    27.96   0.0458   0.0458    608.8   -59.51   -59.51; trap level;
 337       6.983      0.2    14.19     35.1    27.96    0.044    0.044    633.4   -61.55   -61.55; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       14.19 m
    conc  dilutn    width distnce    time
   (ppm)               (m)     (m)   (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 4.39E-2   635.2     14.32    90.0 0.00411     0.0      0.0      0.2 3.00E-4
 4.39E-2   634.1     14.76   100.0   0.018     0.0      0.0      0.2 3.00E-4
 .....
 7.04E-3  3973.0     123.0  1660.0   2.185     0.0      0.0      0.2 3.00E-4
 6.99E-3  4001.9     123.9  1670.0   2.199     0.0      0.0      0.2 3.00E-4
 6.94E-3  4030.9     124.8  1680.0   2.212     0.0      0.0      0.2 3.00E-4
 6.89E-3  4059.9     125.7  1690.0   2.226     0.0      0.0      0.2 3.00E-4
 6.84E-3  4089.1     126.6  1700.0    2.24     0.0      0.0      0.2 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 7/4/2019 10:48:19 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
       0.0       0.2    -135.0      35.1      28.0       0.0       0.0       0.2     225.0    0.0003     22.49
      15.0       0.2    -135.0      35.1      27.9       0.0       0.0       0.2     225.0    0.0003     22.53
      20.0       0.2    -135.0      35.2      27.7       0.0       0.0       0.2     225.0    0.0003     22.67
      60.0       0.2    -135.0      35.2      27.6       0.0       0.0       0.2     225.0    0.0003      22.7
      70.0       0.2    -135.0      35.2      27.4       0.0       0.0       0.2     225.0    0.0003     22.76
      80.0       0.2    -135.0      35.2      26.8       0.0       0.0       0.2     225.0    0.0003     22.96
      90.0       0.2    -135.0      35.0      26.1       0.0       0.0       0.2     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal   Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)    (C)   (ppm)
    0.15    60.0   -90.0   225.0     1.0   100.0  6000.0    30.0    0.05    37.0   45.0    28.0

Simulation:
Froude number:      31.99; effluent density (sigma-T)     17.26; effluent velocity     2.829(m/s);
        Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     30.0      0.2      0.15     37.0     45.0     28.0     28.0      1.0      0.0      0.0;
 100    31.59      0.2     1.043    35.45    30.06    3.865    3.865    7.211   -0.216   -0.216;
 200    33.61      0.2     3.827    35.24    28.04    0.604    0.604     46.1   -2.788   -2.788;
 228    34.32      0.2     5.004    35.22    27.89    0.359    0.359    77.66   -9.355   -9.355; local maximum rise or
 300    30.31      0.2     9.805    35.21    27.73   0.0918   0.0918    303.3   -35.28   -35.28;
 352    25.14      0.2     16.42     35.2     27.7   0.0328   0.0328    849.3   -71.37   -71.37; acute zone;
 367    23.13      0.2     19.06     35.2    27.69   0.0244   0.0244   1143.0   -90.72   -90.72; trap level;
 391    19.85      0.2      24.2     35.2     27.7   0.0151   0.0151   1838.5   -163.6   -163.6; local maximum rise or
 400    21.68      0.2     26.09     35.2     27.7    0.013    0.013   2138.7   -202.1   -202.1;
 405    22.72      0.2     27.41     35.2     27.7   0.0118   0.0118   2361.3   -221.5   -221.5; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      27.41 m
    conc  dilutn    width distnce     time
   (ppm)              (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 1.17E-2  2366.8    27.78   320.0  0.00941      0.0      0.0      0.2 3.00E-4
 .....
 7.02E-3  3974.7    63.36   880.0    0.787      0.0      0.0      0.2 3.00E-4
 6.95E-3  4018.6    64.08   890.0    0.801      0.0      0.0      0.2 3.00E-4
 6.87E-3  4062.7     64.8   900.0    0.815      0.0      0.0      0.2 3.00E-4
```

Port Depth = 50 m

```
/ UM3. 7/4/2019 11:00:16 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
       0.0       0.2    -135.0      35.1      28.0       0.0       0.0       0.2     225.0    0.0003     22.49
 .....
      80.0       0.2    -135.0      35.2      26.8       0.0       0.0       0.2     225.0    0.0003     22.96
      90.0       0.2    -135.0      35.0      26.1       0.0       0.0       0.2     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal   Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)    (C)   (ppm)
    0.15    40.0   -90.0   225.0     1.0   100.0  6000.0    50.0    0.05    37.0   45.0    28.0

Simulation:
Froude number:      31.94; effluent density (sigma-T)     17.26; effluent velocity     2.829(m/s);
        Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     50.0      0.2      0.15     37.0     45.0     28.0     28.0      1.0      0.0      0.0;
 100    51.59      0.2     1.043    35.45    30.02    3.865    3.865    7.211   -0.216   -0.216;
 200    53.61      0.2     3.827    35.24    27.99    0.604    0.604    46.09   -2.788   -2.788;
 228    54.32      0.2     5.001    35.22    27.84    0.359    0.359    77.56   -9.364   -9.364; local maximum rise or
 300     50.3      0.2     9.803    35.21    27.68   0.0919   0.0919    303.1   -35.22   -35.22;
 352    45.14      0.2     16.42     35.2    27.65   0.0328   0.0328    848.9   -71.25   -71.25; acute zone;
 367    43.12      0.2     19.06     35.2    27.65   0.0244   0.0244   1142.5   -90.54   -90.54; trap level;
 392    39.71      0.2     24.43     35.2    27.65   0.0149   0.0149   1874.3   -173.6   -173.6; local maximum rise or
 400    41.87      0.2     26.33     35.2    27.65   0.0128   0.0128   2178.9   -232.3   -232.3;
 405    42.92      0.2     27.67     35.2    27.65   0.0116   0.0116   2405.7   -253.9   -253.9; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      27.67 m
    conc  dilutn    width distnce     time
   (ppm)              (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 1.15E-2  2416.5    27.72   360.0  0.00132      0.0      0.0      0.2 3.00E-4
 1.15E-2  2410.0    28.27   370.0   0.0152      0.0      0.0      0.2 3.00E-4
 .....
 7.04E-3  3964.0    62.56   910.0    0.765      0.0      0.0      0.2 3.00E-4
 6.96E-3  4008.0    63.28   920.0    0.779      0.0      0.0      0.2 3.00E-4
 6.89E-3  4052.2     64.0   930.0    0.793      0.0      0.0      0.2 3.00E-4
 6.81E-3  4096.7    64.72   940.0    0.807      0.0      0.0      0.2 3.00E-4
 6.74E-3  4141.4    65.44   950.0    0.821      0.0      0.0      0.2 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 7/4/2019 11:07:18 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0       0.2    -135.0      35.1      28.0       0.0       0.0       0.2     225.0    0.0003     22.49
.....
      90.0       0.2    -135.0      35.0      26.1       0.0       0.0       0.2     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    15.0   -90.0   225.0     1.0   100.0  6000.0    75.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:     31.45; effleunt density (sigma-T)     17.26; effleunt velocity     2.829(m/s);
        Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step      (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0     75.0      0.2      0.15     37.0     45.0     28.0     28.0      1.0       0.0       0.0;
 100    76.59      0.2     1.043    35.45    29.52    3.865    3.865    7.209    -0.216    -0.216;
 200    78.59      0.2     3.814    35.24    27.34     0.61     0.61    45.67    -2.789    -2.789;
 224    79.11      0.2     4.712    35.23    27.18    0.405    0.405    68.73    -7.684    -7.684; local maximum rise o
 280    76.49      0.2     7.828    35.21    27.02    0.144    0.144    192.7    -24.04    -24.04; trap level;
 300    75.31      0.2     9.562    35.21    27.03   0.0972   0.0972    286.4     -36.8     -36.8;
 303    75.29      0.2     9.745    35.21    27.03   0.0936   0.0936    297.4     -41.1     -41.1; local maximum rise o
 317    76.46      0.2     10.95     35.2    27.04   0.0739   0.0739    376.7    -57.64    -57.64; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      10.95 m
   conc  dilutn   width distnce     time
  (ppm)             (m)     (m)    (hrs)   (ppm)    (s-1)    (m/s)(m0.67/s2)
 7.38E-2   377.2   11.29    90.0  0.0118     0.0      0.0      0.2 3.00E-4
.....
 6.89E-2   404.4   15.12   180.0   0.137     0.0      0.0      0.2 3.00E-4
 6.76E-2   412.2   15.57   190.0   0.151     0.0      0.0      0.2 3.00E-4
 6.62E-2   420.6   16.02   200.0   0.165     0.0      0.0      0.2 3.00E-4
.....
 7.02E-3  3988.2   160.3  2130.0   2.845     0.0      0.0      0.2 3.00E-4
 6.97E-3  4012.6   161.3  2140.0   2.859     0.0      0.0      0.2 3.00E-4
 6.93E-3  4036.9   162.3  2150.0   2.873     0.0      0.0      0.2 3.00E-4
 6.89E-3  4061.4   163.3  2160.0   2.887     0.0      0.0      0.2 3.00E-4
 6.85E-3  4085.9   164.3  2170.0   2.901     0.0      0.0      0.2 3.00E-4
```

Appendix A.3 Discharge at 45 °C and 0.5 m/s ambient current

Port Depth = 0 m

```
/ UM3. 7/4/2019 10:18:11 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0       0.5    -135.0      35.1      28.0       0.0       0.0       0.5     225.0    0.0003     22.49
.....
      90.0       0.5    -135.0      35.0      26.1       0.0       0.0       0.5     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    90.0   -90.0   225.0     1.0   100.0  6000.0     0.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:     32.53; effleunt density (sigma-T)     17.26; effleunt velocity     2.829(m/s);
        Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step      (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0      0.0      0.5      0.15     37.0     45.0     28.0     28.0      1.0       0.0       0.0;
  10   0.0681      0.5     0.181    36.66    41.95    22.97    22.97    1.218  -0.00101  -0.00101; matched energy radia
 100    0.792      0.5     0.827    35.39     30.6    4.285    4.285    6.506    -0.203    -0.203;
 200    1.903      0.5     2.397    35.14    28.37    0.628    0.628    44.37    -3.489    -3.489;
 247     2.81      0.5     3.802    35.12    28.14    0.248    0.248    112.5    -24.94    -24.94; local maximum rise o
 263    2.205      0.5     4.449    35.11     28.1     0.18     0.18    154.5    -44.88    -44.88; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       4.45 m
   conc  dilutn   width distnce     time
  (ppm)             (m)     (m)    (hrs)   (ppm)    (s-1)    (m/s)(m0.67/s2)
 0.17996   154.8   4.526    70.0 0.00363     0.0      0.0      0.5 3.00E-4
.....
 6.97E-2   401.2   15.95   820.0    0.42     0.0      0.0      0.5 3.00E-4
 6.89E-2   405.8   16.13   830.0   0.426     0.0      0.0      0.5 3.00E-4
 6.81E-2   410.4   16.31   840.0   0.431     0.0      0.0      0.5 3.00E-4
 6.73E-2   414.9    16.5   850.0   0.437     0.0      0.0      0.5 3.00E-4
 6.66E-2   419.5   16.68   860.0   0.443     0.0      0.0      0.5 3.00E-4
.....
 7.01E-3  3991.3   158.8  5610.0   3.081     0.0      0.0      0.5 3.00E-4
 7.00E-3  4001.1   159.2  5620.0   3.087     0.0      0.0      0.5 3.00E-4
 6.98E-3  4010.9   159.6  5630.0   3.093     0.0      0.0      0.5 3.00E-4
 6.96E-3  4020.7   160.0  5640.0   3.098     0.0      0.0      0.5 3.00E-4
 6.95E-3  4030.5   160.4  5650.0   3.104     0.0      0.0      0.5 3.00E-4
```

Port Depth = 10 m

```
/ UM3. 7/4/2019 10:25:23 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: ------------------------------------

Ambient Table:
      Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
          m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
        0.0       0.5    -135.0      35.1      28.0       0.0       0.0       0.5     225.0    0.0003     22.49
       15.0       0.5    -135.0      35.1      27.9       0.0       0.0       0.5     225.0    0.0003     22.53
       20.0       0.5    -135.0      35.2      27.7       0.0       0.0       0.5     225.0    0.0003     22.67
       60.0       0.5    -135.0      35.2      27.6       0.0       0.0       0.5     225.0    0.0003      22.7
       70.0       0.5    -135.0      35.2      27.4       0.0       0.0       0.5     225.0    0.0003     22.76
       80.0       0.5    -135.0      35.2      26.8       0.0       0.0       0.5     225.0    0.0003     22.96
       90.0       0.5    -135.0      35.0      26.1       0.0       0.0       0.5     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    80.0   -90.0   225.0     1.0   100.0  6000.0    10.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:      32.47; effleunt density (sigma-T)     17.26; effleunt velocity     2.829(m/s);
         Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step       (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0      10.0      0.5      0.15     37.0     45.0     28.0     28.0      1.0       0.0       0.0;
 100     10.79      0.5     0.827    35.39    30.54    4.285    4.285    6.505    -0.203    -0.203;
 200      11.9      0.5     2.397    35.14    28.31    0.628    0.628    44.37     -3.49     -3.49;
 247      12.8      0.5     3.802    35.12    28.07    0.248    0.248    112.5     -25.2     -25.2; local maximum rise o
 296     10.85      0.5     6.157    35.11    27.98   0.0938   0.0938    296.9    -71.59    -71.59; acute zone;
 300     10.65      0.5     6.405    35.11    27.97   0.0867   0.0867    321.4    -75.45    -75.45;
 348     7.641      0.5     10.29     35.1    27.95   0.0335   0.0335    831.5    -149.4    -149.4; trap level;
 367      6.11      0.5     12.42     35.1    27.95    0.023    0.023   1211.4    -222.0    -222.0; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       12.42 m
    conc  dilutn    width distnce     time
   (ppm)             (m)     (m)     (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 2.29E-2  1215.0   12.52   320.0 0.00335      0.0      0.0      0.5 3.00E-4
.....|
 7.02E-3  3980.4   56.39  2260.0    1.081      0.0      0.0      0.5 3.00E-4
 6.99E-3  3999.9   56.67  2270.0    1.087      0.0      0.0      0.5 3.00E-4
 6.96E-3  4019.4   56.94  2280.0    1.092      0.0      0.0      0.5 3.00E-4
 6.92E-3  4039.0   57.22  2290.0    1.098      0.0      0.0      0.5 3.00E-4
 6.89E-3  4058.5    57.5  2300.0    1.103      0.0      0.0      0.5 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 7/4/2019 10:30:02 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: ------------------------------------

Ambient Table:
      Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
          m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
        0.0       0.5    -135.0      35.1      28.0       0.0       0.0       0.5     225.0    0.0003     22.49
       15.0       0.5    -135.0      35.1      27.9       0.0       0.0       0.5     225.0    0.0003     22.53
       20.0       0.5    -135.0      35.2      27.7       0.0       0.0       0.5     225.0    0.0003     22.67
       60.0       0.5    -135.0      35.2      27.6       0.0       0.0       0.5     225.0    0.0003      22.7
       70.0       0.5    -135.0      35.2      27.4       0.0       0.0       0.5     225.0    0.0003     22.76
       80.0       0.5    -135.0      35.2      26.8       0.0       0.0       0.5     225.0    0.0003     22.96
       90.0       0.5    -135.0      35.0      26.1       0.0       0.0       0.5     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    60.0   -90.0   225.0     1.0   100.0  6000.0    30.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:      31.99; effleunt density (sigma-T)     17.26; effleunt velocity     2.829(m/s);
         Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step       (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0      30.0      0.5      0.15     37.0     45.0     28.0     28.0      1.0       0.0       0.0;
 100     30.79      0.5     0.827    35.48    30.33    4.286    4.286    6.503    -0.203    -0.203;
 200      31.9      0.5     2.396    35.24    28.06    0.628    0.628    44.34    -3.495    -3.495;
 247     32.77      0.5     3.801    35.22    27.82    0.248    0.248    112.5    -26.66    -26.66; local maximum rise o
 296     30.82      0.5     6.155    35.21    27.73   0.0939   0.0939    296.8    -71.02    -71.02; acute zone;
 300     30.62      0.5     6.403    35.21    27.72   0.0867   0.0867    321.2    -74.76    -74.76;
 380     24.62      0.5     14.12     35.2    27.69   0.0178   0.0178   1566.0    -229.0    -229.0; trap level;
 400     22.39      0.5     17.22     35.2    27.69    0.012    0.012   2327.1    -353.4    -353.4;
 405     22.38      0.5     18.09     35.2    27.69   0.0108   0.0108   2569.3    -466.0    -466.0; local maximum rise o
 416     24.42      0.5     20.17     35.2    27.69  0.00872  0.00872   3194.5    -624.8    -624.8; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       20.17 m
    conc  dilutn    width distnce     time
   (ppm)             (m)     (m)     (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 8.69E-3  3205.1    20.3   890.0 0.00357      0.0      0.0      0.5 3.00E-4
 8.70E-3  3201.3   20.49   900.0 0.00913      0.0      0.0      0.5 3.00E-4
.....|
 6.99E-3  3987.2   33.85  1520.0    0.354      0.0      0.0      0.5 3.00E-4
 6.95E-3  4011.1   34.09  1530.0    0.359      0.0      0.0      0.5 3.00E-4
```

Port Depth = 50 m

```
/ UM3. 7/4/2019 10:34:07 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: ------------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0       0.5    -135.0      35.1      28.0       0.0       0.0       0.5     225.0    0.0003     22.49
.....
      90.0       0.5    -135.0      35.0      26.1       0.0       0.0       0.5     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    40.0   -90.0   225.0     1.0   100.0  6000.0    50.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:      31.94; effluent density (sigma-T)     17.26; effleunt velocity     2.829(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     50.0      0.5     0.15     37.0     45.0     28.0     28.0      1.0      0.0      0.0;
 100    50.79      0.5    0.827    35.48    30.28    4.286    4.286    6.503   -0.203   -0.203;
 200     51.9      0.5    2.396    35.24    28.01    0.628    0.628    44.34   -3.495   -3.495;
 246     52.8      0.5    3.764    35.22    27.78    0.253    0.253    110.2   -23.46   -23.46; local maximum rise o
 296    50.82      0.5    6.155    35.21    27.68   0.0939   0.0939    296.7   -70.93   -70.93; acute zone;
 300    50.62      0.5    6.403    35.21    27.67   0.0867   0.0867    321.2   -74.66   -74.66;
 380    44.61      0.5    14.12     35.2    27.64   0.0178   0.0178   1566.0   -228.6   -228.6; trap level;
 400    42.39      0.5    17.22     35.2    27.64    0.012    0.012   2326.9   -352.3   -352.3;
 405    42.29      0.5    18.09     35.2    27.64   0.0108   0.0108   2569.1   -458.7   -458.7; local maximum rise o
 417    44.52      0.5    20.37     35.2    27.64  0.00855  0.00855   3258.3   -634.1   -634.1; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       20.37 m
    conc  dilutn    width distnce     time
   (ppm)              (m)     (m)    (hrs)   (ppm)   (s-1)   (m/s)(m0.67/s2)
 8.51E-3  3271.7    20.43   900.0 0.00178     0.0     0.0     0.5 3.00E-4
.....
 7.01E-3  3977.7    33.32  1500.0   0.335     0.0     0.0     0.5 3.00E-4
 6.97E-3  4001.2    33.55  1510.0   0.341     0.0     0.0     0.5 3.00E-4
 6.93E-3  4024.9    33.78  1520.0   0.346     0.0     0.0     0.5 3.00E-4
 6.89E-3  4048.8    34.02  1530.0   0.352     0.0     0.0     0.5 3.00E-4
 6.85E-3  4072.9    34.25  1540.0   0.357     0.0     0.0     0.5 3.00E-4
 6.81E-3  4097.2    34.48  1550.0   0.363     0.0     0.0     0.5 3.00E-4
 6.76E-3  4121.6    34.72  1560.0   0.368     0.0     0.0     0.5 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 7/4/2019 10:38:09 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: ------------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0       0.5    -135.0      35.1      28.0       0.0       0.0       0.5     225.0    0.0003     22.49
      15.0       0.5    -135.0      35.1      27.9       0.0       0.0       0.5     225.0    0.0003     22.53
      20.0       0.5    -135.0      35.2      27.7       0.0       0.0       0.5     225.0    0.0003     22.67
      60.0       0.5    -135.0      35.2      27.6       0.0       0.0       0.5     225.0    0.0003      22.7
      70.0       0.5    -135.0      35.2      27.4       0.0       0.0       0.5     225.0    0.0003     22.76
      80.0       0.5    -135.0      35.2      26.8       0.0       0.0       0.5     225.0    0.0003     22.96
      90.0       0.5    -135.0      35.0      26.1       0.0       0.0       0.5     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    15.0   -90.0   225.0     1.0   100.0  6000.0    75.0    0.05    37.0    45.0    28.0

Simulation:
Froude number:      31.45; effluent density (sigma-T)     17.26; effleunt velocity     2.829(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     75.0      0.5     0.15     37.0     45.0     28.0     28.0      1.0      0.0      0.0;
 100    75.79      0.5    0.827    35.48    29.82    4.287    4.287      6.5   -0.203   -0.203;
 200     76.9      0.5    2.395    35.24    27.43    0.629    0.629    44.31   -3.509   -3.509;
 241    77.62      0.5    3.583    35.22    27.17    0.279    0.279    99.78   -21.23   -21.23; local maximum rise o
 291    75.77      0.5    5.857    35.21    27.06    0.104    0.104    268.6   -60.74   -60.74; trap level;
 300    75.36      0.5    6.402    35.21    27.06   0.0868   0.0868    321.0   -71.26   -71.26; acute zone;
 313    75.02      0.5     7.28     35.2    27.07   0.0671   0.0671    415.2   -110.8   -110.8; local maximum rise o
 323    75.76      0.5    8.035     35.2    27.07    0.055    0.055    506.1   -142.4   -142.4; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of        8.03 m
    conc  dilutn    width distnce     time
   (ppm)              (m)     (m)    (hrs)   (ppm)   (s-1)   (m/s)(m0.67/s2)
 5.49E-2   507.2    8.159   210.0 0.00478     0.0     0.0     0.5 3.00E-4
.....
 7.02E-3  3984.6    87.44  3470.0   1.816     0.0     0.0     0.5 3.00E-4
 7.00E-3  3999.1    87.76  3480.0   1.821     0.0     0.0     0.5 3.00E-4
 6.97E-3  4013.7    88.08  3490.0   1.827     0.0     0.0     0.5 3.00E-4
 6.95E-3  4028.3     88.4  3500.0   1.833     0.0     0.0     0.5 3.00E-4
 6.92E-3  4042.9    88.73  3510.0   1.838     0.0     0.0     0.5 3.00E-4
```

APPENDIX B VPLUMES RESULTS FOR COOLING WATER DISCHARGE MODELLING

Appendix B.1 Discharge at 45 °C and 0.05 m/s ambient current

Port Depth = 2 m

```
/ UM3. 7/16/2019 8:05:07 AM
Case 1; ambient file c:\plumes\VP plume 1.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0      0.05    -135.0      35.1      28.0       0.0       0.0      0.05    -135.0    0.0003     22.49
      15.0      0.05    -135.0      35.1      27.9       0.0       0.0      0.05    -135.0    0.0003     22.53
      20.0      0.05    -135.0      35.2      27.7       0.0       0.0      0.05    -135.0    0.0003     22.67
      60.0      0.05    -135.0      35.2      27.6       0.0       0.0      0.05    -135.0    0.0003      22.7
      70.0      0.05    -135.0      35.2      27.4       0.0       0.0      0.05    -135.0    0.0003     22.76
      80.0      0.05    -135.0      35.2      26.8       0.0       0.0      0.05    -135.0    0.0003     22.96
      90.0      0.05    -135.0      35.0      26.1       0.0       0.0      0.05    -135.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppm)
   0.254    88.0   -90.0   225.0     1.0   100.0  5000.0     2.0    0.12    35.0     45.0  2000.0

Simulation:
Froude number:      18.44; effleunt density (sigma-T)     15.77; effleunt velocity     2.368(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0      2.0     0.05    0.254     35.0     45.0   2000.0   2000.0      1.0      0.0      0.0;
 100    5.909     0.05    1.986    35.09    30.32    276.1    276.1    7.203   -0.204   -0.204;
 132    8.149     0.05    4.108    35.09    29.37    165.0    165.0    12.05   -0.642   -0.642; begin overlap;
 200    9.005     0.05    6.428    35.09    29.18    142.7    142.7    13.93   -1.149   -1.149;
 244    9.063     0.05    6.791    35.09    29.17    141.8    141.8    14.02   -1.329   -1.329; local maximum rise or
 300    8.953     0.05    6.275    35.09    29.17    141.4    141.4    14.05   -1.571   -1.571;
 349    8.151     0.05     5.07    35.09    29.07    130.8    130.8    15.19    -2.04    -2.04; end overlap;
 398    1.255     0.05    6.708     35.1    28.41    52.54    52.54    37.82   -4.118   -4.118; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       6.71 m
    conc  dilutn    width distnce    time
   (ppm)             (m)     (m)    (hrs)   (ppm)   (s-1)   (m/s)(m0.67/s2)
  52.515   37.84   7.283    10.0  0.0232     0.0     0.0    0.05 3.00E-4
  .....
  3.1076   643.3   157.8   540.0   2.968     0.0     0.0    0.05 3.00E-4
 3.03255   659.3   161.7   550.0   3.023     0.0     0.0    0.05 3.00E-4
 2.95889   675.7   165.6   560.0   3.079     0.0     0.0    0.05 3.00E-4
 2.88966   691.9   169.6   570.0   3.134     0.0     0.0    0.05 3.00E-4
 2.82309   708.2   173.6   580.0    3.19     0.0     0.0    0.05 3.00E-4
```

Port Depth = 10 m

```
/ UM3. 7/4/2019 1:27:26 PM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
      Depth    Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
          m        m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
        0.0       0.05    -135.0      35.1      28.0       0.0       0.0      0.05     225.0    0.0003     22.49
       15.0       0.05    -135.0      35.1      27.9       0.0       0.0      0.05     225.0    0.0003     22.53
 .....
       80.0       0.05    -135.0      35.2      26.8       0.0       0.0      0.05     225.0    0.0003     22.96
       90.0       0.05    -135.0      35.0      26.1       0.0       0.0      0.05     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppm)
   0.254    80.0   -90.0   225.0     1.0   100.0  6000.0    10.0    0.12    35.0     45.0  2000.0

Simulation:
Froude number:       18.42; effluent density (sigma-T)     15.77; effluent velocity     2.368(m/s);
          Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step        (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0       10.0     0.05    0.254     35.0     45.0   2000.0   2000.0      1.0       0.0       0.0;
 100      13.91     0.05    1.987    35.09    30.28    276.1    276.1    7.202    -0.204    -0.204;
 131       16.1     0.05    4.043    35.09    29.34    167.0    167.0     11.9    -0.627    -0.627; begin overlap;
 200      16.93     0.05     6.38     35.1    29.14    145.1    145.1    13.69    -1.105    -1.105;
 244      16.98     0.05    6.735     35.1    29.13    144.3    144.3    13.77    -1.266    -1.266; local maximum rise o
 300      16.88     0.05    6.219     35.1    29.13    144.1    144.1     13.8     -1.48     -1.48;
 350      16.12     0.05    4.967     35.1    29.04    134.1    134.1    14.82    -1.916    -1.916; end overlap;
 400      9.132     0.05    6.718     35.1    28.36    52.75    52.75    37.67    -4.006    -4.006;
 426      3.907     0.05    9.088     35.1     28.2    31.52    31.52    63.03    -5.632    -5.632; matched energy radia
 427      3.684     0.05      9.2     35.1    28.19     30.9     30.9    64.29    -5.706    -5.706; matched energy radia
 428      3.459     0.05    9.313     35.1    28.19     30.3     30.3    65.58    -5.781    -5.781; matched energy radia
 434      2.075     0.05    10.03     35.1    28.16     26.9     26.9    73.85    -6.256    -6.256; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of      10.03 m
    conc   dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)    (ppm)     (s-1)     (m/s)(m0.67/s2)
  26.851     74.0    10.21    10.0   0.0064      0.0       0.0      0.05 3.00E-4
 | .....
 3.11598    641.4    120.4   420.0    2.284      0.0       0.0      0.05 3.00E-4
  3.0263    660.4    124.0   430.0     2.34      0.0       0.0      0.05 3.00E-4
 2.94083    679.6    127.6   440.0    2.395      0.0       0.0      0.05 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 7/4/2019 1:35:29 PM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
      Depth    Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
          m        m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
        0.0       0.05    -135.0      35.1      28.0       0.0       0.0      0.05     225.0    0.0003     22.49
 .....
       90.0       0.05    -135.0      35.0      26.1       0.0       0.0      0.05     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppm)
   0.254    60.0   -90.0   225.0     1.0   100.0  6000.0    30.0    0.12    35.0     45.0  2000.0

Simulation:
Froude number:        18.2; effluent density (sigma-T)     15.77; effluent velocity     2.368(m/s);
          Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step        (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0       30.0     0.05    0.254     35.0     45.0   2000.0   2000.0      1.0       0.0       0.0;
 100      33.91     0.05    1.991    35.17    30.06    276.1    276.1    7.202    -0.204    -0.204;
 .....
 244       37.0     0.05    6.751    35.19    28.91    143.5    143.5    13.85    -1.307    -1.307; local maximum rise o
 300      36.89     0.05    6.233    35.19    28.91    143.2    143.2    13.88    -1.542    -1.542;
 349       36.1     0.05    5.024    35.19    28.82    132.7    132.7    14.98      -2.0      -2.0; end overlap;
 400      28.87     0.05    6.733    35.19    28.11     51.3     51.3    38.73    -4.141    -4.141;
 450      17.49     0.05    12.29    35.19    27.85    19.06    19.06    104.2    -7.805    -7.805; trap level;
 460       15.7     0.05    14.45    35.19    27.85    16.37    16.37    121.3    -8.577    -8.577; begin overlap;
 500      13.38     0.05    19.09    35.18    27.86    14.11    14.11    140.8     -10.2     -10.2;
 556      12.72     0.05    21.12    35.17    27.86    13.71    13.71    144.9    -11.73    -11.73; local maximum rise o
 600      13.12     0.05    20.19    35.17    27.86    13.64    13.64    145.6     -12.9     -12.9;
 643      15.56     0.05    17.93    35.17    27.86    12.59    12.59    157.9    -14.94    -14.94; end overlap;
 651      17.88     0.05    18.88    35.16    27.86    10.98    10.98    180.9     -16.3     -16.3; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      18.88 m
    conc   dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)    (ppm)     (s-1)     (m/s)(m0.67/s2)
 10.9777    181.0    20.23    30.0   0.0386      0.0       0.0      0.05 3.00E-4
 .....
  3.1275    638.3    92.03   300.0    1.539      0.0       0.0      0.05 3.00E-4
 3.02075    660.9     95.3   310.0    1.594      0.0       0.0      0.05 3.00E-4
 2.91978    683.8     98.6   320.0     1.65      0.0       0.0      0.05 3.00E-4
```

Port Depth = 50 m

```
/ UM3. 7/4/2019 2:38:56 PM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir    Disprsn    Density
         m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg   m0.67/s2    sigma-T
       0.0       0.05     -135.0       35.1       28.0        0.0        0.0       0.05      225.0     0.0003      22.49
 .....
      90.0       0.05     -135.0       35.0       26.1        0.0        0.0       0.05      225.0     0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)       ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    40.0   -90.0   225.0      1.0   100.0  6000.0    50.0    0.12    35.0    45.0  2000.0

Simulation:
Froude number:      18.18; effleunt density (sigma-T)     15.77; effleunt velocity     2.368(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     50.0     0.05    0.254     35.0     45.0   2000.0   2000.0      1.0      0.0      0.0;
 100    53.91     0.05    1.992    35.17    30.02    276.1    276.1    7.201   -0.204   -0.204;
 131    56.08     0.05    4.049    35.18    29.07    167.5    167.5    11.86   -0.626   -0.626; begin overlap;
 200    56.94     0.05    6.393    35.19    28.87    144.6    144.6    13.74    -1.13    -1.13;
 244    56.99     0.05    6.748    35.19    28.86    143.7    143.7    13.83   -1.305   -1.305; local maximum rise o
 300    56.88     0.05    6.229    35.19    28.86    143.4    143.4    13.86   -1.539   -1.539;
 349     56.1     0.05    5.019    35.19    28.77    132.9    132.9    14.95   -1.996   -1.996; end overlap;
 400    48.87     0.05    6.724    35.19    28.06    51.38    51.38    38.67   -4.133   -4.133;
 500    21.15     0.05     22.9     35.2    27.72    7.092    7.092    280.1   -15.06   -15.06;
 501    20.79     0.05    23.22     35.2    27.72    6.953    6.953    285.7   -15.26   -15.26; matched energy radia
 506    18.95     0.05    24.85     35.2    27.72    6.298    6.298    315.4   -16.32   -16.32; trap level;
 509    18.24     0.05    25.94     35.2    27.72    6.048    6.048    328.5   -16.77   -16.77; begin overlap;
 578    16.16     0.05    32.61     35.2    27.73    5.675    5.675    350.0   -19.05   -19.05; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of      32.61 m
    conc  dilutn   width distnce     time
   (ppm)             (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 5.66521   350.7   33.32    30.0    0.017      0.0      0.0     0.05 3.00E-4
 .....
 3.08599   645.7   82.78   210.0    1.017      0.0      0.0     0.05 3.00E-4
 2.97494   669.9   85.94   220.0    1.073      0.0      0.0     0.05 3.00E-4
 2.87005   694.5   89.13   230.0    1.128      0.0      0.0     0.05 3.00E-4
  2.7709   719.4   92.37   240.0    1.184      0.0      0.0     0.05 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 7/4/2019 2:42:31 PM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir    Disprsn    Density
         m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg   m0.67/s2    sigma-T
       0.0       0.05     -135.0       35.1       28.0        0.0        0.0       0.05      225.0     0.0003      22.49
 .....
      90.0       0.05     -135.0       35.0       26.1        0.0        0.0       0.05      225.0     0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)       ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    15.0   -90.0   225.0      1.0   100.0  6000.0    75.0    0.12    35.0    45.0  2000.0

Simulation:
Froude number:      17.96; effleunt density (sigma-T)     15.77; effleunt velocity     2.368(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     75.0     0.05    0.254     35.0     45.0   2000.0   2000.0      1.0      0.0      0.0;
 100    78.91     0.05    2.001    35.17    29.47    276.1    276.1      7.2   -0.205   -0.205;
 129     80.9     0.05    3.924    35.18    28.49    174.0    174.0    11.42   -0.586   -0.586; begin overlap;
 200     81.7     0.05    6.264    35.18    28.26    151.8    151.8    13.09   -1.044   -1.044;
 243    81.74     0.05    6.594    35.18    28.25    151.0    151.0    13.16   -1.189   -1.189; local maximum rise o
 300    81.65     0.05     6.07    35.18    28.25    150.8    150.8    13.18   -1.392   -1.392;
 351    80.88     0.05    4.788    35.18    28.14    139.8    139.8    14.21   -1.816   -1.816; end overlap;
 400    74.17     0.05    6.535    35.19    27.43    55.97    55.97    35.49   -3.743   -3.743;
 424    69.86     0.05    9.356    35.19    27.37     34.8     34.8    57.08   -5.222   -5.222; trap level;
 449    66.48     0.05    13.53     35.2    27.39    23.24    23.24    85.46    -7.01    -7.01; begin overlap;
 500    63.64     0.05    18.45     35.2    27.42    17.22    17.22    115.4   -10.25   -10.25;
 529    63.34     0.05    19.09     35.2    27.42     16.8     16.8    118.2   -11.82   -11.82; local maximum rise o
 581    64.94     0.05    18.48     35.2    27.43    15.66    15.66    126.8   -15.35   -15.35; end overlap;
 598    68.35     0.05    20.95     35.2    27.44    11.78    11.78    168.6   -19.11   -19.11; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of     20.95 m
    conc  dilutn   width distnce     time
   (ppm)             (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 11.7645   168.8   21.54    30.0   0.0165      0.0      0.0     0.05 3.00E-4
 .....
 3.08669   646.8   111.0   350.0    1.794      0.0      0.0     0.05 3.00E-4
 2.99323   667.0   114.5   360.0     1.85      0.0      0.0     0.05 3.00E-4
 2.90436   687.5   118.0   370.0    1.905      0.0      0.0     0.05 3.00E-4
```

Appendix B.2 Discharge at 45 °C and 0.2 m/s ambient current

Port Depth = 2 m

```
/ UM3. 7/16/2019 8:09:18 AM
Case 1; ambient file c:\plumes\VP plume 1.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
       0.0       0.2    -135.0      35.1      28.0       0.0       0.0       0.2    -135.0    0.0003     22.49
      15.0       0.2    -135.0      35.1      27.9       0.0       0.0       0.2    -135.0    0.0003     22.53
      20.0       0.2    -135.0      35.2      27.7       0.0       0.0       0.2    -135.0    0.0003     22.67
      60.0       0.2    -135.0      35.2      27.6       0.0       0.0       0.2    -135.0    0.0003      22.7
      70.0       0.2    -135.0      35.2      27.4       0.0       0.0       0.2    -135.0    0.0003     22.76
      80.0       0.2    -135.0      35.2      26.8       0.0       0.0       0.2    -135.0    0.0003     22.96
      90.0       0.2    -135.0      35.0      26.1       0.0       0.0       0.2    -135.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)       ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppm)
   0.254    88.0   -90.0   225.0      1.0   100.0  5000.0     2.0    0.12    35.0     45.0  2000.0

Simulation:
Froude number:       18.44; effluent density (sigma-T)      15.77; effluent velocity      2.368(m/s);
        Depth  Amb-cur     P-dia  Eff-sal      Temp  Polutnt  4/3Eddy   Dilutn   x-posn    y-posn
Step      (m)    (m/s)       (m)    (psu)       (C)    (ppm)    (ppm)       ()      (m)       (m)
   0      2.0      0.2     0.254     35.0      45.0   2000.0   2000.0      1.0      0.0       0.0;
 100    4.402      0.2     1.764    35.09     30.35    278.4    278.4    7.142   -0.383    -0.383;
 200    6.588      0.2     5.216     35.1     28.45    57.26    57.26     34.7   -4.397    -4.397;
 208    6.643      0.2     5.361     35.1     28.43     54.3     54.3    36.59   -5.726    -5.726; local maximum rise o
 262    3.998      0.2      8.27     35.1     28.15    21.87    21.87    90.83   -16.26    -16.26; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of        8.27 m
    conc  dilutn    width distnce    time
   (ppm)              (m)     (m)   (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
  21.845   90.96    8.526    30.0 0.00972     0.0      0.0      0.2 3.00E-4
. . . .
 3.08164   648.4     81.6  1250.0   1.704     0.0      0.0      0.2 3.00E-4
 3.05244   654.6    82.38  1260.0   1.718     0.0      0.0      0.2 3.00E-4
 3.02369   660.8    83.17  1270.0   1.732     0.0      0.0      0.2 3.00E-4
 2.99539   667.1    83.96  1280.0   1.746     0.0      0.0      0.2 3.00E-4
 2.96752   673.4    84.75  1290.0    1.76     0.0      0.0      0.2 3.00E-4
 2.94009   679.7    85.54  1300.0   1.774     0.0      0.0      0.2 3.00E-4
 2.91308   686.0    86.33  1310.0   1.787     0.0      0.0      0.2 3.00E-4
 2.88647   692.3    87.13  1320.0   1.801     0.0      0.0      0.2 3.00E-4
```

Port Depth = 10 m

```
/ UM3. 7/5/2019 11:06:40 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
       0.0       0.2    -135.0      35.1      28.0       0.0       0.0       0.2     225.0    0.0003     22.49
      15.0       0.2    -135.0      35.1      27.9       0.0       0.0       0.2     225.0    0.0003     22.53
      20.0       0.2    -135.0      35.2      27.7       0.0       0.0       0.2     225.0    0.0003     22.67
      60.0       0.2    -135.0      35.2      27.6       0.0       0.0       0.2     225.0    0.0003      22.7
      70.0       0.2    -135.0      35.2      27.4       0.0       0.0       0.2     225.0    0.0003     22.76
      80.0       0.2    -135.0      35.2      26.8       0.0       0.0       0.2     225.0    0.0003     22.96
      90.0       0.2    -135.0      35.0      26.1       0.0       0.0       0.2     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)       ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppm)
   0.254    80.0   -90.0   225.0      1.0   100.0  6000.0    10.0    0.12    35.0     45.0  2000.0

Simulation:
Froude number:       18.42; effluent density (sigma-T)      15.77; effluent velocity      2.368(m/s);
        Depth  Amb-cur     P-dia  Eff-sal      Temp  Polutnt  4/3Eddy   Dilutn   x-posn    y-posn
Step      (m)    (m/s)       (m)    (psu)       (C)    (ppm)    (ppm)       ()      (m)       (m)
   0     10.0      0.2     0.254     35.0      45.0   2000.0   2000.0      1.0      0.0       0.0;
 100     12.4      0.2     1.764    35.09      30.3    278.4    278.4    7.141   -0.383    -0.383;
 200    14.58      0.2     5.213     35.1      28.4    57.33    57.33    34.66   -4.391    -4.391;
 208    14.64      0.2     5.357     35.1     28.38    54.37    54.37    36.54   -5.716    -5.716; local maximum rise o
 300    8.936      0.2     12.04     35.1     28.01    10.32    10.32    192.5   -26.33    -26.33;
 318    7.066      0.2     14.41     35.1     27.99    7.227    7.227    274.9   -33.49    -33.49; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       14.41 m
    conc  dilutn    width distnce    time
   (ppm)              (m)     (m)   (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 7.20603   275.7    14.53    50.0 0.00367     0.0      0.0      0.2 3.00E-4
 7.21925   275.2    14.97    60.0  0.0176     0.0      0.0      0.2 3.00E-4
. . . .
 3.06609   650.5    47.05   640.0   0.823     0.0      0.0      0.2 3.00E-4
 3.02457   659.4     47.7   650.0   0.837     0.0      0.0      0.2 3.00E-4
 2.98396   668.4    48.36   660.0   0.851     0.0      0.0      0.2 3.00E-4
 2.94423   677.5    49.01   670.0   0.865     0.0      0.0      0.2 3.00E-4
 2.90535   686.6    49.67   680.0   0.879     0.0      0.0      0.2 3.00E-4
 2.86731   695.7    50.34   690.0   0.893     0.0      0.0      0.2 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 7/5/2019 11:13:57 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
      Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
          m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
        0.0       0.2    -135.0      35.1      28.0       0.0       0.0       0.2     225.0    0.0003     22.49
       15.0       0.2    -135.0      35.1      27.9       0.0       0.0       0.2     225.0    0.0003     22.53
       20.0       0.2    -135.0      35.2      27.7       0.0       0.0       0.2     225.0    0.0003     22.67
       60.0       0.2    -135.0      35.2      27.6       0.0       0.0       0.2     225.0    0.0003      22.7
       70.0       0.2    -135.0      35.2      27.4       0.0       0.0       0.2     225.0    0.0003     22.76
       80.0       0.2    -135.0      35.2      26.8       0.0       0.0       0.2     225.0    0.0003     22.96
       90.0       0.2    -135.0      35.0      26.1       0.0       0.0       0.2     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)       ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppm)
   0.254    60.0   -90.0   225.0      1.0   100.0  6000.0    30.0    0.12    35.0     45.0  2000.0

Simulation:
Froude number:       18.2; effluent density (sigma-T)     15.77; effluent velocity      2.368(m/s);
       Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step     (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0    30.0      0.2    0.254     35.0     45.0   2000.0   2000.0      1.0       0.0       0.0;
 100    32.4      0.2    1.764    35.17    30.09    278.6    278.6    7.137    -0.382    -0.382;
 200   34.56      0.2    5.187    35.19    28.17    57.91    57.91    34.31    -4.346    -4.346;
 208   34.61      0.2    5.327    35.19    28.14     55.0     55.0    36.12    -5.645    -5.645; local maximum rise or
 300   28.93      0.2    11.96     35.2    27.76    10.45    10.45    190.1    -25.74    -25.74;
 370   19.46      0.2    24.02     35.2    27.71    2.613    2.613    760.3    -67.66    -67.66; trap level;
 373   18.94      0.2    24.77     35.2    27.71    2.462    2.462    806.8    -71.01    -71.01; acute zone;
 383   18.33      0.2    26.01     35.2    27.71    2.246    2.246    884.4    -79.97    -79.97; local maximum rise or
 398   20.18      0.2     27.8    35.19    27.72    1.952    1.952   1017.6    -95.21    -95.21; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      27.80 m
    conc  dilutn    width distnce     time
   (ppm)              (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 1.94703  1020.3    28.09   140.0  0.00744      0.0      0.0      0.2 3.00E-4
 1.94946  1019.0    28.64   150.0   0.0213      0.0      0.0      0.2 3.00E-4
  1.9504  1018.5    29.19   160.0   0.0352      0.0      0.0      0.2 3.00E-4
 1.95094  1018.3    29.75   170.0   0.0491      0.0      0.0      0.2 3.00E-4
  1.9512  1018.1    30.31   180.0    0.063      0.0      0.0      0.2 3.00E-4
 1.95098  1018.2    30.87   190.0   0.0769      0.0      0.0      0.2 3.00E-4
```

Port Depth = 50 m

```
/ UM3. 7/5/2019 11:27:43 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
      Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
          m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
        0.0       0.2    -135.0      35.1      28.0       0.0       0.0       0.2     225.0    0.0003     22.49
       15.0       0.2    -135.0      35.1      27.9       0.0       0.0       0.2     225.0    0.0003     22.53
       20.0       0.2    -135.0      35.2      27.7       0.0       0.0       0.2     225.0    0.0003     22.67
       60.0       0.2    -135.0      35.2      27.6       0.0       0.0       0.2     225.0    0.0003      22.7
       70.0       0.2    -135.0      35.2      27.4       0.0       0.0       0.2     225.0    0.0003     22.76
       80.0       0.2    -135.0      35.2      26.8       0.0       0.0       0.2     225.0    0.0003     22.96
       90.0       0.2    -135.0      35.0      26.1       0.0       0.0       0.2     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)       ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppm)
   0.254    40.0   -90.0   225.0      1.0   100.0  6000.0    50.0    0.12    35.0     45.0  2000.0

Simulation:
Froude number:      18.18; effluent density (sigma-T)     15.77; effluent velocity      2.368(m/s);
       Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step     (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0    50.0      0.2    0.254     35.0     45.0   2000.0   2000.0      1.0       0.0       0.0;
 100    52.4      0.2    1.764    35.17    30.04    278.6    278.6    7.137    -0.382    -0.382;
 200   54.56      0.2    5.185    35.19    28.12    57.97    57.97    34.27    -4.341    -4.341;
 208   54.61      0.2    5.324    35.19     28.1    55.07    55.07    36.08    -5.636    -5.636; local maximum rise or
 300   48.93      0.2    11.95     35.2    27.71    10.46    10.46    189.8    -25.69    -25.69;
 373    38.9      0.2    24.73     35.2    27.66    2.466    2.466    805.7    -70.78    -70.78; acute zone;
 385   36.51      0.2    27.88     35.2    27.66    1.944    1.944   1021.8    -86.43    -86.43; trap level;
 400   33.21      0.2    32.39     35.2    27.66    1.444    1.444   1375.2    -116.4    -116.4;
 411   31.41      0.2    35.95     35.2    27.66    1.175    1.175   1690.9    -170.9    -170.9; local maximum rise or
 425   36.07      0.2    40.76     35.2    27.66    0.913    0.913   2176.8    -250.1    -250.1; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      40.76 m
    conc  dilutn    width distnce     time
   (ppm)              (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 0.91005  2182.9    41.15   360.0  0.00868      0.0      0.0      0.2 3.00E-4
 0.91111  2180.3    41.77   370.0   0.0226      0.0      0.0      0.2 3.00E-4
 0.91156  2179.2     42.4   380.0   0.0365      0.0      0.0      0.2 3.00E-4
 0.91182  2178.6    43.03   390.0   0.0503      0.0      0.0      0.2 3.00E-4
   0.912  2178.2    43.66   400.0   0.0642      0.0      0.0      0.2 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 7/5/2019 11:31:26 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir    Disprsn    Density
         m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg   m0.67/s2    sigma-T
       0.0        0.2     -135.0       35.1       28.0        0.0        0.0        0.2      225.0     0.0003      22.49
.....
      90.0        0.2     -135.0       35.0       26.1        0.0        0.0        0.2      225.0     0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    15.0   -90.0   225.0     1.0   100.0  6000.0    75.0    0.12    35.0    45.0  2000.0

Simulation:
Froude number:      17.96; effleunt density (sigma-T)      15.77; effleunt velocity      2.368(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     75.0      0.2    0.254     35.0     45.0   2000.0   2000.0      1.0      0.0      0.0;
 100     77.4      0.2    1.765    35.17    29.52    278.8    278.8    7.129   -0.382   -0.382;
 200    79.45      0.2    5.057    35.19    27.46    61.03    61.03    32.55   -4.028   -4.028;
 208    79.49      0.2     5.17    35.19    27.43    58.49    58.49    33.96   -5.096   -5.096; local maximum rise or
 291    74.95      0.2    10.54     35.2    27.09    13.56    13.56    146.4   -21.64   -21.64; trap level;
 300    74.22      0.2    11.55     35.2    27.09    11.35    11.35    175.0   -25.22   -25.22;
 317    73.19      0.2    13.33     35.2    27.11    8.576    8.576    231.6    -38.3    -38.3; local maximum rise or
 334    74.91      0.2    15.14     35.2    27.12    6.611    6.611    300.4   -55.32   -55.32; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      15.14 m
   conc   dilutn    width distnce     time
  (ppm)               (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 6.58745    301.5   15.22    80.0  0.00246     0.0      0.0      0.2 3.00E-4
 6.60245    300.8   15.67    90.0   0.0163     0.0      0.0      0.2 3.00E-4
.....
 3.08979    645.2   44.85   620.0    0.752     0.0      0.0      0.2 3.00E-4
 3.04684    654.3   45.49   630.0    0.766     0.0      0.0      0.2 3.00E-4
 3.00484    663.5   46.13   640.0     0.78     0.0      0.0      0.2 3.00E-4
 2.96377    672.7   46.78   650.0    0.794     0.0      0.0      0.2 3.00E-4
 2.92359    682.0   47.43   660.0    0.808     0.0      0.0      0.2 3.00E-4
  2.8843    691.3   48.08   670.0    0.822     0.0      0.0      0.2 3.00E-4
 2.84585    700.7   48.74   680.0    0.836     0.0      0.0      0.2 3.00E-4
 2.80823    710.1    49.4   690.0     0.85     0.0      0.0      0.2 3.00E-4
```

Appendix B.3 Discharge at 45 °C and 0.5 m/s ambient current

Port Depth = 2 m

```
/ UM3. 7/16/2019 8:11:39 AM
Case 1; ambient file c:\plumes\VP plume 1.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir    Disprsn    Density
         m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg   m0.67/s2    sigma-T
       0.0        0.5     -135.0       35.1       28.0        0.0        0.0        0.5     -135.0     0.0003      22.49
      15.0        0.5     -135.0       35.1       27.9        0.0        0.0        0.5     -135.0     0.0003      22.53
      20.0        0.5     -135.0       35.2       27.7        0.0        0.0        0.5     -135.0     0.0003      22.67
      60.0        0.5     -135.0       35.2       27.6        0.0        0.0        0.5     -135.0     0.0003       22.7
      70.0        0.5     -135.0       35.2       27.4        0.0        0.0        0.5     -135.0     0.0003      22.76
      80.0        0.5     -135.0       35.2       26.8        0.0        0.0        0.5     -135.0     0.0003      22.96
      90.0        0.5     -135.0       35.0       26.1        0.0        0.0        0.5     -135.0     0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    88.0   -90.0   225.0     1.0   100.0  5000.0     2.0    0.12    35.0    45.0  2000.0

Simulation:
Froude number:      18.44; effleunt density (sigma-T)      15.77; effleunt velocity      2.368(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0      2.0      0.5    0.254     35.0     45.0   2000.0   2000.0      1.0      0.0      0.0;
 100    3.101      0.5    1.284    35.08    30.76    326.7    326.7    6.087    -0.31    -0.31;
 200    4.703      0.5    3.602     35.1    28.38    47.88    47.88     41.5   -6.877   -6.877;
 214    4.948      0.5    4.124     35.1    28.28    36.37    36.37    54.63   -15.75   -15.75; local maximum rise or
 258    3.106      0.5    6.324     35.1     28.1    15.27    15.27    130.1   -41.35   -41.35; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       6.32 m
   conc   dilutn    width distnce     time
  (ppm)               (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 15.2097    130.6   6.344    60.0  8.47E-4     0.0      0.0      0.5 3.00E-4
.....
 3.08897    646.6   43.43  1920.0    1.034     0.0      0.0      0.5 3.00E-4
 3.07108    650.4   43.68  1930.0     1.04     0.0      0.0      0.5 3.00E-4
 3.05336    654.2   43.93  1940.0    1.045     0.0      0.0      0.5 3.00E-4
 3.03581    657.9   44.19  1950.0    1.051     0.0      0.0      0.5 3.00E-4
 3.01842    661.7   44.44  1960.0    1.056     0.0      0.0      0.5 3.00E-4
  3.0012    665.5    44.7  1970.0    1.062     0.0      0.0      0.5 3.00E-4
 2.98414    669.4   44.95  1980.0    1.068     0.0      0.0      0.5 3.00E-4
 2.96725    673.2   45.21  1990.0    1.073     0.0      0.0      0.5 3.00E-4
```

Port Depth = 10 m

```
/ UM3. 7/5/2019 10:48:31 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
      Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol    Decay   Far-spd   Far-dir   Disprsn   Density
          m       m/s       deg       psu         C     kg/kg      s-1       m/s       deg  m0.67/s2   sigma-T
        0.0       0.5    -135.0      35.1      28.0       0.0      0.0       0.5     225.0    0.0003     22.49
       15.0       0.5    -135.0      35.1      27.9       0.0      0.0       0.5     225.0    0.0003     22.53
       20.0       0.5    -135.0      35.2      27.7       0.0      0.0       0.5     225.0    0.0003     22.67
       60.0       0.5    -135.0      35.2      27.6       0.0      0.0       0.5     225.0    0.0003      22.7
       70.0       0.5    -135.0      35.2      27.4       0.0      0.0       0.5     225.0    0.0003     22.76
       80.0       0.5    -135.0      35.2      26.8       0.0      0.0       0.5     225.0    0.0003     22.96
       90.0       0.5    -135.0      35.0      26.1       0.0      0.0       0.5     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    80.0   -90.0   225.0     1.0   100.0  6000.0    10.0    0.12    35.0    45.0  2000.0

Simulation:
Froude number:      18.42; effleunt density (sigma-T)     15.77; effleunt velocity     2.368(m/s);
         Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step       (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0      10.0      0.5    0.254     35.0     45.0   2000.0   2000.0      1.0      0.0      0.0;
 100      11.1      0.5    1.284    35.08    30.72    326.7    326.7    6.087    -0.31    -0.31;
 200      12.7      0.5    3.602     35.1    28.33    47.89    47.89     41.5   -6.881   -6.881;
 214     12.94      0.5    4.123     35.1    28.23    36.39    36.39     54.6    -15.8    -15.8; local maximum rise o
 300     8.548      0.5    9.564     35.1    27.98     6.65     6.65    298.8    -71.5    -71.5; acute zone;
 328     6.165      0.5    12.61     35.1    27.97     3.82     3.82    520.2   -106.2   -106.2; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of      12.61 m
    conc  dilutn   width distnce     time
   (ppm)             (m)     (m)    (hrs)   (ppm)   (s-1)    (m/s)(m0.67/s2)
 3.81071   521.4   12.78   160.0 0.00548     0.0     0.0     0.5 3.00E-4
 3.81384   521.0   12.95   170.0   0.011     0.0     0.0     0.5 3.00E-4
.....
 3.05325   651.6   21.26   620.0   0.261     0.0     0.0     0.5 3.00E-4
 3.02849   656.9   21.46   630.0   0.267     0.0     0.0     0.5 3.00E-4
 3.00389   662.4   21.66   640.0   0.272     0.0     0.0     0.5 3.00E-4
 2.97947   667.8   21.86   650.0   0.278     0.0     0.0     0.5 3.00E-4
 2.95522   673.3   22.06   660.0   0.283     0.0     0.0     0.5 3.00E-4
 2.93133   678.8   22.26   670.0   0.289     0.0     0.0     0.5 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 7/5/2019 10:51:10 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
      Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol    Decay   Far-spd   Far-dir   Disprsn   Density
          m       m/s       deg       psu         C     kg/kg      s-1       m/s       deg  m0.67/s2   sigma-T
        0.0       0.5    -135.0      35.1      28.0       0.0      0.0       0.5     225.0    0.0003     22.49
       15.0       0.5    -135.0      35.1      27.9       0.0      0.0       0.5     225.0    0.0003     22.53
       20.0       0.5    -135.0      35.2      27.7       0.0      0.0       0.5     225.0    0.0003     22.67
       60.0       0.5    -135.0      35.2      27.6       0.0      0.0       0.5     225.0    0.0003      22.7
       70.0       0.5    -135.0      35.2      27.4       0.0      0.0       0.5     225.0    0.0003     22.76
       80.0       0.5    -135.0      35.2      26.8       0.0      0.0       0.5     225.0    0.0003     22.96
       90.0       0.5    -135.0      35.0      26.1       0.0      0.0       0.5     225.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    60.0   -90.0   225.0     1.0   100.0  6000.0    30.0    0.12    35.0    45.0  2000.0

Simulation:
Froude number:       18.2; effleunt density (sigma-T)     15.77; effleunt velocity     2.368(m/s);
         Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step       (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0      30.0      0.5    0.254     35.0     45.0   2000.0   2000.0      1.0      0.0      0.0;
 100      31.1      0.5    1.283    35.17    30.51    326.9    326.9    6.083    -0.31    -0.31;
 200      32.7      0.5      3.6     35.2    28.09    47.93    47.93    41.45    -6.92    -6.92;
 213     32.94      0.5    4.087     35.2    27.99    37.05    37.05    53.62    -14.8    -14.8; local maximum rise o
 300     28.51      0.5    9.563     35.2    27.73    6.649    6.649    298.8   -70.27   -70.27;
 301     28.43      0.5    9.658     35.2    27.73    6.519    6.519    304.7   -71.19   -71.19; acute zone;
 378     19.85      0.5    20.69     35.2     27.7    1.419    1.419   1400.0   -218.5   -218.5; trap level;
 385     19.11      0.5    22.17     35.2     27.7    1.235    1.235   1608.2   -255.8   -255.8; local maximum rise o
 391     20.47      0.5    23.34     35.2     27.7    1.114    1.114   1783.0   -293.3   -293.3; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      23.34 m
    conc  dilutn   width distnce     time
   (ppm)             (m)     (m)    (hrs)   (ppm)   (s-1)    (m/s)(m0.67/s2)
 1.11006  1789.6   23.45   420.0  0.0029     0.0     0.0     0.5 3.00E-4
 1.11155  1787.2   23.66   430.0 0.00845     0.0     0.0     0.5 3.00E-4
 1.11222  1786.1   23.86   440.0   0.014     0.0     0.0     0.5 3.00E-4
 1.11263  1785.5   24.07   450.0  0.0196     0.0     0.0     0.5 3.00E-4
  1.1129  1785.0   24.28   460.0  0.0251     0.0     0.0     0.5 3.00E-4
 1.11311  1784.7   24.49   470.0  0.0307     0.0     0.0     0.5 3.00E-4
```

Port Depth = 50 m

```
/ UM3. 7/5/2019 10:53:30 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir    Disprsn    Density
         m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg    m0.67/s2   sigma-T
       0.0        0.5     -135.0       35.1       28.0        0.0        0.0        0.5      225.0     0.0003      22.49
      15.0        0.5     -135.0       35.1       27.9        0.0        0.0        0.5      225.0     0.0003      22.53
      20.0        0.5     -135.0       35.2       27.7        0.0        0.0        0.5      225.0     0.0003      22.67
      60.0        0.5     -135.0       35.2       27.6        0.0        0.0        0.5      225.0     0.0003       22.7
      70.0        0.5     -135.0       35.2       27.4        0.0        0.0        0.5      225.0     0.0003      22.76
      80.0        0.5     -135.0       35.2       26.8        0.0        0.0        0.5      225.0     0.0003      22.96
      90.0        0.5     -135.0       35.0       26.1        0.0        0.0        0.5      225.0     0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    40.0   -90.0   225.0     1.0   100.0  6000.0    50.0    0.12    35.0    45.0  2000.0

Simulation:
Froude number:       18.18; effluent density (sigma-T)     15.77; effluent velocity     2.368(m/s);
        Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     50.0      0.5     0.254     35.0     45.0   2000.0   2000.0      1.0      0.0      0.0;
 100     51.1      0.5     1.283    35.17    30.46    326.9    326.9    6.083    -0.31    -0.31;
 200     52.7      0.5       3.6     35.2    28.04    47.93    47.93    41.45   -6.923   -6.923;
 213    52.94      0.5     4.086     35.2    27.94    37.05    37.05    53.62   -14.87   -14.87; local maximum rise o
 300     48.5      0.5     9.565     35.2    27.68    6.646    6.646    298.9   -70.22   -70.22;
 301    48.43      0.5      9.66     35.2    27.68    6.516    6.516    304.9   -71.14   -71.14; acute zone;
 378    39.84      0.5     20.69     35.2    27.65    1.418    1.418   1400.7   -218.3   -218.3; trap level;
 400    36.27      0.5     25.73     35.2    27.65    0.917    0.917   2165.4   -363.2   -363.2;
 403    36.17      0.5      26.5     35.2    27.65    0.864    0.864   2297.9   -429.5   -429.5; local maximum rise o
 415    39.57      0.5     29.85     35.2    27.65    0.682    0.682   2914.3   -619.9   -619.9; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       29.85 m
   conc  dilutn   width distnce    time
  (ppm)             (m)     (m)   (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 0.67872  2926.9   29.92   880.0 0.00185     0.0      0.0      0.5 3.00E-4
 0.67979  2922.3   30.14   890.0  0.0074     0.0      0.0      0.5 3.00E-4
 0.68026  2920.2   30.37   900.0   0.013     0.0      0.0      0.5 3.00E-4
 0.68054  2919.0   30.59   910.0  0.0185     0.0      0.0      0.5 3.00E-4
 0.68073  2918.2   30.82   920.0  0.0241     0.0      0.0      0.5 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 7/5/2019 10:55:28 AM
Case 1; ambient file c:\plumes\VP plume 7.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir    Disprsn    Density
         m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg    m0.67/s2   sigma-T
       0.0        0.5     -135.0       35.1       28.0        0.0        0.0        0.5      225.0     0.0003      22.49
 .....
      90.0        0.5     -135.0       35.0       26.1        0.0        0.0        0.5      225.0     0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    15.0   -90.0   225.0     1.0   100.0  6000.0    75.0    0.12    35.0    45.0  2000.0

Simulation:
Froude number:       17.96; effluent density (sigma-T)     15.77; effluent velocity     2.368(m/s);
        Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     75.0      0.5     0.254     35.0     45.0   2000.0   2000.0      1.0      0.0      0.0;
 100     76.1      0.5     1.283    35.17    29.99    327.1    327.1    6.078    -0.31    -0.31;
 200    77.69      0.5     3.598     35.2    27.42    47.99    47.99    41.39   -7.079   -7.079;
 210    77.86      0.5     3.967     35.2    27.33    39.37    39.37    50.46   -13.05   -13.05; local maximum rise o
 281    74.69      0.5     7.908     35.2    27.11    9.743    9.743    203.9   -54.63   -54.63; trap level;
 295    73.83      0.5     9.081     35.2    27.12    7.384    7.384    269.0   -71.07   -71.07; acute zone;
 300    73.54      0.5     9.542     35.2    27.12    6.688    6.688    297.0   -81.06   -81.06;
 304    73.45      0.5     9.927     35.2    27.13    6.179    6.179    321.5   -97.61   -97.61; local maximum rise o
 316    74.68      0.5     11.17     35.2    27.13    4.876    4.876    407.3   -137.7   -137.7; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       11.17 m
   conc  dilutn   width distnce    time
  (ppm)             (m)     (m)   (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 4.86104   408.6   11.25   200.0  0.0029     0.0      0.0      0.5 3.00E-4
 .....
 3.05806   651.2   24.47   910.0   0.397     0.0      0.0      0.5 3.00E-4
 3.03317   656.5   24.68   920.0   0.403     0.0      0.0      0.5 3.00E-4
 3.00858   661.9   24.89   930.0   0.408     0.0      0.0      0.5 3.00E-4
 2.98427   667.3    25.1   940.0   0.414     0.0      0.0      0.5 3.00E-4
 2.96026   672.8   25.32   950.0    0.42     0.0      0.0      0.5 3.00E-4
 2.93654   678.2   25.53   960.0   0.425     0.0      0.0      0.5 3.00E-4
  2.9131   683.7   25.74   970.0   0.431     0.0      0.0      0.5 3.00E-4
 2.88994   689.2   25.95   980.0   0.436     0.0      0.0      0.5 3.00E-4
```

Appendix B.4 Discharge at 65 °C and 0.05 m/s ambient current

Port Depth = 2 m

```
/ UM3. 7/16/2019 8:17:10 AM
Case 1; ambient file c:\plumes\VP plume 1.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
       0.0      0.05    -135.0      35.1      28.0       0.0       0.0      0.05    -135.0    0.0003    22.49
 .....
      90.0      0.05    -135.0      35.0      26.1       0.0       0.0      0.05    -135.0    0.0003    23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    88.0   -90.0   225.0     1.0   100.0  5000.0     2.0   0.022    35.0    65.0  2000.0

Simulation:
Froude number:      2.093; effleunt density (sigma-T)     5.142; effleunt velocity     0.434(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0      2.0     0.05    0.254     35.0     65.0   2000.0   2000.0      1.0      0.0      0.0;
  29    2.371     0.05    0.638    35.04    50.12   1195.8   1195.8    1.659  -0.0159  -0.0159; begin overlap;
 100    2.432     0.05    1.336    35.04    48.94   1132.3   1132.3    1.751  -0.0313  -0.0313;
 165    2.434     0.05    1.503    35.04    48.91   1130.8   1130.8    1.753  -0.0344  -0.0344; local maximum rise or
 200    2.433     0.05    1.459    35.04    48.91   1130.8   1130.8    1.753  -0.0359  -0.0359;
 300    2.385     0.05    0.755    35.04    48.65   1116.6   1116.6    1.775  -0.0511  -0.0511;
 305     2.35     0.05     0.69    35.05    47.94   1078.3   1078.3    1.838  -0.0566  -0.0566; end overlap;
 385   0.0885     0.05    1.125    35.09    32.12    223.1    223.1    8.825   -0.361   -0.361; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       1.13 m
    conc  dilutn    width distnce     time
   (ppm)              (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 177.858   11.11    1.906    10.0   0.0527     0.0      0.0     0.05 3.00E-4
 .....
 24.8212   80.44    14.18   100.0    0.553     0.0      0.0     0.05 3.00E-4
 22.0603   90.52    15.95   110.0    0.608     0.0      0.0     0.05 3.00E-4
 .....
 3.16523   631.7    111.3   460.0    2.553     0.0      0.0     0.05 3.00E-4
 3.06925   651.5    114.8   470.0    2.608     0.0      0.0     0.05 3.00E-4
 2.97802   671.4    118.3   480.0    2.664     0.0      0.0     0.05 3.00E-4
 2.89123   691.6    121.8   490.0    2.719     0.0      0.0     0.05 3.00E-4
 2.80856   712.0    125.4   500.0    2.775     0.0      0.0     0.05 3.00E-4
 2.72977   732.5    129.1   510.0     2.83     0.0      0.0     0.05 3.00E-4
```

Port Depth = 10 m

```
/ UM3. 7/14/2019 3:23:46 PM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
       0.0      0.05    -135.0      35.1      28.0       0.0       0.0      0.05    -135.0    0.0003    22.49
 .....
      90.0      0.05    -135.0      35.0      26.1       0.0       0.0      0.05    -135.0    0.0003    23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    80.0   -90.0   225.0     1.0   100.0  5000.0    10.0   0.022    35.0    65.0 2.00E+9

Simulation:
Froude number:      2.092; effleunt density (sigma-T)     5.142; effleunt velocity     0.434(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     10.0     0.05    0.254     35.0     65.0  2.000E+9 2.000E+9     1.0      0.0      0.0;
  29    10.37     0.05    0.638    35.04     50.1  1.196E+9 1.196E+9   1.659  -0.0159  -0.0159; begin overlap;
 100    10.43     0.05    1.336    35.04    48.92  1.133E+9 1.133E+9    1.75  -0.0313  -0.0313;
 165    10.43     0.05    1.503    35.04     48.9  1.131E+9 1.131E+9   1.753  -0.0344  -0.0344; local maximum rise or
 200    10.43     0.05    1.459    35.04     48.9  1.131E+9 1.131E+9   1.753  -0.0359  -0.0359;
 300    10.38     0.05    0.755    35.04    48.63  1.117E+9 1.117E+9   1.775   -0.051   -0.051;
 305    10.35     0.05    0.689    35.05    47.93  1.079E+9 1.079E+9   1.837  -0.0565  -0.0565; end overlap;
 400    7.437     0.05    1.346    35.09    31.01  1.658E+8 1.658E+8   11.87   -0.475   -0.475;
 492    0.833     0.05    4.174     35.1    28.47  2.682E+7 2.682E+7   73.32   -2.188   -2.188; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       4.17 m
    conc  dilutn    width distnce     time
   (ppm)              (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 2.17E+7   90.95    6.956    25.0    0.122     0.0      0.0     0.05 3.00E-4
 1.45E+7   136.1    10.66    50.0    0.261     0.0      0.0     0.05 3.00E-4
 1.05E+7   189.1    14.86    75.0    0.399     0.0      0.0     0.05 3.00E-4
 8.03E+6   247.9     19.5   100.0    0.538     0.0      0.0     0.05 3.00E-4
 6.39E+6   311.9    24.54   125.0    0.677     0.0      0.0     0.05 3.00E-4
 5.24E+6   380.7    29.95   150.0    0.816     0.0      0.0     0.05 3.00E-4
 4.40E+6   453.8    35.71   175.0    0.955     0.0      0.0     0.05 3.00E-4
 3.76E+6   531.1     41.8   200.0    1.094     0.0      0.0     0.05 3.00E-4
 3.26E+6   612.4     48.2   225.0    1.233     0.0      0.0     0.05 3.00E-4
 2.86E+6   697.4    54.89   250.0    1.372     0.0      0.0     0.05 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 7/14/2019 3:29:51 PM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
      Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
          m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
        0.0      0.05    -135.0      35.1      28.0       0.0       0.0      0.05    -135.0    0.0003     22.49
.....
       90.0      0.05    -135.0      35.0      26.1       0.0       0.0      0.05    -135.0    0.0003     23.03
Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)       ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppm)
   0.254    60.0   -90.0   225.0      1.0   100.0  5000.0    30.0   0.022    35.0     65.0 2.00E+9

Simulation:
Froude number:      2.083; effleunt density (sigma-T)     5.142; effleunt velocity      0.434(m/s);
         Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step       (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0      30.0     0.05     0.254     35.0     65.0 2.000E+9 2.000E+9      1.0       0.0       0.0;
  29     30.37     0.05     0.639    35.08    50.04 1.198E+9 1.198E+9    1.656   -0.0158   -0.0158; begin overlap;
 100     30.43     0.05     1.337    35.09    48.89 1.137E+9 1.137E+9    1.744   -0.0309   -0.0309;
 165     30.43     0.05     1.504    35.09    48.86 1.135E+9 1.135E+9    1.746   -0.0339   -0.0339; local maximum rise o
 200     30.43     0.05      1.46    35.09    48.86 1.135E+9 1.135E+9    1.746   -0.0353   -0.0353;
 300     30.38     0.05     0.754    35.09     48.6 1.121E+9 1.121E+9    1.768   -0.0502   -0.0502;
 305     30.35     0.05     0.688    35.09     47.9 1.084E+9 1.084E+9    1.828   -0.0556   -0.0556; end overlap;
 400     27.44     0.05     1.339    35.18    30.79 1.667E+8 1.667E+8    11.81     -0.47     -0.47;
 500     19.99     0.05     4.569     35.2    28.12 2.301E+7 2.301E+7    85.46    -2.451    -2.451;
 532     16.22     0.05     7.185    35.18    27.96 1.220E+7 1.220E+7    161.0    -3.965    -3.965; trap level;
 547     14.92     0.05     8.891    35.17    27.94 9.624E+6 9.624E+6    204.3    -4.723    -4.723; begin overlap;
 600     12.63     0.05     12.84    35.14    27.93 6.426E+6 6.426E+6    305.9    -7.472    -7.472;
 628      12.3     0.05     13.51    35.14    27.93 6.052E+6 6.052E+6    324.9    -9.257    -9.257; local maximum rise o
 664     13.05     0.05     13.49    35.14    27.93 5.706E+6 5.706E+6    344.6    -11.89    -11.89; end overlap;
 688     15.96     0.05     15.26    35.13    27.92 4.099E+6 4.099E+6    479.6     -15.8     -15.8; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       15.26 m
   conc  dilutn    width distnce     time
  (ppm)              (m)     (m)    (hrs)    (ppm)    (s-1)     (m/s)(m0.67/s2)
 4.10E+6   479.8   16.65    30.0   0.0425      0.0      0.0      0.05 3.00E-4
.....
 3.18E+6   619.7   26.64    80.0     0.32      0.0      0.0      0.05 3.00E-4
 2.97E+6   665.7   28.82    90.0    0.376      0.0      0.0      0.05 3.00E-4
 2.77E+6   714.1   31.06   100.0    0.431      0.0      0.0      0.05 3.00E-4
```

Port Depth = 50 m

```
/ UM3. 7/14/2019 3:31:29 PM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
      Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
          m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
        0.0      0.05    -135.0      35.1      28.0       0.0       0.0      0.05    -135.0    0.0003     22.49
.....|
       90.0      0.05    -135.0      35.0      26.1       0.0       0.0      0.05    -135.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)       ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppm)
   0.254    40.0   -90.0   225.0      1.0   100.0  5000.0    50.0   0.022    35.0     65.0 2.00E+9

Simulation:
Froude number:      2.082; effleunt density (sigma-T)     5.142; effleunt velocity      0.434(m/s);
         Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step       (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0      50.0     0.05     0.254     35.0     65.0 2.000E+9 2.000E+9      1.0       0.0       0.0;
  29     50.37     0.05      0.64    35.08    50.02 1.198E+9 1.198E+9    1.655   -0.0158   -0.0158; begin overlap;
 100     50.43     0.05     1.337    35.09    48.87 1.137E+9 1.137E+9    1.744   -0.0309   -0.0309;
 165     50.43     0.05     1.504    35.09    48.84 1.135E+9 1.135E+9    1.746   -0.0339   -0.0339; local maximum rise o
 200     50.43     0.05      1.46    35.09    48.84 1.135E+9 1.135E+9    1.746   -0.0353   -0.0353;
 300     50.38     0.05     0.754    35.09    48.59 1.122E+9 1.122E+9    1.767   -0.0501   -0.0501;
 305     50.35     0.05     0.688    35.09    47.89 1.084E+9 1.084E+9    1.828   -0.0555   -0.0555; end overlap;
 400     47.44     0.05     1.339    35.18    30.74 1.667E+8 1.667E+8     11.8     -0.47     -0.47;
 500     39.99     0.05     4.567     35.2    28.07 2.302E+7 2.302E+7    85.42     -2.45     -2.45;
 600     24.08     0.05     15.58     35.2    27.73 3.177E+6 3.177E+6    618.8    -10.49    -10.49;
 622     19.25     0.05     20.44     35.2    27.72 2.055E+6 2.055E+6    956.6    -14.31    -14.31; trap level;
 625     18.82     0.05     21.16     35.2    27.72 1.975E+6 1.975E+6    995.4    -14.71    -14.71; begin overlap;
 687     17.41     0.05     24.51     35.2    27.72 1.835E+6 1.835E+6   1071.5    -17.27    -17.27; local maximum rise o
 700     17.45     0.05     24.42     35.2    27.72 1.834E+6 1.834E+6   1071.9    -17.65    -17.65;
 751     19.29     0.05     22.73     35.2    27.72 1.742E+6 1.742E+6   1128.2    -20.27    -20.27; end overlap;
4/3 Power Law.  Farfield dispersion based on wastefield width of       22.73 m
   conc  dilutn    width distnce     time
  (ppm)              (m)     (m)    (hrs)    (ppm)    (s-1)     (m/s)(m0.67/s2)
 1.74E+6  1131.0    23.0    30.0  0.00744      0.0      0.0      0.05 3.00E-4
 1.74E+6  1128.8   25.08    40.0    0.063      0.0      0.0      0.05 3.00E-4
 1.73E+6  1138.0   27.22    50.0    0.119      0.0      0.0      0.05 3.00E-4
 1.68E+6  1169.0   29.41    60.0    0.174      0.0      0.0      0.05 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 7/14/2019 3:33:49 PM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0      0.05    -135.0      35.1      28.0       0.0       0.0      0.05    -135.0    0.0003     22.49
      15.0      0.05    -135.0      35.1      27.9       0.0       0.0      0.05    -135.0    0.0003     22.53
      20.0      0.05    -135.0      35.2      27.7       0.0       0.0      0.05    -135.0    0.0003     22.67
      60.0      0.05    -135.0      35.2      27.6       0.0       0.0      0.05    -135.0    0.0003      22.7
      70.0      0.05    -135.0      35.2      27.4       0.0       0.0      0.05    -135.0    0.0003     22.76
      80.0      0.05    -135.0      35.2      26.8       0.0       0.0      0.05    -135.0    0.0003     22.96
      90.0      0.05    -135.0      35.0      26.1       0.0       0.0      0.05    -135.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    15.0   -90.0   225.0     1.0   100.0  5000.0    75.0   0.022    35.0    65.0 2.00E+9

Simulation:
Froude number:       2.072; effluent density (sigma-T)     5.142; effluent velocity     0.434(m/s);
        Depth  Amb-cur     P-dia   Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step      (m)    (m/s)       (m)     (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0      75.0     0.05     0.254      35.0     65.0 2.000E+9 2.000E+9      1.0       0.0       0.0;
  29     75.37     0.05     0.641     35.08    49.84 1.200E+9 1.200E+9    1.652   -0.0158   -0.0158; begin overlap;
 100     75.43     0.05     1.338     35.09    48.71 1.141E+9 1.141E+9    1.738   -0.0305   -0.0305;
 165     75.43     0.05     1.505     35.09    48.68 1.139E+9 1.139E+9     1.74   -0.0334   -0.0334; local maximum rise o1
 200     75.43     0.05      1.46     35.09    48.68 1.139E+9 1.139E+9     1.74   -0.0348   -0.0348;
 300     75.38     0.05     0.753     35.09    48.42 1.126E+9 1.126E+9    1.761   -0.0494   -0.0494;
 305     75.35     0.05     0.687     35.09    47.72 1.089E+9 1.089E+9     1.82   -0.0547   -0.0547; end overlap;
 400     72.45     0.05     1.337     35.18    30.34 1.675E+8 1.675E+8    11.75    -0.467    -0.467;
 500     65.11     0.05     4.697      35.2    27.83 2.312E+7 2.312E+7    85.03    -2.492    -2.492;
 600     51.65     0.05     17.11      35.2    27.63 3.191E+6 3.191E+6    616.0    -11.65    -11.65;
 621     48.08     0.05     21.87      35.2    27.63 2.105E+6 2.105E+6    933.7    -16.53    -16.53; trap level;
 665     42.63     0.05     31.04      35.2    27.63 1.144E+6 1.144E+6   1718.4     -36.2     -36.2; local maximum rise o1
 693     47.22     0.05     35.63      35.2    27.63 851472.4 851472.4   2308.6    -57.79    -57.79; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      35.63 m
    conc  dilutn   width distnce     time
   (ppm)             (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 8.51E+5  2310.5    37.6    90.0  0.0459     0.0      0.0     0.05 3.00E-4
 8.51E+5  2310.7   40.04   100.0   0.101     0.0      0.0     0.05 3.00E-4
```

Appendix B.5 Discharge at 65 °C and 0.2 m/s ambient current

Port Depth = 2 m

```
/ UM3. 7/16/2019 8:21:02 AM
Case 1; ambient file c:\plumes\VP plume 1.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0       0.2    -135.0      35.1      28.0       0.0       0.0       0.2    -135.0    0.0003     22.49
.....
      90.0       0.2    -135.0      35.0      26.1       0.0       0.0       0.2    -135.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    88.0   -90.0   225.0     1.0   100.0  5000.0     2.0   0.022    35.0    65.0  2000.0

Simulation:
Froude number:       2.093; effluent density (sigma-T)     5.142; effluent velocity     0.434(m/s);
        Depth  Amb-cur     P-dia   Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step      (m)    (m/s)       (m)     (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0       2.0      0.2     0.254      35.0     65.0   2000.0   2000.0      1.0       0.0       0.0;
  23     2.114      0.2     0.383     35.03     53.6   1383.9   1383.9    1.436  -0.00868  -0.00868; begin overlap;
 100     2.308      0.2     0.692     35.06    43.08    815.4    815.4    2.425    -0.104    -0.104;
 158     2.357      0.2     0.777     35.06    41.19    713.6    713.6    2.768    -0.227    -0.227; local maximum rise o1
 200     2.316      0.2     0.758     35.07    40.27    663.9    663.9    2.975    -0.348    -0.348;
 204     2.302      0.2     0.757     35.07    39.91    644.4    644.4    3.064    -0.368    -0.368; end overlap;
 300      1.38      0.2     1.637     35.09    29.85    100.6    100.6    19.56    -1.664    -1.664;
 301     1.366      0.2     1.653      35.1    29.81    98.62    98.62    19.95    -1.689    -1.689; matched energy radial
 325     0.991      0.2     2.094      35.1    29.12    61.32    61.32    32.08    -2.415    -2.415; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       2.09 m
    conc  dilutn   width distnce     time
   (ppm)             (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 61.2811   32.09   2.247    10.0 0.00914     0.0      0.0      0.2 3.00E-4
.....
 3.16767   630.8   56.91  1100.0   1.523     0.0      0.0      0.2 3.00E-4
 3.12955   638.5   57.61  1110.0   1.537     0.0      0.0      0.2 3.00E-4
  3.0922   646.2    58.3  1120.0   1.551     0.0      0.0      0.2 3.00E-4
 3.05558   654.0    59.0  1130.0   1.565     0.0      0.0      0.2 3.00E-4
 3.01968   661.8    59.7  1140.0   1.579     0.0      0.0      0.2 3.00E-4
 2.98447   669.6   60.41  1150.0   1.592     0.0      0.0      0.2 3.00E-4
 2.94995   677.4   61.12  1160.0   1.606     0.0      0.0      0.2 3.00E-4
 2.91608   685.3   61.83  1170.0    1.62     0.0      0.0      0.2 3.00E-4
```

Port Depth = 10 m

```
/ UM3. 7/15/2019 9:42:18 AM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir    Disprsn    Density
         m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg   m0.67/s2    sigma-T
       0.0        0.2     -135.0       35.1       28.0        0.0        0.0        0.2     -135.0     0.0003      22.49
      15.0        0.2     -135.0       35.1       27.9        0.0        0.0        0.2     -135.0     0.0003      22.53
      20.0        0.2     -135.0       35.2       27.7        0.0        0.0        0.2     -135.0     0.0003      22.67
      60.0        0.2     -135.0       35.2       27.6        0.0        0.0        0.2     -135.0     0.0003       22.7
      70.0        0.2     -135.0       35.2       27.4        0.0        0.0        0.2     -135.0     0.0003      22.76
      80.0        0.2     -135.0       35.2       26.8        0.0        0.0        0.2     -135.0     0.0003      22.96
      90.0        0.2     -135.0       35.0       26.1        0.0        0.0        0.2     -135.0     0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    80.0   -90.0   225.0     1.0   100.0  5000.0    10.0   0.022    35.0    65.0  2000.0

Simulation:
Froude number:      2.092; effleunt density (sigma-T)     5.142; effleunt velocity     0.434(m/s);
         Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn    y-posn
Step       (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)       (m)
   0      10.0      0.2     0.254     35.0     65.0   2000.0   2000.0      1.0      0.0       0.0;
  23     10.11      0.2     0.383    35.03    53.58   1383.9   1383.9    1.436 -0.00868 -0.00868; begin overlap;
 100     10.31      0.2     0.692    35.06    43.05    815.7    815.7    2.424   -0.104    -0.104;
 158     10.36      0.2     0.776    35.06    41.17    714.1    714.1    2.767   -0.227    -0.227; local maximum rise o
 200     10.32      0.2     0.758    35.07    40.25    664.5    664.5    2.972   -0.348    -0.348;
 204      10.3      0.2     0.757    35.07    39.89    645.1    645.1    3.061   -0.367    -0.367; end overlap;
 300     9.381      0.2     1.635    35.09     29.8    100.8    100.8    19.52   -1.661    -1.661;
 400     7.097      0.2     4.411     35.1     28.2    13.91    13.91    141.4   -7.456    -7.456;
 463     4.044      0.2     8.263     35.1    28.03    3.994    3.994    492.2   -19.42    -19.42; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of      8.26 m
    conc  dilutn   width distnce     time
   (ppm)             (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 3.98435   493.5   8.355    30.0  0.00352     0.0      0.0      0.2 3.00E-4
 ....
 3.10852   634.9    14.4   180.0    0.212     0.0      0.0      0.2 3.00E-4
 3.02665   652.3   14.84   190.0    0.226     0.0      0.0      0.2 3.00E-4
 2.94716   670.1   15.28   200.0     0.24     0.0      0.0      0.2 3.00E-4
 2.87005   688.4   15.73   210.0    0.254     0.0      0.0      0.2 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 7/15/2019 9:45:53 AM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir    Disprsn    Density
         m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg   m0.67/s2    sigma-T
       0.0        0.2     -135.0       35.1       28.0        0.0        0.0        0.2     -135.0     0.0003      22.49
      15.0        0.2     -135.0       35.1       27.9        0.0        0.0        0.2     -135.0     0.0003      22.53
      20.0        0.2     -135.0       35.2       27.7        0.0        0.0        0.2     -135.0     0.0003      22.67
      60.0        0.2     -135.0       35.2       27.6        0.0        0.0        0.2     -135.0     0.0003       22.7
      70.0        0.2     -135.0       35.2       27.4        0.0        0.0        0.2     -135.0     0.0003      22.76
      80.0        0.2     -135.0       35.2       26.8        0.0        0.0        0.2     -135.0     0.0003      22.96
      90.0        0.2     -135.0       35.0       26.1        0.0        0.0        0.2     -135.0     0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    60.0   -90.0   225.0     1.0   100.0  5000.0    30.0   0.022    35.0    65.0  2000.0

Simulation:
Froude number:      2.083; effleunt density (sigma-T)     5.142; effleunt velocity     0.434(m/s);
         Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn    y-posn
Step       (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)       (m)
   0      30.0      0.2     0.254     35.0     65.0   2000.0   2000.0      1.0      0.0       0.0;
  23     30.11      0.2     0.383    35.06    53.51   1384.4   1384.4    1.435 -0.00867 -0.00867; begin overlap;
 100     30.31      0.2     0.692    35.12    42.96    818.9    818.9    2.414   -0.103    -0.103;
 158     30.36      0.2     0.775    35.13     41.1    719.1    719.1    2.747   -0.224    -0.224; local maximum rise o
 200     30.31      0.2     0.755    35.13    40.21    671.7    671.7     2.94   -0.341    -0.341;
 205      30.3      0.2     0.755    35.14    39.76    647.6    647.6    3.049   -0.365    -0.365; end overlap;
 300     29.39      0.2     1.619    35.19    29.59    102.8    102.8    19.14   -1.628    -1.628;
 400     27.13      0.2     4.366     35.2    27.94    14.19    14.19    138.6   -7.304    -7.304;
 500     21.24      0.2     11.81     35.2    27.73    1.958    1.958   1003.8   -33.17    -33.17;
 517     19.54      0.2     13.99     35.2    27.72    1.399    1.399   1405.6   -43.26    -43.26; trap level;
 532      18.5      0.2     15.77     35.2    27.72    1.108    1.108   1774.0   -56.87    -56.87; local maximum rise o
 545     19.87      0.2     17.13    35.19    27.72    0.935    0.935   2102.5   -71.05    -71.05; trap level, acute zo
4/3 Power Law.  Farfield dispersion based on wastefield width of     17.13 m
    conc  dilutn   width distnce     time
   (ppm)             (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 0.93353  2105.8   17.57   110.0   0.0132     0.0      0.0      0.2 3.00E-4
 0.93418  2104.3   18.04   120.0   0.0271     0.0      0.0      0.2 3.00E-4
 0.93447  2103.6   18.52   130.0    0.041     0.0      0.0      0.2 3.00E-4
```

Port Depth = 50 m

```
/ UM3. 7/15/2019 9:48:06 AM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol     Decay    Far-spd    Far-dir   Disprsn    Density
         m        m/s        deg        psu          C      kg/kg       s-1        m/s        deg   m0.67/s2    sigma-T
       0.0        0.2     -135.0       35.1       28.0        0.0       0.0        0.2     -135.0     0.0003      22.49
.....
      90.0        0.2     -135.0       35.0       26.1        0.0       0.0        0.2     -135.0     0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    40.0   -90.0   225.0     1.0   100.0  5000.0    50.0   0.022    35.0    65.0  2000.0

Simulation:
Froude number:      2.082; effleunt density (sigma-T)     5.142; effleunt velocity     0.434(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     50.0      0.2    0.254     35.0     65.0   2000.0   2000.0      1.0      0.0      0.0;
  23    50.11      0.2    0.383    35.06     53.5   1384.5   1384.5    1.435 -0.00867 -0.00867; begin overlap;
 100    50.31      0.2    0.692    35.12    42.93    819.1    819.1    2.414   -0.103   -0.103;
 158    50.35      0.2    0.775    35.13    41.07    719.5    719.5    2.746   -0.223   -0.223; local maximum rise o1
 200    50.31      0.2    0.755    35.13    40.19    672.2    672.2    2.938   -0.341   -0.341;
 205     50.3      0.2    0.755    35.14    39.74    648.2    648.2    3.046   -0.365   -0.365; end overlap;
 300    49.39      0.2    1.618    35.19    29.55    102.9    102.9    19.11   -1.626   -1.626;
 400    47.13      0.2    4.363     35.2    27.89    14.21    14.21    138.4   -7.296   -7.296;
 500    41.24      0.2    11.81     35.2    27.68    1.961    1.961   1002.4   -33.13   -33.13;
 547    35.79      0.2    18.84     35.2    27.66    0.773    0.773   2542.5   -70.97   -70.97; acute zone;
 555    34.61      0.2     20.4     35.2    27.66     0.66     0.66   2978.9   -82.14   -82.14; trap level;
 580    31.07      0.2    26.12     35.2    27.66    0.404    0.404   4868.6   -167.6   -167.6; local maximum rise o1
 592    34.26      0.2    29.29     35.2    27.67    0.321    0.321   6128.1   -240.5   -240.5; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      29.29 m
    conc  dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)    (ppm)     (s-1)     (m/s)(m0.67/s2)
 0.32016  6139.9   29.83   350.0  0.0136      0.0       0.0       0.2 3.00E-4
  0.3204  6135.3   30.39   360.0  0.0275      0.0       0.0       0.2 3.00E-4
 0.32052  6133.0   30.96   370.0  0.0414      0.0       0.0       0.2 3.00E-4
 0.32059  6131.6   31.53   380.0  0.0553      0.0       0.0       0.2 3.00E-4
 0.32062  6131.1    32.1   390.0  0.0692      0.0       0.0       0.2 3.00E-4
 0.32055  6132.3   32.67   400.0  0.0831      0.0       0.0       0.2 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 7/15/2019 9:54:17 AM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol     Decay    Far-spd    Far-dir   Disprsn    Density
         m        m/s        deg        psu          C      kg/kg       s-1        m/s        deg   m0.67/s2    sigma-T
       0.0        0.2     -135.0       35.1       28.0        0.0       0.0        0.2     -135.0     0.0003      22.49
      15.0        0.2     -135.0       35.1       27.9        0.0       0.0        0.2     -135.0     0.0003      22.53
      20.0        0.2     -135.0       35.2       27.7        0.0       0.0        0.2     -135.0     0.0003      22.67
      60.0        0.2     -135.0       35.2       27.6        0.0       0.0        0.2     -135.0     0.0003       22.7
      70.0        0.2     -135.0       35.2       27.4        0.0       0.0        0.2     -135.0     0.0003      22.76
      80.0        0.2     -135.0       35.2       26.8        0.0       0.0        0.2     -135.0     0.0003      22.96
      90.0        0.2     -135.0       35.0       26.1        0.0       0.0        0.2     -135.0     0.0003      23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    15.0   -90.0   225.0     1.0   100.0  5000.0    75.0   0.022    35.0    65.0  2000.0

Simulation:
Froude number:      2.072; effleunt density (sigma-T)     5.142; effleunt velocity     0.434(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     75.0      0.2    0.254     35.0     65.0   2000.0   2000.0      1.0      0.0      0.0;
  23    75.11      0.2    0.383    35.06    53.34   1384.9   1384.9    1.435 -0.00865 -0.00865; begin overlap;
 100    75.31      0.2    0.692    35.12    42.67    821.8    821.8    2.405   -0.102   -0.102;
 158    75.35      0.2    0.774    35.13    40.81    723.7    723.7    2.729   -0.221   -0.221; local maximum rise o1
 200    75.31      0.2    0.754    35.13    39.94    677.9    677.9    2.913   -0.336   -0.336;
 205     75.3      0.2    0.752    35.13     39.5    654.9    654.9    3.015   -0.359   -0.359; end overlap;
 300     74.4      0.2    1.606    35.19    29.09    104.5    104.5    18.82   -1.603   -1.603;
 400    72.16      0.2    4.336     35.2    27.47    14.42    14.42    136.3   -7.329   -7.329;
 449    70.04      0.2     7.08     35.2    27.39    5.465    5.465    359.6   -16.61   -16.61; trap level;
 482    68.24      0.2    9.826     35.2     27.4    2.856    2.856    688.3   -42.85   -42.85; local maximum rise o1
 499    69.81      0.2    11.48     35.2    27.41    2.087    2.087    941.8   -70.87   -70.87; acute zone;
 500     69.9      0.2     11.6     35.2    27.41    2.046    2.046    960.6   -72.16   -72.16; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      11.60 m
    conc  dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)    (ppm)     (s-1)     (m/s)(m0.67/s2)
 2.04323   962.0   11.92   110.0   0.011      0.0       0.0       0.2 3.00E-4
 2.04478   961.3   12.34   120.0  0.0249      0.0       0.0       0.2 3.00E-4
 2.04518   961.1   12.76   130.0  0.0388      0.0       0.0       0.2 3.00E-4
```

Appendix B.6 Discharge at 65 °C and 0.5 m/s ambient current

Port Depth = 2 m

```
/ UM3. 7/16/2019 8:15:08 AM
Case 1; ambient file c:\plumes\VP plume 1.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2   sigma-T
       0.0       0.5    -135.0      35.1      28.0       0.0       0.0       0.5    -135.0    0.0003     22.49
      15.0       0.5    -135.0      35.1      27.9       0.0       0.0       0.5    -135.0    0.0003     22.53
      20.0       0.5    -135.0      35.2      27.7       0.0       0.0       0.5    -135.0    0.0003     22.67
      60.0       0.5    -135.0      35.2      27.6       0.0       0.0       0.5    -135.0    0.0003      22.7
      70.0       0.5    -135.0      35.2      27.4       0.0       0.0       0.5    -135.0    0.0003     22.76
      80.0       0.5    -135.0      35.2      26.8       0.0       0.0       0.5    -135.0    0.0003     22.96
      90.0       0.5    -135.0      35.0      26.1       0.0       0.0       0.5    -135.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppm)
   0.254    88.0   -90.0   225.0     1.0   100.0  5000.0     2.0   0.022    35.0     65.0  2000.0

Simulation:
Froude number:       2.093; effluent density (sigma-T)      5.142; effluent velocity      0.434(m/s);
          Depth  Amb-cur     P-dia  Eff-sal      Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step        (m)    (m/s)       (m)    (psu)       (C)    (ppm)    (ppm)       ()       (m)       (m)
   0        2.0      0.5     0.254     35.0      65.0   2000.0   2000.0      1.0       0.0       0.0;
   1      2.003      0.5     0.256     35.0     64.47   1971.3   1971.3    1.014-3.560E-5-3.560E-5; begin overlap;
 100      2.163      0.5     0.443    35.05     44.68    902.0    902.0    2.194   -0.0799   -0.0799;
 116       2.19      0.5     0.473    35.06      41.7    741.1    741.1    2.667    -0.122    -0.122; end overlap;
 158      2.279      0.5      0.63    35.08     34.19    335.1    335.1     5.88    -0.811    -0.811; local maximum rise o1
 200      2.082      0.5     0.901    35.09     30.68    145.9    145.9    13.49    -2.515    -2.515;
 293      1.078      0.5     2.192     35.1     28.42    23.13    23.13    85.02    -10.27    -10.27; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of      2.19 m
    conc  dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
   23.09   85.16   2.243    20.0 0.00304      0.0      0.0      0.5 3.00E-4
 .....
 3.05924   652.3   23.25  1360.0   0.747      0.0      0.0      0.5 3.00E-4
 3.03247   658.1   23.45  1370.0   0.753      0.0      0.0      0.5 3.00E-4
 3.00608   663.9   23.66  1380.0   0.759      0.0      0.0      0.5 3.00E-4
 2.98008   669.7   23.87  1390.0   0.764      0.0      0.0      0.5 3.00E-4
 2.95445   675.5   24.08  1400.0    0.77      0.0      0.0      0.5 3.00E-4
 2.92919   681.3   24.28  1410.0   0.775      0.0      0.0      0.5 3.00E-4
```

Port Depth = 10 m

```
/ UM3. 7/15/2019 10:18:30 AM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: -----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2   sigma-T
       0.0       0.5    -135.0      35.1      28.0       0.0       0.0       0.5    -135.0    0.0003     22.49
      15.0       0.5    -135.0      35.1      27.9       0.0       0.0       0.5    -135.0    0.0003     22.53
      20.0       0.5    -135.0      35.2      27.7       0.0       0.0       0.5    -135.0    0.0003     22.67
      60.0       0.5    -135.0      35.2      27.6       0.0       0.0       0.5    -135.0    0.0003      22.7
      70.0       0.5    -135.0      35.2      27.4       0.0       0.0       0.5    -135.0    0.0003     22.76
      80.0       0.5    -135.0      35.2      26.8       0.0       0.0       0.5    -135.0    0.0003     22.96
      90.0       0.5    -135.0      35.0      26.1       0.0       0.0       0.5    -135.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppm)
   0.254    80.0   -90.0   225.0     1.0   100.0  5000.0    10.0   0.022    35.0     65.0  2000.0

