Amulet Development:
Offshore Project Proposal

Revision 2

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0	7 May 2020	Submission for NOPSEMA review	NLK	BMC	BMC
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Executive Summary

ES1. Introduction

The Amulet Development will be centred on the Amulet field, located within Commonwealth waters on the North West Shelf, offshore of mainland Western Australia (WA), ~132 km north of Dampier (Figure ES-1). The field lies in ~85–90 m of water within retention lease WA-8-L in the Carnarvon Basin, and contains light crude oil.

KATO Energy Pty Ltd (KATO) plans to develop the Amulet 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 Amulet field has previously been appraised by Tap (Shelfal) Pty Ltd, with three wells drilled in 2006. The Amulet field is classified as a small field with a short life span and proven contingent resource of 6.9 MMstb.

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

- site survey of the proposed location of subsea infrastructure
- drilling of up to two production wells, one dual-purpose production/water injection well, and allowance for a sidetrack
- 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.

The Talisman oil field is ~3.5 km to the west of Amulet, within WA-8-L, which has been produced but was shut-in in 1992 and since abandoned. Due to its proximity to the Amulet field, KATO may choose to reinstate production from the Talisman field. If the subsea tieback option is selected for development of the adjacent Talisman field, the following additional components covered in this OPP are:

- site survey of the proposed location of subsea infrastructure
- drilling of up to two production wells and allowance for a sidetrack (note these Talisman wells will be drilled regardless of the field development option chosen)
- installation of a production flowline and service umbilical between the MOPU and Talisman field
- installation of associated subsea infrastructure at Talisman, if the subsea tieback option is selected
- operation of the Talisman subsea facilities

- decommissioning and removal of Talisman subsea 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.

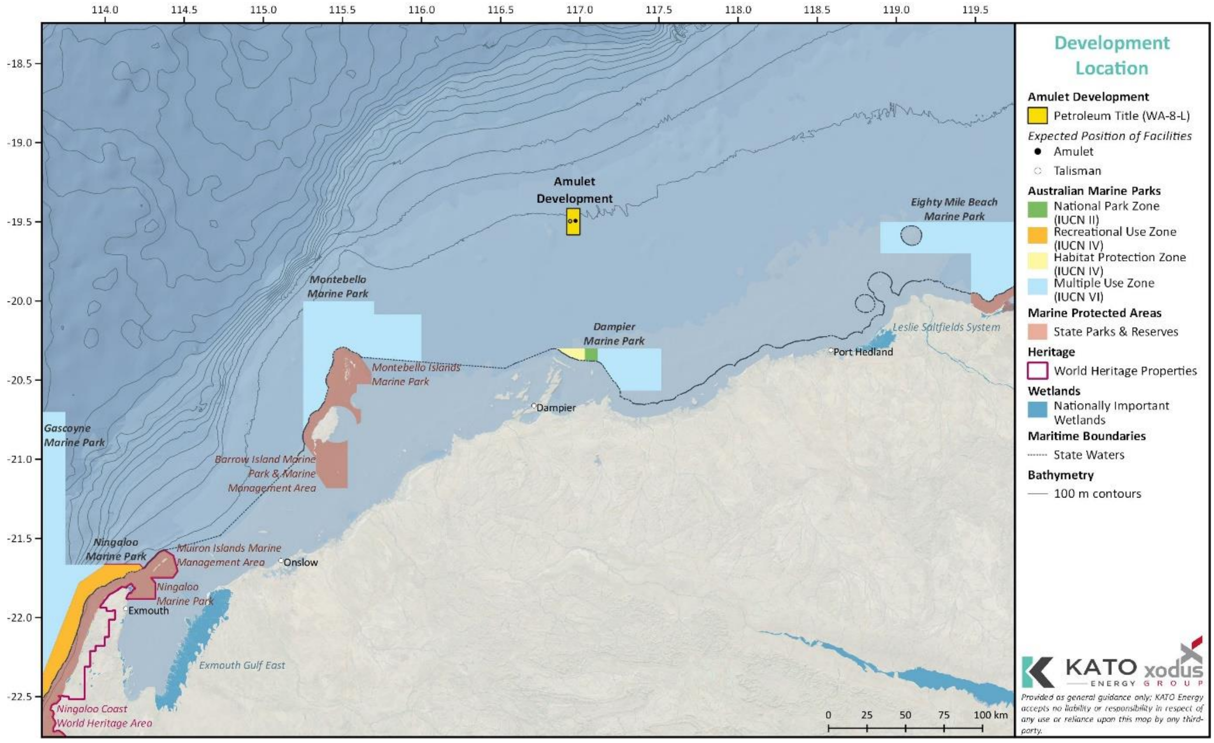


Figure ES-1 Location of Amulet Development

Titleholder Details

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

KATO is an Australian company that was formed to combine 100% ownership of the Amulet 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-1provides the details of titleholders within which the petroleum activity will take place.