Simulation:
Froude number:       2.092; effluent density (sigma-T)      5.142; effluent velocity      0.434(m/s);
          Depth  Amb-cur     P-dia  Eff-sal      Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step        (m)    (m/s)       (m)    (psu)       (C)    (ppm)    (ppm)       ()       (m)       (m)
   0       10.0      0.5     0.254     35.0      65.0   2000.0   2000.0      1.0       0.0       0.0;
   1       10.0      0.5     0.256     35.0     64.47   1971.3   1971.3    1.014-3.560E-5-3.560E-5; begin overlap;
 100      10.16      0.5     0.443    35.05     44.65    902.1    902.1    2.193   -0.0799   -0.0799;
 116      10.19      0.5     0.473    35.06     41.67    741.2    741.2    2.666    -0.122    -0.122; end overlap;
 158      10.28      0.5      0.63    35.08     34.14    335.2    335.2    5.878    -0.811    -0.811; local maximum rise o1
 200      10.08      0.5     0.901    35.09     30.64    145.9    145.9    13.49    -2.514    -2.514;
 300      8.956      0.5     2.347     35.1     28.31    20.14    20.14    97.64     -11.4     -11.4;
 400      5.853      0.5     6.296     35.1      28.0     2.78     2.78    707.3    -51.23    -51.23;
 421      4.717      0.5      7.75     35.1     27.99    1.834    1.834   1072.0    -71.13    -71.13; acute zone;
 430      4.155      0.5     8.472     35.1     27.99    1.535    1.535   1281.1    -82.23    -82.23; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of      8.47 m
    conc  dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)    (ppm)    (s-1)    (m/s)(m0.67/s2)
 1.52972  1285.3   8.527   120.0 0.00206      0.0      0.0      0.5 3.00E-4
 1.53217  1283.2   8.675   130.0 0.00762      0.0      0.0      0.5 3.00E-4
 1.53302  1282.5   8.823   140.0  0.0132      0.0      0.0      0.5 3.00E-4
  1.5335  1282.1   8.972   150.0  0.0187      0.0      0.0      0.5 3.00E-4
  1.5338  1281.8   9.122   160.0  0.0243      0.0      0.0      0.5 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 7/15/2019 10:27:19 AM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: ------------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0       0.5    -135.0      35.1      28.0       0.0       0.0       0.5    -135.0    0.0003     22.49
      15.0       0.5    -135.0      35.1      27.9       0.0       0.0       0.5    -135.0    0.0003     22.53
      20.0       0.5    -135.0      35.2      27.7       0.0       0.0       0.5    -135.0    0.0003     22.67
      60.0       0.5    -135.0      35.2      27.6       0.0       0.0       0.5    -135.0    0.0003      22.7
      70.0       0.5    -135.0      35.2      27.4       0.0       0.0       0.5    -135.0    0.0003     22.76
      80.0       0.5    -135.0      35.2      26.8       0.0       0.0       0.5    -135.0    0.0003     22.96
      90.0       0.5    -135.0      35.0      26.1       0.0       0.0       0.5    -135.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    60.0   -90.0   225.0     1.0   100.0  5000.0    30.0   0.022    35.0    65.0  2000.0

Simulation:
Froude number:       2.083; effleunt density (sigma-T)     5.142; effleunt velocity      0.434(m/s);
        Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step      (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0     30.0      0.5     0.254     35.0     65.0   2000.0   2000.0      1.0       0.0       0.0;
   1     30.0      0.5     0.256     35.0    64.46   1971.3   1971.3    1.014-3.559E-5-3.559E-5; begin overlap;
 100    30.16      0.5     0.443    35.11    44.53    903.3    903.3     2.19  -0.0798   -0.0798;
 116    30.19      0.5     0.473    35.13    41.53    742.6    742.6    2.661    -0.122    -0.122; end overlap;
 158    30.28      0.5      0.63    35.17    33.95    336.1    336.1    5.861    -0.813    -0.813; local maximum rise or
 200    30.08      0.5       0.9    35.19    30.41    146.3    146.3    13.45    -2.497    -2.497;
 300    28.96      0.5     2.344     35.2    28.05     20.2     20.2    97.35    -11.32    -11.32;
 400    25.85      0.5     6.286     35.2    27.73    2.788    2.788    705.2    -50.37    -50.37;
 423     24.6      0.5     7.893     35.2    27.72    1.768    1.768   1112.0    -71.33    -71.33; acute zone;
 482    19.73      0.5     14.16     35.2     27.7     0.55     0.55   3576.8    -184.2    -184.2; trap level;
 489    19.28      0.5     15.17     35.2     27.7    0.478    0.478   4108.6    -218.9    -218.9; local maximum rise or
 494     20.2      0.5     15.91     35.2    27.71    0.435    0.435   4518.2    -250.4    -250.4; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      15.91 m
    conc   dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)     (ppm)     (s-1)     (m/s)(m0.67/s2)
 0.43369   4532.9    16.01   360.0  0.00323       0.0       0.0      0.5 3.00E-4
 0.43423   4527.1     16.2   370.0  0.00879       0.0       0.0      0.5 3.00E-4
 0.43446   4524.6    16.38   380.0   0.0143       0.0       0.0      0.5 3.00E-4
```

Port Depth = 50 m

```
/ UM3. 7/15/2019 10:29:05 AM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: ------------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0       0.5    -135.0      35.1      28.0       0.0       0.0       0.5    -135.0    0.0003     22.49
      15.0       0.5    -135.0      35.1      27.9       0.0       0.0       0.5    -135.0    0.0003     22.53
      20.0       0.5    -135.0      35.2      27.7       0.0       0.0       0.5    -135.0    0.0003     22.67
      60.0       0.5    -135.0      35.2      27.6       0.0       0.0       0.5    -135.0    0.0003      22.7
      70.0       0.5    -135.0      35.2      27.4       0.0       0.0       0.5    -135.0    0.0003     22.76
      80.0       0.5    -135.0      35.2      26.8       0.0       0.0       0.5    -135.0    0.0003     22.96
      90.0       0.5    -135.0      35.0      26.1       0.0       0.0       0.5    -135.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    40.0   -90.0   225.0     1.0   100.0  5000.0    50.0   0.022    35.0    65.0  2000.0

Simulation:
Froude number:       2.082; effleunt density (sigma-T)     5.142; effleunt velocity      0.434(m/s);
        Depth  Amb-cur     P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn    x-posn    y-posn
Step      (m)    (m/s)       (m)    (psu)      (C)    (ppm)    (ppm)       ()       (m)       (m)
   0     50.0      0.5     0.254     35.0     65.0   2000.0   2000.0      1.0       0.0       0.0;
   1     50.0      0.5     0.256     35.0    64.46   1971.3   1971.3    1.014-3.559E-5-3.559E-5; begin overlap;
 100    50.16      0.5     0.443    35.11    44.51    903.4    903.4     2.19  -0.0798   -0.0798;
 116    50.19      0.5     0.473    35.13     41.5    742.7    742.7     2.66    -0.122    -0.122; end overlap;
 158    50.28      0.5     0.629    35.17    33.91    336.2    336.2     5.86    -0.813    -0.813; local maximum rise or
 200    50.08      0.5       0.9    35.19    30.36    146.3    146.3    13.44    -2.496    -2.496;
 300    48.96      0.5     2.344     35.2     28.0     20.2     20.2    97.32    -11.32    -11.32;
 400    45.86      0.5     6.286     35.2    27.68    2.788    2.788    705.0    -50.36    -50.36;
 423     44.6      0.5     7.892     35.2    27.67    1.768    1.768   1111.7    -71.31    -71.31; acute zone;
 488    39.06      0.5     15.02     35.2    27.65    0.488    0.488   4027.1    -205.6    -205.6; trap level;
 500    37.65      0.5     16.92     35.2    27.65    0.385    0.385   5107.4    -263.3    -263.3;
 513    36.46      0.5     19.24     35.2    27.65    0.298    0.298   6607.0    -422.6    -422.6; local maximum rise or
 525     38.9      0.5     21.67     35.2    27.65    0.235    0.235   8379.2    -607.5    -607.5; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      21.67 m
    conc   dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs)     (ppm)     (s-1)     (m/s)(m0.67/s2)
 0.23351   8418.7    21.69   860.0  5.04E-4       0.0       0.0      0.5 3.00E-4
 0.23397   8401.8    21.89   870.0  0.00606       0.0       0.0      0.5 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 7/15/2019 10:31:05 AM
Case 1; ambient file c:\plumes\VP plume 0.001.db; Diffuser table record 1: ----------------------------------

Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol    Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg      s-1       m/s       deg  m0.67/s2   sigma-T
       0.0       0.5    -135.0      35.1      28.0       0.0      0.0       0.5    -135.0    0.0003     22.49
      15.0       0.5    -135.0      35.1      27.9       0.0      0.0       0.5    -135.0    0.0003     22.53
      20.0       0.5    -135.0      35.2      27.7       0.0      0.0       0.5    -135.0    0.0003     22.67
      60.0       0.5    -135.0      35.2      27.6       0.0      0.0       0.5    -135.0    0.0003      22.7
      70.0       0.5    -135.0      35.2      27.4       0.0      0.0       0.5    -135.0    0.0003     22.76
      80.0       0.5    -135.0      35.2      26.8       0.0      0.0       0.5    -135.0    0.0003     22.96
      90.0       0.5    -135.0      35.0      26.1       0.0      0.0       0.5    -135.0    0.0003     23.03

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
   0.254    15.0   -90.0   225.0     1.0   100.0  5000.0    75.0   0.022    35.0    65.0  2000.0

Simulation:
Froude number:       2.072; effleunt density (sigma-T)     5.142; effleunt velocity     0.434(m/s);
        Depth  Amb-cur    P-dia  Eff-sal     Temp  Polutnt  4/3Eddy   Dilutn   x-posn   y-posn
Step      (m)    (m/s)      (m)    (psu)      (C)    (ppm)    (ppm)       ()      (m)      (m)
   0     75.0      0.5    0.254     35.0     65.0   2000.0   2000.0      1.0      0.0      0.0;
   1     75.0      0.5    0.256     35.0    64.46   1971.3   1971.3    1.014-3.558E-5-3.558E-5; begin overlap;
 100    75.16      0.5    0.443    35.11    44.23    904.4    904.4    2.187  -0.0797  -0.0797;
 116    75.19      0.5    0.473    35.13    41.19    743.9    743.9    2.656   -0.122   -0.122; end overlap;
 158    75.28      0.5    0.629    35.17    33.48    337.0    337.0    5.845   -0.814   -0.814; local maximum rise or
 200    75.08      0.5    0.899    35.19    29.87    146.7    146.7    13.41   -2.485   -2.485;
 300    73.96      0.5    2.341     35.2    27.51    20.25    20.25    97.09   -11.35   -11.35;
 382    71.69      0.5    5.256     35.2    27.29    3.991    3.991    492.4   -42.39   -42.39; trap level;
 400    70.94      0.5    6.281     35.2     27.3    2.795    2.795    703.3    -63.4    -63.4;
 404     70.8      0.5    6.535     35.2     27.3    2.582    2.582    761.3   -72.77   -72.77; acute zone;
 407    70.82      0.5    6.732     35.2    27.31    2.433    2.433    807.9   -88.65   -88.65; local maximum rise or
 419    71.65      0.5    7.579     35.2    27.31    1.918    1.918   1024.6   -124.9   -124.9; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       7.58 m
   conc  dilutn   width distnce    time
  (ppm)             (m)     (m)   (hrs)   (ppm)   (s-1)   (m/s)(m0.67/s2)
 1.91214  1028.0   7.628   180.0 0.00191     0.0     0.0     0.5 3.00E-4
 1.91532  1026.2    7.77   190.0 0.00746     0.0     0.0     0.5 3.00E-4
 1.91639  1025.6   7.913   200.0   0.013     0.0     0.0     0.5 3.00E-4
```

Appendix E: Corowa Development – Quantitative Oil Spill Modelling

KATO OIL QUANTITATIVE SPILL RISK ASSESSMENT - REPORT

Corowa Field – Subsurface Corowa Light Crude and Surface Marine Gas Oil Spills

MAW0843J.000
Kato Oil QSRA – Corowa
Report
Rev 2
25 October 2019

rpsgroup.com

Contents

Tables

Figures

EXECUTIVE SUMMARY

RPS was commissioned by Kato Energy to conduct a quantitative oil spill risk assessment for two hydrocarbon spill scenarios associated with the Corowa field in permit area WA-41-R, located approximately 60 km offshore in Onslow in 85 m of water. The field lies in the Carnarvon Basin on the North West Shelf of Australia.

The main objectives of the study were: (i) to quantify the movement and fate of spilled hydrocarbons that could result if the defined spill scenarios were to occur; and (ii) to quantify risks to sensitive receptors (emergent features, submerged features and shorelines) posed by the spill scenarios, on the basis of the probability of exposure above defined exposure concentrations.

Kato identified two hypothetical hydrocarbon spill scenarios that could potentially occur within the Corowa field. These scenarios were modelled and assessed over defined seasonal periods: summer southwest winds (September to March), (ii) the transitional periods (April and August) and (iii) winter southeast winds (May and July). This approach assists in identifying the sensitive receptors that would be at risk of exposure on a seasonal basis.

Details of the scenarios are as follows:

- A long-term (80 day) uncontrolled subsea release of 410,280 m^3 of Corowa Light Crude within the Corowa field (114° 33' 26.20" E, 21° 28' 59.40" S), representing loss of containment after a loss of well control.

- A short-term (6-hour) uncontrolled surface release of 500 m^3 of marine gas oil within the Corowa field (114° 33' 26.20" E, 21° 28' 59.40" S), representing a rupture of a support vessel tank.

These scenarios were modelled in a stochastic manner (i.e. a total of 150 for the subsea well blowout and 300 for the short-term surface release) varying only the sequence of wind and current that affected the spill areas, over the seasonal periods.

Oil spill modelling was undertaken using a three-dimensional oil spill trajectory and weathering model, SIMAP (Spill Impact Mapping and Analysis Program), which is designed to simulate the transport, spreading and weathering of specific oil types under the influence of changing meteorological and oceanographic forces.

Near-field subsurface discharge modelling was undertaken using OILMAP, which predicts the centreline velocity, buoyancy, width and trapping depth (if any) of the rising gas and oil plumes.

The main findings of the study are as follows:

Metocean Influences

- Large scale drift currents will have a significant influence on the trajectory of any oil spilled at the modelled release site, irrespective of the seasonal conditions. The prevailing drift currents will determine the trajectory of oil that is entrained beneath the water surface.

- Interactions with the prevailing wind will provide additional variation in the trajectory of spilled oil and marked variation in the prevailing drift current and wind conditions will be expected over the duration of a long-term release. This will be expected to increase the spread of hydrocarbon during any single event.

Oil Characteristics and Weathering Behaviour

- The composition of Corowa Light Crude contains a high proportion of volatile compounds, and a small proportion of residual hydrocarbons that will not evaporate at atmospheric temperatures. If exposed to the atmosphere, around 80% of the mass will be expected to evaporate in around 24 hours and another 14% within a few days. The influence of entrainment will regulate the degree of mass retention in the environment.

- The composition of marine gas oil contains a high proportion of volatile compounds, and a small proportion of residual hydrocarbons that will not evaporate at atmospheric temperatures. If exposed to the atmosphere, around 65% of the mass will be expected to evaporate in around 24 hours and another 32% within a few days. The influence of entrainment will regulate the degree of mass retention in the environment.

- During the subsea release, large droplets have the potential to reach the surface within minutes of the release, with floating slicks likely to be formed under typical wind conditions. It is likely that the bulk of the oil mass at any time will be found in the wave-mixed layer. Evaporation rates will be high for any surfacing oil, given the large proportion of volatile compounds within the oil. Considering the spill volume, there is potential for dissolution of soluble aromatic compounds.

- During the surface release, floating slicks are likely to be formed under light wind conditions. Given the low viscosity of the oil, entrainment into the water column is likely to occur under all but very light wind conditions. It is likely that the bulk of the oil mass at any time will be entrained within the water column. Evaporation rates will be very high, given the large proportion of volatile compounds within the oil. Any residual fraction will persist in the environment until degradation processes occur. Considering the spill volumes, there is potential for dissolution of soluble aromatic compounds.

Summary of Modelling Results

Long-Term (80-day) subsea well blowout of Corowa Light Crude within the Corowa field

Deterministic Modelling Assessment

One deterministic spill case was identified from the set of stochastic results based on the following criteria:

- Replicate simulation with the maximum oil volume accumulation on all shoreline receptors.

Deterministic Case 1: Maximum oil volume loading on shorelines

- The maximum oil volume loading on shorelines during a single spill event was predicted as 1,092 m^3 for a spill commencing in summer (run 25). During this deterministic case, the maximum oil loading was distributed across Ningaloo MP (State) and Ningaloo Coast World Heritage Area (WH).

- The maximum distance from the spill location to the outer edge of hydrocarbon exposure during this spill is predicted as 661.5 km for entrained oil at concentrations equal to or greater than the moderate (100 ppb) threshold.

Stochastic Modelling Assessment

- Floating oil concentrations at the low threshold (1 g/m^2) could travel up to 1,167 km from the release location, with distances reducing at the moderate (10 g/m^2; 476 km) and high (25 g/m^2; 393 km) thresholds across all seasons.

- The highest probabilities of shoreline contact by floating oil at the moderate threshold (10 g/m^2) is predicted at Murion Islands Marine Management Area as 40% in winter.

- Minimum times of arrival at the moderate floating oil threshold (10 g/m^2) is predicted for the Murion Islands Marine Management Area shoreline receptor as 10 hours in winter.

- The worst-case potential volume of oil accumulating on a given receptor shoreline is forecast at Ningaloo Marine Park (State) and Ningaloo Coast World Heritage Area with an accumulated concentration and volume of 19.3 kg/m^2 and 1,092 m^3, respectively.

- The worst-case maximum length of shoreline with concentrations exceeding the moderate threshold (100 g/m^2) was calculated as 68 km at the Ningaloo Coast WH and Ningaloo MP (State) in summer.

- Instantaneous entrained oil concentrations at the low threshold (10 ppb) could travel up to 1,680 km from the release location in transitional months, with the distances reducing at the moderate (100 ppb; 1,173 km) and high (1,000 ppb; 610 km) threshold.

- The probability of contact by entrained oil concentrations at the moderate threshold (100 ppb) is predicted to be greatest at Ningaloo Coast World Heritage Area, Ningaloo Marine Park and the Gascoyne Marine Park with a probability of 100% across all seasons. Entrained oil at the moderate threshold is predicted to arrive at these receptors within 29 hours after the release commences.

- The worst-case instantaneous entrained oil concentration at any receptor is predicted at Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western and Billfish and Western Skipjack Fisheries as 50,458 ppb.

- The seasonal cross-sectional transections in the vicinity of the release site indicate that entrained oil concentrations at or greater than the moderate (100 ppb) and high (1,000 ppb) thresholds are not expected to exceed depths of around 40 m and 30 m BMSL, respectively, in any season. Therefore, limiting benthic contact below this depth.

- Time-integrated entrained oil exposure at or above the 960 ppb.h threshold could travel up to 1,195 km from the release location, with the distance reducing to 1,173 km and 365 km as contact thresholds increase to 9,600 ppb.h and 96,000 ppb.h, respectively.

- The probability of contact by time-integrated exposure of entrained oil concentrations at the 96,000 ppb.h threshold is predicted to be greatest at the Marine Turtle, Seabirds, Sharks and Whales Biologically Important Areas with a probability of 100% across all seasons.

- The worst-case maximum entrained oil integrated exposure is predicted at the Marine Turtle, Seabirds, Sharks and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 2,139,096 ppb.h.

- Instantaneous dissolved aromatic hydrocarbon concentrations at the low (10 ppb) threshold could travel up to 861 km from the release location, with distances reducing at the moderate (50 ppb; 597 km) and high (400 ppb; 129 km) thresholds across all seasons.

- The probability of contact by dissolved aromatic hydrocarbon concentrations at the moderate threshold (50 ppb) is predicted to be greatest at the Ancient Coastline at 125 m Depth Contour and Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula Key Ecological Features with probabilities of 100% across all seasons.

- The worst-case dissolved aromatic hydrocarbon concentrations at any receptor is predicted at Ancient Coastline at 125 m Depth Contour Key Ecologically Feature, Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales, and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries as 1,047 ppb.

- The seasonal cross-sectional transections in the vicinity of the release site indicate that dissolved aromatic hydrocarbon concentrations at or greater than the high (400 ppb) threshold are not expected to reach depths greater than approximately 80 m BMSL. Therefore, limiting benthic contact below this depth.

- Time integrated dissolved aromatic hydrocarbons exposure at or above 960 ppb.h could travel up to 198 km from the release site, with the distance reducing to 102 km as the contact threshold increases to 4,800 ppb.h.

- The probability of contact by dissolved aromatic hydrocarbon exposure at the 4,800 ppb.h threshold was predicted to be greatest at the Marine Turtles, Seabirds, Sharks and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries with a probability of 92% in the surface layer (0-10 m) in summer.

- The worst-case maximum dissolved aromatic hydrocarbon exposure concentration at any receptor is predicted at Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 19,679 ppb.h.

- Note, the highest probabilities and concentrations of entrained oil and dissolved aromatic hydrocarbons are generally expected to occur within the surface layer (0-10 m), with probabilities expected to reduce with depth.

Short-Term (6-hour) surface release of marine gas oil after a rupture of a supply vessel tank

Deterministic Modelling Assessment

One deterministic spill case was identified from the set of stochastic results based on the following criteria:

- Replicate simulation with the maximum oil volume accumulation on all shoreline receptors.

Deterministic Case 1: Maximum oil volume loading on shorelines

- The maximum oil volume loading on shorelines during a single spill event was predicted as 185 m^3 for a spill commencing in summer (run 2). During this spill simulation, the maximum oil loading along an individual shoreline receptor was predicted at Murion Islands Marine Management Area.

- The maximum distance from the spill location to the outer edge of hydrocarbon exposure during this spill is predicted as 33 km for shoreline oil at concentrations exceeding the moderate (100 g/m^2) threshold.

Stochastic Modelling Assessment

- Floating oil concentrations at the low threshold (1 g/m^2) could travel up to 178 km from the release location, with distances reducing at the moderate (10 g/m^2; 50 km) and high (25 g/m^2; 18 km) thresholds.

- The highest probabilities of floating oil contact at the low threshold (1 g/m^2) is forecast at the Muiron Islands Marine Management Area (summer; 5%, winter; 10%, and transitional months; 4%).

- Floating oil at the low threshold is predicted to arrive at the Southern Pilbara - Islands within 9 hours after a spill commencement in winter.

- The worst-case oil accumulation on a shoreline is predicted for the Murion Islands Marine Management Area receptor with an accumulated concentration and volume of 3.3 kg/m^2 and 185 m^3, respectively.

- The worst-case maximum length of shoreline with concentrations exceeding the low threshold (10 g/m^2) was calculated as 23 km for the Ningaloo WH and Shark Bay WH in transitional months

- Instantaneous entrained oil concentrations at the low threshold (10 ppb) could travel up to 957 km from the release location in winter, with distances reducing at the moderate (100 ppb; 674 km) and high (1,000 ppb; 304 km) thresholds.

- The probability of contact by entrained oil concentrations at the low threshold (10 ppb) is predicted to be greatest at the Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries with probabilities of 54-68% across all seasons. Entrained oil at the low threshold is predicted to arrive at these receptors within 1 hour after the release commences.

- The worst-case instantaneous entrained oil concentration at any receptor is predicted Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries as 10,865 ppb in summer.

- The seasonal cross-sectional transections in the vicinity of the release site indicate that entrained oil concentrations at or greater than the moderate (100 ppb) and high (1,000 ppb) thresholds are not expected to exceed depths of around 60 m and 25 m BMSL, respectively, across any season. Therefore, limiting benthic contact below this depth.

- Time-integrated entrained oil exposure at or above the 960 ppb.h threshold could travel up to 578 km from the release location, with the distance reducing to 172 km as the contact threshold increases to 9,600 ppb.h.
- The probability of contact by time-integrated exposure of entrained oil concentrations at the 9,600 ppb.h threshold is predicted to be greatest at Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries with a probability of 14% in the surface layer (0-10 m) in transitional months.
- The worst-case maximum entrained oil integrated exposure is predicted at the Ancient Coastline at 125 m Depth Contour Key Ecological Feature, Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries as 65,338 ppb.h.
- Instantaneous dissolved aromatic hydrocarbon concentrations at the low (10 ppb) threshold could travel up to 827 km from the release location, with distances reducing at the moderate (50 ppb; 272 km) threshold and no exposure predicted above 400 ppb.
- The probability of contact by dissolved aromatic hydrocarbon concentrations at the low threshold (10 ppb) is predicted to be greatest at Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and Western Skipjack Fishery with probabilities of 21-29% across all seasons.
- The worst-case dissolved aromatic hydrocarbon concentrations at any receptor is predicted at the Marine Turtle, Seabirds, Seabirds and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries as 275 ppb in summer.
- The seasonal cross-sectional transections in the vicinity of the release site indicate that dissolved aromatic hydrocarbon concentrations at or greater than the moderate (50 ppb) threshold are not expected to reach depths greater than approximately 50 m BMSL. Therefore, limiting benthic interaction below this depth.
- Time integrated dissolved aromatic hydrocarbon exposure at or above 960 ppb.h could travel up to 7 km from the release site.
- The probability of contact by dissolved aromatic hydrocarbon exposure at the 960 ppb.h threshold was predicted to be greatest at the Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries with a probability of 7% in the surface layer (0-10 m) in transitional months.
- The worst-case maximum dissolved aromatic hydrocarbon exposure concentration at any receptor is predicted at the Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery as 3,609 ppb.h.
- Note, the highest probabilities and concentrations of entrained oil and dissolved aromatic hydrocarbons are generally expected to occur within the surface layer (0-10 m), with probabilities expected to reduce with depth.

1 INTRODUCTION

1.1 Background

RPS was commissioned by Kato Energy (Kato) to conduct a quantitative oil spill risk assessment for two hydrocarbon spill scenarios associated with the Corowa field in permit area WA-41-R, located approximately 60 km offshore in Onslow in 85 m of water. The field lies in the Carnarvon Basin on the North West Shelf of Australia (Figure 1.1).

The main objectives of the study were: (i) to quantify the movement and fate of spilled hydrocarbons that could result if the defined spill scenarios were to occur; and (ii) to quantify risks to sensitive receptors (emergent features, submerged features and shorelines) posed by the spill scenarios, on the basis of the probability of exposure above defined exposure concentrations.

Kato identified two hypothetical hydrocarbon spill scenarios that could potentially occur within the Corowa field. These scenarios were modelled and assessed over defined seasonal periods: summer southwest winds (September to March), (ii) the transitional periods (April and August) and (iii) winter southeast winds (May and July). This approach assists in identifying the shorelines that would be at risk of exposure on a seasonal basis.

Details of the scenarios are as follows:

- A long-term (80-day) uncontrolled subsea release of 410,280 m^3 of Corowa Light Crude within the Corowa field (114° 33' 26.20" E, 21° 28' 59.40" S), representing loss of containment after a loss of well control.

- A short-term (6-hour) uncontrolled surface release of 500 m^3 of marine gas oil within the Corowa field (114° 33' 26.20" E, 21° 28' 59.40" S), representing a rupture of a support vessel tank.

The physical and chemical properties of Corowa Light Crude and marine gas oil were applied.

Table 1.1 Summary of the hydrocarbon spill scenarios assessed in this study.

Description	Oil Type	Spilled Volume (m^3)	Discharge rate	Release Coordinates	Release Depth (BMSL)	Spill Duration	Simulation Duration
Subsea release after a well blow out	Corowa Light Crude	410,280	10,107-3,655 m^3/day	114° 33' 26.20" E 21° 28' 59.40" S	85 m	80 days	108 days
Surface release after a rupture of the support vessel tank	Marine gas oil	500	83.3 m^3/hour	114° 33' 26.20" E 21° 28' 59.40" S	0 m	6 hours	30 days

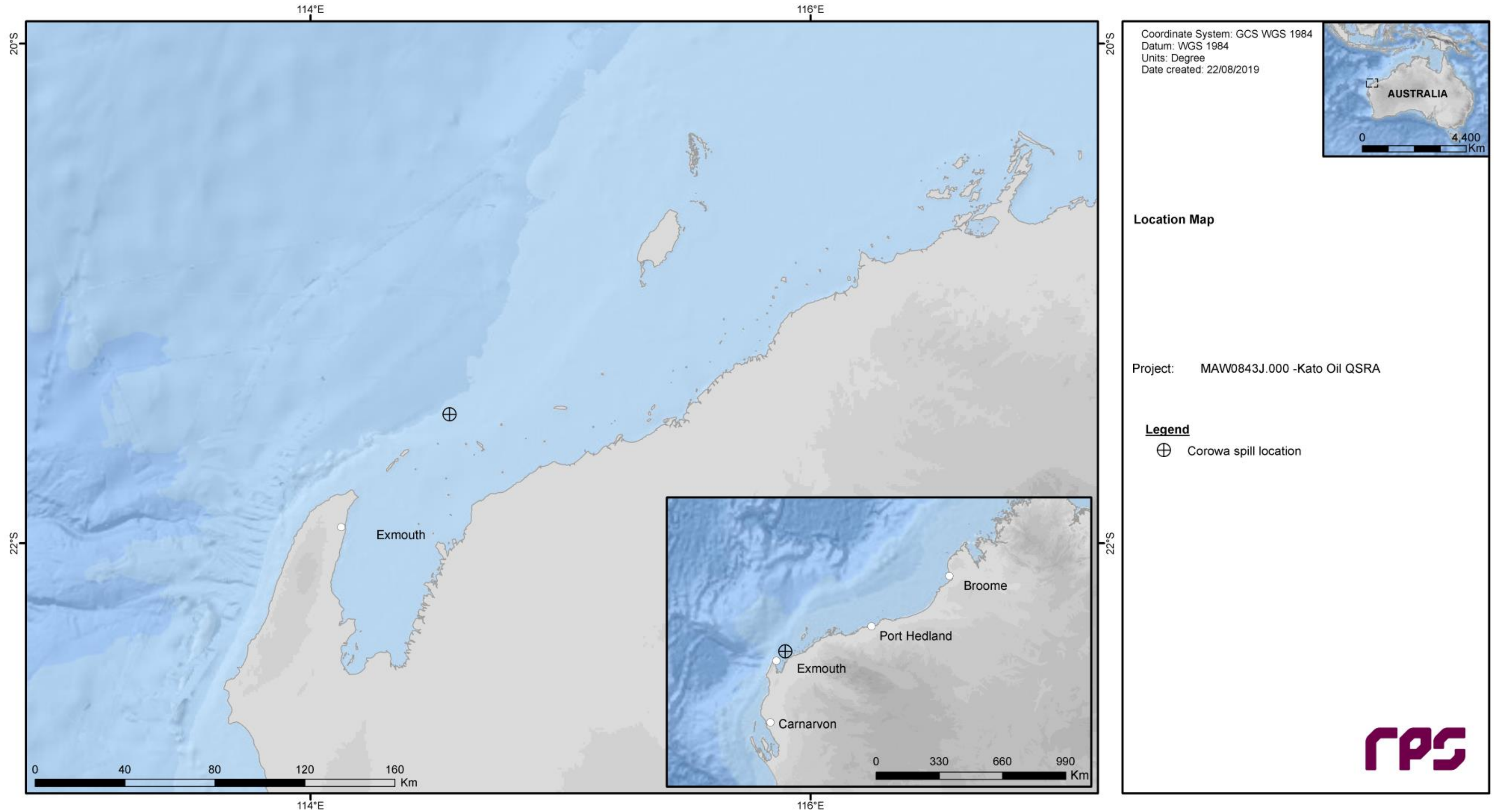


Figure 1.1 Location of the modelled hydrocarbon spill scenarios release site within the Corowa field.

1.2 What is Oil Spill Modelling?

Oil spill modelling is a valuable tool widely used for risk assessment, emergency response and contingency planning where it can be particularly helpful to proponents and decision makers. By modelling a series of the most likely oil spill scenarios, decisions concerning suitable response measures and strategic locations for deploying equipment and materials can be made, and the locations at most risk can be identified. The two types of oil spill modelling often used are stochastic and deterministic modelling.

In this study, oil spill modelling was undertaken using a three-dimensional oil spill trajectory and weathering model, SIMAP (Spill Impact Mapping and Analysis Program), which is designed to simulate the transport, spreading and weathering of specific oil types under the influence of changing meteorological and oceanographic forces. For the subsea release near-field subsurface discharge modelling was undertaken using OILMAP, which predicts the centreline velocity, buoyancy, width and trapping depth (if any) of the rising gas and oil plumes.

1.2.1 Stochastic Modelling (Multiple Spill Simulations)

Stochastic oil spill modelling is created by overlaying a great number (often hundreds) of individual, computer-simulated hypothetical spills (NOPSEMA, 2018; Figure 1.2).

Stochastic modelling is a common means of assessing the potential risks from oil spills related to new projects and facilities. Stochastic modelling typically utilises hydrodynamic data for the location in combination with historic wind data. Typically, 100-250 iterations of the model will be run utilising the data that is most relevant to the season or timing of the project.

The outcomes are often presented as a probability of exposure which is primarily used for risk assessment purposes and to understand the range of environments that could be influenced or impacted by a spill. Elements of the stochastic modelling can also be used in oil spill preparedness and planning.

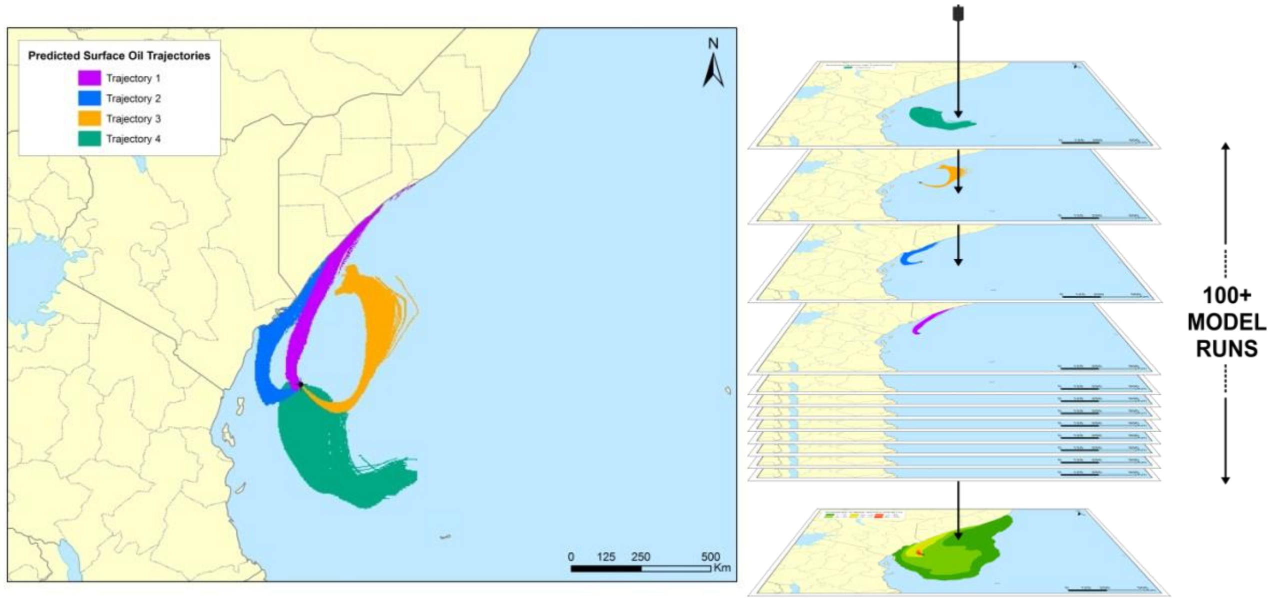


Figure 1.2 Examples of four individual spill trajectories (four replicate simulations) predicted by SIMAP for a spill scenario. The frequency of contact with given locations is used to calculate the probability of impacts during a spill. Essentially, all model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability.

1.2.2 Deterministic Modelling (Single Spill Simulation)

Deterministic modelling is the predictive modelling of a single incident subject to a single sample of wind and weather conditions over time (NOPSEMA, 2018; Figure 1.3).

Deterministic modelling is often paired with stochastic modelling to place the large stochastic footprint into perspective. This deterministic analysis is generally a single run selected from the stochastic analysis and serves as the basis for developing the plans and equipment needs for a realistic spill response.

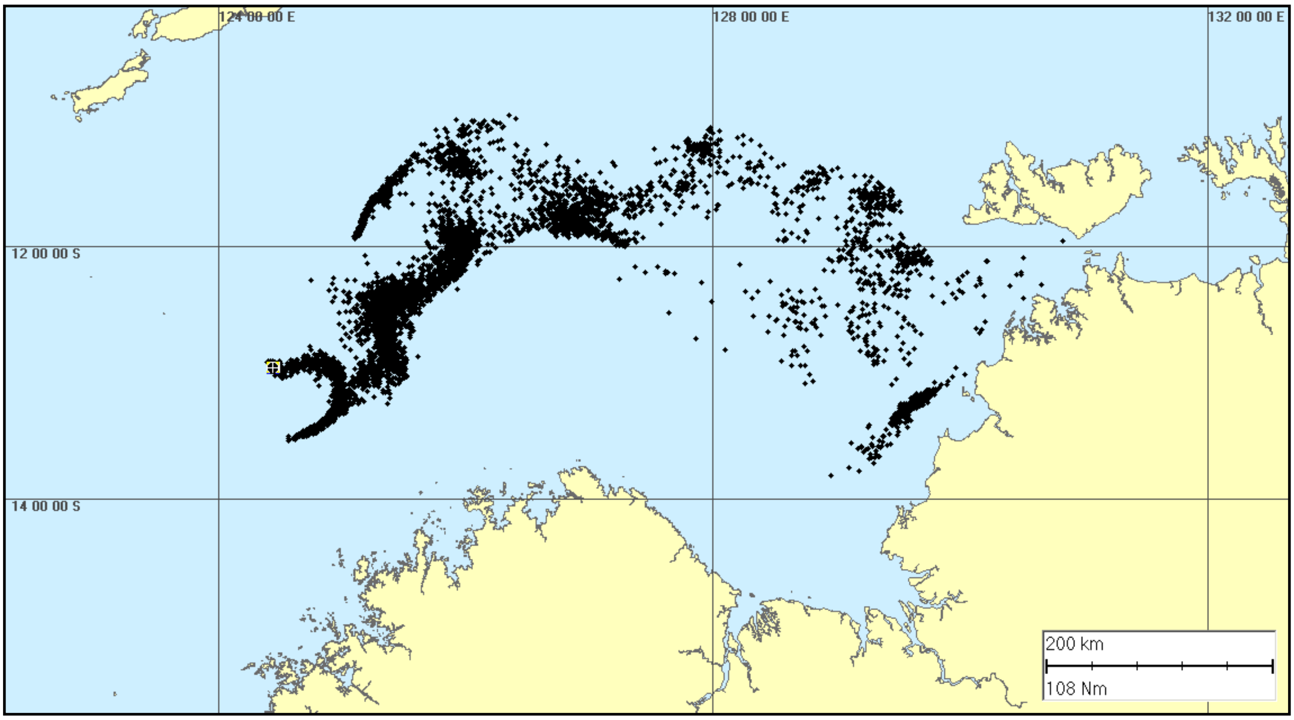


Figure 1.3 Example of an individual spill trajectory predicted by SIMAP for a spill scenario.

1.3 Report Structure

The near-field and far-field computational models, risk assessment methodology, environmental data used as input to the models, environmental threshold trigger levels defined for the assessment, characteristics of the oil type used in the modelling of the defined scenarios and plume discharge characteristics for the subsurface release scenario are described in detail in Section 2.

Contour figures and tabulated results showing risk estimates for the nominated receptors, produced for defined floating oil, entrained oil and dissolved aromatic hydrocarbon threshold concentrations and shoreline accumulation, are presented in Section 3 to summarise the deterministic and stochastic modelling outcomes.

The overall findings of the study are summarised in Section 4.

2 MODELLING METHODOLOGY

2.1 Description of the Models

2.1.1 SIMAP

The spill modelling was carried out using a purpose-developed oil spill trajectory and fates model, SIMAP (Spill Impact Mapping and Assessment Program). This model is designed to simulate the transport and weathering processes that affect the outcomes of hydrocarbon spills to the sea, accounting for the specific oil type, spill scenario, and prevailing wind and current patterns.

SIMAP is the evolution of the United States Environmental Protection Agency (US EPA) Natural Resource Damage Assessment model (French & Rines, 1997; French, 1998; French *et al.*, 1999) and is designed to simulate the fate and effects of spilled oils and fuels for both the surface slick and the three-dimensional plume that is generated in the water column. SIMAP includes algorithms to account for both physical transport and weathering processes. The latter are important for accounting for the partitioning of the spilled mass over time between the water surface (surface slick), water column (entrained oil and dissolved compounds), atmosphere (evaporated compounds) and land (stranded oil). The model also accounts for the interaction between weathering and transport processes.

The physical algorithms calculate transport and spreading by physical forces, including surface tension, gravity and wind and current forces for both surface slicks and oil within the water column. The fates algorithms calculate all of the weathering processes known to be important for oil spilled to marine waters. These include droplet and slick formation, entrainment by wave action, emulsification, dissolution of soluble components, sedimentation, evaporation, bacterial and photo-chemical decay and shoreline interactions. These algorithms account for the specific oil type being considered.

Entrainment is the physical process where globules of oil are transported from the sea surface into the water column by wind and wave-induced turbulence or be generated subsea by a pressurised discharge at depth. It has been observed that entrained oil is broken into droplets of varying sizes. Small droplets spread and diffuse into the water column, while larger ones rise rapidly back to the surface (Delvigne & Sweeney, 1988; Delvigne, 1991).

Dissolution is the process by which soluble hydrocarbons enter the water from a surface slick or from entrained droplets. The lower molecular weight hydrocarbons tend to be both more volatile and more soluble than those of higher molecular weight.

The formation of water-in-oil emulsions, or mousse, which is termed ‘emulsification’, depends on oil composition and sea state. Emulsified oil can contain as much as 80% water in the form of micrometre-sized droplets dispersed within a continuous phase of oil (Wheeler, 1978; Daling & Brandvik, 1991; Bobra, 1991; Daling et al., 1997; Fingas, 1995; Fingas, 1997).

Evaporation can result in the transfer of large proportions of spilled oil from the sea surface to the atmosphere, depending on the type of oil (Gundlach & Boehm, 1981).

Evaporation rates vary over space and time dependent on the prevailing sea temperatures, wind and current speeds, the surface area of the slick and entrained droplets that are exposed to the atmosphere as well as the state of weathering of the oil. Evaporation rates will decrease over time, depending on the calculated rate of loss of the more volatile compounds. By this process, the model can differentiate between the fates of different oil types.

Sedimentation of hydrocarbons occurs when the specific gravity increases over that of the surrounding seawater. Several processes may act on entrained oil and surface slicks to increase density: weathering (evaporation, dissolution and emulsification), adhesion or sorption onto suspended particles or detrital matter, and incorporation of sediment into oil during interaction with suspended particulates, bottom sediments, and shorelines.

Decay (degradation) of hydrocarbons may occur as the result of photolysis, which is a chemical process energised by ultraviolet light form the sun, and by biological breakdown, termed biodegradation. Many types of marine organisms ingest, metabolise and utilise oil as a carbon source, producing carbon dioxide and water as by-products.

Many types of marine organisms ingest, metabolise and utilise oil as a carbon source, producing carbon dioxide and water as by-products. The biodegradable portion of various crude oils range from 11 to 90% (NRC, 1985, 1989).

Entrainment, dissolution and emulsification rates are correlated to wave energy, which is accounted for by estimating wave heights from the sustained wind speed, direction and fetch (i.e. distance downwind from land barriers) at different locations in the domain. Dissolution rates are dependent upon the proportion of soluble, short-chained hydrocarbon compounds, and the surface area at the oil/water interface of slicks. Dissolution rates are also strongly affected by the level of turbulence. For example, dissolution rates will be relatively high at the site of the release for a deep-sea discharge at high pressure.

In contrast, the release of hydrocarbons onto the water surface will not generate high concentrations of soluble compounds. However, subsequent exposure of the surface slick to breaking waves will enhance entrainment of oil into the upper water column as oil droplets, which will enhance dissolution of the soluble components. Because the compounds that have high solubility also have high volatility, the processes of evaporation and dissolution will be in dynamic competition with the balance dictated by the nature of the release and the weather conditions that affect the oil after release. The SIMAP weathering algorithms include terms to represent these dynamic processes. Technical descriptions of the algorithms used in SIMAP and validations against real spill events are provided in French (1998), French et al. (1999) and French-McCay (2004).

Input specifications for oil types include the density, viscosity, pour-point, distillation curve (volume of oil distilled off versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges. The model calculates a distribution of the oil by mass into the following components:

- Surface-bound or floating oil.
- Entrained oil (non-dissolved oil droplets that are physically entrained by wave action).
- Dissolved hydrocarbons (principally the aromatic and short-chained aliphatic compounds).
- Evaporated hydrocarbons.
- Sedimented hydrocarbons.
- Decayed hydrocarbons.

2.1.2 OILMAP

SIMAP uses specifications of the depth of release to represent spills onto the water surface or into the water column. For subsurface release scenarios, where oil will initially be entrained in the water column as droplets of oil in suspension, it is necessary to define the size-distribution of the droplets and their initial vertical distribution following the initial (within minutes) discharge processes. These processes include the jet induced by the discharge and the dynamic evolution of any associated gas plume. This size distribution will regulate the time for oil droplets to rise to near the sea surface and affect their ability to surface and become floating oil.

High pressure releases (such as a pipeline rupture or gas/oil blowout) tend to generate a distribution with a small to median size (300 µm or less; Johansen, 2003). Due to their larger surface area to volume ratio, droplets of decreasing size will rise under buoyancy at a quadratically slower rate due to viscous resistance exerted by the surrounding water, which can be theoretically derived using Stokes' Law:

$$V = 2 * 9.81 * R^2(\rho_o - \rho_w) / 9\mu$$

Where: V is the rising velocity of oil droplets; ρ_o and ρ_w are the mass density of oil and water, respectively; R is the radius of the oil droplet; and µ is the dynamic viscosity of water.

If oil is discharged with little or no gas, the oil droplets must rise to the surface under their own buoyancy (resisted by water viscosity) after the dissipation of a relatively short (~1-2 m) discharge jet. However, if gas is discharged with the oil, it will rapidly expand on exiting the pressurised reservoir and continue to expand as it rises, and water pressure reduces. As the discharge moves upward, the density difference between the expanding gas bubbles in the plume and the receiving water results in a buoyant force which drives the plume of gas, oil and water towards the surface.

Oil in the release is rapidly mixed by the turbulence in the rising plume. These droplets (typically a few micrometres to millimetres in diameter) are rapidly transported upward by the rising plume; their individual rise velocities contributing little to their upward motion. As the plume rises, it continues to entrain ambient water, which reduces the buoyancy of the mixture and increases the radius of the plume (Chen & Yapa, 2007; Spaulding *et al.*, 2000).

In shallow water (<200 m) the rising plume of gas, oil and water will tend to reach the sea surface before deflecting as a radial, surface flow zone which will spread the oil droplets rapidly away from the centre of the plume (Spaulding *et al.*, 2000). The velocity and oil concentrations in this surface flow zone decrease while the depth of the zone increases. Finally, in the far field, where the plume buoyancy has been dissipated, ambient currents and the turbulence generated by wind generated waves will determine the subsequent transport and dispersion of the oil droplets.

As water depths increase, the buoyancy of the rising plume is likely to be lost before the plume reaches the surface, because the gas begins to dissolve into the water column due to increased water temperatures and the density of the plume equalises with the surrounding water (Chen & Yapa, 2007; Spaulding *et al.*, 2000). This results in a situation where the oil droplets will have a further distance to rise to the surface under their own buoyancy and be subject to horizontal displacement due to the prevailing water currents. The reduced velocity of these droplets will also increase their susceptibility to trapping by stratification in the water column and mixing in the near surface layer (typically 5-10 m depth) generated by surface waves.

As water depths increase further (beyond ~600 m), resulting in higher pressure and colder temperatures at the release depth, a further complication can arise due to part or all of the gas volume converting to a hydrate structure – a solid ice-like lattice structure with specific gravities on the order of 0.92 to 0.96 (Chen & Yapa, 2007; Spaulding *et al.*, 2000). The conversion of the gas into gas-hydrates deprives the plume of its principal source of buoyancy, leaving the oil droplets and gas hydrates to rise a longer distance under their own buoyancy to reach the surface. Hence, oil droplets will have a longer period during which they will be subject to horizontal transport by currents acting at the depth that they occupy.

OILMAP is an oil spill trajectory and fates model extended for the prediction of oil from subsurface oil/gas blowouts, including those in deep water (>600 m) where gas hydrate formation can affect the fate of discharged oil (Spaulding *et al.*, 2000). The blowout model predicts the centreline velocity, buoyancy, width and trapping depth (if any) of the rising gas plume. Inputs to the model include the depth (hence water pressure); discharge rate; hole size; oil density and viscosity, and the vertical temperature/salinity profile of the receiving water. This model was applied to supply the plume dimensions to the SIMAP model, for the long-term discharge simulations. The droplet size distribution was calculated using a modified form of the OILMAP droplet size algorithm (Li *et al.*, 2017). For releases in shallow water (<300 m) or with high gas to oil ratios, the modified algorithm improves the accuracy of the droplet prediction with a scaled pressure term that represents a balance between ambient hydrostatic pressure and the reservoir pressure. The typical effect of the inclusion of reservoir pressure in the droplet size algorithm is to increase predicted droplet sizes relative to those that would have been predicted if ambient hydrostatic pressure alone were used.

2.2 Calculation of Exposure Risks

The stochastic model within SIMAP performs many simulations for a given spill site, randomly varying the spill time for each simulation. The model uses the spill time to select samples of current and wind data from a long time series of wind and current data for the area. Hence, the transport and weathering of each slick will be subject to a different sample of wind and current conditions.

This stochastic sampling approach provides an objective measure of the possible outcomes of a spill, because environmental conditions will be selected at a rate that is proportional to the frequency that these conditions occur over the study region. More simulations will tend to use the most commonly occurring conditions, while conditions that are more unusual will be represented less frequently.

During each simulation, the SIMAP model records the location (by latitude, longitude and depth) of each of the particles (representing a given mass of oil) on or in the water column, at regular time steps. For any particles that contact a shoreline, the model records the accumulation of oil mass that arrives on each section of shoreline over time, less any mass that is lost to evaporation and/or subsequent removal by current and wind forces.

The collective records from all simulations are then analysed by dividing the study region into a three-dimensional grid. For oil particles that are classified as being at the water surface (floating oil), the sum of the mass in all oil particles (including accounting for spreading and dispersion effects) located within a grid cell, divided by the area of the cell provides estimates of the concentration of oil in that grid cell, at each time step. For entrained and dissolved oil particles, concentrations are calculated at each time step by summing the mass of particles within a grid cell and dividing by the volume of the grid cell.

The concentrations of oil calculated for each grid cell, at each time step, are then analysed to determine whether concentration estimates exceed defined threshold concentrations over time.

Risks are then summarised as follows:

- The probability of exposure to a location is calculated by dividing the number of spill simulations where any instantaneous contact occurred above a specified threshold at that location by the total number of replicate spill simulations. For example, if contact occurred at a location (above a specified threshold) during 21 out of 100 simulations, a probability of exposure of 21% is indicated.

- The minimum potential time to a shoreline location is calculated by the shortest time over which oil at a concentration above a threshold was calculated to travel from the source to the location in any of the replicate simulations.

- The maximum potential concentration of oil predicted for each shoreline section is the greatest mass per m^2 of shoreline calculated to strand at any location within that section during any of the replicate simulations.

- The average of the maximum concentrations of oil predicted to potentially accumulate on each shoreline section is calculated by determining the greatest mass per m^2 of shoreline during each replicate simulation and calculating an average of these estimates across the simulations. Note that this statistic has been previously referred to as the “mean expected maximum” in earlier reports.

- Similar treatments are undertaken for entrained oil and dissolved aromatic hydrocarbons.

Thus, the minimum time to shoreline and the maximum potential concentration estimates indicate the worst potential outcome of the modelled spill scenario for each section of shoreline. However, the average over the replicates presents an average of the potential outcomes, in terms of oil that could strand.

Note also that results quoted for sections of shoreline or shoal are derived for any individual location within that section or shoal, as a conservative estimate. Locations will represent shoreline lengths of the order of ~1 km, while sections or regions will represent shorelines spanning tens to hundreds of kilometres and we do not imply that the maximum potential concentrations quoted will occur over the full extent of each section. We therefore warn against multiplying the maximum concentration estimates by the full area of the section because this will greatly overestimate the total volume expected on that section.

The maximum entrained hydrocarbon and maximum dissolved aromatic hydrocarbon concentration are calculated for water locations surrounding each defined shoreline (see Section 2.2.1). These zones are defined to provide a buffer area around shallow (<10 m) habitats to allow for spatial errors in model forecasts. The greatest calculated value at any time step during any replicate simulation is listed. These values therefore represent worst-case localised estimates (within a grid cell). The averages over all replicate values represent a central tendency of these simulated worst-case estimates.

2.2.1 Sensitive Receptor Areas

Individual grid cells were grouped by geographic bounds to define sensitive receptor areas for special consideration. Sensitive receptor areas included sections of shorelines, islands, reefs, Australian and State marine and national parks, special management zones and key ecological features (Figure 2.1 to Figure 2.9). The bounds of the sensitive receptor areas were defined with buffer zones defined with consideration of the bathymetry bordering each receptor, natural boundaries, or sensible legislative boundaries. Risks of exposure were separately calculated for each sensitive receptor area and have been tabulated.

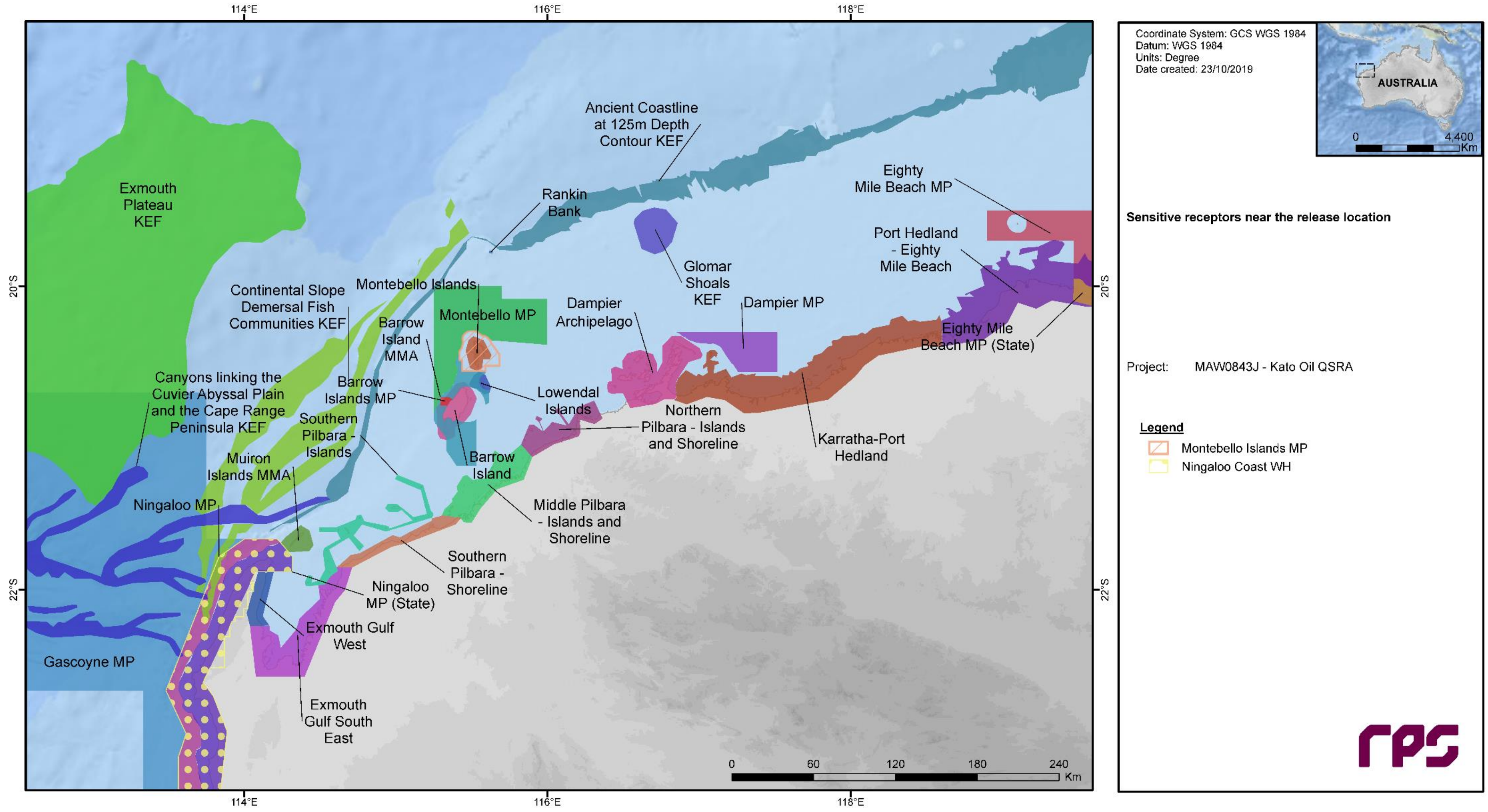


Figure 2.1 Locations of sensitive receptors in close proximity to the Corowa release location.

Note: Figure does not include Biologically Important Areas and Fisheries receptors. Refer to Figure 2.7 and Figure 2.8.

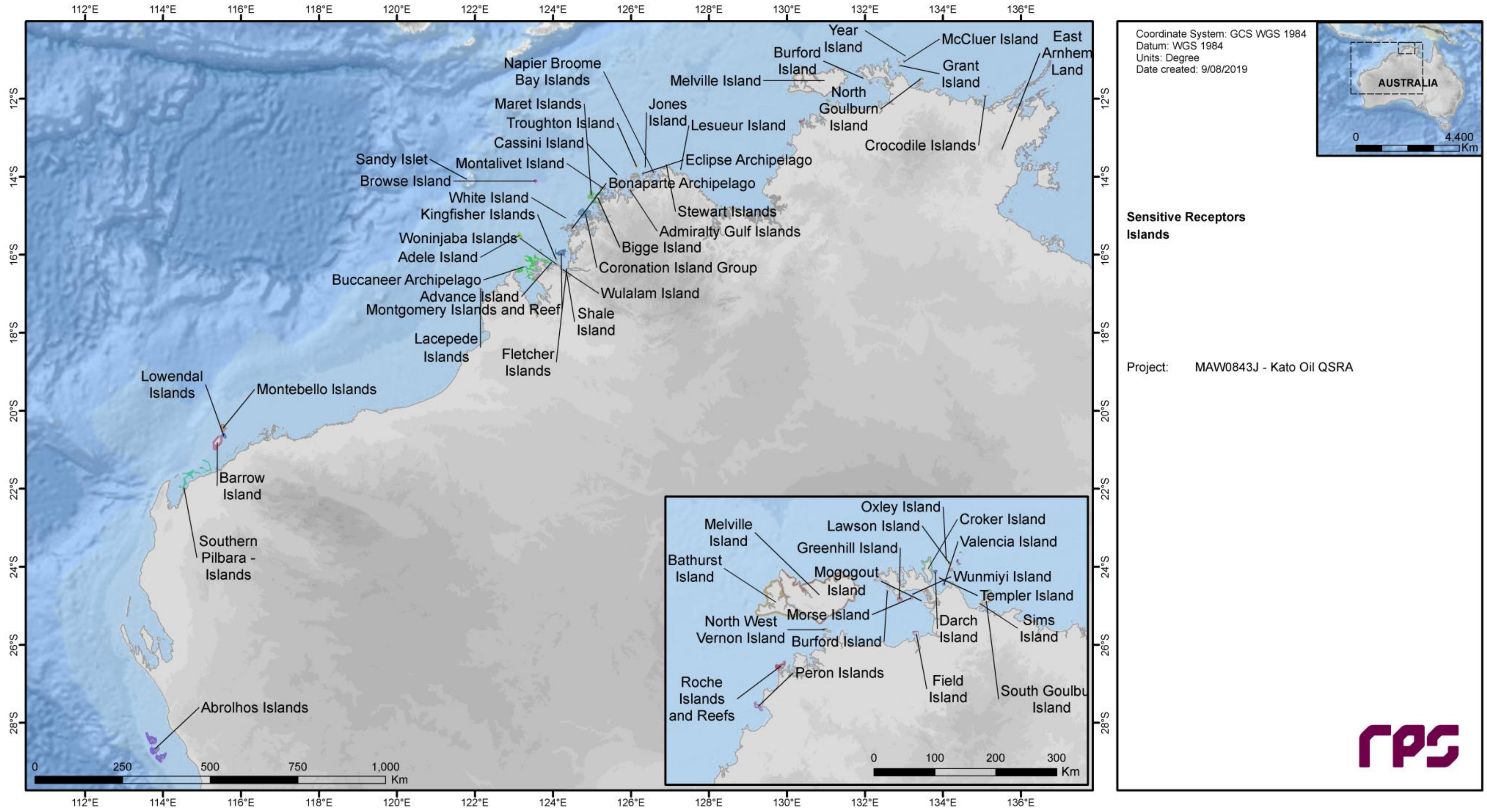


Figure 2.2 Locations of Island sensitive receptors within the study region.

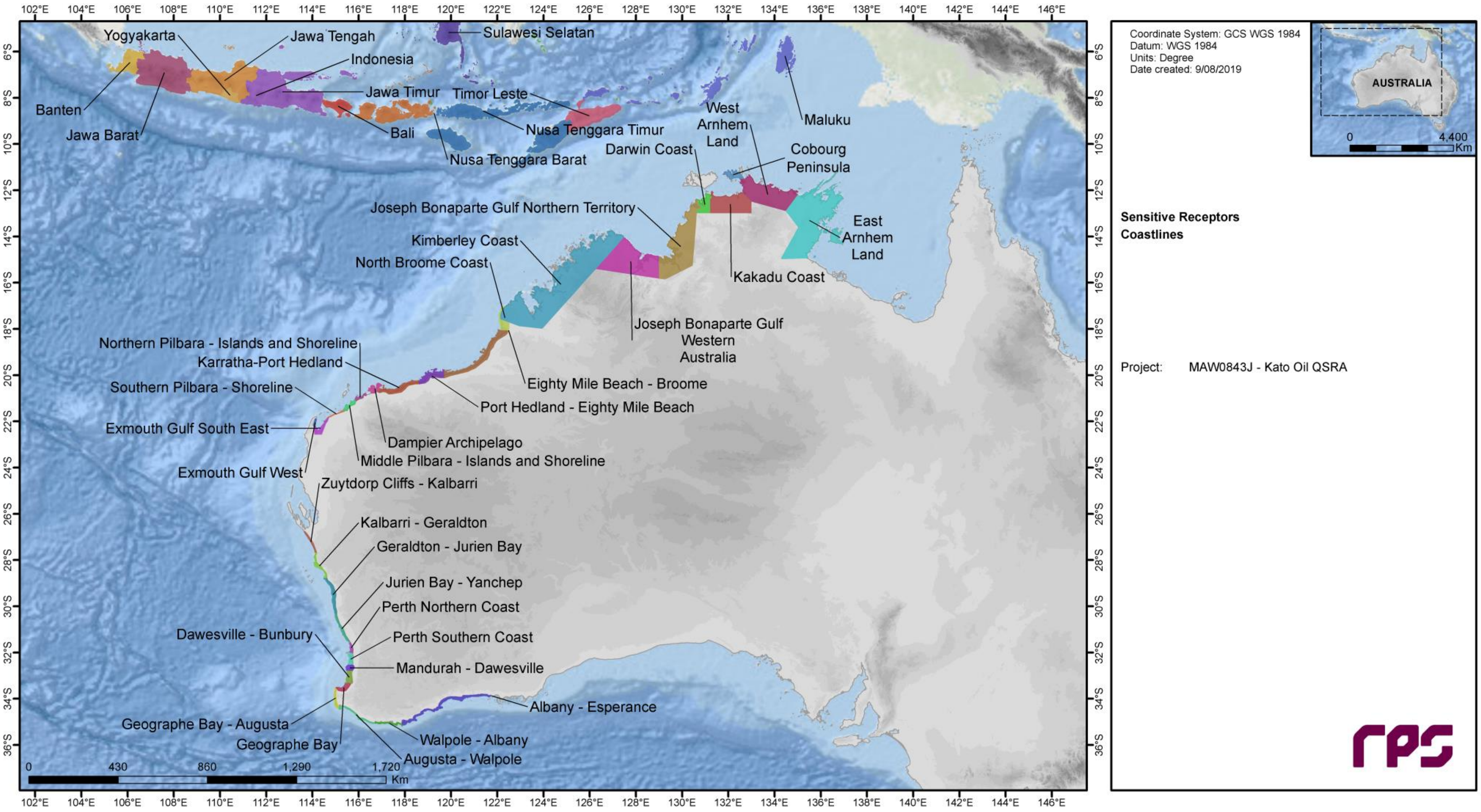


Figure 2.3 Locations of Coastline sensitive receptors within the study region.

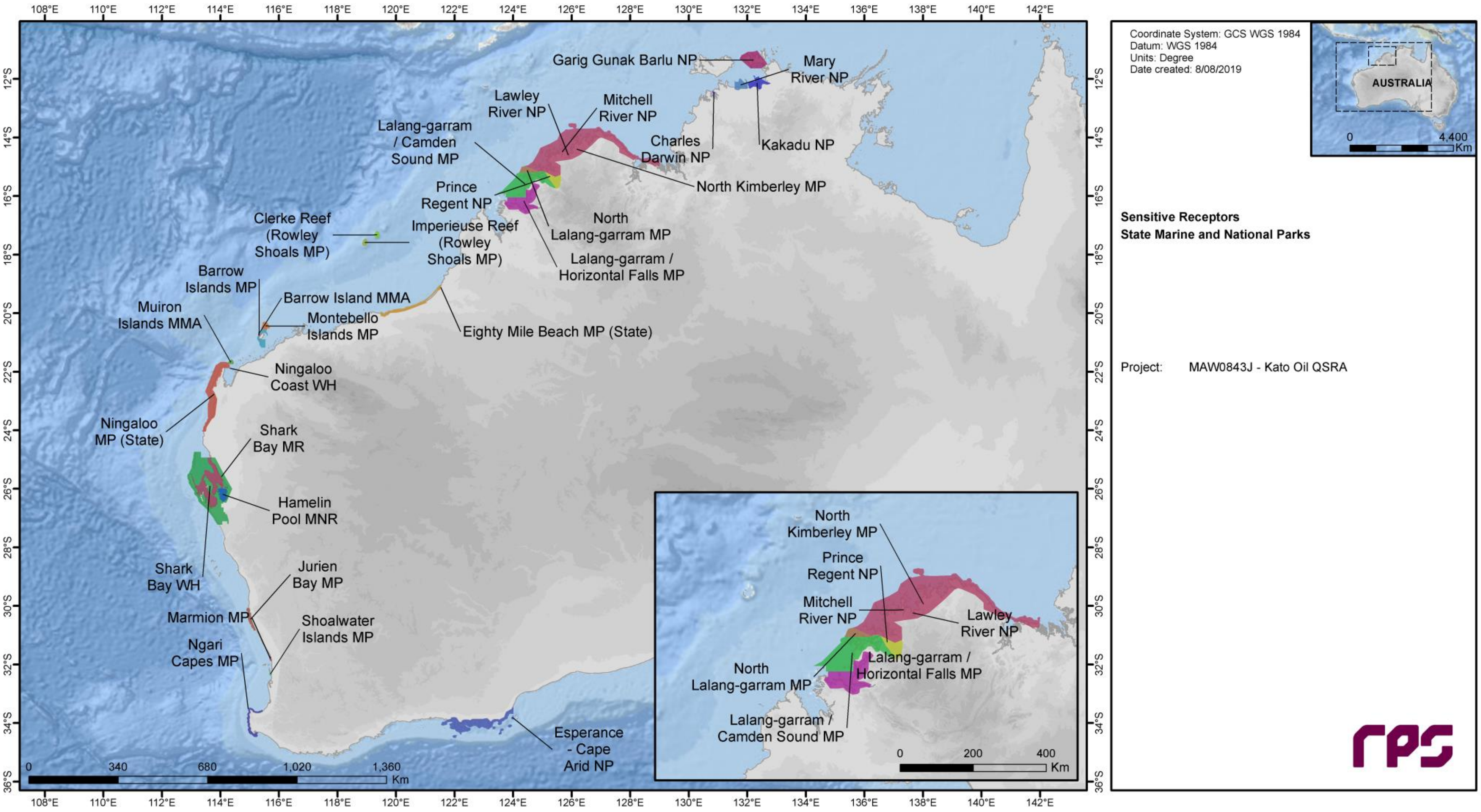


Figure 2.4 Locations of State Marine and National Park sensitive receptors within the study region.

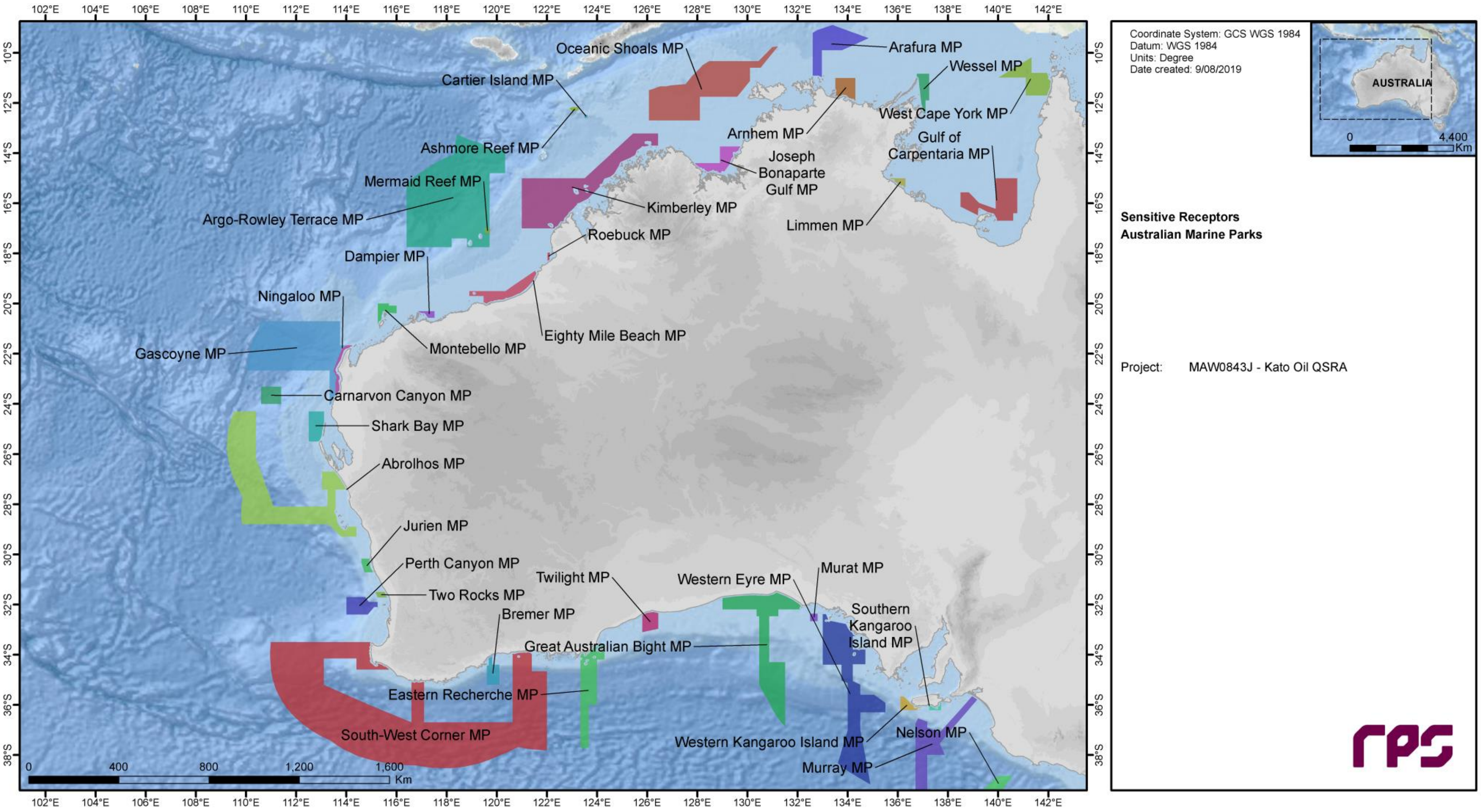


Figure 2.5 Locations of Australian Marine Park sensitive receptors within the study region.

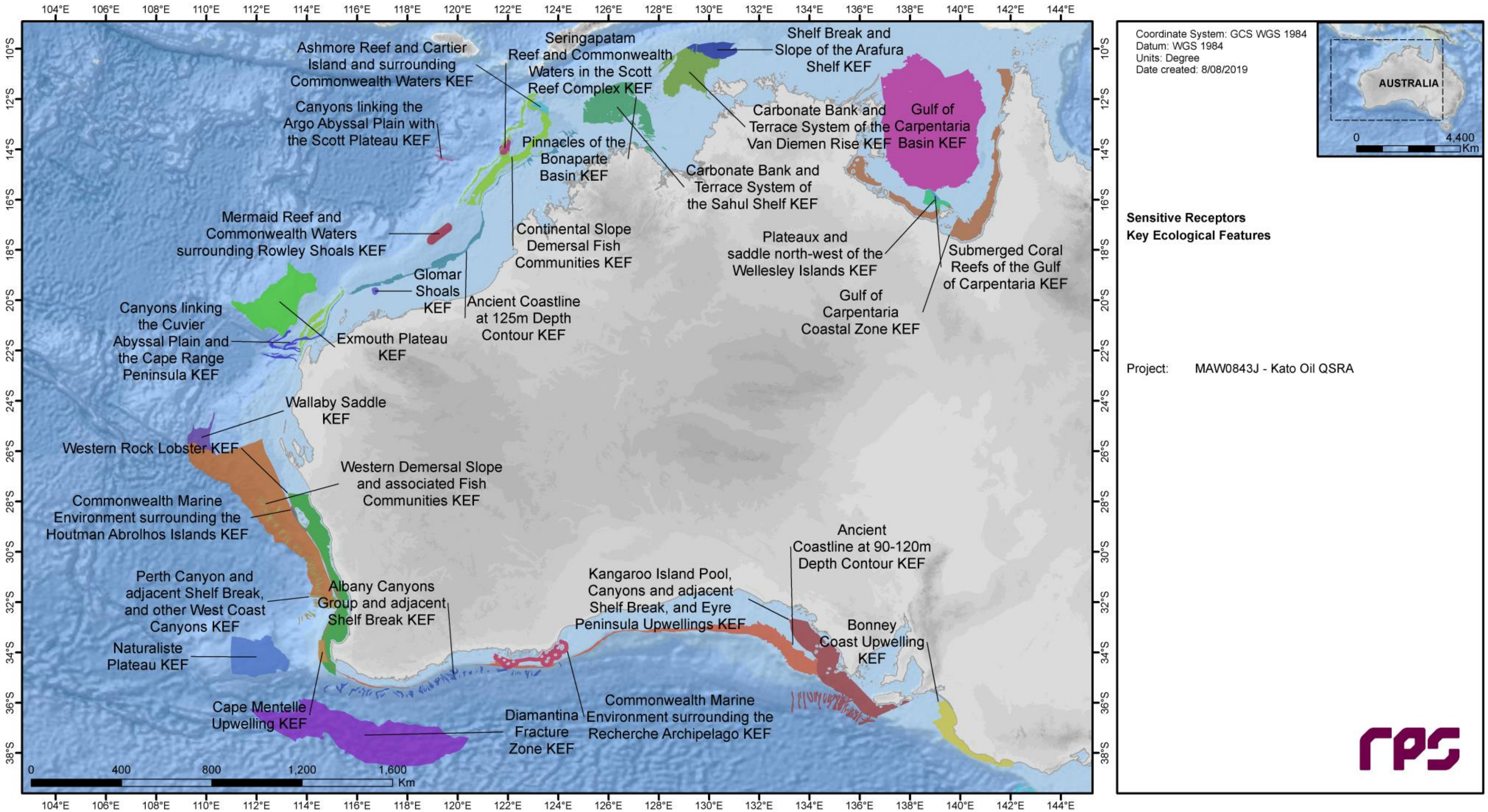


Figure 2.6 Locations of Key Ecological Features (KEF) sensitive receptors within the study region.

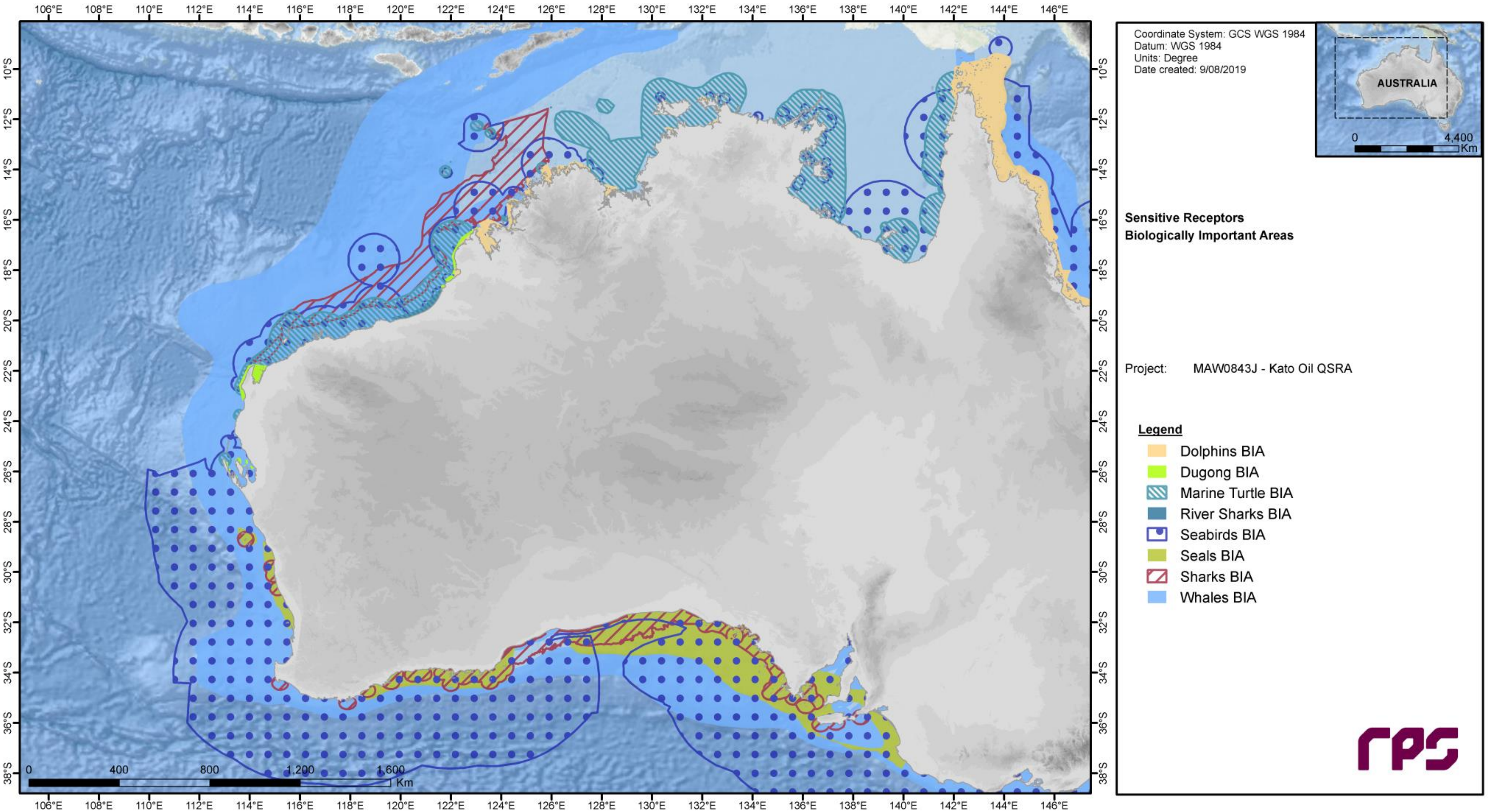


Figure 2.7 Locations of Biologically Important Areas (BIA) sensitive receptors within the study region.

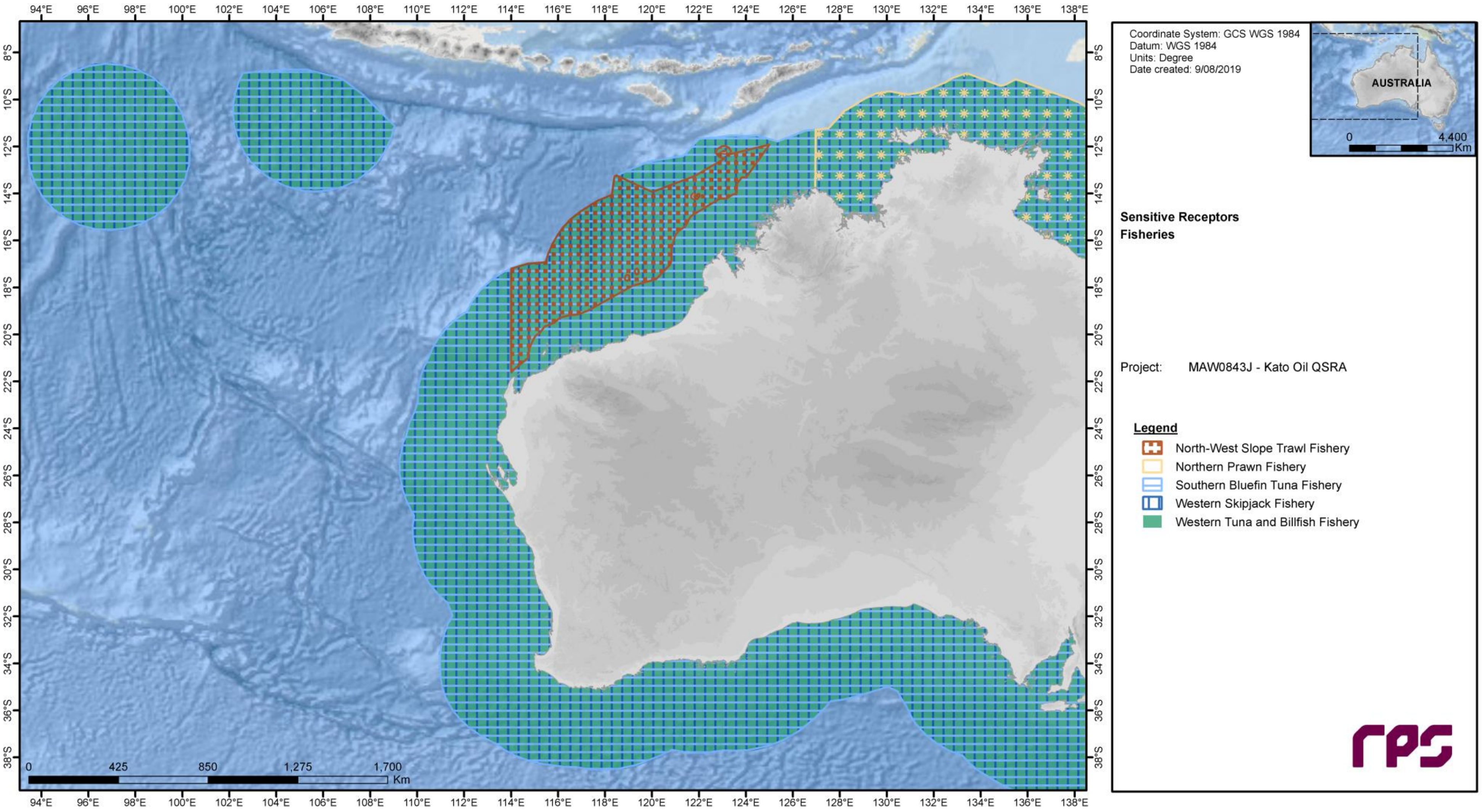


Figure 2.8 Locations of Fishery sensitive receptors within the study region.

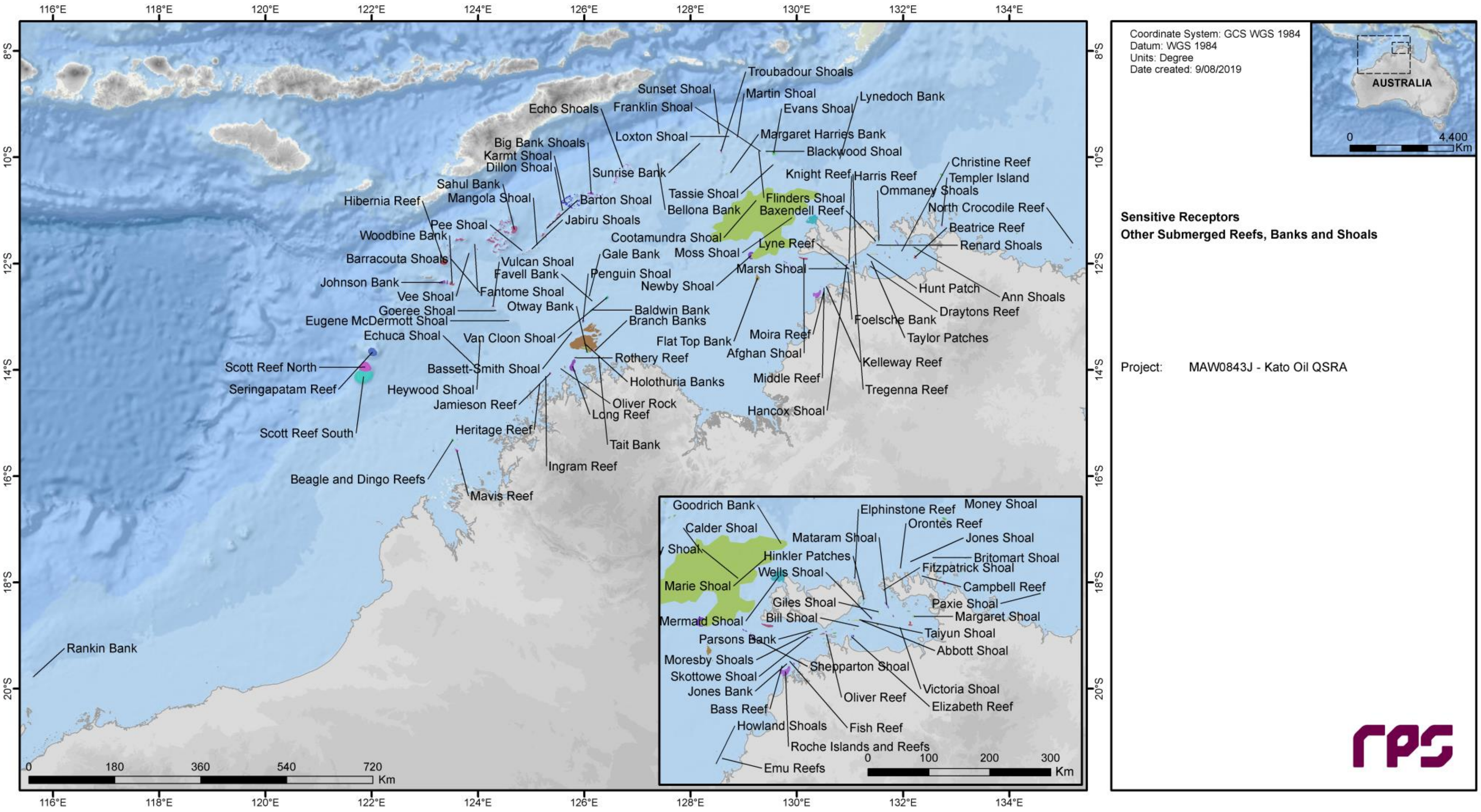


Figure 2.9 Locations of submerged Reef, Shoal and Bank sensitive receptors within the study region.

2.3 Inputs to the Risk Assessment

2.3.1 Current Data

2.3.1.1 Background

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region of the North West Shelf and among the islands of the Dampier Archipelago and the Barrow, Lowendal and Montebello Island groups. However, the offshore regions with water depths exceeding 100-200 m experience significant large-scale drift currents; including the Holloway and Leeuwin currents. These drift currents can be relatively strong (1-2 knots) and complex, manifesting as a series of eddies, meandering currents and connecting flows. These offshore drift currents also tend to persist longer (days to weeks) than tidal current flows (hours between reversals) and thus will have greater influence upon the net trajectory of slicks over time scales exceeding a few hours.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (multiple hours to days) and result in long trajectories. Hence, the current-induced transport of oil can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is critical to consider all these potential advective mechanisms to accurately predict patterns of potential transport from a given spill location.

To appropriately allow for temporal and spatial variation in the current field, spill modelling requires the current speed and direction over a spatial grid covering the potential migration of oil. As measured current data is not available for simultaneous periods over a network of locations covering the wide area of this study, the analysis relied upon hindcasts of the circulation generated by numerical modelling. Estimates of the net currents were derived by combining predictions of the drift currents, which were available from mesoscale ocean models, with estimates of the tidal currents generated by an RPS model set up for the study area.

2.3.1.2 Mesoscale Circulation Model

Large-scale and mesoscale ocean circulation (also referred to as drift currents) will be the dominant driver of long-term (> several days) transport of effluent plumes. Mesoscale ocean processes are generally defined as having horizontal spatial scales of 10-500 km, and periods of 10-200 days, and processes with scales greater than this are referred to as large-scale. The major persistent large-scale and mesoscale surface currents off Western Australia are presented in Figure 2.10. They are characterised as follows:

- **Buoyancy driven circulation.** The main buoyancy-driven feature in the region is the Indonesian Throughflow (ITF) and the Holloway Current which conducts warm water from the equator into the Indian Ocean. Buoyancy gradients across the continental shelf due to differential heating and cooling and/or surface runoff may also drive three-dimensional circulation patterns.

- **Wind (Ekman) driven circulation.** The Australian North West Shelf has an annual wind cycle (easterly winds during winter, south-westerly winds during summer) which drives seasonal variability in surface circulation patterns.

- **Eddies and jets.** These non-linear features evolve from the large-scale and mesoscale flow field interacting with the bathymetry. These are random features and it is generally hard to predict their exact timing and location.

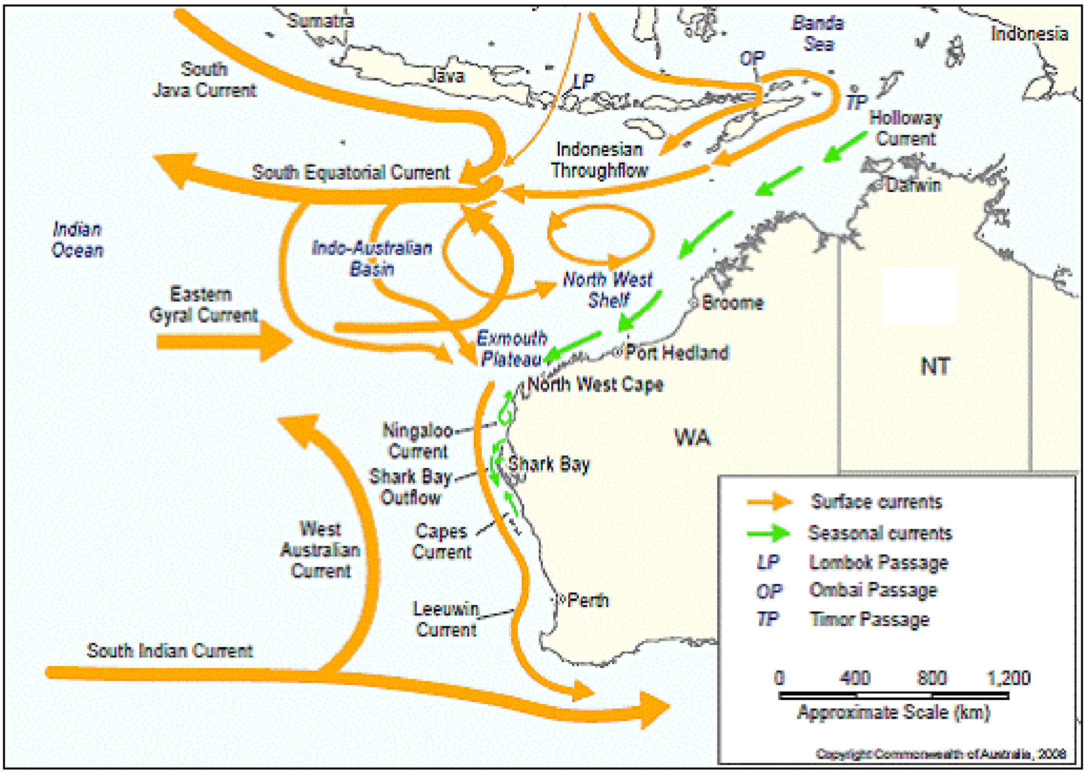


Figure 2.10 A map of the major currents off the Western Australian coast (DEWHA, 2008).

2.3.1.2.1 Description of the Mesoscale Model: HYCOM

Representation of the drift currents was available from the output of the global circulation model the Hybrid Coordinate Ocean Model (HYCOM; Bleck, 2002; Chassignet et al., 2007, 2009), created by the National Ocean Partnership Program (NOPP), as part of the US Global Ocean Data Assimilation Experiment (GODAE). The HYCOM model is a three-dimensional model that assimilates ocean observations of sea surface temperature, sea surface salinity and surface height, obtained by satellite observations, along with atmospheric forcing conditions from atmospheric models to predict drift currents generated by such forces as wind shear, density and sea height variations and the rotation of the earth.

The HYCOM model is configured to combine the three vertical coordinate types currently in use in ocean models: depth (z-levels), density (isopycnal layers), and terrain-following (σ-levels). 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. Thus, this hybrid coordinate system allows for the extension of the geographic range of applicability to shallow coastal seas and unstratified parts of the world ocean. It maintains the significant advantages of an isopycnal model in stratified regions while allowing more vertical resolution near the surface and in shallow coastal areas, hence providing a better representation of the upper ocean physics. The model has global coverage with a horizontal resolution of 1/12th of a degree (approximately 7 km at mid-latitudes) and a temporal resolution of one day.

A hindcast data set of HYCOM currents was obtained for a ten-year period spanning 2009 to 2018 (inclusive).

Figure 2.11 shows the seasonal distributions of current speeds and directions for the HYCOM data point closest to the Corowa field. Note that the convention for defining current direction is the direction the current is flowing *towards*. The data indicates average current speeds are similar between the winter (0 15 m/s) and transitional months (0.16 m/s), maximum current speeds are predicted at approximately 0.83 m/s in summer months. North-westerly currents are dominant in all seasons.

The extracted current data near the release locations provides an insight into the expected initial behaviour of any released oil due to the drift currents along. Oil moving beyond the release sites would be subject to considerable variation in the drift current regime.

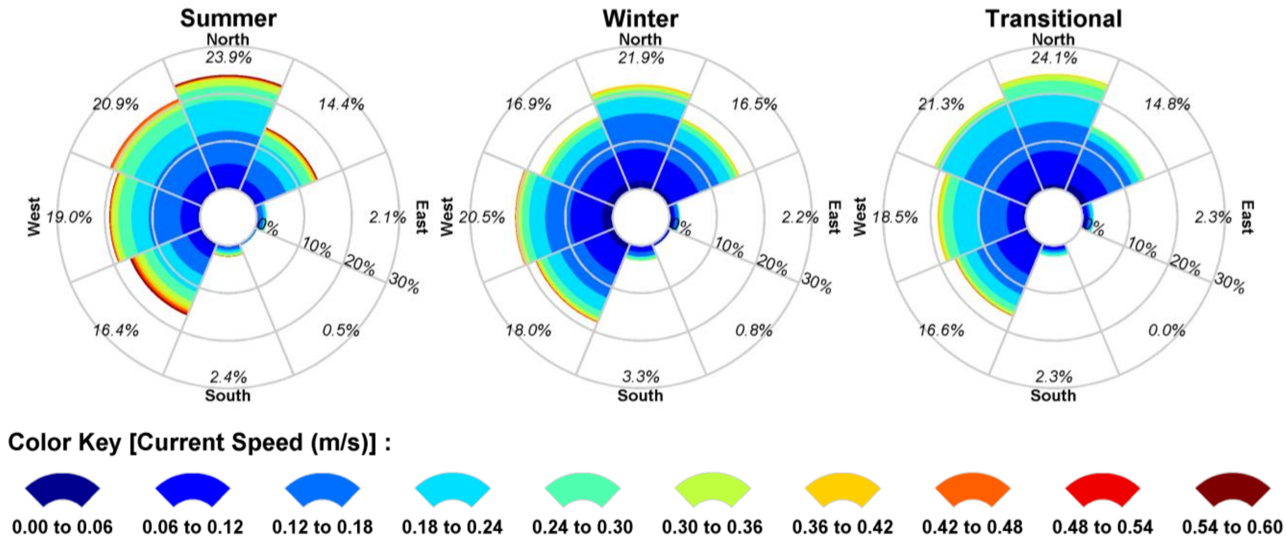


Figure 2.11 Seasonal current distribution (2009-2018, inclusive) derived from the HYCOM database at the point closest to the Corowa field. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.3.1.3 Tidal Circulation Model

2.3.1.3.1 Description of Tidal Model: HYDROMAP

As the HYCOM model does not include tidal forcing, and because the data is only available at a daily frequency, a tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP.

The model formulations and output (current speed, direction and sea level) of this model have been validated through field measurements around the world for more than 25 years (Isaji & Spaulding, 1984, 1986; Isaji *et al.*, 2001; Zigic *et al.*, 2003). HYDROMAP current data has also been widely used as input to forecasts and hindcasts of oil spill migrations in Australian waters. This modelling system forms part of the National Marine Oil Spill Contingency Plan for the Australian Maritime Safety Authority (AMSA, 2002).

HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. The model employs a sophisticated dynamically nested-gridding strategy, supporting up to six levels of spatial resolution within a single domain. This allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, or of interest to a study.

The numerical solution methodology of HYDROMAP follows that of Davies (1977a, 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 & Spaulding (1984).

2.3.1.3.2 Tidal Grid Setup

A HYDROMAP model was established over a domain that extended approximately 4,800 km east-west by 4,200 km north-south over the eastern Indian Ocean. The grid extends beyond Eucla in the south and beyond Indonesia in the north (Figure 2.12).

Four layers of sub-gridding were applied to provide variable resolution throughout the domain. The resolution at the primary level was 15 km. The finer levels were defined by subdividing these cells into 4, 16 and 64 cells, resulting in resolutions of 7.5 km, 3.75 km and 1.88 km. The finer grids were allocated in a step-wise fashion to areas where higher resolution of circulation patterns was required to resolve flows through channels, around shorelines or over more complex bathymetry. Approximately 156,000 cells were used to define the region.

Bathymetric data used to define the three-dimensional shape of the study domain was extracted from the CMAP electronic chart database and supplemented where necessary with manual digitisation of chart data supplied by the Australian Hydrographic Office. Depths in the domain ranged from shallow intertidal areas through to approximately 7,200 m.

2.3.1.3.3 Tidal Boundary Conditions

Ocean boundary data for the HYDROMAP model was obtained from the TOPEX/Poseidon global tidal database (TPXO7.2) of satellite-measured altimetry data, which provided estimates of tidal amplitudes and phases for the eight dominant tidal constituents (designated as K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1) at a horizontal scale of approximately 0.25°. Using the tidal data, sea surface heights are firstly calculated along the open boundaries at each time step in the model.

The TOPEX/Poseidon satellite data is produced, and quality controlled by the US National Atmospheric and Space Agency (NASA). The satellites, equipped with two highly accurate altimeters capable of taking sea level measurements accurate to less than ±5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out more than 62,000 orbits of the planet. The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen, 1995; Ludicone *et al.*, 1998; Matsumoto *et al.*, 2000; Kostianoy *et al.*, 2003; Yaremchuk & Tangdong, 2004; Qiu & Chen, 2010). As such, the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

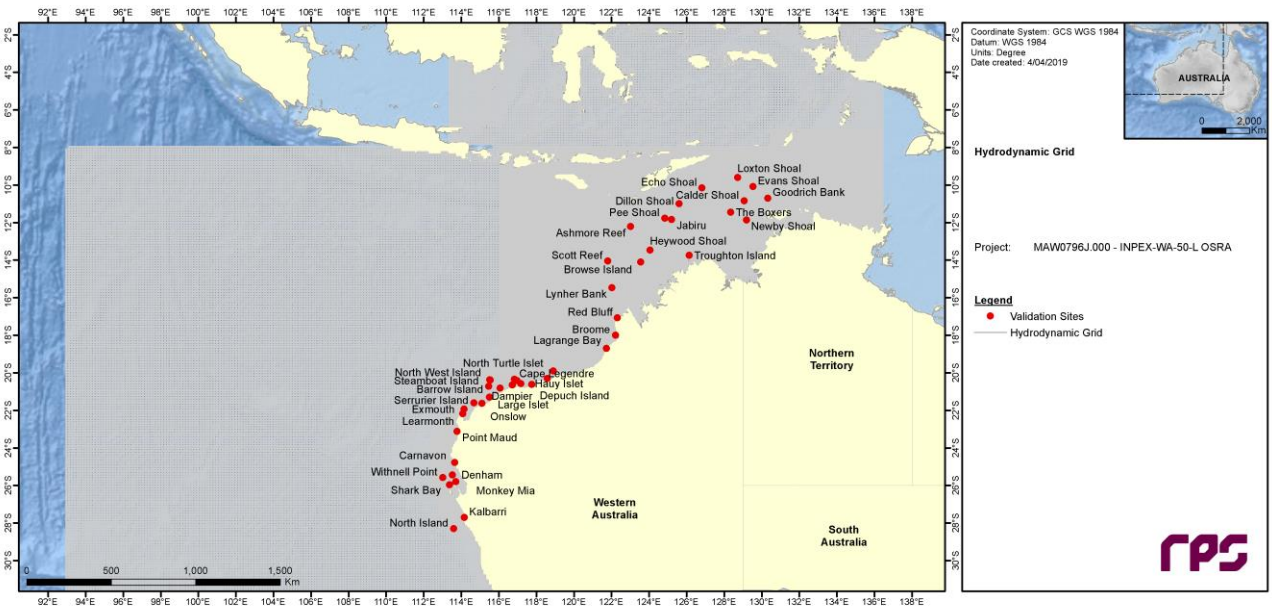


Figure 2.12 Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing the full domain in context with the continental land mass and the locations available for tidal comparisons (red labelled dots). Higher-resolution areas are indicated by the denser mesh zones.

2.3.1.3.4 Tidal Elevation Validation

For the purpose of verification of the tidal predictions, the model output was compared against independent predictions of tides using the XTide database (Flater, 1998). The XTide database contains harmonic tidal constituents derived from measured water level data at locations around the world. Overall there are more than 120 tidal stations within the HYDROMAP model domain, however some of these are located in areas that were not sufficient resolved by this large scale ocean model. However, more than 80 stations along the coastline were suitable for comparison of the model performance with the observed data. These stations covered the mid to northwest of the Western Australian coastline, in order to encompass the region of the release locations for the range of marine discharges for the project (Figure 3.1, Figure 3.2, Figure 3.3). For the purposes of brevity and clarity, a selected representative subset of twenty of the tidal stations (blue dots on Figure 3.1, Figure 3.2, Figure 3.3) have been presented in the timeseries plots and results tables.

Water level time series for the subset of twenty stations are shown in Figure 3.4 for a one-month period (January 2018). All comparisons show that the model produces a very good match to the known tidal behaviour for a wide range of tidal amplitudes and clearly represents the varying diurnal and semi-diurnal nature of the tidal signal. In addition to the plots, time-series comparisons were completed for a six-month period from January to July 2018 and the statistics are summarised in Table 3.1. The statistics indicate excellent model performance over a wide region.