Table ES-1 Licence and Titleholder Details

Title	Name	Operator	Titleholder Details
WA-8-L	Amulet	KATO Energy	Tamarind Amulet Pty Ltd Skye Energy 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 Amulet Development is located entirely in Commonwealth waters and therefore falls under Commonwealth jurisdiction, triggering this key legislation, as summarised in Table ES-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-2 Overview of Key Commonwealth Legislation

Legislation	Scope
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)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.
EPBC Act	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 (MNES). The aims of the EPBC Act are to: • protect matters of MNES • provide for Commonwealth environmental assessment and approval processes • provide for an integrated system for biodiversity conservation and management of protected areas. MNES identified as relevant to the Amulet Development are: • Migratory species under international agreements • Commonwealth marine environment • World heritage properties

Legislation	Scope
	• National heritage places • Listed threatened species and communities • Ramsar wetlands.

ES3. Description of the Project

Project Overview

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

Whilst the preferred Talisman field development option is to drill extended reach deviated wells through the conductor deck of the MOPU; if the subsea tieback system option is selected, the following additional components will be incorporated specifically for the development of the Talisman field:

9. Talisman subsea trees (production wells) and jumpers to the manifold
10. Talisman manifold to commingle production from nearby Talisman wells
11. Production flowline and service umbilical from Talisman manifold to MOPU (Figure ES-2).

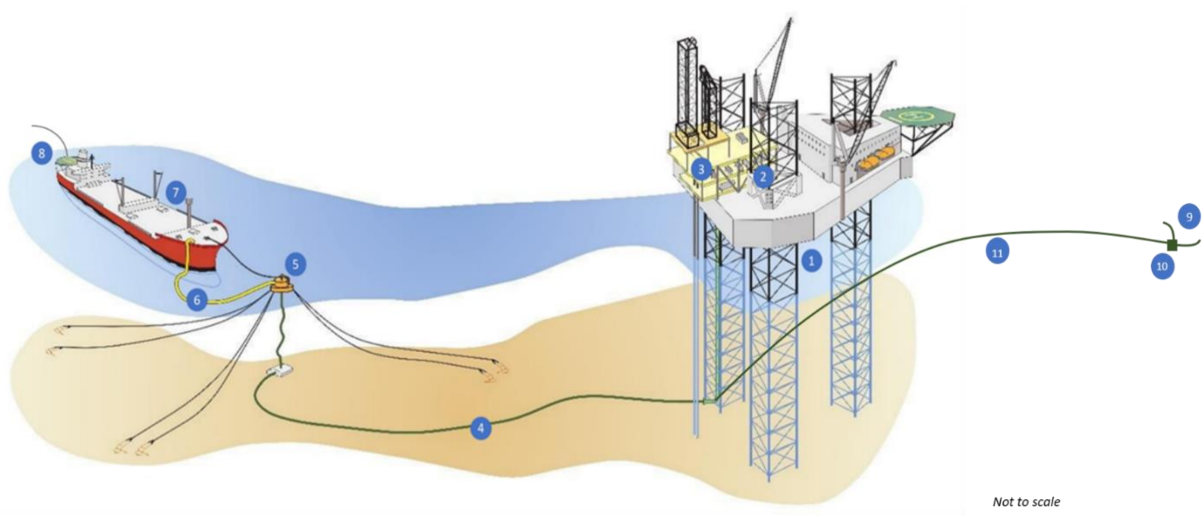


Figure ES-1-1 Amulet Development Infrastructure

The proposed location of the MOPU is optimised for the primary target oil field, Amulet. The Talisman field is ~4 km to the west of the Amulet field, which has been produced, but was shut-in in 1992 and has since been abandoned. Due to its proximity to the Amulet field, KATO may choose to reinstate production from the Talisman field.

In the event that drilling the Talisman wells from the MOPU location is not technically feasible, an alternative will be to reinstate production from the Talisman field using a subsea gathering system tied back to the MOPU via ~3.5 km flowline (Section 4.3.2). As this subsea tieback option presents the greater potential environmental impact, it has been used as the basis for impact assessment in this OPP.

KATO's business strategy is to develop multiple small marginal discovered fields which are currently uneconomic and subsequently 'stranded'. KATO will unlock the resource in these fields by using the relocatable honeybee production system to move from one field to the next.

At the time of writing, KATO's portfolio consists of Amulet, and the Corowa Development. The Corowa Development is centred on the Corowa field located within Commonwealth waters on the NWS, which lie in ~90 m of water within production licence WA-41-R, and contains light crude oil. Corowa is ~335 km south-east of the Amulet Development. A separate OPP for Corowa has been submitted to NOPSEMA (KATO 2020j). Future fields will be the subject of separate OPP/s, once identified and acquired/confirmed.

There is potential there may also be exploration targets within the WA-8-L permit area, that are as yet undiscovered and therefore undefined. Whilst on location drilling the Amulet and Talisman wells, KATO may take the opportunity to drill an exploration well into a nearby oil prospect that is within reach of the drill rig.

Exploration activities such as drilling are not within scope of the OPP process; if undertaken, this activity will be covered by a separate Environment Plan (EP).