The model skill was further evaluated through a comparison of the predicted and observed tidal constituents, derived from an analysis of model-predicted time-series at each of the locations. The comparison data for the selected 20 stations is summarised in Table 3.2 and scatter plots of the observed and modelled amplitude (top) and phase (bottom) of the five dominant tidal constituents (S2, M2, N2, K1 and O1) for all relevant stations within the model domain (>80) are presented in Figure 3.6. The red line on each plot shows the 1:1 line, which would indicate a perfect match between the modelled and observed data. Note that the data is generally closely aligned to the 1:1 line demonstrating the high quality of the model performance.

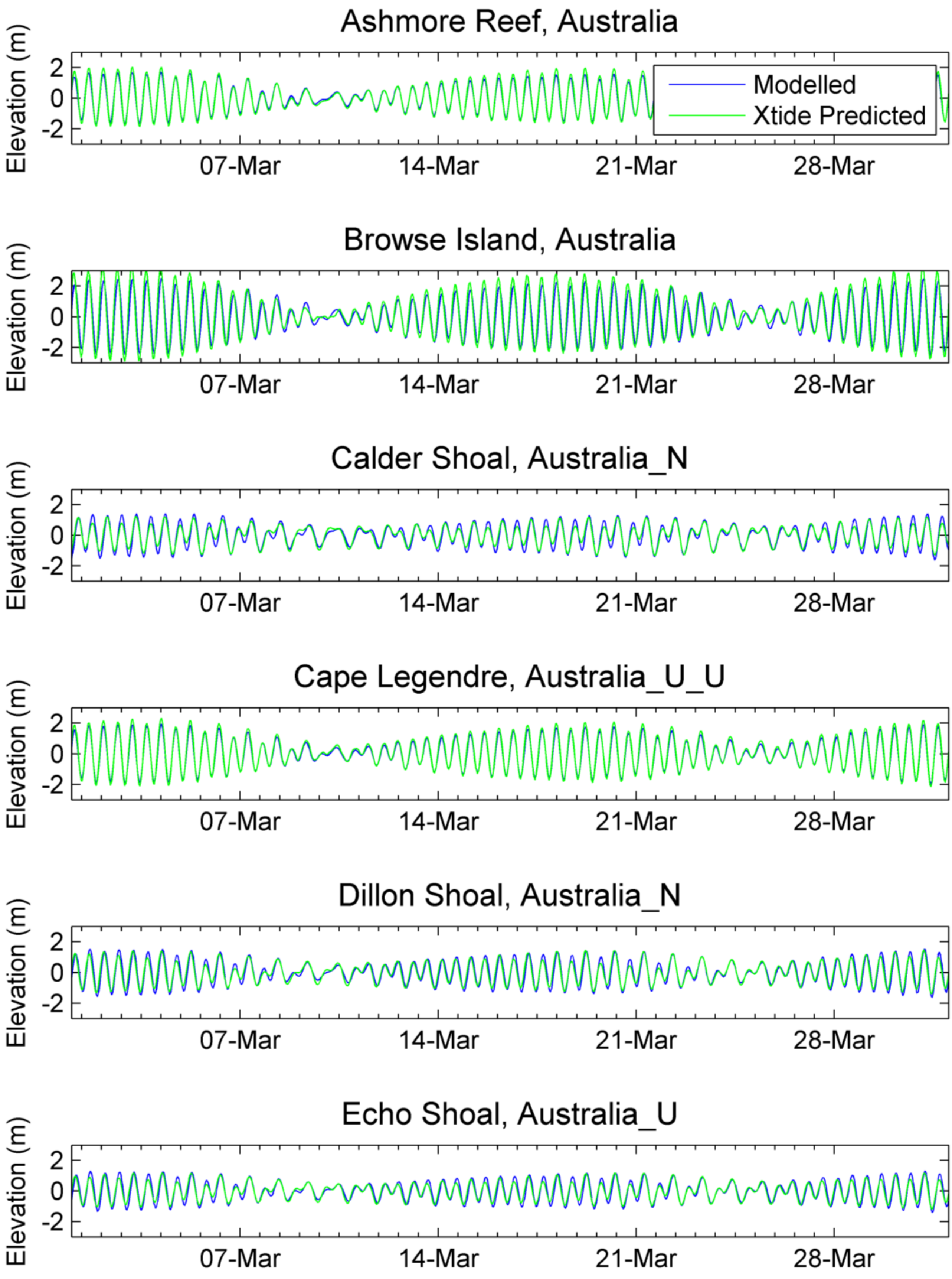


Figure 2.13 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

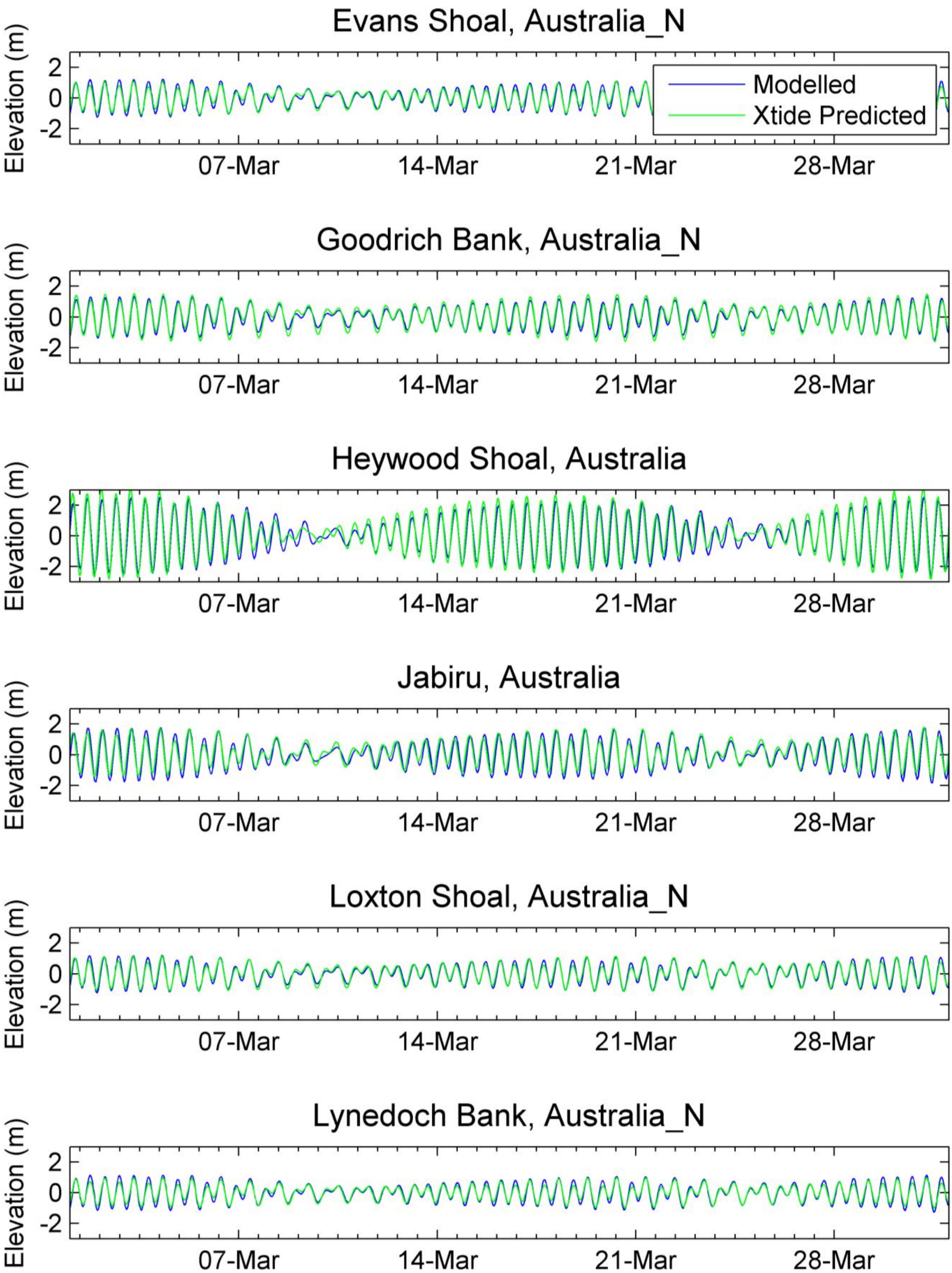


Figure 2.14 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

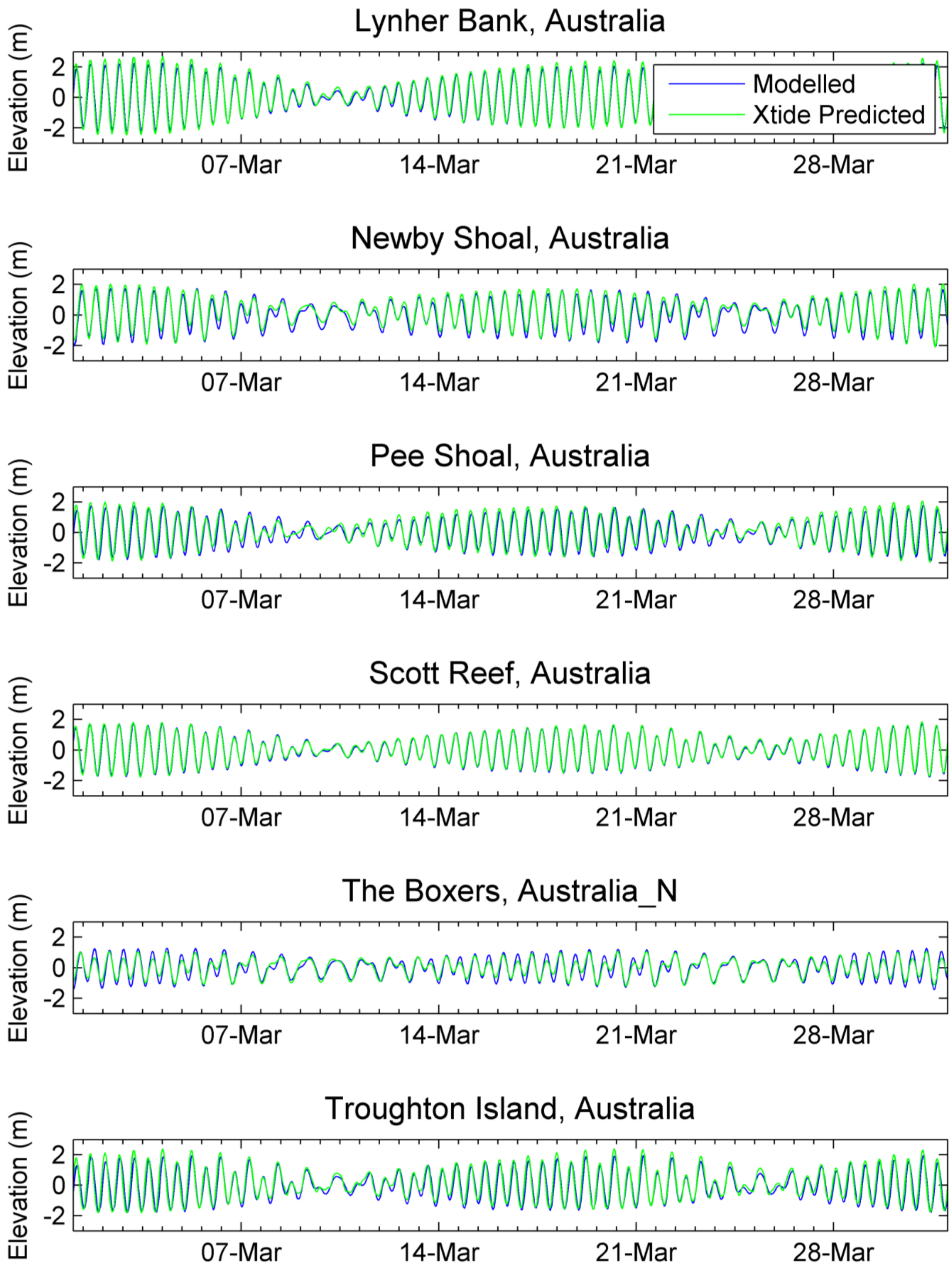


Figure 2.15 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

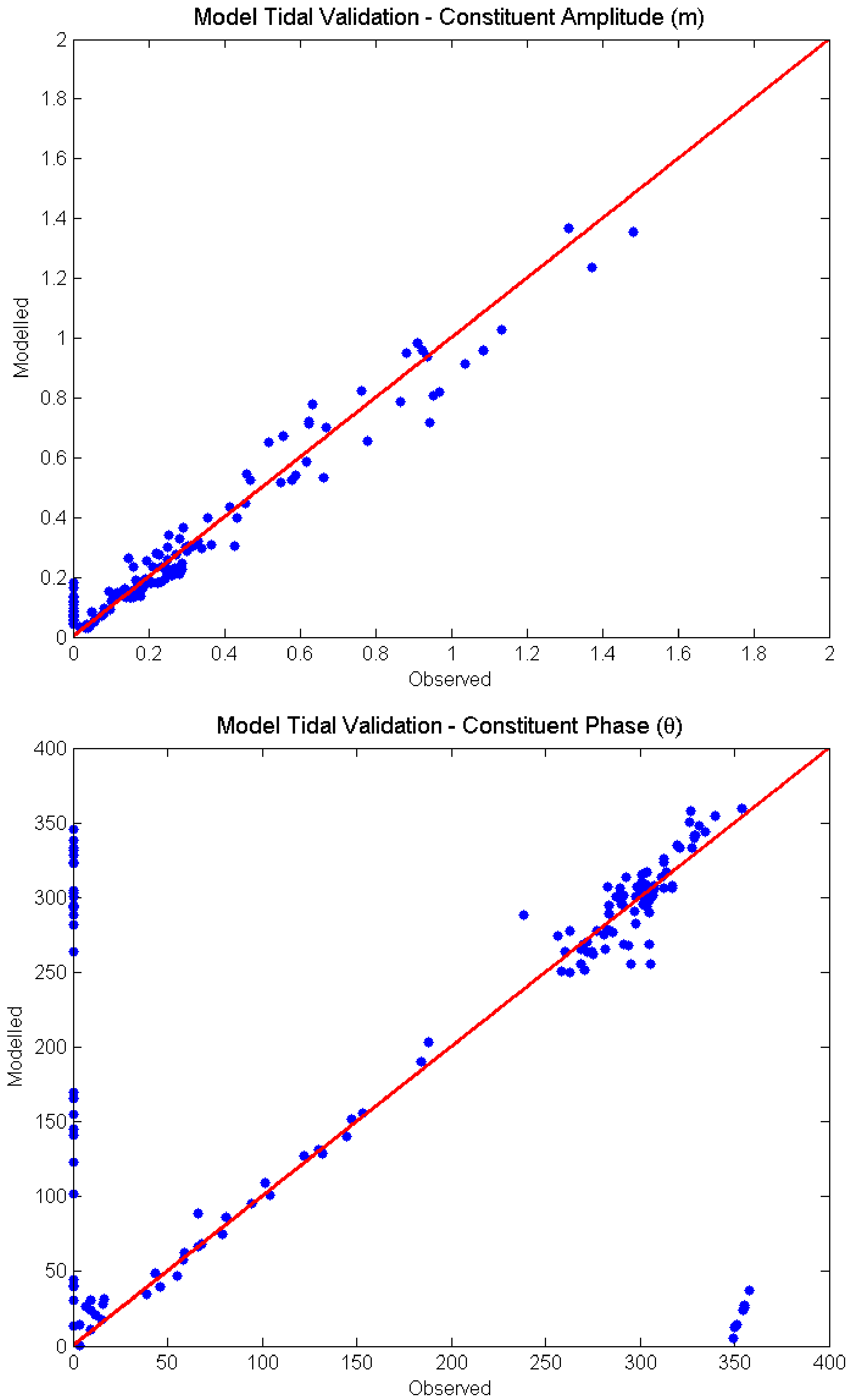


Figure 2.16 Comparisons between predicted tidal constituent amplitudes (top) and phases (bottom) from HYDROMAP and XTide at all stations in the tidal model domain. The red line indicates a 1:1 correlation between the respective data sets.

2.3.1.3.5 Tidal Currents at the Site

Figure 2.17 show the seasonal distributions of current speeds and directions for the HYDROMAP data point closest to the Corowa field. Note that the convention for defining current direction is the direction towards which the current flows.

The data indicates cyclical tidal flow directions are predominantly along east-west axis across all seasons, with maximum speeds of around 0.2 m/s.

The extracted current data near the spill locations provides an insight into the expected initial behaviour of any released oil due to the tidal currents alone. Oil moving beyond the release sites, particularly towards the coast, would be subject to considerable variation in the tidal current regime.

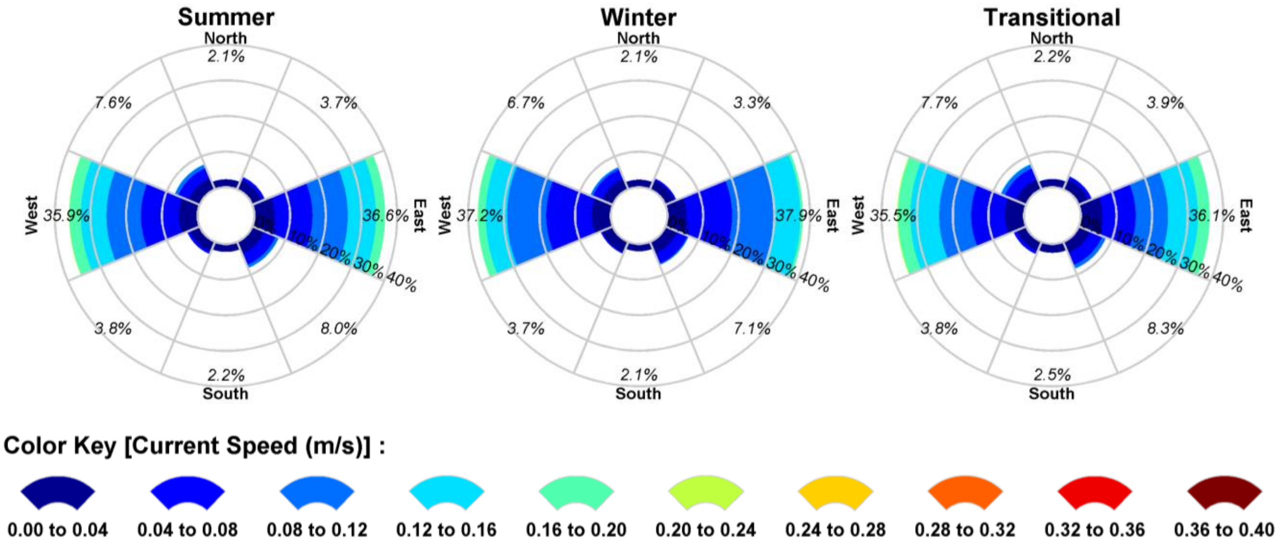


Figure 2.17 Seasonal current distribution (2009-2018, inclusive) derived from the HYDROMAP database at the point closest to the Corowa field. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.3.2 Wind Data

To account for the influence of the wind on surface-bound oil slicks, representation of the wind conditions was provided by spatial wind fields sourced from the National Center for Environmental Prediction (NCEP), via the National Oceanic and Atmospheric Administration (NOAA) and Cooperative Institute for Research in Environmental Sciences (CIRES) Climate Diagnostics Center (CDC). The NCEP Climate Forecast System Reanalysis (CFSR; Saha *et al.*, 2010) is a fully-coupled, data-assimilative hindcast model representing the interaction between the Earth's oceans, land and atmosphere. The gridded data output, including surface winds, is available at 0.25° resolution and 1-hourly time intervals.

Time series of wind speed and direction were extracted from the CFSR database for all nodes in the model domain for the same temporal coverage as the current data (2009-2018, inclusive). The data was assumed to be a suitably representative sample of the wind conditions over the study area for future years.

Figure 2.18 shows the seasonal distributions of wind speeds and directions for the CFSR data point closest to the Corowa field. Note that the convention for defining wind direction is the direction *from* which the wind blows.

The wind roses indicate higher average wind speeds are likely during the summer months, with direction predominantly south-westerly. Lower average wind speeds are likely to occur during the transitional months with southerly winds being most common.

The extracted wind data near the release sites suggests possible initial trajectories due to the wind acting on surface slicks in the absence of any current effects. Note that the actual trajectories of surface slicks will be the net result of a combination of the prevailing wind and current vectors acting at a given time and location.

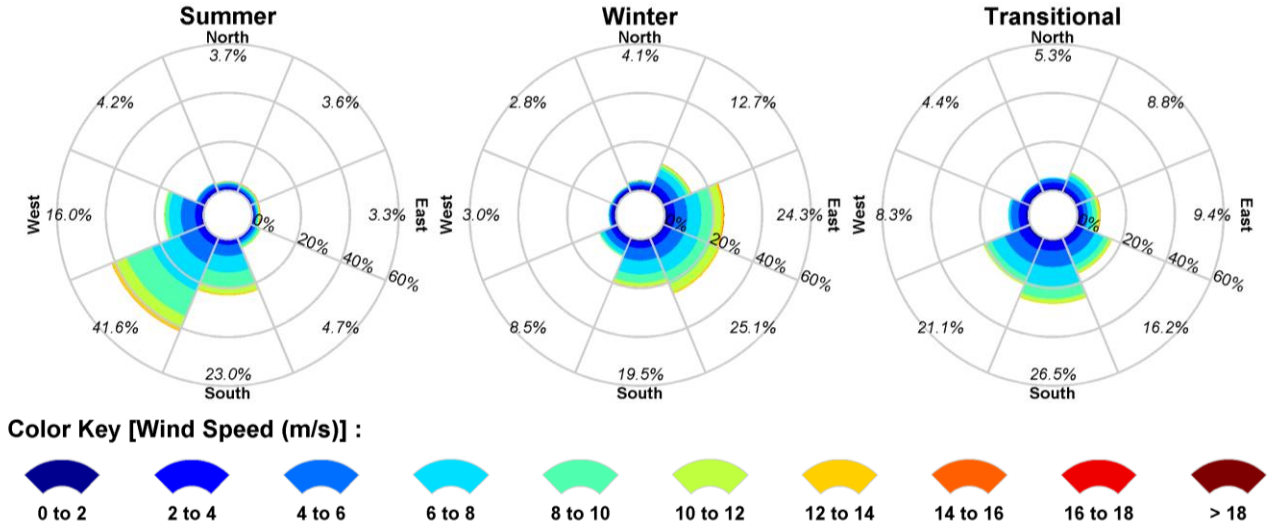


Figure 2.18 Wind distribution for simulation periods (2009-2018, inclusive) derived from the CFSR database at the point closest to the Corowa field. The colour key shows the wind magnitude, the compass direction provides the direction from which the wind is blowing, and the size of the wedge gives the percentage of the record.

2.3.3 Water Temperature and Salinity Data

The World Ocean Atlas 2013 (WOA13) is provided by NOAA and is a hindcast model of the climatological fields of in situ temperature, salinity, and several additional variables (NOAA, 2013a). WOA13 has a 0.25° resolution and has standard depth levels ranging from the water surface to 5,500 m (Locarnini *et al.*, 2013; Zweng *et al.*, 2013). Vertical profiles of sea temperature and salinity at the spill location were retrieved from a data point (21° 30' 0.0" S, 114° 30' 0.0" E) in the WOA13 database nearby to the Corowa field, with monthly averages used as input to both SIMAP and OILMAP.

Figure 2.19 shows the variation in water temperature and salinity both monthly and over depth. Surface mixing to depths of 20 m is evident across all months. The average temperature varies between approximately 21-30 °C across the year, while the average salinity over this depth range varies between approximately 34.5-35.1 PSU year-round.

2.3.4 Dispersion

A horizontal dispersion coefficient of 10 m^2/s was used to account for dispersive processes acting at the surface that are below the scale of resolution of the input current field, based on typical values for open waters (Okubo 1971). Dispersion rates within the water column (applicable for entrained and dissolved plumes of hydrocarbons) were specified at 1 m^2/s, based on empirical data for the dispersion of hydrocarbon plumes over the North-West Shelf (King & McAllister 1998).

2.3.5 Replication

Multiple replicate simulations were completed for each scenario to test for trends and variations in the trajectory and weathering of spilled oil, with an even number of replicates completed using samples of metocean data that commenced within each month. For each of the Corowa scenarios, a total of 50 (subsea well blowout) and 100 (short-term surface release) were run per season (i.e. annual total of 150; subsea well blowout and 300; short-term surface release).

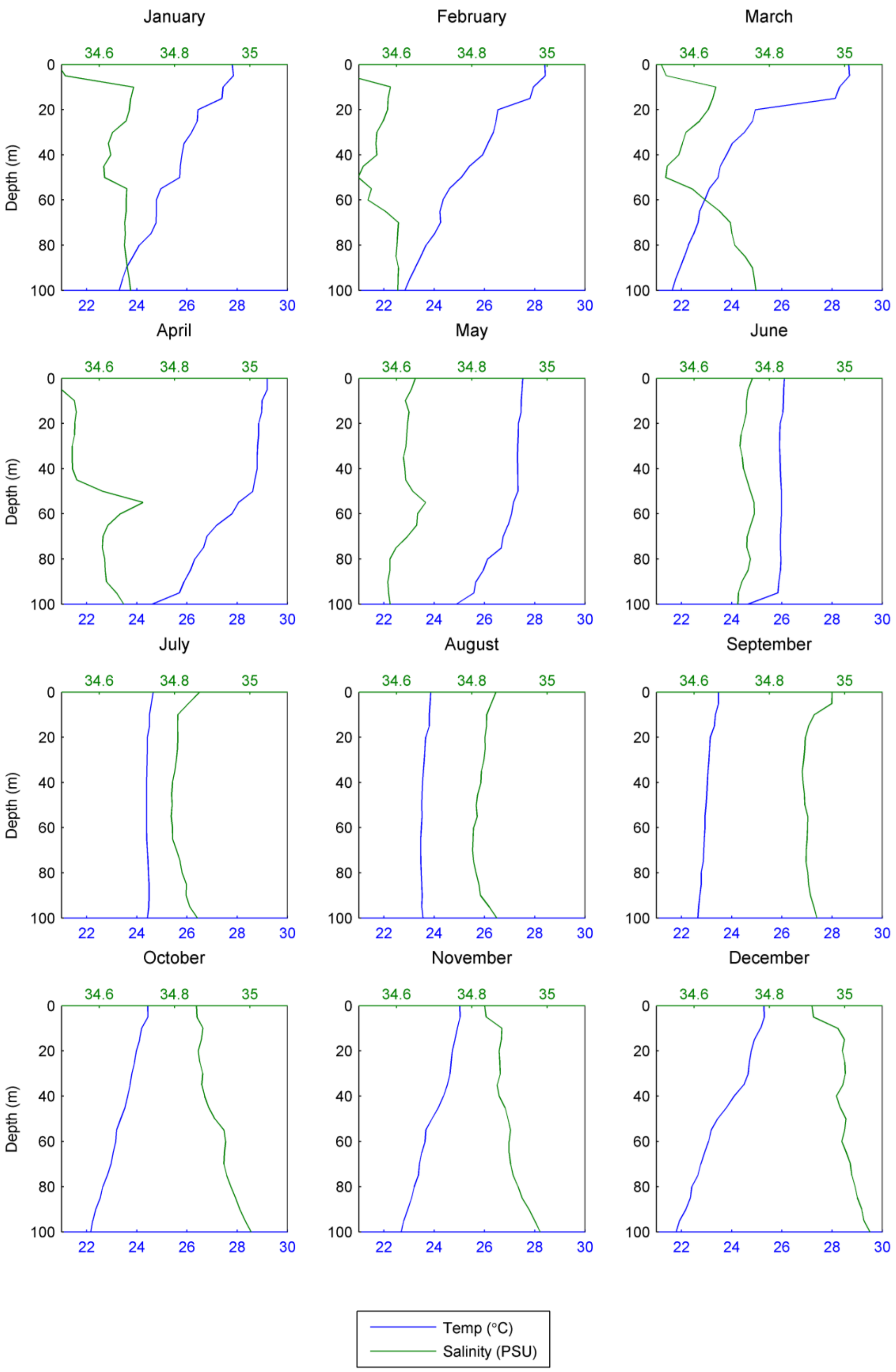


Figure 2.19 The temperature (blue line) and salinity (green line) profile derived from the WOA09 database at the point closest to the Corowa field, representative of the period 2009-2018, inclusive (NOAA 2009). Depth of 0 m is the sea surface.

2.3.6 Contact Thresholds

2.3.6.1 Overview

The SIMAP model will track oil concentrations to very low levels. Hence, it is useful to define meaningful threshold concentrations for the recording of contact by oil components and determining the probability of exposure at a location (calculated from the number of replicate simulations in which this contact occurred).

The judgement of meaningful levels is complicated and will depend upon the mode of action, sensitivity of the biota contacted, the duration of the contact and the toxicity of the compounds that are represented in the oil. The latter factor is further complicated by the change in the composition of an oil type over time due to weathering processes. Without specific testing of the oil types, at different states of weathering against a wide range of the potential local receptors, such considerations are beyond the scope of this investigation.

For this case, thresholds for floating, entrained and dissolved aromatic hydrocarbons were specified by Kato (with guidance from the NOPSEMA oil spill modelling bulletin also taken into consideration; NOPSEMA 2019) for use in defining the potential zone of influence of the spill event. These thresholds are summarised in Table 2.1 and discussed afterwards.

Table 2.1 Summary of the thresholds applied in this study.

Threshold	Floating oil concentration	Shoreline oil concentration	Instantaneous entrained oil concentration	Instantaneous dissolved aromatic hydrocarbon concentration	Time-integrated entrained oil concentration	Time-integrated dissolved aromatic hydrocarbon concentration
Low	1 g/m^2	10 g/m^2	10 ppb	10 ppb	960 ppb.hrs	960 ppb.hrs
Moderate	10 g/m^2	100 g/m^2	100 ppb	50 ppb	9,600 ppb.hrs	4,800 ppb.hrs
High	25 g/m^2	1,000 g/m^2	1,000 ppb	400 ppb	96,000 ppb.hrs	38,400 ppb.hrs

2.3.6.2 Floating Oil

Floating oil concentrations are relevant to describing the risks of oil coating emergent reefs, vegetation in the littoral zone and shoreline habitats, as well as the risk to wildlife found on the water surface, such as marine mammals, reptiles and birds. Floating oil is also visible at relatively low concentrations. Hence, the area affected by visible oil, which might trigger social or economic impacts, will be larger than the area where biological impacts might be expected.

Estimates for the minimal thickness of floating oil that might result in harm to seabirds through ingestion from preening of contaminated feathers, or the loss of the thermal protection of their feathers, has been estimated by different researchers at approximately 10 g/m^2 (French, 2000) to 25 g/m^2 (Koops *et al.*, 2004). Hence, the 10 g/m^2 threshold is likely to be moderately conservative in terms of environmental harm for effects on seabirds, for example. Studies have indicated that a concentration of surface oil 25 g/m^2 or greater would be harmful for most birds that contact the hydrocarbons at this concentration (Scholten *et al.*, 1996; Koops *et al.*, 2004).

The 1 g/m^2 threshold represents the practical limit of observing hydrocarbon sheens in the marine environment, this threshold is considered below levels which would cause environmental harm and is more indicative of the areas perceived to be affected due to its visibility on the sea-surface. The 1 g/m^2 threshold is not considered to be of significant biological impact but may be visible to the human eye.

It is important to note that real spill events generate surface slicks that break up into multiple patches separated by areas of open water. Concentrations calculated and presented in this study represent necessary areal averaging over discrete model cells, and therefore indicate the potential for both higher and lower relative concentrations in the surrounding space.

2.3.6.3 Shoreline Oil

French *et al.* (1996) and French-McCay (2009) have defined an oil exposure threshold of 100 g/m^2 for shorebirds and wildlife (furbearing aquatic mammals and marine reptiles) on or along the shore, which is based on studies for sub-lethal and lethal impacts. The 100 g/m^2 threshold has been used in previous environmental risk assessment studies (French-McCay *et al.*, 2004, 2011, 2012; French McCay, 2003; NOAA, 2013). This threshold is also recommended in AMSA's foreshore assessment guide as the acceptable minimum thickness that does not inhibit the potential for recovery and is best remediated by natural coastal processes alone (AMSA, 2015b).

A threshold of 10 g/m^2 has been defined and would likely represent the zone of potential 'low' exposure. This exposure zone represents the area visibly contacted by the spill and defines the outer boundary of the area of influence from a hydrocarbon spill. Threshold of 1,000 g/m^2 will define the zones of potential 'high' exposure on shorelines, respectively. Contact within this exposure zones may result in impacts to the marine environment.

2.3.6.4 Instantaneous Entrained Oil

Oil can be entrained into the water column from surface slicks due to wind and wave-induced turbulence or be generated subsea by a pressurised discharge at depth. Entrained oil presents several possible mechanisms for exerting exposure. The entrained oil droplets may contain soluble compounds and hence have the potential to generate elevated concentrations of dissolved hydrocarbons (e.g. if mixed by breaking waves against a shoreline). Physical and chemical effects of the entrained oil droplets have also been demonstrated through direct contact with organisms; for example, through physical coating of gills and body surfaces, or accidental ingestion (NRC, 2005).

The 10 ppb threshold represents the lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) (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 is trapped against a shoreline for periods of several days or more. The 10 ppb threshold exposure zone is not considered to be of significant biological impact. This exposure zone represents the area contacted by the spill and conservatively defines the outer boundary of the area of influence from a hydrocarbon spill.

The 100 ppb threshold is considered conservative in terms of potential for toxic effects leading to mortality for sensitive mature individuals and early life stages of species. This threshold has been defined as moderate to indicate a potential zone of acute exposure, which is more meaningful over shorter exposure durations. The 1,000 ppb threshold has been selected to define the high exposure zone. Contact within this exposure zone may result in impacts to the marine environment.

2.3.6.5 Time-integrated Entrained Oil Exposure

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, 2005).

Exceedances of 10 ppb, 100 ppb and 1,000 ppb over 96 hours (i.e. 960 ppb.hrs, 9,600 ppb.hrs and 96,000 ppb.hrs) were applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high). Similar to dissolved oil, the entrained oil thresholds were assessed over 96 hours timeframe to consider chronic exposure of receptors as a means of comparing similar durations encountered in laboratory studies. Thereby, for each simulation, the concentrations in each grid cell were calculated as a moving average, stepping by an hour each calculation.

2.3.6.6 Instantaneous Dissolved Aromatic Hydrocarbons

Dissolved aromatic compounds reported LC50 for PAHs (polynuclear aromatic hydrocarbons) with 96 hr exposure range between 6 ppb and 410 ppb for sensitive species (2.5th-percentile species) and insensitive species (97.5th-percentile species) respectively, with an average of ~50 ppb (French-McCay, 2002). Note that the values for LC50 increases as the time of exposure decreases, as marine organisms can typically tolerate higher concentrations of toxic hydrocarbons over short durations (French, 2000; Pace *et al.*, 1995). Actual toxicity depends on both concentration and the duration of exposure, being a balance between acute and chronic effects.

As an indication of potential exposure, thresholds for concentrations of dissolved aromatic hydrocarbons were defined at 10 ppb (low exposure), 50 ppb (moderate exposure) and 400 ppb (high exposure).

2.3.6.7 Time-Integrated Dissolved Aromatic Hydrocarbons Exposure

The mode of action of soluble (dissolved) hydrocarbons is a narcotic effect resulting from interference with cell function that occurs as hydrocarbons are absorbed across cell membranes within the tissues of organisms (French-McCay, 2002). The narcotic effect varies among specific hydrocarbon compounds, with these variations mostly attributable to the lipid solubility of the compounds. Over periods of hours to a few days, the narcotic effect has been found to be additive, both for the range of soluble hydrocarbons that are present and with increasing exposure concentration (French, 2000; NRC, 2005; Di Toro et al., 2007). The effect of exposure time is, however, not additive in a linear fashion.

Organisms exposed to soluble hydrocarbons display toxic responses that follow an exponential relationship with time of exposure (Figure 2.20), with highest concentrations required for a given end-point – e.g. LC50 or NOEC (no observed effect concentration) – over only short-term exposure (e.g. 1-2 hours) and decreasing concentrations required as exposure times increase up to time intervals where the required concentration reaches an asymptote. This is due to the fact that concentrations of hydrocarbons take time to be absorbed and build up in the tissues of organisms until an equilibrium is reached, when rates of absorption into and desorption from the lipid phase of the organism are equal (i.e. the uptake of chemical by the organism is the same as the elimination of the chemical by the organism; French-McCay, 2002; NRC, 2005). Toxic responses in the organism occur when the concentration of the nonpolar organic chemicals in the tissues reaches a critical concentration.

Because the toxicity of dissolved hydrocarbons to aquatic organisms increases with time of exposure, organisms may be unaffected by brief exposures to a given concentration but affected at long exposures (French-McCay, 2002). It can be seen from Figure 2.20 that back-projecting from the concentration times exposure duration required to cause an effect after longer duration (such as 96 hours of exposure) to that required for a shorter duration (such as 1 to 6 hours), assuming a linear relationship over time, would indicate an effective concentration that is substantially more conservative (lower concentration required for the effect) than is observed for an exponential relationship. For example, in Figure 2.20, carrying a linear line back from the effect concentration indicated for aquatic organism over 96 hours of continuous exposure (<100 ppb) to that required with 6 hours of exposure, assuming a linear relationship, would indicate an effect concentration ~500 ppb. However, the observed relationship summarised by the exponential curve for this species indicates concentrations >2,000 ppb would be required over this short duration to produce the same endpoint. These considerations indicate that the assessments for exposure based on instantaneous thresholds are likely to be conservative because they are derived from toxicity assessments over longer exposure durations and can be triggered in the exposure assessment by exposure durations as short as one hour.

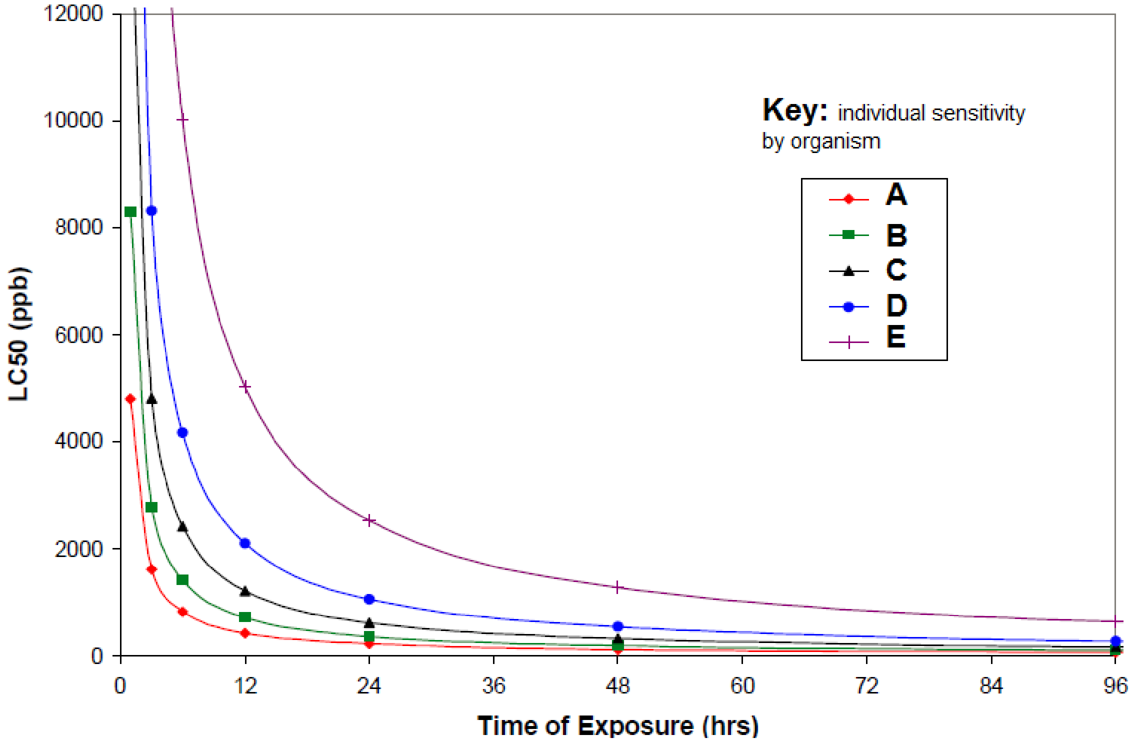


Figure 2.20 Illustrative representation of the general relationship between effect concentration, exposure time and species sensitivity (from high sensitivity A to low sensitivity E) to dissolved aromatic hydrocarbons. Data are conceptual values only.

The time-integrated exposure can be used to more realistically quantify the cumulative impact of a contaminant on biota over time and compare the values to lethal or sublethal concentrations obtained in toxicity tests. Most toxicity tests have been conducted over exposure periods of 96 hours to quantify the minimum concentration required, when maintained at a constant level, for a defined acute response (mortality or physiological effect, e.g. LC50 or EC50, respectively). The duration of 96 hours is applied assuming this exposure would be longer than required for equilibrium to occur.

In this study, the integrated exposure for each cell location was calculated by addition of the concentration of soluble aromatic hydrocarbons calculated at each subsequent time step over rolling 96-hour periods. This is equivalent to calculating the average concentration (over any 96 hours) multiplied by the exposure duration (96 hours). For example, if the concentrations experienced at each hour over any 96 hours added to 10 ppb, the integrated exposure level would be 960 ppb.hr. Note that these calculations only consider what concentrations were available for potential absorption and no assumption is made about the rates of uptake or depuration of these concentrations by organisms that might be present.

As illustrated in Figure 2.20, the sensitivity of a given type or life stage of organism has been found to vary so that very sensitive organisms will be affected by lower initial and saturation concentrations and more tolerant organisms will cope with higher initial and saturation concentrations. To quantify the probability of overexposure for species of varying sensitivity, the integrated exposure calculated over rolling 96-hour periods were compared to a series of thresholds, expressed in units of concentration-hours. A threshold of 4,800 ppb.hr is indicative of exposure to an average concentration of 50 ppb over 96 hours. A threshold of 38,400 ppb.hr is indicative of exposure to an average concentration of 400 ppb over 96 hours.

2.3.7 Oil Characteristics

2.3.7.1 Overview

The physical and chemical properties of Corowa Light Crude and marine gas oil will determine the way it behaves in the marine environment, Table 2.2 outlines their physical characteristics and boiling point ranges.

Table 2.2 Characteristics of the oil type used in the modelling of the long-term subsea well blowout and the short-term surface release.

Oil Type	Density (g/cm^3)	Viscosity (cP)	Component	Volatile (%)	Semi-Volatile (%)	Low Volatility (%)	Residual (%)	Aromatics (%)
			Boiling point (BP) (°C)	< 180 C4 to C10	180 – 265 C11 to C15	265 – 380 C16 to C20	> 380 > C20	Of whole oil < 380 BP
Marine gas oil	0.8430 [at 13 °C]	4.0 [at 13 °C]	% of total	16.4	49.0	31.9	2.7	4.6
			% aromatics	1.9	1.1	1.6	-	-
Corowa Light Crude	0.7783 [at 15 °C]	0.54 [at 20 °C]	% of total	56.2	23.5	14.4	5.9	1.8
			% aromatics	0.5	1.2	0.1	-	-

The boiling points are dictated by the length of the carbon chains, with the longer and more complex compounds having a higher boiling point, and therefore lower volatility and evaporation rate.

The aromatic components within the volatile to low volatility range are also soluble (with decreasing solubility following decreasing volatility), hence will dissolve across the oil-water interface. The rate of dissolution will increase with increase in surface area. Hence, dissolution rates will be higher under discharge conditions that generate smaller oil droplets.

Atmospheric weathering will commence when oil droplets float to the water surface. Typical evaporation times once the hydrocarbons reach the surface and is exposed to the atmosphere are around:

- Up to 12 hours for the C4 to C10 compounds (or less than 180 °C BP);
- Up to 24 hours for the C11 to C15 compounds (180 – 265 °C BP);
- Several days for the C16 to C20 compounds (265 – 380 °C BP); and
- N/A for the residual compounds (BP>380 °C), which will resist evaporation, persist in the marine environment for longer periods, and be subject to relatively slow degradation.

The fate of oil in the marine environment will depend greatly on the proportion of oil that reaches the surface after rising through the water column. Oil at surface will be subject to atmospheric weathering and will be transported by prevailing currents and wind. Oil that entrains or dissolves in the water column will be transported by prevailing current and hence, will follow a different path. Oil in the water column will also be subject to different weathering processes in comparison to floating oil. Hence, discharge conditions (which affect droplet size distributions and rise times) will have a strong influence on exposure risks for surrounding resources.

2.3.7.2 Corowa Light Crude

The modelled Corowa Light Crude (API 50.3) has a low dynamic viscosity (0.54 cP at 20 °C) and pour point (-42 °C) relative to seawater temperatures around the Corowa field, as a result oil will flow and spread rapidly if spilled onto the sea surface and may be readily broken up into droplets and entrained into the upper few metres of the water column by wave action.

Note, Corowa Light Crude has an actual viscosity of 2.05 cP at 20 °C, with a pour point of -13 °C. The difference in pour point is not expected to have any adverse impact on the model outcomes given that that both values (i.e. actual of -13 °C and modelled of -42 °C) are well below ambient seawater temperatures. The difference in viscosity values (i.e. actual of 2.05 cP and modelled at 0.54 cP) may have a small impact on model outcomes, however given that the smaller viscosity was modelled this would be a greater initial rate of spreading and therefore would be a more conservative outcome.

The modelled Corowa Light Crude is composed of hydrocarbons with a wide range of boiling points and volatilities at atmospheric temperatures, which will evaporate at different rates on exposure to the atmosphere. Evaporation rates will increase with temperature, but in general, about 56.2% of the oil mass should evaporate within the first 12 hours (BP < 180 °C); a further 23.5% should evaporate within the first 24 hours (180 °C < BP < 265 °C); and a further 14.4% should evaporate over several days (265 °C < BP < 380 °C). The oil contains a relatively low proportion (5.9% by mass) of hydrocarbon compounds that will not evaporate at atmospheric temperatures. These compounds may persist in the marine environment for weeks to months, typically as waxy solids.

Soluble aromatic hydrocarbons contribute approximately 1.8% by mass of the whole oil. Around 0.5% by mass is highly soluble and highly volatile. The fate of this component, which include the BTEX compounds, will vary depending on the release conditions and subsequent setting, with a higher proportion likely to dissolve into the water column in the case of an energetic subsea discharge. Volatile aromatic hydrocarbons that remain in the oil mixture at surface will tend to evaporate rapidly.

2.3.7.3 Marine Gas Oil

Marine gas oil (API 36.4) contains a relatively low proportion (2.7% by mass) of hydrocarbon compounds that will not evaporate at atmospheric temperatures. These compounds will persist in the marine environment.

The unweathered mixture has a low dynamic viscosity (4.0 cP). The pour point of the whole oil (-36 °C) ensures that it will remain in a liquid state over the annual temperature range observed on the North West Shelf.

The condensate is composed of hydrocarbons that have a wide range of boiling points and volatilities at atmospheric temperatures, and which will begin to evaporate at different rates on exposure to the atmosphere. Evaporation rates will increase with temperature, but in general about 16.4% of the oil mass should evaporate within the first 12 hours (BP < 180 °C), a further 49% should evaporate within the first 24 hours (180 °C < BP < 265 °C), and a further 31.9% should evaporate over several days (265 °C < BP < 380 °C).

Soluble aromatic hydrocarbons contribute approximately 4.6% by mass of the whole oil. Around 1.9% by mass is highly soluble and highly volatile. The fate of this component, which include the BTEX compounds, will vary depending on the release conditions and subsequent setting.

2.3.8 Weathering Characteristics

2.3.8.1 Overview

A series of model weather tests were conducted to illustrate the potential behaviour of Corowa Light Crude and marine gas oil when exposed at the water surface to idealised and representative environmental conditions:

- Instantaneous release onto the water surface at a discharge rate of 50 m^3/hr under calm wind conditions (constant 5 knots), assuming low seasonal water temperature (27 °C) and average air temperature (25 °C). Slick also subject to ambient tidal and drift currents.
- Instantaneous release onto the water surface at a discharge rate or 50 m^3/hr under variable wind conditions (4-19 knots, drawn from representative data files), assuming low seasonal water temperature (27 °C) and average air temperature (25 °C). Slick also subject to ambient tidal and drift currents.

- Continuous subsea release of Corowa Light Crude for 80 days at the rate specified for the subsea well blowout (decreasing from 10,107 m^3/day to 3,655 m^3/day), for one example time-series of ambient conditions in the study area, followed by a further 4-week post spill period.

The first case is indicative of cumulative weathering rates for the whole oil under calm conditions that would not generate entrainment. The second case presents conditions that may cause a minor degree of entrainment. Both scenarios provide examples of potential behaviour during periods of a spill event, once the oil reaches the surface. The third case is useful to assess the longer-term fate and mass balance of the subsea spill scenario while accounting for a wider range of more realistic conditions.

2.3.8.2 Corowa Light Crude

The results for the constant-wind case (Figure 2.21) indicate wind conditions will have a large impact on the proportion of Corowa Light Crude that remains afloat. If very calm wind conditions persisted over the weathering period, about 7% of the spilled volume would likely persist on the sea surface after 7 days, with negligible levels of entrainment. Around 82% of the spilled volume would be expected to evaporate within the first 24 hours.

However, under a variable-wind case generating more wave-action at the sea surface (Figure 2.22), little oil mass (<1%) would be expected on the sea surface after 7 days. This is largely due to the higher wind speeds within this test case (usually > 2.6 m/s) generating significant entrainment events, with almost all the oil mass becoming entrained when the wind speed first exceeds 7 m/s in the simulation. The higher proportion of entrained oil predicted in the variable-wind case also results in a larger proportion of the oil dissolving: 0.5% after 24 hours compared with < 0.1% under calm conditions.

The evaporation rate observed in the first 24 hours is similar in both weathering tests. However, as the wind speed increases in the variable-wind case, increased entrainment slightly reduces the proportion of oil available for evaporation, resulting in around 72.6% of the spilled volume expected to evaporate after 7 days as compared to 90.9% for the lower-wind case.

Biological and photochemical degradation is predicted to be greater in the variable-wind case with a rate of ~1% per day and an accumulated total of 7% after 7 days. In comparison to a rate of ~0.2% and an accumulated total of 1.2% in the constant-wind case. The slow degradation of this weathered condensate will extend the area of potential effect, requiring the break-up and dispersion of the slicks to reduce concentrations below the thresholds considered in this study.

Predictions for the fate of Corowa Light Condensate when released from the seabed at a decreasing rate over 80 days under variable conditions are shown in Figure 2.23. The results indicate that crude would initially build up in the water column in entrained form, but this representation would steadily decrease over the duration of the simulation, with around 21% of the volume 2 days after the spill commencement to around 3% by the end of the simulation. Losses are predominately due to evaporation (83%) and degradation (14%) after 94 days. A low volume of oil is expected to surface over time (<2% after day 2), due to the high evaporation rates. Evaporation and decay losses represent approximately 83% (340,532 m^3) and 14% (57,439 m^3), respectively, of the total oil mass by the end of the simulation period.

2.3.8.3 Marine Gas Oil

The results for the constant-wind case (Figure 2.24) indicate that a significant proportion of marine gas oil will tend to persist on the sea surface (~27% after 7 days) during calm wind conditions, with negligible levels of entrainment and around 59% of the spilled volume expected to evaporate within the first 24 hours.

The results for the variable-wind case (Figure 2.25) indicate that the wind conditions will have a large impact on the proportion of marine gas oil that remains afloat, with little oil mass predicted to persist on the sea surface after 7 days (<1%). This is largely due to the higher wind speeds within this test case (usually >2.6 m/s) generating significant entrainment events, with almost all the oil mass becoming entrained when the wind speed first exceeds 8 m/s in the simulation. The higher proportion of entrained oil predicted in the variable-wind case also results in a larger proportion of the oil dissolving:0.6% after 24 hours compared with <0.1% under calm conditions.

The evaporation rate observed in the first 24 hours is similar in both weathering tests. However, as the wind speed increases in the variable-wind case, increased entrainment slightly reduces the proportion of oil available for evaporation, resulting in around 64% of the spilled volume expected to evaporate after 7 days as compared to 71% for the lower-wind case.

Biological and photochemical degradation is predicted to contribute to the decay of the floating slicks at a similar rate for both weathering cases, with an approximate rate of <1% per day and an accumulated total of about 2.4-2.6% after 7 days. The slow degradation of this weathered condensate will extend the area of potential effect, requiring the break-up and dispersion of the slicks to reduce concentrations below the thresholds considered in this study.

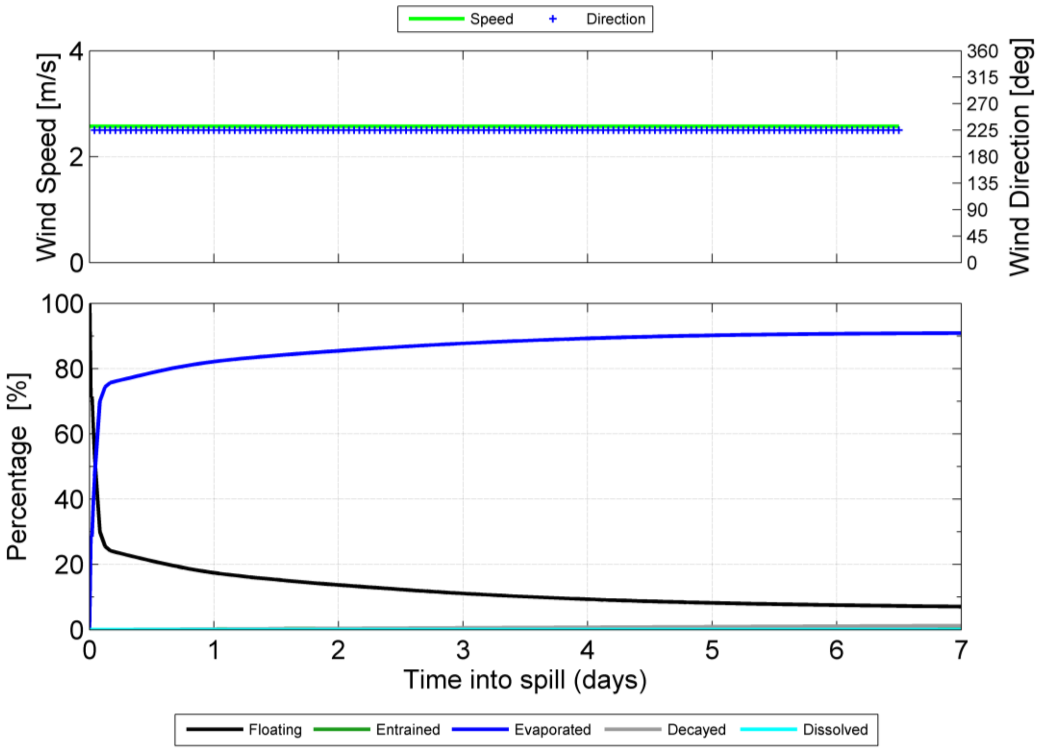


Figure 2.21 Mass balance plot representing, as proportion (bottom panel), the weathering of Corowa Light Crude spilled into the water column as a one-off release (50 m^3) and subject to a constant 5 kn (2.6 m/s) wind at 27 °C water temperature and 25 °C air temperature.

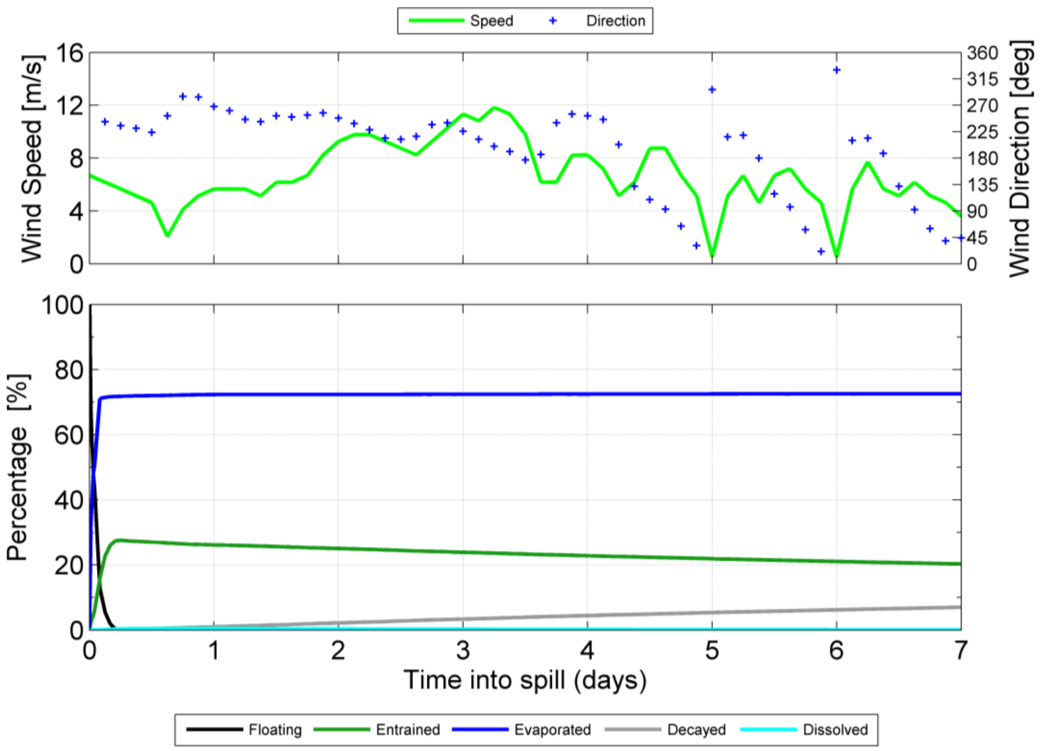


Figure 2.22 Mass balance plot representing, as proportion (bottom panel), the weathering of Corowa Light Crude spilled into the water column as a one-off release (50 m^3) and subject to variable wind at 27 °C water temperature and 25 °C air temperature.

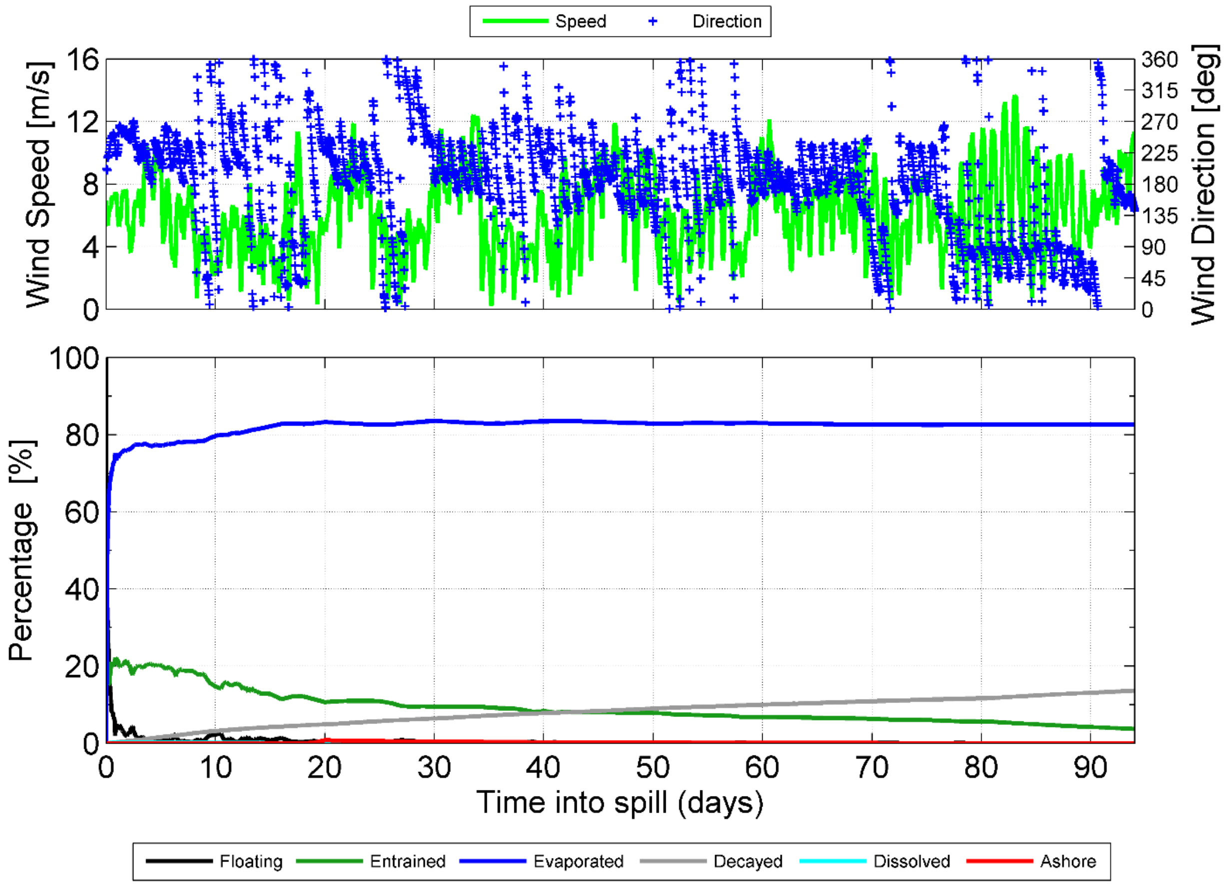


Figure 2.23 Mass balance plot representing, as proportion (bottom panel), the weathering of a continuous subsea release of 410,280 m^3 of Corowa Light Crude and subject to time varying environmental conditions.

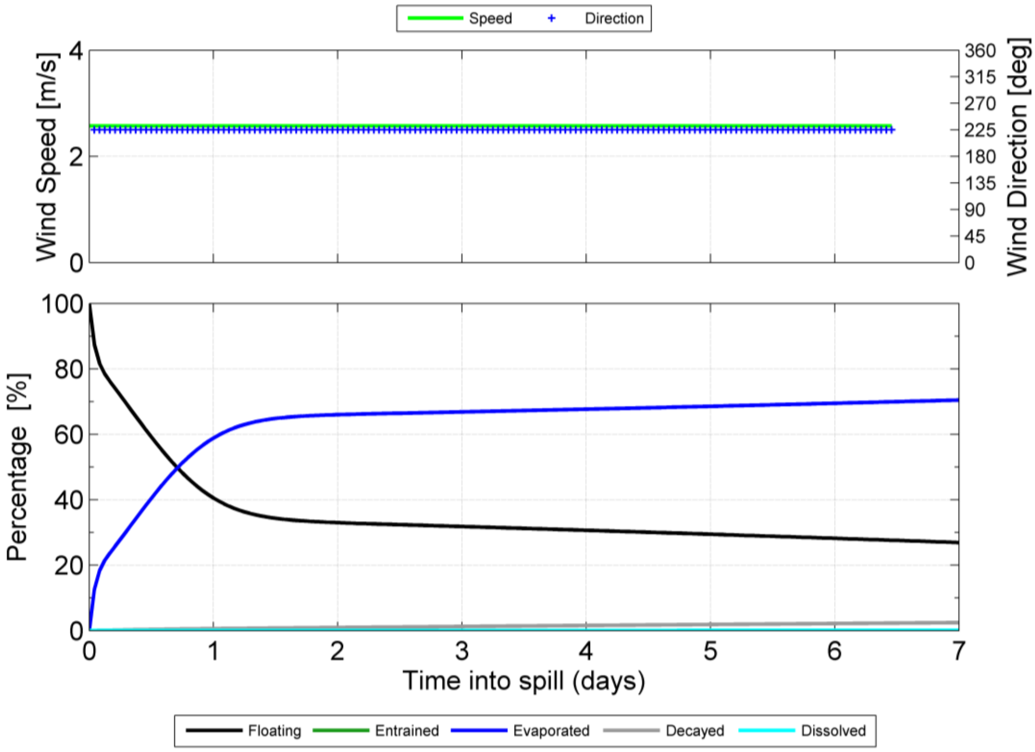


Figure 2.24 Mass balance plot representing, as proportion (bottom panel), the weathering of marine gas oil spilled into the water column as a one-off release (50 m^3) and subject to a constant 5 kn (2.6 m/s) wind at 27 °C water temperature and 25 °C air temperature.

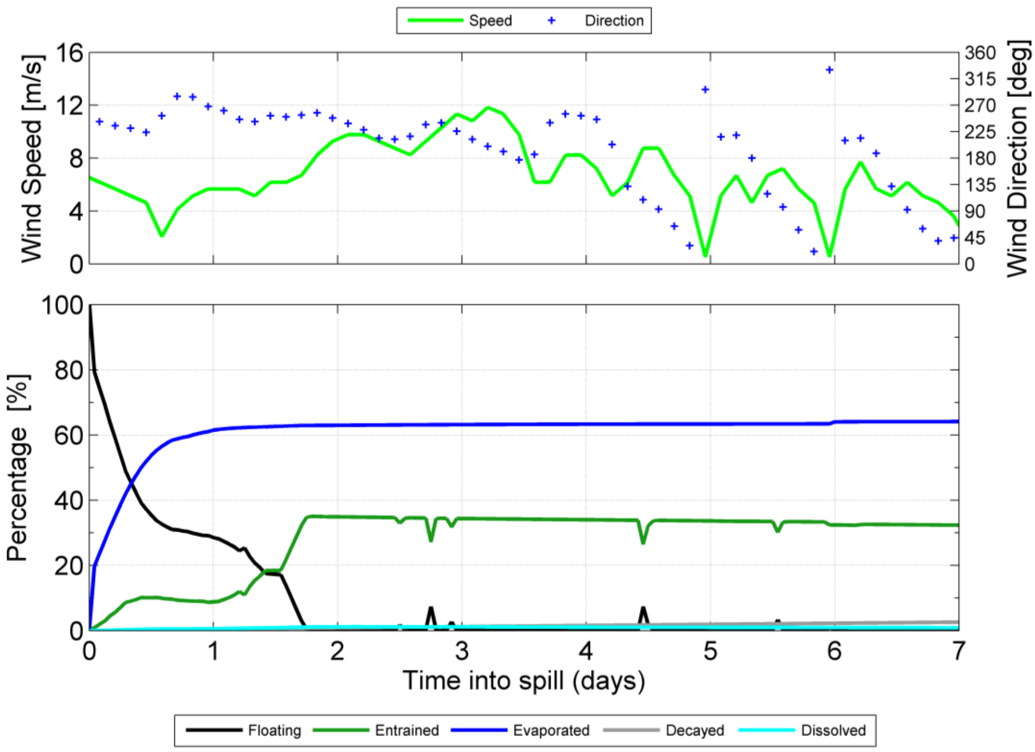


Figure 2.25 Mass balance plot representing, as proportion (bottom panel), the weathering of marine gas oil spilled into the water column as a one-off release (50 m^3) and subject to variable wind at 27 °C water temperature and 25 °C air temperature.

2.3.9 Subsurface Discharge Characteristics

2.3.9.1 Overview

High-pressure releases that involve mixed gas and oil will tend to generate relatively small droplet sizes that have slow rise rates, due to viscous resistance imparted by the surrounding seawater, and may become trapped by density layers in the water column (Chen & Yapa, 2002). The buoyancy of the gas cloud may lift entrained oil droplets towards the surface and, in the case of blowouts in relatively shallow water (<100-200 m), the rising column of gas and entrained water can lift the oil to the surface at a substantially faster rate than would occur from the relative buoyancy of the oil alone, opposed by the viscosity of the water column.

For deeper releases (200-500 m), the gas will expand to entrain oil droplets towards the surface, but the gas and oil will then tend to separate before the oil surfaces because the gas either goes into solution or accelerates away from the oil droplets. The height at which the gas lift ceases is referred to as the trapping height. The rate at which oil rises from the trapping height will be determined by a number of factors, including the relative buoyancy of the oil versus local water density, the size of the droplets (increased viscous resistance for smaller sizes), the presence of density barriers in the water column and the action of shear currents that might be present in the water column.

Given the water temperature and pressure that would be expected at the specified discharge depth, the potential for methane and other gases to convert to gas hydrates (semi-solid crystalline structures that would affect the buoyancy of the plume; Figure 2.26) was not considered in this study.

The OILMAP model, described in Section 2.1.2, was used in this study to predict the behaviour of the rising plume of gas-oil-water and the oil droplet distribution resulting from the subsea discharge at the Corowa spill site.

Inputs to the OILMAP model included specification of the discharge rate, hole size, gas-to-oil ratio, and the temperature of the oil on exiting and before subsequent cooling by the ambient water. The model input also included temperature and salinity profiles representative of the location. Summaries of the inputs to and outputs of the OILMAP simulations for the subsea blowout are presented in the following section.

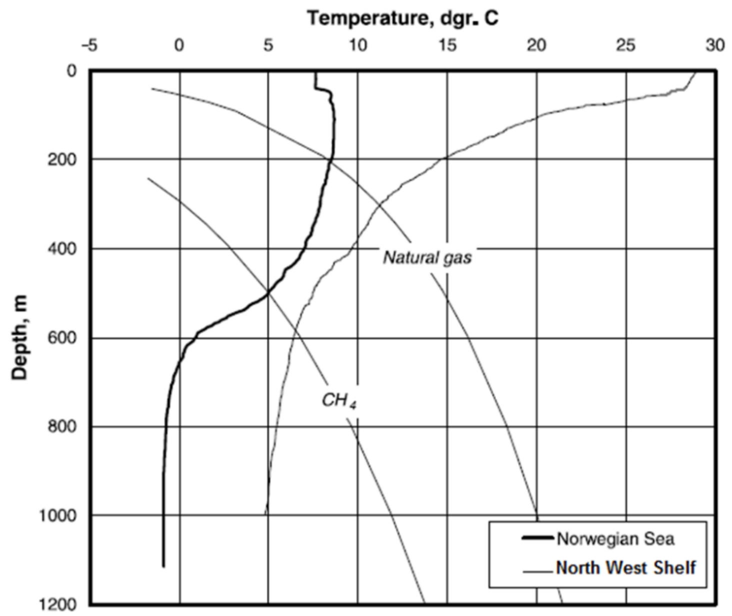


Figure 2.26 Theoretical equilibrium lines for hydrate formation based on the temperature and pressure at the release point. The line for "natural gas" assumes 80% methane, 10% ethane and 10% propane. Typical indicative sea temperature profiles with depth are indicated (Johansen, 2003).

2.3.9.2 Long-term (80-day) subsea well blowout of Corowa Light Crude within the Corowa field

The OILMAP input parameters and the resulting output parameters that were used as input into SIMAP for the subsea well blowout are presented in Table 2.3. The model input also included temperature and salinity profiles representative of the location.

The results of the OILMAP simulation for the subsea well blowout predict that discharge will generate a cone of rising gas that will entrain the oil droplets and ambient sea water up to the water surface. The mixed plume is initially forecast to jet towards the water surface with a vertical velocity of around 1.9 m/s, gradually slowing and increasing in plume diameter as more ambient water is entrained. The diameter of the central cone of rising water and oil at the point of surfacing is predicted to be approximately 10.5 m.

The low discharge velocity and turbulence generated by the expanding gas plume is predicted to generate relatively large oil droplets 1,000-9,000 µm in diameter that will have very fast rise velocities 7-12 cm/s. These droplets will be subject to mixing due to turbulence generated by the lateral displacement of the rising plume, as well as vertical mixing induced by wind and breaking waves. Therefore, after reaching the surface layer (3-10 m deep, depending on the conditions) due to the lift produced by the rising plume, the droplets will then surface due to their high buoyancy relative to other mixing processes.

The ongoing nature of the release combined with the high volatility of the mixture may present other hazards, including conditions that may lead to high local concentrations of atmospheric volatiles. These issues should be considered when evaluating the practicality of response operations at or near the blowout site.

Table 2.3 Near-field subsurface discharge model parameters for the subsea blowout.

OILMAP	Parameter	Value
Inputs	Release depth (m BMSL)	85
	Oil density (g/cm^3) (at 15 °C)	0.7783
	Oil viscosity (cP) (at 20 °C)	0.54
	Oil temperature (°C)	69.8
	Hole diameter (m) [in]	0.76 [30]
	Gas:oil ratio (m^3/m^3) [scf/bbl]	140 [5.6]
	Oil flow rate (m^3/d) [bbl/d]	10,107 - 3,655 [63,568 – 22,987]
Outputs	Plume diameter (m)	10.5
	Plume height (m ASB)	85 (surface)
	Plume initial rise velocity (m/s)	1.9
	Plume terminal velocity (m/s)	0.9
Predicted Oil Droplet Size Distribution	20% droplets of size (µm)	1,000
	20% droplets of size (µm)	3,000
	20% droplets of size (µm)	5,000
	20% droplets of size (µm)	7,000
	20% droplets of size (µm)	9,000

3 MODELLING RESULTS

3.1 Overview

3.1.1 Deterministic Modelling

While the stochastic modelling results provide an objective indication of all locations that maybe exposed or contacted by oil above the reporting thresholds, the approach describes a larger potential area of influence than can be expected from any one single spill event. To understand the potential area that might be affected during an isolated (single) spill event, it is helpful to analyse the outcomes of individual in more detail for each scenario.

For each scenario, one unmitigated replicate from each scenario was identified from the set of stochastic results based on the following criteria:

- Replicate simulation with the maximum oil volume accumulation on shorelines.

The replicate from each scenario with the maximum oil volume accumulation on shorelines was then further analysed, and the following additional deterministic outputs have been presented:

- The ***zones of potential oil exposure on the sea surface*** – the highest concentration at each grid cell to occur during at least one time-step (1 hr) and classified relative to the threshold (i.e. low exposure: 1–10 g/m^2; moderate exposure: 10–25 g/m^2 and high exposure: ≥ 25 g/m^2).

- The ***maximum potential hydrocarbon loading on shorelines*** – is determined by identifying the maximum loading for grid cell and classified relative to the threshold (i.e. low exposure: 10-100 g/m^2; moderate exposure: 100-1,000 g/m^2 and high exposure: ≥ 1,000 g/m^2).

- The ***zones of potential instantaneous entrained oil exposure*** – the highest concentration at each grid cell to occur during at least one time-step (1 hr) and classified relative to the threshold (i.e. low exposure: 10-100 ppb; moderate exposure: 100-1,000 ppb and high exposure: ≥ 1,000 ppb).

- The ***zones of potential time-integrated entrained oil exposure*** – the highest concentration at each grid cell to occur during at least one time-step and classified relative to the threshold (i.e. low exposure: 960-9,600 ppb.hrs; moderate exposure: 9,600-96,000 ppb.hrs and high exposure: ≥ 96,000 ppb).

- The ***zones of potential instantaneous dissolved hydrocarbon exposure*** – the highest concentration at each grid cell to occur during at least one time-step (1 hr) and classified relative to the threshold (i.e. low exposure: 10-50 ppb; moderate exposure: 50-400 ppb and high exposure: ≥ 400 ppb).

- The ***zones of potential time-integrated dissolved hydrocarbon exposure*** – the highest concentration at each grid cell to occur during at least one time-step and classified relative to the threshold (i.e. low exposure: 960-4,800 ppb; moderate exposure: 4,800-38,400 ppb and high exposure: ≥ 38,400 ppb).

- ***Timeseries compilation of zones of potential surface (floating and shoreline) and in-water (entrained and aromatic) exposure*** – areal exposure of floating oil (at ≥ 10 g/m^2), shoreline oil (≥ 100 g/m^2), entrained oil (≥ 100 ppb) and dissolved aromatic hydrocarbons (≥ 50 ppb) at discrete time intervals during each deterministic scenario.

3.1.2 Stochastic Modelling

If readers are not fully familiar with how to interpret stochastic modelling outputs, please refer to the relevant NOPSEMA factsheet (NOPSEMA, 2018) before reading this report section.

Predictions for the probability of contact and time to contact by oil concentrations equalling or exceeding defined thresholds for floating and shoreline oil, entrained oil and dissolved aromatic hydrocarbons are provided in the following sections to summarise the results of the seasonal stochastic modelling.

Contour maps present estimates for the seasonal probability of contact by instantaneous concentrations of at least the defined minimum threshold concentrations. These contours summarise the outcomes for all replicate simulations commencing across the seasonal periods –50 (long-term subsea well blowout) and 100 (short-term surface release) replicate simulations for each season giving a total of 150 and 300 replicate simulations, respectively.

Tables are presented to summarise estimates of contact risk for locations within potentially sensitive receptors that were defined by Kato. All sensitive receptors were included in the analysis, with those outlined here being the receptors shown to be at risk of contact for each scenario in this study.

The stochastic results are calculated and presented as follows:

- The ***zones of potential oil exposure on the sea surface*** – the highest concentration at each grid cell to occur during at least one time-step (1 hr) across all 50 or 100 simulations and classified relative to the threshold (i.e. low exposure: 1–10 g/m^2; moderate exposure: 10–25 g/m^2, high exposure: ≥ 25 g/m^2).

- ***The maximum potential hydrocarbon loading on shorelines*** – is determined by identifying the maximum loading for grid cell and classified relative to the threshold (i.e. low exposure: 10-100 g/m^2, moderate exposure: 100-1,000 g/m^2 and high exposure: ≥ 1,000 g/m^2).

- ***The maximum local accumulated concentration averaged over all replicate spills*** - the greatest concentration calculated for any point on the shoreline after averaging over all replicate simulations.

- ***The maximum local accumulated concentration in the worst replicate spill*** - the greatest accumulation predicted for any point on the shoreline during any replicate simulation, and thus represents an extreme estimate.

- ***The average volume of oil ashore*** – is determined by averaging the volume of oil ashore across all simulations predicted to make shoreline contact.

- ***The maximum volume of oil ashore in the worst replicate spill*** – the greatest volume of oil predicted for any point on the shoreline during any replicate simulation, and thus represents an extreme estimate.

- ***The zones of potential instantaneous entrained oil exposure*** – the highest concentration at each grid cell to occur during at least one time-step (1 hr) across all 50 or 100 simulations and classified relative to the threshold (i.e. low exposure: 10-100 ppb; moderate exposure: 100-1,000 ppb and high exposure: ≥ 1,000 ppb).

- ***The zones of potential time-integrated entrained oil exposure*** – the highest concentration at each grid cell to occur during at least one time-step across all 50 or 100 simulations and classified relative to the threshold (i.e. low exposure: 960-9,600 ppb.hrs; moderate exposure: 9,600-96,000 ppb.hrs and high exposure: ≥ 96,000 ppb).

- ***The zones of potential instantaneous dissolved hydrocarbon exposure*** – the highest concentration at each grid cell to occur during at least one time-step (1 hr) across all 50 or 100 simulations and classified relative to the threshold (i.e. low exposure: 10-50 ppb; moderate exposure: 50-400 ppb and high exposure: ≥ 400 ppb).

- ***The zones of potential time-integrated dissolved hydrocarbon exposure*** – the highest concentration at each grid cell to occur during at least one time-step across all 50 or 100 simulations and classified relative to the threshold (i.e. low exposure: 960-4,800 ppb; moderate exposure: 4,800-38,400 ppb and high exposure: ≥ 38,400 ppb).

Note that it is possible that oil films arriving at concentrations that are less than the threshold may accumulate over the course of a spill event to result in concentrations that apparently exceed the threshold. Hence, the mean expected, and maximum concentrations of accumulated oil can exceed the threshold applied to the probability calculations for the arrival of floating oil even where no instantaneous exceedances above threshold are predicted. It is important to understand that the two parameters (floating concentration and shoreline concentration) are quite distinct, calculated in different ways and representative of alternative outcomes. The floating probability estimates, and the shoreline accumulative estimates should therefore be treated as independent estimators of different exposure outcomes, and not directly compared.

Readers should note that the contour maps presented in the stochastic modelling results, do not represent the predicted coverage of any one hydrocarbon spill or a depiction of a slick or plume at any instant in time. Rather, the contours are a composite of many theoretical slick paths, integrated over the full duration of the simulations relevant to each scenario. The stochastic modelling contour maps should be treated as indications of the probability of exposure at defined concentrations, for individual locations, at some point in time after the defined spill commences, given the trends and variations in metocean conditions that occur around the study area.

Locations with higher probability ratings were exposed during a greater number of spill simulations, indicating that the combination of the prevailing wind and current conditions are more likely to result in contact to these locations if the spill scenario were to occur in the future. The areas outside of the lowest-percentage contour indicate that contact will be less likely under the range of prevailing conditions for this region than areas falling within higher probability contours. It is important to note that the probabilities are derived from the samples of data used in the modelling. Therefore, locations that are not calculated to receive exposure at threshold concentrations or greater in any of the replicate simulations might possibly be contacted if very unusual conditions were to occur. Hence, we do not attribute a probability of nil to areas beyond the lowest probability contour.

3.2 Long-term (80-day) subsea well blowout of Corowa Light Crude within the Corowa field

3.2.1 Overview

This scenario investigated the probability of exposure to oil for surrounding regions is there was a long-term (80-day) release of Corowa Light Crude, assuming a variable (decreasing) rate of discharge due to depressurisation, and totalling 410,280 m^3 from a depth of 85 m at a location (114° 33' 26.20" E, 21° 28' 59.40" S) within the Corowa field.

Exposure probabilities and other statistics have been calculated for individual locations, and for areas classified as potentially sensitive to exposure from multiple replicate simulations. Outcomes of the stochastic simulations were screened to identify worst-case simulations, in terms of the volumes of oil calculated on shorelines, through accumulation, over the spill and post-spill period. Calculations for accumulation accounts for the volume of oil stranding less the volume of oil that is lost through weathering and refloating. Maximum accumulation during simulations was the highest volume at any time. Analysis of these worst-case (deterministic) simulations is provided first to illustrate potential outcomes from a single spill event. Results of the full stochastic analysis are then presented to account for the variability of metocean conditions on the probability of outcomes.

3.2.2 Deterministic Assessment Results

3.2.2.1 Deterministic Case 1: Maximum oil volume loading on all shorelines

3.2.2.1.1 Discussion of Results

The summary of the worst-case outcomes for the long-term subsea well blowout scenario, based on calculations for accumulation of oil volumes on sensitive resources that are permanently above water level are presented in Table 3.1.

The maximum oil volume loading on all shorelines during a single spill event was predicted as 1,092 m^3, for a spill commencing in summer (run 25; Table 3.1). During this deterministic case, the maximum oil loading was distributed across Ningaloo State Marine Park (MP) and Ningaloo Coast World Heritage Area (WH).

Table 3.1 Summary table of regional worst-case outcomes for the replicate with maximum oil volume loading on all shoreline receptors.

Case	Selection Criteria	Season	Run No.	Volume	Worst Receptor Contacted
1	Maximum oil volume loading on shorelines*	Summer	25	1,092 m^3	Ningaloo MP (State) and Ningaloo Coast WH

* Volume results refer to model predictions for all shorelines in the region, not for any specific receptor.

Figure 3.1 to Figure 3.6 show the zones of potential exposure for floating oil, shoreline oil, instantaneous and time-integrated entrained oil and instantaneous and time-integrated dissolved aromatic hydrocarbon concentrations, at low, moderate and high contact thresholds.

The maximum distance from the spill location to the outer edge of hydrocarbon exposure (at the assessed thresholds) during this spill is predicted as 661.5 km for entrained oil at concentrations equal to or greater than 100 ppb. The zone of potential exposure attributed to floating oil (10 g/m^2) is relatively small by comparison, reflecting the volatility and low viscosity of the oil mixture. The shoreline accumulation in this case is limited to North Muirion Island and isolated locations along the Ningaloo Coast.

Calculations for the horizontal and vertical distribution of entrained oil and dissolved aromatic hydrocarbon concentrations during this deterministic case have been illustrated as cross-section plots in Figure 3.7 to Figure 3.10. The plots summarise the highest concentrations ever calculated for locations along contour lines relative to the bathymetry and indicate that entrained plumes may come close to shore but will tend to remain over the shelf slope.

Figure 3.11 shows a time-series of the predicted concentrations of surface, in-water (entrained and dissolved) and shoreline oil during the deterministic case at intervals of 1 day, 3 days, 1 week and 2 weeks following the commencement of the spill.

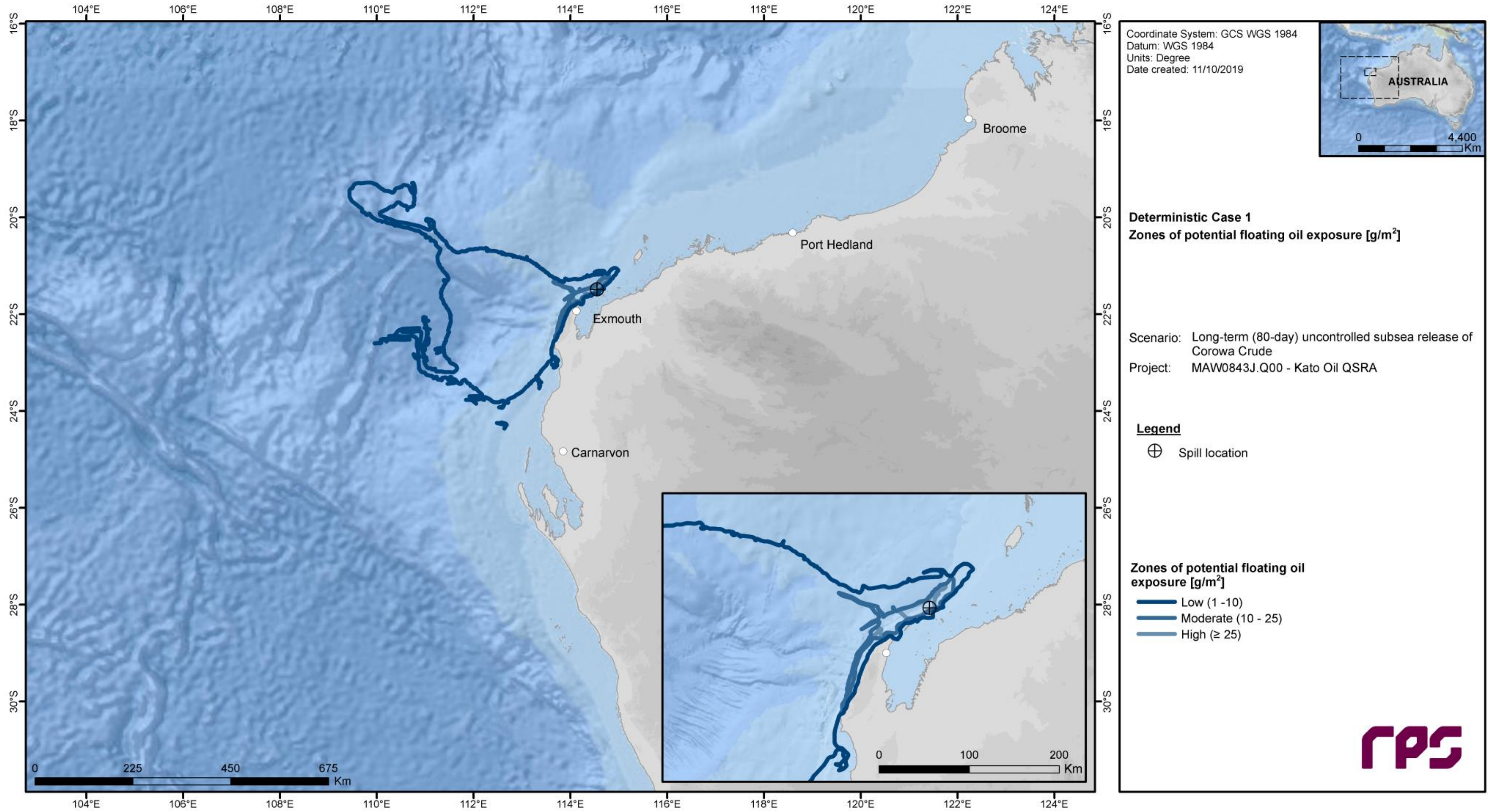


Figure 3.1 Predicted zones of potential floating oil exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 25).

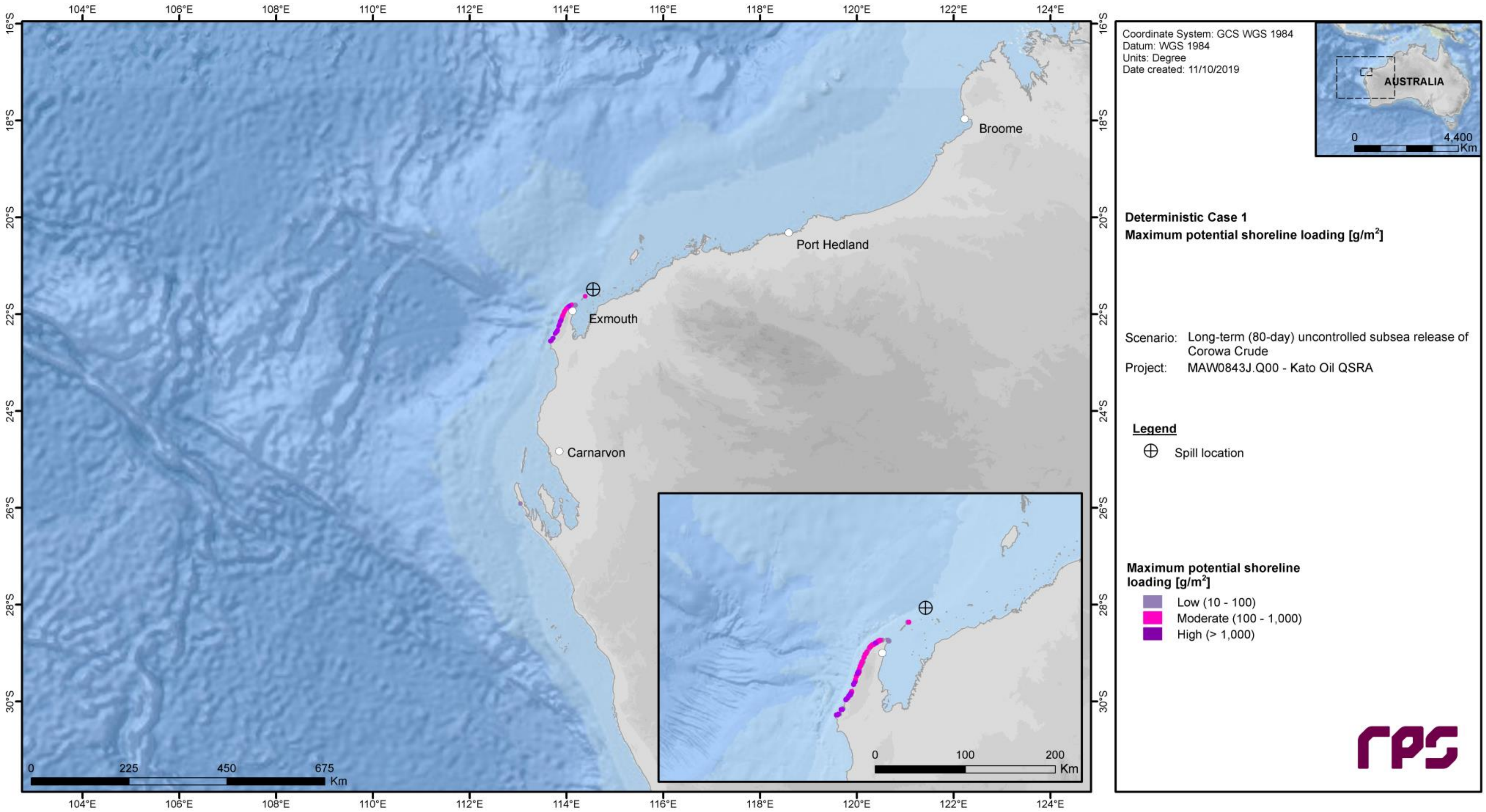


Figure 3.2 Predicted maximum potential shoreline loading resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 25).

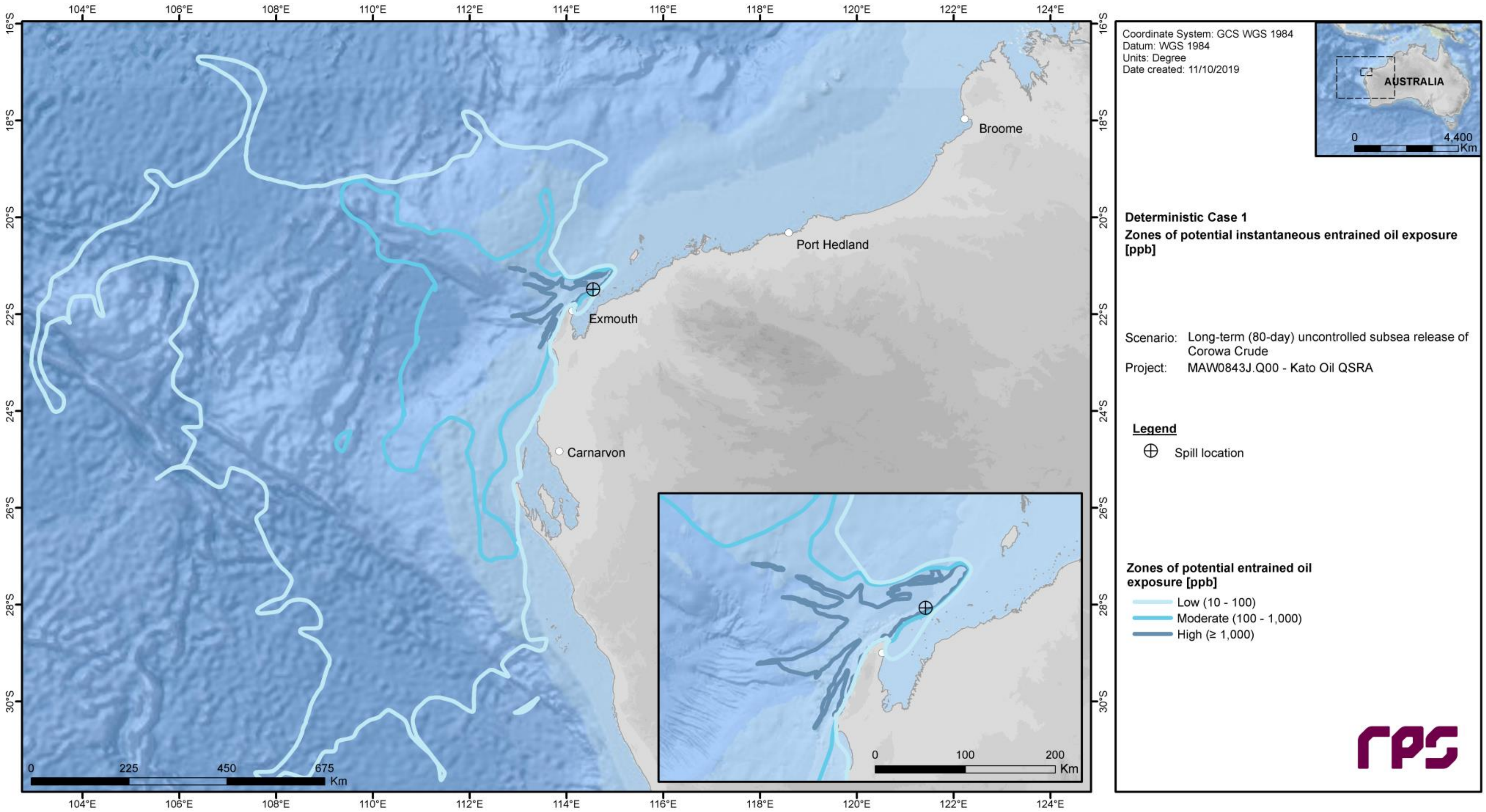


Figure 3.3 Predicted zones of potential instantaneous entrained oil exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 25).

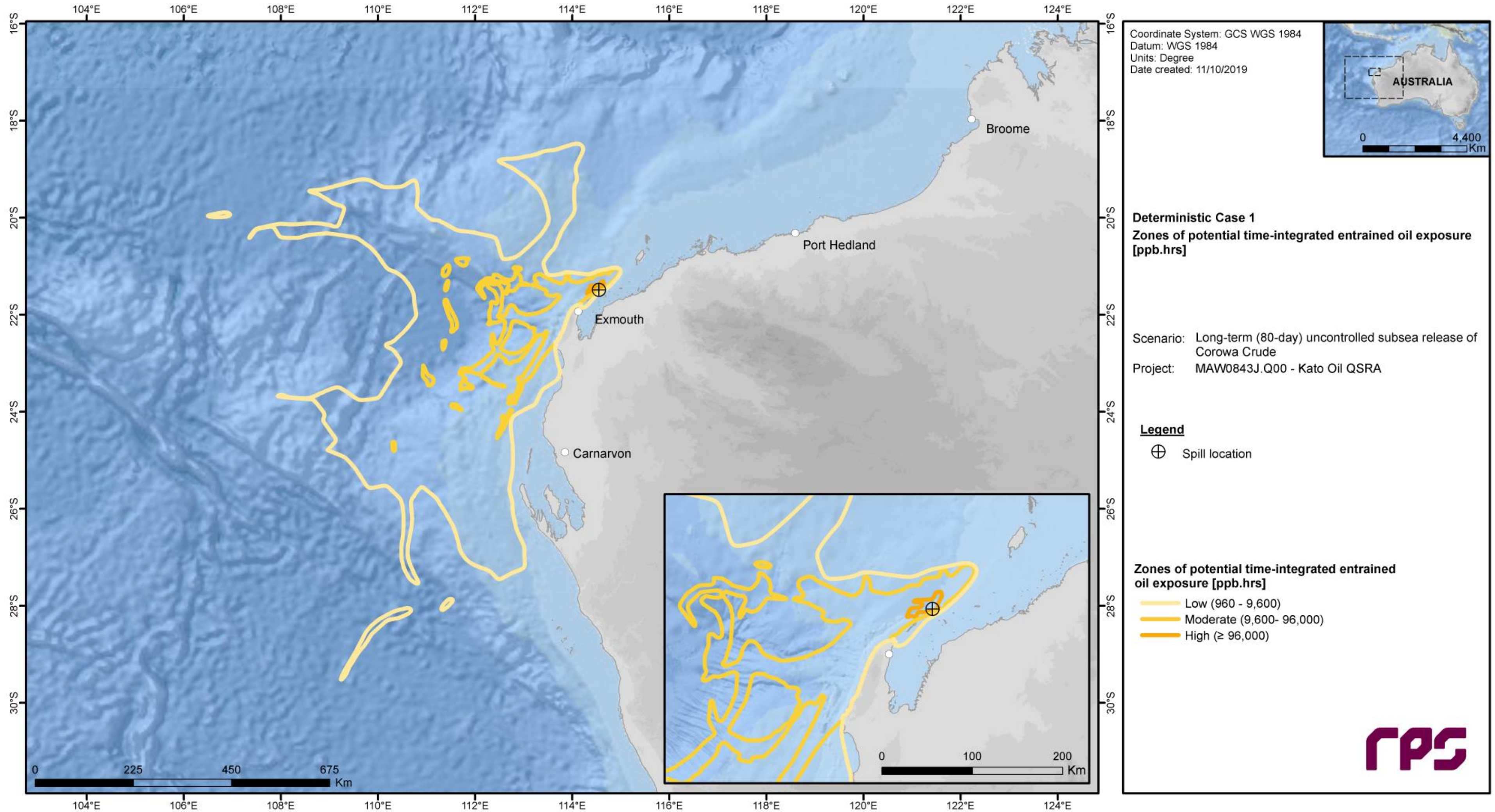


Figure 3.4 Predicted zones of potential time-integrated entrained oil exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 25).

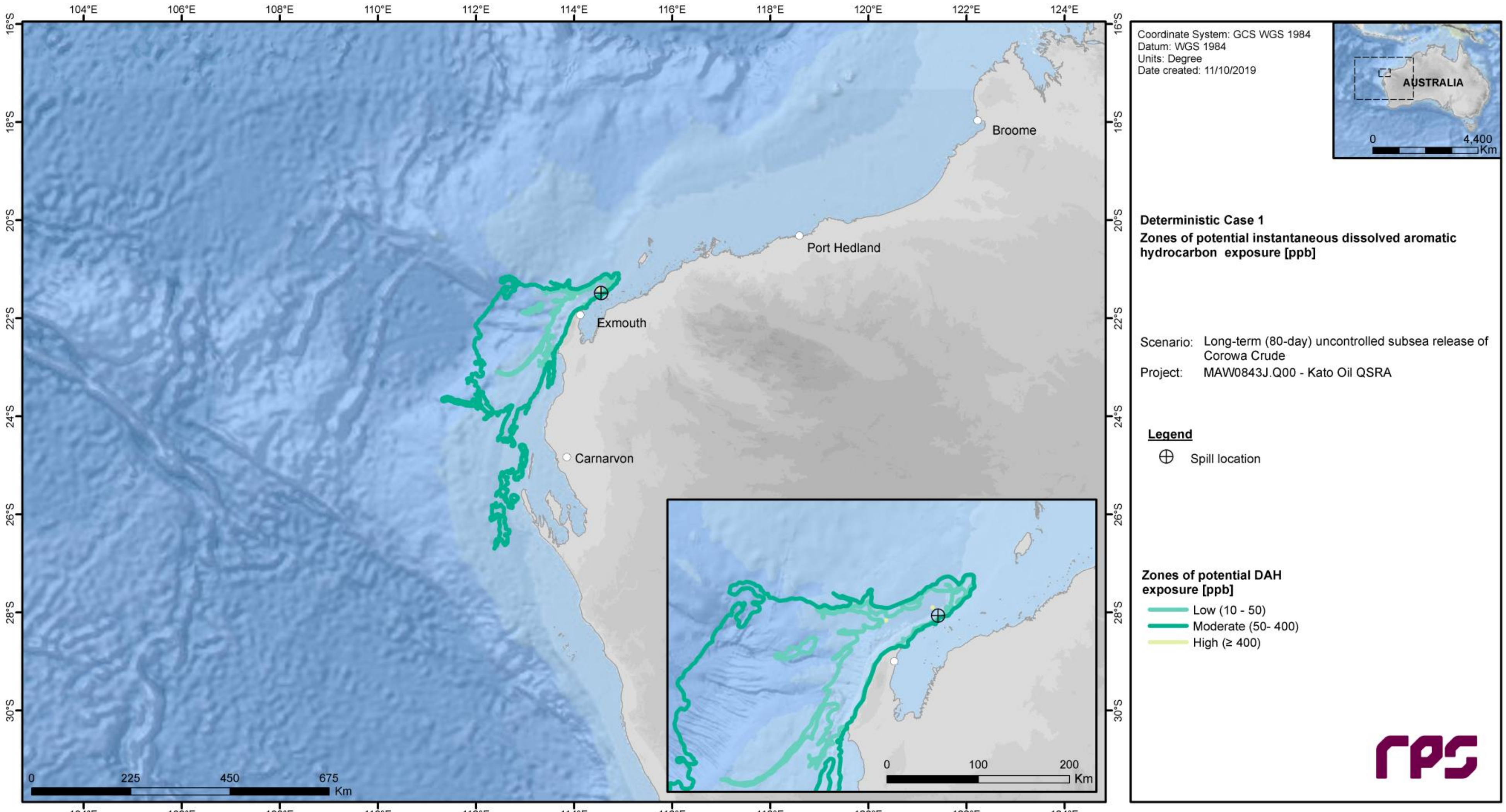


Figure 3.5 Predicted zones of potential instantaneous dissolved aromatic hydrocarbon exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 25).

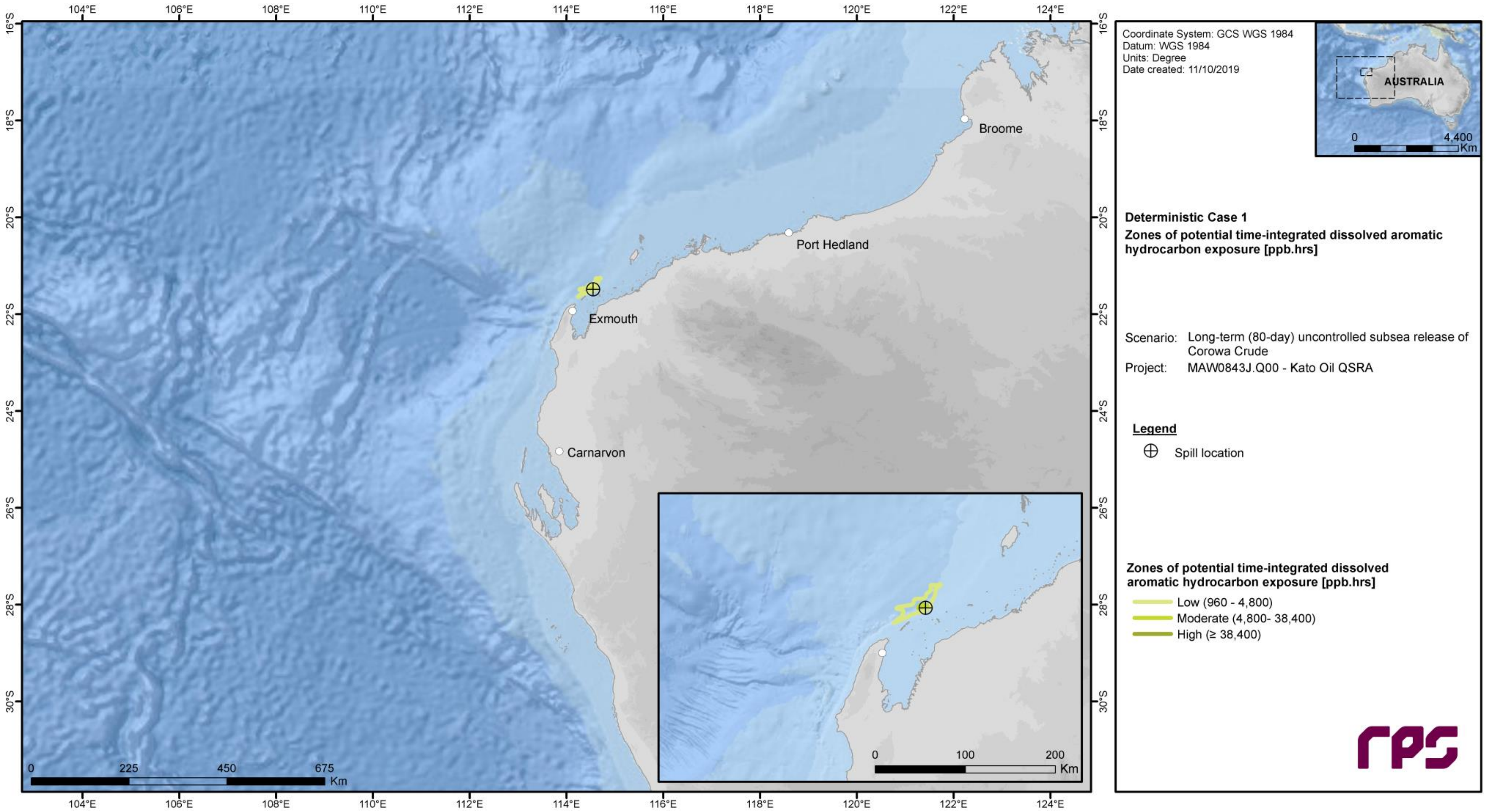


Figure 3.6 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, for the deterministic case with the <u>largest oil volume loading on shorelines</u> (summer, run 25).

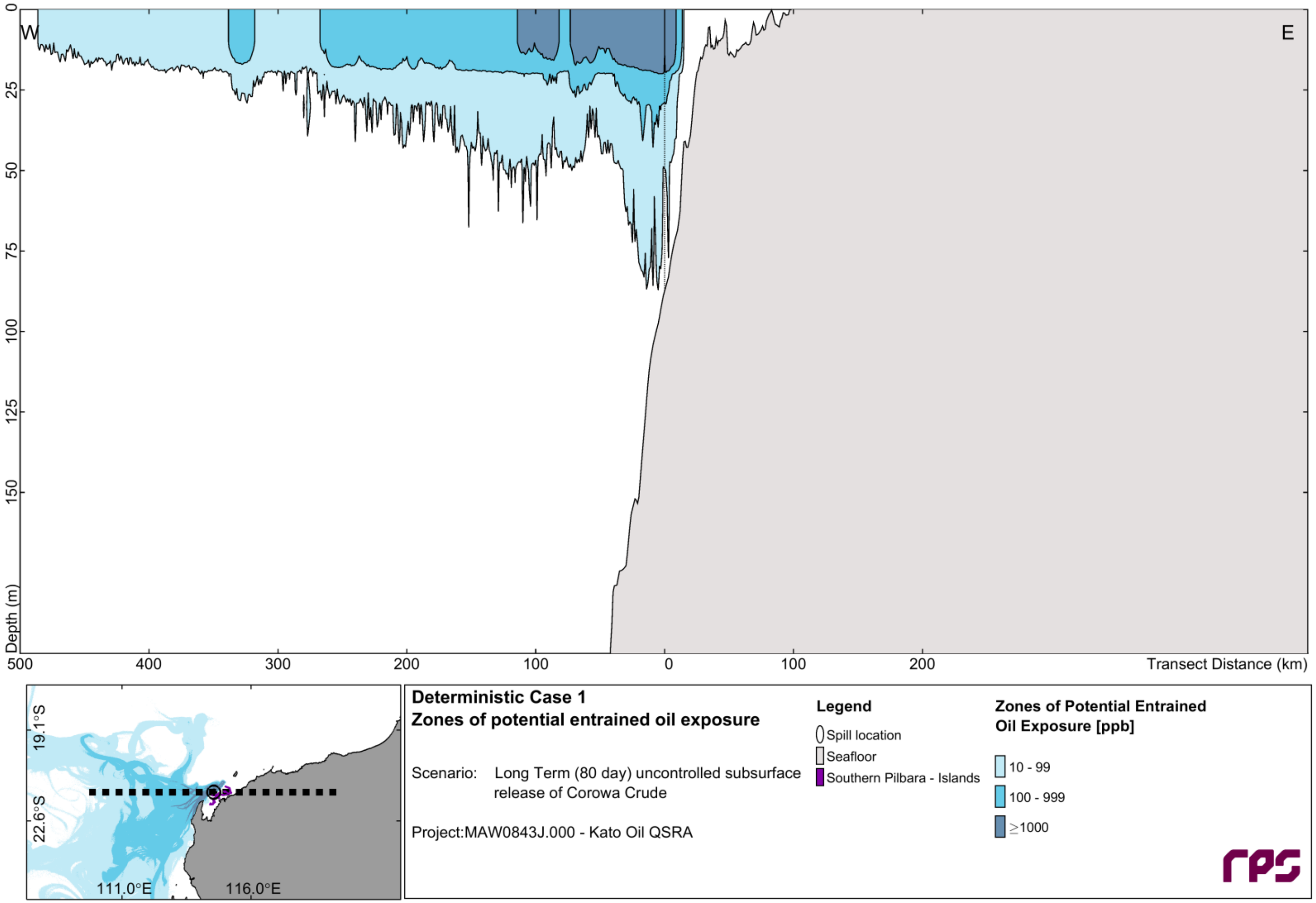


Figure 3.7 **East-West cross-section transect of predicted maximum entrained oil concentrations from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 25). The figure shows the maximum concentration calculated for each location over the duration of the simulation.**

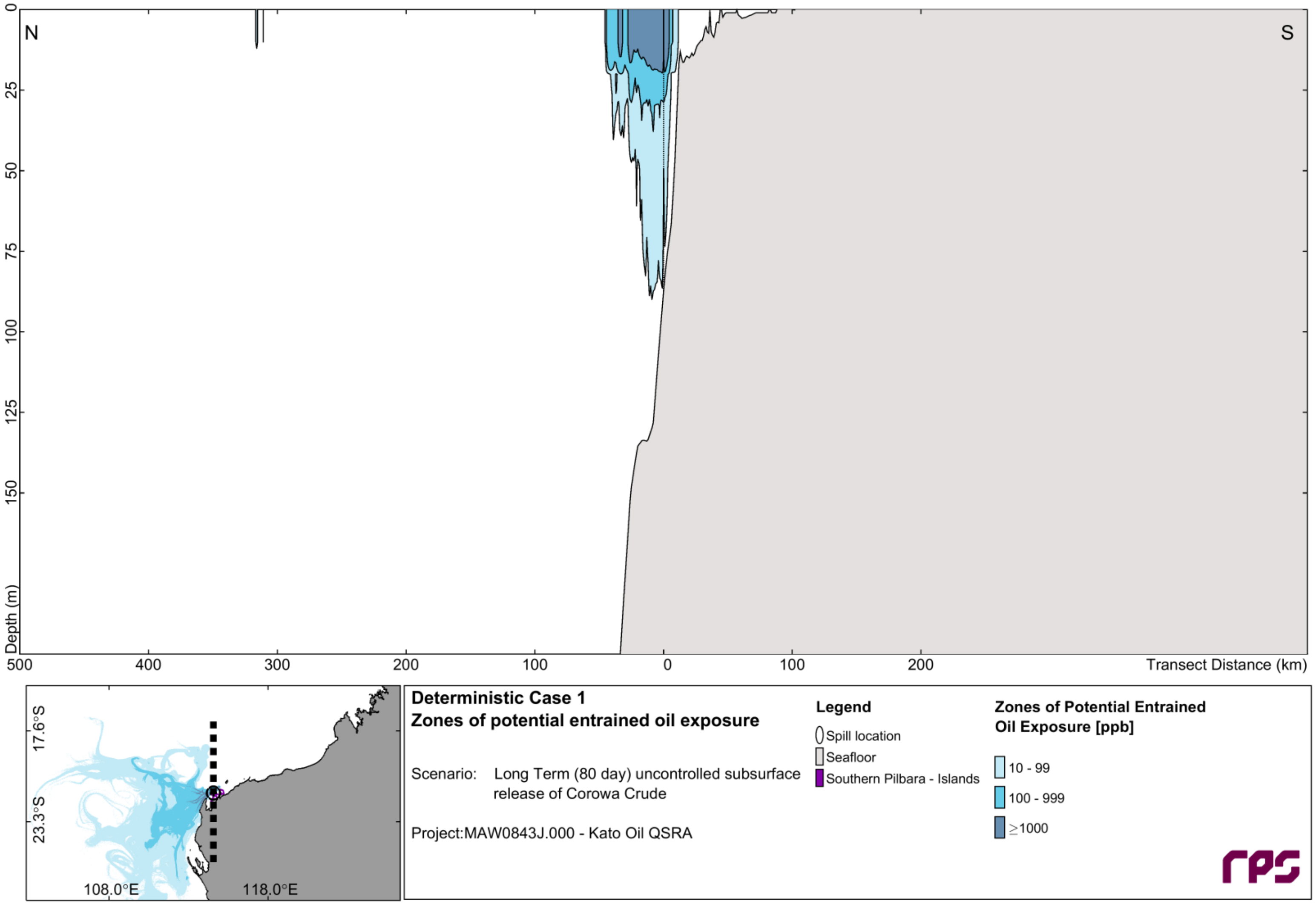


Figure 3.8 North-South cross-section transect of predicted maximum entrained oil concentrations from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 25). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

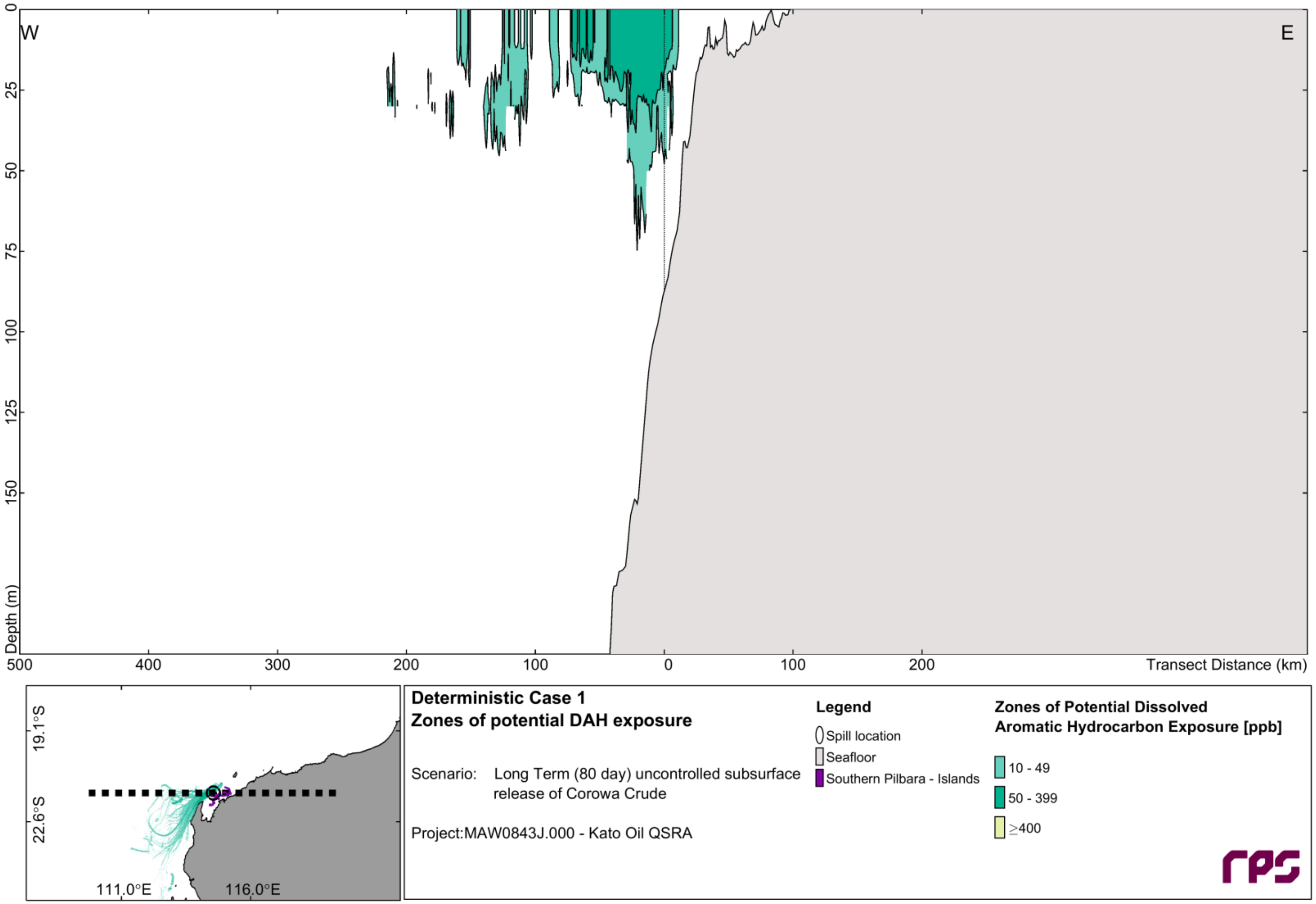


Figure 3.9 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, for the deterministic case with the <u>largest oil volume loading on shorelines</u> (summer, run 25). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

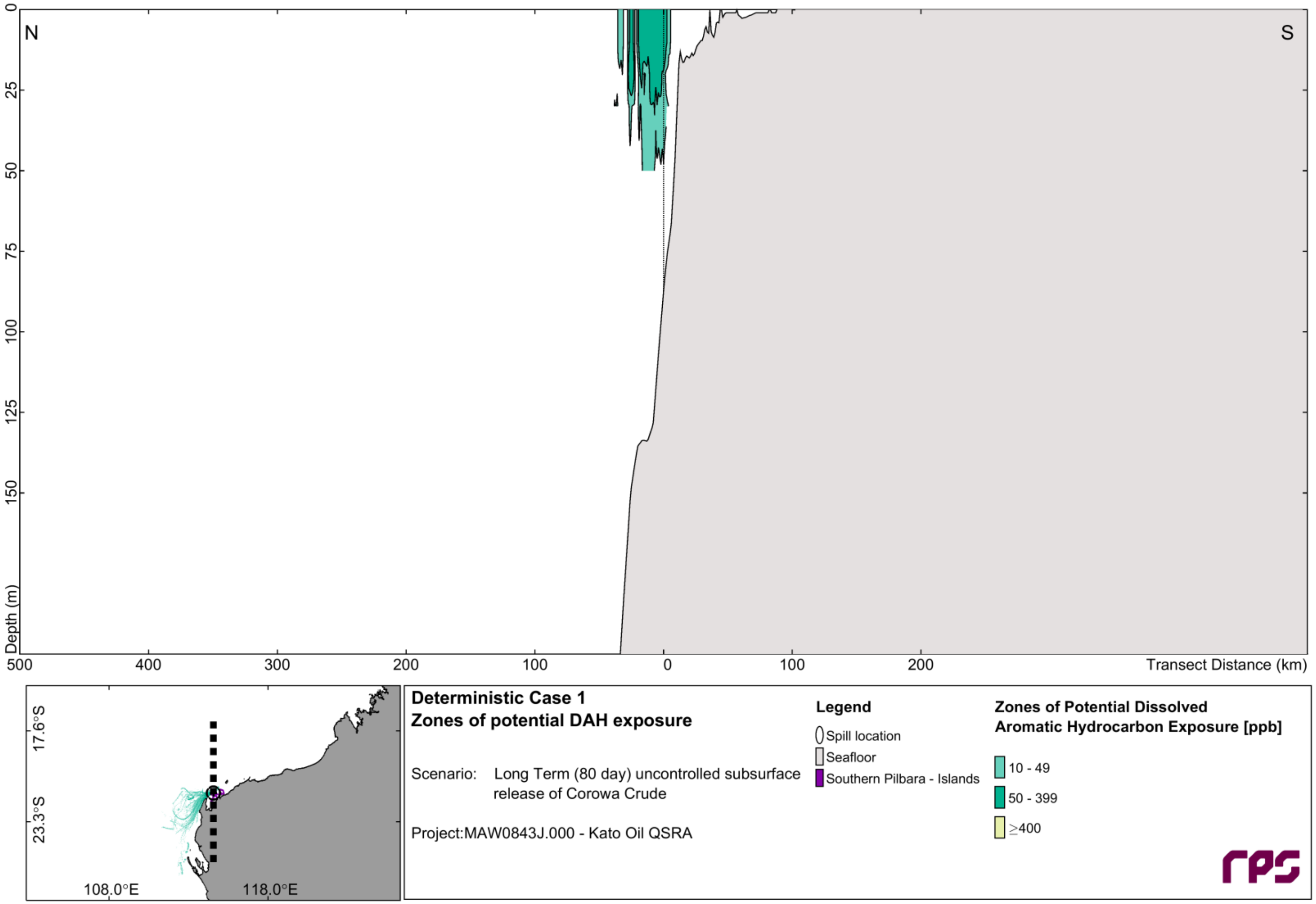


Figure 3.10 North-South cross-section transect of predicted dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 25). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

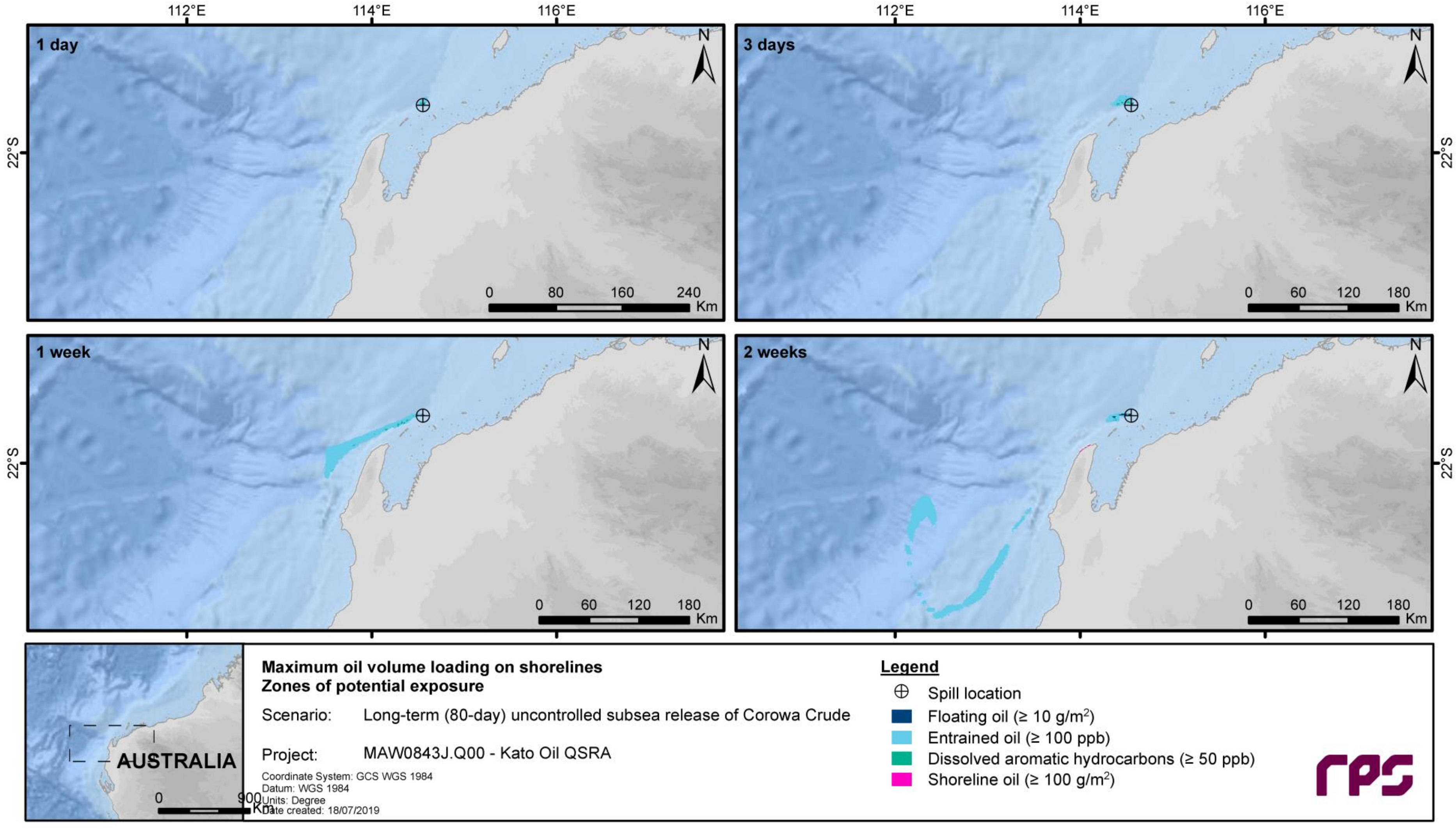


Figure 3.11 Time varying areal extent of predicted zones of potential exposure for floating oil (≥ 10 g/m^2) entrained oil (≥ 100 ppb), dissolved aromatic hydrocarbons (≥ 50 ppb) and shoreline oil (≥ 100 g/m^2) resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 25).

3.2.3 Stochastic Assessment Results

3.2.3.1 Discussion of Results

3.2.3.1.1 Floating and Shoreline Oil

Floating oil concentrations at the low threshold (1 g/m^2) could travel up to 1,167 km from the release location, with distances reducing at the moderate (10 g/m^2; 476 km) and high (25 g/m^2; 393 km) thresholds across all seasons (Table 3.2).

The seasonal zones of potential exposure at the assessed contact thresholds are depicted in Figure 3.12 (summer), Figure 3.22 (winter) and Figure 3.32 (transitional) for floating oil and Figure 3.13 (summer), Figure 3.23 (winter) and Figure 3.33 (transitional) for shoreline oil.

Table 3.2 Maximum distances from the release location to zones of floating oil exposure.

	Floating oil exposure thresholds		
	Low 1 g/m^2	Moderate 10 g/m^2	High 25 g/m^2
Maximum distance travelled (km) by a spill trajectory across all seasons	1,167	476	393

The highest probabilities of floating oil contact at the moderate threshold (10 g/m^2) is forecast at Murion Islands Marine Management Area (MMA; summer; 32%, winter; 40%, and transitional months; 30%). Floating oil at the moderate threshold is predicted to arrive at Murion Islands MMA within 33 hours after a spill commencement in winter (Table 3.10).

Floating oil concentrations at the high exposure threshold (25 g/m^2) might pass over several submerged receptors (Table 3.5, Table 3.10 and Table 3.15). The highest probabilities were forecast for the Marine Turtle Biologically Important Area (BIA), Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and Western Skipjack Fishery at 100% across all seasons.

The worst-case oil accumulation on a shoreline is predicted for the Ningaloo Marine Park (MP; State) and Ningaloo Coast WH receptors in summer, with an accumulated concentration and volume of 19.3 kg/m^3 and 1,092 m^3, respectively (Table 3.5).

The worst-case maximum length of shoreline with concentrations exceeding the moderate threshold (100 g/m^2) was calculated as 68 km at the Ningaloo MP (State) and Ningaloo Coast WH in summer (Table 3.5).

3.2.3.1.2 Entrained Oil - Instantaneous

Entrained oil concentrations at the low threshold (10 ppb) could travel up to 1,680 km from the release location in transitional months, with the distances reducing at the moderate (100 ppb; 1,173 km) and high (1,000 ppb; 610 km) thresholds (Table 3.3).

The seasonal zones of potential instantaneous entrained oil exposure at the assessed contact thresholds are depicted in Figure 3.14 (summer), Figure 3.24 (winter) and Figure 3.34 (transitional).

Table 3.3 Maximum distances from the release location to zones of entrained oil exposure.

	Entrained oil exposure thresholds		
	Low 10 ppb	Moderate 100 ppb	High 1,000 ppb
Maximum distance travelled (km) by a spill trajectory across all seasons	1,680	1,173	610

The probability of contact by entrained oil concentrations at the moderate threshold (100 ppb) is predicted to be greatest at Ningaloo Coast WH, Ningaloo MP and Gascoyne MP with a probability of 100% across all seasons (Table 3.6, Table 3.11 and Table 3.16). Entrained oil at the moderate threshold is predicted to arrive at these receptors within 29 hours after the release commences.

The worst-case instantaneous entrained oil concentration at any receptor is predicted at BIAs for Marine Turtles, Seabirds, Sharks and Whales, and at the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack fisheries as 50,458 ppb in summer (Table 3.6).

The cross-sectional transects (summer; Figure 3.15 and Figure 3.16, winter; Figure 3.25 and Figure 3.26, transitional months; Figure 3.35 and Figure 3.36) of maximum entrained oil concentrations in the vicinity of the release site show that concentrations above the moderate (100 ppb) and high (1,000 ppb) thresholds are not expected to exceed depths of around 40 m and 30 m BMSL, respectively, in any season. Therefore, limiting benthic interaction below this depth.

3.2.3.1.3 Entrained Oil – Exposure

Time-integrated entrained oil exposure at or above the 960 ppb.h threshold could travel up to 1,195 km from the release location in transitional months, with the distance reducing to 1,173 km and 356 km as contact thresholds increase to 9,600 ppb.h and 96,000 ppb.h, respectively.

The seasonal zones of potential time-integrated entrained oil exposure at the assessed contact thresholds are depicted in Figure 3.17 (summer), Figure 3.27 (winter) and Figure 3.37 (transitional).

Entrained oil exposure above the 96,000 ppb.h threshold was predicted to be greatest at the Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA as well as several other receptors with 100% probability in the surface layer (0-10 m) across all seasons (Table 3.7, Table 3.12 and Table 3.17).

The worst-case maximum entrained oil integrated exposure is predicted at the Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery as 2,139,096 ppb.h in summer (Table 3.7).

3.2.3.1.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Instantaneous dissolved aromatic hydrocarbon concentrations at the low (10 ppb) threshold could travel up to 861 km from the release location, with distances reducing at the moderate (50 ppb; 597 km) and high (400 ppb; 129 km) thresholds across all seasons (Table 3.4).

The seasonal zones of potential instantaneous dissolved aromatic hydrocarbon exposure at all assessed contact thresholds are depicted in Figure 3.18 (summer), Figure 3.28 (winter) and Figure 3.38 (transitional).

Table 3.4 Maximum distances from the release location to zones of dissolved aromatic hydrocarbon exposure.

	Dissolved aromatic hydrocarbon exposure threshold		
	Low 10 ppb	Moderate 50 ppb	High 400 ppb
Maximum distance travelled (km) by a spill trajectory across all seasons	861	597	129

The probability of contact by dissolved aromatic hydrocarbon concentrations at the moderate threshold (50 ppb) is predicted to be greatest at Ancient Coastline at 125m Depth Contour Key Ecological Feature (KEF), Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF with probabilities of 100% across all seasons (Table 3.8, Table 3.13 and Table 3.18).

The worst-case dissolved aromatic hydrocarbon concentrations at any receptor is predicted at the Ancient Coastline at 125m Depth Contour KEF, Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and Western Skipjack Fishery as 1,047 ppb in summer (Table 3.8).

The cross-sectional transects (summer; Figure 3.19 and Figure 3.20, winter; Figure 3.29 and Figure 3.30, transitional; Figure 3.39 and Figure 3.40) of maximum dissolved aromatic hydrocarbon concentrations in the vicinity of the release site show that concentrations above the high (400 ppb) threshold are not expected to exceed depths of around 80 m BMSL in any season. Therefore, limiting benthic interaction below this depth.

3.2.3.1.5 Dissolved Aromatic Hydrocarbons - Exposure

Time-integrated dissolved aromatic hydrocarbons exposure at or above 960 ppb.h could occur up to 198 km from the release site in transitional months, with the distance reducing to 102 km as the contact threshold increases to 4,800 ppb.h.

The seasonal zones of potential time-integrated dissolved aromatic hydrocarbon exposure at all assessed contact thresholds are depicted in Figure 3.21 (summer), Figure 3.31 (winter) and Figure 3.41 (transitional).

The probability of contact by dissolved aromatic hydrocarbon exposure at the 4,800 ppb.h threshold was predicted to be greatest at the Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors with probabilities of 92% (summer), 74% (winter) and 70% (transitional) in the surface layer (0-10 m; Table 3.9, Table 3.14 and Table 3.19).

The worst-case maximum dissolved aromatic hydrocarbon exposure concentration is predicted at the Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery as 19,679 ppb.h in summer (Table 3.9).

3.2.3.2 Summer

3.2.3.2.1 Floating and Shoreline Oil

Table 3.5 Expected floating and shoreline oil outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in summer months.

	Receptors	Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
Islands	Abrolhos Islands	<2	<2	<2	NC	NC	NC	2	2	<2	1,807	1,884	NC	6.6	321	<1	19	<1	27	<1	4	NC	NC
	Barrow Island	2	<2	<2	756	NC	NC	10	<2	<2	778	NC	NC	3.5	93	<1	3	2	12	NC	NC	NC	NC
	Lacepede Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Lowendal Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.2	10	<1	<1	NC	NC	NC	NC	NC	NC
	Montebello Islands	<2	<2	<2	NC	NC	NC	8	<2	<2	1,053	NC	NC	1.7	32	<1	<1	<1	5	NC	NC	NC	NC
	Sandy Islet	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	64	16	4	21	209	210	82	70	22	210	210	275	549	3,522	13	65	7	24	2	9	<1	2
Coastlines	Dampier Archipelago	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Exmouth Gulf South East	<2	<2	<2	NC	NC	NC	6	<2	<2	1,459	NC	NC	2	51	<1	<1	<1	1	NC	NC	NC	NC
	Exmouth Gulf West	2	<2	<2	720	NC	NC	48	6	<2	456	794	NC	22	189	<1	8	3	9	<1	2	NC	NC
	Geraldton - Jurien Bay	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Jurien Bay - Yanchep	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.2	8.4	<1	<1	NC	NC	NC	NC	NC	NC
	Kalbarri - Geraldton	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Karratha-Port Hedland	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Kimberley Coast	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.2	7.7	<1	<1	NC	NC	NC	NC	NC	NC
	North Broome Coast	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Perth Northern Coast	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Shoreline	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
State Marine and National Parks	Barrow Island MMA	2	<2	<2	756	NC	NC	8	<2	<2	1,125	NC	NC	3.5	93	<1	2	<1	5	NC	NC	NC	NC
	Barrow Islands MP	2	<2	<2	749	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NA	NA	NA	NA	NA	NA
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	<0.1	3.6	<1	<1	NC	NC	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.2	9.2	<1	<1	NC	NC	NC	NC	NC	NC
	Marmion MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

	Receptors	Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
	Montebello Islands MP*	2	<2	<2	530	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Muiron Islands MMA	100	32	8	23	66	67	84	62	16	71	78	315	403	3,664	29	152	8	13	5	12	<1	5
	Ningaloo Coast WH	100	26	10	38	63	179	100	86	34	83	99	220	1,001	19,288	184	1,092	44	119	22	68	4	21
	Ningaloo MP (State)	94	16	4	61	150	179	100	86	34	83	99	220	1,001	19,288	184	1,092	44	119	22	68	4	21
	Shark Bay MR	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Shark Bay WH	<2	<2	<2	NC	NC	NC	2	<2	<2	772	NC	NC	0.4	22	<1	<1	<1	2	NC	NC	NC	NC
Australian Marine Parks	Abrolhos MP*	6	<2	<2	921	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Argo-Rowley Terrace MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carnarvon Canyon MP*	18	<2	<2	664	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Cartier Island MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Dampier MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Eighty Mile Beach MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Gascoyne MP*	88	16	4	52	110	260	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jurien Bay MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jurien MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Kimberley MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Reef MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Montebello MP*	4	<2	<2	256	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ningaloo MP*	100	26	10	38	63	184	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Perth Canyon MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Shark Bay MP*	10	2	<2	560	2,066	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Two Rocks MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF*	100	90	42	8	14	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ancient Coastline at 90-120m Depth Contour KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF*†	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Canyons linking the Argo Abyssal Plain	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Receptors		Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
	with the Scott Plateau KEF*																						
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF*	100	56	20	9	35	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Continental Slope Demersal Fish Communities KEF*	94	16	4	31	138	259	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Exmouth Plateau KEF*	30	4	<2	136	392	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Glomar Shoals KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF*†	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF*†	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wallaby Saddle KEF*	4	<2	<2	921	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Demersal Slope and associated Fish Communities KEF*	10	<2	<2	1,313	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Rock Lobster KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Biologically Important Areas	Dolphins BIA*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dugong BIA*	92	16	6	61	76	179	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marine Turtle BIA*†	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seabirds BIA*†	100	10	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seals BIA*†	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sharks BIA*	100	100	10	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Whales BIA*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	North-West Slope Trawl Fishery*	92	20	8	31	156	242	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Southern Bluefin Tuna Fishery*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Receptors		Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
	Western Skipjack Fishery*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Tuna and Billfish Fishery*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Rankin Bank*	2	<2	<2	638	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Scott Reef North*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Scott Reef South*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seringapatam Reef*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Woodbine Bank*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NC: No contact to receptor predicted for specified threshold.

* Floating oil will not accumulate on submerged features and at open ocean locations. NA: Not applicable.

† Receptor is considered as submerged, any accumulation occurring on emerged features within this receptor is captured under the associated shoreline receptor in the table.

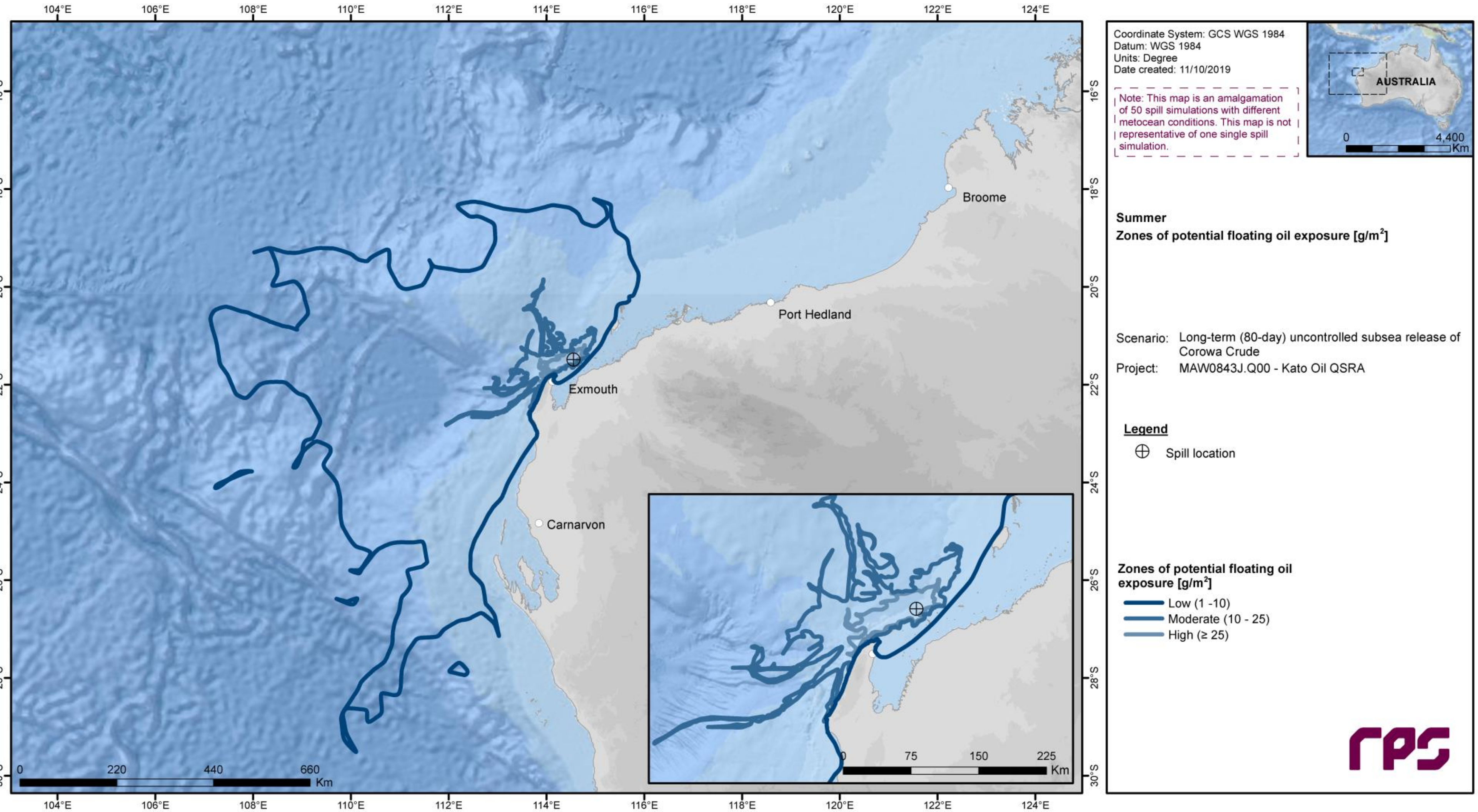


Figure 3.12 Predicted zones of potential floating oil exposure resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in summer.

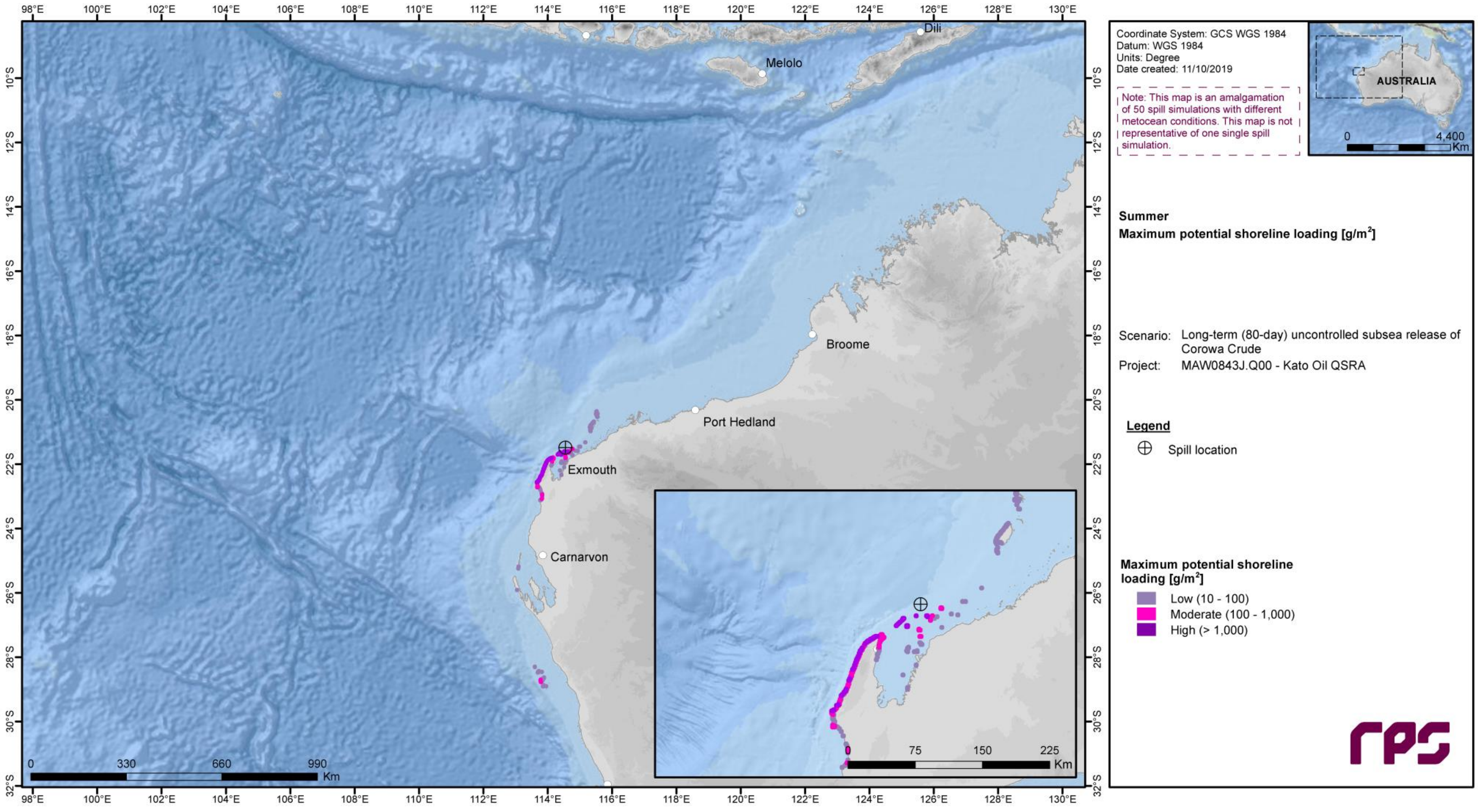


Figure 3.13 Predicted maximum potential shoreline loading resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in summer.

3.2.3.2.2 Entrained Oil - Instantaneous

Table 3.6 Expected instantaneous entrained oil outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in summer months.

Receptors		Probability (%) of entrained hydrocarbon concentration contact			Minimum time to receptor waters (hours) at			Maximum entrained hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Abrolhos Islands	6	2	<2	1,371	1,872	NC	9	350
	Barrow Island	44	22	8	329	414	760	121	1,567
	Lacepede Islands	<2	<2	<2	NC	NC	NC	NC	NC
	Lowendal Islands	28	16	<2	744	818	NC	28	200
	Montebello Islands	38	16	<2	339	833	NC	65	712
	Sandy Islet	<2	<2	<2	NC	NC	NC	<1	3
	Southern Pilbara - Islands	98	90	44	22	57	168	1,071	5,995
Coastlines	Dampier Archipelago	<2	<2	<2	NC	NC	NC	<1	7
	Exmouth Gulf South East	30	<2	<2	557	NC	NC	9	75
	Exmouth Gulf West	92	34	<2	107	403	NC	102	560
	Geraldton - Jurien Bay	4	<2	<2	1,455	NC	NC	<1	19
	Jurien Bay - Yanchep	6	<2	<2	1,459	NC	NC	2	80
	Kalbarri - Geraldton	<2	<2	<2	NC	NC	NC	<1	2
	Karratha-Port Hedland	<2	<2	<2	NC	NC	NC	<1	3
	Kimberley Coast	<2	<2	<2	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	14	<2	<2	755	NC	NC	3	31
	North Broome Coast	<2	<2	<2	NC	NC	NC	NC	NC
	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<1	3
	Perth Northern Coast	2	<2	<2	1,866	NC	NC	2	65
	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC	NC	<1	4
	Southern Pilbara - Shoreline	40	2	<2	405	982	NC	14	122
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC	NC	<1	5
State Marine and National Parks	Barrow Island MMA	48	26	8	329	415	743	126	1,567
	Barrow Islands MP	42	16	2	467	714	815	89	1,054
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	<1	6
	Imperieuse Reef (Rowley Shoals MP)	2	<2	<2	1,550	NC	NC	<1	21
	Marmion MP	<2	<2	<2	NC	NC	NC	<1	10
	Montebello Islands MP	40	18	4	323	337	833	103	1,205
	Muiron Islands MMA	100	100	96	23	29	66	2,782	8,569
	Ningaloo Coast WH	100	100	98	34	43	56	2,929	12,988
	Ningaloo MP (State)	100	100	96	49	59	60	2,687	11,253
	Shark Bay MR	2	<2	<2	1,487	NC	NC	<1	11
	Shark Bay WH	16	<2	<2	678	NC	NC	5	57
Australian Marine Parks	Abrolhos MP	68	20	<2	517	633	NC	43	381
	Argo-Rowley Terrace MP	34	<2	<2	849	NC	NC	9	71
	Carnarvon Canyon MP	92	46	4	333	399	672	153	1,109
	Cartier Island MP	<2	<2	<2	NC	NC	NC	NC	NC
	Dampier MP	2	<2	<2	1,639	NC	NC	<1	12
	Eighty Mile Beach MP	<2	<2	<2	NC	NC	NC	<1	4
	Gascoyne MP	100	100	88	44	49	71	1,897	9,362
	Jurien Bay MP	6	<2	<2	1,430	NC	NC	2	80
	Jurien MP	6	2	<2	1,361	2,006	NC	4	108
	Kimberley MP	2	<2	<2	1,626	NC	NC	<1	24
	Mermaid Reef MP	<2	<2	<2	NC	NC	NC	<1	3
	Montebello MP	50	30	8	151	171	335	155	1,595
	Ningaloo MP	100	100	98	34	43	56	2,929	12,988
	Perth Canyon MP	6	2	<2	1,688	2,251	NC	5	102
	Shark Bay MP	82	42	<2	344	469	NC	82	924
	Two Rocks MP	4	<2	<2	1,837	NC	NC	2	58

Receptors		Probability (%) of entrained hydrocarbon concentration contact			Minimum time to receptor waters (hours) at			Maximum entrained hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	100	100	100	7	7	8	10,649	23,958
	Ancient Coastline at 90-120m Depth Contour KEF	6	2	<2	1,316	1,738	NC	6	245
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	<2	<2	<2	NC	NC	NC	NC	NC
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	2	<2	<2	1,275	NC	NC	<1	12
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	100	100	100	10	10	11	6,843	19,199
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	10	2	<2	727	1,840	NC	8	296
	Continental Slope Demersal Fish Communities KEF	100	100	100	22	23	24	3,382	9,362
	Exmouth Plateau KEF	100	90	22	112	114	137	604	3,647
	Glomar Shoals KEF §	4	<2	<2	379	527	NC	21	31
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	2	<2	<2	1,520	NC	NC	<1	21
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	18	4	<2	549	1,472	NC	8	125
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	<2	<2	<2	NC	NC	NC	<1	6
	Wallaby Saddle KEF	64	14	<2	529	642	NC	37	269
	Western Demersal Slope and associated Fish Communities KEF	66	22	<2	436	718	NC	54	459
	Western Rock Lobster KEF	8	2	<2	788	1,730	NC	7	254
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC	NC	NC	NC
	Dugong BIA	100	100	96	54	59	60	2,687	11,253
	Marine Turtle BIA	100	100	102	1	1	2	24,069	50,458
	Seabirds BIA	100	100	102	1	1	2	24,069	50,458
	Seals BIA	8	2	<2	802	1,860	NC	9	350
	Sharks BIA	100	100	100	1	1	2	24,069	50,458
	Whales BIA	100	100	100	1	1	2	24,069	50,458
Fisheries	North-West Slope Trawl Fishery	100	100	100	22	23	24	3,382	9,053
	Southern Bluefin Tuna Fishery	100	100	100	1	1	2	24,069	50,458
	Western Skipjack Fishery	100	100	100	1	1	2	24,069	50,458
	Western Tuna and Billfish Fishery	100	100	100	1	1	2	24,069	50,458
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal §	<2	<2	<2	NC	NC	NC	<1	<1
	Rankin Bank §	16	<2	<2	364	470	NC	17	30
	Scott Reef North	<2	<2	<2	NC	NC	NC	<1	6
	Scott Reef South	<2	<2	<2	NC	NC	NC	<1	6
	Seringapatam Reef	<2	<2	<2	NC	NC	NC	<1	5
	Woodbine Bank	<2	<2	<2	NC	NC	NC	NC	NC

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

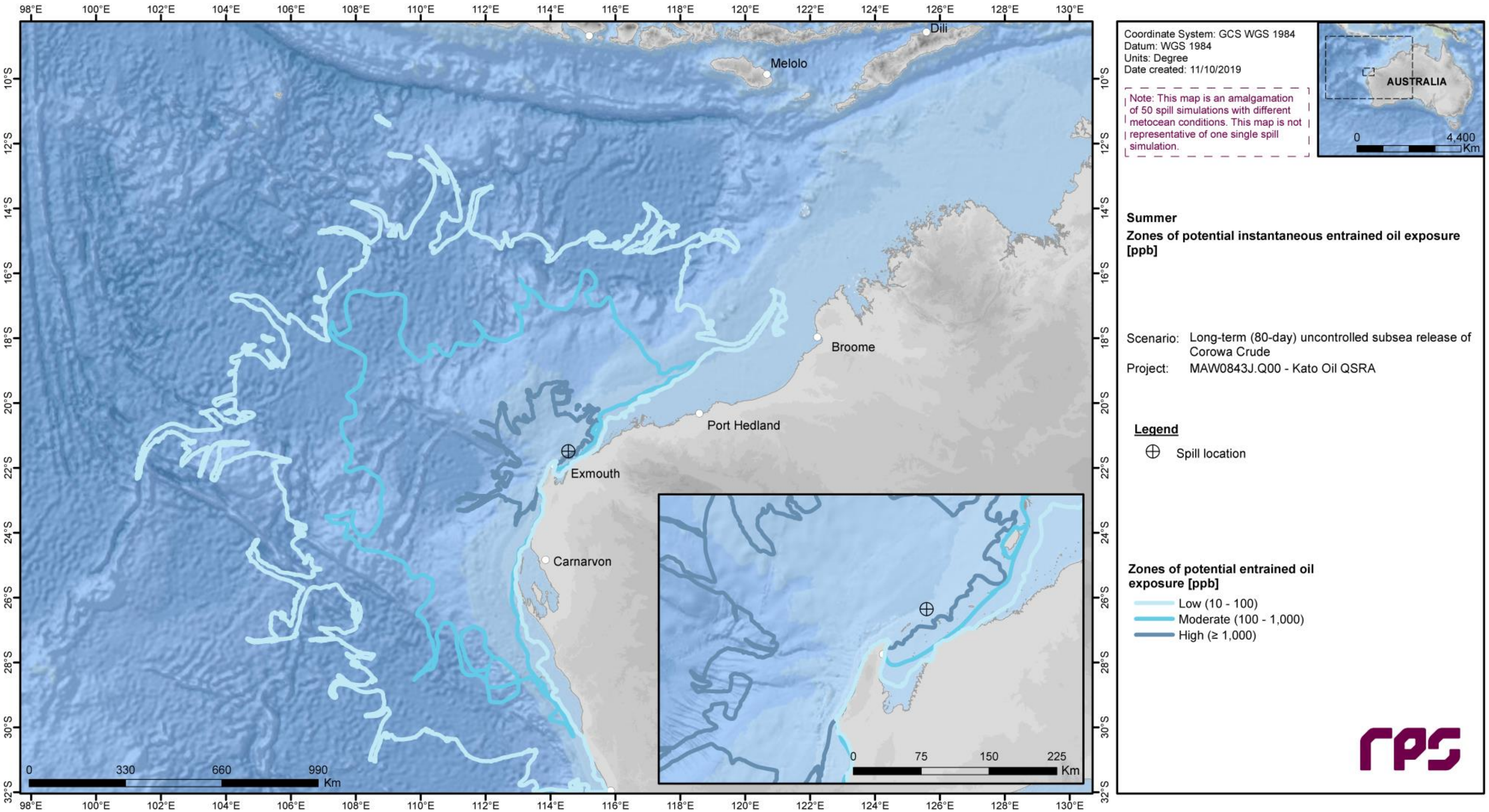


Figure 3.14 Predicted zones of potential entrained oil exposure resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in summer months.

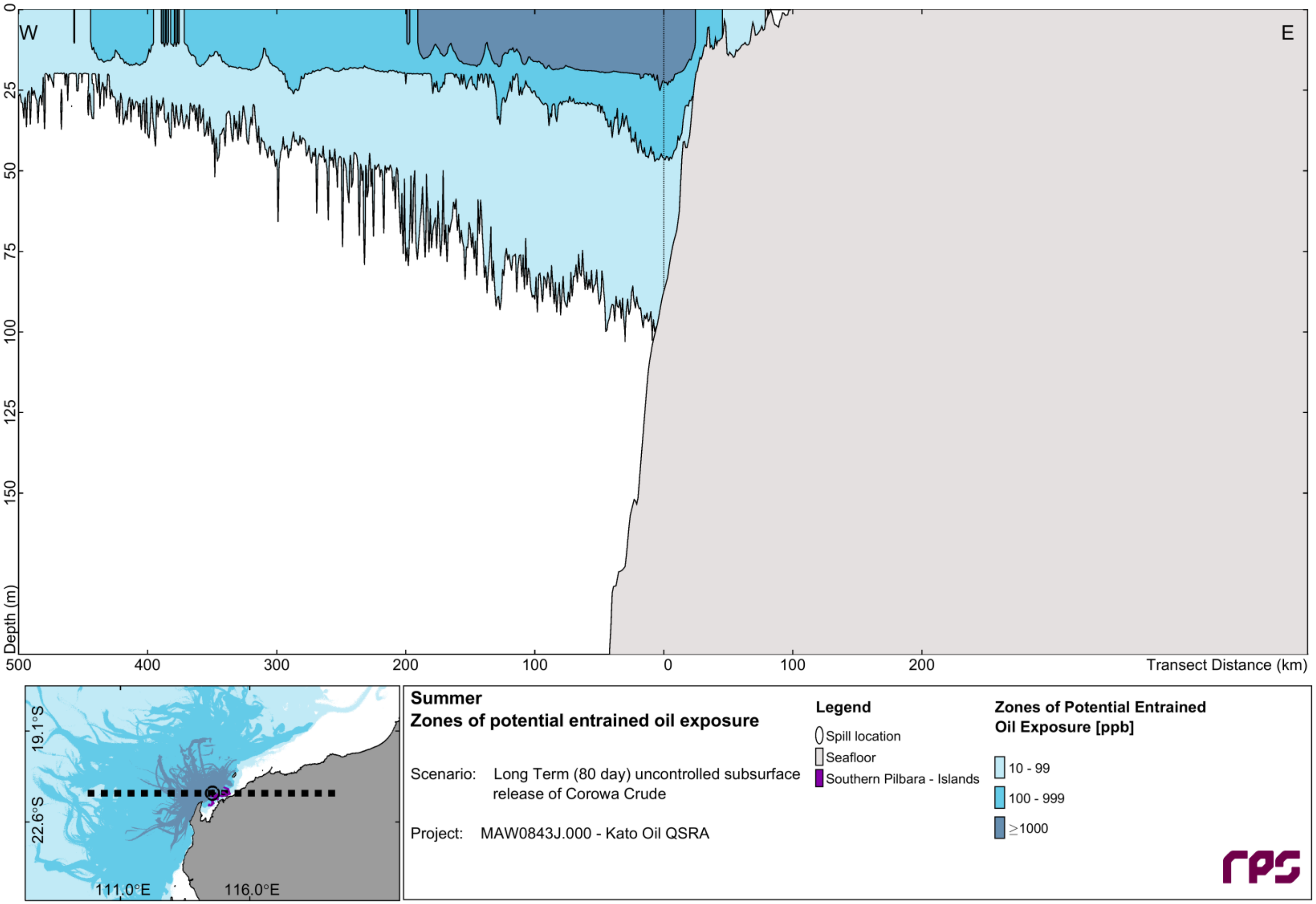


Figure 3.15 East-West cross-section transect of predicted maximum entrained oil concentration resulting from a long-term (80-day) subsea release of Corowa Crude within the Corowa field, commencing in the summer season. The results were calculated from 50 spill trajectories.

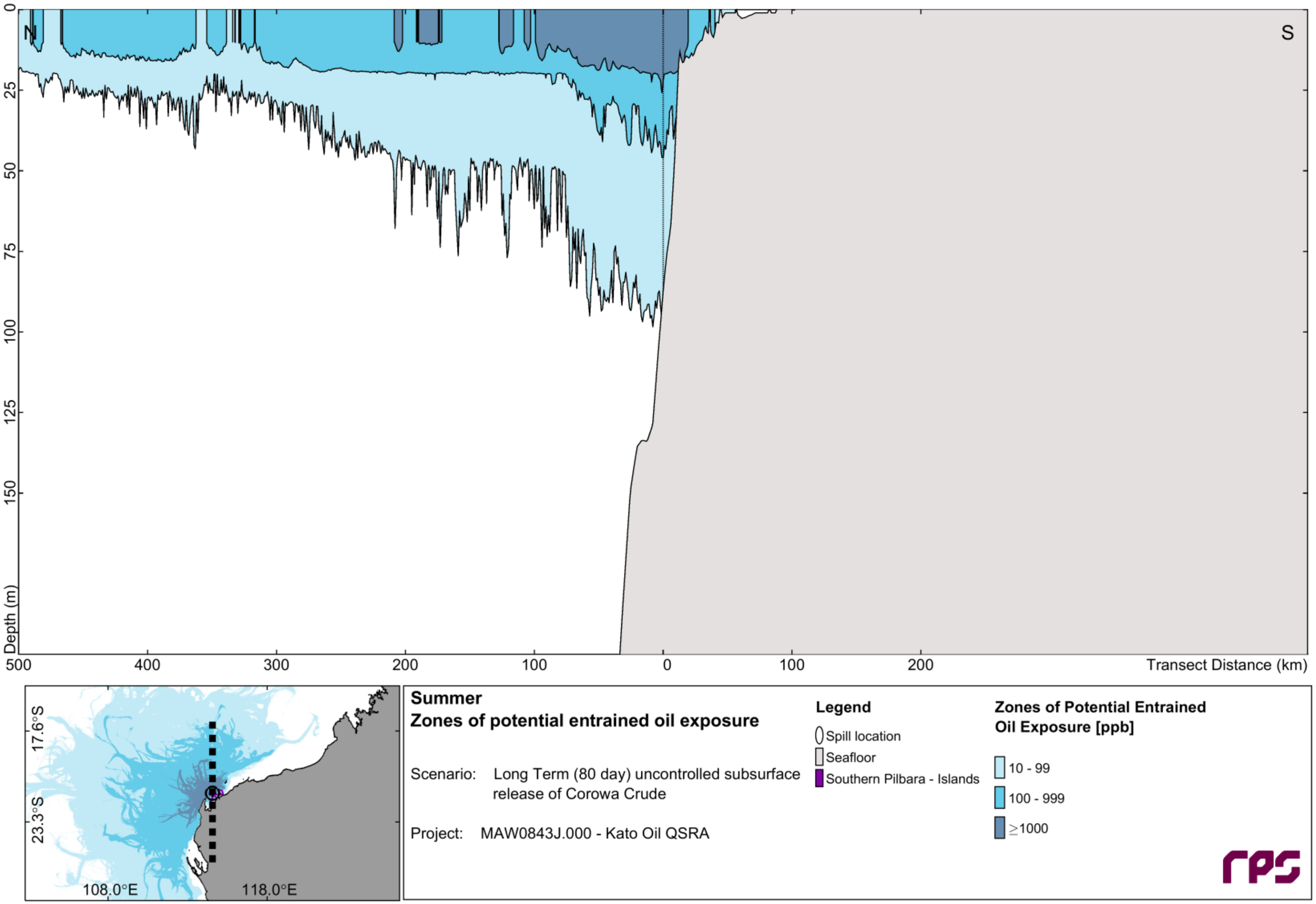


Figure 3.16 North-South cross-section transect of predicted maximum entrained oil concentration resulting from a long-term (80-day) subsea release of Corowa Crude within the Corowa field, commencing in the summer season. <u>The results were calculated from 50 spill trajectories.</u>

3.2.3.2.3 Entrained Oil - Exposure

Table 3.7 Expected entrained oil exposure outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in summer months.

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	Abrolhos Islands	Probability (%) >960	4	NC	NC	NC	NC	BS
		Probability (%) >9,600	2	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	17,719	403	128	56	11	BS
	Barrow Island	Probability (%) >960	34	8	6	NC	BS	BS
		Probability (%) >9,600	14	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	63,304	7,762	1,667	426	BS	BS
	Lacepede Islands	Probability (%) >960	NC	BS	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	BS	BS	BS	BS	BS
	Lowendal Islands	Probability (%) >960	26	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	8,366	94	12	BS	BS	BS
	Montebello Islands	Probability (%) >960	30	8	NC	NC	BS	BS
		Probability (%) >9,600	4	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	12,283	1,956	563	27	BS	BS
	Sandy Islet	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	18	1	NC	NC	NC	NC
	Southern Pilbara - Islands	Probability (%) >960	86	46	14	BS	BS	BS
		Probability (%) >9,600	56	4	NC	BS	BS	BS
		Probability (%) >96,000	4	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	204,748	19,857	2,453	BS	BS	BS
Coastlines	Dampier Archipelago	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	126	13	6	NC	BS	BS
	Exmouth Gulf South East	Probability (%) >960	4	BS	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS	BS

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Probability (%) >96,000	NC	BS	BS	BS	BS	BS
	Maximum Integrated Exposure	1,107	BS	BS	BS	BS	BS
Exmouth Gulf West	Probability (%) >960	76	NC	BS	BS	BS	BS
	Probability (%) >9,600	16	NC	BS	BS	BS	BS
	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	21,438	749	BS	BS	BS	BS
Geraldton - Jurien Bay	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	732	53	18	5	BS	BS
Jurien Bay - Yanchep	Probability (%) >960	2	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	3,702	146	36	6	BS	BS
Kalbarri - Geraldton	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	14	9	2	NC	BS	BS
Karratha-Port Hedland	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >9,600	NC	NC	BS	BS	BS	BS
	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	34	3	BS	BS	BS	BS
Kimberley Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >9,600	NC	NC	NC	NC	NC	BS
	Probability (%) >96,000	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Middle Pilbara - Islands and Shoreline	Probability (%) >960	2	NC	BS	BS	BS	BS
	Probability (%) >9,600	NC	NC	BS	BS	BS	BS
	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	1,023	49	BS	BS	BS	BS
North Broome Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >9,600	NC	NC	NC	NC	NC	BS
	Probability (%) >96,000	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Northern Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >9,600	NC	NC	BS	BS	BS	BS
	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	15	1	BS	BS	BS	BS

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Perth Northern Coast	Probability (%) >960	2	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	3,861	300	61	NC	BS	BS
	Port Hedland - Eighty Mile Beach	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	32	1	BS	BS	BS	BS
	Southern Pilbara - Shoreline	Probability (%) >960	20	BS	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	5,988	BS	BS	BS	BS	BS
	Zuytdorp Cliffs - Kalbarri	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	37	18	9	3	NC	BS
State Marine and National Parks	Barrow Island MMA	Probability (%) >960	36	8	6	NC	BS	BS
		Probability (%) >9,600	14	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	69,553	7,367	1,979	476	BS	BS
	Barrow Islands MP	Probability (%) >960	34	8	6	NC	BS	BS
		Probability (%) >9,600	14	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	57,602	7,973	1,819	319	BS	BS
	Clerke Reef (Rowley Shoals MP)	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	86	9	1	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	807	28	7	2	NC	NC
	Marmion MP	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	479	30	7	BS	BS	BS

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Montebello Islands MP	Probability (%) >960	32	8	NC	NC	BS	BS
		Probability (%) >9,600	8	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	41,074	2,774	732	80	BS	BS
	Muiron Islands MMA	Probability (%) >960	100	88	42	2	NC	BS
		Probability (%) >9,600	96	12	NC	NC	NC	BS
		Probability (%) >96,000	12	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	198,746	29,100	3,576	1,031	98	BS
	Ningaloo Coast WH	Probability (%) >960	100	98	92	8	NC	NC
		Probability (%) >9,600	98	36	4	NC	NC	NC
		Probability (%) >96,000	40	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	693,725	44,425	12,110	1,838	196	14
	Ningaloo MP (State)	Probability (%) >960	100	98	92	8	NC	NC
		Probability (%) >9,600	94	36	4	NC	NC	NC
		Probability (%) >96,000	40	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	693,725	44,425	12,110	1,838	196	11
	Shark Bay MR	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	225	60	BS	BS	BS	BS
	Shark Bay WH	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	920	119	80	51	18	BS
Australian Marine Parks	Abrolhos MP	Probability (%) >960	42	NC	NC	NC	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	14,515	824	232	73	47	11
	Argo-Rowley Terrace MP	Probability (%) >960	8	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,181	220	80	31	6	2
	Carnarvon Canyon MP	Probability (%) >960	60	8	NC	NC	NC	NC
		Probability (%) >9,600	16	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Maximum Integrated Exposure	18,175	1,670	387	99	19	8
Cartier Island MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Dampier MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	212	15	10	NC	BS	BS
Eighty Mile Beach MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	32	3	NC	NC	BS	BS
Gascoyne MP	Probability (%) >960	100	94	22	4	NC	NC
	Probability (%) >9,600	98	4	NC	NC	NC	NC
	Probability (%) >96,000	6	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	178,423	24,139	7,783	1,567	153	47
Jurien Bay MP	Probability (%) >960	2	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	3,704	166	36	4	BS	BS
Jurien MP	Probability (%) >960	2	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	3,614	162	43	19	9	3
Kimberley MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	878	36	8	2	1	NC
Mermaid Reef MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	18	3	NC	NC	NC	NC
Montebello MP	Probability (%) >960	42	12	6	NC	NC	NC
	Probability (%) >9,600	20	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	75,285	6,848	2,003	520	48	1
	Ningaloo MP	Probability (%) >960	100	96	62	2	NC	NC
		Probability (%) >9,600	98	8	NC	NC	NC	NC
		Probability (%) >96,000	12	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	203,661	19,865	4,425	1,420	161	14
	Perth Canyon MP	Probability (%) >960	4	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	6,163	518	134	45	19	5
	Shark Bay MP	Probability (%) >960	56	6	NC	NC	NC	NC
		Probability (%) >9,600	6	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	23,485	2,449	525	248	91	26
	Two Rocks MP	Probability (%) >960	2	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	1,033	113	53	10	3	BS
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	100	100	78	2	NC	NC
		Probability (%) >9,600	100	66	NC	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	516,865	57,842	8,623	2,201	273	31
	Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	4	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,350	203	84	39	21	5
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	160	21	10	6	1	NC
		Probability (%) >960	100	100	48	2	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >9,600	100	36	NC	NC	NC	NC
	Probability (%) >96,000	80	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	396,596	36,788	6,533	1,014	194	25
Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	4	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	4,780	267	87	51	23	9
Continental Slope Demersal Fish Communities KEF	Probability (%) >960	100	100	16	4	NC	NC
	Probability (%) >9,600	100	4	NC	NC	NC	NC
	Probability (%) >96,000	8	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	224,739	24,139	7,783	1,567	82	16
Exmouth Plateau KEF	Probability (%) >960	96	50	6	NC	NC	NC
	Probability (%) >9,600	58	NC	NC	NC	NC	NC
	Probability (%) >96,000	2	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	179,906	6,880	2,170	464	92	17
Glomar Shoals KEF	Probability (%) >960	4	2	NC	NC	NC	BS
	Probability (%) >9,600	2	NC	NC	NC	NC	BS
	Probability (%) >96,000	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	29,411	2,366	490	89	11	BS
Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	807	32	7	2	NC	NC
Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	6	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	5,945	473	104	45	11	4
Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	47	10	9	3	NC	NC
Wallaby Saddle KEF	Probability (%) >960	36	NC	NC	NC	NC	NC
	Probability (%) >9,600	2	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	10,148	395	133	69	18	3

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	34	2	NC	NC	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	13,774	1,122	284	132	35	10
	Western Rock Lobster KEF	Probability (%) >960	4	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,794	211	87	51	21	9
Biologically Important Areas	Dolphins BIA	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Dugong BIA	Probability (%) >960	100	98	92	8	NC	NC
		Probability (%) >9,600	94	36	4	NC	NC	NC
		Probability (%) >96,000	40	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	693,725	44,425	12,110	1,838	196	13
	Marine Turtle BIA	Probability (%) >960	100	100	92	8	NC	NC
		Probability (%) >9,600	100	86	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2,139,096	67,340	12,110	2,867	273	31
	Seabirds BIA	Probability (%) >960	100	100	92	8	NC	NC
		Probability (%) >9,600	100	86	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2,139,096	67,340	12,110	2,867	273	31
	Seals BIA	Probability (%) >960	4	NC	NC	NC	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	17,719	403	128	56	21	2
	Sharks BIA	Probability (%) >960	100	100	82	8	NC	NC
		Probability (%) >9,600	100	86	2	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2,139,096	67,340	11,388	2,867	273	31
	Whales BIA	Probability (%) >960	100	100	92	8	NC	NC
		Probability (%) >9,600	100	86	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Maximum Integrated Exposure	2,139,096	67,340	12,110	2,867	273	47
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	100	100	16	2	NC	NC
		Probability (%) >9,600	100	4	NC	NC	NC	NC
		Probability (%) >96,000	6	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	257,261	22,747	5,189	1,099	75	17
	Southern Bluefin Tuna Fishery	Probability (%) >960	100	100	92	8	NC	NC
		Probability (%) >9,600	100	86	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2,139,096	67,340	12,110	2,867	273	47
	Western Skipjack Fishery	Probability (%) >960	100	100	92	8	NC	NC
		Probability (%) >9,600	100	86	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2,139,096	67,340	12,110	2,867	273	47
	Western Tuna and Billfish Fishery	Probability (%) >960	100	100	92	8	NC	NC
		Probability (%) >9,600	100	86	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2,139,096	67,340	12,110	2,867	273	47
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	9	1	NC	NC	BS	BS
	Rankin Bank	Probability (%) >960	14	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	5,317	560	133	BS	BS	BS
	Scott Reef North	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	47	10	5	2	NC	NC
	Scott Reef South	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	37	8	9	3	NC	NC
	Seringapatam Reef	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	25	3	1	NC	NC	NC
Woodbine Bank	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >9,600	NC	NC	NC	NC	NC	BS
	Probability (%) >96,000	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

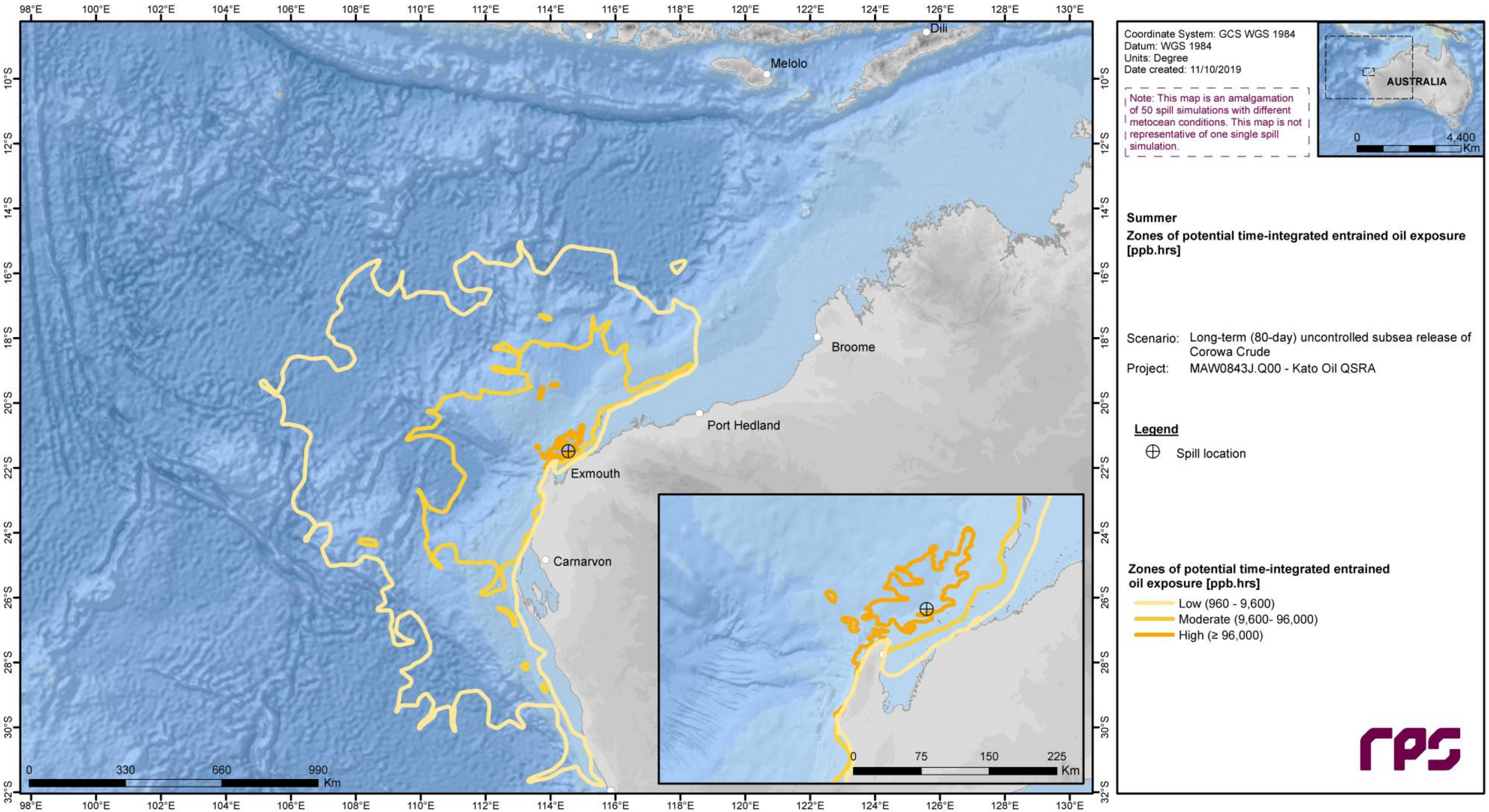


Figure 3.17 Predicted zones of potential time-integrated entrained oil exposure resulting from a long-term (80-day) subsurface release of Corowa Light Crude within the Corowa field, starting in summer months.

3.2.3.2.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Table 3.8 Expected dissolved aromatic hydrocarbons outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in summer months.

Receptors		Probability (%) of dissolved aromatic concentration			Maximum dissolved aromatic hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Abrolhos Islands	<2	<2	<2	<1	<1
Islands	Barrow Island	6	2	<2	2	65
Islands	Lacepede Islands	<2	<2	<2	NC	NC
Islands	Lowendal Islands	<2	<2	<2	<1	<1
Islands	Montebello Islands	<2	<2	<2	<1	4
Islands	Sandy Islet	<2	<2	<2	NC	NC
Islands	Southern Pilbara - Islands	74	26	<2	43	342
Coastlines	Dampier Archipelago	<2	<2	<2	NC	NC
Coastlines	Exmouth Gulf South East	<2	<2	<2	<1	2
Coastlines	Exmouth Gulf West	22	6	<2	8	146
Coastlines	Geraldton - Jurien Bay	<2	<2	<2	NC	NC
Coastlines	Jurien Bay - Yanchep	<2	<2	<2	NC	NC
Coastlines	Kalbarri - Geraldton	<2	<2	<2	NC	NC
Coastlines	Karratha-Port Hedland	<2	<2	<2	NC	NC
Coastlines	Kimberley Coast	<2	<2	<2	NC	NC
Coastlines	Middle Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC
Coastlines	North Broome Coast	<2	<2	<2	NC	NC
Coastlines	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC
Coastlines	Perth Northern Coast	<2	<2	<2	NC	NC
Coastlines	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC
Coastlines	Southern Pilbara - Shoreline	<2	<2	<2	<1	3
Coastlines	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC
State Marine and National Parks	Barrow Island MMA	6	2	<2	3	65
State Marine and National Parks	Barrow Islands MP	6	<2	<2	3	46
State Marine and National Parks	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC
State Marine and National Parks	Imperieuse Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC
State Marine and National Parks	Marmion MP	<2	<2	<2	NC	NC
State Marine and National Parks	Montebello Islands MP	<2	<2	<2	<1	5
State Marine and National Parks	Muiron Islands MMA	100	92	<2	102	359
State Marine and National Parks	Ningaloo Coast WH	100	84	2	107	499
State Marine and National Parks	Ningaloo MP (State)	100	84	2	107	480

Receptors		Probability (%) of dissolved aromatic concentration ≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	Maximum dissolved aromatic hydrocarbon concentration (ppb) averaged over all replicate simulations	at any depth, in the worst replicate
	Shark Bay MR	<2	<2	<2	<1	<1
	Shark Bay WH	2	<2	<2	<1	20
Australian Marine Parks	Abrolhos MP	2	<2	<2	<1	13
	Argo-Rowley Terrace MP	<2	<2	<2	NC	NC
	Carnarvon Canyon MP	14	2	<2	3	74
	Cartier Island MP	<2	<2	<2	NC	NC
	Dampier MP	<2	<2	<2	NC	NC
	Eighty Mile Beach MP	<2	<2	<2	NC	NC
	Gascoyne MP	100	74	2	74	485
	Jurien Bay MP	<2	<2	<2	NC	NC
	Jurien MP	<2	<2	<2	NC	NC
	Kimberley MP	<2	<2	<2	NC	NC
	Mermaid Reef MP	<2	<2	<2	NC	NC
	Montebello MP	8	6	<2	5	151
	Ningaloo MP	100	84	2	92	499
	Perth Canyon MP	<2	<2	<2	NC	NC
	Shark Bay MP	16	2	<2	5	110
	Two Rocks MP	<2	<2	<2	NC	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	100	100	16	276	1,047
	Ancient Coastline at 90-120m Depth Contour KEF	<2	<2	<2	<1	<1
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	<2	<2	<2	NC	NC
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	<2	<2	<2	NC	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	100	100	10	218	831
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	<2	<2	<2	<1	<1
	Continental Slope Demersal Fish Communities KEF	100	84	2	89	492
	Exmouth Plateau KEF	46	8	<2	15	209
	Glomar Shoals KEF §	<2	<2	<2	NC	NC
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	<2	<2	<2	NC	NC

Receptors		Probability (%) of dissolved aromatic concentration ≥ 10 ppb	Probability (%) of dissolved aromatic concentration ≥ 50 ppb	Probability (%) of dissolved aromatic concentration ≥ 400 ppb	Maximum dissolved aromatic hydrocarbon concentration (ppb) averaged over all replicate simulations	Maximum dissolved aromatic hydrocarbon concentration (ppb) at any depth, in the worst replicate
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	<2	<2	<2	<1	<1
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	<2	<2	<2	NC	NC
	Wallaby Saddle KEF	<2	<2	<2	<1	5
	Western Demersal Slope and associated Fish Communities KEF	8	2	<2	3	88
	Western Rock Lobster KEF	<2	<2	<2	<1	<1
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC
Biologically Important Areas	Dugong BIA	100	84	2	107	480
Biologically Important Areas	Marine Turtle BIA	100	100	30	347	1,047
Biologically Important Areas	Seabirds BIA	100	100	30	347	1,047
Biologically Important Areas	Seals BIA	<2	<2	<2	<1	<1
Biologically Important Areas	Sharks BIA	100	100	30	347	1,047
Biologically Important Areas	Whales BIA	100	100	30	347	1,047
Fisheries	North-West Slope Trawl Fishery	100	86	2	89	502
Fisheries	Southern Bluefin Tuna Fishery	100	100	30	347	1,047
Fisheries	Western Skipjack Fishery	100	100	30	347	1,047
Fisheries	Western Tuna and Billfish Fishery	100	100	30	347	1,047
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal §	<2	<2	<2	NC	NC
Other Submerged Reefs, Banks and Shoals	Rankin Bank §	<2	<2	<2	<1	4
Other Submerged Reefs, Banks and Shoals	Scott Reef North	<2	<2	<2	NC	NC
Other Submerged Reefs, Banks and Shoals	Scott Reef South	<2	<2	<2	NC	NC
Other Submerged Reefs, Banks and Shoals	Seringapatam Reef	<2	<2	<2	NC	NC
Other Submerged Reefs, Banks and Shoals	Woodbine Bank	<2	<2	<2	NC	NC

NC: No contact to receptor predicted for specified threshold

§ Probabilities and maximum concentrations calculated at depth of submerged feature

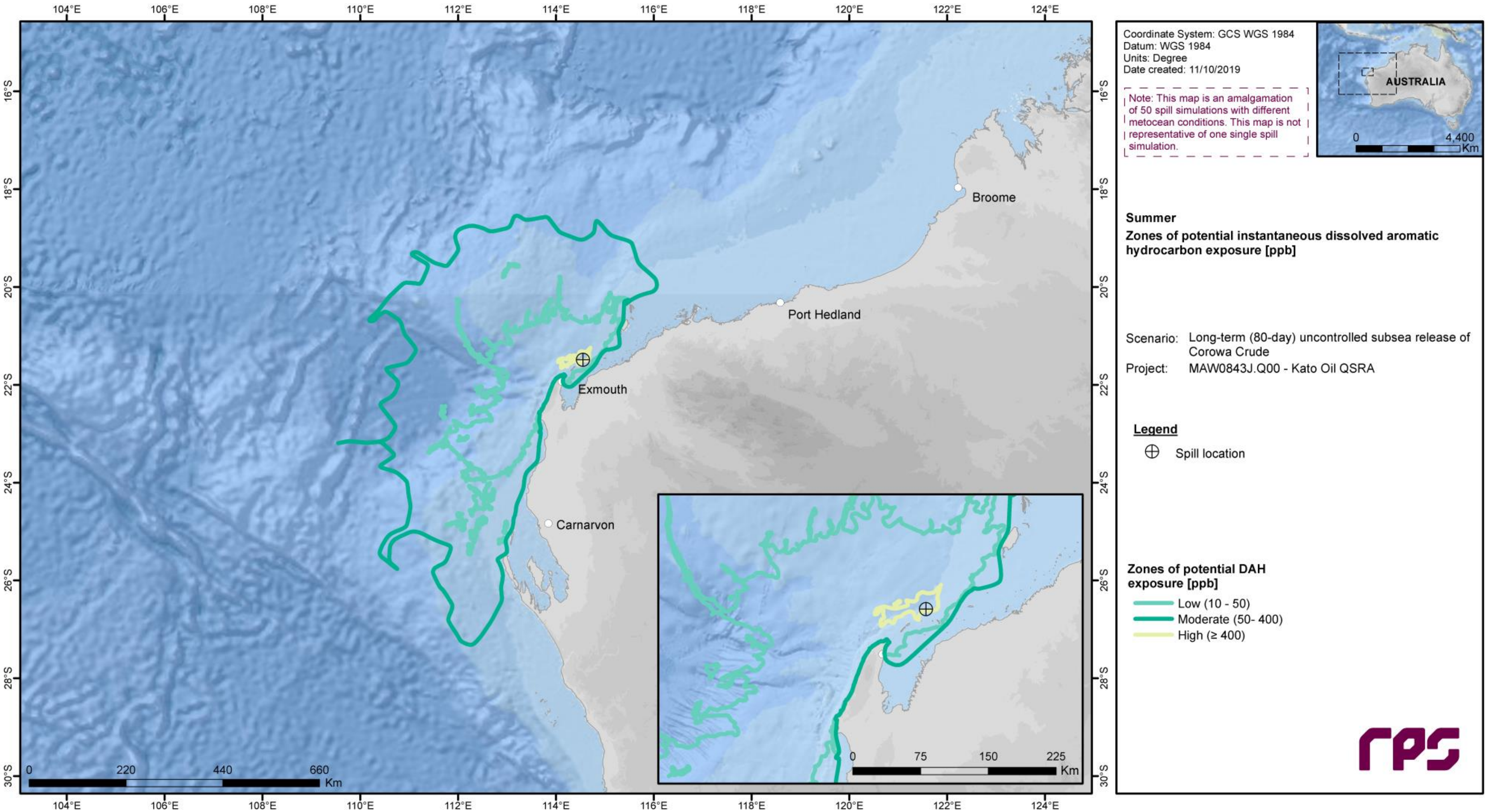


Figure 3.18 Predicted zones of potential instantaneous dissolved aromatic hydrocarbon exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in summer months.

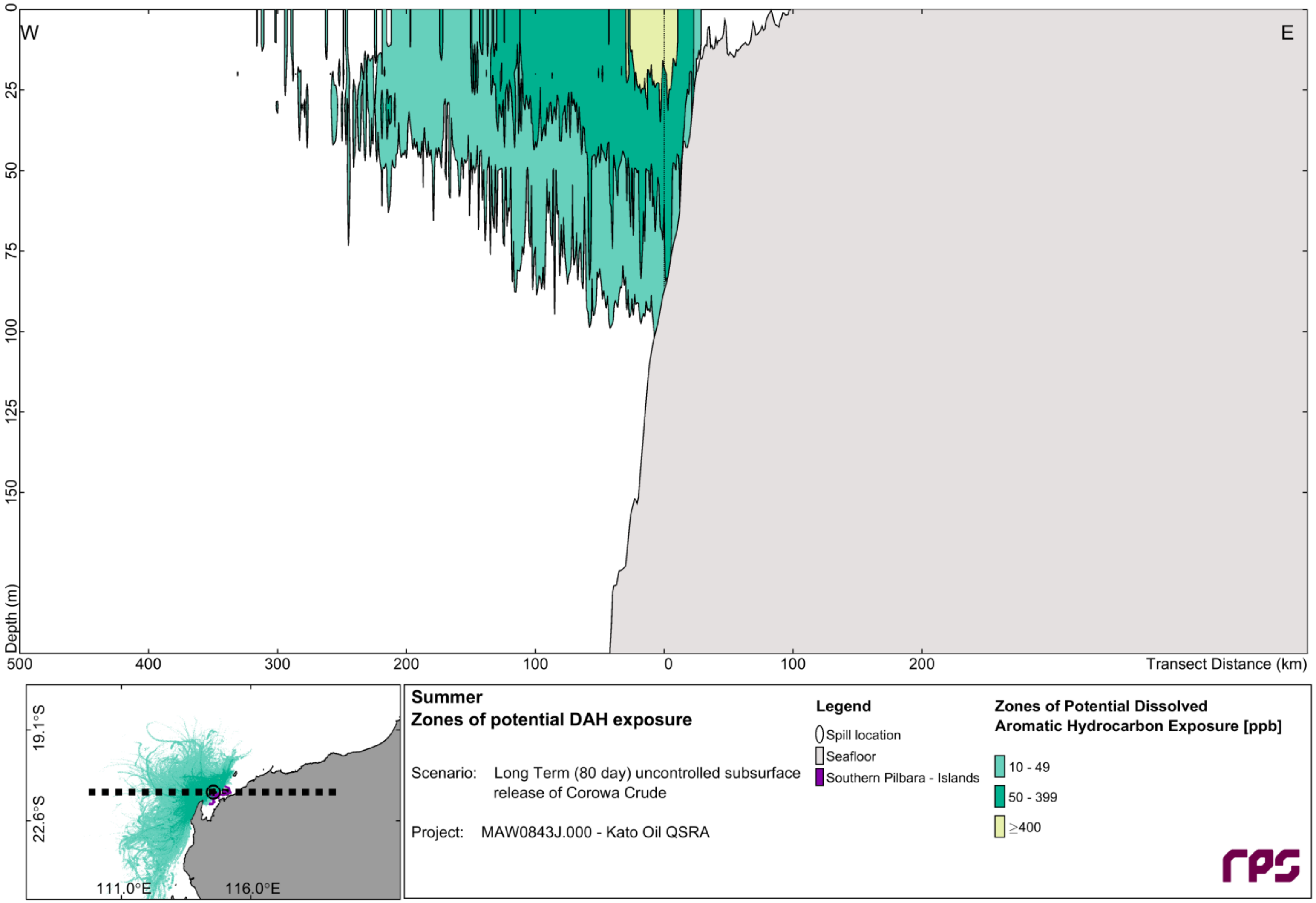


Figure 3.19 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, commencing in the summer season. The results were calculated from 50 spill trajectories.

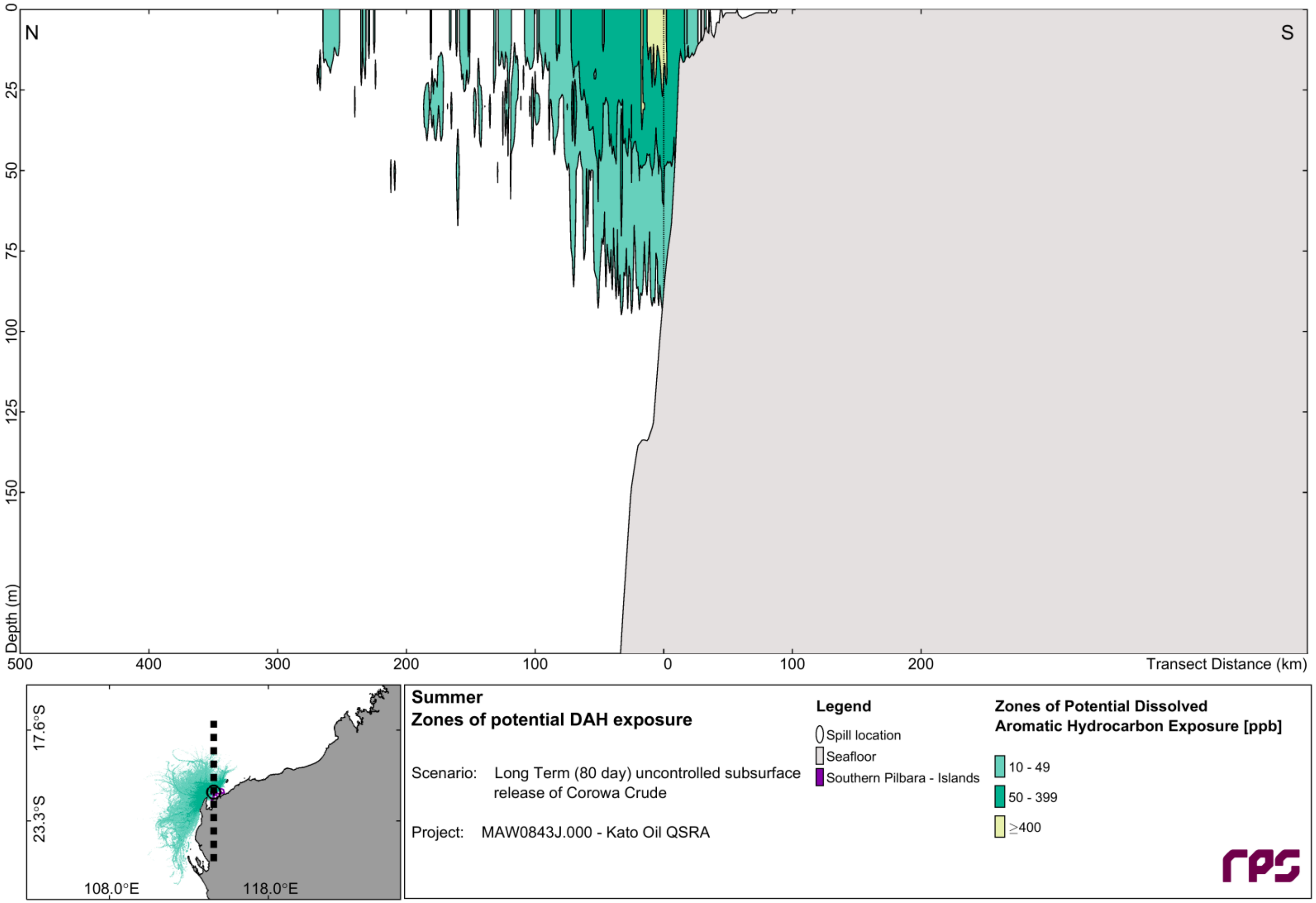


Figure 3.20 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, commencing in the summer season. The results were calculated from 50 spill trajectories.

3.2.3.2.5 Dissolved Aromatic Hydrocarbons - Exposure

Table 3.9 Expected dissolved aromatic hydrocarbons exposure outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in summer months.

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	Abrolhos Islands	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
	Barrow Island	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	323	341	535	164	BS	BS
	Lacepede Islands	Probability (%) >960	NC	BS	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	BS	BS	BS	BS	BS
	Lowendal Islands	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS	BS
	Montebello Islands	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	5	NC	NC	NC	BS	BS
	Sandy Islet	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	Probability (%) >960	4	2	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	3,811	1,749	486	BS	BS	BS
Coastlines	Dampier Archipelago	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Exmouth Gulf South East	Probability (%) >960	NC	BS	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS	BS

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Probability (%) >38,400	NC	BS	BS	BS	BS	BS
	Maximum Integrated Exposure	5	BS	BS	BS	BS	BS
Exmouth Gulf West	Probability (%) >960	2	NC	BS	BS	BS	BS
	Probability (%) >4,800	NC	NC	BS	BS	BS	BS
	Probability (%) >38,400	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	1,553	290	BS	BS	BS	BS
Geraldton - Jurien Bay	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Jurien Bay - Yanchep	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Kalbarri - Geraldton	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Karratha-Port Hedland	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >4,800	NC	NC	BS	BS	BS	BS
	Probability (%) >38,400	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
Kimberley Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >4,800	NC	NC	NC	NC	NC	BS
	Probability (%) >38,400	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Middle Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >4,800	NC	NC	BS	BS	BS	BS
	Probability (%) >38,400	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
North Broome Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >4,800	NC	NC	NC	NC	NC	BS
	Probability (%) >38,400	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Northern Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >4,800	NC	NC	BS	BS	BS	BS
	Probability (%) >38,400	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Perth Northern Coast	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Port Hedland - Eighty Mile Beach	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
	Southern Pilbara - Shoreline	Probability (%) >960	NC	BS	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	14	BS	BS	BS	BS	BS
	Zuytdorp Cliffs - Kalbarri	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
State Marine and National Parks	Barrow Island MMA	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	517	341	573	164	BS	BS
	Barrow Islands MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	323	305	19	12	BS	BS
	Clerke Reef (Rowley Shoals MP)	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Marmion MP	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS	BS

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Montebello Islands MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	7	3	3	NC	BS	BS
	Muiron Islands MMA	Probability (%) >960	26	4	4	2	NC	BS
		Probability (%) >4,800	2	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	5,607	1,542	2,141	1,137	141	BS
	Ningaloo Coast WH	Probability (%) >960	42	26	16	2	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8,525	3,861	4,657	1,556	135	NC
	Ningaloo MP (State)	Probability (%) >960	42	26	16	2	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8,525	3,861	4,657	1,556	135	NC
	Shark Bay MR	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	1	NC	BS	BS	BS	BS
	Shark Bay WH	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	29	NC	NC	3	NC	BS
Australian Marine Parks	Abrolhos MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	22	14	3	NC	NC
	Argo-Rowley Terrace MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Carnarvon Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Maximum Integrated Exposure	92	166	347	70	21	NC
Cartier Island MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Dampier MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Eighty Mile Beach MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Gascoyne MP	Probability (%) >960	2	2	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	2,402	1,445	877	484	125	5
Jurien Bay MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Jurien MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Kimberley MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Mermaid Reef MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Montebello MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	619	789	645	483	NC	NC
	Ningaloo MP	Probability (%) >960	6	4	2	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2,160	1,540	1,732	1,289	85	NC
	Perth Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Shark Bay MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	564	406	215	221	93	7
	Two Rocks MP	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	100	38	6	NC	NC	NC
		Probability (%) >4,800	10	2	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,930	6,222	2,960	914	107	11
	Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
		Probability (%) >960	98	22	6	2	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >4,800	8	2	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8,019	6,222	2,013	1,046	77	6
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	8	4	2	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,221	1,911	2,231	462	62	2
	Exmouth Plateau KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	528	696	862	153	27	1
	Glomar Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Wallaby Saddle KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	7	13	3	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	160	148	108	84	12	NC
	Western Rock Lobster KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Biologically Important Areas	Dolphins BIA	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Dugong BIA	Probability (%) >960	42	26	16	2	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8,525	3,861	4,657	1,556	135	NC
	Marine Turtle BIA	Probability (%) >960	100	60	16	2	NC	NC
		Probability (%) >4,800	92	4	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	19,679	9,422	4,849	1,737	350	11
	Seabirds BIA	Probability (%) >960	100	60	16	2	NC	NC
		Probability (%) >4,800	92	4	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	19,679	9,422	4,849	1,737	350	11
	Seals BIA	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Sharks BIA	Probability (%) >960	100	60	10	2	NC	NC
		Probability (%) >4,800	92	4	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	19,679	9,422	4,849	1,737	350	11
	Whales BIA	Probability (%) >960	100	60	16	2	NC	NC
		Probability (%) >4,800	92	4	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Maximum Integrated Exposure	19,679	9,422	4,849	1,737	350	11
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	8	4	2	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,221	2,095	2,231	462	43	3
	Southern Bluefin Tuna Fishery	Probability (%) >960	100	60	16	2	NC	NC
		Probability (%) >4,800	92	4	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	19,679	9,422	4,849	1,737	350	11
	Western Skipjack Fishery	Probability (%) >960	100	60	16	2	NC	NC
		Probability (%) >4,800	92	4	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	19,679	9,422	4,849	1,737	350	11
	Western Tuna and Billfish Fishery	Probability (%) >960	100	60	16	2	NC	NC
		Probability (%) >4,800	92	4	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	19,679	9,422	4,849	1,737	350	11
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Rankin Bank	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	2	3	BS	BS	BS
	Scott Reef North	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Scott Reef South	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Seringapatam Reef	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Woodbine Bank	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >4,800	NC	NC	NC	NC	NC	BS
	Probability (%) >38,400	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

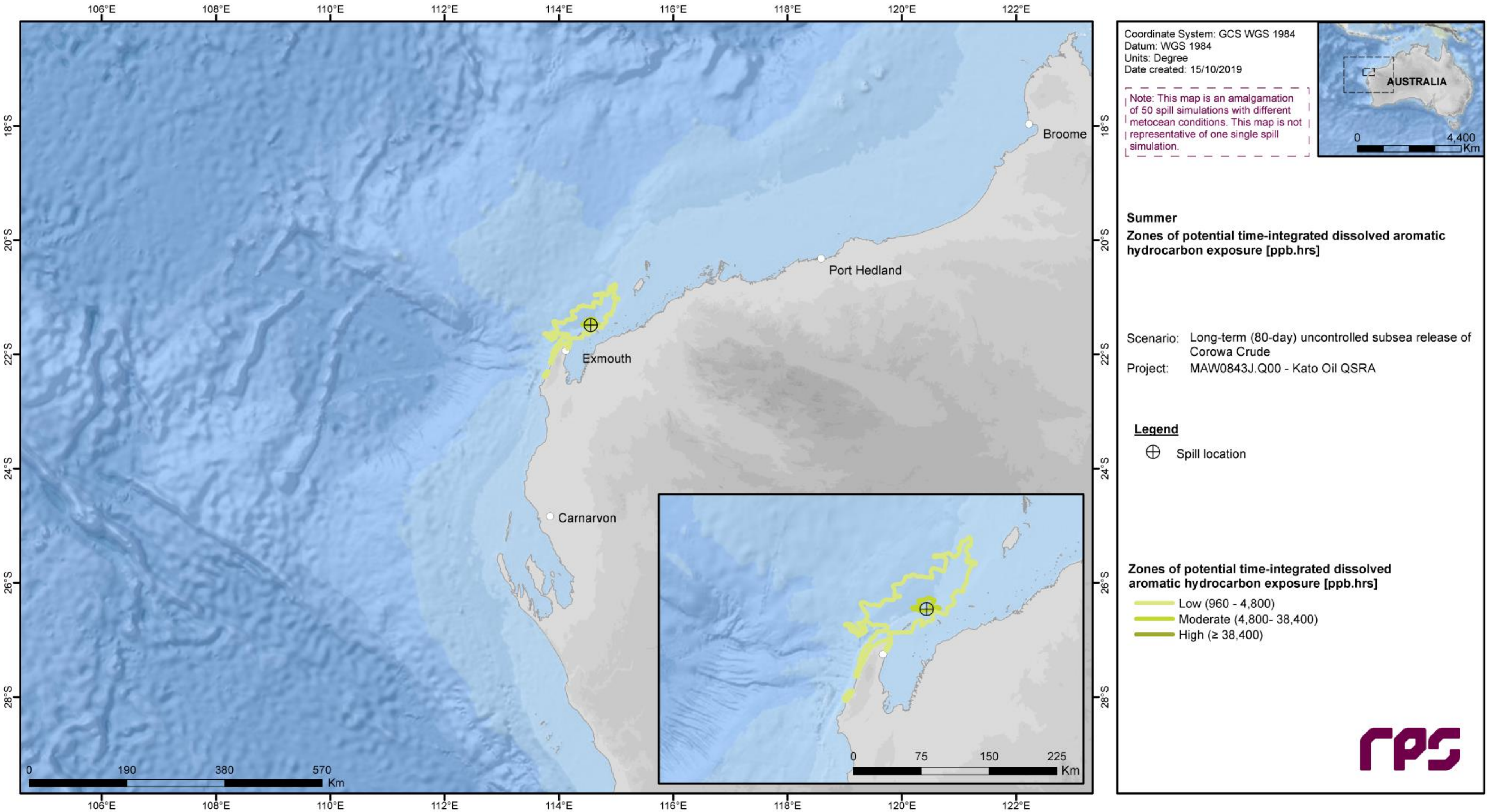


Figure 3.21 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure resulting from a long-term (80-day) subsurface release of Corowa Light Crude within the Corowa field, starting in summer months.

3.2.3.3 Winter

3.2.3.3.1 Floating and Shoreline Oil

Table 3.10 Expected floating and shoreline oil outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in winter months.

	Receptors	Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
Islands	Abrolhos Islands	<2	<2	<2	NC	NC	NC	4	<2	<2	938	NC	NC	2.7	94	<1	6	<1	15	NC	NC	NC	NC
Islands	Barrow Island	<2	<2	<2	NC	NC	NC	2	<2	<2	1,498	NC	NC	0.4	19	<1	<1	<1	1	NC	NC	NC	NC
Islands	Lacepede Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Islands	Lowendal Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Islands	Montebello Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.1	5.3	<1	<1	NC	NC	NC	NC	NC	NC
Islands	Sandy Islet	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Islands	Southern Pilbara - Islands	62	22	6	36	37	190	56	50	30	39	190	222	1,528	7,728	30	138	4	23	2	13	<1	3
Coastlines	Dampier Archipelago	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Exmouth Gulf South East	<2	<2	<2	NC	NC	NC	10	<2	<2	1,133	NC	NC	4.7	79	<1	3	<1	6	NC	NC	NC	NC
Coastlines	Exmouth Gulf West	8	<2	<2	247	NC	NC	26	8	<2	272	323	NC	15	183	<1	9	2	10	<1	3	NC	NC
Coastlines	Geraldton - Jurien Bay	<2	<2	<2	NC	NC	NC	2	<2	<2	1,285	NC	NC	0.3	14	<1	<1	<1	1	NC	NC	NC	NC
Coastlines	Jurien Bay - Yanchep	<2	<2	<2	NC	NC	NC	4	<2	<2	1,139	NC	NC	1.2	33	<1	4	<1	7	NC	NC	NC	NC
Coastlines	Kalbarri - Geraldton	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Karratha-Port Hedland	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Kimberley Coast	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Middle Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	North Broome Coast	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Perth Northern Coast	<2	<2	<2	NC	NC	NC	4	<2	<2	1,303	NC	NC	0.5	21	<1	2	<1	3	NC	NC	NC	NC
Coastlines	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Southern Pilbara - Shoreline	<2	<2	<2	NC	NC	NC	2	<2	<2	2,001	NC	NC	0.3	15	<1	<1	<1	1	NC	NC	NC	NC
Coastlines	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC	NC	2	<2	<2	1,297	NC	NC	0.2	13	<1	<1	<1	4	NC	NC	NC	NC
State Marine and National Parks	Barrow Island MMA	<2	<2	<2	NC	NC	NC	2	<2	<2	1,498	NC	NC	0.4	19	<1	<1	<1	1	NC	NC	NC	NC
State Marine and National Parks	Barrow Islands MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NA	NA	NA	NA	NA	NA
State Marine and National Parks	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
State Marine and National Parks	Imperieuse Reef (Rowley Shoals MP)	2	<2	<2	2,016	NC	NC	4	2	<2	990	1,852	NC	11	510	<1	11	<1	8	<1	2	NC	NC
State Marine and National Parks	Marmion MP*	<2	<2	<2	NC	NC	NC	<2	<2	<2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

	Receptors	Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
	Montebello Islands MP*	<2	<2	<2	NC	NC	NC	<2	<2	<2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Muiron Islands MMA	98	40	4	26	33	57	72	48	16	154	178	191	307	6,739	29	289	8	13	4	13	<1	8
	Ningaloo Coast WH	92	18	10	33	52	55	74	50	14	55	83	208	300	2,139	47	240	28	90	10	46	<1	4
	Ningaloo MP (State)	78	8	2	35	52	195	74	50	14	55	83	208	300	2,139	47	240	28	90	10	46	<1	4
	Shark Bay MR	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Shark Bay WH	<2	<2	<2	NC	NC	NC	6	<2	<2	775	NC	NC	1.2	35	<1	2	<1	8	NC	NC	NC	NC
Australian Marine Parks	Abrolhos MP*	4	<2	<2	834	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Argo-Rowley Terrace MP*	2	<2	<2	1,491	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carnarvon Canyon MP*	6	<2	<2	515	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Cartier Island MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Dampier MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Eighty Mile Beach MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Gascoyne MP*	80	10	8	39	139	163	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jurien Bay MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jurien MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Kimberley MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Reef MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Montebello MP*	2	<2	<2	2,102	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ningaloo MP*	92	18	10	33	53	55	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Perth Canyon MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Shark Bay MP*	4	<2	<2	593	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Two Rocks MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF*	100	94	70	6	7	10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ancient Coastline at 90-120m Depth Contour KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF*†	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF*	100	84	56	8	12	32	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

	Receptors	Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Continental Slope Demersal Fish Communities KEF*	96	20	8	39	91	110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Exmouth Plateau KEF*	34	2	<2	175	414	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Glomar Shoals KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF*†	2	<2	<2	2,016	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF*†	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wallaby Saddle KEF*	4	<2	<2	834	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Demersal Slope and associated Fish Communities KEF*	2	<2	<2	589	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Rock Lobster KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Biologically Important Areas	Dolphins BIA*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dugong BIA*	72	8	2	36	59	195	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marine Turtle BIA*†	100	10	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seabirds BIA*†	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seals BIA*†	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sharks BIA*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Whales BIA*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	North-West Slope Trawl Fishery*	98	20	10	45	91	102	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Southern Bluefin Tuna Fishery*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Skipjack Fishery*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Tuna and Billfish Fishery*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other Submerg	Eugene McDermott Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Rankin Bank*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Receptors	Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m^2)		Maximum accumulated volume (m^3) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m^2		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m^2		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m^2	
	≥ 1 g/m^2	≥ 10 g/m^2	≥ 25 g/m^2	≥ 1 g/m^2	≥ 10 g/m^2	≥ 25 g/m^2	≥ 10 g/m^2	≥ 100 g/m^2	≥ 1,000 g/m^2	≥ 10 g/m^2	≥ 100 g/m^2	≥ 1,000 g/m^2	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
Scott Reef North*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scott Reef South*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Seringapatam Reef*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Woodbine Bank*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NC: No contact to receptor predicted for specified threshold. NA: Not applicable.

* Floating oil will not accumulate on submerged features and at open ocean locations.

† Receptor is considered as submerged, any accumulation occurring on emerged features within this receptor is captured under the associated shoreline receptor in the table.

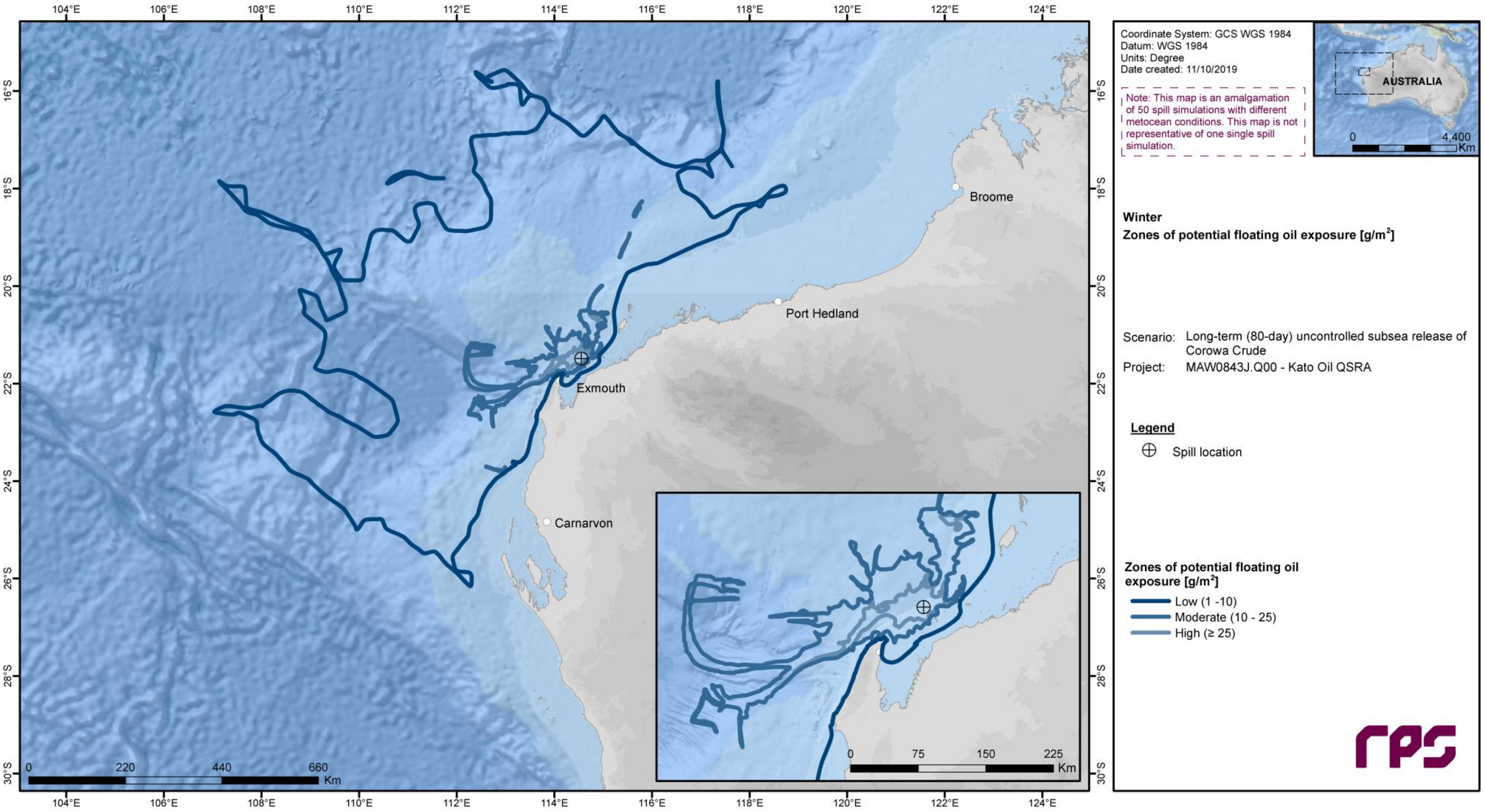


Figure 3.22 Predicted zones of potential floating oil exposure resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in winter.

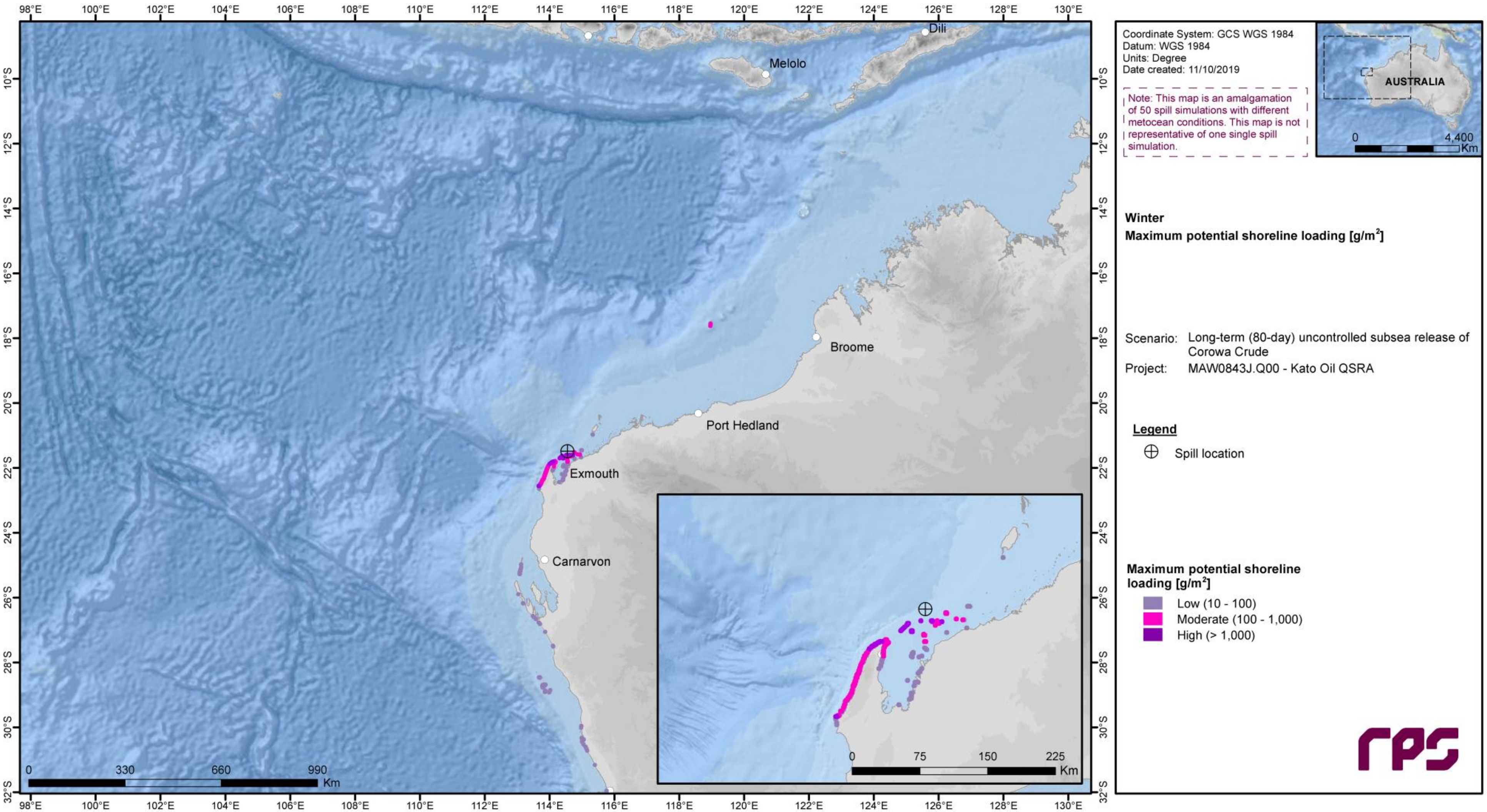


Figure 3.23 Predicted maximum potential shoreline loading resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in winter.

3.2.3.3.2 Entrained Oil - Instantaneous

Table 3.11 Expected instantaneous entrained oil outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in winter months.

Receptors		Probability (%) of entrained hydrocarbon concentration contact			Minimum time (hours) to receptor waters			Maximum entrained hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Abrolhos Islands	16	2	<2	766	929	NC	10	331
	Barrow Island	16	8	<2	870	914	NC	11	170
	Lacepede Islands	<2	<2	<2	NC	NC	NC	<1	3
	Lowendal Islands	8	<2	<2	897	NC	NC	6	87
	Montebello Islands	14	<2	<2	658	NC	NC	6	77
	Sandy Islet	<2	<2	<2	NC	NC	NC	<1	2
	Southern Pilbara - Islands	98	96	46	36	37	192	1,105	5,176
Coastlines	Dampier Archipelago	<2	<2	<2	NC	NC	NC	NC	NC
	Exmouth Gulf South East	16	<2	<2	623	NC	NC	5	58
	Exmouth Gulf West	94	44	<2	59	71	NC	135	740
	Geraldton - Jurien Bay	8	<2	<2	898	NC	NC	5	65
	Jurien Bay - Yanchep	8	<2	<2	897	NC	NC	3	79
	Kalbarri - Geraldton	<2	<2	<2	NC	NC	NC	<1	10
	Karratha-Port Hedland	<2	<2	<2	NC	NC	NC	NC	NC
	Kimberley Coast	<2	<2	<2	NC	NC	NC	<1	3
	Middle Pilbara - Islands and Shoreline	2	<2	<2	915	NC	NC	<1	13
	North Broome Coast	<2	<2	<2	NC	NC	NC	<1	4
	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<1	<1
	Perth Northern Coast	10	2	<2	912	1,097	NC	7	188
	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC	NC	NC	NC
	Southern Pilbara - Shoreline	24	2	<2	646	1,947	NC	8	138
	Zuytdorp Cliffs - Kalbarri	2	<2	<2	1,660	NC	NC	<1	13
State Marine and National Parks	Barrow Island MMA	20	6	<2	611	894	NC	10	161
	Barrow Islands MP	14	8	<2	875	948	NC	11	170
	Clerke Reef (Rowley Shoals MP)	6	<2	<2	1,167	NC	NC	<1	21
	Imperieuse Reef (Rowley Shoals MP)	6	<2	<2	805	NC	NC	4	72
	Marmion MP	4	<2	<2	1,136	NC	NC	2	61
	Montebello Islands MP	16	4	<2	630	1,079	NC	8	114
	Muiron Islands MMA	100	100	98	19	20	24	2,718	7,460
	Ningaloo Coast WH	100	100	90	29	30	33	2,396	11,047
	Ningaloo MP (State)	100	98	80	33	33	34	1,877	11,047
	Shark Bay MR	4	<2	<2	977	NC	NC	2	19
	Shark Bay WH	10	<2	<2	516	NC	NC	4	39
Australian Marine Parks	Abrolhos MP	76	16	<2	399	551	NC	48	592
	Argo-Rowley Terrace MP	32	10	<2	611	631	NC	26	293
	Carnarvon Canyon MP	70	30	<2	336	412	NC	89	700
	Cartier Island MP	<2	<2	<2	NC	NC	NC	NC	NC
	Dampier MP	<2	<2	<2	NC	NC	NC	NC	NC
	Eighty Mile Beach MP	<2	<2	<2	NC	NC	NC	NC	NC
	Gascoyne MP	100	100	92	31	32	36	1,924	6,743
	Jurien Bay MP	8	<2	<2	895	NC	NC	3	79
	Jurien MP	6	2	<2	772	1,067	NC	4	102
	Kimberley MP	<2	<2	<2	NC	NC	NC	<1	4
	Mermaid Reef MP	<2	<2	<2	NC	NC	NC	<1	6
	Montebello MP	52	24	<2	416	573	NC	67	392
	Ningaloo MP	100	100	90	29	30	33	2,396	8,696
	Perth Canyon MP	16	2	<2	877	1,129	NC	7	214
	Shark Bay MP	70	38	2	223	229	393	89	1,164
	Two Rocks MP	6	<2	<2	890	NC	NC	3	88
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	100	100	100	5	6	8	7,850	18,761
	Ancient Coastline at 90-120m Depth Contour KEF	16	2	<2	680	795	NC	7	225
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	<2	<2	<2	NC	NC	NC	NC	NC

Receptors		Probability (%) of entrained hydrocarbon concentration contact			Minimum time (hours) to receptor waters			Maximum entrained hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	4	<2	<2	1,443	NC	NC	2	48
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	100	100	100	7	9	12	6,336	15,210
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	16	2	<2	732	898	NC	9	277
	Continental Slope Demersal Fish Communities KEF	100	100	100	29	36	43	3,295	15,568
	Exmouth Plateau KEF	100	100	20	133	142	165	646	4,335
	Glomar Shoals KEF §	<2	<2	<2	NC	NC	NC	<1	4
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	6	<2	<2	766	NC	NC	4	82
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	38	2	<2	433	637	NC	11	214
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	<2	<2	<2	NC	NC	NC	<1	4
	Wallaby Saddle KEF	72	14	<2	418	564	NC	48	368
	Western Demersal Slope and associated Fish Communities KEF	64	24	<2	297	313	NC	50	816
	Western Rock Lobster KEF	16	2	<2	672	789	NC	8	231
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC	NC	<1	2
	Dugong BIA	100	100	76	35	35	42	1,877	11,047
	Marine Turtle BIA	100	100	100	1	1	1	19,585	46,837
	Seabirds BIA	100	100	100	1	1	1	19,585	46,837
	Seals BIA	16	2	<2	750	918	NC	10	331
	Sharks BIA	100	100	100	1	1	1	19,585	46,837
	Whales BIA	100	100	100	1	1	1	19,585	46,837
Fisheries	North-West Slope Trawl Fishery	100	100	100	37	43	51	3,295	15,568
	Southern Bluefin Tuna Fishery	100	100	100	1	1	1	19,585	46,837
	Western Skipjack Fishery	100	100	100	1	1	1	19,585	46,837
	Western Tuna and Billfish Fishery	100	100	100	1	1	1	19,585	46,837
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal §	<2	<2	<2	NC	NC	NC	NC	NC
	Rankin Bank §	<2	<2	<2	761	NC	NC	4	7
	Scott Reef North	<2	<2	<2	NC	NC	NC	<1	3
	Scott Reef South	<2	<2	<2	NC	NC	NC	<1	4
	Seringapatam Reef	<2	<2	<2	NC	NC	NC	<1	3
	Woodbine Bank	<2	<2	<2	NC	NC	NC	NC	NC

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

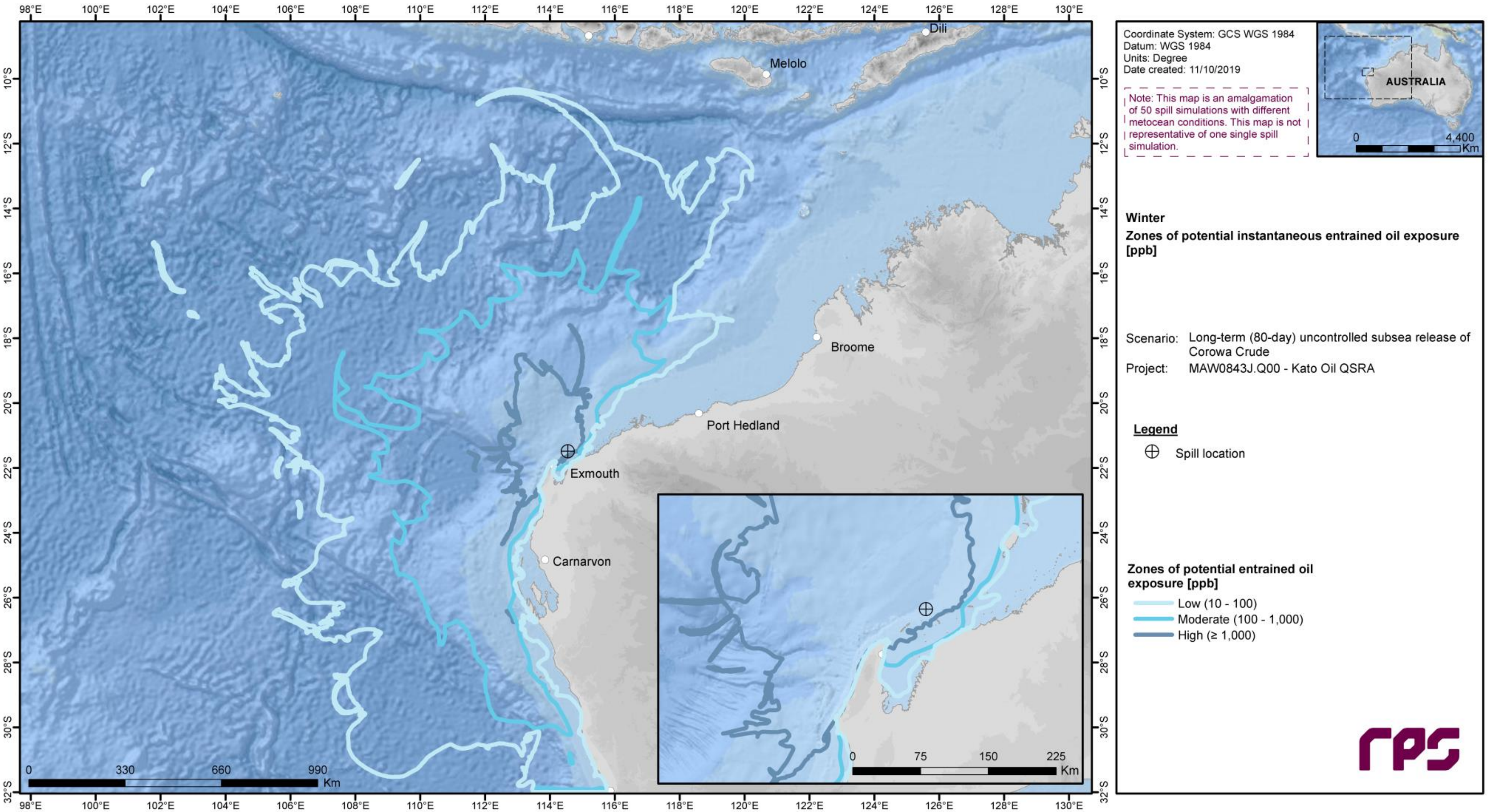


Figure 3.24 Predicted zones of potential instantaneous entrained oil exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in winter months.

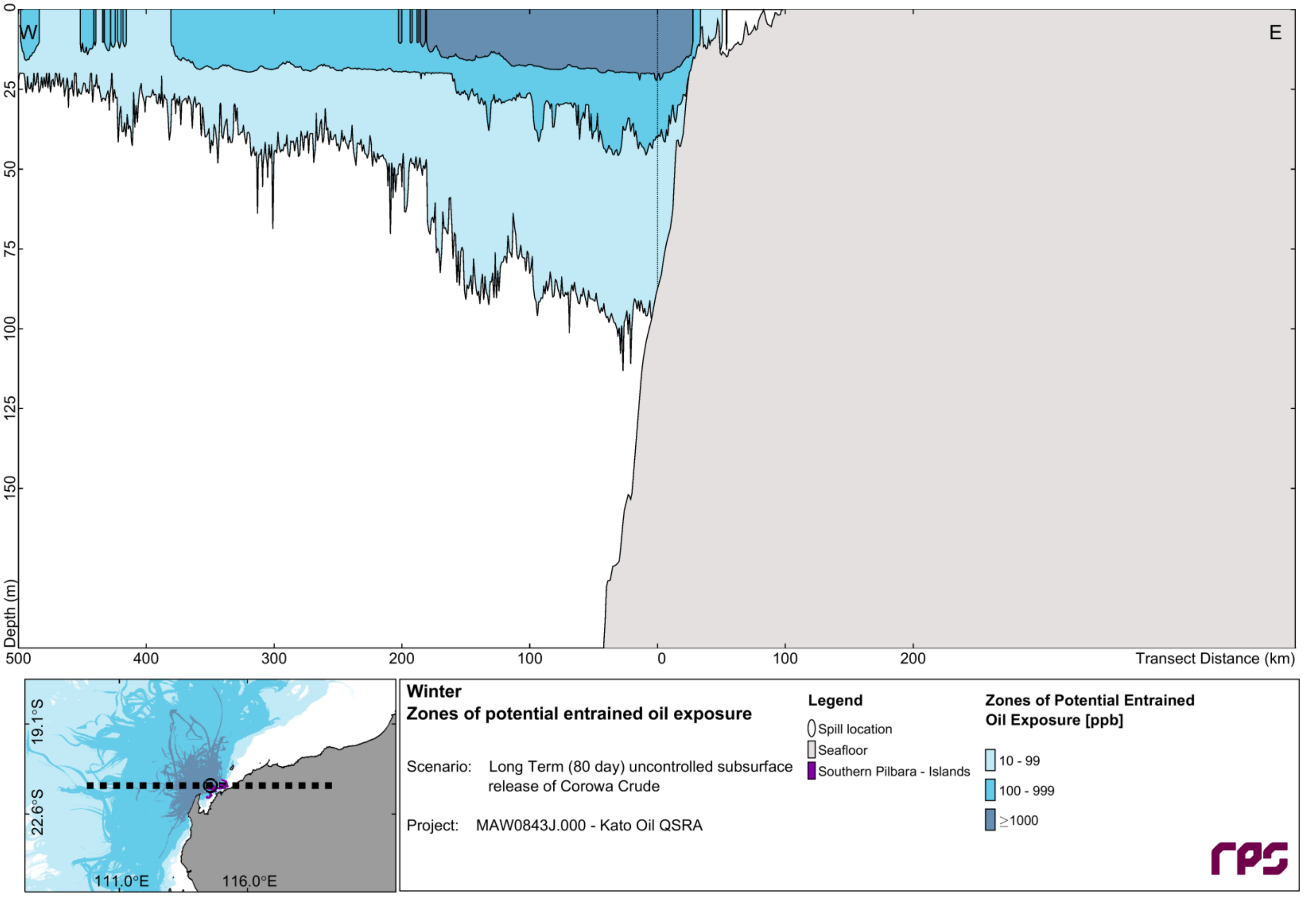


Figure 3.25 East-West cross-section transect of predicted maximum entrained oil concentration resulting from a long-term (80-day) subsea release of Corowa Crude within the Corowa field, commencing in the winter season. The results were calculated from 50 spill trajectories.

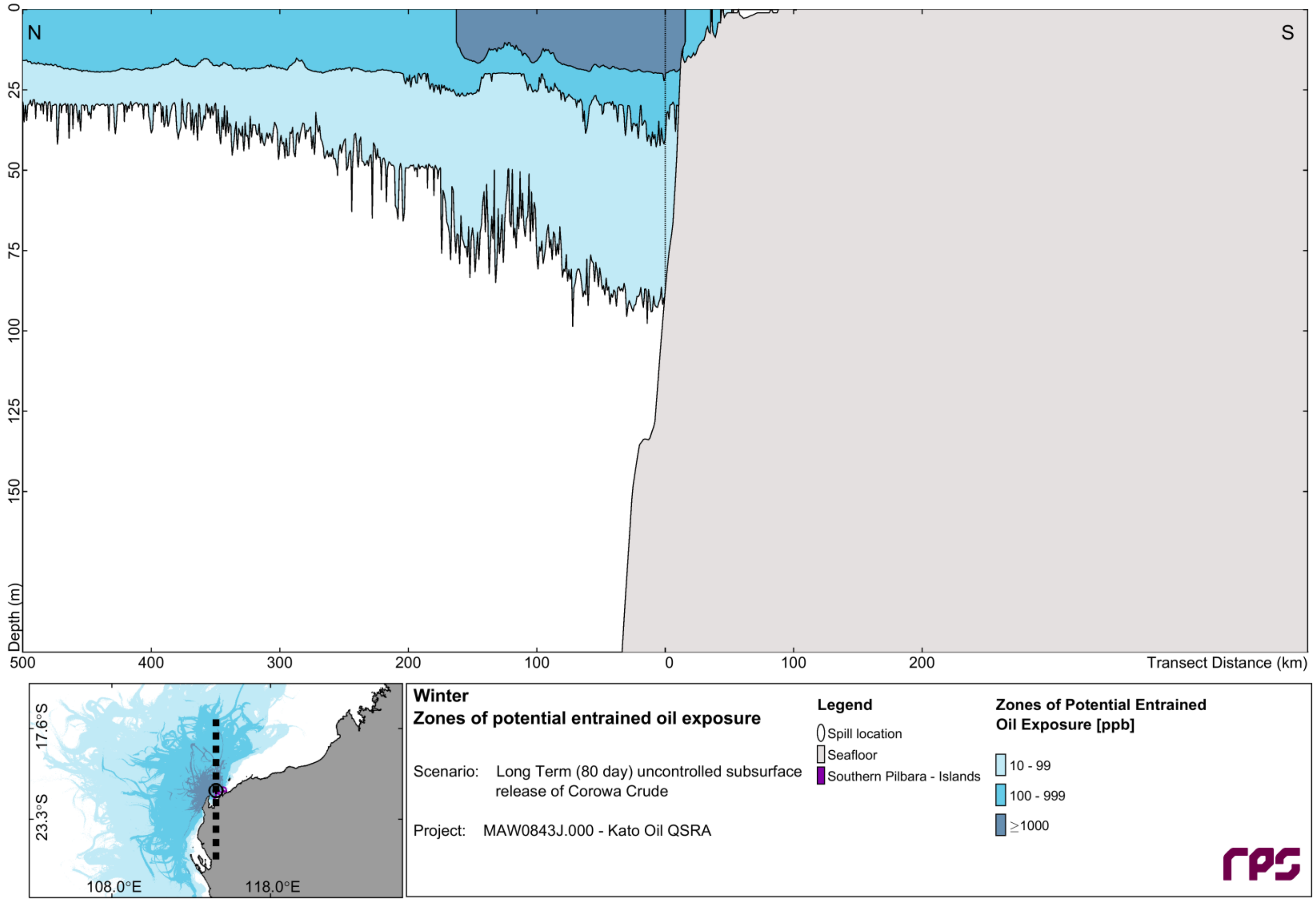


Figure 3.26 North-South cross-section transect of predicted maximum entrained oil concentration resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, commencing in the winter season. The results were calculated from 50 spill trajectories.

3.2.3.3.3 Entrained Oil - Exposure

Table 3.12 Expected entrained oil exposure outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in summer months.

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	Abrolhos Islands	Probability (%) >960	6	NC	NC	NC	NC	BS
		Probability (%) >9,600	2	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	15,188	336	113	40	5	BS
	Barrow Island	Probability (%) >960	8	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	7,017	448	107	34	BS	BS
	Lacepede Islands	Probability (%) >960	NC	BS	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	16	BS	BS	BS	BS	BS
	Lowendal Islands	Probability (%) >960	6	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	1,460	43	NC	BS	BS	BS
	Montebello Islands	Probability (%) >960	6	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	3,463	174	33	2	BS	BS
	Sandy Islet	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	13	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	Probability (%) >960	92	40	NC	BS	BS	BS
		Probability (%) >9,600	50	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	86,854	6,765	948	BS	BS	BS
	Dampier Archipelago	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Exmouth Gulf South East	Probability (%) >960	2	BS	BS	BS	BS	BS
	Probability (%) >9,600	NC	BS	BS	BS	BS	BS
	Probability (%) >96,000	NC	BS	BS	BS	BS	BS
	Maximum Integrated Exposure	1,473	BS	BS	BS	BS	BS
Exmouth Gulf West	Probability (%) >960	66	4	BS	BS	BS	BS
	Probability (%) >9,600	22	NC	BS	BS	BS	BS
	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	33,760	2,121	BS	BS	BS	BS
Geraldton - Jurien Bay	Probability (%) >960	6	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	3,632	195	43	7	BS	BS
Jurien Bay - Yanchep	Probability (%) >960	2	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	3,327	139	57	7	BS	BS
Kalbarri - Geraldton	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	193	32	18	1	BS	BS
Karratha-Port Hedland	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >9,600	NC	NC	BS	BS	BS	BS
	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
Kimberley Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >9,600	NC	NC	NC	NC	NC	BS
	Probability (%) >96,000	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	14	NC	NC	NC	NC	BS
Middle Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >9,600	NC	NC	BS	BS	BS	BS
	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	98	3	BS	BS	BS	BS
North Broome Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >9,600	NC	NC	NC	NC	NC	BS

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	24	1	NC	NC	NC	BS
	Northern Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
	Perth Northern Coast	Probability (%) >960	4	NC	NC	NC	BS	BS
		Probability (%) >9,600	2	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	12,528	954	106	7	BS	BS
	Port Hedland - Eighty Mile Beach	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
	Southern Pilbara - Shoreline	Probability (%) >960	4	BS	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	7,661	BS	BS	BS	BS	BS
	Zuytdorp Cliffs - Kalbarri	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	293	38	32	6	1	BS
State Marine and National Parks	Barrow Island MMA	Probability (%) >960	8	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	6,610	448	116	51	BS	BS
	Barrow Islands MP	Probability (%) >960	8	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	7,017	407	68	29	BS	BS
	Clerke Reef (Rowley Shoals MP)	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	318	28	20	NC	1	NC
		Probability (%) >960	6	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Imperieuse Reef (Rowley Shoals MP)	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2,743	178	41	7	NC	NC
	Marmion MP	Probability (%) >960	2	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	4,334	229	20	BS	BS	BS
	Montebello Islands MP	Probability (%) >960	8	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	6,408	286	98	7	BS	BS
	Muiron Islands MMA	Probability (%) >960	98	92	22	NC	NC	BS
		Probability (%) >9,600	96	6	NC	NC	NC	BS
		Probability (%) >96,000	12	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	175,964	11,993	3,203	716	77	BS
	Ningaloo Coast WH	Probability (%) >960	100	92	70	10	NC	NC
		Probability (%) >9,600	94	18	2	NC	NC	NC
		Probability (%) >96,000	26	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	687,668	35,982	10,971	2,240	164	27
	Ningaloo MP (State)	Probability (%) >960	98	90	70	4	NC	NC
		Probability (%) >9,600	86	18	2	NC	NC	NC
		Probability (%) >96,000	26	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	687,668	35,982	10,971	1,269	156	14
	Shark Bay MR	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	753	111	BS	BS	BS	BS
	Shark Bay WH	Probability (%) >960	4	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	1,894	264	93	52	11	BS
Australian Marine Parks	Abrolhos MP	Probability (%) >960	30	NC	NC	NC	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	10,867	576	159	87	31	12

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Argo-Rowley Terrace MP	Probability (%) >960	22	NC	NC	NC	NC	NC
	Probability (%) >9,600	4	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	12,158	839	170	45	10	4
Carnarvon Canyon MP	Probability (%) >960	40	4	NC	NC	NC	NC
	Probability (%) >9,600	6	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	20,806	1,092	337	77	13	5
Cartier Island MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Dampier MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Eighty Mile Beach MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Gascoyne MP	Probability (%) >960	100	100	36	6	NC	NC
	Probability (%) >9,600	98	10	NC	NC	NC	NC
	Probability (%) >96,000	8	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	193,219	19,522	7,085	1,506	136	40
Jurien Bay MP	Probability (%) >960	2	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	3,327	156	57	11	BS	BS
Jurien MP	Probability (%) >960	2	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	3,159	159	52	18	3	NC
Kimberley MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Maximum Integrated Exposure	20	5	2	NC	NC	NC
	Mermaid Reef MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	30	8	6	NC	NC	NC
	Montebello MP	Probability (%) >960	32	2	NC	NC	NC	NC
		Probability (%) >9,600	6	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	12,453	1,231	370	167	28	5
	Ningaloo MP	Probability (%) >960	100	92	42	10	NC	NC
		Probability (%) >9,600	94	10	NC	NC	NC	NC
		Probability (%) >96,000	8	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	249,741	22,631	8,190	2,240	164	27
	Perth Canyon MP	Probability (%) >960	4	2	NC	NC	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,294	1,014	293	57	15	5
	Shark Bay MP	Probability (%) >960	52	2	NC	NC	NC	NC
		Probability (%) >9,600	8	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	25,357	1,086	329	172	67	22
	Two Rocks MP	Probability (%) >960	2	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	6,461	346	61	25	8	BS
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	100	100	66	2	NC	NC
		Probability (%) >9,600	100	42	NC	NC	NC	NC
		Probability (%) >96,000	98	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	466,423	28,214	5,543	1,106	203	22
	Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	6	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,009	513	137	56	22	6
	Ashmore Reef and Cartier Island and surrounding	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Commonwealth Waters KEF	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	Probability (%) >960	2	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	1,088	79	21	5	2	NC
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	100	100	68	10	NC	NC
	Probability (%) >9,600	100	32	2	NC	NC	NC
	Probability (%) >96,000	92	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	418,356	45,491	11,681	1,775	338	24
Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	4	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	4,367	235	47	28	31	6
Continental Slope Demersal Fish Communities KEF	Probability (%) >960	100	100	52	10	NC	NC
	Probability (%) >9,600	100	12	NC	NC	NC	NC
	Probability (%) >96,000	18	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	247,245	28,332	8,582	1,557	198	41
Exmouth Plateau KEF	Probability (%) >960	100	70	10	2	NC	NC
	Probability (%) >9,600	64	NC	NC	NC	NC	NC
	Probability (%) >96,000	8	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	136,192	8,149	2,454	1,230	94	20
Glomar Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >9,600	NC	NC	NC	NC	NC	BS
	Probability (%) >96,000	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	82	13	13	4	1	BS
Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	Probability (%) >960	6	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	3,243	215	41	8	1	NC
Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	6	2	NC	NC	NC	NC
	Probability (%) >9,600	2	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	13,265	991	273	65	19	12
	Probability (%) >960	NC	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	26	7	NC	NC	NC	NC
	Wallaby Saddle KEF	Probability (%) >960	24	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	5,041	408	138	44	10	4
	Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	32	2	NC	NC	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,803	1,014	339	129	31	12
	Western Rock Lobster KEF	Probability (%) >960	6	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,245	516	153	56	25	7
Biologically Important Areas	Dolphins BIA	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	6	NC	NC	NC	NC	NC
	Dugong BIA	Probability (%) >960	100	90	70	4	NC	NC
		Probability (%) >9,600	92	18	2	NC	NC	NC
		Probability (%) >96,000	26	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	687,668	35,982	10,971	1,269	164	14
	Marine Turtle BIA	Probability (%) >960	100	100	72	10	NC	NC
		Probability (%) >9,600	100	60	2	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,501,303	45,491	11,681	2,240	410	27
	Seabirds BIA	Probability (%) >960	100	100	72	10	NC	NC
		Probability (%) >9,600	100	60	2	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,501,303	45,491	11,681	2,240	410	41
	Seals BIA	Probability (%) >960	6	NC	NC	NC	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,188	954	141	43	19	6

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Sharks BIA	Probability (%) >960	100	100	72	10	NC	NC
		Probability (%) >9,600	100	60	2	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,501,303	45,491	11,681	2,081	410	24
	Whales BIA	Probability (%) >960	100	100	72	10	NC	NC
		Probability (%) >9,600	100	60	2	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,501,303	45,491	11,681	2,240	410	41
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	100	100	56	2	NC	NC
		Probability (%) >9,600	100	12	NC	NC	NC	NC
		Probability (%) >96,000	18	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	274,216	23,059	5,142	1,425	198	41
	Southern Bluefin Tuna Fishery	Probability (%) >960	100	100	72	10	NC	NC
		Probability (%) >9,600	100	60	2	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,501,303	45,491	11,681	2,240	410	41
	Western Skipjack Fishery	Probability (%) >960	100	100	72	10	NC	NC
		Probability (%) >9,600	100	60	2	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,501,303	45,491	11,681	2,240	410	41
	Western Tuna and Billfish Fishery	Probability (%) >960	100	100	72	10	NC	NC
		Probability (%) >9,600	100	60	2	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,501,303	45,491	11,681	2,240	410	41
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Rankin Bank	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	474	71	67	BS	BS	BS
	Scott Reef North	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Maximum Integrated Exposure	26	2	NC	NC	NC	NC
	Scott Reef South	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	19	1	NC	NC	NC	NC
	Seringapatam Reef	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8	7	NC	NC	NC	NC
	Woodbine Bank	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

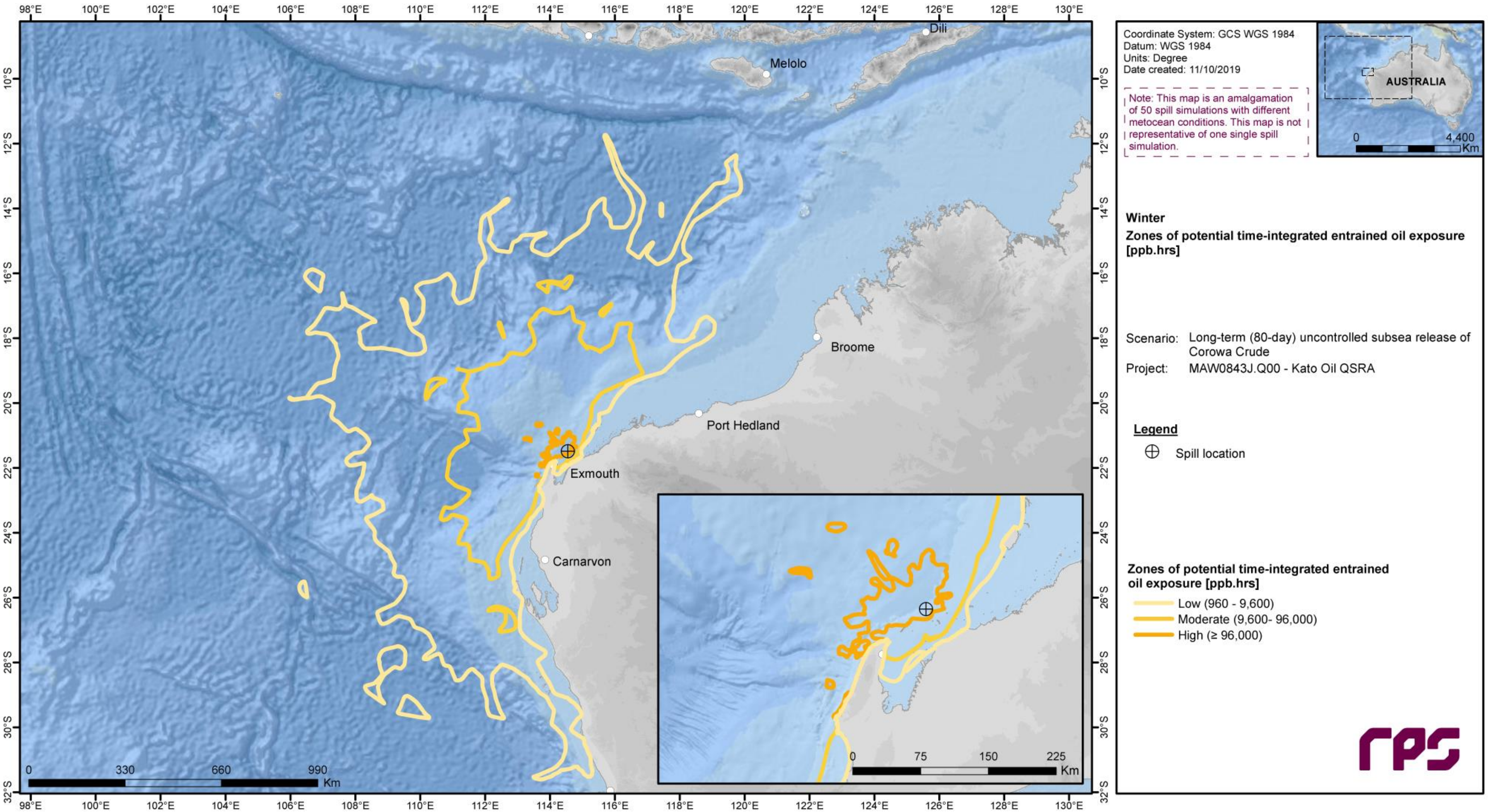


Figure 3.27 Predicted zones of potential time-integrated entrained oil exposure resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in winter months.

3.2.3.3.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Table 3.13 Expected instantaneous dissolved aromatic hydrocarbons outcomes at sensitive receptors resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in winter months.

Receptors		Probability (%) of dissolved aromatic concentration			Maximum dissolved aromatic hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Abrolhos Islands	<2	<2	<2	NC	NC
	Barrow Island	<2	<2	<2	<1	<1
	Lacepede Islands	<2	<2	<2	NC	NC
	Lowendal Islands	<2	<2	<2	NC	NC
	Montebello Islands	<2	<2	<2	<1	<1
	Sandy Islet	<2	<2	<2	NC	NC
	Southern Pilbara - Islands	74	30	<2	46	291
Coastlines	Dampier Archipelago	<2	<2	<2	NC	NC
	Exmouth Gulf South East	<2	<2	<2	<1	2
	Exmouth Gulf West	18	4	<2	8	100
	Geraldton - Jurien Bay	<2	<2	<2	NC	NC
	Jurien Bay - Yanchep	<2	<2	<2	NC	NC
	Kalbarri - Geraldton	<2	<2	<2	NC	NC
	Karratha-Port Hedland	<2	<2	<2	NC	NC
	Kimberley Coast	<2	<2	<2	NC	NC
	Middle Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC
	North Broome Coast	<2	<2	<2	NC	NC
	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC
	Perth Northern Coast	<2	<2	<2	NC	NC
	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC
	Southern Pilbara - Shoreline	<2	<2	<2	<1	3
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC
State Marine and National Parks	Barrow Island MMA	<2	<2	<2	<1	<1
	Barrow Islands MP	<2	<2	<2	<1	<1
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC
	Marmion MP	<2	<2	<2	NC	NC
	Montebello Islands MP	<2	<2	<2	<1	<1
	Muiron Islands MMA	100	94	<2	101	313
	Ningaloo Coast WH	100	86	2	91	623

Receptors		Probability (%) of dissolved aromatic concentration			Maximum dissolved aromatic hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
	Ningaloo MP (State)	100	66	2	78	623
	Shark Bay MR	<2	<2	<2	NC	NC
	Shark Bay WH	2	<2	<2	<1	29
Australian Marine Parks	Abrolhos MP	2	<2	<2	<1	30
	Argo-Rowley Terrace MP	<2	<2	<2	<1	<1
	Carnarvon Canyon MP	4	2	<2	2	65
	Cartier Island MP	<2	<2	<2	NC	NC
	Dampier MP	<2	<2	<2	NC	NC
	Eighty Mile Beach MP	<2	<2	<2	NC	NC
	Gascoyne MP	100	82	<2	81	322
	Jurien Bay MP	<2	<2	<2	NC	NC
	Jurien MP	<2	<2	<2	NC	NC
	Kimberley MP	<2	<2	<2	NC	NC
	Mermaid Reef MP	<2	<2	<2	NC	NC
	Montebello MP	2	<2	<2	<1	12
	Ningaloo MP	100	86	2	91	424
	Perth Canyon MP	<2	<2	<2	NC	NC
	Shark Bay MP	6	2	<2	2	54
	Two Rocks MP	<2	<2	<2	NC	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	100	100	8	255	1,041
	Ancient Coastline at 90-120m Depth Contour KEF	<2	<2	<2	NC	NC
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	<2	<2	<2	NC	NC
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	<2	<2	<2	NC	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	100	100	8	205	814
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	<2	<2	<2	NC	NC
	Continental Slope Demersal Fish Communities KEF	100	90	2	97	555
	Exmouth Plateau KEF	54	8	<2	16	164
	Glomar Shoals KEF §	<2	<2	<2	NC	NC
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	<2	<2	<2	NC	NC
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	<2	<2	<2	<1	2

Receptors		Probability (%) of dissolved aromatic concentration ≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	Maximum dissolved aromatic hydrocarbon concentration (ppb) averaged over all replicate simulations	at any depth, in the worst replicate
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	<2	<2	<2	NC	NC
	Wallaby Saddle KEF	2	<2	<2	<1	15
	Western Demersal Slope and associated Fish Communities KEF	2	<2	<2	<1	35
	Western Rock Lobster KEF	<2	<2	<2	<1	<1
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC
	Dugong BIA	100	72	2	78	623
	Marine Turtle BIA	100	100	18	316	1,041
	Seabirds BIA	100	100	18	316	1,041
	Seals BIA	<2	<2	<2	NC	NC
	Sharks BIA	100	100	18	316	1,041
	Whales BIA	100	100	18	316	1,041
Fisheries	North-West Slope Trawl Fishery	100	94	2	107	563
	Southern Bluefin Tuna Fishery	100	100	18	316	1,041
	Western Skipjack Fishery	100	100	18	316	1,041
	Western Tuna and Billfish Fishery	100	100	18	316	1,041
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal §	<2	<2	<2	NC	NC
	Rankin Bank §	<2	<2	<2	<1	NC
	Scott Reef North	<2	<2	<2	NC	NC
	Scott Reef South	<2	<2	<2	NC	NC
	Seringapatam Reef	<2	<2	<2	NC	NC
	Woodbine Bank	<2	<2	<2	NC	NC

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

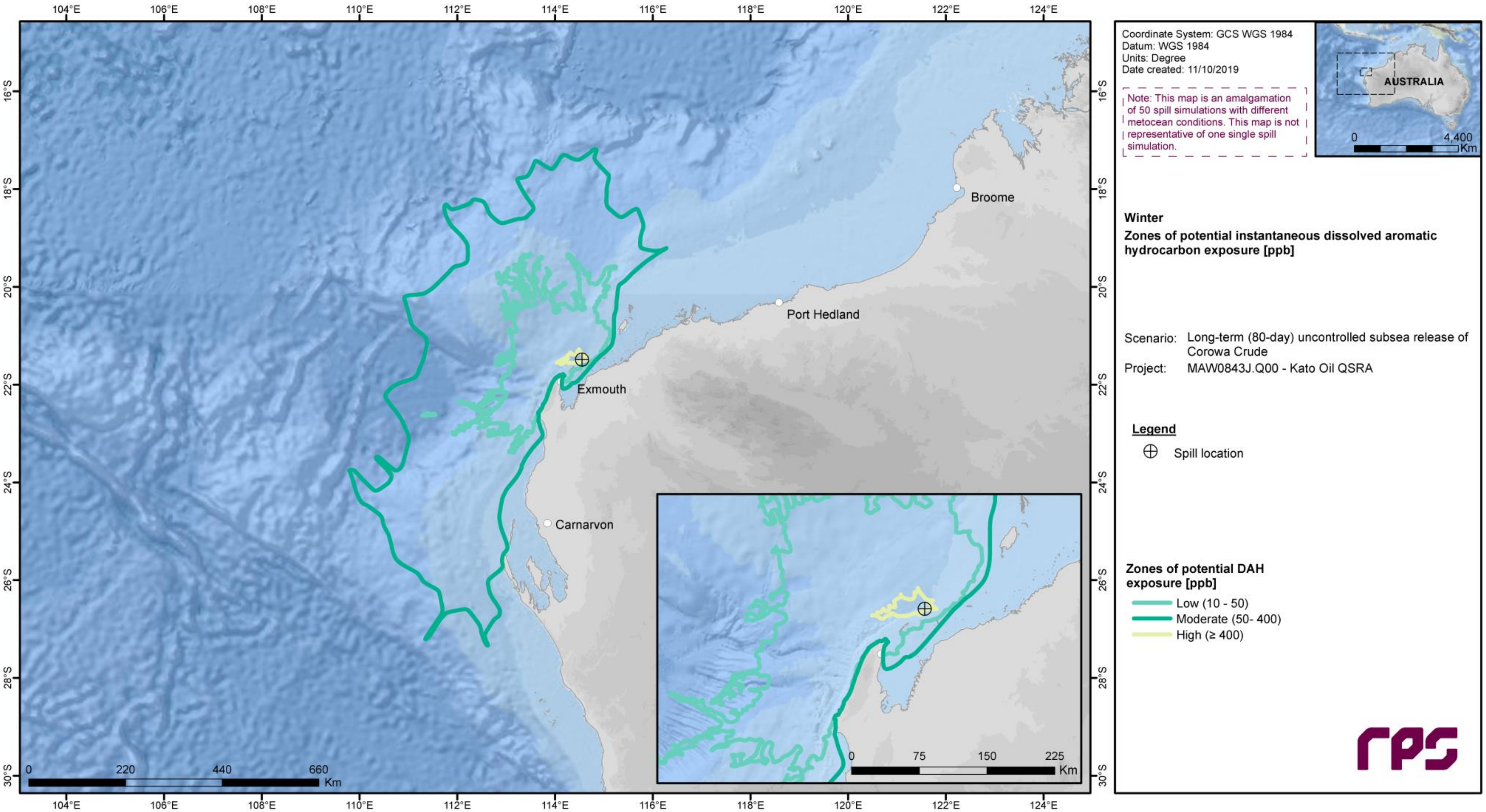


Figure 3.28 Predicted zones of potential instantaneous dissolved aromatic hydrocarbon exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in winter months.

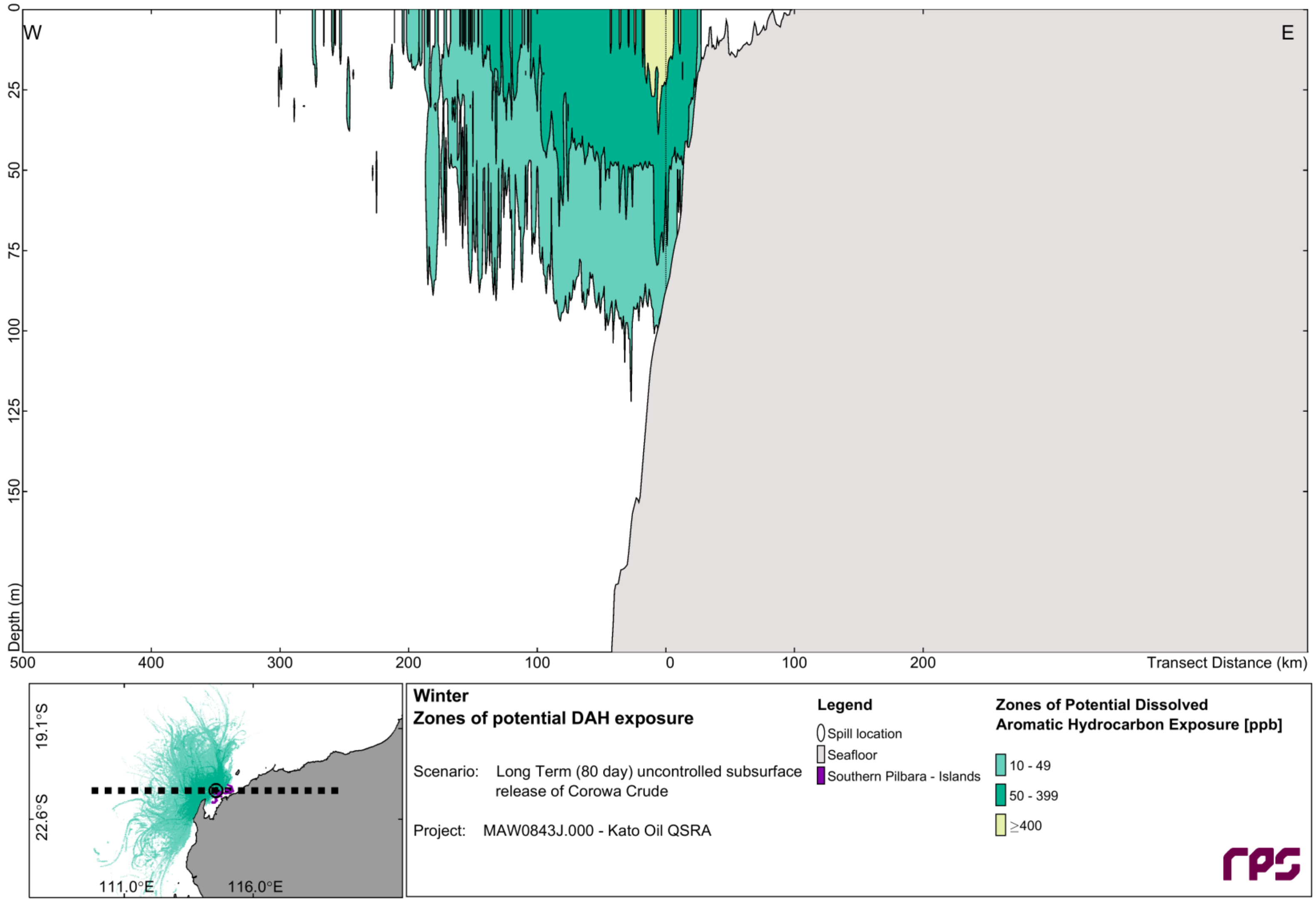


Figure 3.29 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Corowa Crude within the Corowa field, commencing in the winter season. The results were calculated from 50 spill trajectories.

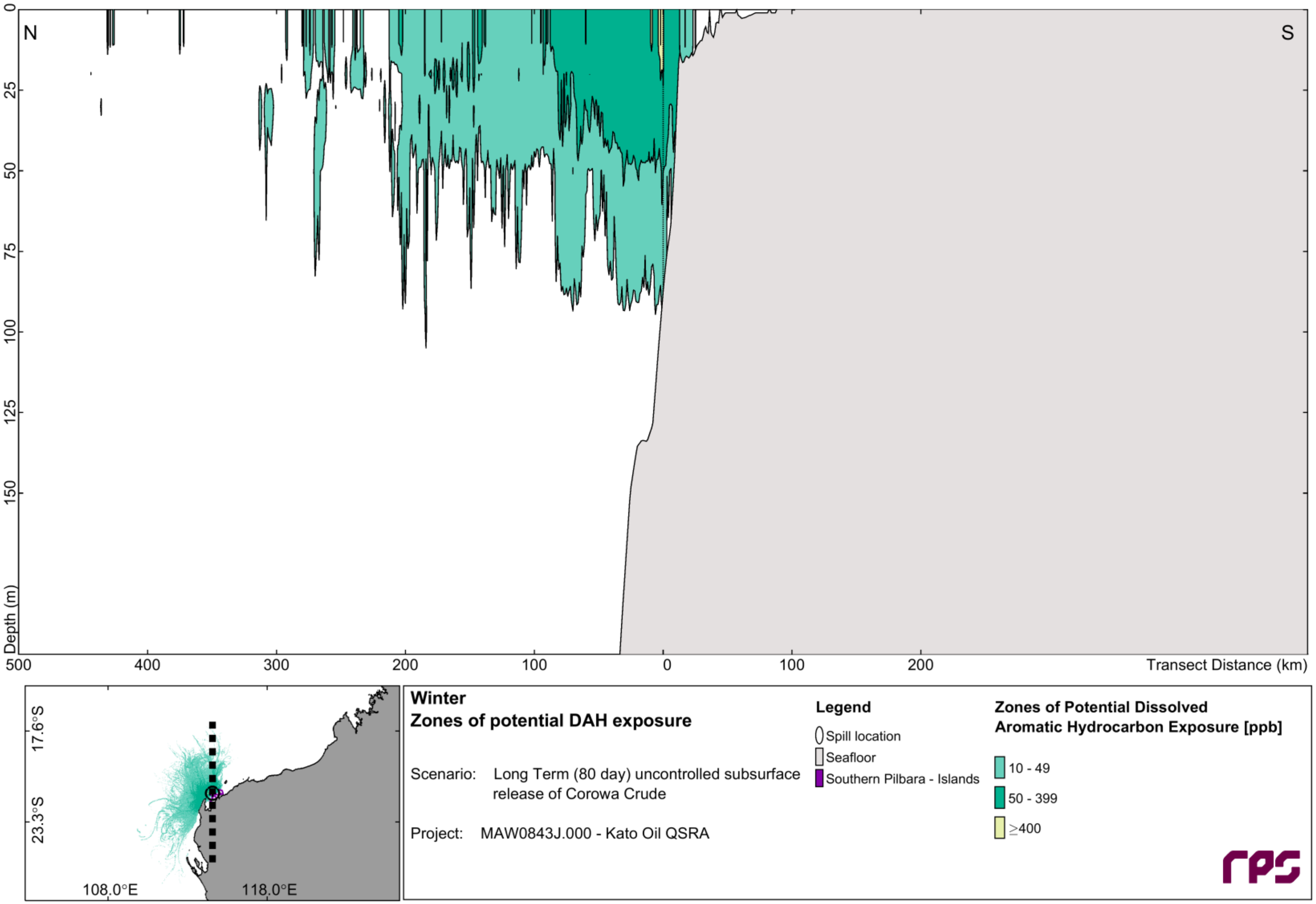


Figure 3.30 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Corowa Crude within the Corowa field, commencing in the winter season. The results were calculated from 50 spill trajectories.

3.2.3.3.5 Dissolved Aromatic Hydrocarbons Exposure Outcomes

Table 3.14 Expected time-integrated dissolved aromatic hydrocarbons exposure outcomes at sensitive receptors resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in winter months.

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	Abrolhos Islands	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
	Barrow Island	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Lacepede Islands	Probability (%) >960	NC	BS	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	BS	BS	BS	BS	BS
	Lowendal Islands	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS	BS
	Montebello Islands	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Sandy Islet	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	Probability (%) >960	2	2	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	1,216	1,102	391	BS	BS	BS
	Dampier Archipelago	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Exmouth Gulf South East	Probability (%) >960	NC	BS	BS	BS	BS	BS
	Probability (%) >4,800	NC	BS	BS	BS	BS	BS
	Probability (%) >38,400	NC	BS	BS	BS	BS	BS
	Maximum Integrated Exposure	4	BS	BS	BS	BS	BS
Exmouth Gulf West	Probability (%) >960	2	NC	BS	BS	BS	BS
	Probability (%) >4,800	NC	NC	BS	BS	BS	BS
	Probability (%) >38,400	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	1,274	262	BS	BS	BS	BS
Geraldton - Jurien Bay	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Jurien Bay - Yanchep	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Kalbarri - Geraldton	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Karratha-Port Hedland	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >4,800	NC	NC	BS	BS	BS	BS
	Probability (%) >38,400	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
Kimberley Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >4,800	NC	NC	NC	NC	NC	BS
	Probability (%) >38,400	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Middle Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >4,800	NC	NC	BS	BS	BS	BS
	Probability (%) >38,400	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
North Broome Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >4,800	NC	NC	NC	NC	NC	BS

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
	Northern Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
	Perth Northern Coast	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Port Hedland - Eighty Mile Beach	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
	Southern Pilbara - Shoreline	Probability (%) >960	NC	BS	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	19	BS	BS	BS	BS	BS
	Zuytdorp Cliffs - Kalbarri	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
State Marine and National Parks	Barrow Island MMA	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Barrow Islands MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Clerke Reef (Rowley Shoals MP)	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
		Probability (%) >960	NC	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Imperieuse Reef (Rowley Shoals MP)	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Marmion MP	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS	BS
	Montebello Islands MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Muiron Islands MMA	Probability (%) >960	34	4	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	4,094	1,597	948	295	37	BS
	Ningaloo Coast WH	Probability (%) >960	34	12	8	NC	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,834	3,494	2,727	707	95	1
	Ningaloo MP (State)	Probability (%) >960	34	12	8	NC	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,834	3,494	2,727	619	95	NC
	Shark Bay MR	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
	Shark Bay WH	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	109	NC	NC	NC	NC	BS
Australian Marine Parks	Abrolhos MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	5	61	5	2	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Argo-Rowley Terrace MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Carnarvon Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	73	65	123	21	4	NC
Cartier Island MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Dampier MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Eighty Mile Beach MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Gascoyne MP	Probability (%) >960	2	4	2	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	1,778	2,268	1,550	683	95	8
Jurien Bay MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Jurien MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Kimberley MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Mermaid Reef MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Montebello MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	26	37	26	26	6	NC
	Ningaloo MP	Probability (%) >960	12	4	4	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2,626	1,686	1,908	707	78	1
	Perth Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Shark Bay MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	89	83	81	37	11	NC
	Two Rocks MP	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	100	32	8	NC	NC	NC
		Probability (%) >4,800	8	2	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,480	7,648	2,977	626	104	NC
	Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Ashmore Reef and Cartier Island and surrounding	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Commonwealth Waters KEF	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	98	20	10	2	NC	NC
	Probability (%) >4,800	2	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	5,735	4,425	2,522	1,403	102	7
Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Continental Slope Demersal Fish Communities KEF	Probability (%) >960	12	8	4	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	2,976	2,982	2,506	861	94	3
Exmouth Plateau KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	393	435	345	278	30	3
Glomar Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >4,800	NC	NC	NC	NC	NC	BS
	Probability (%) >38,400	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	4	NC	NC	NC	NC
	Probability (%) >960	NC	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Wallaby Saddle KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1	36	5	1	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	49	56	48	17	6	NC
	Western Rock Lobster KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Biologically Important Areas	Dolphins BIA	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Dugong BIA	Probability (%) >960	34	12	8	NC	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,834	3,494	2,727	619	95	NC
	Marine Turtle BIA	Probability (%) >960	100	38	10	2	NC	NC
		Probability (%) >4,800	74	4	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,564	12,477	4,525	1,403	184	13
	Seabirds BIA	Probability (%) >960	100	38	10	2	NC	NC
		Probability (%) >4,800	74	4	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,564	12,477	4,525	1,403	184	13
	Seals BIA	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Sharks BIA	Probability (%) >960	100	38	10	2	NC	NC
		Probability (%) >4,800	74	4	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,564	12,477	4,525	1,403	184	13
	Whales BIA	Probability (%) >960	100	38	10	2	NC	NC
		Probability (%) >4,800	74	4	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,564	12,477	4,525	1,403	184	13
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	10	6	2	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2,789	2,055	1,723	861	146	5
	Southern Bluefin Tuna Fishery	Probability (%) >960	100	38	10	2	NC	NC
		Probability (%) >4,800	74	4	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,564	12,477	4,525	1,403	184	13
	Western Skipjack Fishery	Probability (%) >960	100	38	10	2	NC	NC
		Probability (%) >4,800	74	4	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,564	12,477	4,525	1,403	184	13
	Western Tuna and Billfish Fishery	Probability (%) >960	100	38	10	2	NC	NC
		Probability (%) >4,800	74	4	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,564	12,477	4,525	1,403	184	13
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Rankin Bank	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS	BS
	Scott Reef North	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Scott Reef South	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Seringapatam Reef	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Woodbine Bank	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >4,800	NC	NC	NC	NC	NC	BS
	Probability (%) >38,400	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

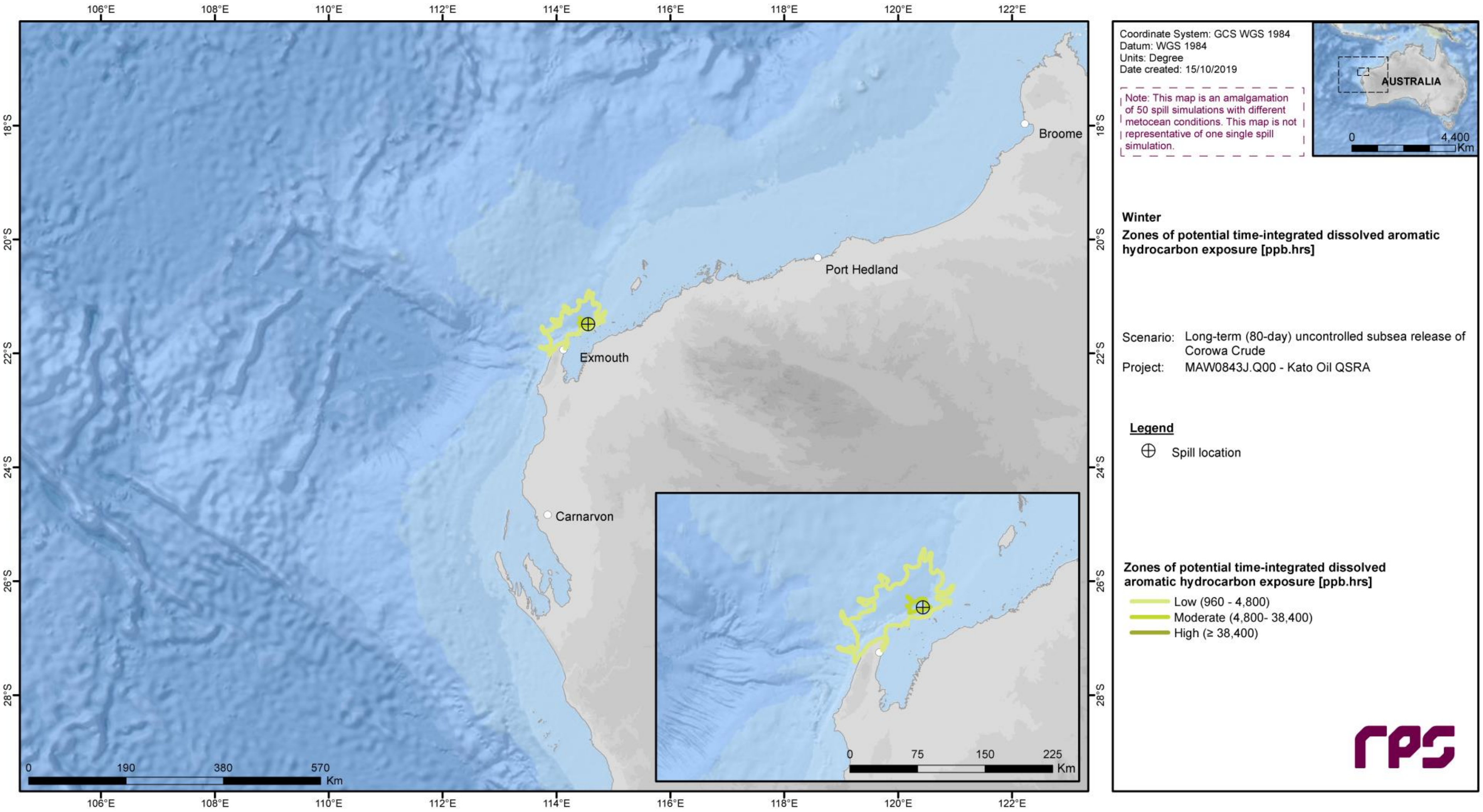


Figure 3.31 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in winter months.

3.2.3.4 Transitional

3.2.3.4.1 Floating and Shoreline Oil

Table 3.15 Expected floating and shoreline oil outcomes at sensitive receptors resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in transitional months.

Receptors		Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
Islands	Abrolhos Islands	<2	<2	<2	NC	NC	NC	8	2	<2	1,324	1,357	NC	4.5	145	<1	9	<1	25	<1	2	NC	NC
	Barrow Island	<2	<2	<2	NC	NC	NC	6	<2	<2	1,501	NC	NC	1.6	39	<1	2	<1	6	NC	NC	NC	NC
	Lacepede Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Lowendal Islands	<2	<2	<2	NC	NC	NC	2	<2	<2	2,239	NC	NC	0.2	12	<1	<1	<1	1	NC	NC	NC	NC
	Montebello Islands	<2	<2	<2	NC	NC	NC	2	<2	<2	1,563	NC	NC	0.4	15	<1	<1	<1	2	NC	NC	NC	NC
	Sandy Islet	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	46	16	14	36	37	47	54	26	16	38	61	91	753	6,590	17	146	4	22	2	10	<1	4
Coastlines	Dampier Archipelago	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Exmouth Gulf South East	<2	<2	<2	NC	NC	NC	2	<2	<2	1,012	NC	NC	0.3	17	<1	<1	<1	1	NC	NC	NC	NC
	Exmouth Gulf West	2	<2	<2	142	NC	NC	30	<2	<2	179	NC	NC	12	77	<1	3	2	8	NC	NC	NC	NC
	Geraldton - Jurien Bay	<2	<2	<2	NC	NC	NC	4	<2	<2	1,978	NC	NC	0.6	16	<1	<1	<1	2	NC	NC	NC	NC
	Jurien Bay - Yanchep	<2	<2	<2	NC	NC	NC	8	<2	<2	1,542	NC	NC	2.4	43	<1	4	<1	7	NC	NC	NC	NC
	Kalbarri - Geraldton	<2	<2	<2	NC	NC	NC	2	<2	<2	1,555	NC	NC	0.3	18	<1	<1	<1	2	NC	NC	NC	NC
	Karratha-Port Hedland	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Kimberley Coast	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.2	8.6	<1	<1	NC	NC	NC	NC	NC	NC
	North Broome Coast	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Perth Northern Coast	<2	<2	<2	NC	NC	NC	2	<2	<2	2,153	NC	NC	0.4	14	<1	<1	<1	1	NC	NC	NC	NC
	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Shoreline	<2	<2	<2	NC	NC	NC	4	<2	<2	1,351	NC	NC	0.9	29	<1	<1	<1	2	NC	NC	NC	NC
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.2	9.1	<1	<1	NC	NC	NC	NC	NC	NC
State Marine and National Parks	Barrow Island MMA	2	<2	<2	1,786	NC	NC	4	<2	<2	1,501	NC	NC	0.6	25	<1	<1	<1	2	NC	NC	NC	NC
	Barrow Islands MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NA	NA	NA	NA	NA	NA
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Marmion MP*	<2	<2	<2	NC	NC	NC	<2	<2	<2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

	Receptors	Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
	Montebello Islands MP*	6	<2	<2	1,794	NC	NC	2	<2	<2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Muiron Islands MMA	100	30	8	18	70	123	74	52	14	34	97	234	666	8,369	45	355	7	13	5	13	<1	8
	Ningaloo Coast WH	88	22	10	32	34	36	72	56	26	71	84	104	1,040	6,888	105	485	32	91	15	45	3	15
	Ningaloo MP (State)	76	16	<2	46	54	NC	72	56	26	71	84	104	1,040	6,888	105	485	32	91	15	45	3	15
	Shark Bay MR	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Shark Bay WH	<2	<2	<2	NC	NC	NC	2	<2	<2	1,127	NC	NC	0.3	16	<1	2	<1	7	NC	NC	NC	NC
Australian Marine Parks	Abrolhos MP*	6	<2	<2	549	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Argo-Rowley Terrace MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carnarvon Canyon MP*	22	<2	<2	335	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Cartier Island MP	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dampier MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Eighty Mile Beach MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Gascoyne MP*	86	28	14	40	69	223	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jurien Bay MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jurien MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Kimberley MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Reef MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Montebello MP*	6	<2	<2	1,699	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ningaloo MP*	88	22	10	32	34	36	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Perth Canyon MP*	16	<2	<2	1,672	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Shark Bay MP*	22	14	4	396	541	549	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Two Rocks MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF*	100	84	52	8	9	14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ancient Coastline at 90-120m Depth Contour KEF*	14	<2	<2	2,022	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF*†	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF*	100	60	24	16	17	25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

	Receptors	Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m^2)		Maximum accumulated volume (m^3) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Continental Slope Demersal Fish Communities KEF*	90	28	14	33	101	106	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Exmouth Plateau KEF*	46	6	<2	147	1,077	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Glomar Shoals KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF*†	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF*	16	<2	<2	840	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF*†	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wallaby Saddle KEF*	4	<2	<2	631	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Demersal Slope and associated Fish Communities KEF*	16	<2	<2	432	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Rock Lobster KEF*	14	<2	<2	1,954	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Biologically Important Areas	Dolphins BIA*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dugong BIA*	76	8	8	42	43	45	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marine Turtle BIA*†	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seabirds BIA*†	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seals BIA*†	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sharks BIA*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Whales BIA*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	North-West Slope Trawl Fishery*	90	20	10	44	107	109	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Southern Bluefin Tuna Fishery*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Skipjack Fishery*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Tuna and Billfish Fishery*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Oth er	Eugene McDermott Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Receptors	Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time (hours) to receptor for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
Rankin Bank*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scott Reef North*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scott Reef South*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Seringapatam Reef*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Woodbine Bank*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NC: No contact to receptor predicted for specified threshold.

* Floating oil will not accumulate on submerged features and at open ocean locations. NA: Not applicable.

† Receptor is considered as submerged, any accumulation occurring on emerged features within this receptor is captured under the associated shoreline receptor in the table.

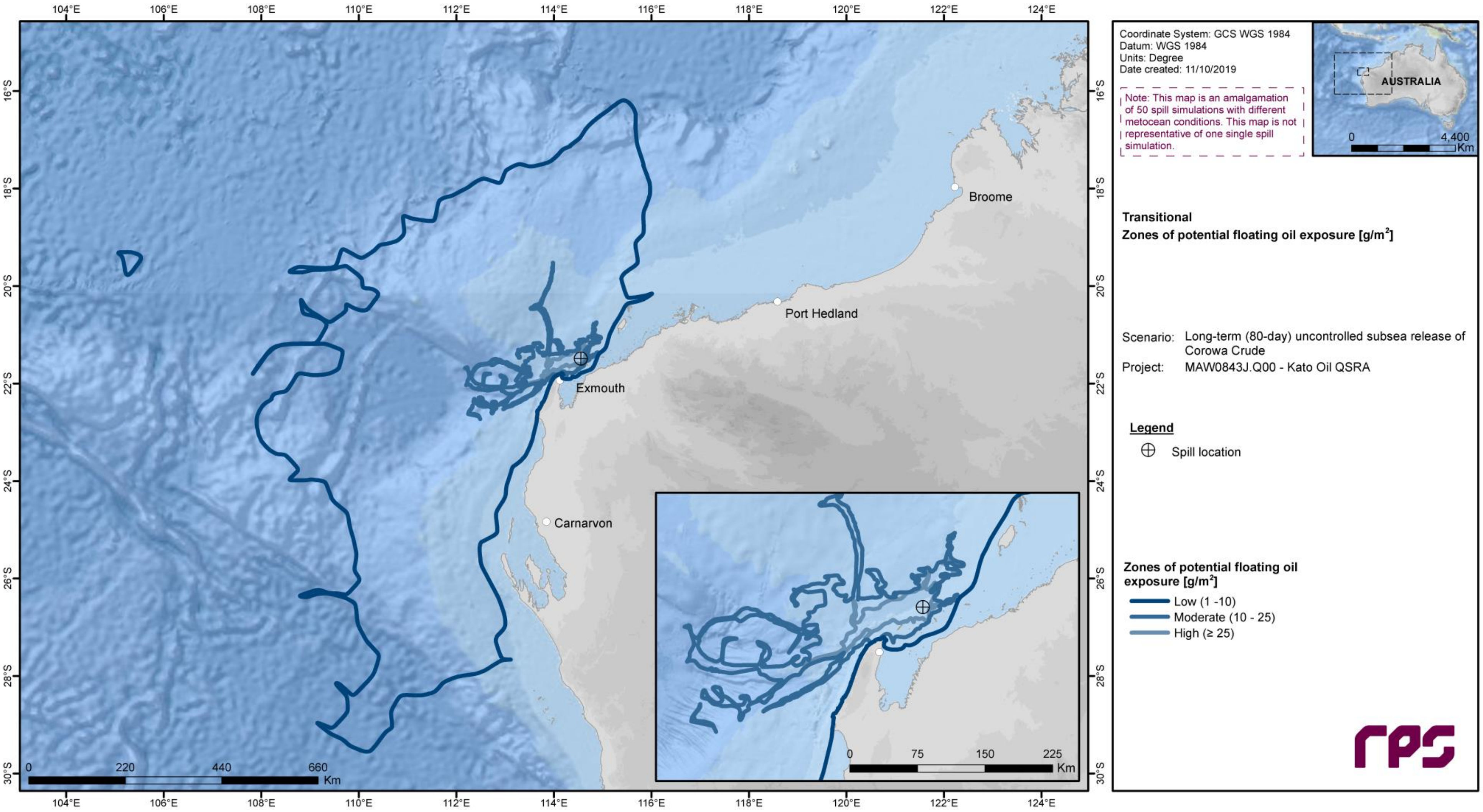


Figure 3.32 Predicted zones of potential floating oil exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in transitional months.

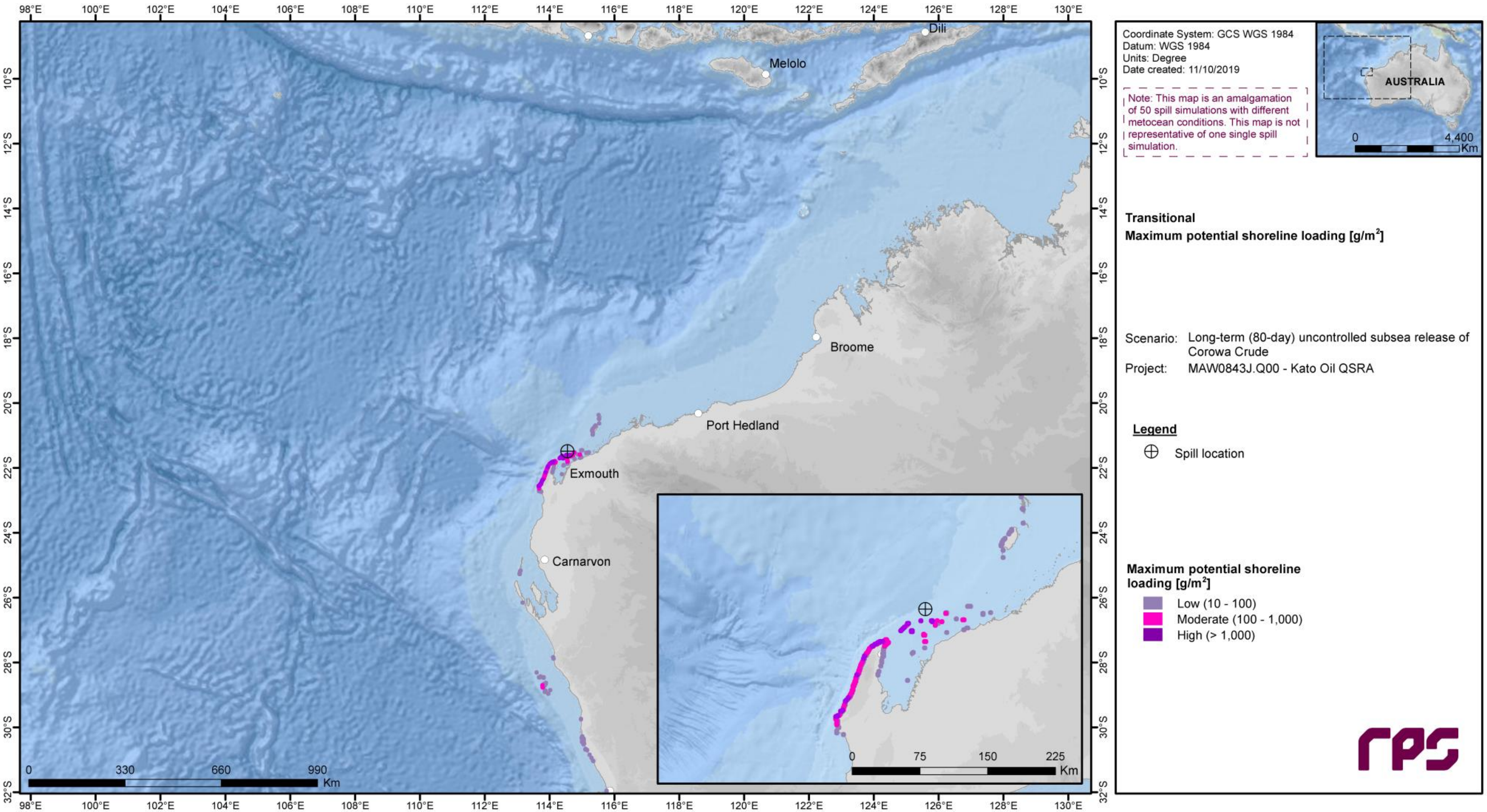


Figure 3.33 Predicted maximum potential shoreline loading resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in transitional months.

3.2.3.4.2 Entrained Oil - Instantaneous

Table 3.16 Expected instantaneous entrained oil outcomes at sensitive receptors resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in transitional months.

Receptors		Probability (%) of entrained hydrocarbon concentration contact at			Minimum time (hour) to receptor waters at			Maximum entrained hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Abrolhos Islands	30	2	<2	763	1,338	NC	16	557
	Barrow Island	28	2	<2	443	722	NC	13	197
	Lacepede Islands	<2	<2	<2	NC	NC	NC	NC	NC
	Lowendal Islands	6	2	<2	728	898	NC	3	118
	Montebello Islands	22	6	<2	491	924	NC	13	135
	Sandy Islet	<2	<2	<2	NC	NC	NC	<1	2
	Southern Pilbara - Islands	98	88	30	34	46	50	785	6,076
Coastlines	Dampier Archipelago	<2	<2	<2	NC	NC	NC	<1	2
	Exmouth Gulf South East	26	<2	<2	431	NC	NC	10	88
	Exmouth Gulf West	88	40	<2	96	110	NC	83	380
	Geraldton - Jurien Bay	10	<2	<2	1,353	NC	NC	3	31
	Jurien Bay - Yanchep	16	<2	<2	1,046	NC	NC	5	98
	Kalbarri - Geraldton	4	<2	<2	1,562	NC	NC	<1	16
	Karratha-Port Hedland	<2	<2	<2	NC	NC	NC	NC	NC
	Kimberley Coast	<2	<2	<2	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<1	10
	North Broome Coast	<2	<2	<2	NC	NC	NC	NC	NC
	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<1	3
	Perth Northern Coast	20	4	<2	1,328	1,845	NC	12	197
	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC	NC	NC	NC
	Southern Pilbara - Shoreline	32	8	<2	428	1,149	NC	19	178
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC	NC	<1	8
State Marine and National Parks	Barrow Island MMA	28	8	<2	405	715	NC	16	284
	Barrow Islands MP	28	4	<2	645	716	NC	14	193
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	<1	2
	Imperieuse Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	<1	<1
	Marmion MP	4	<2	<2	1,553	NC	NC	3	44
	Montebello Islands MP	24	8	<2	361	504	NC	20	229
	Muiron Islands MMA	100	100	88	16	18	24	2,583	6,636
	Ningaloo Coast WH	100	102	82	28	29	30	2,465	10,766
	Ningaloo MP (State)	100	96	76	36	37	50	2,029	10,766
	Shark Bay MR	6	<2	<2	651	NC	NC	2	17
	Shark Bay WH	28	<2	<2	474	NC	NC	10	78
Australian Marine Parks	Abrolhos MP	68	26	<2	401	461	NC	42	501
	Argo-Rowley Terrace MP	26	4	<2	573	606	NC	11	323
	Carnarvon Canyon MP	88	34	4	228	321	552	147	1,173
	Cartier Island MP	<2	<2	<2	NC	NC	NC	<1	2
	Dampier MP	<2	<2	<2	NC	NC	NC	<1	2
	Eighty Mile Beach MP	<2	<2	<2	NC	NC	NC	NC	NC
	Gascoyne MP	102	102	84	38	39	48	2,518	11,981
	Jurien Bay MP	16	<2	<2	1,154	NC	NC	5	98
	Jurien MP	26	2	<2	892	1,470	NC	8	141
	Kimberley MP	<2	<2	<2	NC	NC	NC	<1	3
	Mermaid Reef MP	<2	<2	<2	NC	NC	NC	<1	4
	Montebello MP	44	16	<2	334	347	NC	49	654
	Ningaloo MP	102	102	82	28	29	30	2,465	9,346
	Perth Canyon MP	40	14	<2	912	1,572	NC	22	286
	Shark Bay MP	74	42	<2	186	204	NC	90	730
	Two Rocks MP	14	<2	<2	1,157	NC	NC	5	82
Key Eco logi	Ancient Coastline at 125m Depth Contour KEF	102	102	102	5	6	8	7,801	18,130

Receptors		Probability (%) of entrained hydrocarbon concentration contact at			Minimum time (hour) to receptor waters at			Maximum entrained hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
	Ancient Coastline at 90-120m Depth Contour KEF	34	2	<2	716	1,202	NC	15	345
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	<2	<2	<2	NC	NC	NC	<1	2
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	6	<2	<2	1,309	NC	NC	3	64
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	102	102	102	10	10	13	6,489	15,468
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	34	2	<2	694	1,306	NC	15	460
	Continental Slope Demersal Fish Communities KEF	100	102	100	31	33	44	2,999	15,284
	Exmouth Plateau KEF	100	92	16	134	138	185	387	2,210
	Glomar Shoals KEF §	<2	<2	<2	1,847	2,015	NC	7	10
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	<2	<2	<2	NC	NC	NC	<1	5
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	46	16	<2	429	708	NC	36	312
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	2	<2	<2	2,040	NC	NC	<1	12
	Wallaby Saddle KEF	64	6	<2	423	503	NC	25	195
	Western Demersal Slope and associated Fish Communities KEF	60	40	<2	264	360	NC	89	572
	Western Rock Lobster KEF	34	2	<2	707	1,197	NC	15	358
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC	NC	NC	NC
	Dugong BIA	100	100	68	38	40	48	2,029	10,766
	Marine Turtle BIA	100	100	100	1	1	2	21,613	45,443
	Seabirds BIA	100	100	100	1	1	2	21,613	45,443
	Seals BIA	30	4	<2	757	1,325	NC	16	557
	Sharks BIA	100	100	100	1	1	2	21,613	45,443
	Whales BIA	100	100	100	1	1	2	21,613	45,443
Fisheries	North-West Slope Trawl Fishery	100	100	100	33	38	48	2,999	15,284
	Southern Bluefin Tuna Fishery	100	100	100	1	1	2	21,613	45,443
	Western Skipjack Fishery	100	100	100	1	1	2	21,613	45,443
	Western Tuna and Billfish Fishery	100	100	100	1	1	2	21,613	45,443
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal §	<2	<2	<2	NC	NC	NC	NC	NC
	Rankin Bank §	2	<2	<2	428	NC	NC	6	13
	Scott Reef North	<2	<2	<2	NC	NC	NC	<1	6
	Scott Reef South	<2	<2	<2	NC	NC	NC	<1	2
	Seringapatam Reef	2	<2	<2	2,040	NC	NC	<1	11
	Woodbine Bank	<2	<2	<2	NC	NC	NC	<1	2

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature

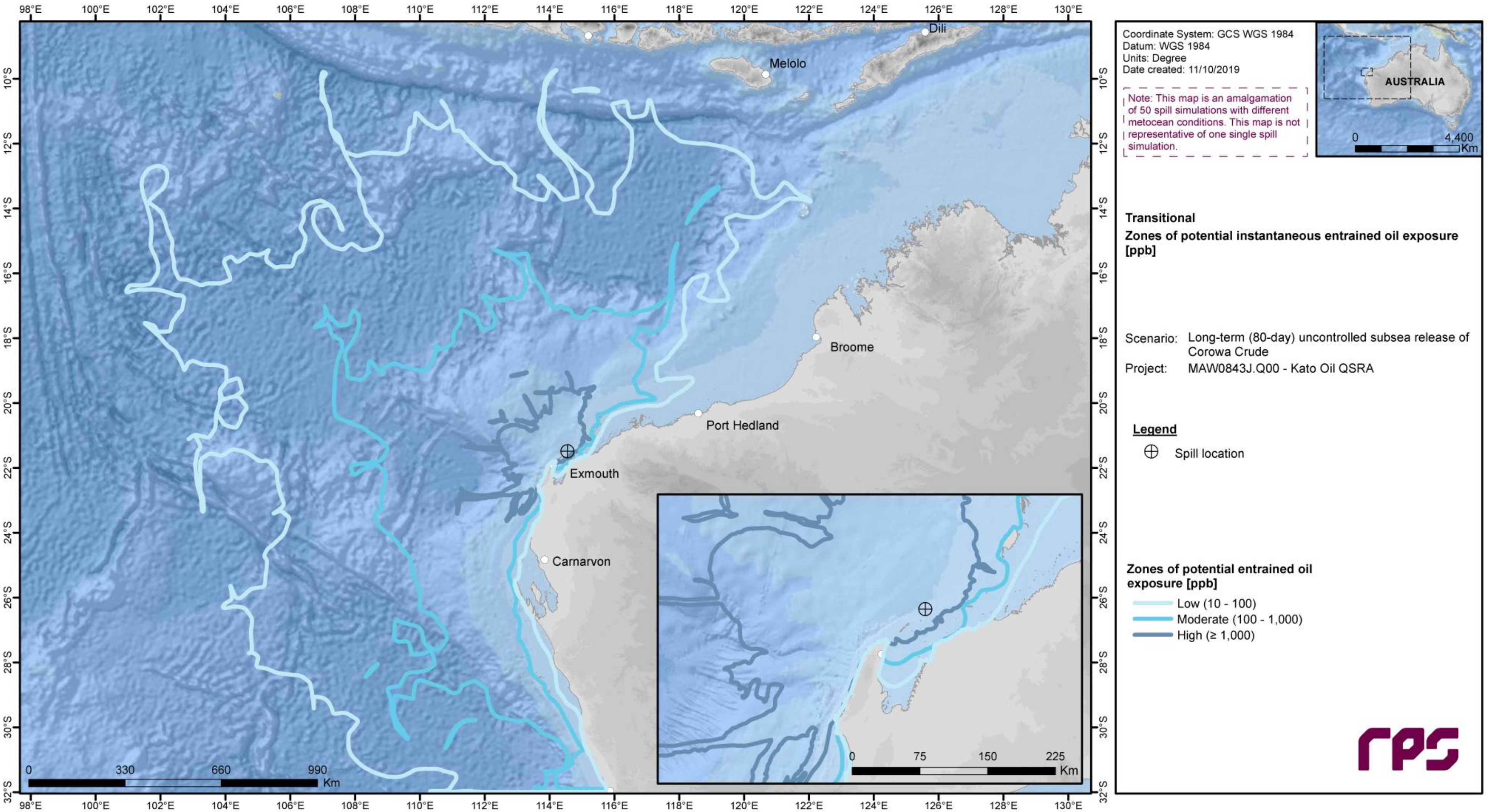


Figure 3.34 Predicted zones of potential instantaneous entrained oil exposure resulting from a long-term (80 day) subsea release of Corowa Light Crude within the Corowa field, starting in transitional months.

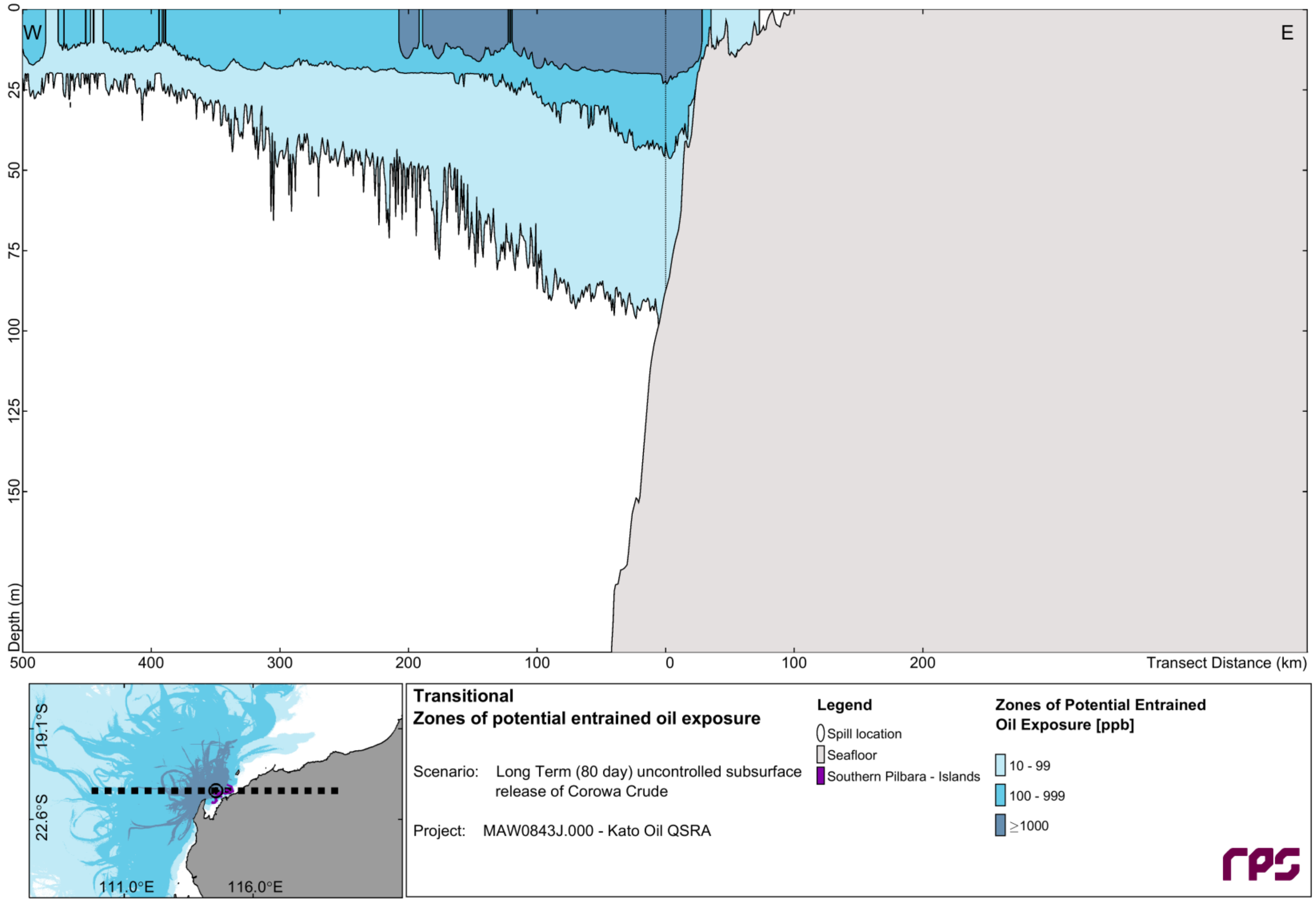


Figure 3.35 East-West cross-section transect of predicted maximum entrained oil concentration resulting from a long-term (80-day) subsea release of Corowa Crude within the Corowa field, commencing in the transitional period. The results were calculated from 50 spill trajectories.

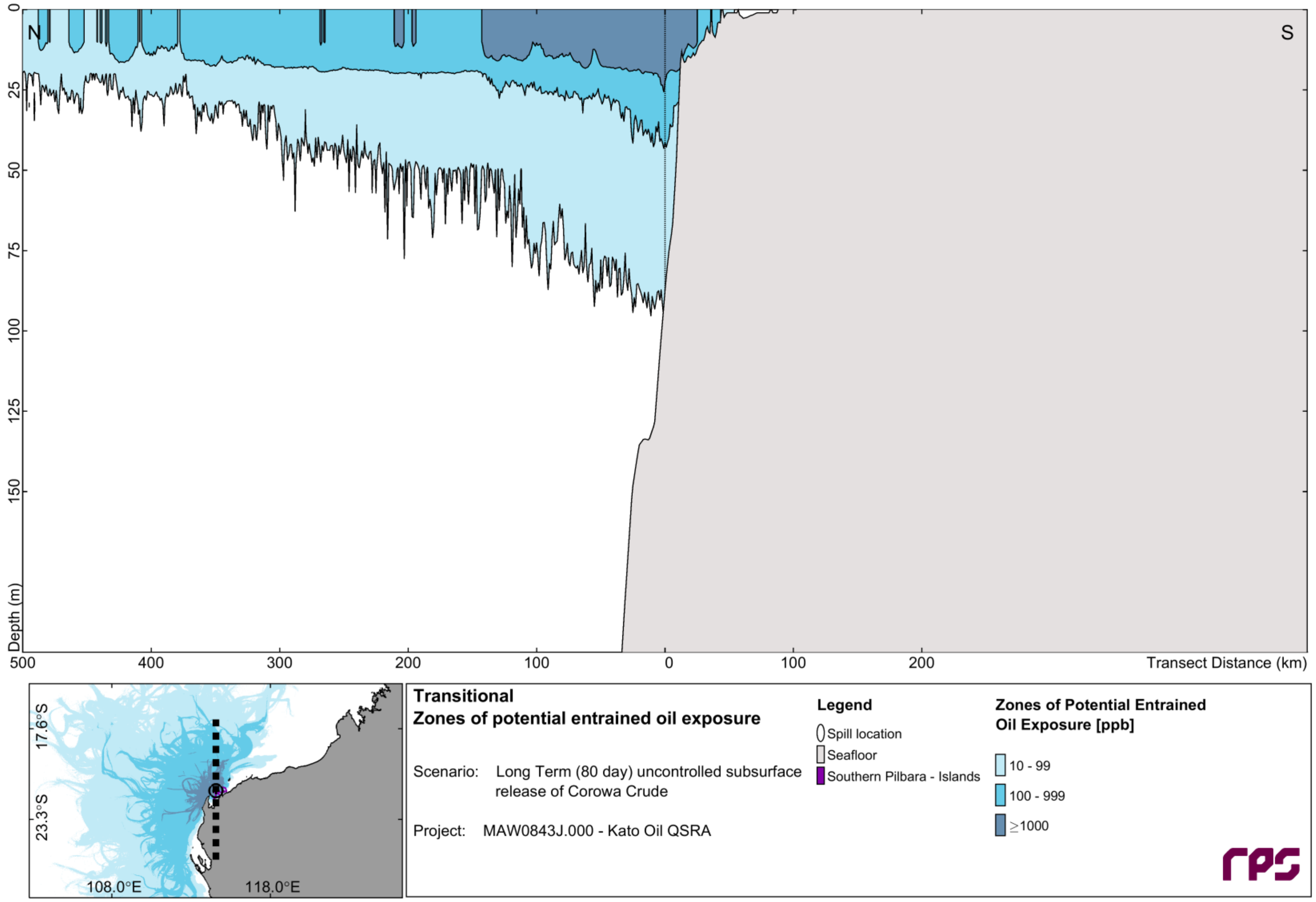


Figure 3.36 North-South cross-section transect of predicted maximum entrained oil concentration resulting from a long-term (80-day) subsea release of Corowa Crude within the Corowa field, commencing in the transitional period. The results were calculated from 50 spill trajectories.

3.2.3.4.3 Entrained Oil - Exposure

Table 3.17 Expected time-integrated entrained oil exposure outcomes at sensitive receptors resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in transitional months.

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	Abrolhos Islands	Probability (%) >960	16	NC	NC	NC	NC	BS
		Probability (%) >9,600	2	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	24,681	544	132	57	17	BS
	Barrow Island	Probability (%) >960	10	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	8,692	520	104	9	BS	BS
	Lacepede Islands	Probability (%) >960	NC	BS	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	BS	BS	BS	BS	BS
	Lowendal Islands	Probability (%) >960	2	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	1,897	52	1	BS	BS	BS
	Montebello Islands	Probability (%) >960	10	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	3,738	344	51	4	BS	BS
	Sandy Islet	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	10	4	1	NC	NC	NC
	Southern Pilbara - Islands	Probability (%) >960	84	36	4	BS	BS	BS
		Probability (%) >9,600	44	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	95,517	5,043	1,749	BS	BS	BS
Coastlines	Dampier Archipelago	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	4	4	NC	NC	BS	BS
	Exmouth Gulf South East	Probability (%) >960	8	BS	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS	BS

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Probability (%) >96,000	NC	BS	BS	BS	BS	BS
	Maximum Integrated Exposure	1,993	BS	BS	BS	BS	BS
Exmouth Gulf West	Probability (%) >960	62	NC	BS	BS	BS	BS
	Probability (%) >9,600	6	NC	BS	BS	BS	BS
	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	26,932	478	BS	BS	BS	BS
Geraldton - Jurien Bay	Probability (%) >960	2	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	1,121	47	47	11	BS	BS
Jurien Bay - Yanchep	Probability (%) >960	6	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	5,328	210	68	9	BS	BS
Kalbarri - Geraldton	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	507	57	19	1	BS	BS
Karratha-Port Hedland	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >9,600	NC	NC	BS	BS	BS	BS
	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
Kimberley Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >9,600	NC	NC	NC	NC	NC	BS
	Probability (%) >96,000	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Middle Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >9,600	NC	NC	BS	BS	BS	BS
	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	178	5	BS	BS	BS	BS
North Broome Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >9,600	NC	NC	NC	NC	NC	BS
	Probability (%) >96,000	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Northern Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >9,600	NC	NC	BS	BS	BS	BS
	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	11	2	BS	BS	BS	BS

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Perth Northern Coast	Probability (%) >960	18	2	NC	NC	BS	BS
		Probability (%) >9,600	2	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	13,840	1,058	107	2	BS	BS
	Port Hedland - Eighty Mile Beach	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
	Southern Pilbara - Shoreline	Probability (%) >960	14	BS	BS	BS	BS	BS
		Probability (%) >9,600	4	BS	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	9,760	BS	BS	BS	BS	BS
	Zuytdorp Cliffs - Kalbarri	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	188	30	11	1	NC	BS
State Marine and National Parks	Barrow Island MMA	Probability (%) >960	12	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	8,181	619	158	21	BS	BS
	Barrow Islands MP	Probability (%) >960	10	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	8,692	404	52	9	BS	BS
	Clerke Reef (Rowley Shoals MP)	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	13	2	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2	NC	NC	NC	NC	NC
	Marmion MP	Probability (%) >960	2	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	3,130	159	15	BS	BS	BS
	Montebello Islands MP	Probability (%) >960	16	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	7,708	475	193	21	BS	BS
	Muiron Islands MMA	Probability (%) >960	98	84	36	2	NC	BS
		Probability (%) >9,600	94	2	NC	NC	NC	BS
		Probability (%) >96,000	10	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	145,327	10,579	2,123	1,033	76	BS
	Ningaloo Coast WH	Probability (%) >960	100	90	80	6	NC	NC
		Probability (%) >9,600	90	28	2	NC	NC	NC
		Probability (%) >96,000	42	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	406,893	22,986	9,855	1,433	230	29
	Ningaloo MP (State)	Probability (%) >960	98	84	80	6	NC	NC
		Probability (%) >9,600	78	28	2	NC	NC	NC
		Probability (%) >96,000	42	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	406,893	22,986	9,855	1,433	230	28
	Shark Bay MR	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	242	107	BS	BS	BS	BS
	Shark Bay WH	Probability (%) >960	8	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	1,157	133	135	71	17	BS
Australian Marine Parks	Abrolhos MP	Probability (%) >960	40	2	NC	NC	NC	NC
		Probability (%) >9,600	4	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	18,888	961	176	65	26	10
	Argo-Rowley Terrace MP	Probability (%) >960	8	NC	NC	NC	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	12,721	876	234	75	7	1
	Carnarvon Canyon MP	Probability (%) >960	50	10	NC	NC	NC	NC
		Probability (%) >9,600	14	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	14,543	1,363	305	92	29	4
	Cartier Island MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	5	1	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Dampier MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	1	NC	NC	NC	BS	BS
Eighty Mile Beach MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Gascoyne MP	Probability (%) >960	100	94	30	12	NC	NC
	Probability (%) >9,600	96	16	4	NC	NC	NC
	Probability (%) >96,000	12	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	237,859	31,496	10,431	2,266	179	24
Jurien Bay MP	Probability (%) >960	6	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	5,457	244	69	12	BS	BS
Jurien MP	Probability (%) >960	2	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	5,148	232	90	25	14	5
Kimberley MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	7	NC	NC	NC	NC	NC
Mermaid Reef MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	37	4	NC	NC	NC	NC
Montebello MP	Probability (%) >960	22	2	NC	NC	NC	NC
	Probability (%) >9,600	6	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	18,740	1,472	394	145	35	NC
Ningaloo MP	Probability (%) >960	100	90	30	NC	NC	NC
	Probability (%) >9,600	90	4	NC	NC	NC	NC
	Probability (%) >96,000	6	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	158,530	10,094	3,112	790	83	29
Perth Canyon MP	Probability (%) >960	28	2	NC	NC	NC	NC
	Probability (%) >9,600	10	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	21,218	1,605	340	88	20	8
	Shark Bay MP	Probability (%) >960	54	2	NC	NC	NC	NC
		Probability (%) >9,600	8	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	19,890	1,034	273	165	87	38
	Two Rocks MP	Probability (%) >960	2	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	3,710	186	55	16	9	BS
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	100	100	70	6	NC	NC
		Probability (%) >9,600	100	54	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	448,744	42,997	10,766	2,179	266	26
	Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	28	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	4,856	299	116	66	23	5
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8	4	3	NC	NC	NC
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	Probability (%) >960	4	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,235	88	31	6	1	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	100	100	62	6	NC	NC
		Probability (%) >9,600	100	32	NC	NC	NC	NC
		Probability (%) >96,000	78	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	374,493	27,794	8,384	1,392	111	22
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	14	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	6,368	328	100	53	23	7
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	100	100	30	12	NC	NC
		Probability (%) >9,600	100	16	4	NC	NC	NC
		Probability (%) >96,000	18	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	319,803	31,496	10,431	2,266	120	21

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Exmouth Plateau KEF	Probability (%) >960	94	40	4	NC	NC	NC
		Probability (%) >9,600	44	NC	NC	NC	NC	NC
		Probability (%) >96,000	2	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	102,842	6,354	1,210	397	72	14
	Glomar Shoals KEF	Probability (%) >960	6	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	4,940	255	75	10	NC	BS
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	60	7	1	NC	NC	NC
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	28	2	NC	NC	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	18,742	1,605	334	87	20	6
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	265	32	14	7	1	NC
	Wallaby Saddle KEF	Probability (%) >960	32	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	5,467	221	82	56	11	4
	Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	48	2	NC	NC	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	21,218	1,605	340	87	24	9
	Western Rock Lobster KEF	Probability (%) >960	28	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8,642	607	135	79	23	7
Biologically Important Areas	Dolphins BIA	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Dugong BIA	Probability (%) >960	100	84	80	6	NC	NC
		Probability (%) >9,600	82	28	2	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >96,000	42	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	406,893	22,986	9,855	1,433	230	25
	Marine Turtle BIA	Probability (%) >960	100	100	80	12	NC	NC
		Probability (%) >9,600	100	68	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,368,824	50,320	10,950	2,608	266	29
	Seabirds BIA	Probability (%) >960	100	100	80	12	NC	NC
		Probability (%) >9,600	100	68	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,368,824	50,320	10,950	2,608	266	29
	Seals BIA	Probability (%) >960	18	2	NC	NC	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	24,681	1,058	135	57	23	5
	Sharks BIA	Probability (%) >960	100	100	80	12	NC	NC
		Probability (%) >9,600	100	68	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,368,824	50,320	10,950	2,608	266	27
	Whales BIA	Probability (%) >960	100	100	80	12	NC	NC
		Probability (%) >9,600	100	68	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,368,824	50,320	10,950	2,608	266	44
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	100	100	42	2	NC	NC
		Probability (%) >9,600	100	8	NC	NC	NC	NC
		Probability (%) >96,000	18	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	319,803	27,007	6,678	1,150	99	21
	Southern Bluefin Tuna Fishery	Probability (%) >960	100	100	80	12	NC	NC
		Probability (%) >9,600	100	68	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,368,824	50,320	10,950	2,608	266	44
	Western Skipjack Fishery	Probability (%) >960	100	100	80	12	NC	NC
		Probability (%) >9,600	100	68	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,368,824	50,320	10,950	2,608	266	44
	Western Tuna and Billfish Fishery	Probability (%) >960	100	100	80	12	NC	NC
		Probability (%) >9,600	100	68	4	NC	NC	NC
		Probability (%) >96,000	100	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,368,824	50,320	10,950	2,608	266	44

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Rankin Bank	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	673	96	55	BS	BS	BS
	Scott Reef North	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	128	19	9	7	1	NC
	Scott Reef South	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	18	9	4	1	NC	NC
	Seringapatam Reef	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	229	24	8	3	NC	NC
	Woodbine Bank	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	4	3	2	NC	NC	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

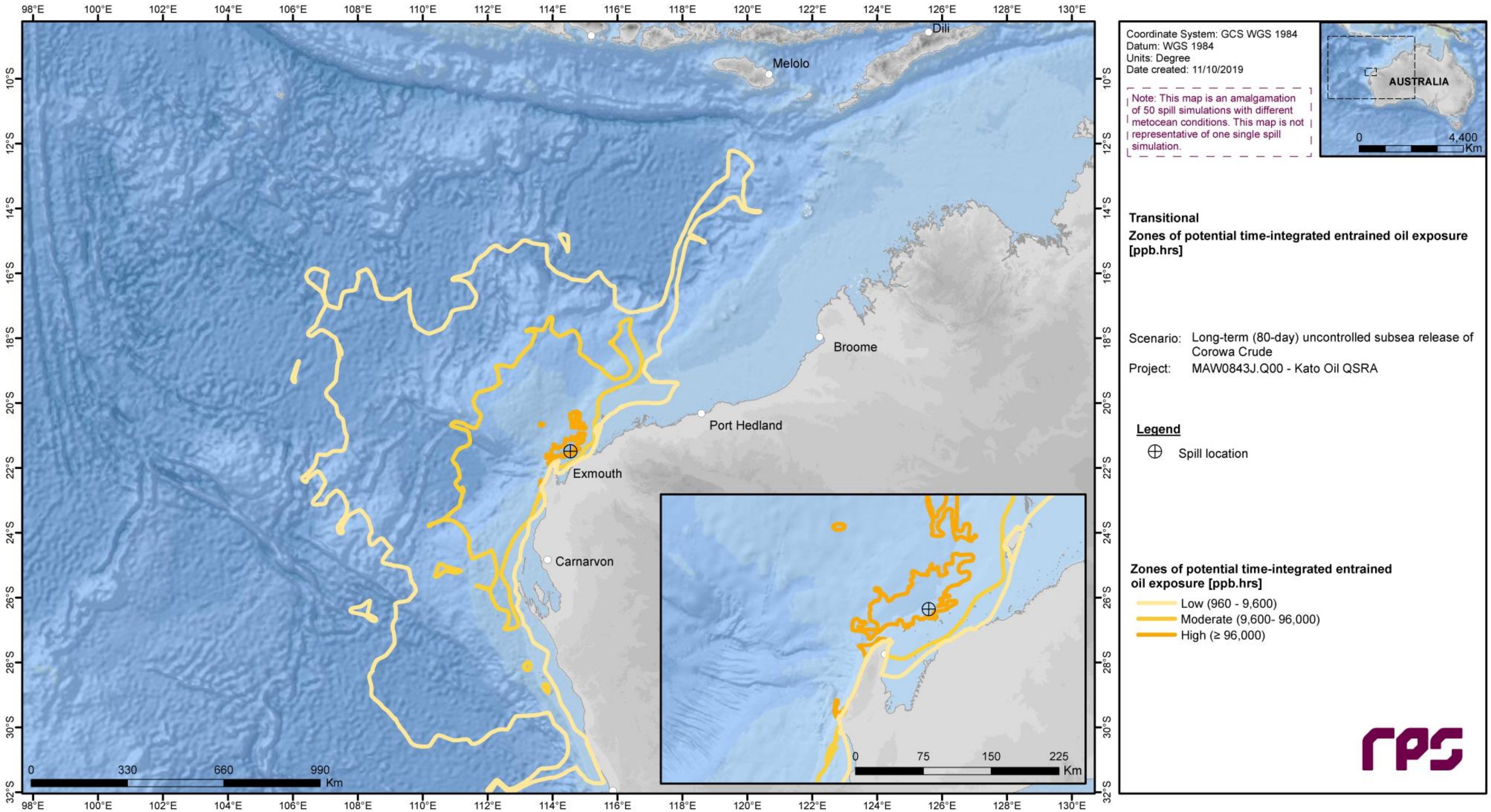


Figure 3.37 Predicted zones of potential time-integrated entrained oil exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in transitional months.

3.2.3.4.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Table 3.18 Expected instantaneous dissolved aromatic hydrocarbons outcomes at sensitive receptors resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in transitional months.

Receptors		Probability (%) of dissolved aromatic concentration			Maximum dissolved aromatic hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Abrolhos Islands	<2	<2	<2	<1	<1
	Barrow Island	<2	<2	<2	<1	<1
	Lacepede Islands	<2	<2	<2	NC	NC
	Lowendal Islands	<2	<2	<2	NC	NC
	Montebello Islands	<2	<2	<2	<1	<1
	Sandy Islet	<2	<2	<2	NC	NC
	Southern Pilbara - Islands	74	30	<2	36	208
Coastlines	Dampier Archipelago	<2	<2	<2	NC	NC
	Exmouth Gulf South East	<2	<2	<2	<1	3
	Exmouth Gulf West	16	2	<2	5	56
	Geraldton - Jurien Bay	<2	<2	<2	NC	NC
	Jurien Bay - Yanchep	<2	<2	<2	NC	NC
	Kalbarri - Geraldton	<2	<2	<2	NC	NC
	Karratha-Port Hedland	<2	<2	<2	NC	NC
	Kimberley Coast	<2	<2	<2	NC	NC
	Middle Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC
	North Broome Coast	<2	<2	<2	NC	NC
	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC
	Perth Northern Coast	<2	<2	<2	NC	NC
	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC
	Southern Pilbara - Shoreline	<2	<2	<2	<1	<1
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC
State Marine and National Parks	Barrow Island MMA	<2	<2	<2	<1	<1
	Barrow Islands MP	<2	<2	<2	<1	<1
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC
	Marmion MP	<2	<2	<2	NC	NC
	Montebello Islands MP	<2	<2	<2	<1	3
	Muiron Islands MMA	100	82	2	92	574
	Ningaloo Coast WH	100	78	4	89	685
	Ningaloo MP (State)	100	64	2	86	490

Receptors		Probability (%) of dissolved aromatic concentration ≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	Maximum dissolved aromatic hydrocarbon concentration (ppb) averaged over all replicate simulations	at any depth, in the worst replicate
	Shark Bay MR	<2	<2	<2	<1	5
	Shark Bay WH	2	<2	<2	<1	30
Australian Marine Parks	Abrolhos MP	4	<2	<2	<1	32
	Argo-Rowley Terrace MP	<2	<2	<2	NC	NC
	Carnarvon Canyon MP	6	2	<2	3	87
	Cartier Island MP	<2	<2	<2	NC	NC
	Dampier MP	<2	<2	<2	NC	NC
	Eighty Mile Beach MP	<2	<2	<2	NC	NC
	Gascoyne MP	100	82	4	99	566
	Jurien Bay MP	<2	<2	<2	NC	NC
	Jurien MP	<2	<2	<2	<1	<1
	Kimberley MP	<2	<2	<2	NC	NC
	Mermaid Reef MP	<2	<2	<2	NC	NC
	Montebello MP	<2	<2	<2	<1	9
	Ningaloo MP	100	78	4	89	685
	Perth Canyon MP	<2	<2	<2	NC	NC
	Shark Bay MP	14	2	<2	5	125
	Two Rocks MP	<2	<2	<2	NC	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	100	100	8	254	1,015
	Ancient Coastline at 90-120m Depth Contour KEF	<2	<2	<2	<1	<1
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	<2	<2	<2	NC	NC
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	<2	<2	<2	NC	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	102	102	8	219	739
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	<2	<2	<2	<1	2
	Continental Slope Demersal Fish Communities KEF	100	86	4	90	628
	Exmouth Plateau KEF	40	8	<2	11	201
	Glomar Shoals KEF §	<2	<2	<2	NC	NC
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	<2	<2	<2	NC	NC
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	4	<2	<2	<1	27

Receptors		Probability (%) of dissolved aromatic concentration ≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	Maximum dissolved aromatic hydrocarbon concentration (ppb) averaged over all replicate simulations	at any depth, in the worst replicate
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	<2	<2	<2	NC	NC
	Wallaby Saddle KEF	<2	<2	<2	<1	4
	Western Demersal Slope and associated Fish Communities KEF	10	2	<2	4	89
	Western Rock Lobster KEF	<2	<2	<2	<1	<1
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC
	Dugong BIA	98	62	2	86	490
	Marine Turtle BIA	100	100	38	326	1,143
	Seabirds BIA	100	100	38	326	1,143
	Seals BIA	<2	<2	<2	<1	<1
	Sharks BIA	100	100	38	326	1,143
	Whales BIA	100	100	38	326	1,143
Fisheries	North-West Slope Trawl Fishery	100	86	2	90	628
	Southern Bluefin Tuna Fishery	100	100	38	326	1,143
	Western Skipjack Fishery	100	100	38	326	1,143
	Western Tuna and Billfish Fishery	100	100	38	326	1,143
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal §	<2	<2	<2	NC	NC
	Rankin Bank §	<2	<2	<2	<1	NC
	Scott Reef North	<2	<2	<2	NC	NC
	Scott Reef South	<2	<2	<2	NC	NC
	Seringapatam Reef	<2	<2	<2	NC	NC
	Woodbine Bank	<2	<2	<2	NC	NC

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature

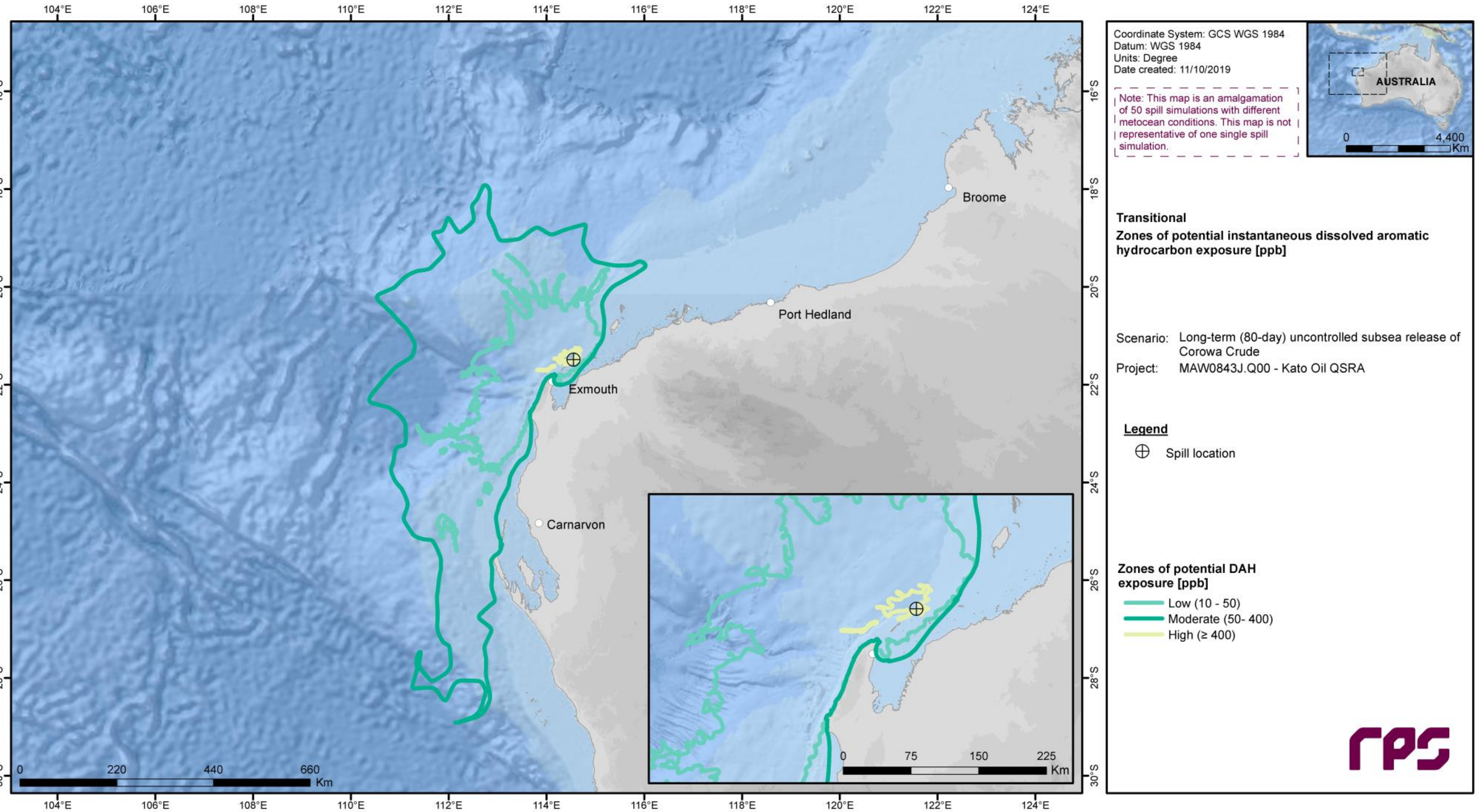


Figure 3.38 **Predicted zones of potential instantaneous dissolved aromatic hydrocarbon (DAH) exposure resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in transitional months.**

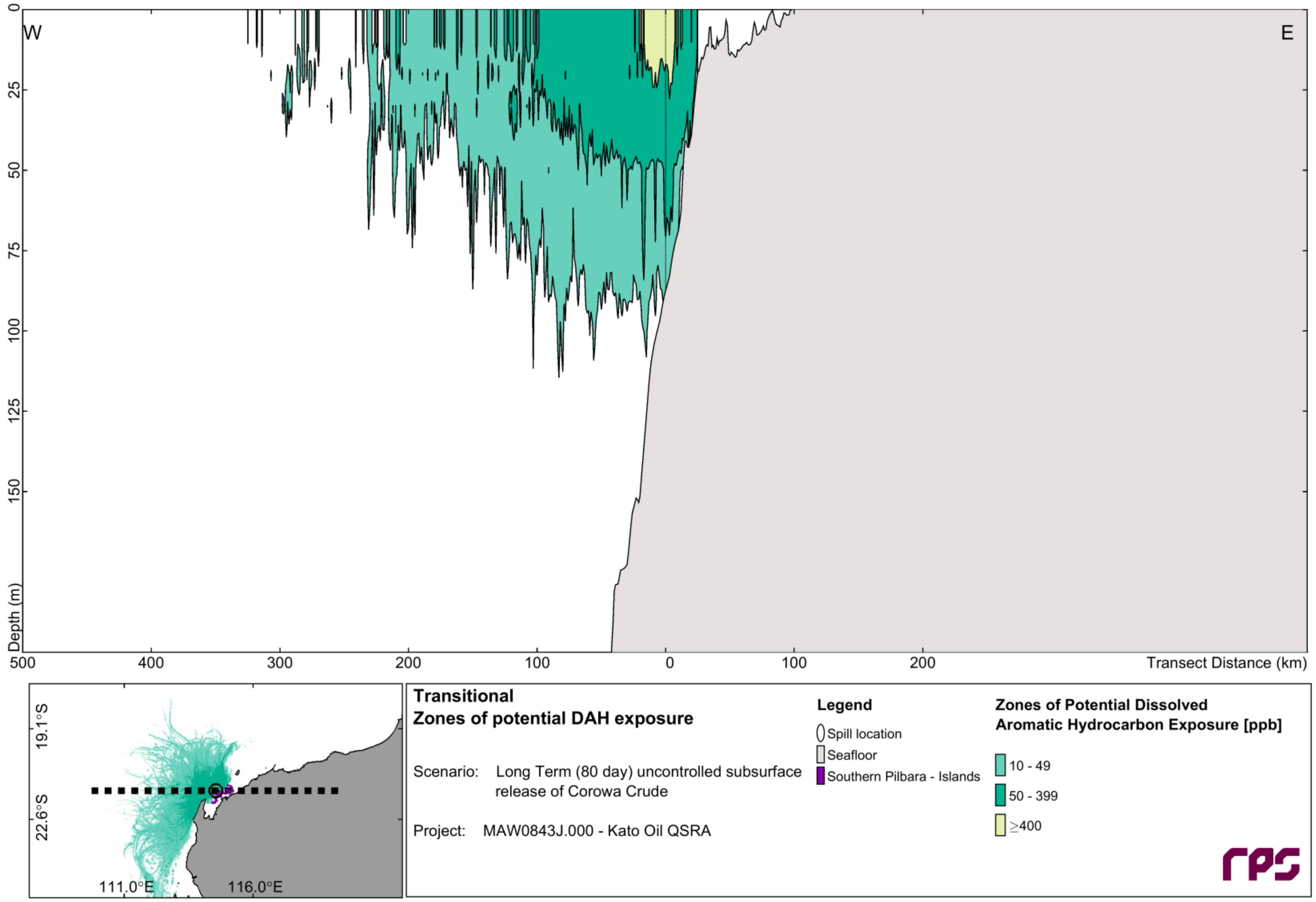


Figure 3.39 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Corowa Crude within the Corowa field, commencing in the transitional period. The results were calculated from 50 spill trajectories.

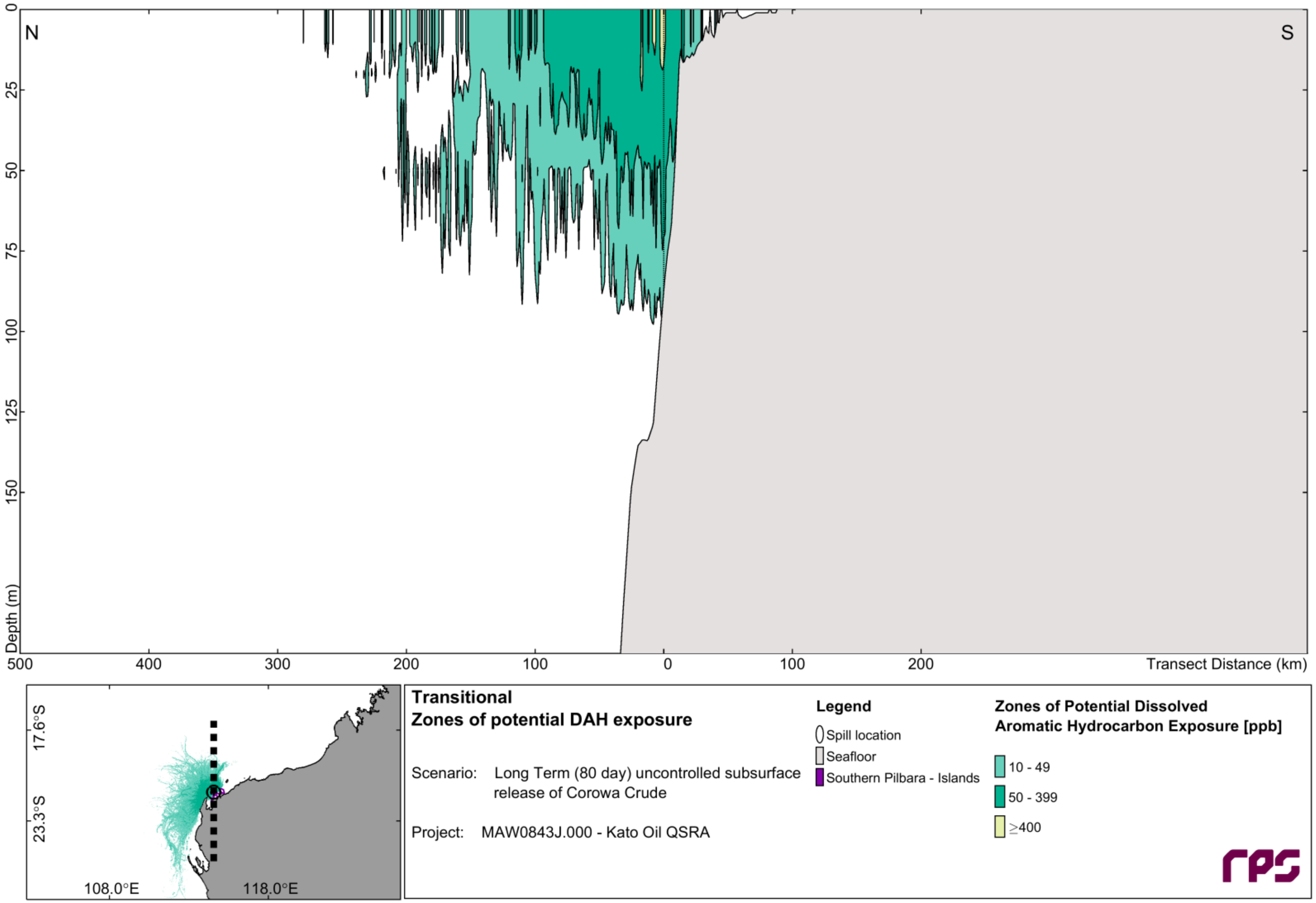


Figure 3.40 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, commencing in the transitional period. The results were calculated from 50 spill trajectories.

3.2.3.4.5 Dissolved Aromatic Hydrocarbons - Exposure

Table 3.19 Expected time-integrated dissolved aromatic hydrocarbons exposure outcomes at sensitive receptors resulting from a long-term (80-day) subsea release of Corowa Light Crude within the Corowa field, starting in transitional months.

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	Abrolhos Islands	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	2	BS
	Barrow Island	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Lacepede Islands	Probability (%) >960	NC	BS	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	BS	BS	BS	BS	BS
	Lowendal Islands	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS	BS
	Montebello Islands	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Sandy Islet	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	Probability (%) >960	4	2	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	1,079	2,401	291	BS	BS	BS
Coastlines	Dampier Archipelago	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Exmouth Gulf South East	Probability (%) >960	NC	BS	BS	BS	BS	BS
	Probability (%) >4,800	NC	BS	BS	BS	BS	BS
	Probability (%) >38,400	NC	BS	BS	BS	BS	BS
	Maximum Integrated Exposure	2	BS	BS	BS	BS	BS
Exmouth Gulf West	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >4,800	NC	NC	BS	BS	BS	BS
	Probability (%) >38,400	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	479	256	BS	BS	BS	BS
Geraldton - Jurien Bay	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Jurien Bay - Yanchep	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Kalbarri - Geraldton	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Karratha-Port Hedland	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >4,800	NC	NC	BS	BS	BS	BS
	Probability (%) >38,400	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
Kimberley Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >4,800	NC	NC	NC	NC	NC	BS
	Probability (%) >38,400	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Middle Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS	BS
	Probability (%) >4,800	NC	NC	BS	BS	BS	BS
	Probability (%) >38,400	NC	NC	BS	BS	BS	BS
	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
North Broome Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >4,800	NC	NC	NC	NC	NC	BS
	Probability (%) >38,400	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
	Probability (%) >960	NC	NC	BS	BS	BS	BS

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Northern Pilbara - Islands and Shoreline	Probability (%) >4,800	NC	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
	Perth Northern Coast	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Port Hedland - Eighty Mile Beach	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
	Southern Pilbara - Shoreline	Probability (%) >960	NC	BS	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	6	BS	BS	BS	BS	BS
	Zuytdorp Cliffs - Kalbarri	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
State Marine and National Parks	Barrow Island MMA	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	1	NC	NC	NC	BS	BS
	Barrow Islands MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Clerke Reef (Rowley Shoals MP)	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Marmion MP	Probability (%) >960	NC	NC	NC	BS	BS	BS

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS	BS
	Montebello Islands MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	3	NC	NC	NC	BS	BS
	Muiron Islands MMA	Probability (%) >960	32	8	4	2	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	3,432	2,408	1,387	1,519	19	BS
	Ningaloo Coast WH	Probability (%) >960	42	14	12	NC	NC	NC
		Probability (%) >4,800	2	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	5,706	3,088	3,028	720	125	5
	Ningaloo MP (State)	Probability (%) >960	42	14	12	NC	NC	NC
		Probability (%) >4,800	2	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	5,706	3,088	3,028	720	125	2
	Shark Bay MR	Probability (%) >960	NC	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	10	BS	BS	BS	BS
	Shark Bay WH	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	44	139	138	9	NC	BS
Australian Marine Parks	Abrolhos MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	30	43	53	37	2	NC
	Argo-Rowley Terrace MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Carnarvon Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	167	112	78	15	5	1
Cartier Island MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Dampier MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Eighty Mile Beach MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Gascoyne MP	Probability (%) >960	12	4	2	NC	NC	NC
	Probability (%) >4,800	NC	NC	2	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	2,682	2,022	5,174	842	125	7
Jurien Bay MP	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Jurien MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Kimberley MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Mermaid Reef MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Montebello MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	32	19	19	22	NC	NC
	Ningaloo MP	Probability (%) >960	6	4	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,792	1,840	912	424	63	5
	Perth Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Shark Bay MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	340	219	321	140	35	NC
	Two Rocks MP	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	100	36	6	NC	NC	NC
		Probability (%) >4,800	10	2	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,714	5,883	6,168	927	141	7
	Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	2	NC
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Canyons linking the Argo Abyssal Plain with the	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Scott Plateau KEF	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	98	30	8	2	NC	NC
	Probability (%) >4,800	4	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	5,633	4,155	3,551	1,327	158	4
Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	1	NC	2	2	NC
Continental Slope Demersal Fish Communities KEF	Probability (%) >960	14	6	4	2	NC	NC
	Probability (%) >4,800	NC	NC	2	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	3,972	2,127	5,174	1,406	150	2
Exmouth Plateau KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	465	511	537	152	20	4
Glomar Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC	BS
	Probability (%) >4,800	NC	NC	NC	NC	NC	BS
	Probability (%) >38,400	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	19	51	53	11	1	NC
Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Probability (%) >960	NC	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Wallaby Saddle KEF	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	5	8	9	1	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	128	103	159	100	28	NC
	Western Rock Lobster KEF	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	1	2	NC
Biologically Important Areas	Dolphins BIA	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Dugong BIA	Probability (%) >960	42	14	12	NC	NC	NC
		Probability (%) >4,800	2	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	5,706	3,088	3,028	720	125	5
	Marine Turtle BIA	Probability (%) >960	100	46	12	2	NC	NC
		Probability (%) >4,800	70	2	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,088	6,045	6,168	1,519	141	10
	Seabirds BIA	Probability (%) >960	100	46	12	2	NC	NC
		Probability (%) >4,800	70	2	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,088	6,045	6,168	1,519	158	10
	Seals BIA	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	3	NC
	Sharks BIA	Probability (%) >960	100	46	12	2	NC	NC
		Probability (%) >4,800	70	2	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,088	6,045	6,168	1,468	141	10

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Whales BIA	Probability (%) >960	100	46	12	2	NC	NC
		Probability (%) >4,800	70	2	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,088	6,045	6,168	1,519	158	10
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	8	4	2	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,571	2,419	2,180	1,406	146	1
	Southern Bluefin Tuna Fishery	Probability (%) >960	100	46	12	2	NC	NC
		Probability (%) >4,800	70	2	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,088	6,045	6,168	1,519	158	10
	Western Skipjack Fishery	Probability (%) >960	100	46	12	2	NC	NC
		Probability (%) >4,800	70	2	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,088	6,045	6,168	1,519	158	10
	Western Tuna and Billfish Fishery	Probability (%) >960	100	46	12	2	NC	NC
		Probability (%) >4,800	70	2	2	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,088	6,045	6,168	1,519	158	10
Other Submerged Reefs, Banks and Shoals	Eugene McDermott Shoal	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
	Rankin Bank	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	9	BS	BS	BS
	Scott Reef North	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Scott Reef South	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Seringapatam Reef	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Woodbine Bank	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed

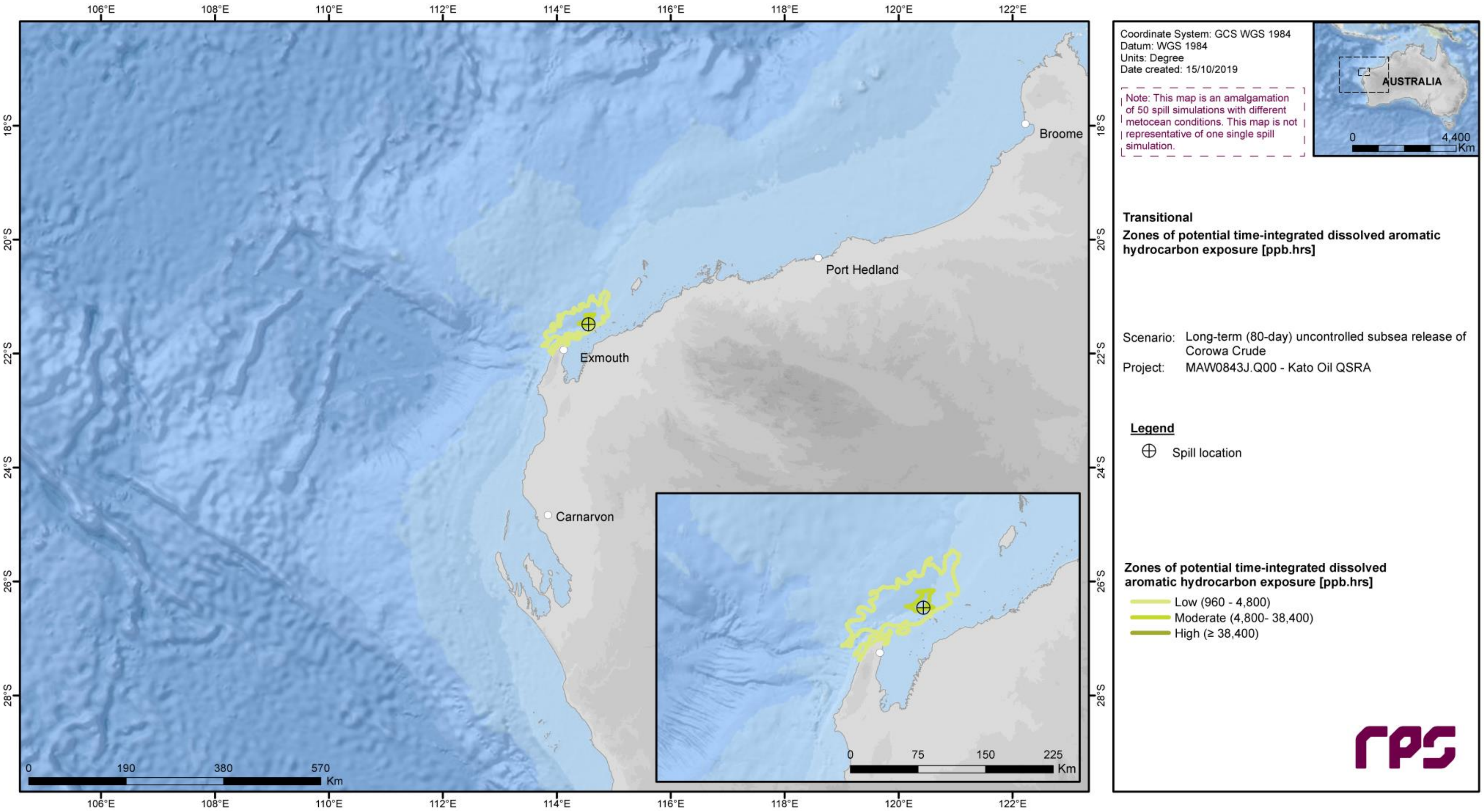


Figure 3.41 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure resulting from a long-term (80-day) subsurface release of Corowa Light Crude within the Corowa field, starting in transitional months.

3.3 Short-term (6-hour) surface release of marine gas oil after a rupture of a supply vessel tank

3.3.1 Overview

This scenario investigated the probability of exposure to surrounding regions by oil resulting from a short-term (6 hours) surface release of 500 m^3 of marine gas oil after a rupture of a support vessel tank (114° 33' 26.20" E, 21° 28' 59.40" S) within the Corowa field.

Exposure probabilities and other statistics have been calculated for individual locations, and for areas classified as potentially sensitive to exposure from multiple replicate simulations. Outcomes of the stochastic simulations were screened to identify worst-case simulations, in terms of the volumes of oil calculated on shorelines, through accumulation, over the spill and post-spill period. Calculations for accumulation accounts for the volume of oil stranding less the volume of oil that is lost through weathering and refloating. Maximum accumulation during simulations was the highest volume at any time. Analysis of these worst-case (deterministic) simulations is provided first to illustrate potential outcomes from a single spill event. Results of the full stochastic analysis are then presented to account for the variability of metocean conditions on the probability of outcomes.

3.3.2 Deterministic Assessment Results

3.3.2.1 Deterministic Case 1: Maximum oil volume loading on all shorelines

3.3.2.1.1 Discussion of Results

The summary of the worst-case outcomes for the short-term (6-hour) surface release, based on calculations for accumulation of oil volumes on sensitive resources that are permanently above water level are presented in Table 3.20.

The maximum oil volume loading on all shorelines during a single spill event was predicted as 185 m^3, for a spill commencing in summer (run 2; Table 3.20). During this deterministic case, the highest accumulation was predicted for the Murion Islands MMA shoreline receptor.

Table 3.20 Summary table of regional worst-case outcomes for the replicate with the maximum oil volume loading on all shoreline receptors.

Case	Selection Criteria	Season	Run No.	Volume	Worst Receptor Contacted
1	Maximum oil volume loading on shorelines*	Summer	2	185 m^3	Murion Islands MMA

* Volume results refer to model predictions for all shorelines in the region, not for any specific receptor.

Figure 3.42 to Figure 3.47 show the zones of potential exposure for floating oil, shoreline oil, instantaneous and time-integrated entrained oil and instantaneous and time-integrated dissolved aromatic hydrocarbon concentrations, at the low, moderate and high contact thresholds. The maximum distance from the spill location to the outer edge of hydrocarbon exposure during this spill is predicted as 33 km for shoreline oil at concentrations exceeding the 100 g/m^2 threshold.

Calculations for the horizontal and vertical distribution of entrained oil and dissolved aromatic hydrocarbon concentrations during the deterministic case have been illustrated as cross-section plots in Figure 3.48 to Figure 3.51. The plots summarise the highest concentrations ever calculated for locations along contour lines relative to the bathymetry.

Figure 3.52 shows time series snapshots of the predicted concentrations of surface, in-water (entrained and dissolved) and shoreline oil during the deterministic case at intervals of 1 day, 3 days, 5 days and 1 week following the commencement of the spill.

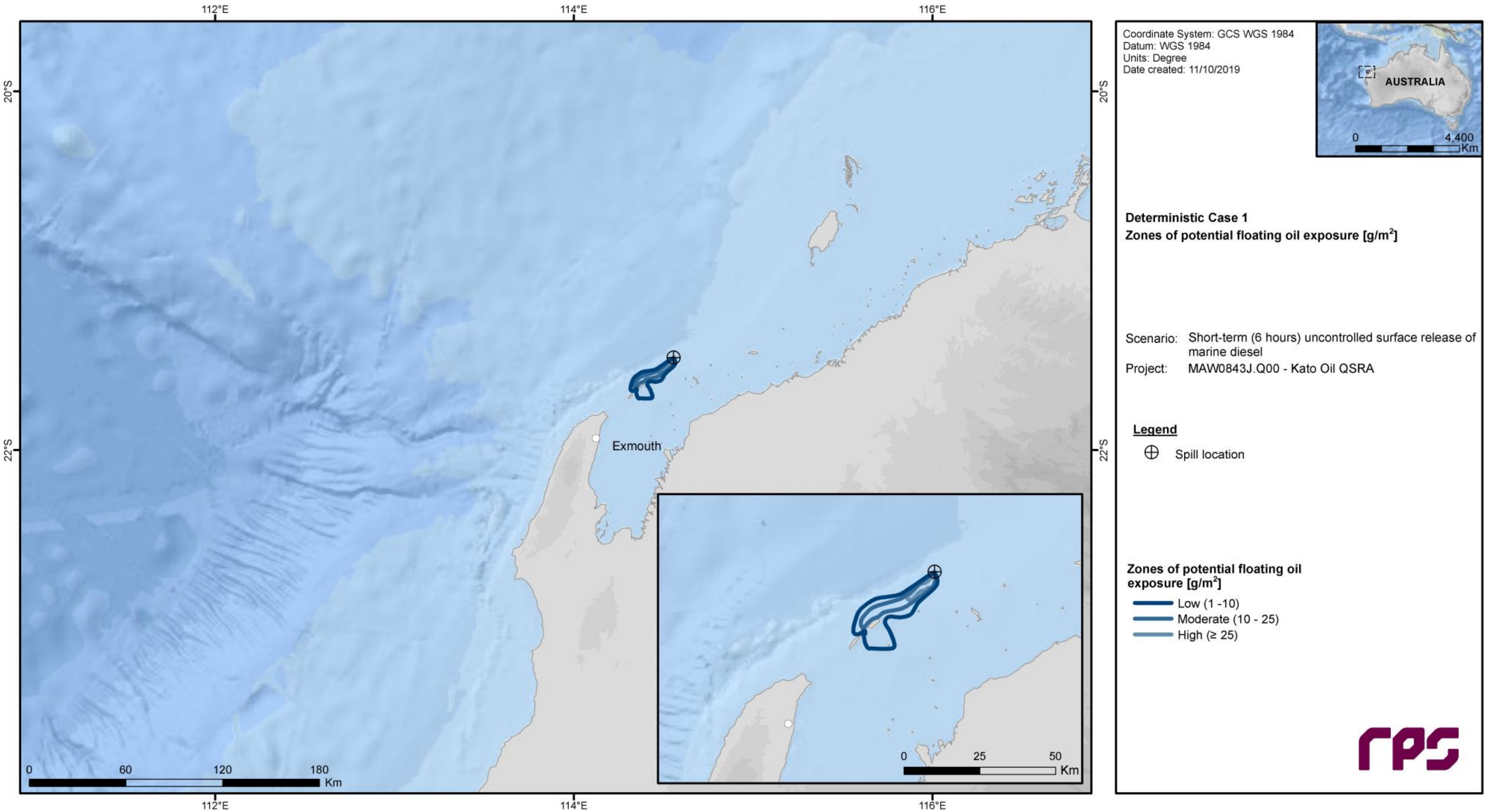


Figure 3.42 Predicted zones of potential floating oil exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 2).

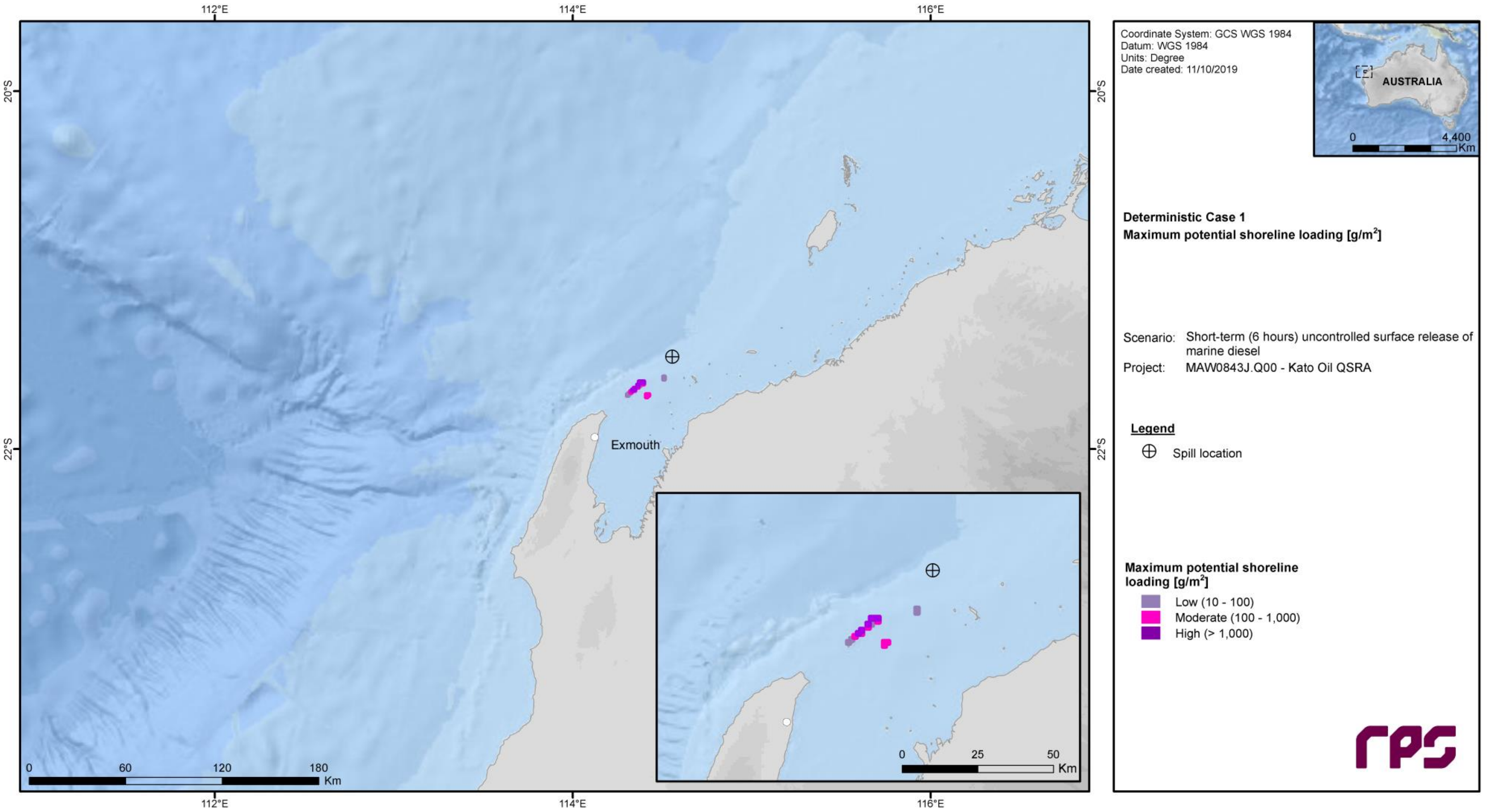


Figure 3.43 Predicted maximum potential shoreline loading resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, for the deterministic case with the <u>largest oil volume loading on shorelines</u> (summer, run 2).

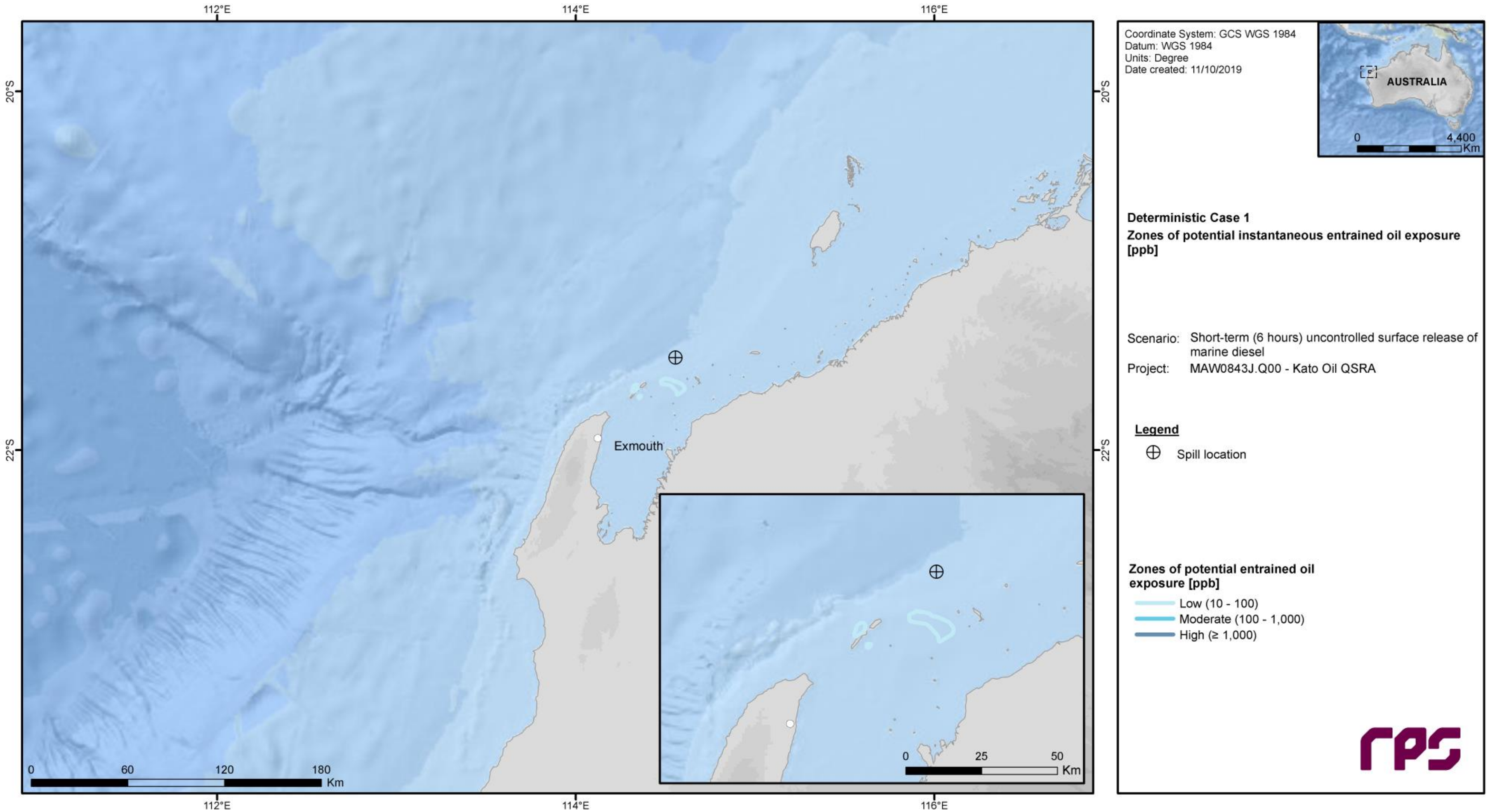


Figure 3.44 Predicted zones of potential instantaneous entrained oil exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, for the deterministic case with the <u>largest oil volume loading on shorelines</u> (summer, run 2).

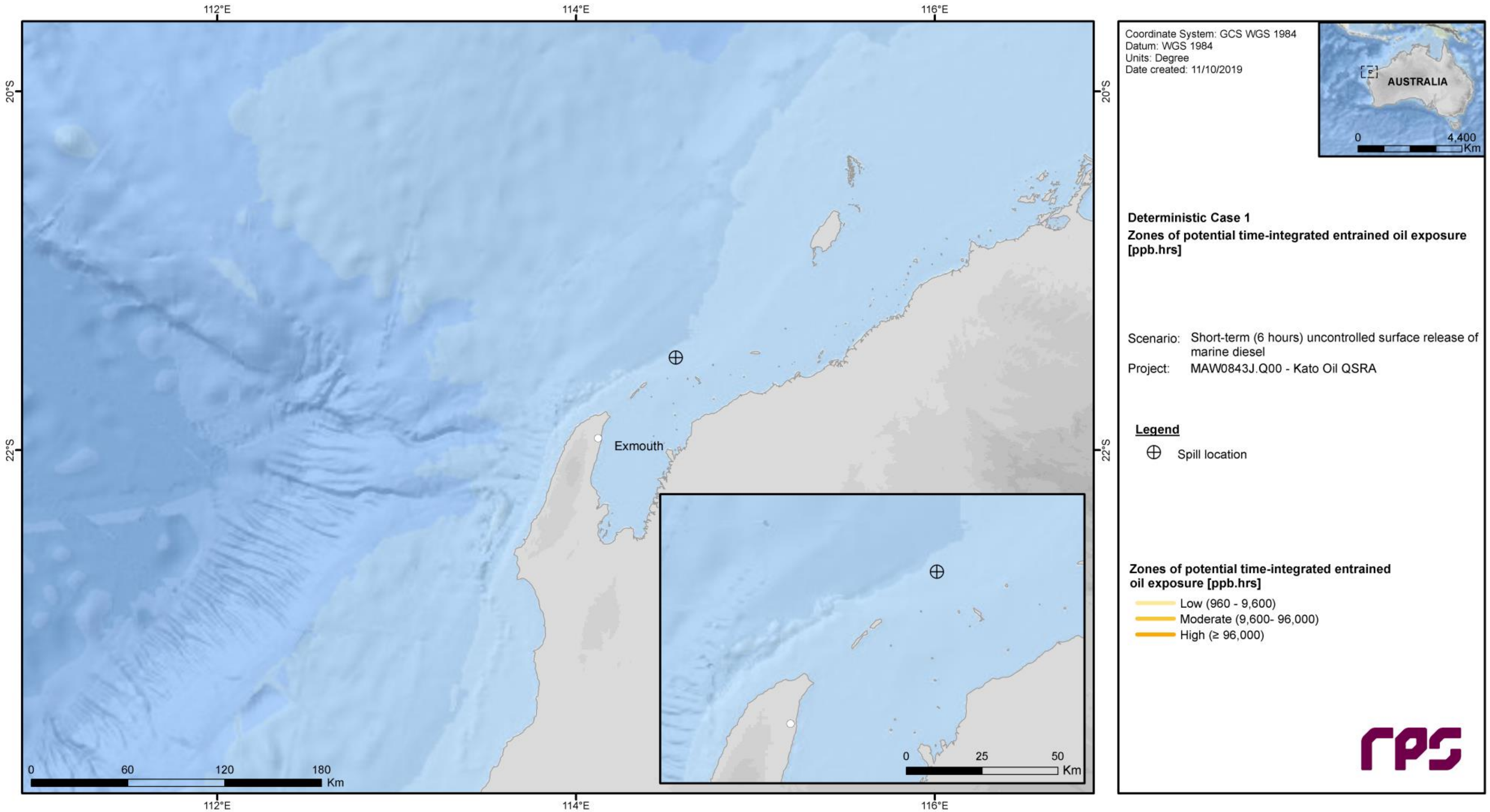


Figure 3.45 Predicted zones of potential time-integrated entrained oil exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, for the deterministic case with the <u>largest oil volume loading on shorelines</u> (summer, run 2).

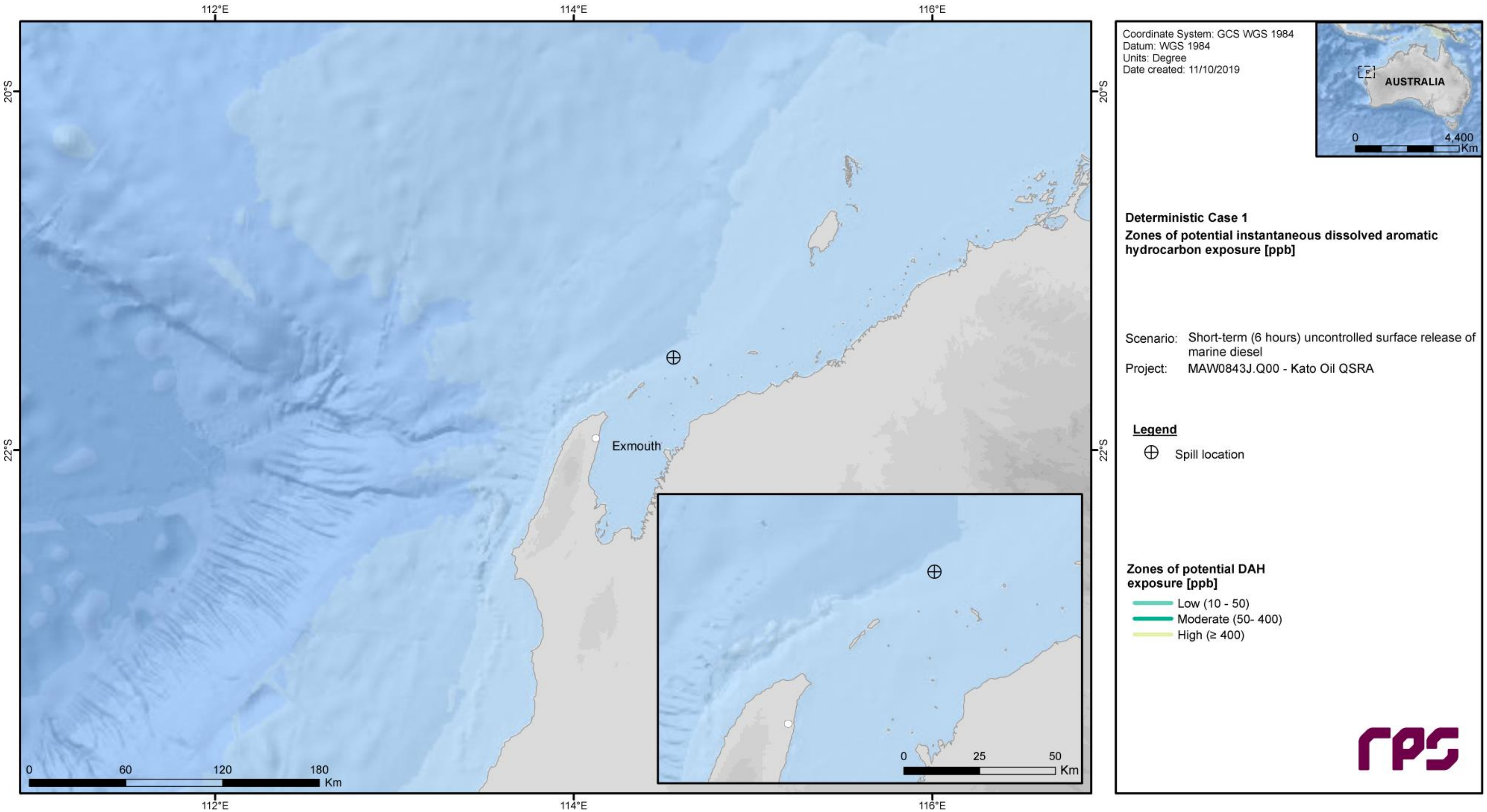


Figure 3.46 Predicted zones of potential instantaneous dissolved aromatic hydrocarbon exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, for the deterministic case with the <u>largest oil volume loading on shorelines</u> (summer, run 2).

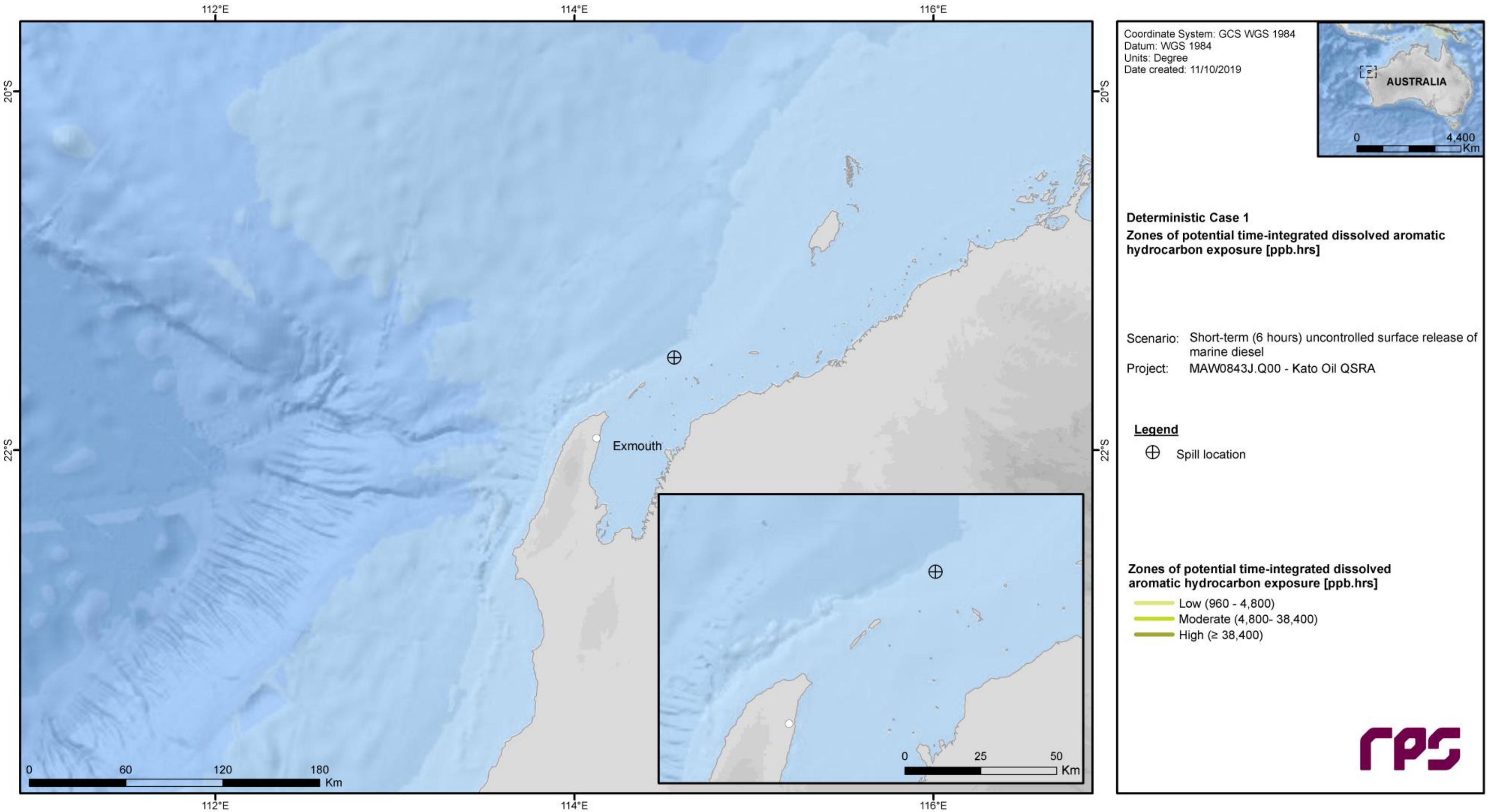


Figure 3.47 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 2).

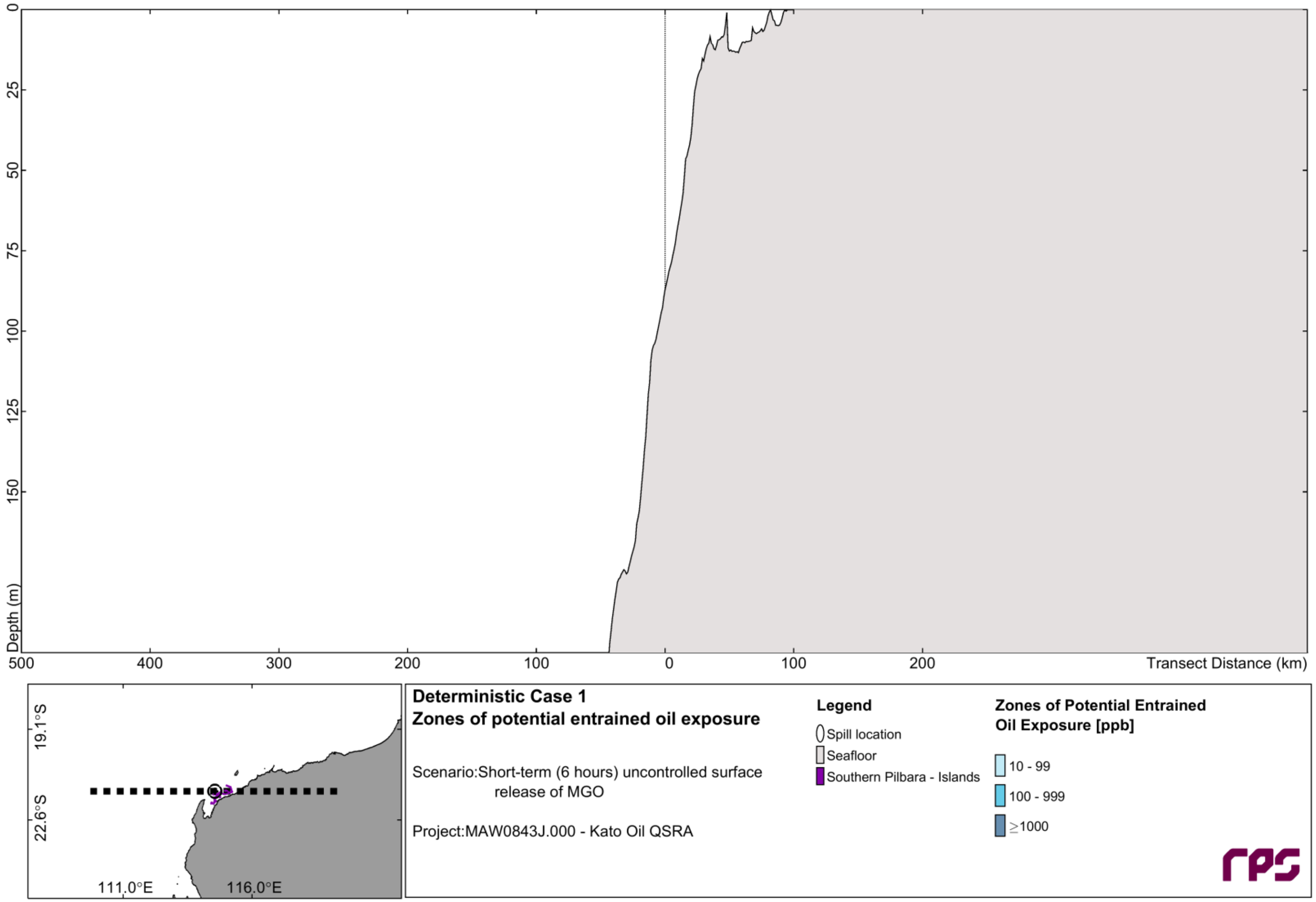


Figure 3.48 East-West cross-section transect of predicted maximum entrained oil concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, for the deterministic case with the <u>largest oil volume loading on shorelines</u> (summer, run 2). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

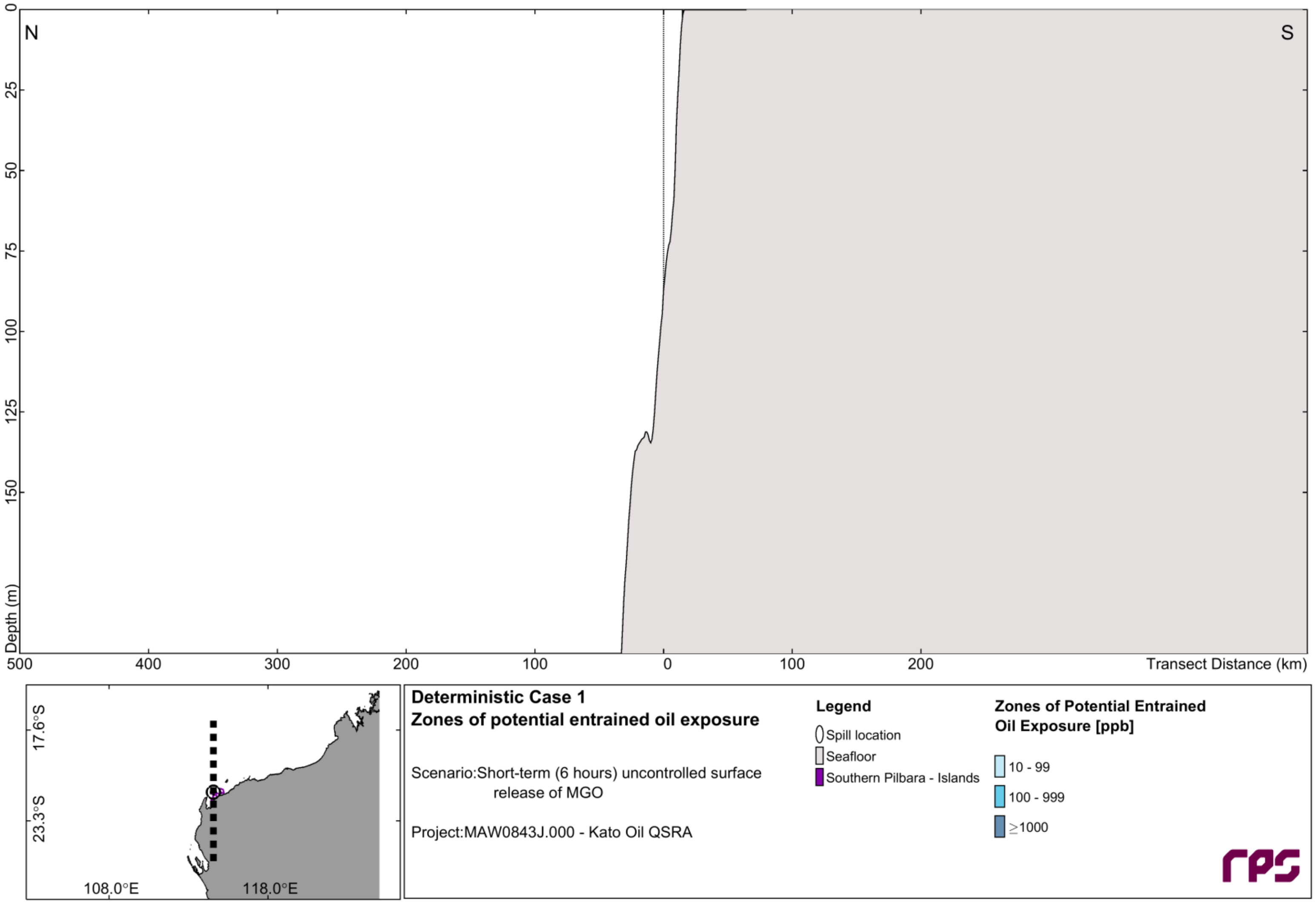


Figure 3.49 North-South cross-section transect of predicted maximum entrained oil concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, for the deterministic case with the <u>largest oil volume loading on shorelines</u> (summer, run 2). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

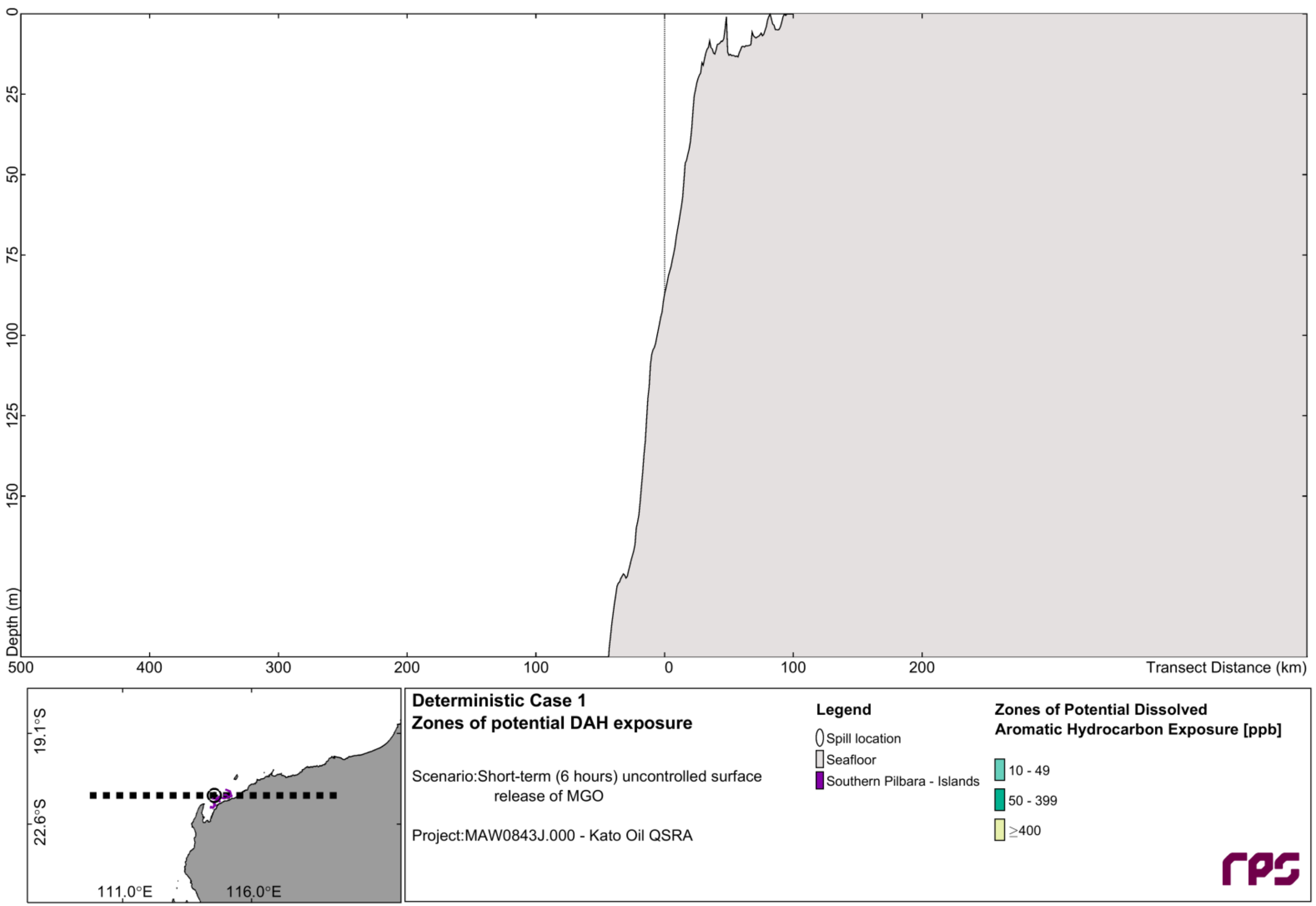


Figure 3.50 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 2). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

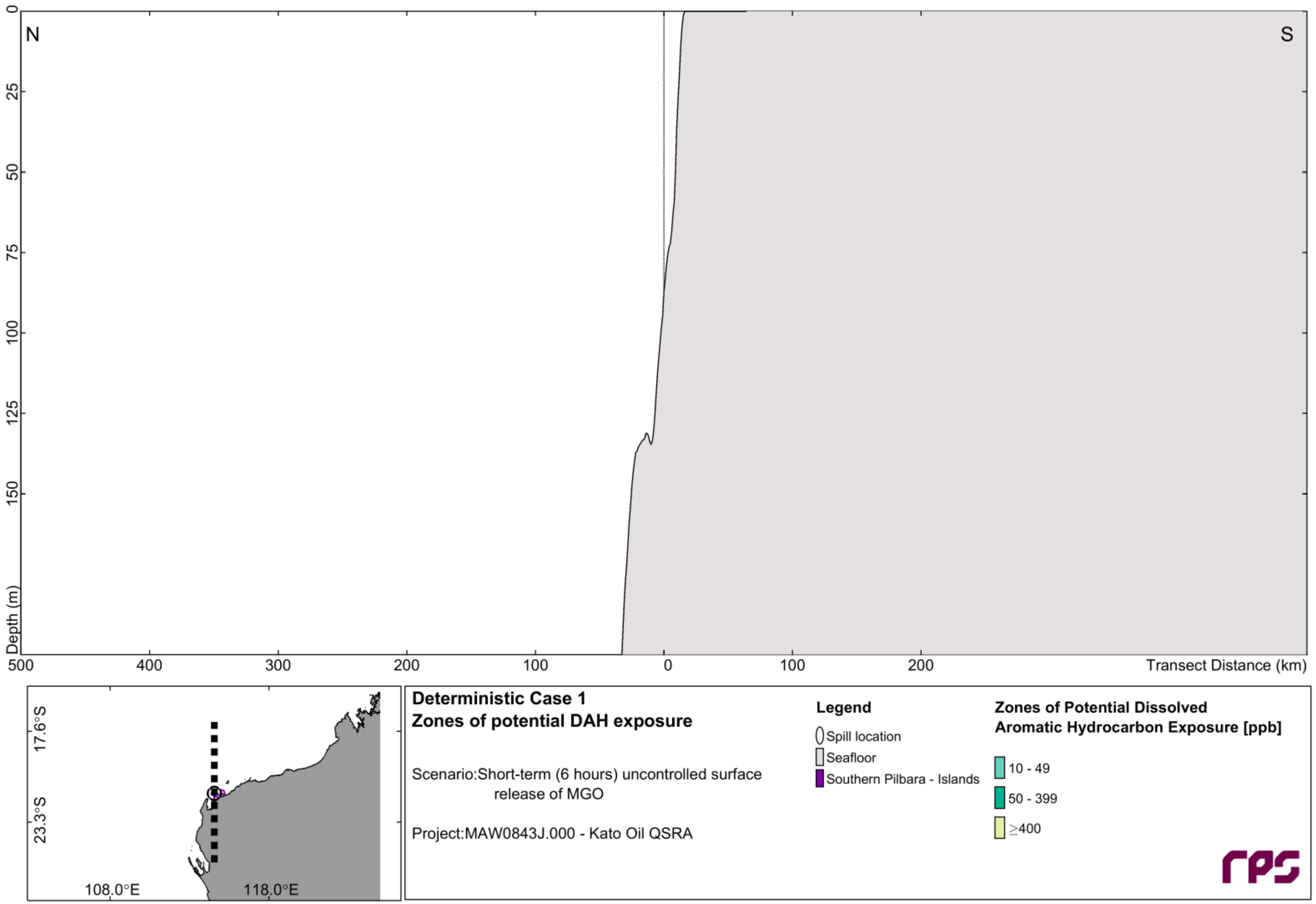


Figure 3.51 North-South cross-section transect of predicted dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 2). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

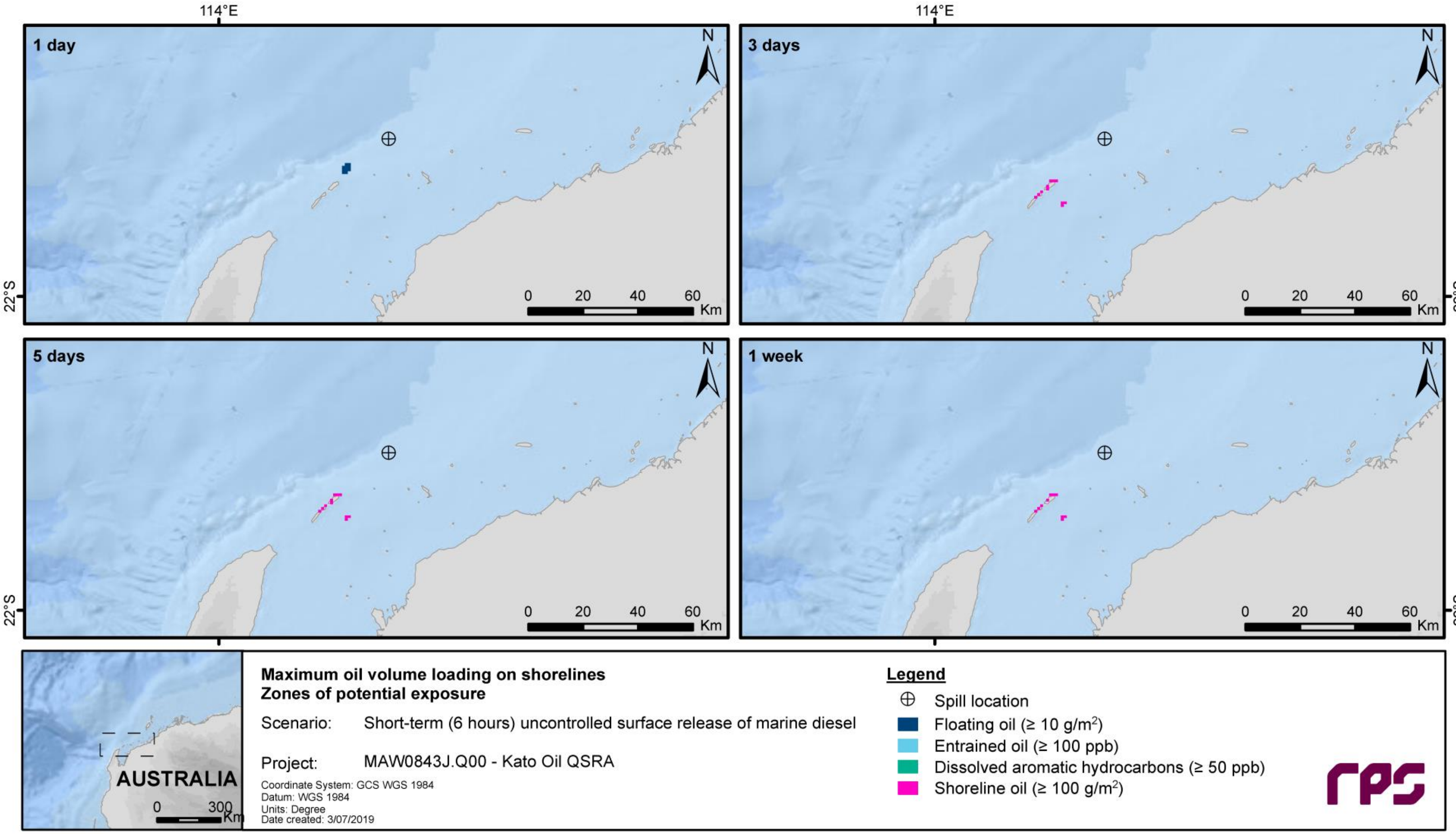


Figure 3.52 Time varying areal extent of predicted zones of potential exposure for floating oil (≥ 10 g/m^2) entrained oil (≥ 100 ppb), dissolved aromatic hydrocarbons (≥ 50 ppb) and shoreline oil (≥ 100 g/m^2) resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, for the deterministic case with the <u>largest oil volume loading on shorelines</u> (summer, run 2).

3.3.3 Stochastic Assessment Results

3.3.3.1 Discussion of Results

3.3.3.1.1 Floating and Shoreline Oil

Floating oil concentrations at the low threshold (1 g/m^2) could travel up to 178 km from the release location, with distances reducing at the moderate (10 g/m^2; 50 km) and high (25 g/m^2; 18 km) thresholds (Table 3.21).

The seasonal zones of potential exposure at the assessed contact thresholds are depicted in Figure 3.53 (summer), Figure 3.63 (winter) and Figure 3.73 (transitional) for floating oil and Figure 3.54 (summer), Figure 3.64 (winter) and Figure 3.74 (transitional) for shoreline oil.

Table 3.21 Maximum distances from the release location to zones of floating oil exposure.

	Floating oil exposure threshold		
	Low 1 g/m^2	Moderate 10 g/m^2	High 25 g/m^2
Maximum distance travelled (km) by a spill trajectory	178	50	18

The highest probabilities of floating oil contact at the low threshold (1 g/m^2) is forecast at the Muiron Islands MMA (summer; 5%, winter; 10%, and transitional months; 4%). Floating oil at the low threshold is predicted to arrive at the Southern Pilbara - Islands within 9 hours after a spill commencement in winter.

Floating oil concentrations at the high exposure threshold (50 g/m^2) might pass over several submerged receptors (Table 3.24, Table 3.29 and Table 3.34). The highest probabilities were forecast for the Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and Western Skipjack Fishery at 53-65% across all seasons.

The worst-case oil accumulation on a shoreline is predicted for the Murion Islands MMA receptor in summer, with an accumulated concentration and volume of 3.3 kg/m^2 and 185 m^3, respectively (Table 3.24).

The worst-case maximum length of shoreline with concentrations exceeding the low threshold (10 g/m^2) was calculated as 23 km for the Ningaloo WH and Shark Bay WH in transitional months (Table 3.34).

3.3.3.1.2 Entrained Oil - Instantaneous

Entrained oil concentrations at the low threshold (10 ppb) could travel up to 957 km from the release location in winter, with distances reducing at the moderate (100 ppb; 674 km) and high (1,000 ppb; 304 km) thresholds (Table 3.22).

Table 3.22 Maximum distances from the release location to zones of entrained oil exposure.

	Entrained oil exposure threshold		
	Low 10 ppb	Moderate 100 ppb	High 1,000 ppb
Maximum distance travelled (km) by a spill trajectory across all seasons	957	674	304

The seasonal zones of potential entrained oil exposure at the assessed contact thresholds are depicted in Figure 3.55 (summer), Figure 3.65 (winter) and Figure 3.75 (transitional).

The probability of contact by entrained oil concentrations at the low (10 ppb) threshold is predicted to be greatest at Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and Western Skipjack Fishery with probabilities of 54-68% across all seasons (Table 3.25, Table 3.30 and Table 3.35). Entrained oil at the low threshold is predicted to arrive at these receptors within 1 hour.

The worst-case instantaneous entrained oil concentration at any receptor is predicted at Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and Western Skipjack Fishery as 10,865 ppb in summer (Table 3.25).

The cross-sectional transects (summer; Figure 3.56 and Figure 3.57, winter; Figure 3.66 and Figure 3.67, transitional months; Figure 3.76 and Figure 3.77) of maximum entrained oil concentrations in the vicinity of the release site show that concentrations above the moderate (100 ppb) and high (1,000 ppb) thresholds are not expected to exceed depths of around 60 m and 25 m BMSL, respectively, across any season. Therefore, limiting benthic interaction below this depth.

3.3.3.1.3 Entrained Oil – Exposure

Time-integrated entrained oil exposure at or above the 960 ppb.h threshold could travel up to 578 km from the release location (transitional months), with the distance reducing to 172 km (summer) as the contact threshold increases to 9,600 ppb.h.

The seasonal zones of potential instantaneous dissolved aromatic hydrocarbon exposure at all assessed contact thresholds are depicted Figure 3.58 (summer), Figure 3.68 (winter) and Figure 3.78 (transitional).

Entrained oil exposure above the 9,600 ppb.h threshold was predicted to be greatest at the Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and Western Skipjack Fishery with probabilities of 14% (transitional months), 9% (summer) and 7% (winter) in the surface layer (0-10 m; Table 3.26, Table 3.31 and Table 3.36).

The worst-case maximum entrained oil integrated exposure is predicted at the Ancient Coastline at 125m Depth Contour KEF, Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery as 65,338 ppb.h in transitional months (Table 3.36).

3.3.3.1.4 Dissolved Aromatic Hydrocarbons – Instantaneous

Instantaneous dissolved aromatic hydrocarbon concentrations at the low (10 ppb) threshold could travel up to 827 km from the release location, with distances reducing at the moderate (50 ppb; 272 km) threshold and no exposure predicted above 400 ppb (Table 3.23).

The seasonal zones of potential dissolved aromatic hydrocarbon exposure at all assessed contact thresholds are depicted in Figure 3.59 (summer), Figure 3.69 (winter) and Figure 3.79 (transitional).

Table 3.23 Maximum distances from the release location to zones of dissolved aromatic hydrocarbon exposure.

	Dissolved aromatic hydrocarbon exposure threshold		
	Low 10 ppb	Moderate 50 ppb	High 400 ppb
Maximum distance travelled (km) by a spill trajectory across all seasons	827	272	-

The probability of contact by dissolved aromatic hydrocarbon concentrations at the low threshold (10 ppb) is predicted to be greatest at Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and Western Skipjack Fishery with probabilities of 21-29% across all seasons (Table 3.27, Table 3.32 and Table 3.37).

The worst-case dissolved aromatic hydrocarbon concentrations at any receptor is predicted at Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and Western Skipjack Fishery as 275 ppb in summer (Table 3.27).

The cross-sectional transects (summer; Figure 3.60 and Figure 3.61, winter; Figure 3.70 and Figure 3.71, transitional months; Figure 3.80 and Figure 3.81) of maximum dissolved aromatic hydrocarbon concentrations in the vicinity of the release site show that concentrations above the moderate (50 ppb) threshold are not expected to exceed depths of around 50 m BMSL in any season. Therefore, limiting benthic interaction below this depth.

3.3.3.1.5 Dissolved Aromatic Hydrocarbons – Exposure

Time-integrated dissolved aromatic hydrocarbons exposure at or above 960 ppb.h are predicted to occur up to 7 km from the release site (winter and transitional months).

The seasonal zones of potential time-integrated dissolved aromatic hydrocarbon exposure at all assessed contact thresholds are depicted in Figure 3.62 (summer), Figure 3.72 (winter) and Figure 3.82 (transitional).

Dissolved aromatic hydrocarbon exposure above the 960 ppb.h threshold was predicted to be greatest at the Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors with probabilities of 7% (transitional months), 6% (summer) and 4% (winter) in the surface layer (0-10 m; Table 3.28, Table 3.33 and Table 3.38).

The worst-case maximum dissolved aromatic hydrocarbon exposure concentration is predicted at the Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery as 3,609 ppb.h in transitional months (Table 3.38).

3.3.3.2 Summer

3.3.3.2.1 Floating and Shoreline Oil

Table 3.24 Expected floating and shoreline oil outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in summer months.

Receptors		Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
Islands	Barrow Island	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC	NC	NC	NC	NC
	Lowendal Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC	NC	NC	NC	NC
	Montebello Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	3	<1	<1	17	NC	NC	5	4	1	18	33	51	25	1,906	<1	35	<1	13	<1	6	<1	1
	Abrolhos Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC	NC	NC	NC	NC
Coastlines	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC	NC	NC	NC	NC
	Exmouth Gulf South East	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC	NC	NC	NC	NC
	Exmouth Gulf West	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
State Marine and National Parks	Muiron Islands MMA	5	2	<1	12	23	NC	7	3	2	24	26	28	70	3,313	4	185	<1	16	<1	11	<1	5
	Barrow Island MMA	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC	NC	NC	NC	NC
	Ningaloo MP (State)	1	<1	<1	55	NC	NC	2	1	<1	59	100	NC	1.3	130	<1	4	NA	NA	NA	NA	NA	NA
	Ningaloo Coast WH	3	<1	<1	42	NC	NC	2	1	<1	59	100	NC	1.3	130	<1	4	<1	8	<1	1	NC	NC
	Shark Bay WH	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	<1	8	<1	1	NC	NC
	Montebello Islands MP	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC	NC	NC	NC	NC
	Barrow Islands MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Montebello MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ningaloo MP*	3	<1	<1	42	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Argo-Rowley Terrace MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Gascoyne MP*	3	<1	<1	50	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carnarvon Canyon MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Shark Bay MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Abrolhos MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF*	37	20	2	4	4	6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Continental Slope Demersal Fish Communities KEF*	3	<1	<1	24	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Glomar Shoals KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

	Receptors	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF*	25	8	1	5	6	16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Exmouth Plateau KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Demersal Slope and associated Fish Communities KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Rock Lobster KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wallaby Saddle KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ancient Coastline at 90-120m Depth Contour KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Biologically Important Areas	Marine Turtle BIA*†	98	94	80	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dugong BIA*	2	<1	<1	52	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seabirds BIA*†	98	94	80	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seals BIA*†	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sharks BIA*	98	94	80	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Whales BIA*	98	94	80	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	Southern Bluefin Tuna Fishery*	98	94	80	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Tuna and Billfish Fishery*	98	94	80	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Skipjack Fishery*	98	94	80	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	North-West Slope Trawl Fishery*	3	<1	<1	25	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Rankin Bank*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NC: No contact to receptor predicted for specified threshold.

* Floating oil will not accumulate on submerged features and at open ocean locations. NA: Not applicable.

† Receptor is considered as submerged, any accumulation occurring on emerged features within this receptor is captured under the associated shoreline receptor in the table.

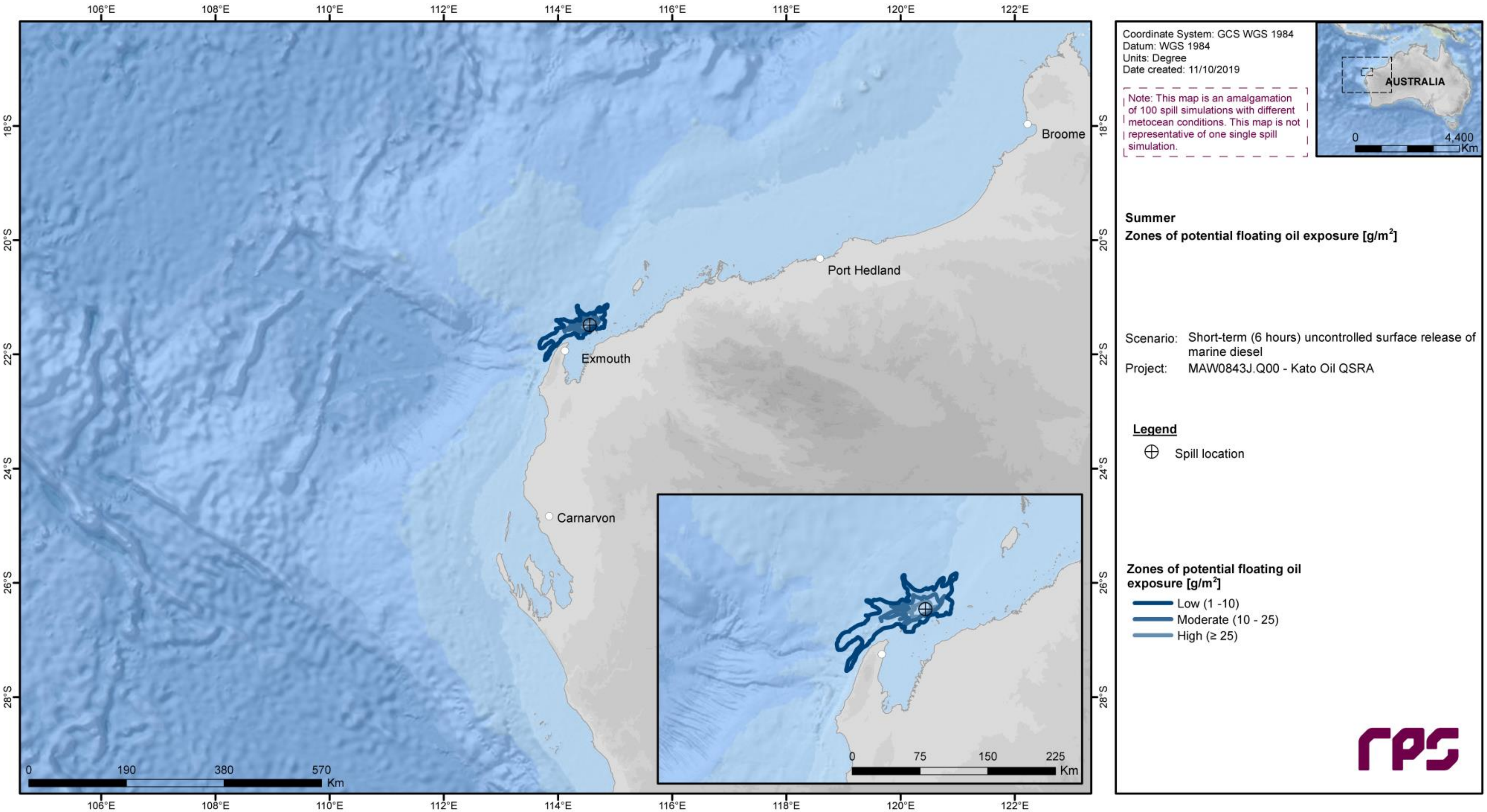


Figure 3.53 Predicted zones of potential floating oil exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in summer.

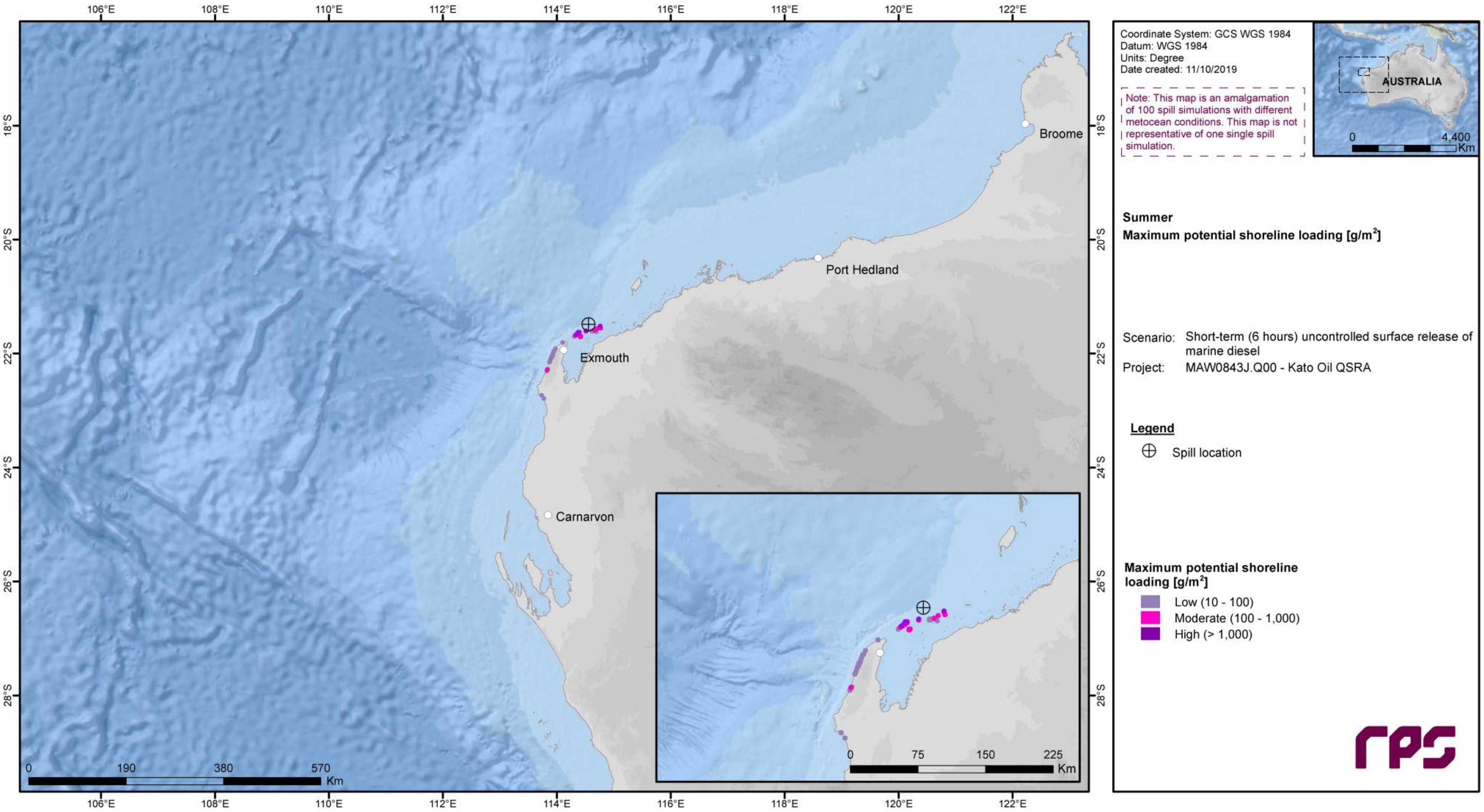


Figure 3.54 Predicted maximum potential shoreline loading resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in summer.

3.3.3.2.2 Entrained Oil - Instantaneous

Table 3.25 Expected instantaneous entrained oil outcomes at sensitive receptors resulting a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in summer months.

Receptors		Probability (%) of entrained hydrocarbon concentration contact at			Minimum time (hours) to receptor waters at			Maximum entrained hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Barrow Island	<1	<1	<1	NC	NC	NC	<1	10
	Lowendal Islands	<1	<1	<1	NC	NC	NC	<1	5
	Montebello Islands	2	<1	<1	461	NC	NC	<1	49
	Southern Pilbara - Islands	8	1	<1	54	97	NC	5	193
	Abrolhos Islands	<1	<1	<1	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	<1	8
Coastlines	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC	NC	<1	7
	Exmouth Gulf South East	<1	<1	<1	NC	NC	NC	<1	2
	Exmouth Gulf West	1	<1	<1	443	NC	NC	<1	16
	Muiron Islands MMA	9	3	1	7	7	9	84	8,086
	Barrow Island MMA	4	<1	<1	214	NC	NC	<1	42
State Marine and National Parks	Ningaloo MP (State)	14	5	1	20	21	22	52	5,000
	Ningaloo Coast WH	19	8	2	19	20	22	64	5,935
	Shark Bay WH	<1	<1	<1	NC	NC	NC	NC	NC
	Montebello Islands MP	5	<1	<1	217	NC	NC	2	97
	Barrow Islands MP	1	<1	<1	651	NC	NC	<1	26
Australian Marine Parks	Montebello MP	8	4	<1	109	113	NC	14	799
	Ningaloo MP	19	8	2	19	20	30	64	5,935
	Argo-Rowley Terrace MP	<1	<1	<1	NC	NC	NC	NC	NC
	Gascoyne MP	27	11	2	30	30	33	41	2,724
	Carnarvon Canyon MP	3	1	<1	381	622	NC	3	243
	Shark Bay MP	2	1	<1	221	224	NC	10	961
	Abrolhos MP	2	<1	<1	694	NC	NC	<1	31
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	50	32	8	4	4	7	178	3,512
	Continental Slope Demersal Fish Communities KEF	35	23	2	20	21	23	98	2,610
	Glomar Shoals KEF §	2	<1	<1	360	393	NC	2	25
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	47	28	5	5	5	10	154	2,949
	Exmouth Plateau KEF	23	7	<1	89	93	NC	16	757
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	<1	<1	<1	NC	NC	NC	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	1	1	<1	508	524	NC	9	822
	Western Rock Lobster KEF	<1	<1	<1	NC	NC	NC	NC	NC
	Wallaby Saddle KEF	1	<1	<1	702	NC	NC	<1	25
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	<1	<1	<1	NC	NC	NC	NC	NC
	Ancient Coastline at 90-120m Depth Contour KEF	<1	<1	<1	NC	NC	NC	NC	NC
Biologically Important Areas	Marine Turtle BIA	68	37	8	1	1	2	178	10,865
	Dugong BIA	17	7	1	23	23	24	52	5,000
	Seabirds BIA	68	37	8	1	1	2	178	10,865
	Seals BIA	<1	<1	<1	NC	NC	NC	NC	NC
	Sharks BIA	68	37	8	1	1	2	178	10,865
	Whales BIA	68	37	8	1	1	2	178	10,865
Fisheries	Southern Bluefin Tuna Fishery	68	37	8	1	1	2	178	10,865
	Western Tuna and Billfish Fishery	68	37	8	1	1	2	178	10,865
	Western Skipjack Fishery	68	37	8	1	1	2	178	10,865
	North-West Slope Trawl Fishery	35	23	2	18	18	21	98	2,518
Banks	Rankin Bank §	2	<1	<1	203	213	NC	3	40

NC: No contact to receptor predicted for specified threshold

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

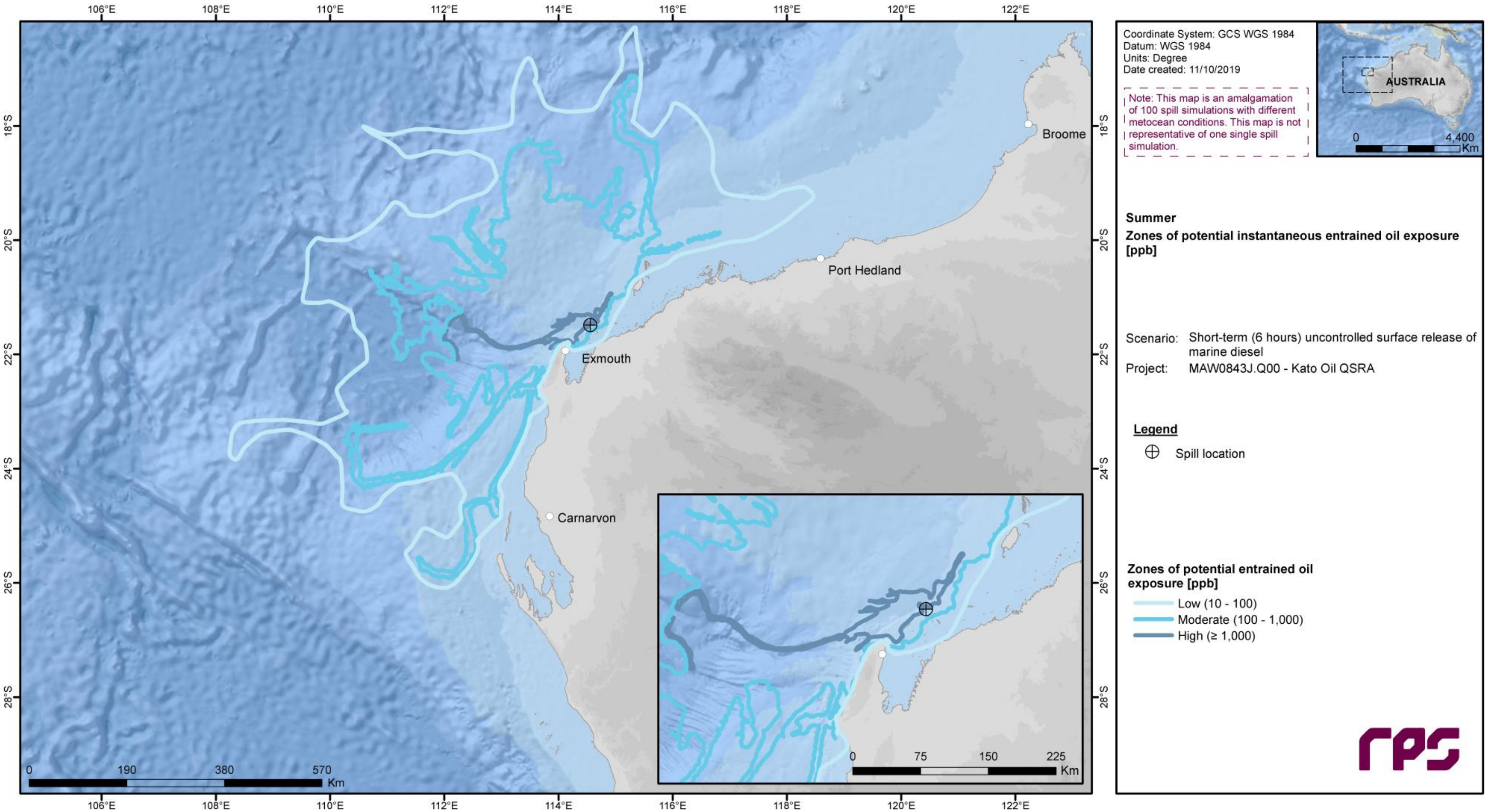


Figure 3.55 Predicted zones of potential instantaneous entrained oil exposure for a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in summer months.

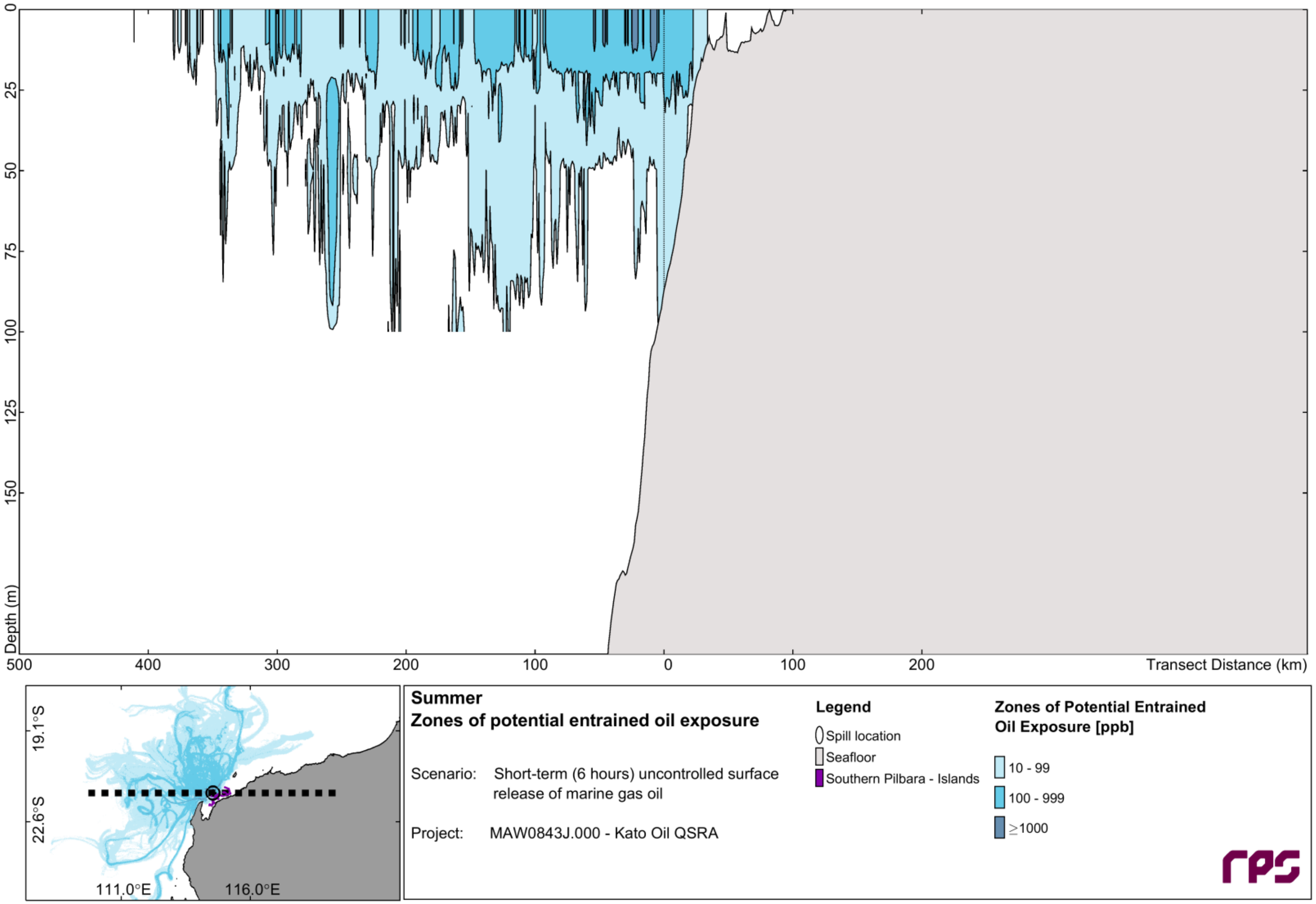


Figure 3.56 East-West cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the summer season. The results were calculated from 100 spill trajectories.

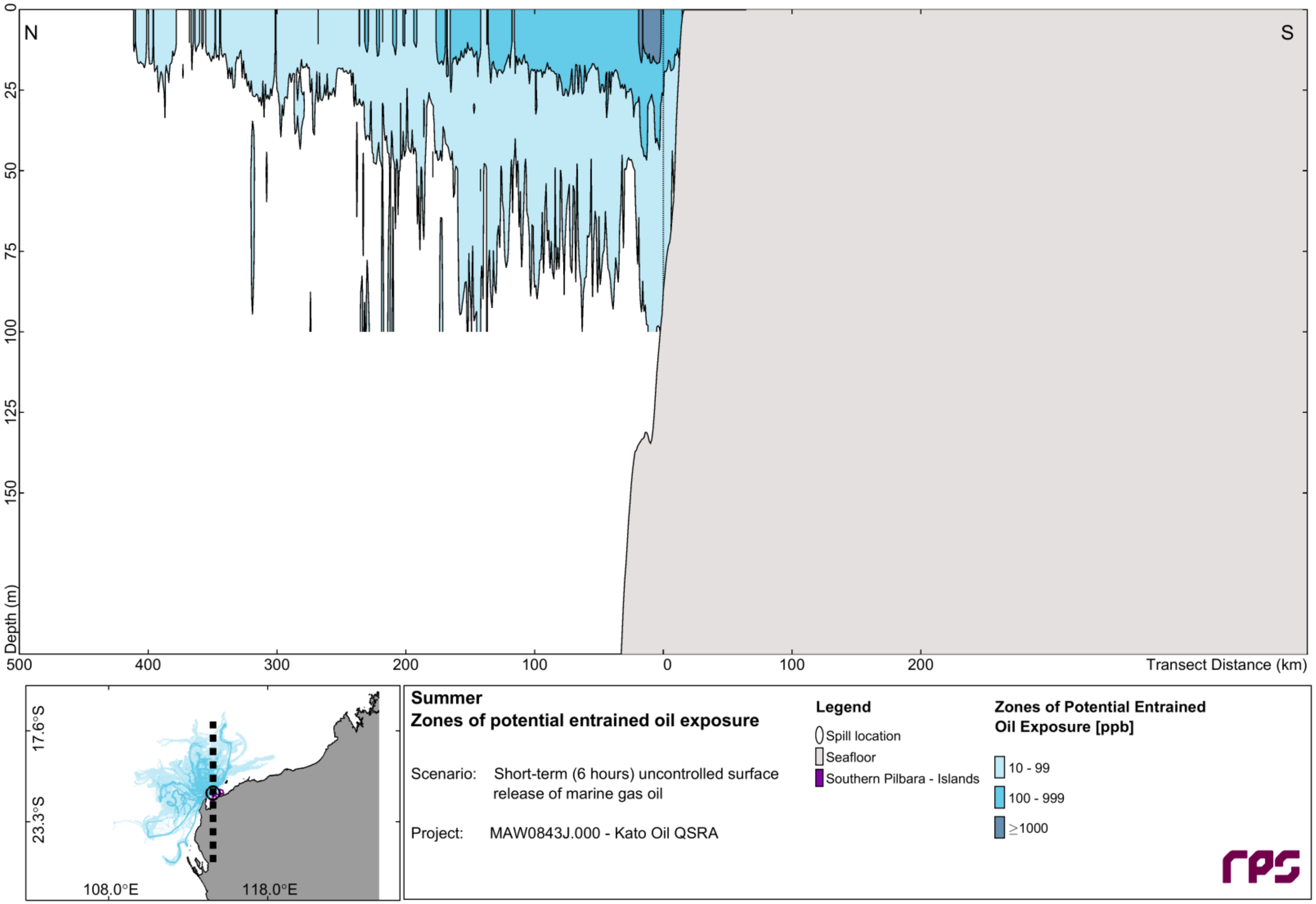


Figure 3.57 **North-South cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the summer season. The results were calculated from 100 spill trajectories.**

3.3.3.2.3 Entrained Oil - Exposure

Table 3.26 Expected time-integrated entrained oil exposure outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in summer months.

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Islands	Barrow Island	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	36	1	1	NC	BS
	Lowendal Islands	Probability (%) >960	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	16	NC	NC	BS	BS
	Montebello Islands	Probability (%) >960	1	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	1,585	185	25	NC	BS
	Southern Pilbara - Islands	Probability (%) >960	2	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	2,165	174	64	BS	BS
	Abrolhos Islands	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	59	NC	BS	BS	BS
Coastlines	Southern Pilbara - Shoreline	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	65	BS	BS	BS	BS
	Exmouth Gulf South East	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	28	BS	BS	BS	BS
	Exmouth Gulf West	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	44	NC	BS	BS	BS
State Marine and National Parks	Muiron Islands MMA	Probability (%) >960	3	1	NC	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	11,209	4,564	246	72	NC
	Barrow Island MMA	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	438	149	50	10	BS
	Ningaloo MP (State)	Probability (%) >960	6	2	NC	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	13,747	8,255	817	413	6
	Ningaloo Coast WH	Probability (%) >960	6	2	NC	NC	NC
		Probability (%) >9,600	1	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,265	12,811	817	413	18
	Shark Bay WH	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Montebello Islands MP	Probability (%) >960	1	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	1,585	185	101	11	BS
	Barrow Islands MP	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	83	8	NC	NC	BS
Australian	Montebello MP	Probability (%) >960	3	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,521	866	548	194	16
	Ningaloo MP	Probability (%) >960	6	1	NC	NC	NC
		Probability (%) >9,600	1	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	15,265	12,811	659	333	18
	Argo-Rowley Terrace MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Gascoyne MP	Probability (%) >960	7	2	1	1	NC
		Probability (%) >9,600	2	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	11,260	8,160	5,250	2,714	200
	Carnarvon Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	934	273	193	108	13
	Shark Bay MP	Probability (%) >960	1	1	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,305	2,250	170	167	45
	Abrolhos MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	67	45	15	4	1
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	34	9	5	1	NC
		Probability (%) >9,600	8	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	48,530	6,000	3,179	1,222	349
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	16	2	1	1	NC
		Probability (%) >9,600	2	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	13,502	5,388	3,873	1,464	118
	Glomar Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	709	169	53	82	13
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	32	4	NC	1	NC
	Probability (%) >9,600	1	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	29,937	5,598	829	1,647	218
Exmouth Plateau KEF	Probability (%) >960	9	2	1	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	8,580	3,278	1,561	755	200
Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	1	1	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	3,434	1,898	262	97	44
Western Rock Lobster KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Wallaby Saddle KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	67	30	7	4	NC
Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Biologically Important Areas	Marine Turtle BIA	Probability (%) >960	34	12	6	1	NC
		Probability (%) >9,600	9	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	51,785	12,811	4,734	1,619	380
	Dugong BIA	Probability (%) >960	6	2	NC	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	13,747	8,255	817	413	14
	Seabirds BIA	Probability (%) >960	34	12	6	1	NC
		Probability (%) >9,600	9	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	51,785	12,811	4,734	1,647	380
	Seals BIA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Sharks BIA	Probability (%) >960	34	12	6	1	NC
		Probability (%) >9,600	9	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	51,785	8,751	4,734	1,619	380
	Whales BIA	Probability (%) >960	34	12	6	1	NC
		Probability (%) >9,600	9	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	51,785	12,811	4,734	1,647	380
Fisheries	Southern Bluefin Tuna Fishery	Probability (%) >960	34	12	6	1	NC
		Probability (%) >9,600	9	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	51,785	12,811	5,250	2,714	380
	Western Tuna and Billfish Fishery	Probability (%) >960	34	12	6	1	NC
		Probability (%) >9,600	9	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	51,785	12,811	5,250	2,714	380
	Western Skipjack Fishery	Probability (%) >960	34	12	6	1	NC
		Probability (%) >9,600	9	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	51,785	12,811	5,250	2,714	380
	North-West Slope Trawl Fishery	Probability (%) >960	16	2	1	1	NC
		Probability (%) >9,600	2	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	13,502	4,901	2,706	1,464	178
Banks	Rankin Bank	Probability (%) >960	1	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	2,084	451	196	29	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

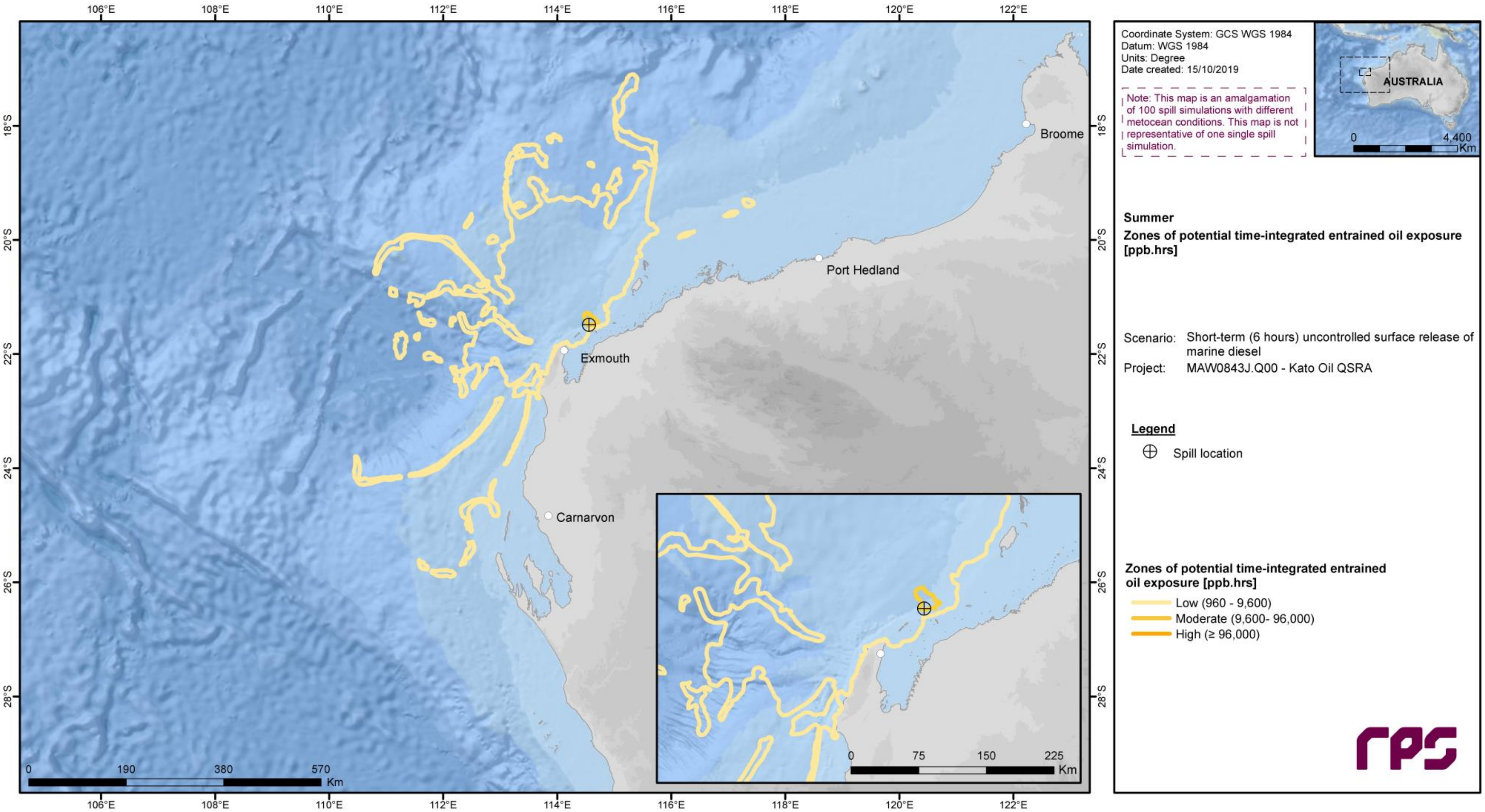


Figure 3.58 Predicted zones of potential time-integrated entrained oil exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting during summer.

3.3.3.2.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Table 3.27 Expected instantaneous dissolved aromatic hydrocarbons outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in summer months.

Receptors		Probability (%) of dissolved aromatic concentration at			Maximum dissolved aromatic hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Barrow Island	<1	<1	<1	<1	<1
	Lowendal Islands	<1	<1	<1	NC	NC
	Montebello Islands	<1	<1	<1	<1	2
	Southern Pilbara - Islands	1	<1	<1	<1	26
	Abrolhos Islands	<1	<1	<1	NC	NC
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC
Coastlines	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC
	Exmouth Gulf South East	<1	<1	<1	NC	NC
	Exmouth Gulf West	<1	<1	<1	<1	<1
State Marine and National Parks	Muiron Islands MMA	2	1	<1	2	165
	Barrow Island MMA	<1	<1	<1	<1	2
	Ningaloo MP (State)	7	2	<1	2	149
	Ningaloo Coast WH	7	2	<1	2	149
	Shark Bay WH	<1	<1	<1	NC	NC
	Montebello Islands MP	<1	<1	<1	<1	9
	Barrow Islands MP	<1	<1	<1	<1	<1
Australian Marine Parks	Montebello MP	1	<1	<1	<1	49
	Ningaloo MP	7	1	<1	2	103
	Argo-Rowley Terrace MP	<1	<1	<1	<1	<1
	Gascoyne MP	7	1	<1	2	102
	Carnarvon Canyon MP	<1	<1	<1	<1	8
	Shark Bay MP	1	<1	<1	<1	27
	Abrolhos MP	<1	<1	<1	<1	<1
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	22	5	<1	8	145
	Continental Slope Demersal Fish Communities KEF	12	4	<1	5	141
	Glomar Shoals KEF §	1	<1	<1	<1	16
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	16	5	<1	8	145
	Exmouth Plateau KEF	3	<1	<1	<1	50

Receptors		Probability (%) of dissolved aromatic concentration at ≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	Maximum dissolved aromatic hydrocarbon concentration (ppb) averaged over all replicate simulations	at any depth, in the worst replicate
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	<1	<1	<1	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	1	<1	<1	<1	20
	Western Rock Lobster KEF	<1	<1	<1	NC	NC
	Wallaby Saddle KEF	<1	<1	<1	<1	<1
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	<1	<1	<1	NC	NC
	Ancient Coastline at 90-120m Depth Contour KEF	<1	<1	<1	NC	NC
Biologically Important Areas	Marine Turtle BIA	28	8	<1	10	275
	Dugong BIA	7	2	<1	2	131
	Seabirds BIA	28	8	<1	10	275
	Seals BIA	<1	<1	<1	NC	NC
	Sharks BIA	28	8	<1	10	275
	Whales BIA	28	8	<1	10	275
Fisheries	Southern Bluefin Tuna Fishery	28	8	<1	10	275
	Western Tuna and Billfish Fishery	28	8	<1	10	275
	Western Skipjack Fishery	28	8	<1	10	275
	North-West Slope Trawl Fishery	13	4	<1	5	112
Banks	Rankin Bank §	<1	<1	<1	<1	3

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

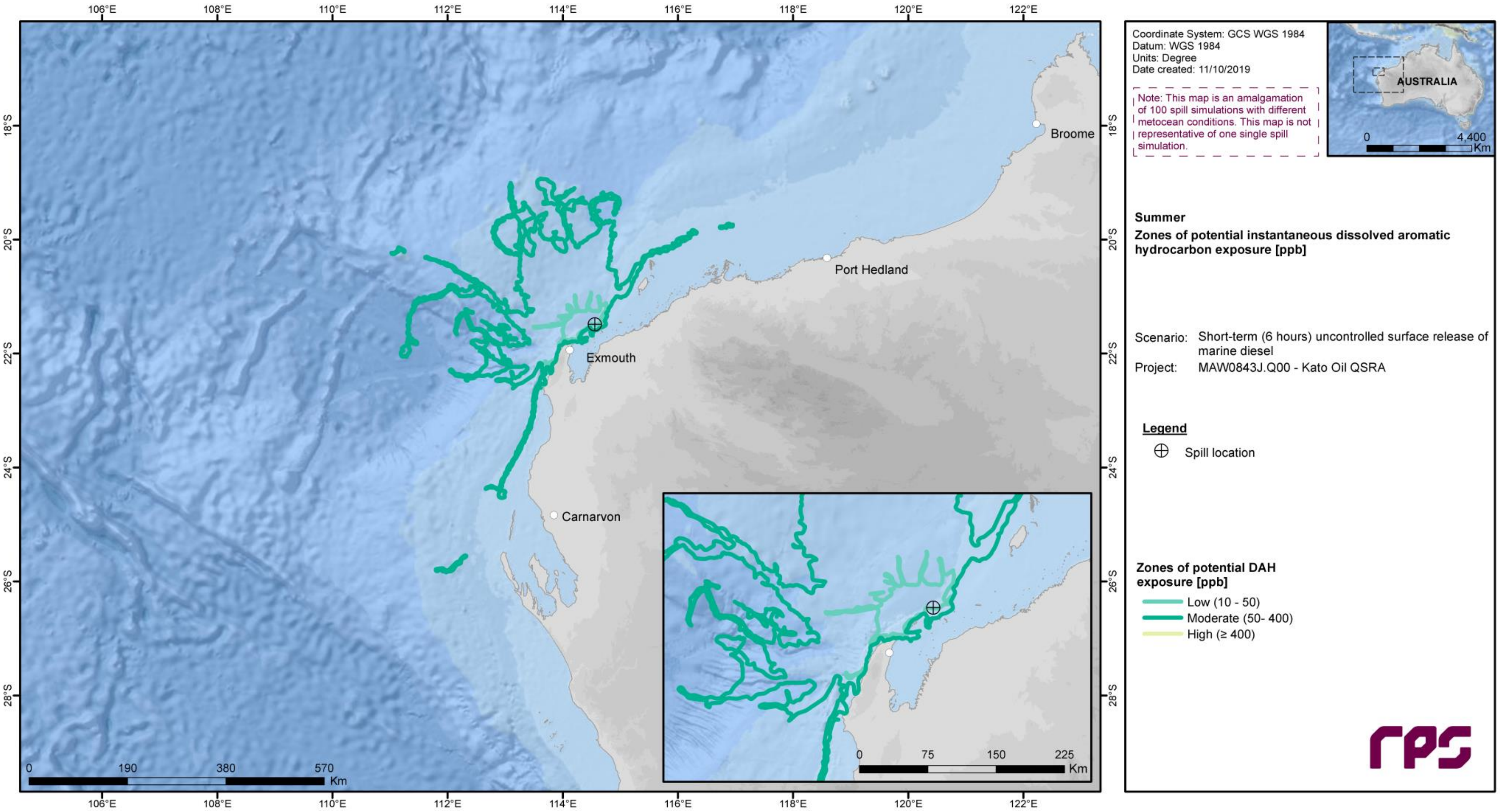


Figure 3.59 Predicted zones of potential instantaneous dissolved aromatic hydrocarbon exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in summer months.

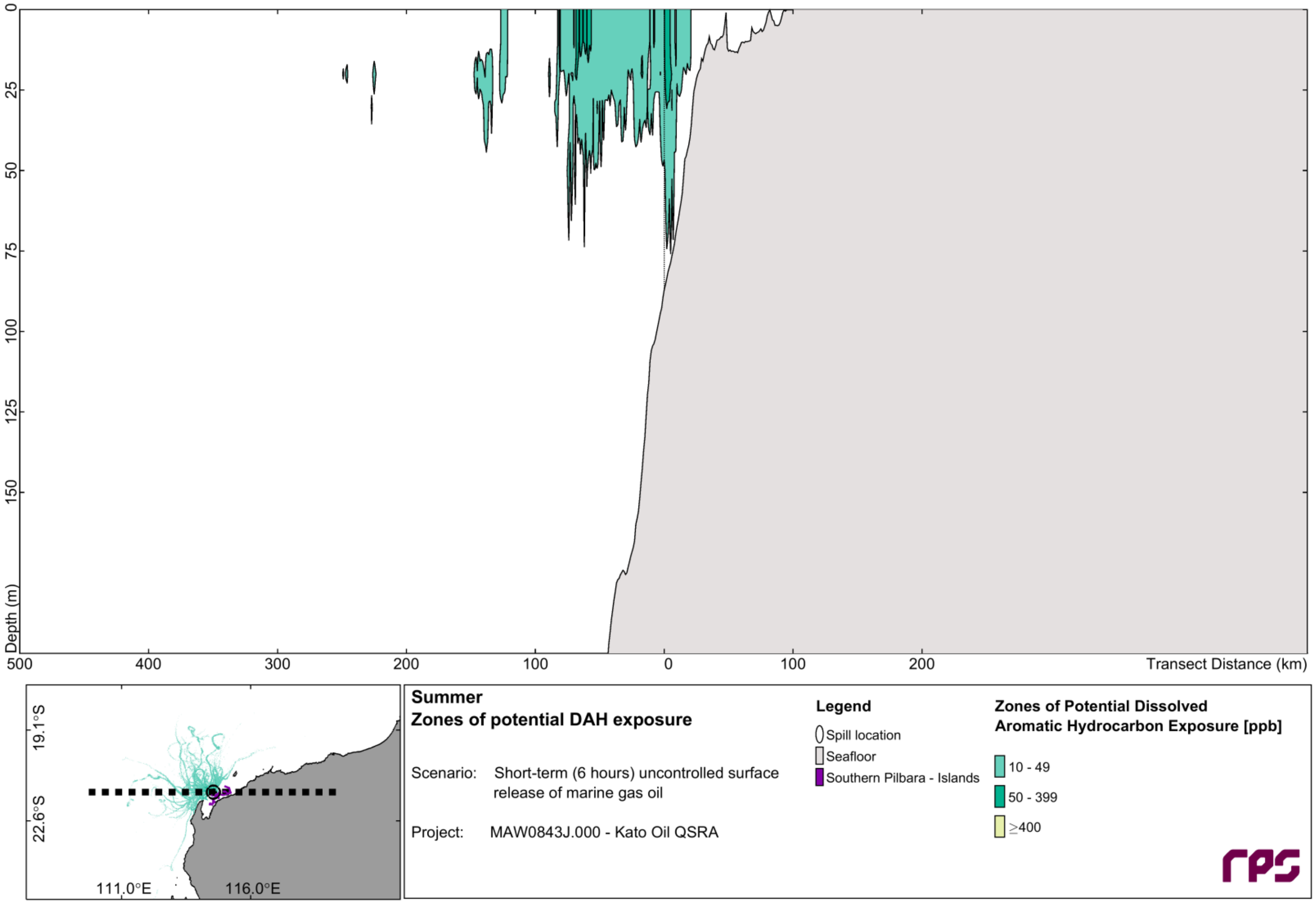


Figure 3.60 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the summer season. The results were calculated from 100 spill trajectories.

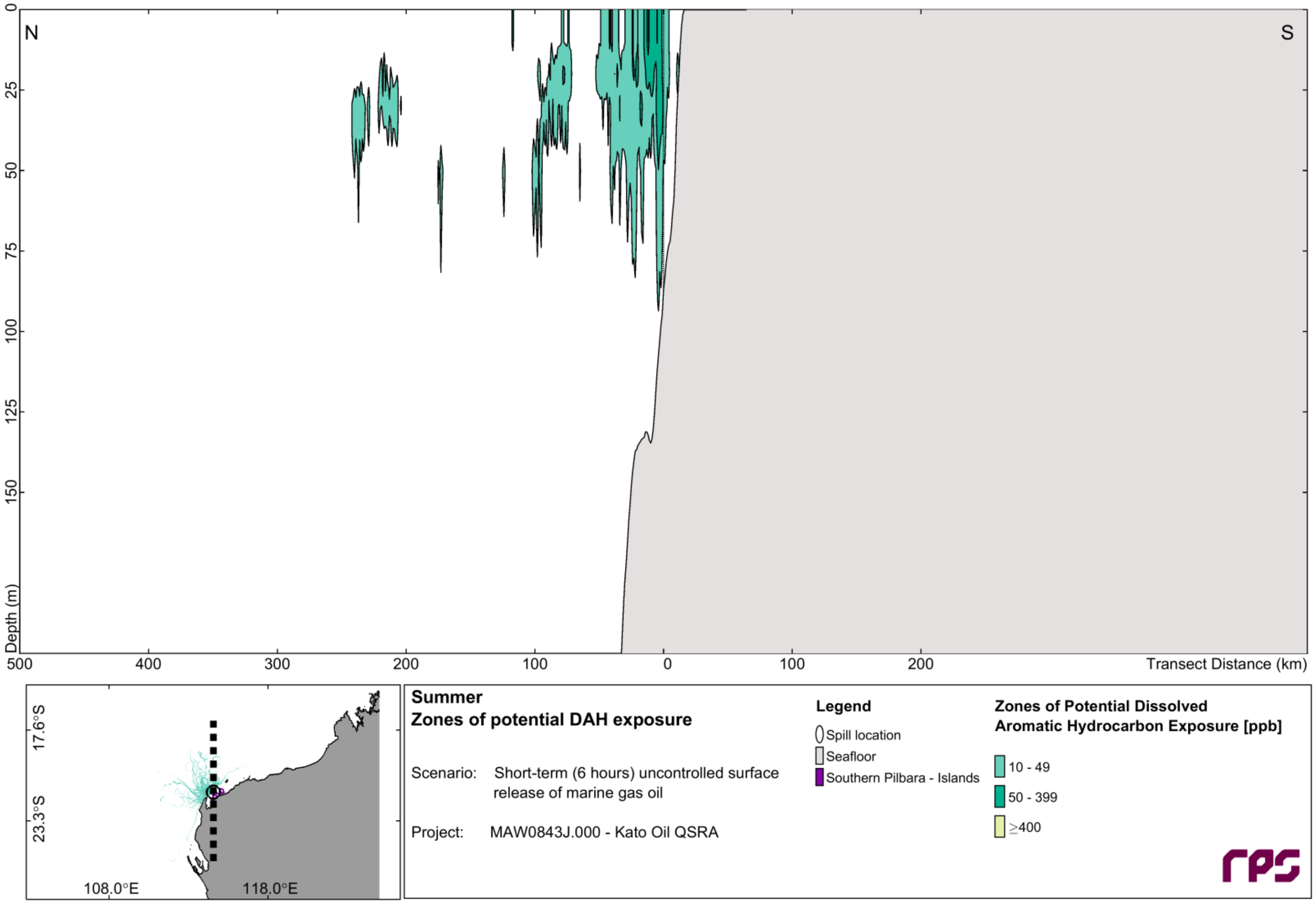


Figure 3.61 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the summer season. The results were calculated from 100 spill trajectories.

3.3.3.2.5 Dissolved Aromatic Hydrocarbons - Exposure

Table 3.28 Expected time-integrated dissolved aromatic hydrocarbons exposure outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in summer months.

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Islands	Barrow Island	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Lowendal Islands	Probability (%) >960	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS
	Montebello Islands	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	2	3	2	NC	BS
	Southern Pilbara - Islands	Probability (%) >960	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	208	46	4	BS	BS
	Abrolhos Islands	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS
Coastlines	Southern Pilbara - Shoreline	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	BS	BS	BS	BS
	Exmouth Gulf South East	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	NC	BS	BS	BS	BS
	Exmouth Gulf West	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS
State Marine and National Parks	Muiron Islands MMA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	280	141	35	1	NC
	Barrow Island MMA	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	1	2	1	BS
	Ningaloo MP (State)	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	543	396	260	82	9
	Ningaloo Coast WH	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	543	396	282	82	17
	Shark Bay WH	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Montebello Islands MP	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	7	8	10	7	BS
	Barrow Islands MP	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
Australian	Montebello MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	79	75	52	22	6
	Ningaloo MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	425	327	282	45	17
	Argo-Rowley Terrace MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	2	NC	NC	NC	NC
	Gascoyne MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	168	312	266	115	28
	Carnarvon Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	5	14	16	14	8
	Shark Bay MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	14	43	90	38	4
	Abrolhos MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1	1	1	1	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	659	606	548	156	87
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	378	419	270	254	30
	Glomar Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	5	4	34	20	3
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	670	625	345	111	42
Exmouth Plateau KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	97	187	165	112	70
Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	14	65	65	41	5
Western Rock Lobster KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Wallaby Saddle KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	1	NC	NC
Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Biologically Important Areas	Marine Turtle BIA	Probability (%) >960	6	3	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,408	3,082	2,699	634	132
	Dugong BIA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	543	396	260	82	9
	Seabirds BIA	Probability (%) >960	6	3	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,408	3,082	2,699	634	132
	Seals BIA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Sharks BIA	Probability (%) >960	6	3	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,408	3,082	2,699	634	132
	Whales BIA	Probability (%) >960	6	3	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,408	3,082	2,699	634	132
Fisheries	Southern Bluefin Tuna Fishery	Probability (%) >960	6	3	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,408	3,082	2,699	634	132
	Western Tuna and Billfish Fishery	Probability (%) >960	6	3	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,408	3,082	2,699	634	132
	Western Skipjack Fishery	Probability (%) >960	6	3	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	3,408	3,082	2,699	634	132
	North-West Slope Trawl Fishery	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	378	419	270	268	43
Banks	Rankin Bank	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	31	34	30	10	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed

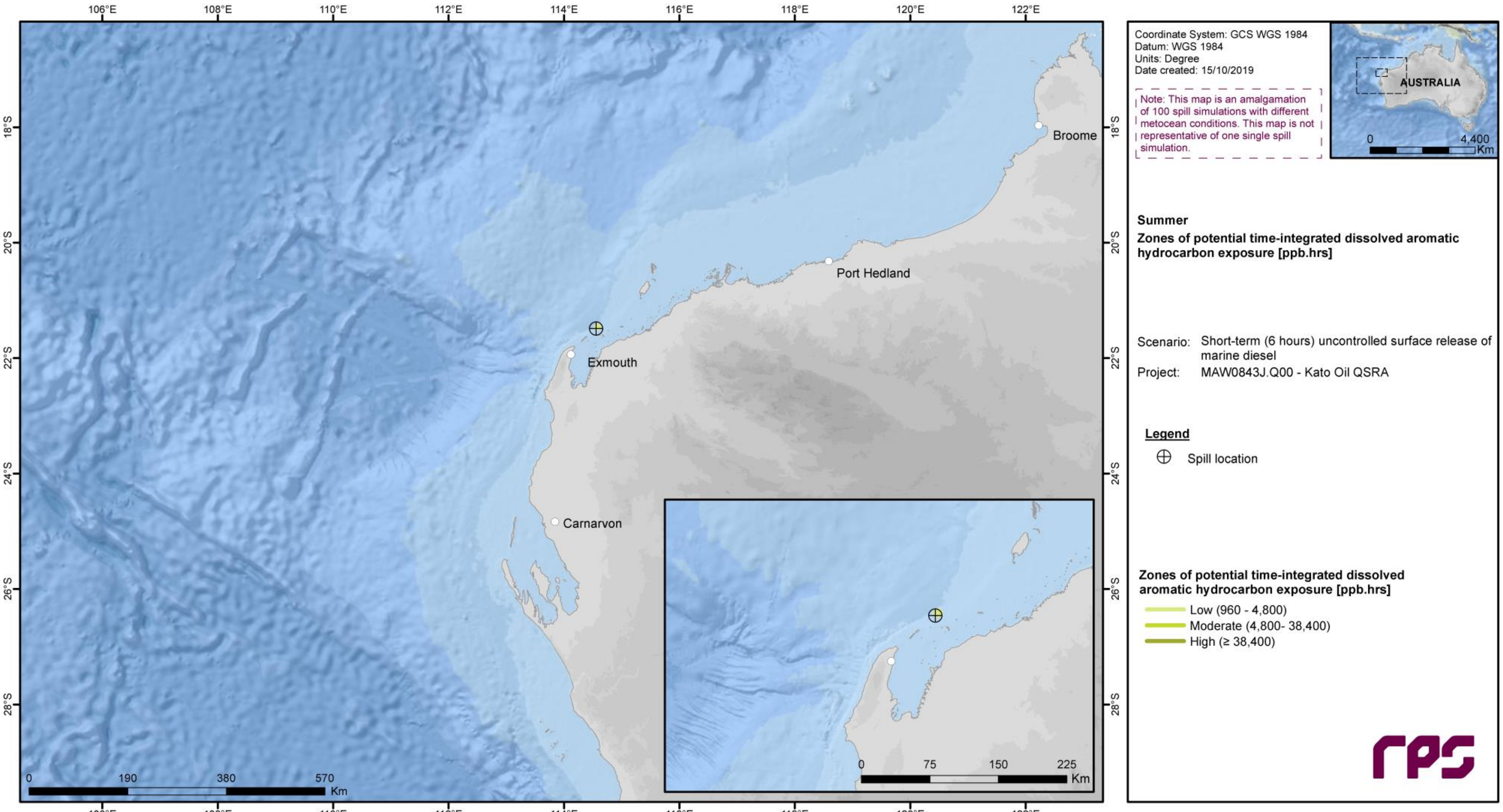


Figure 3.62 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting during summer.

3.3.3.3 Winter

3.3.3.3.1 Floating and Shoreline Oil

Table 3.29 Expected floating and shoreline oil outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in winter months.

Receptors		Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
Islands	Barrow Island	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Islands	Lowendal Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Islands	Montebello Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Islands	Southern Pilbara - Islands	3	<1	<1	9	NC	NC	4	2	1	9	10	32	34	2,989	<1	48	<1	4	<1	2	<1	2
Islands	Abrolhos Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Islands	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Exmouth Gulf South East	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Exmouth Gulf West	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
State Marine and National Parks	Muiron Islands MMA	10	2	<1	13	15	NC	4	2	<1	20	21	NC	12	555	<1	14	<1	9	<1	2	NC	NC
State Marine and National Parks	Barrow Island MMA	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
State Marine and National Parks	Ningaloo MP (State)	1	<1	<1	36	NC	NC	1	<1	<1	110	NC	NC	0.2	24	<1	<1	NA	NA	NA	NA	NA	NA
State Marine and National Parks	Ningaloo Coast WH	3	<1	<1	34	NC	NC	1	<1	<1	110	NC	NC	0.2	24	<1	<1	<1	3	NC	NC	NC	NC
State Marine and National Parks	Shark Bay WH	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	<1	3	NC	NC	NC	NC
State Marine and National Parks	Montebello Islands MP	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
State Marine and National Parks	Barrow Islands MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Montebello MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Ningaloo MP*	3	<1	<1	34	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Argo-Rowley Terrace MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Gascoyne MP*	3	<1	<1	67	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Carnarvon Canyon MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Shark Bay MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Abrolhos MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological	Ancient Coastline at 125m Depth Contour KEF*	26	14	3	5	6	8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological	Continental Slope Demersal Fish Communities KEF*	2	<1	<1	29	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Receptors		Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
	Glomar Shoals KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF*	20	8	1	7	9	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Exmouth Plateau KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Demersal Slope and associated Fish Communities KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Rock Lobster KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wallaby Saddle KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ancient Coastline at 90-120m Depth Contour KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Biologically Important Areas	Marine Turtle BIA*†	98	89	79	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dugong BIA*	2	<1	<1	78	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seabirds BIA*†	98	89	79	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seals BIA*†	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sharks BIA*	98	89	79	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Whales BIA*	98	89	79	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	Southern Bluefin Tuna Fishery*	98	89	79	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Tuna and Billfish Fishery*	98	89	79	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Skipjack Fishery*	98	89	79	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	North-West Slope Trawl Fishery*	2	<1	<1	29	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Rankin Bank*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NC: No contact to receptor predicted for specified threshold.

* Floating oil will not accumulate on submerged features and at open ocean locations. NA: Not applicable.

† Receptor is considered as submerged, any accumulation occurring on emerged features within this receptor is captured under the associated shoreline receptor in the table.

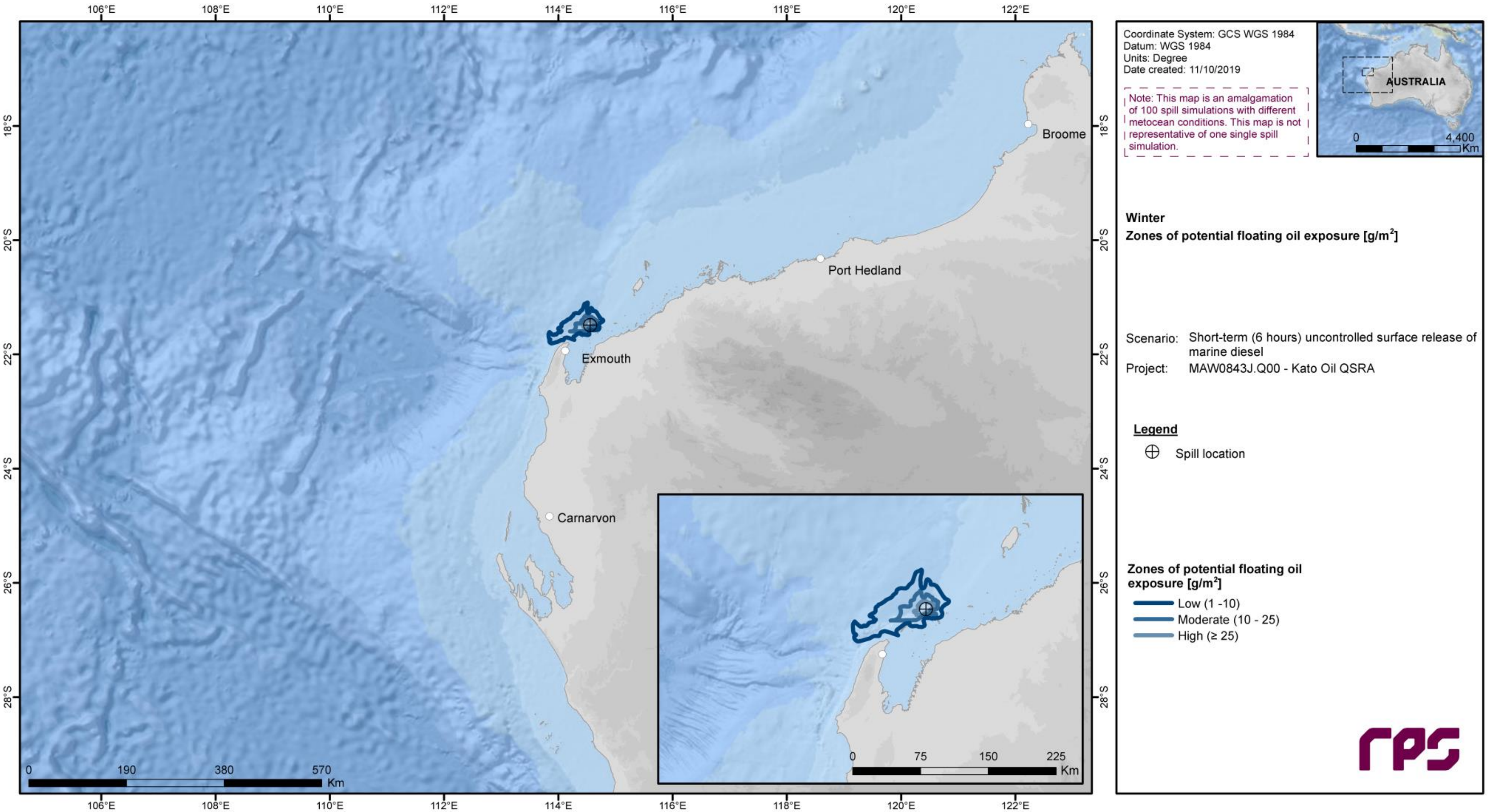


Figure 3.63 Predicted zones of potential floating oil exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in winter.

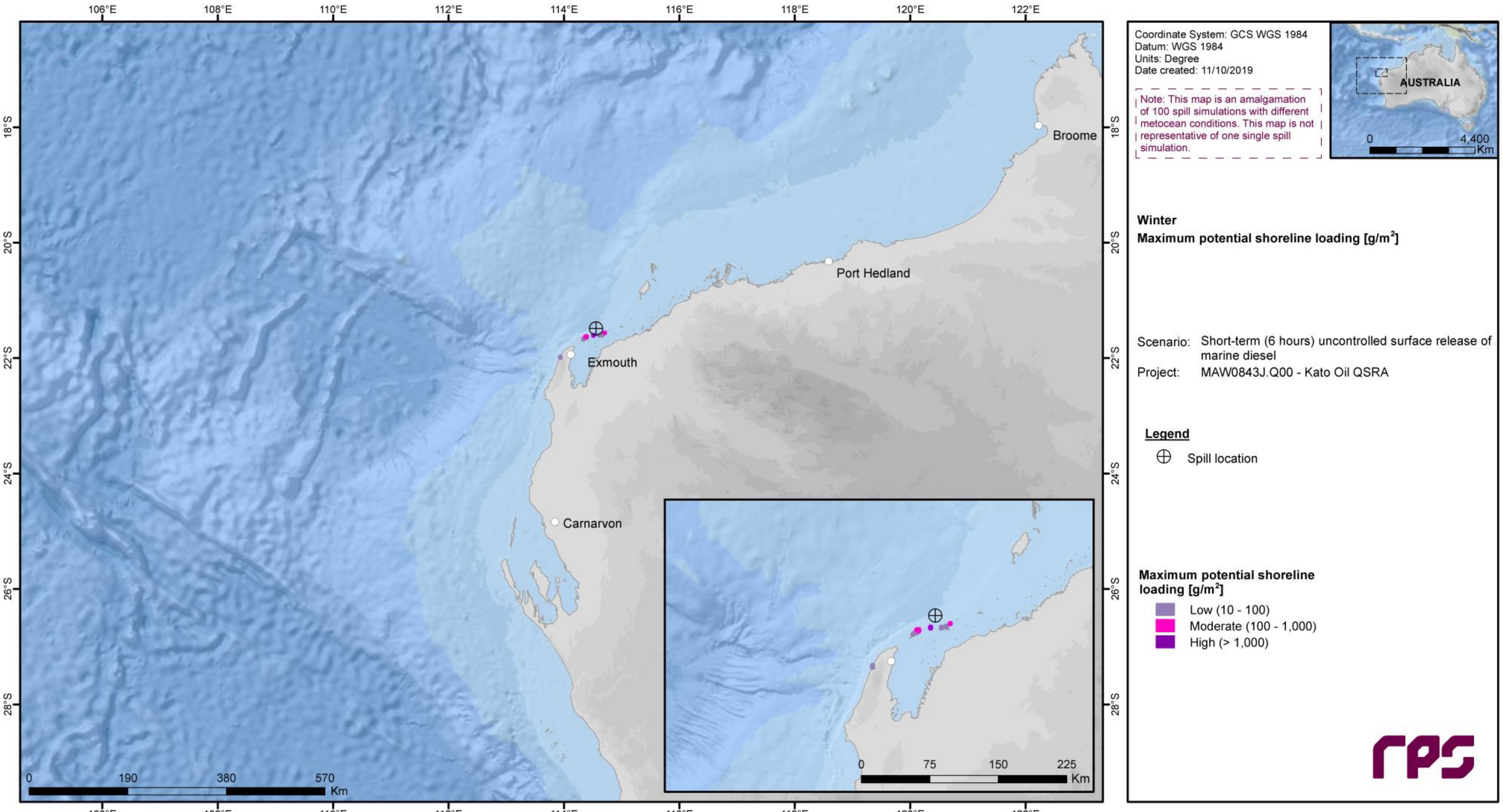


Figure 3.64 Predicted maximum potential shoreline loading resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in winter.

3.3.3.3.2 Entrained Oil - Instantaneous

Table 3.30 Expected instantaneous entrained oil outcomes at sensitive receptors resulting a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in winter months.

Receptors		Probability (%) of entrained hydrocarbon concentration contact at			Minimum time (hours) to receptor waters at			Maximum entrained hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Barrow Island	1	<1	<1	202	NC	NC	<1	12
	Lowendal Islands	<1	<1	<1	NC	NC	NC	NC	NC
	Montebello Islands	<1	<1	<1	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	7	2	<1	8	8	NC	6	362
	Abrolhos Islands	<1	<1	<1	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
Coastlines	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
	Exmouth Gulf South East	<1	<1	<1	NC	NC	NC	NC	NC
	Exmouth Gulf West	<1	<1	<1	NC	NC	NC	NC	NC
State Marine and National Parks	Muiron Islands MMA	12	5	1	11	12	12	29	1,722
	Barrow Island MMA	<1	<1	<1	NC	NC	NC	<1	5
	Ningaloo MP (State)	11	8	1	30	31	32	32	1,643
	Ningaloo Coast WH	25	10	1	25	26	32	34	1,643
	Shark Bay WH	<1	<1	<1	NC	NC	NC	NC	NC
	Montebello Islands MP	<1	<1	<1	NC	NC	NC	NC	NC
	Barrow Islands MP	<1	<1	<1	NC	NC	NC	NC	NC
Australian Marine Parks	Montebello MP	1	<1	<1	396	NC	NC	<1	11
	Ningaloo MP	25	10	1	25	26	32	34	1,523
	Argo-Rowley Terrace MP	<1	<1	<1	NC	NC	NC	NC	NC
	Gascoyne MP	33	13	2	32	35	41	65	1,418
	Carnarvon Canyon MP	2	<1	<1	374	NC	NC	<1	83
	Shark Bay MP	4	1	<1	350	404	NC	2	118
	Abrolhos MP	2	<1	<1	586	NC	NC	<1	96
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	40	20	7	5	6	8	115	2,521
	Continental Slope Demersal Fish Communities KEF	39	15	2	24	27	39	65	1,586
	Glomar Shoals KEF §	<1	<1	<1	NC	NC	NC	NC	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	36	17	4	7	8	11	91	2,521
	Exmouth Plateau KEF	24	8	<1	140	152	NC	16	483
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	<1	<1	<1	NC	NC	NC	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	4	1	<1	431	544	NC	2	107
	Western Rock Lobster KEF	<1	<1	<1	NC	NC	NC	NC	NC
	Wallaby Saddle KEF	1	<1	<1	594	NC	NC	<1	60
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	<1	<1	<1	NC	NC	NC	<1	<1
	Ancient Coastline at 90-120m Depth Contour KEF	<1	<1	<1	NC	NC	NC	NC	NC
Biologically Important Areas	Marine Turtle BIA	54	23	7	1	1	3	140	3,827
	Dugong BIA	15	8	1	34	35	65	32	1,009
	Seabirds BIA	54	23	7	1	1	3	140	3,827
	Seals BIA	<1	<1	<1	NC	NC	NC	NC	NC
	Sharks BIA	54	23	7	1	1	3	140	3,827
	Whales BIA	54	23	7	1	1	3	140	3,827
Fisheries	Southern Bluefin Tuna Fishery	54	23	7	1	1	3	140	3,827
	Western Tuna and Billfish Fishery	54	23	7	1	1	3	140	3,827
	Western Skipjack Fishery	54	23	7	1	1	3	140	3,827
	North-West Slope Trawl Fishery	37	15	1	25	29	39	57	1,371
Banks	Rankin Bank §	<1	<1	<1	NC	NC	NC	NC	NC

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

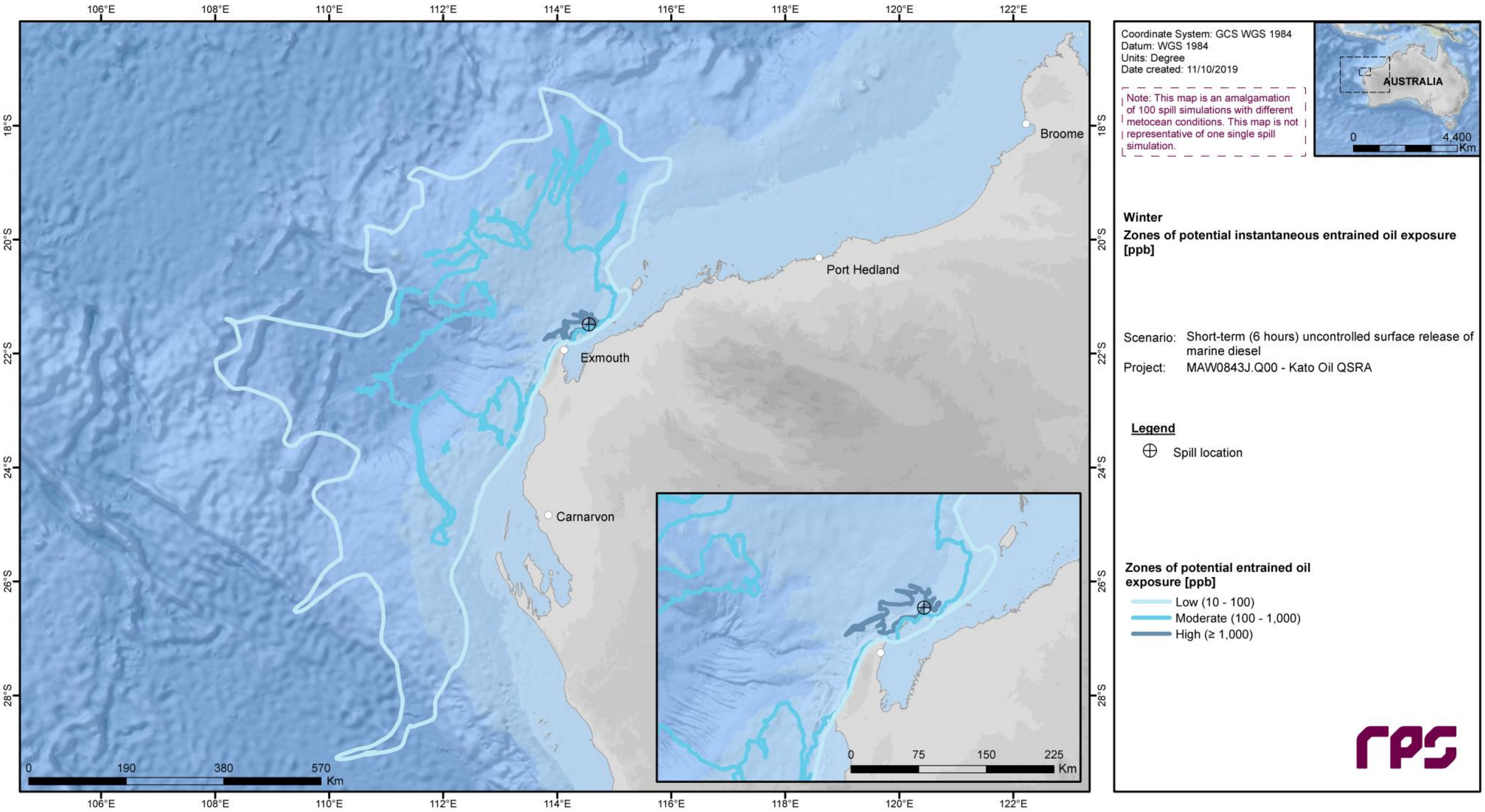


Figure 3.65 Predicted zones of potential instantaneous entrained oil exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in winter months.

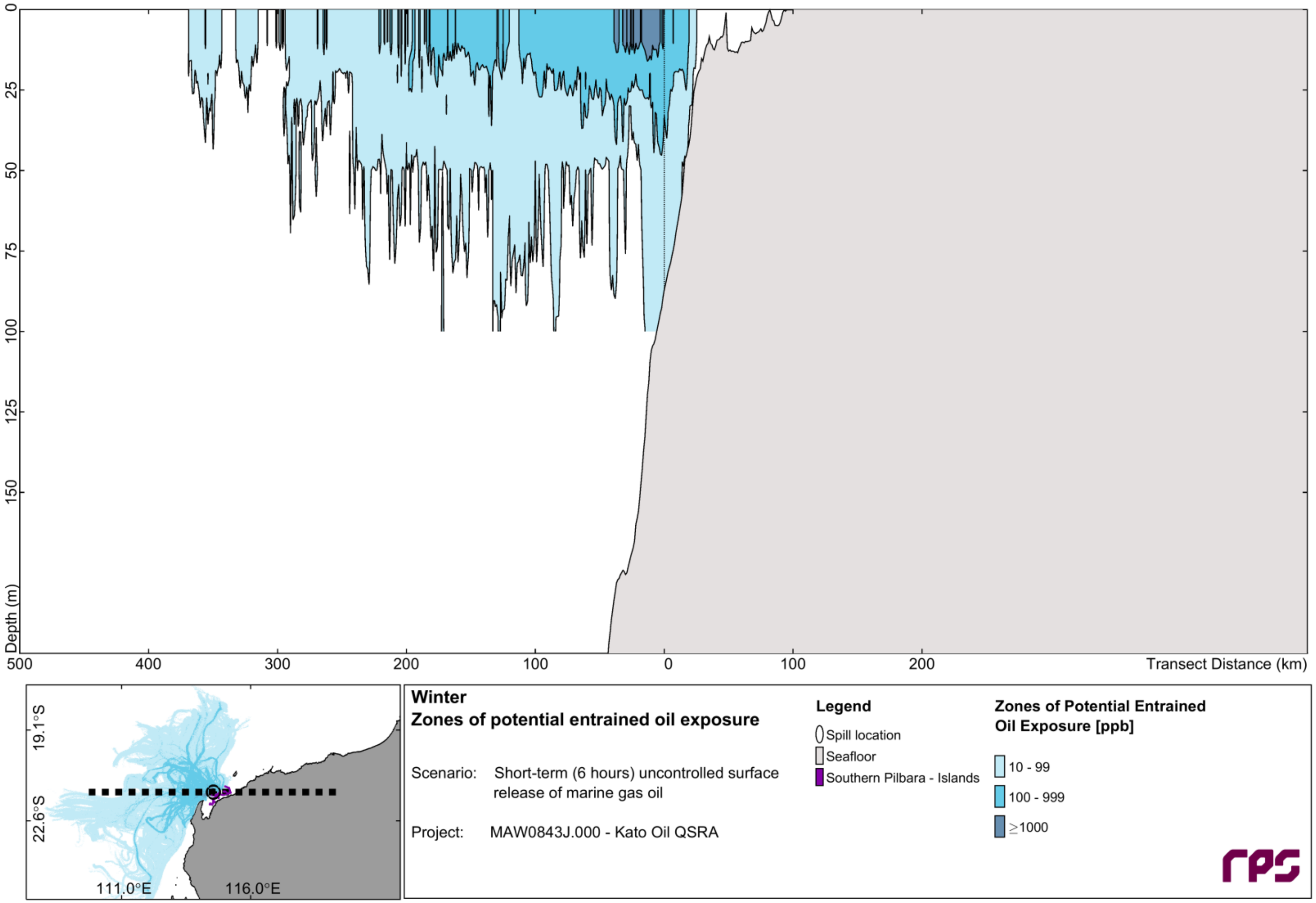


Figure 3.66 East-West cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the winter season. The results were calculated from 100 spill trajectories.

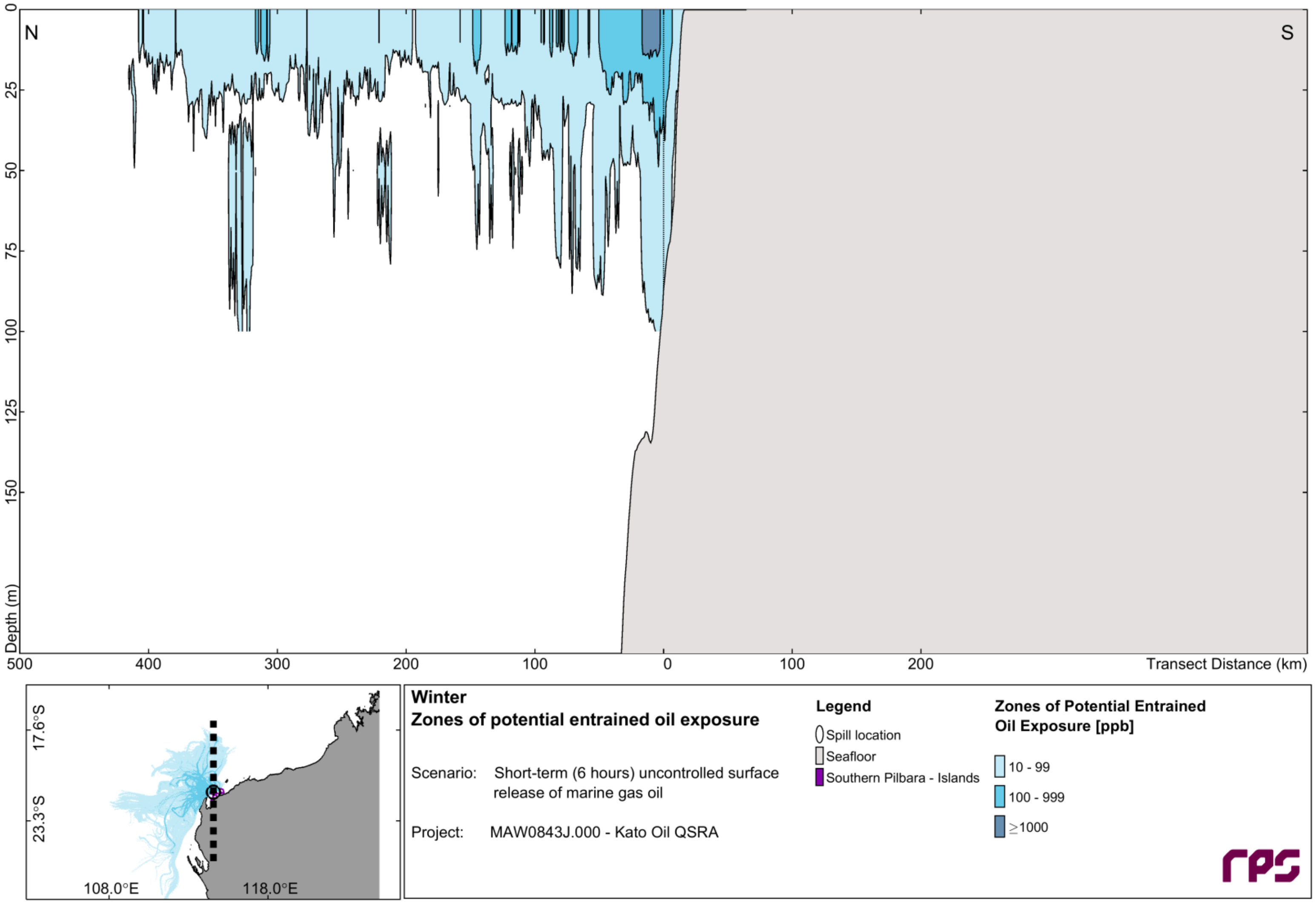


Figure 3.67 North-South cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the winter season. The results were calculated from 100 spill trajectories.

3.3.3.3.3 Entrained Oil - Exposure

Table 3.31 Expected time-integrated entrained oil exposure outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in summer months.

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Islands	Barrow Island	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	11	NC	NC	NC	BS
	Lowendal Islands	Probability (%) >960	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS
	Montebello Islands	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Southern Pilbara - Islands	Probability (%) >960	2	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	2,369	469	127	BS	BS
	Abrolhos Islands	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS
Coastlines	Southern Pilbara - Shoreline	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	BS	BS	BS	BS
	Exmouth Gulf South East	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	NC	BS	BS	BS	BS
	Exmouth Gulf West	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS
State Marine and National Parks	Muiron Islands MMA	Probability (%) >960	4	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	4,943	350	29	7	3
	Barrow Island MMA	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	10	NC	NC	NC	BS
	Ningaloo MP (State)	Probability (%) >960	8	2	1	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	9,879	2,247	1,339	289	3
	Ningaloo Coast WH	Probability (%) >960	9	2	1	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	9,879	2,418	1,339	289	10
	Shark Bay WH	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Montebello Islands MP	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Barrow Islands MP	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
Australian Marine	Montebello MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	76	7	NC	NC	1
	Ningaloo MP	Probability (%) >960	9	2	1	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	9,879	2,418	1,319	227	10
	Argo-Rowley Terrace MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Gascoyne MP	Probability (%) >960	13	3	1	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	10,305	4,168	2,056	868	201
	Carnarvon Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	951	402	112	73	24
	Shark Bay MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	520	161	124	29	2
	Abrolhos MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	377	85	113	18	1
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	22	9	3	1	NC
		Probability (%) >9,600	5	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	38,680	5,354	2,775	2,208	334
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	16	3	1	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,807	4,168	2,637	633	277
	Glomar Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	22	6	3	1	NC
		Probability (%) >9,600	5	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	26,186	4,953	1,855	1,197	242
	Exmouth Plateau KEF	Probability (%) >960	7	1	1	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,227	1,902	1,667	579	162
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	534	200	140	112	9
	Western Rock Lobster KEF	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Wallaby Saddle KEF	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	170	31	8	NC	NC
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Biologically Important Areas	Marine Turtle BIA	Probability (%) >960	25	11	5	2	NC
		Probability (%) >9,600	7	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	48,568	10,755	5,092	3,310	565
	Dugong BIA	Probability (%) >960	8	2	1	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	9,879	2,247	1,339	289	10
	Seabirds BIA	Probability (%) >960	25	11	5	2	NC
		Probability (%) >9,600	7	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	48,568	10,755	5,092	3,310	565
	Seals BIA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Sharks BIA	Probability (%) >960	25	11	5	2	NC
		Probability (%) >9,600	7	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	48,568	10,755	5,092	3,310	565
	Whales BIA	Probability (%) >960	25	11	5	2	NC
		Probability (%) >9,600	7	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	48,568	10,755	5,092	3,310	565
Fisheries	Southern Bluefin Tuna Fishery	Probability (%) >960	25	11	5	2	NC
		Probability (%) >9,600	7	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	48,568	10,755	5,092	3,310	565
	Western Tuna and Billfish Fishery	Probability (%) >960	25	11	5	2	NC
		Probability (%) >9,600	7	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	48,568	10,755	5,092	3,310	565
	Western Skipjack Fishery	Probability (%) >960	25	11	5	2	NC
		Probability (%) >9,600	7	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	48,568	10,755	5,092	3,310	565
	North-West Slope Trawl Fishery	Probability (%) >960	16	3	1	NC	NC
		Probability (%) >9,600	2	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	19,009	3,964	2,637	633	277
Banks	Rankin Bank	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

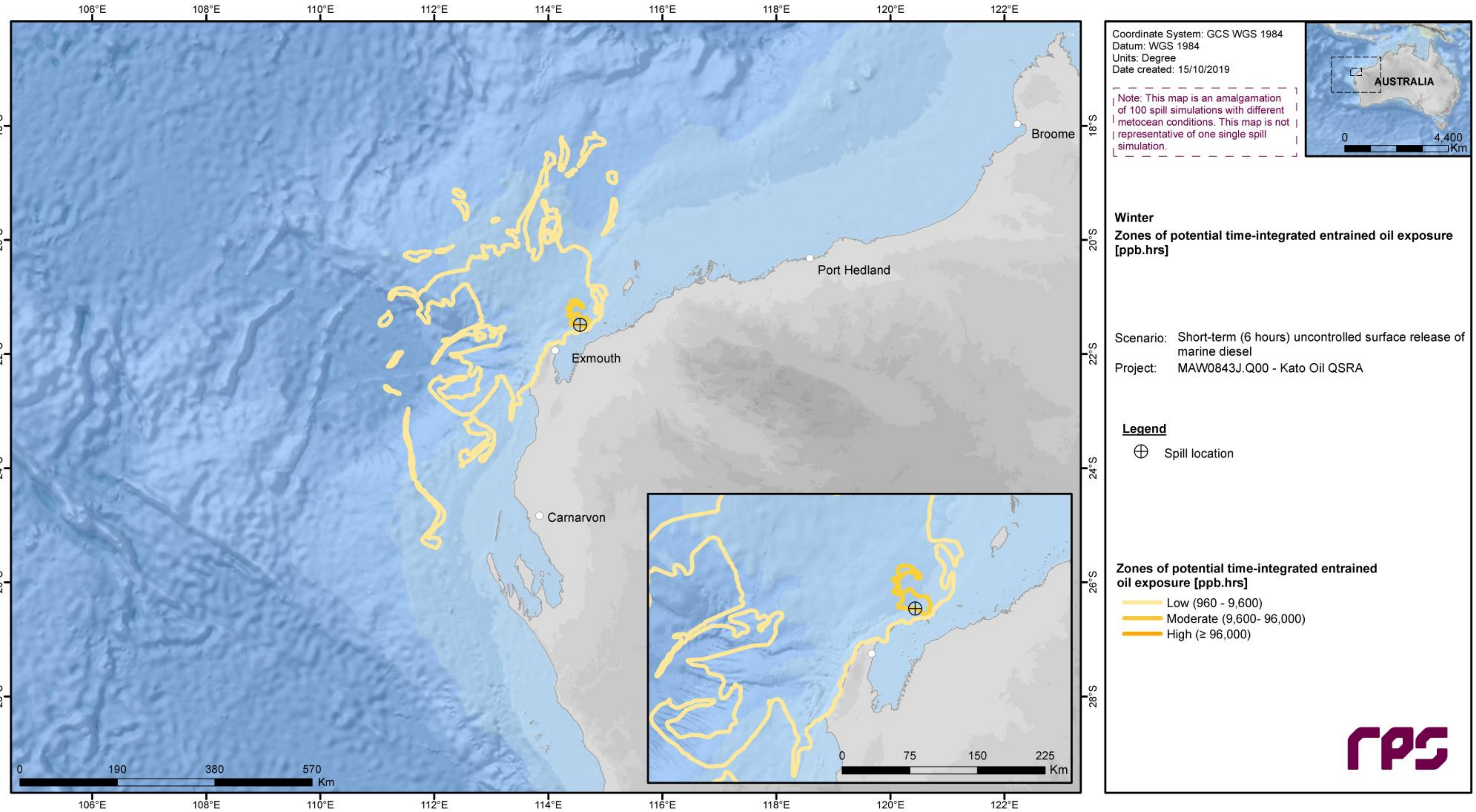


Figure 3.68 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting during winter.

3.3.3.3.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Table 3.32 Expected instantaneous dissolved aromatic hydrocarbons outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in winter months.

Receptors		Probability (%) of dissolved aromatic concentration at			Maximum dissolved aromatic hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Barrow Island	<1	<1	<1	<1	<1
	Lowendal Islands	<1	<1	<1	NC	NC
	Montebello Islands	<1	<1	<1	NC	NC
	Southern Pilbara - Islands	1	<1	<1	<1	27
	Abrolhos Islands	<1	<1	<1	NC	NC
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC
Coastlines	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC
	Exmouth Gulf South East	<1	<1	<1	NC	NC
	Exmouth Gulf West	<1	<1	<1	NC	NC
State Marine and National Parks	Muiron Islands MMA	2	<1	<1	<1	46
	Barrow Island MMA	<1	<1	<1	<1	<1
	Ningaloo MP (State)	5	1	<1	2	92
	Ningaloo Coast WH	8	2	<1	3	114
	Shark Bay WH	<1	<1	<1	NC	NC
	Montebello Islands MP	<1	<1	<1	NC	NC
	Barrow Islands MP	<1	<1	<1	NC	NC
Australian Marine Parks	Montebello MP	<1	<1	<1	<1	<1
	Ningaloo MP	8	2	<1	3	114
	Argo-Rowley Terrace MP	<1	<1	<1	NC	NC
	Gascoyne MP	8	2	<1	3	124
	Carnarvon Canyon MP	<1	<1	<1	<1	7
	Shark Bay MP	1	<1	<1	<1	31
	Abrolhos MP	1	<1	<1	<1	14
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	14	3	<1	5	133
	Continental Slope Demersal Fish Communities KEF	13	2	<1	3	124
	Glomar Shoals KEF §	<1	<1	<1	NC	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	11	2	<1	4	149
	Exmouth Plateau KEF	2	1	<1	<1	55

Receptors		Probability (%) of dissolved aromatic concentration at ≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	Maximum dissolved aromatic hydrocarbon concentration (ppb) averaged over all replicate simulations	at any depth, in the worst replicate
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	<1	<1	<1	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	2	<1	<1	<1	19
	Western Rock Lobster KEF	<1	<1	<1	NC	NC
	Wallaby Saddle KEF	<1	<1	<1	<1	<1
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	<1	<1	<1	NC	NC
	Ancient Coastline at 90-120m Depth Contour KEF	<1	<1	<1	NC	NC
Biologically Important Areas	Marine Turtle BIA	21	7	<1	8	149
	Dugong BIA	5	1	<1	2	101
	Seabirds BIA	21	7	<1	8	149
	Seals BIA	<1	<1	<1	NC	NC
	Sharks BIA	21	7	<1	8	149
	Whales BIA	21	7	<1	8	149
Fisheries	Southern Bluefin Tuna Fishery	21	7	<1	8	149
	Western Tuna and Billfish Fishery	21	7	<1	8	149
	Western Skipjack Fishery	21	7	<1	8	149
	North-West Slope Trawl Fishery	9	2	<1	3	86
Banks	Rankin Bank §	<1	<1	<1	NC	NC

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature

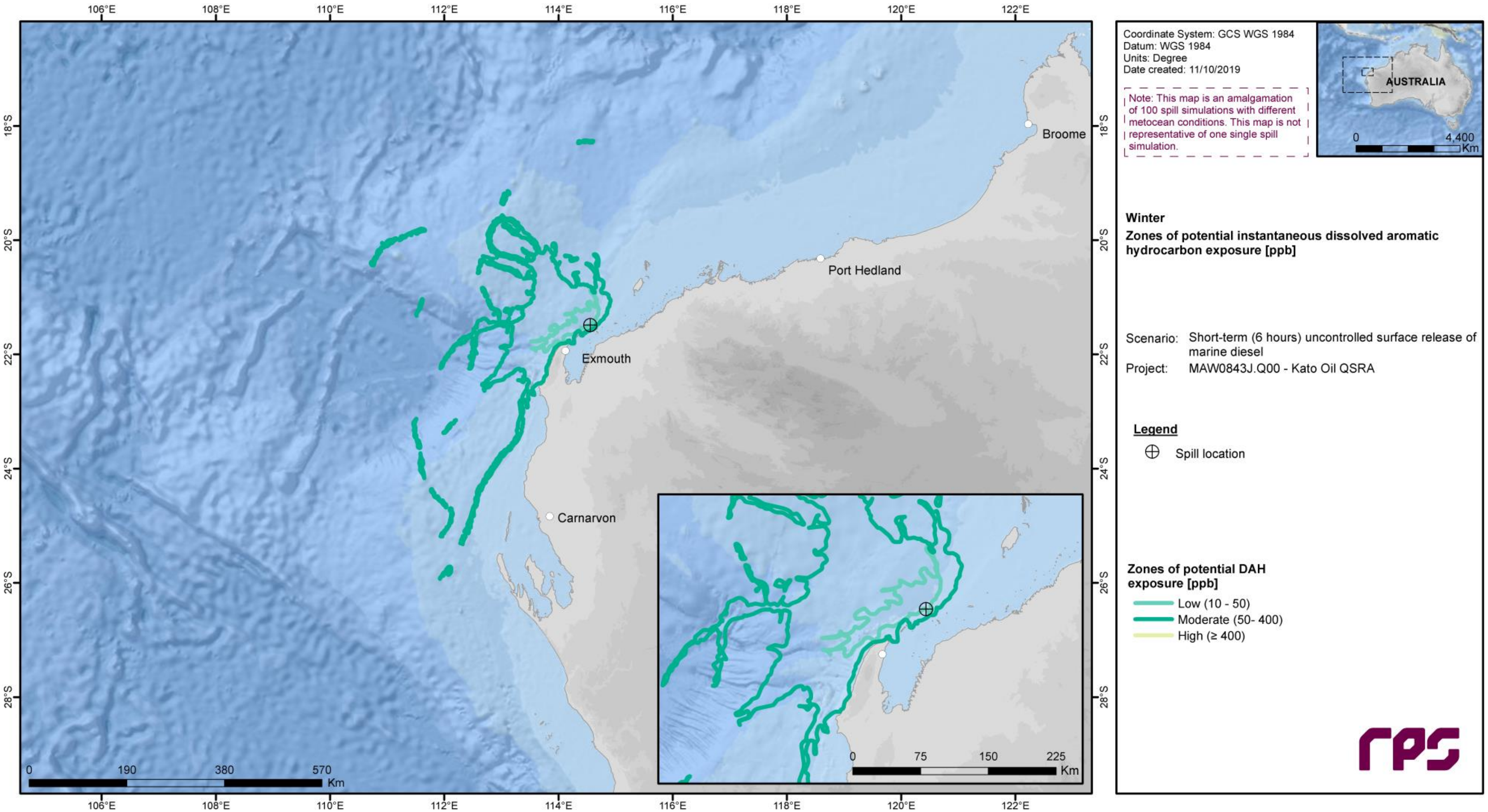


Figure 3.69 Predicted zones of potential dissolved aromatic hydrocarbon exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in winter months.

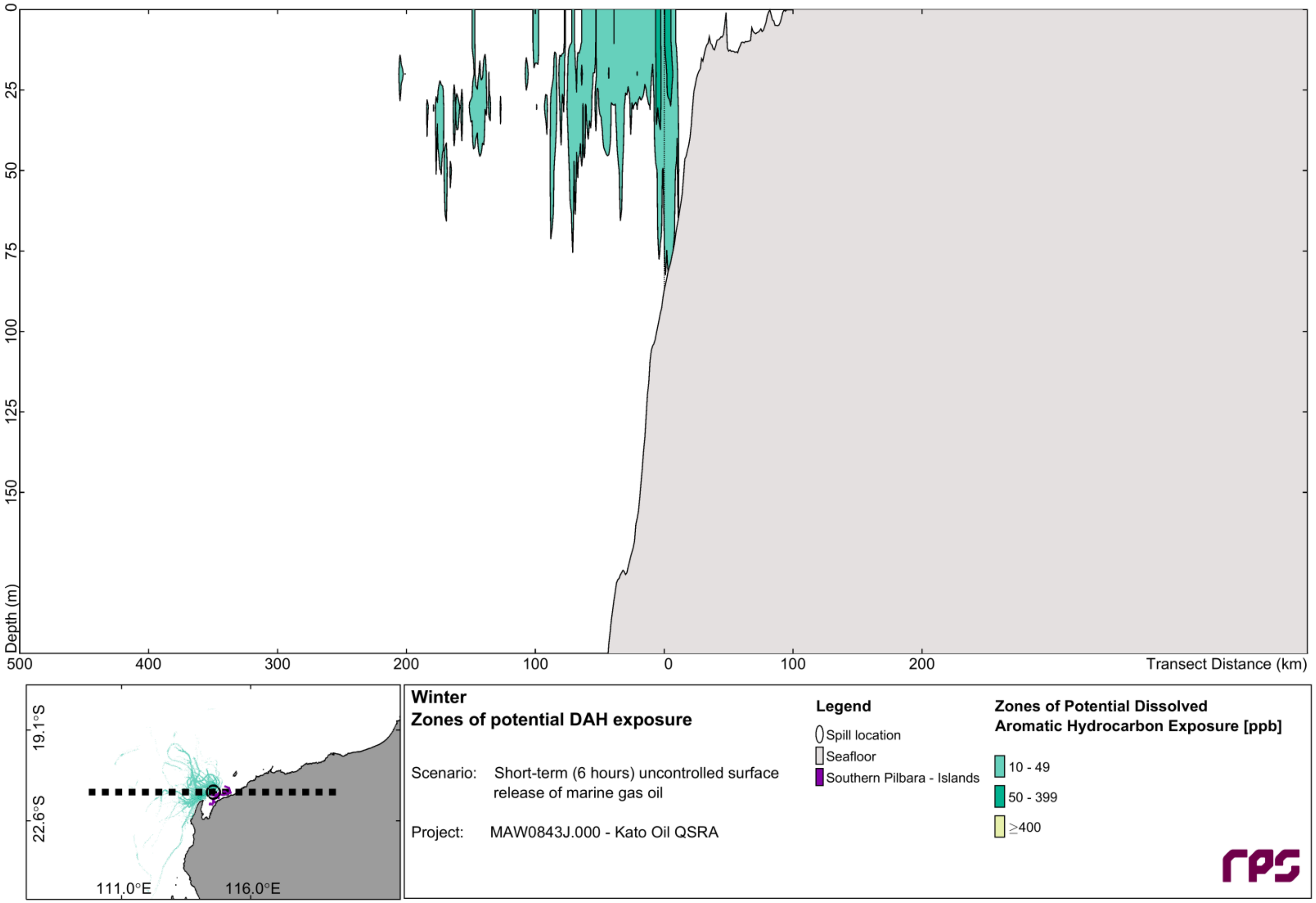


Figure 3.70 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the winter season. The results were calculated from 100 spill trajectories.

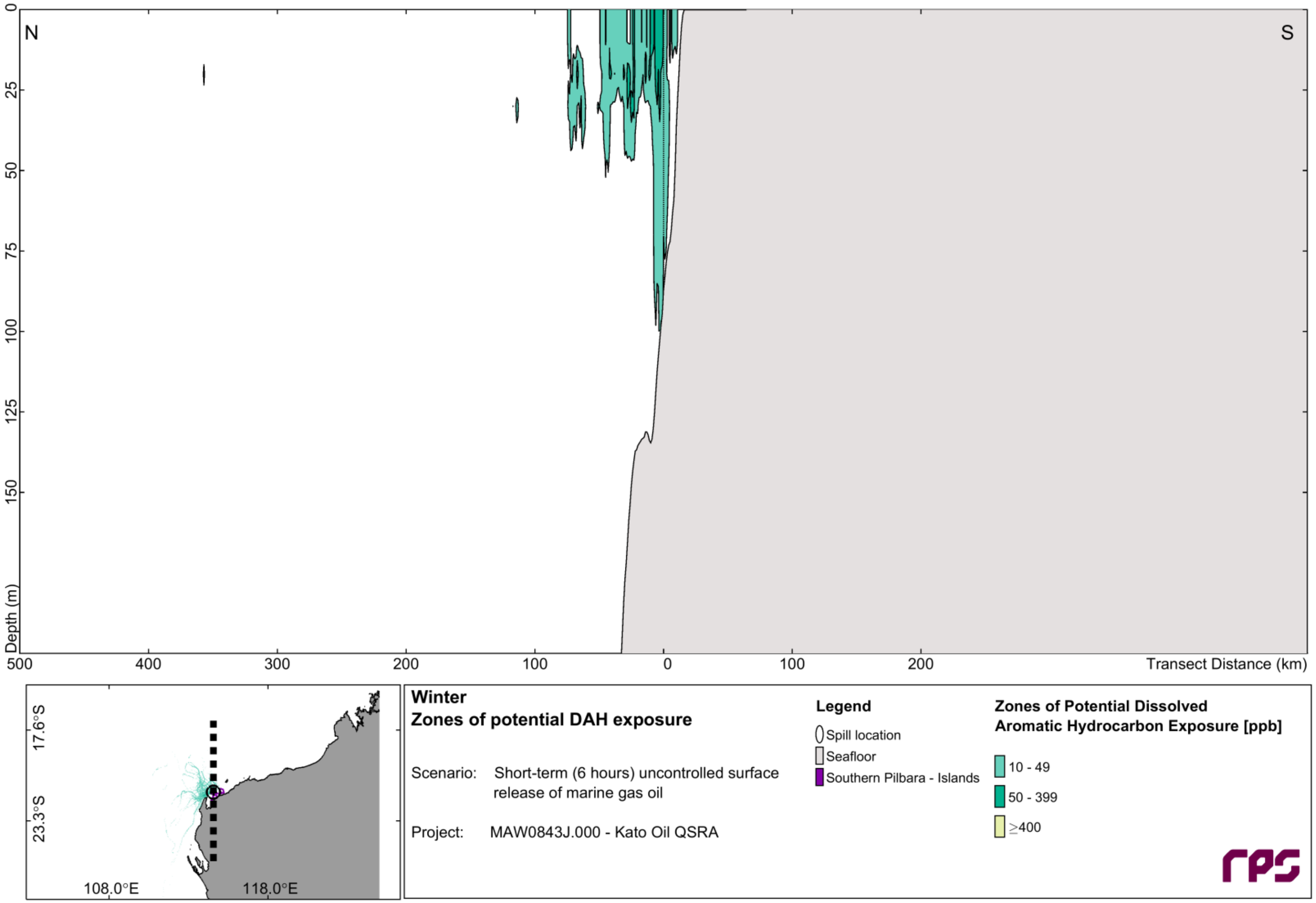


Figure 3.71 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the winter season. The results were calculated from 100 spill trajectories.

3.3.3.3.5 Dissolved Aromatic Hydrocarbons - Exposure

Table 3.33 Expected time-integrated dissolved aromatic hydrocarbons exposure outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in winter months.

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Islands	Barrow Island	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Lowendal Islands	Probability (%) >960	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS
	Montebello Islands	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Southern Pilbara - Islands	Probability (%) >960	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	121	63	8	BS	BS
	Abrolhos Islands	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS
Coastlines	Southern Pilbara - Shoreline	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	BS	BS	BS	BS
	Exmouth Gulf South East	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	NC	BS	BS	BS	BS
	Exmouth Gulf West	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS
State Marine and National Parks	Muiron Islands MMA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	223	130	21	NC	NC
	Barrow Island MMA	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Ningaloo MP (State)	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	262	496	238	51	4
	Ningaloo Coast WH	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	262	496	238	62	6
	Shark Bay WH	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Montebello Islands MP	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Barrow Islands MP	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
Australian	Montebello MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Ningaloo MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	254	496	238	62	6
	Argo-Rowley Terrace MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Gascoyne MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	353	266	297	158	64
	Carnarvon Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1	13	18	NC	NC
	Shark Bay MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	70	55	11	18	2
	Abrolhos MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	22	13	2	2	1
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	738	521	871	482	243
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	616	576	344	165	84
		Probability (%) >960	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Glomar Shoals KEF	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	702	463	239	160	111
Exmouth Plateau KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	111	105	114	133	40
Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	10	32	43	22	3
Western Rock Lobster KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Wallaby Saddle KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Biologically Important Areas	Marine Turtle BIA	Probability (%) >960	4	3	1	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,100	2,381	1,492	776	333
	Dugong BIA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	262	496	238	51	4
	Seabirds BIA	Probability (%) >960	4	3	1	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,100	2,381	1,492	776	333
	Seals BIA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Sharks BIA	Probability (%) >960	4	3	1	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,100	2,381	1,492	776	333
	Whales BIA	Probability (%) >960	4	3	1	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,100	2,381	1,492	776	333
Fisheries	Southern Bluefin Tuna Fishery	Probability (%) >960	4	3	1	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,100	2,381	1,492	776	333
	Western Tuna and Billfish Fishery	Probability (%) >960	4	3	1	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,100	2,381	1,492	776	333
	Western Skipjack Fishery	Probability (%) >960	4	3	1	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	3,100	2,381	1,492	776	333
	North-West Slope Trawl Fishery	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	616	410	274	168	84
Banks	Rankin Bank	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

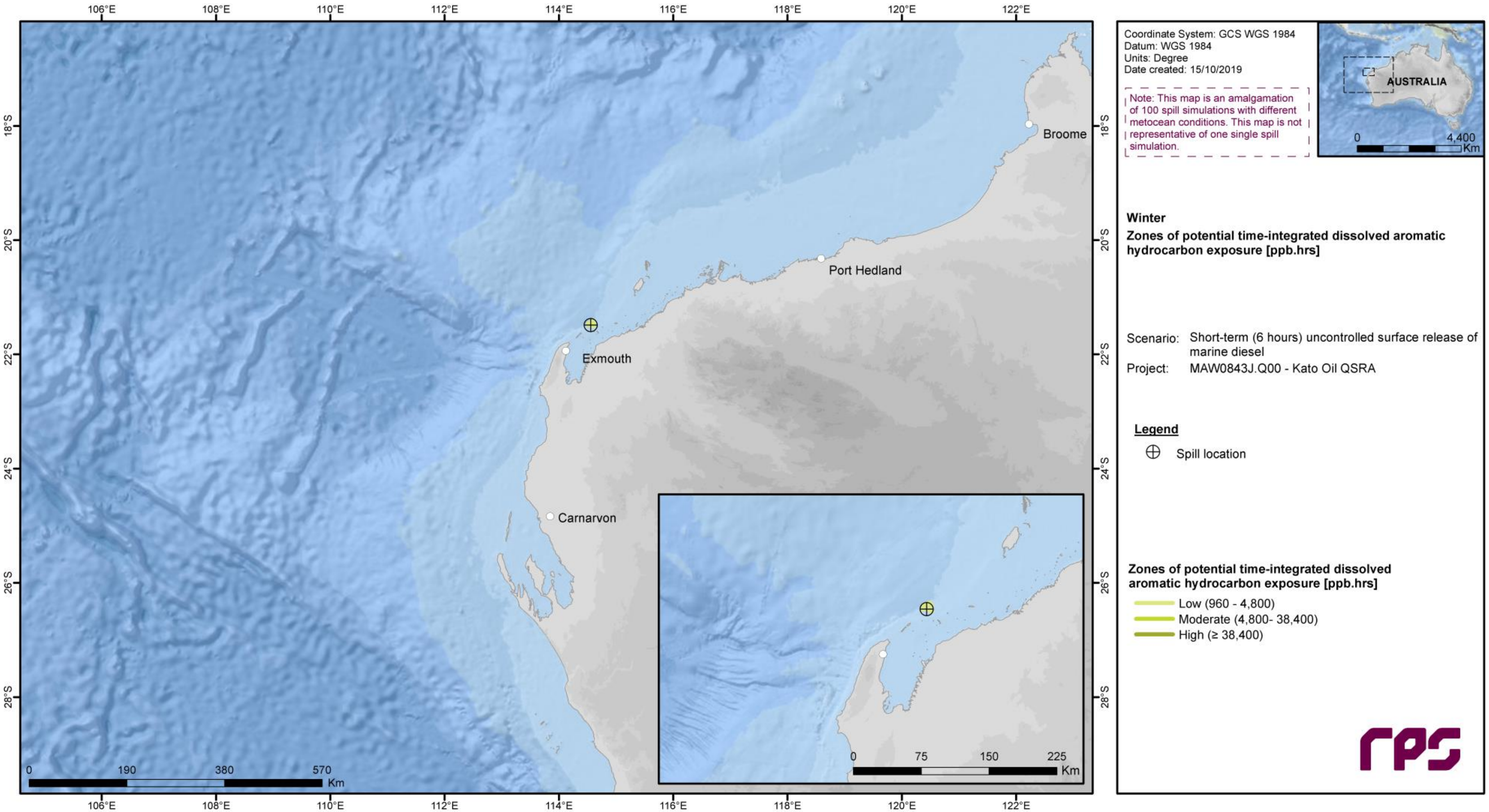


Figure 3.72 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting during winter.

3.3.3.4 Transitional

3.3.3.4.1 Floating and Shoreline Oil

Table 3.34 Expected floating and shoreline oil outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in transitional months.

Receptors		Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
Islands	Barrow Island	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC	NC	NC	NC	NC
Islands	Lowendal Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Islands	Montebello Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Islands	Southern Pilbara - Islands	2	<1	<1	15	NC	NC	3	3	1	14	16	80	18	1,028	<1	18	<1	2	<1	2	<1	1
Islands	Abrolhos Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Islands	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Exmouth Gulf South East	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Exmouth Gulf West	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
State Marine and National Parks	Muiron Islands MMA	4	1	<1	15	18	NC	2	1	<1	25	38	NC	1.6	161	<1	3	<1	6	<1	1	NC	NC
State Marine and National Parks	Barrow Island MMA	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC	NC	NC	NC	NC
State Marine and National Parks	Ningaloo MP (State)	3	<1	<1	34	NC	NC	4	2	1	52	54	57	21	1,661	2	81	NA	NA	NA	NA	NA	NA
State Marine and National Parks	Ningaloo Coast WH	8	<1	<1	31	NC	NC	4	2	1	52	54	57	21	1,661	2	81	<1	23	<1	13	<1	1
State Marine and National Parks	Shark Bay WH	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	<1	23	<1	13	<1	1
State Marine and National Parks	Montebello Islands MP	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
State Marine and National Parks	Barrow Islands MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Montebello MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Ningaloo MP*	8	<1	<1	31	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Argo-Rowley Terrace MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Gascoyne MP*	3	<1	<1	58	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Carnarvon Canyon MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Shark Bay MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Australian Marine Parks	Abrolhos MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF*	43	20	4	4	5	8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Continental Slope Demersal Fish Communities KEF*	4	<1	<1	38	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Glomar Shoals KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

	Receptors	Probability (%) of films arriving at receptors at			Minimum time (hours) to receptor hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations exceeding ≥ 10 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 100 g/m²		Maximum length of shoreline (km) with concentrations exceeding ≥ 1,000 g/m²	
		≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 g/m²	≥ 25 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	≥ 10 g/m²	≥ 100 g/m²	≥ 1,000 g/m²	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill	averaged over all replicate spills	in the worst replicate spill
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF*	31	8	1	6	8	12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Exmouth Plateau KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Demersal Slope and associated Fish Communities KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Rock Lobster KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wallaby Saddle KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ancient Coastline at 90-120m Depth Contour KEF*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Biologically Important Areas	Marine Turtle BIA*†	100	98	89	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dugong BIA*	3	<1	<1	36	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seabirds BIA*†	100	98	89	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seals BIA*†	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sharks BIA*	100	98	89	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Whales BIA*	100	98	89	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	Southern Bluefin Tuna Fishery*	100	98	89	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Tuna and Billfish Fishery*	100	98	89	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Skipjack Fishery*	100	98	89	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	North-West Slope Trawl Fishery*	4	<1	<1	40	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Rankin Bank*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NC: No contact to receptor predicted for specified threshold.

* Floating oil will not accumulate on submerged features and at open ocean locations. NA: Not applicable.

† Receptor is considered as submerged, any accumulation occurring on emerged features within this receptor is captured under the associated shoreline receptor in the table.

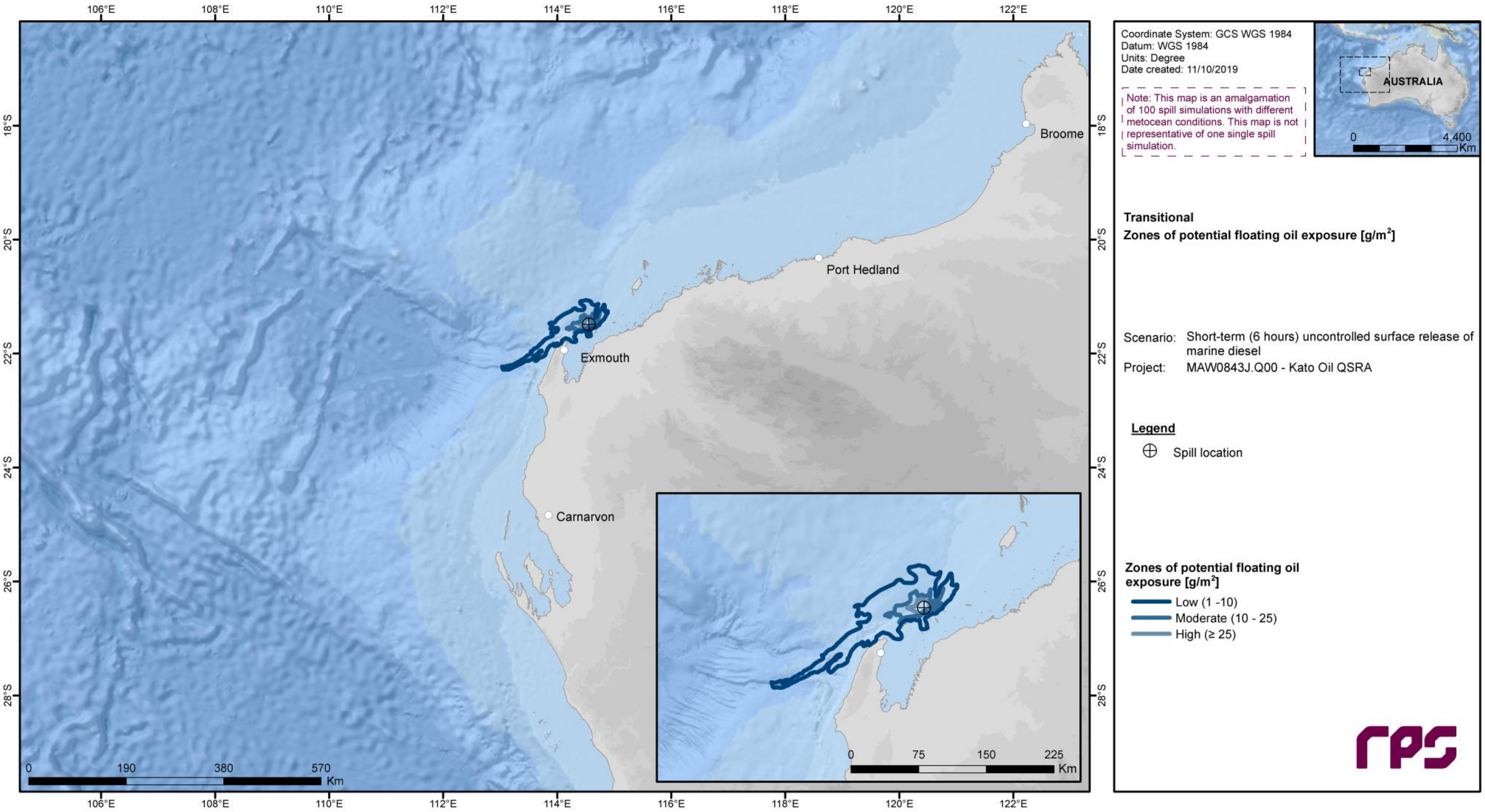


Figure 3.73 Predicted zones of potential floating oil exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in transitional months.

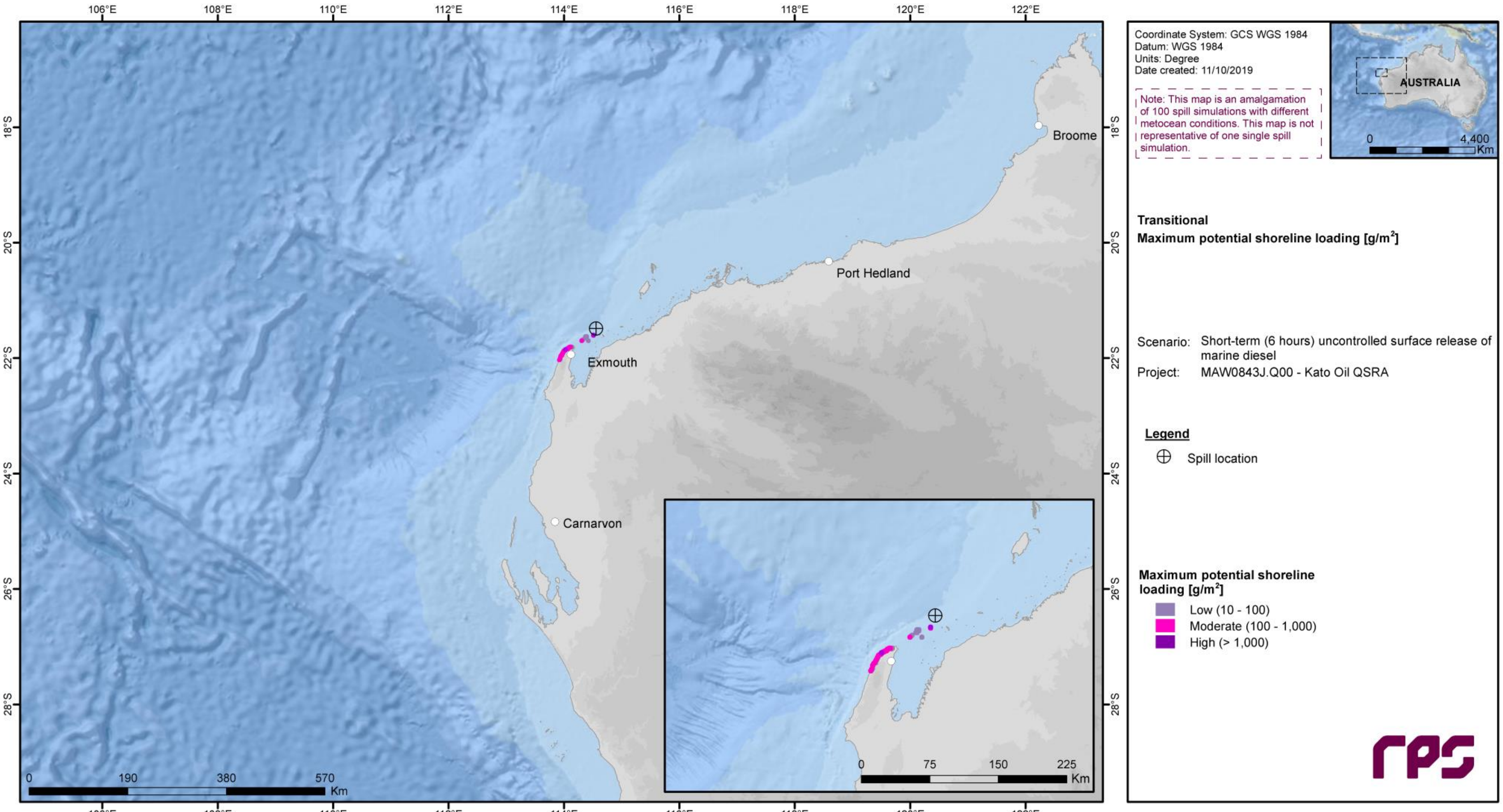


Figure 3.74 Predicted maximum potential shoreline loading resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in transitional months.

3.3.3.4.2 Entrained Oil - Instantaneous

Table 3.35 Expected instantaneous entrained oil outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in transitional months.

Receptors		Probability (%) of entrained hydrocarbon concentration contact at			Minimum time (hours) to receptor waters at			Maximum entrained hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Barrow Island	<1	<1	<1	NC	NC	NC	NC	NC
	Lowendal Islands	<1	<1	<1	NC	NC	NC	NC	NC
	Montebello Islands	<1	<1	<1	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	4	2	<1	14	16	NC	4	297
	Abrolhos Islands	1	<1	<1	666	NC	NC	<1	12
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
Coastlines	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
	Exmouth Gulf South East	<1	<1	<1	NC	NC	NC	NC	NC
	Exmouth Gulf West	<1	<1	<1	NC	NC	NC	NC	NC
State Marine and National Parks	Muiron Islands MMA	7	1	<1	17	27	NC	7	531
	Barrow Island MMA	<1	<1	<1	NC	NC	NC	NC	NC
	Ningaloo MP (State)	19	8	1	34	47	83	21	1,194
	Ningaloo Coast WH	29	11	1	33	40	58	29	1,676
	Shark Bay WH	<1	<1	<1	NC	NC	NC	<1	6
	Montebello Islands MP	<1	<1	<1	NC	NC	NC	NC	NC
	Barrow Islands MP	<1	<1	<1	NC	NC	NC	NC	NC
Australian Marine Parks	Montebello MP	1	1	<1	698	713	NC	2	122
	Ningaloo MP	29	11	1	33	40	58	29	1,676
	Argo-Rowley Terrace MP	1	<1	<1	719	NC	NC	<1	11
	Gascoyne MP	36	11	1	46	49	92	32	1,203
	Carnarvon Canyon MP	7	1	<1	390	588	NC	2	110
	Shark Bay MP	5	1	<1	465	488	NC	2	118
	Abrolhos MP	2	1	<1	591	687	NC	2	117
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	50	34	8	5	5	11	179	2,284
	Continental Slope Demersal Fish Communities KEF	34	15	1	32	36	49	40	1,248
	Glomar Shoals KEF §	<1	<1	<1	NC	NC	NC	NC	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	51	28	4	6	7	15	145	2,713
	Exmouth Plateau KEF	22	7	<1	101	104	NC	12	763
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	1	<1	<1	634	NC	NC	<1	16
	Western Demersal Slope and associated Fish Communities KEF	9	2	<1	401	607	NC	6	385
	Western Rock Lobster KEF	1	<1	<1	647	NC	NC	<1	13
	Wallaby Saddle KEF	1	<1	<1	630	NC	NC	2	100
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	<1	<1	<1	NC	NC	NC	<1	8
	Ancient Coastline at 90-120m Depth Contour KEF	1	<1	<1	690	NC	NC	<1	13
Biologically Important Areas	Marine Turtle BIA	55	37	8	1	1	7	179	2,713
	Dugong BIA	21	8	1	37	47	72	25	1,469
	Seabirds BIA	55	37	8	1	1	7	179	2,713
	Seals BIA	1	<1	<1	666	NC	NC	<1	12
	Sharks BIA	55	37	8	1	1	7	179	2,713
	Whales BIA	55	37	8	1	1	7	179	2,713
Fisheries	Southern Bluefin Tuna Fishery	55	37	8	1	1	7	179	2,713
	Western Tuna and Billfish Fishery	55	37	8	1	1	7	179	2,713
	Western Skipjack Fishery	55	37	8	1	1	7	179	2,713
	North-West Slope Trawl Fishery	34	15	1	35	38	49	40	1,211
Banks	Rankin Bank §	<1	<1	<1	NC	NC	NC	NC	NC

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature

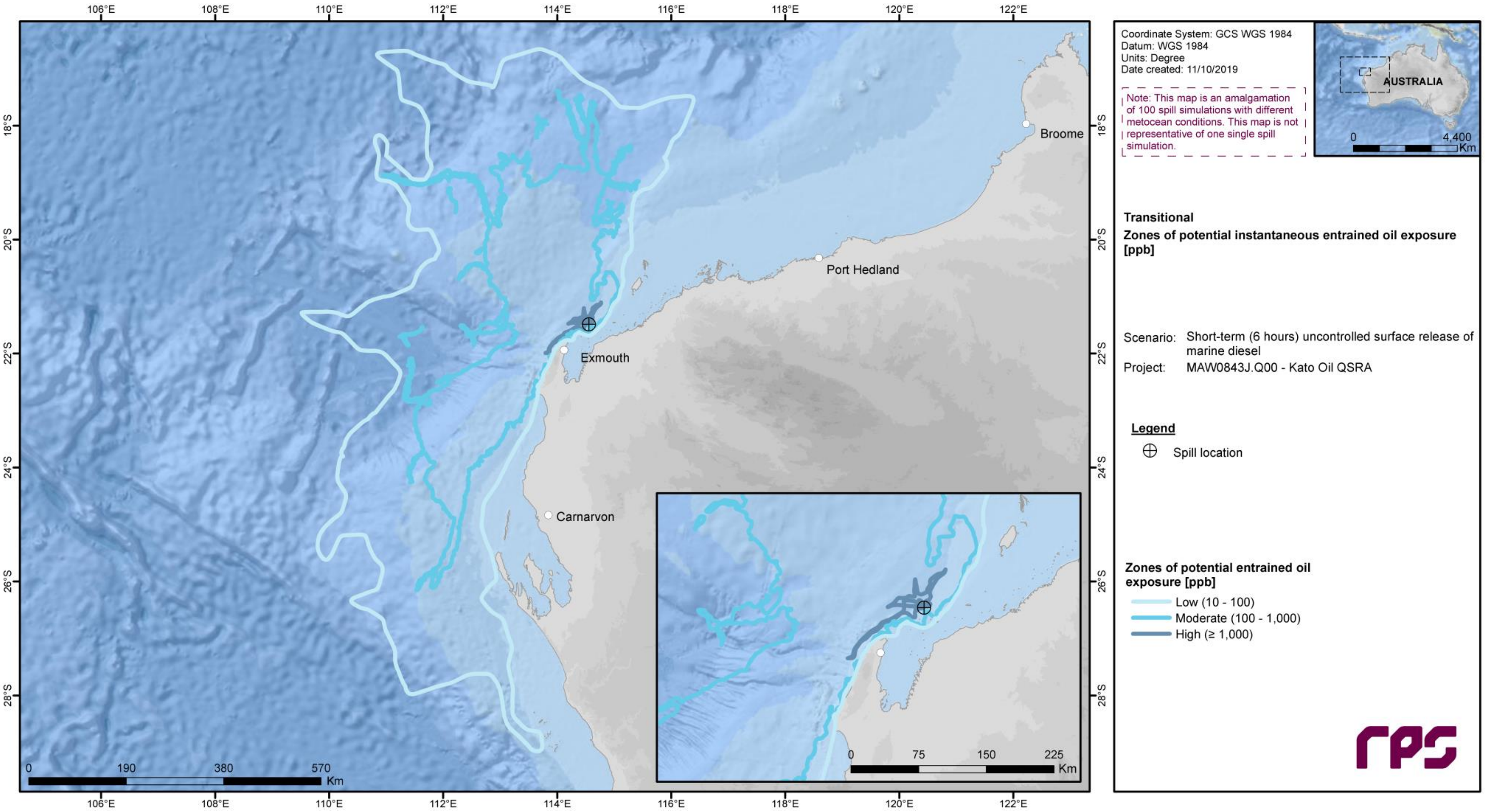


Figure 3.75 Predicted zones of potential instantaneous entrained oil exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in transitional months.

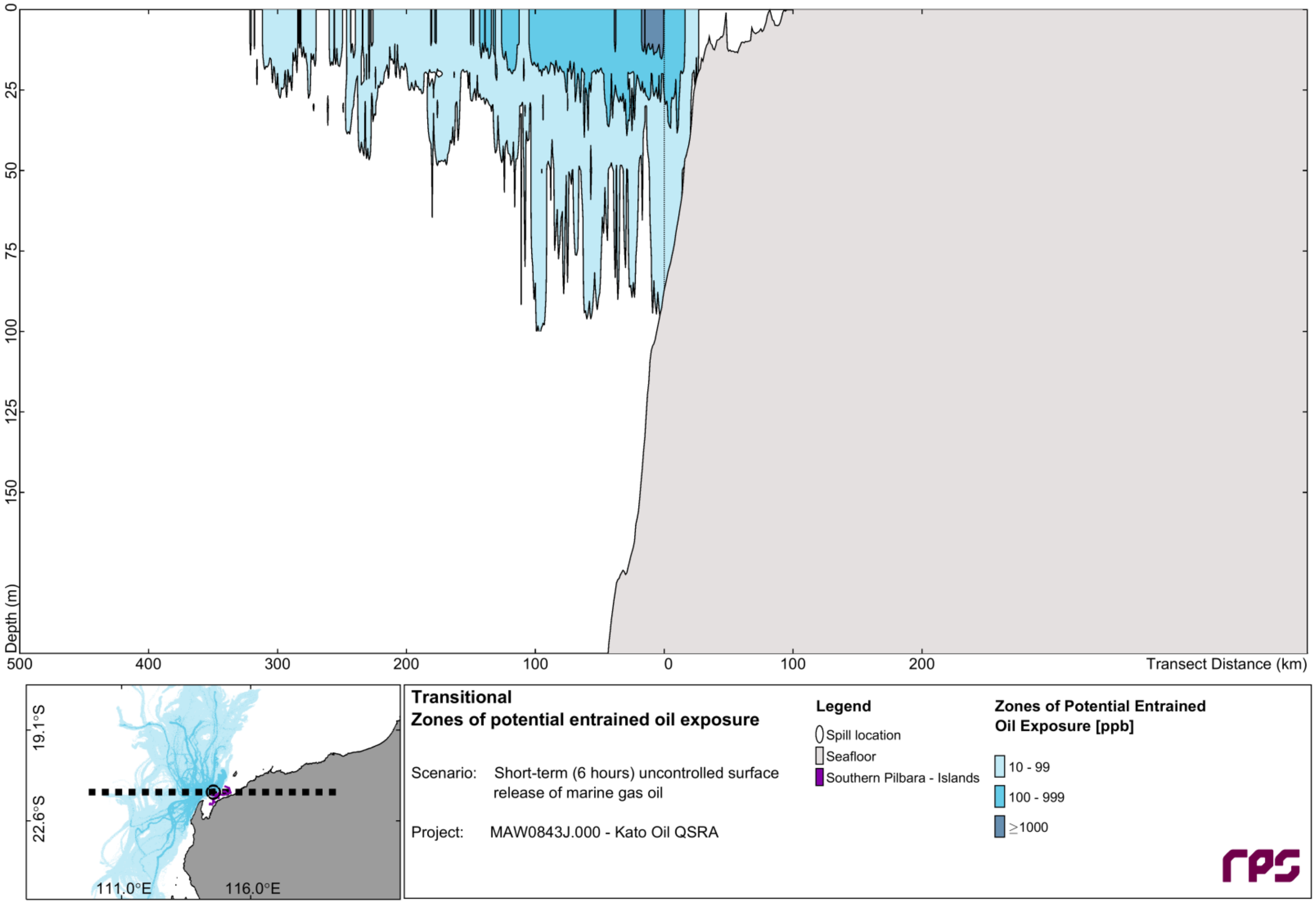


Figure 3.76 East-West cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the transitional period. The results were calculated from 100 spill trajectories.

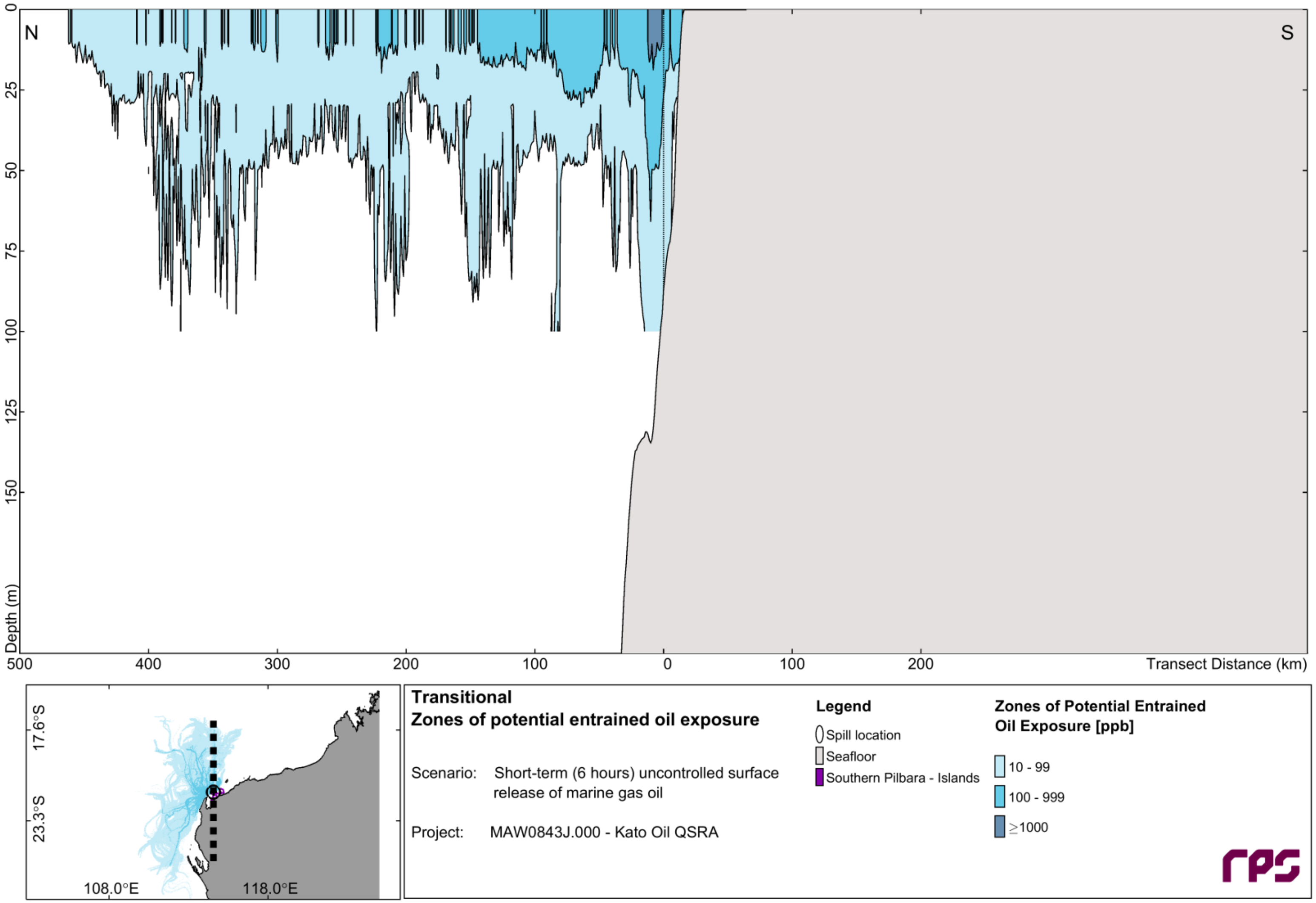


Figure 3.77 North-South cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the transitional period. The results were calculated from 100 spill trajectories.

3.3.3.4.3 Entrained Oil - Exposure

Table 3.36 Expected time-integrated entrained oil exposure outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in transitional months.

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Islands	Barrow Island	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Lowendal Islands	Probability (%) >960	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS
	Montebello Islands	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Southern Pilbara - Islands	Probability (%) >960	2	1	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	4,464	1,101	248	BS	BS
	Abrolhos Islands	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	42	33	30	NC	NC
	Middle Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS
Coastlines	Southern Pilbara - Shoreline	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	BS	BS	BS	BS
	Exmouth Gulf South East	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >9,600	NC	BS	BS	BS	BS
		Probability (%) >96,000	NC	BS	BS	BS	BS

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	NC	BS	BS	BS	BS
	Exmouth Gulf West	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS
State Marine and National Parks	Muiron Islands MMA	Probability (%) >960	1	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,793	614	19	7	NC
	Barrow Island MMA	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Ningaloo MP (State)	Probability (%) >960	6	1	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8,836	1,243	585	196	34
	Ningaloo Coast WH	Probability (%) >960	7	1	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8,836	1,942	891	515	126
	Shark Bay WH	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1	2	12	NC	NC
	Montebello Islands MP	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Barrow Islands MP	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
Australi an	Montebello MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	295	61	1	NC	NC
	Ningaloo MP	Probability (%) >960	7	1	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,508	1,942	891	515	126
	Argo-Rowley Terrace MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8	NC	NC	NC	NC
	Gascoyne MP	Probability (%) >960	8	1	1	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8,419	2,273	1,126	666	308
	Carnarvon Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	580	171	146	43	6
	Shark Bay MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	338	186	201	101	10
	Abrolhos MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	441	213	194	119	12
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	34	15	8	2	NC
		Probability (%) >9,600	10	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	65,338	15,256	9,407	3,055	493
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	14	2	1	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,066	3,059	1,134	567	126
	Glomar Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	33	11	8	2	NC
	Probability (%) >9,600	9	1	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	50,451	13,208	4,878	2,345	355
Exmouth Plateau KEF	Probability (%) >960	4	1	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	3,444	1,417	925	348	160
Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	97	10	3	NC	NC
Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	1	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	1,558	177	112	40	31
Western Rock Lobster KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	84	8	6	3	NC
Wallaby Saddle KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	383	213	190	119	11
Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	13	7	NC	NC	NC
Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	56	5	3	2	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Biologically Important Areas	Marine Turtle BIA	Probability (%) >960	34	15	8	3	NC
		Probability (%) >9,600	14	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	65,338	15,256	9,407	3,055	576
	Dugong BIA	Probability (%) >960	6	1	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	8,836	1,243	735	387	126
	Seabirds BIA	Probability (%) >960	34	15	8	3	NC
		Probability (%) >9,600	14	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	65,338	15,256	9,407	3,055	576
	Seals BIA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	56	33	35	NC	NC
	Sharks BIA	Probability (%) >960	34	15	8	3	NC
		Probability (%) >9,600	14	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	65,338	15,256	9,407	3,055	576
	Whales BIA	Probability (%) >960	34	15	8	3	NC
		Probability (%) >9,600	14	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	65,338	15,256	9,407	3,055	576
Fisheries	Southern Bluefin Tuna Fishery	Probability (%) >960	34	15	8	3	NC
		Probability (%) >9,600	14	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	65,338	15,256	9,407	3,055	576
	Western Tuna and Billfish Fishery	Probability (%) >960	34	15	8	3	NC
		Probability (%) >9,600	14	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	65,338	15,256	9,407	3,055	576
	Western Skipjack Fishery	Probability (%) >960	34	15	8	3	NC
		Probability (%) >9,600	14	1	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	65,338	15,256	9,407	3,055	576
	North-West Slope Trawl Fishery	Probability (%) >960	16	2	1	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,066	3,059	970	567	116
Banks	Rankin Bank	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

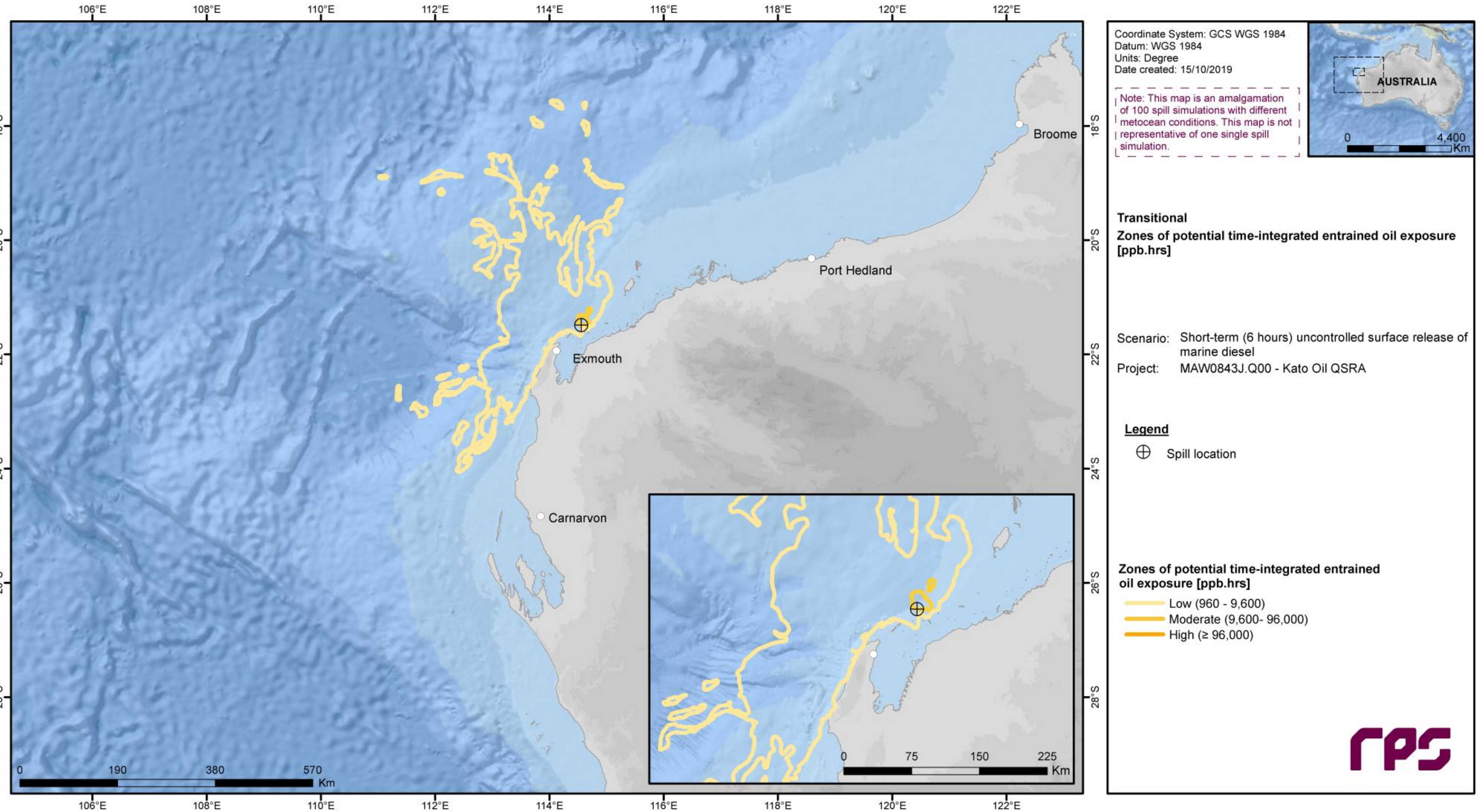


Figure 3.78 Predicted zones of potential time-integrated entrained oil exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting during transitional months.

3.3.3.4.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Table 3.37 Expected instantaneous dissolved aromatic hydrocarbons outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in transitional months.

Receptors		Probability (%) of dissolved aromatic concentration at			Maximum dissolved aromatic hydrocarbon concentration (ppb)	
		≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Barrow Island	<1	<1	<1	NC	NC
	Lowendal Islands	<1	<1	<1	NC	NC
	Montebello Islands	<1	<1	<1	NC	NC
	Southern Pilbara - Islands	1	<1	<1	<1	27
	Abrolhos Islands	<1	<1	<1	<1	<1
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC
Coastlines	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC
	Exmouth Gulf South East	<1	<1	<1	NC	NC
	Exmouth Gulf West	<1	<1	<1	NC	NC
State Marine and National Parks	Muiron Islands MMA	2	<1	<1	<1	19
	Barrow Island MMA	<1	<1	<1	NC	NC
	Ningaloo MP (State)	4	1	<1	<1	59
	Ningaloo Coast WH	7	3	<1	4	122
	Shark Bay WH	<1	<1	<1	<1	<1
	Montebello Islands MP	<1	<1	<1	NC	NC
	Barrow Islands MP	<1	<1	<1	NC	NC
Australian Marine Parks	Montebello MP	<1	<1	<1	<1	<1
	Ningaloo MP	7	3	<1	4	122
	Argo-Rowley Terrace MP	<1	<1	<1	<1	<1
	Gascoyne MP	8	2	<1	3	84
	Carnarvon Canyon MP	<1	<1	<1	<1	6
	Shark Bay MP	<1	<1	<1	<1	9
	Abrolhos MP	<1	<1	<1	<1	3
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	24	4	<1	8	184
	Continental Slope Demersal Fish Communities KEF	10	2	<1	4	122
	Glomar Shoals KEF §	<1	<1	<1	NC	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	12	4	<1	5	140
	Exmouth Plateau KEF	3	1	<1	<1	58
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	<1	<1	<1	<1	<1

Receptors		Probability (%) of dissolved aromatic concentration at ≥ 10 ppb	≥ 50 ppb	≥ 400 ppb	Maximum dissolved aromatic hydrocarbon concentration (ppb) averaged over all replicate simulations	at any depth, in the worst replicate
	Western Demersal Slope and associated Fish Communities KEF	1	<1	<1	<1	19
	Western Rock Lobster KEF	<1	<1	<1	<1	<1
	Wallaby Saddle KEF	<1	<1	<1	<1	2
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	<1	<1	<1	<1	<1
	Ancient Coastline at 90-120m Depth Contour KEF	<1	<1	<1	<1	<1
Biologically Important Areas	Marine Turtle BIA	29	10	<1	13	184
	Dugong BIA	4	1	<1	2	101
	Seabirds BIA	29	10	<1	13	184
	Seals BIA	<1	<1	<1	<1	<1
	Sharks BIA	29	10	<1	13	184
	Whales BIA	29	10	<1	13	184
Fisheries	Southern Bluefin Tuna Fishery	29	10	<1	13	184
	Western Tuna and Billfish Fishery	29	10	<1	13	184
	Western Skipjack Fishery	29	10	<1	13	184
	North-West Slope Trawl Fishery	10	2	<1	4	99
Banks	Rankin Bank §	<1	<1	<1	NC	NC

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

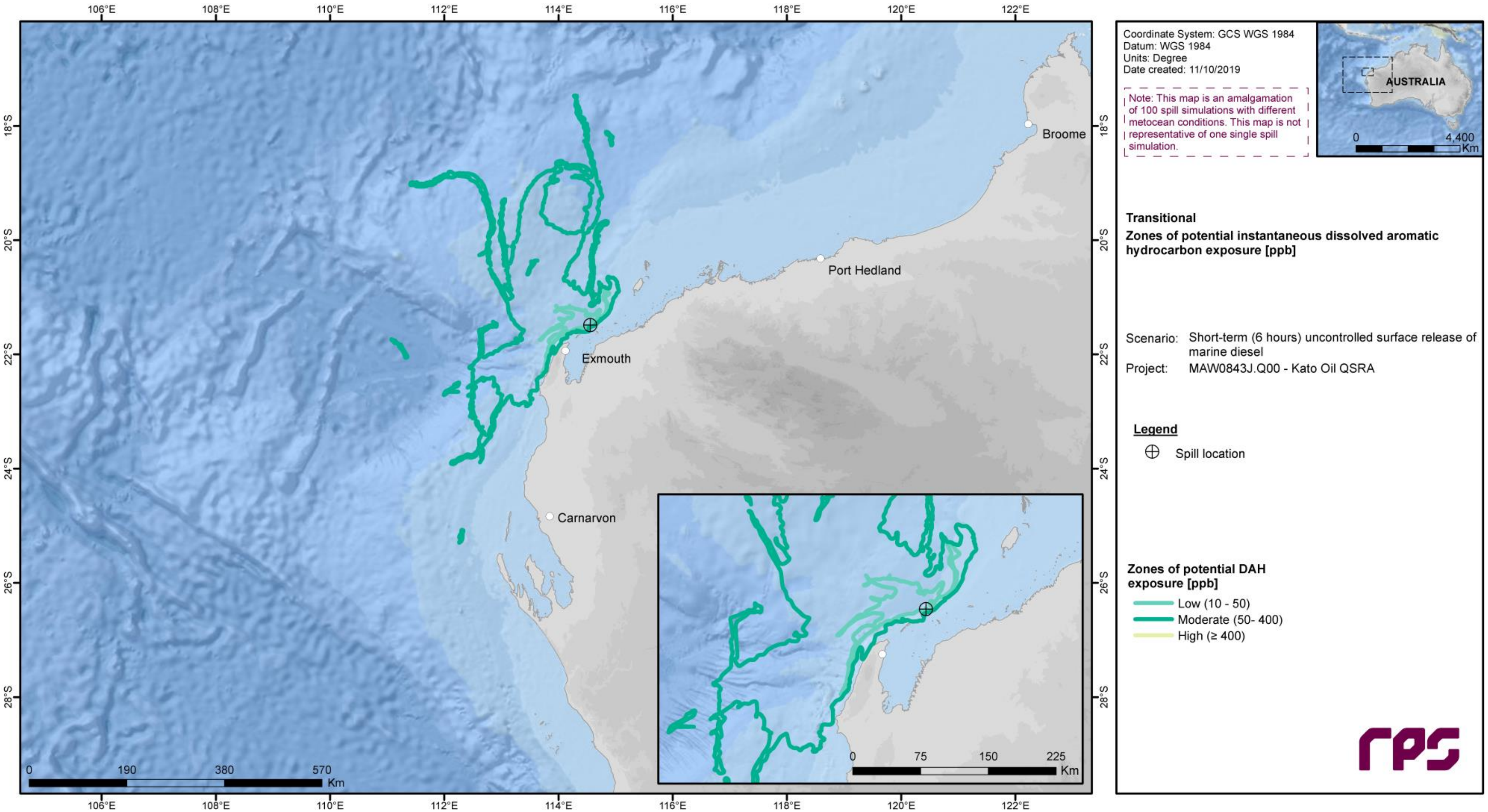


Figure 3.79 Predicted zones of potential instantaneous dissolved aromatic hydrocarbon exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in transitional months.

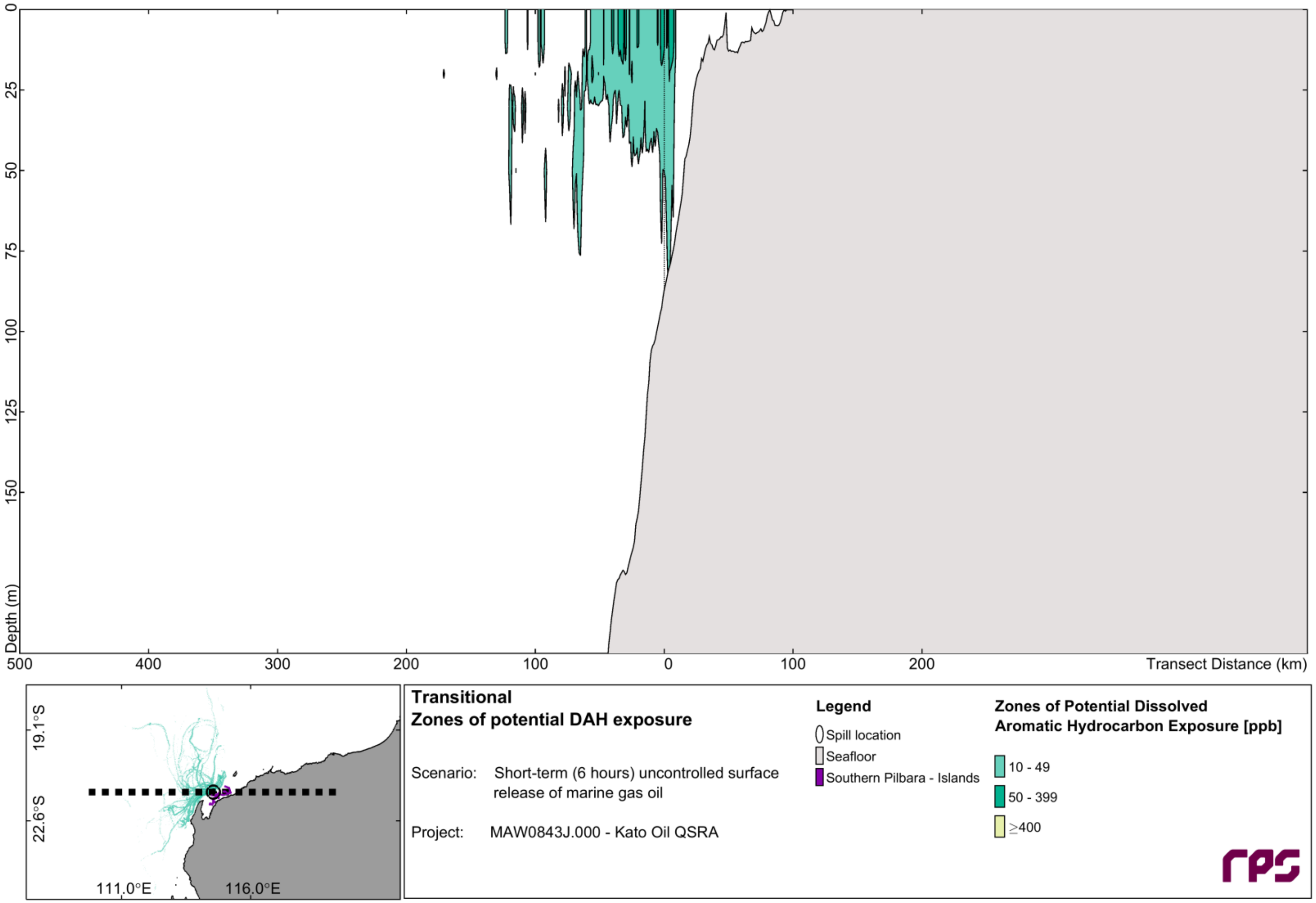


Figure 3.80 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the transitional period. The results were calculated from 100 spill trajectories.

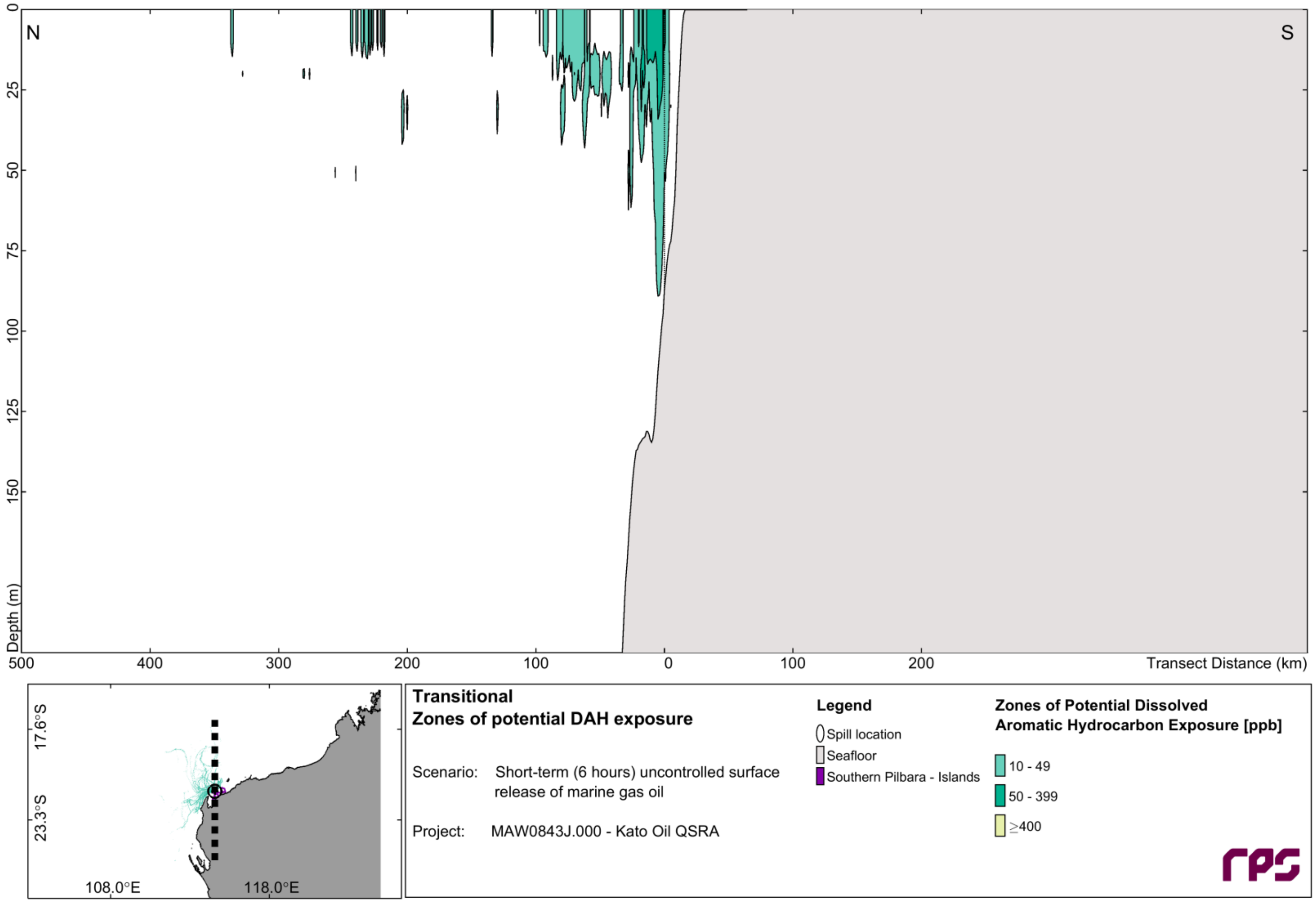


Figure 3.81 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, commencing in the transitional period. The results were calculated from 100 spill trajectories.

3.3.3.4.5 Dissolved Aromatic Hydrocarbons - Exposure

Table 3.38 Expected dissolved aromatic hydrocarbons exposure outcomes at sensitive receptors resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting in transitional months.

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Islands	Barrow Island	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Lowendal Islands	Probability (%) >960	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	NC	NC	NC	BS	BS
	Montebello Islands	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Southern Pilbara - Islands	Probability (%) >960	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	157	29	2	BS	BS
	Abrolhos Islands	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS
Coastlines	Southern Pilbara - Shoreline	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	BS	BS	BS	BS
	Exmouth Gulf South East	Probability (%) >960	NC	BS	BS	BS	BS
		Probability (%) >4,800	NC	BS	BS	BS	BS
		Probability (%) >38,400	NC	BS	BS	BS	BS

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	NC	BS	BS	BS	BS
	Exmouth Gulf West	Probability (%) >960	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	BS	BS	BS
		Probability (%) >38,400	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	NC	NC	BS	BS	BS
State Marine and National Parks	Muiron Islands MMA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	61	112	17	2	NC
	Barrow Island MMA	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Ningaloo MP (State)	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	578	464	136	58	17
	Ningaloo Coast WH	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	578	464	234	63	45
	Shark Bay WH	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Montebello Islands MP	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
	Barrow Islands MP	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS
Australian	Montebello MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC

	Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Ningaloo MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	518	421	234	63	45
	Argo-Rowley Terrace MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Gascoyne MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	248	260	258	207	66
	Carnarvon Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1	5	11	6	3
	Shark Bay MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	14	4	8	4	1
	Abrolhos MP	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	4	2	2	4	1
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	1	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	1,343	691	642	431	123
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	346	490	314	122	53
	Glomar Shoals KEF	Probability (%) >960	NC	NC	NC	NC	NC

Location	Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	876	494	228	180	50
Exmouth Plateau KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	78	102	105	102	33
Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Western Demersal Slope and associated Fish Communities KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	6	7	43	55	8
Western Rock Lobster KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Wallaby Saddle KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	3	2	1	2	1
Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC
Ancient Coastline at 90-120m Depth Contour KEF	Probability (%) >960	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC
	Probability (%) >38,400	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
Biologically Important Features	Marine Turtle BIA	Probability (%) >960	7	6	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,609	2,523	1,464	836	215
	Dugong BIA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	578	464	141	58	15
	Seabirds BIA	Probability (%) >960	7	6	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,609	2,523	1,464	836	215
	Seals BIA	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC
	Sharks BIA	Probability (%) >960	7	6	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,609	2,523	1,464	836	215
	Whales BIA	Probability (%) >960	7	6	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,609	2,523	1,464	836	215
Fisheries	Southern Bluefin Tuna Fishery	Probability (%) >960	7	6	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,609	2,523	1,464	836	215
	Western Tuna and Billfish Fishery	Probability (%) >960	7	6	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	3,609	2,523	1,464	836	215
	Western Skipjack Fishery	Probability (%) >960	7	6	2	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC

Location		Threshold (ppb.h)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL
		Maximum Integrated Exposure	3,609	2,523	1,464	836	215
	North-West Slope Trawl Fishery	Probability (%) >960	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	346	490	314	155	53
Banks	Rankin Bank	Probability (%) >960	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

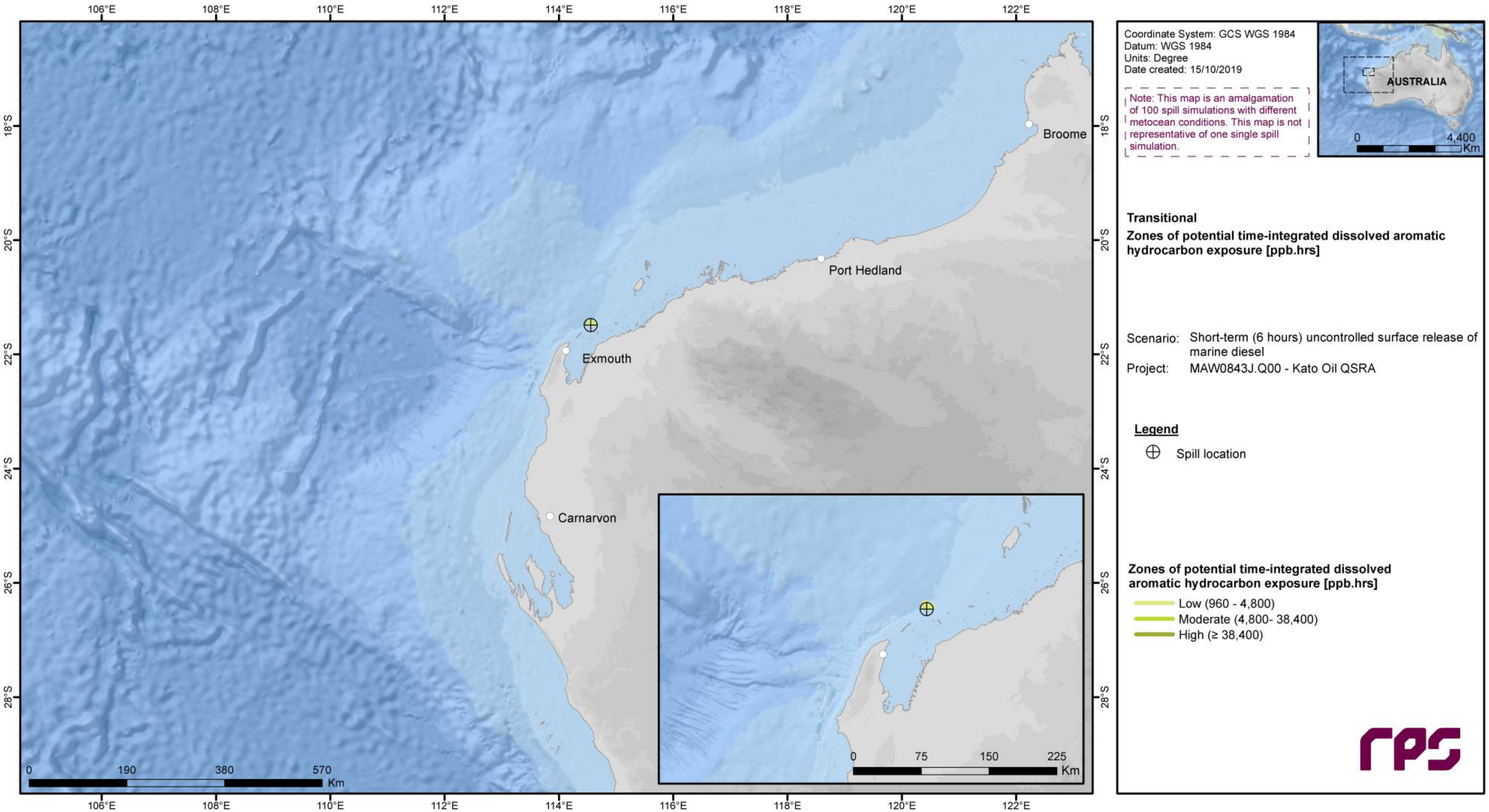


Figure 3.82 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Corowa field, starting during transitional months.

4 CONCLUSION

The main findings of the study are as follows:

Metocean Influences

- Large scale drift currents will have a significant influence on the trajectory of any oil spilled at the modelled release site, irrespective of the seasonal conditions. The prevailing drift currents will determine the trajectory of oil that is entrained beneath the water surface.

- Interactions with the prevailing wind will provide additional variation in the trajectory of spilled oil and marked variation in the prevailing drift current and wind conditions will be expected over the duration of a long-term release. This will be expected to increase the spread of hydrocarbon during any single event.

Oil Characteristics and Weathering Behaviour

- The composition of Corowa Light Crude contains a high proportion of volatile compounds, and a small proportion of residual hydrocarbons that will not evaporate at atmospheric temperatures. If exposed to the atmosphere, around 80% of the mass will be expected to evaporate in around 24 hours and another 14% within a few days. The influence of entrainment will regulate the degree of mass retention in the environment.

- The composition of marine gas oil contains a high proportion of volatile compounds, and a small proportion of residual hydrocarbons that will not evaporate at atmospheric temperatures. If exposed to the atmosphere, around 65% of the mass will be expected to evaporate in around 24 hours and another 32% within a few days. The influence of entrainment will regulate the degree of mass retention in the environment.

- During the subsea release, large droplets have the potential to reach the surface within minutes of the release, with floating slicks likely to be formed under typical wind conditions. It is likely that the bulk of the oil mass at any time will be found in the wave-mixed layer. Evaporation rates will be high for any surfacing oil, given the large proportion of volatile compounds within the oil. Considering the spill volume, there is potential for dissolution of soluble aromatic compounds.

- During the surface release, floating slicks are likely to be formed under light wind conditions. Given the low viscosity of the oil, entrainment into the water column is likely to occur under all but very light wind conditions. It is likely that the bulk of the oil mass at any time will be entrained within the water column. Evaporation rates will be very high, given the large proportion of volatile compounds within the oil. Any residual fraction will persist in the environment until degradation processes occur. Considering the spill volumes, there is potential for dissolution of soluble aromatic compounds.

Summary of Modelling Results

Long-Term (80-day) subsea well blowout of Corowa Light Crude within the Corowa field

Deterministic Modelling Assessment

One deterministic spill case was identified from the set of stochastic results based on the following criteria:

- Replicate simulation with the maximum oil volume accumulation on all shoreline receptors.

Deterministic Case 1: Maximum oil volume loading on shorelines

- The maximum oil volume loading on shorelines during a single spill event was predicted as 1,092 m^3 for a spill commencing in summer (run 25). During this deterministic case, the maximum oil loading was distributed across Ningaloo MP (State) and Ningaloo Coast World Heritage Area (WH).

- The maximum distance from the spill location to the outer edge of hydrocarbon exposure during this spill is predicted as 661.5 km for entrained oil at concentrations equal to or greater than the moderate (100 ppb) threshold.

Stochastic Modelling Assessment

- Floating oil concentrations at the low threshold (1 g/m^2) could travel up to 1,167 km from the release location, with distances reducing at the moderate (10 g/m^2; 476 km) and high (25 g/m^2; 393 km) thresholds across all seasons.
- The highest probabilities of shoreline contact by floating oil at the moderate threshold (10 g/m^2) is predicted at Murion Islands Marine Management Area as 40% in winter.
- Minimum times of arrival at the moderate floating oil threshold (10 g/m^2) is predicted for the Murion Islands Marine Management Area shoreline receptor as 10 hours in winter.
- The worst-case potential volume of oil accumulating on a given receptor shoreline is forecast at Ningaloo Marine Park (State) and Ningaloo Coast World Heritage Area with an accumulated concentration and volume of 19.3 kg/m^2 and 1,092 m^3, respectively.
- The worst-case maximum length of shoreline with concentrations exceeding the moderate threshold (100 g/m^2) was calculated as 68 km at the Ningaloo Coast WH and Ningaloo MP (State) in summer.
- Instantaneous entrained oil concentrations at the low threshold (10 ppb) could travel up to 1,680 km from the release location in transitional months, with the distances reducing at the moderate (100 ppb; 1,173 km) and high (1,000 ppb; 610 km) threshold.
- The probability of contact by entrained oil concentrations at the moderate threshold (100 ppb) is predicted to be greatest at Ningaloo Coast World Heritage Area, Ningaloo Marine Park and the Gascoyne Marine Park with a probability of 100% across all seasons. Entrained oil at the moderate threshold is predicted to arrive at these receptors within 29 hours after the release commences.
- The worst-case instantaneous entrained oil concentration at any receptor is predicted at Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western and Billfish and Western Skipjack Fisheries as 50,458 ppb.
- The seasonal cross-sectional transections in the vicinity of the release site indicate that entrained oil concentrations at or greater than the moderate (100 ppb) and high (1,000 ppb) thresholds are not expected to exceed depths of around 40 m and 30 m BMSL, respectively, in any season. Therefore, limiting benthic contact below this depth.
- Time-integrated entrained oil exposure at or above the 960 ppb.h threshold could travel up to 1,195 km from the release location, with the distance reducing to 1,173 km and 365 km as contact thresholds increase to 9,600 ppb.h and 96,000 ppb.h, respectively.
- The probability of contact by time-integrated exposure of entrained oil concentrations at the 96,000 ppb.h threshold is predicted to be greatest at the Marine Turtle, Seabirds, Sharks and Whales Biologically Important Areas with a probability of 100% across all seasons.
- The worst-case maximum entrained oil integrated exposure is predicted at the Marine Turtle, Seabirds, Sharks and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 2,139,096 ppb.h.
- Instantaneous dissolved aromatic hydrocarbon concentrations at the low (10 ppb) threshold could travel up to 861 km from the release location, with distances reducing at the moderate (50 ppb; 597 km) and high (400 ppb; 129 km) thresholds across all seasons.
- The probability of contact by dissolved aromatic hydrocarbon concentrations at the moderate threshold (50 ppb) is predicted to be greatest at the Ancient Coastline at 125 m Depth Contour and Canyons linking

the Cuvier Abyssal Plain and the Cape Range Peninsula Key Ecological Features with probabilities of 100% across all seasons.

- The worst-case dissolved aromatic hydrocarbon concentrations at any receptor is predicted at Ancient Coastline at 125 m Depth Contour Key Ecologically Feature, Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales, and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries as 1,047 ppb.

- The seasonal cross-sectional transections in the vicinity of the release site indicate that dissolved aromatic hydrocarbon concentrations at or greater than the high (400 ppb) threshold are not expected to reach depths greater than approximately 80 m BMSL. Therefore, limiting benthic contact below this depth.

- Time integrated dissolved aromatic hydrocarbons exposure at or above 960 ppb.h could travel up to 198 km from the release site, with the distance reducing to 102 km as the contact threshold increases to 4,800 ppb.h.

- The probability of contact by dissolved aromatic hydrocarbon exposure at the 4,800 ppb.h threshold was predicted to be greatest at the Marine Turtles, Seabirds, Sharks and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries with a probability of 92% in the surface layer (0-10 m) in summer.

- The worst-case maximum dissolved aromatic hydrocarbon exposure concentration at any receptor is predicted at Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 19,679 ppb.h.

- Note, the highest probabilities and concentrations of entrained oil and dissolved aromatic hydrocarbons are generally expected to occur within the surface layer (0-10 m), with probabilities expected to reduce with depth.

Short-Term (6-hour) surface release of marine gas oil after a rupture of a supply vessel tank

Deterministic Modelling Assessment

One deterministic spill case was identified from the set of stochastic results based on the following criteria:

- Replicate simulation with the maximum oil volume accumulation on all shoreline receptors.

Deterministic Case 1: Maximum oil volume loading on shorelines

- The maximum oil volume loading on shorelines during a single spill event was predicted as 185 m^3 for a spill commencing in summer (run 2). During this spill simulation, the maximum oil loading along an individual shoreline receptor was predicted at Murion Islands Marine Management Area.

- The maximum distance from the spill location to the outer edge of hydrocarbon exposure during this spill is predicted as 33 km for shoreline oil at concentrations exceeding the moderate (100 g/m^2) threshold.

Stochastic Modelling Assessment

- Floating oil concentrations at the low threshold (1 g/m^2) could travel up to 178 km from the release location, with distances reducing at the moderate (10 g/m^2; 50 km) and high (25 g/m^2; 18 km) thresholds.

- The highest probabilities of floating oil contact at the low threshold (1 g/m^2) is forecast at the Muiron Islands Marine Management Area (summer; 5%, winter; 10%, and transitional months; 4%).

- Floating oil at the low threshold is predicted to arrive at the Southern Pilbara - Islands within 9 hours after a spill commencement in winter.

- The worst-case oil accumulation on a shoreline is predicted for the Murion Islands Marine Management Area receptor with an accumulated concentration and volume of 3.3 kg/m^2 and 185 m^3, respectively.
- The worst-case maximum length of shoreline with concentrations exceeding the low threshold (10 g/m^2) was calculated as 23 km for the Ningaloo WH and Shark Bay WH in transitional months
- Instantaneous entrained oil concentrations at the low threshold (10 ppb) could travel up to 957 km from the release location in winter, with distances reducing at the moderate (100 ppb; 674 km) and high (1,000 ppb; 304 km) thresholds.
- The probability of contact by entrained oil concentrations at the low threshold (10 ppb) is predicted to be greatest at the Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries with probabilities of 54-68% across all seasons. Entrained oil at the low threshold is predicted to arrive at these receptors within 1 hour after the release commences.
- The worst-case instantaneous entrained oil concentration at any receptor is predicted Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries as 10,865 ppb in summer.
- The seasonal cross-sectional transections in the vicinity of the release site indicate that entrained oil concentrations at or greater than the moderate (100 ppb) and high (1,000 ppb) thresholds are not expected to exceed depths of around 60 m and 25 m BMSL, respectively, across any season. Therefore, limiting benthic contact below this depth.
- Time-integrated entrained oil exposure at or above the 960 ppb.h threshold could travel up to 578 km from the release location, with the distance reducing to 172 km as the contact threshold increases to 9,600 ppb.h.
- The probability of contact by time-integrated exposure of entrained oil concentrations at the 9,600 ppb.h threshold is predicted to be greatest at Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries with a probability of 14% in the surface layer (0-10 m) in transitional months.
- The worst-case maximum entrained oil integrated exposure is predicted at the Ancient Coastline at 125 m Depth Contour Key Ecological Feature, Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries as 65,338 ppb.h.
- Instantaneous dissolved aromatic hydrocarbon concentrations at the low (10 ppb) threshold could travel up to 827 km from the release location, with distances reducing at the moderate (50 ppb; 272 km) threshold and no exposure predicted above 400 ppb.
- The probability of contact by dissolved aromatic hydrocarbon concentrations at the low threshold (10 ppb) is predicted to be greatest at Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and Western Skipjack Fishery with probabilities of 21-29% across all seasons.
- The worst-case dissolved aromatic hydrocarbon concentrations at any receptor is predicted at the Marine Turtle, Seabirds, Seabirds and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries as 275 ppb in summer.
- The seasonal cross-sectional transections in the vicinity of the release site indicate that dissolved aromatic hydrocarbon concentrations at or greater than the moderate (50 ppb) threshold are not expected to reach depths greater than approximately 50 m BMSL. Therefore, limiting benthic interaction below this depth.
- Time integrated dissolved aromatic hydrocarbon exposure at or above 960 ppb.h could travel up to 7 km from the release site.

- The probability of contact by dissolved aromatic hydrocarbon exposure at the 960 ppb.h threshold was predicted to be greatest at the Biologically Important Areas for Marine Turtles, Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack Fisheries with a probability of 7% in the surface layer (0-10 m) in transitional months.

- The worst-case maximum dissolved aromatic hydrocarbon exposure concentration at any receptor is predicted at the Marine Turtle BIA, Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery as 3,609 ppb.h.

- Note, the highest probabilities and concentrations of entrained oil and dissolved aromatic hydrocarbons are generally expected to occur within the surface layer (0-10 m), with probabilities expected to reduce with depth.

5 REFERENCES

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.

Australian and New Zealand Environment and Conservation Council (ANZECC) and Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, *Australian and New Zealand guidelines for fresh and marine water quality. Volume 1: The guidelines (national water quality management strategy; no. 4*), Australian and New Zealand Environment and Conservation Council and Agricultural and Resource Management Council of Australia and New Zealand, Canberra, ACT, Australia.

Australian Maritime Safety Authority (AMSA) 2002, *National marine oil spill contingency plan*, Australian Maritime Safety Authority, Canberra, ACT, Australia.

Australian Maritime Safety Authority (AMSA) 2015b, National plan guidance on: Response, assessment and termination of cleaning for oil contaminated foreshores, NP-GUI-025, Australian Maritime Safety Authority, Canberra, ACT, Australia.

Chen, F & Yapa PD 2007, 'Estimating the oil droplet size distributions in deepwater oil spills', in Hydraulic Engineering, vol. 133, no. 2, pp. 197-207.

Chen, F & Yapa, PD 2002, 'A model for simulating deepwater oil and gas blowouts – part II: comparison of numerical simulations with "Deep spill" field experiments', Journal of Hydraulic Research, vol. 41, no. 4, pp. 353-365.

Davies, AM 1977a, 'The numerical solutions of the three-dimensional hydrodynamic equations using a B-spline representation of the vertical current profile', in *Bottom Turbulence: Proceedings of the 8th Liege Colloquium on Ocean Hydrodynamics*, ed. Nihoul, JCJ, Elsevier.

Davies, AM 1977b, 'Three-dimensional model with depth-varying eddy viscosity', in *Bottom Turbulence: Proceedings of the 8th Liege Colloquium on Ocean Hydrodynamics*, ed. Nihoul, JCJ, Elsevier.

Di Toro DM, McGrath JA & Stubblefield WA 2007, 'Predicting the toxicity of near and weathered crude oil: toxic potential and the toxicity of saturated mixtures', Environmental Toxicology and Chemistry, vol. 26, no. 1, pp. 24-36.

Flater, D 1998, *XTide: harmonic tide clock and tide predictor* (www.flaterco.com/xtide/).

French McCay, D, Whittier, N, Sankaranarayanan, S, Jennings, J & Etkin, DS 2004, 'Estimation of potential impacts and natural resource damages of oil', *Journal of Hazardous Materials*, vol. 107, no. 1-2, pp. 11-25.

French, D, Reed, M, Jayko, K, Feng, S, Rines, H, Pavignano, S, Isaji, T, Puckett, S, Keller, A, French III, FW, Gifford, D, McCue, J, Brown, G, MacDonald, E, Quirk, J, Natzke, S, Bishop, R, Welsh, M, Phillips, M & Ingram, BS 1996 'Final Report, The CERCLA Type A Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME)', *Technical Documentation, Vol. I – V*, Submitted to the Office of Environmental Policy and Compliance, U.S. Department of the Interior, Washington, DC, USA.

French, DP & Rines, HM 1997, 'Validation and use of spill impact modelling for impact assessment', in Proceedings of the 1997 International Oil Spill Conference, Fort Lauderdale, FL, USA, pp. 829-834.

French, DP 1998, 'Modelling the impacts of the North Cape oil spill', in Proceedings of the 21st Arctic and Marine Oilspill Program (AMOP) Technical Seminar, Edmonton, AB, Canada, pp. 387-430.

French, DP 2000, 'Estimation of oil toxicity using an additive toxicity model', in *Proceedings of the 23rd Arctic and Marine Oil Spill Program Technical Seminar*, Vancouver, British Columbia, Canada, pp. 561-600.

French, DP, Schuttenberg, H & Isaji, T 1999, 'Probabilities of oil exceeding thresholds of concern: Examples from an evaluation for Florida Power and Light', in Proceedings of the 22nd Arctic and Marine Oilspill Program (AMOP) Technical Seminar, Calgary, AB, Canada, 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. 9-12, pp. 341-359.

French-McCay, DP 2004, 'Oil 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', in *Proceedings of the 32nd Arctic and Marine Oilspill Program (AMOP) Technical Seminar on Environmental Contamination and Response*, Vancouver, BC, Canada, pp. 601-654.

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', in *Proceedings of the 34th Arctic and Marine Oilspill Program (AMOP) Technical Seminar on Environmental Contamination and Response*, Banff, AB, Canada, pp. 146-168.

French-McCay, D, Reich, D, Michel, J, Etkin, DS, Symons, L, Helton, D & Wagner J 2012, 'Oil spill consequence analysis of potentially-polluting shipwrecks', in *Proceedings of the 35th Arctic and Marine Oilspill Program (AMOP) Technical Seminar on Environmental Contamination and Response*, Environment Canada, Ottawa, ON, Canada.

Gordon, R 1982, Wind driven circulation in Narragansett Bay, PhD thesis, University of Rhode Island, Kingston, RI, USA.

Isaji, T & Spaulding, ML 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 & Spaulding, ML 1986, 'A numerical model of the M2 and K1 tide in the northwestern Gulf of Alaska', *Journal of Physical Oceanography*, vol. 17, no. 5, pp. 698-704.

Isaji, T, Howlett, E, Dalton, C & Anderson, E 2001, 'Stepwise-continuous-variable-rectangular grid hydrodynamics model', in *Proceedings of the 24th Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, Edmonton, AB, Canada, pp. 597-610.

Johansen, Ø 2003, 'Development and verification of deep-water blowout models', Marine Pollution Bulletin, vol. 47, no. 9-12, pp. 360-368.

King, B & McAllister, FA 1998, 'Modelling the dispersion of produced water discharges', *APPEA Journal*, pp. 681-691.

Koops, W, Jak, RG & van der Veen, DPC 2004, 'Use of dispersants in oil spill response to minimize environmental damage to birds and aquatic organisms', in Proceedings of Interspill 2004, Trondheim, Norway, paper no. 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, MJ, 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.

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.

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.

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2018, At a glance: Oil spill modelling, National Offshore Petroleum Safety and Environmental Management Authority, Perth, WA, Australia.

National Research Council (NRC) 2005, *Oil Spill Dispersants: Efficacy and Effects*, National Research Council of the National Academies, The National Academies Press, Washington, DC, USA.

NOAA 2013, World Ocean Atlas 2013, National Oceanic and Atmospheric Administration, Silver Spring, MD, USA (www.nodc.noaa.gov/OC5/WOA13/).

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) 2019, 'National Offshore Petroleum Safety and Environmental Management Authority Bulletin #1: Oil spill modelling', viewed April 2019', (https://www.nopsema.gov.au/assets/Bulletins/A652993.pdf)

Oke, PR, Brassington, GB, Griffin, DA & Schiller, A 2008, 'The Bluelink ocean data assimilation system (BODAS)', *Ocean Modeling*, vol. 21, no. 1-2, pp. 46-70.

Oke, PR, Brassington, GB, Griffin, DA & Schiller, A 2009, 'Data assimilation in the Australian Bluelink system', *Mercator Ocean Quarterly Newsletter*, no. 34, pp. 35-44.

Okubo, A 1971, 'Oceanic diffusion diagrams', *Deep Sea Research and Oceanographic Abstracts*, vol. 18, no. 8, pp. 789-802.

Owen, A 1980, 'A three-dimensional model of the Bristol Channel', *Journal of Physical Oceanography*, vol. 10, no. 8, pp. 1290-1302.

Pace, CB, Clark, JR & Bragin, GE 1995, 'Comparing crude oil toxicity under standard and environmentally realistic exposures', in Proceedings of the 1995 International Oil Spill Conference, Long Beach, CA, USA, paper no. 327.

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.

Saha, S, Moorthi, S, Pan, HL, Wu, X, Wang, J, Nadiga, S 2010, 'The NCEP climate forecast system reanalysis', *Bulletin of the American Meteorological Society*, vol. 91, pp. 1015-1057.

Schiller, A, Oke, PR, Brassington, GB, Entel, M, Fiedler, R, Griffin, DA & Mansbridge, JV 2008, 'Eddy-resolving ocean circulation in the Asian-Australian region inferred from an ocean reanalysis effort', *Progress in Oceanography*, vol. 76, no. 3, pp. 334-365.

Scholten, MCTh, Kaag, NHBM, Dokkum, HP van, Jak, RG, Schobben, HPM & Slob, W 1996, 'Toxische effecten van olie in het aquatische milieu', TNO-MEP report R96/230, Den Helder, The Netherlands.

Spaulding, ML, Bishnoi, PR, Anderson, E & Isaji, T 2000, 'An integrated model for prediction of oil transport from a deep water blowout', in *Proceedings of the 23rd Arctic and Marine Oil Spill Program Technical Seminar*, Vancouver, BC, Canada, pp. 611-636.

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’, in *Proceedings of the Coasts & Ports 2003 Australasian Conference*, Auckland, New Zealand, paper no. 170.