Location

The Amulet and Talisman fields are located within Commonwealth waters in offshore petroleum permit WA-8-L, located ~132 km north of Dampier in the northwest of Australia in water depths of ~85 m (Figure ES-1).

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 at Amulet. If the subsea tieback option is selected for Talisman field development, there will potentially be facilities and support vessels undertaking activities above the Talisman field. Therefore, the 5 km buffer for the Project Area has also been extended around the expected position of the Talisman manifold.

The final positions of the facilities will be included in the relevant EPs.

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 Amulet Development is detailed in Table ES-3.

KATO's business strategy is to become the titleholder for a number of fields, and with the intent being that, as each field is depleted, it is fully decommissioned and wells P&A'd. The honeybee production system will then relocate to the next field. The order of the fields is not yet decided, and the timing shown in Table ES-3 assumes that the Amulet field will be the first development. If the fields are produced in a different order, the timing of the Amulet Development may be 2–5 years 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 1.5 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 intervention and/or sidetrack program, dependent on reservoir performance in the initial 6–9 months of production.

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

Table ES-3 Preliminary Project Schedule

Phase	Timing*	Indicative Duration
Survey	Q1 2023	1 month
Drilling	Initial campaign – Q2/Q3 2023 Second campaign (if required) – 1 to 2 years after start-up	Initial campaign – 7 months Second campaign (if required) – additional 4 months
Installation, Hook-up and Commissioning	Q3 2023	3 months
Operations	Q4 2023	Between 1.5 and 4.5 years, at best and high estimates of production respectively
Decommissioning	Between 2025 and 2027 (depending on duration of operations)	3 months

**Timing shown is if the Amulet Development is the first field developed using the relocatable honeybee production system of the KATO-owned fields. If the KATO-owned fields are developed in a different order, the timing of Amulet may be later than shown.*

Project Stages

Key phases of the Amulet Project 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; Talisman subsea tieback; flowlines; CALM buoy and mooring arrangements; 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 Amulet.

The comparative environmental assessment showed that the most favourable concept environmentally is Concept 5 – Subsea tieback 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 tieback 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-4 summarises the comparative assessment outcomes.

Table ES-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. • Large development footprint associated with pipeline	X
3	**FPSO**	• While redeployable, the Amulet and Talisman 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 Tieback 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 ~0.65–0.94 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 Amulet Development. Therefore, KATO has undertaken a comparative assessment of the feasible options against all project drivers and criteria, not only against the environmental criteria (Table ES-5).

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

Option	Option Justification	
Fuel gas *Selected option*	• No additional impacts. • This option would offset the use of liquid fuels such as diesel and reduce emissions from the facility to a maximum of ~0.1 MT CO_2-e (P10). • For some of the development life 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	• ~40-60 km length of additional seabed disturbance associated with export pipeline tieback to existing trunkline, resulting in moderate localised impact to benthic habitat. • Additional resources for pipeline manufacture and installation. • Positive impact of reduced atmospheric emissions from natural gas offsets other fuel use in power generation. If feasible, export of associated gas would reduce emissions by a maximum of ~0.06 MT CO_2-e (P10). • 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	• Includes the installation and operation of additional facilities on the MOPU (including power generation, gas treatment, high-pressure gas compression, injection facilities) and construction of a gas injection well. • If technically feasible, reinjection of associated gas would reduce emission by a maximum of ~0.06 MT CO_2-e (P10). • 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.	*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 0.1 MT CO_2-e. Gas is not used. • Moderate level of atmospheric emissions associated with gas flaring. • Flaring would peak at 1.2 MMscf/d (allowing for fuel gas usage) during the initial 6–9 months of production, then decline as the reservoir depletes. • 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 64 scf/stb

Option	Option Justification	
Gas to wire	• ~130 km length of seabed disturbance and shore crossing associated with power export cable resulting in moderate localised impact to benthic habitat. • This option would not reduce emissions from the MOPU facility, but if feasible may offset a maximum of ~0.06 MT CO_2-e (P10) of emissions from power generation facilities utilising other fuel sources. • Not economic due to short project life, cost of export cable and small volumes of gas. • There is no market identified within range (<100 km).	*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. • 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. • If feasible, CNG could reduce emissions by a maximum of ~0.06 MT CO_2-e over the life of the project (P10). • If feasible, Mini-LNG (with feed of ~6 MMscf/d) could reduce emissions by a maximum of ~0.04 MT CO_2-e over the life of the project (P10).	*X*
Carbon Capture and Storage (CCS)	• CCS requires the offshore capture or exhaust gases, removal, treatment, compression and export of compressed separated CO_2 gas to a dedicated CO2 pipeline and disposal facilities either at the MOPU or export and disposal to a third party. • If technically feasible CCS could remove emissions from heat and power fired equipment would reduce emission by a maximum of ~0.1 MT CO_2-e (P10).	*X*

Table ES-6 summarises the key options identified, and those selected for use in Front-End Engineering and Design Phase (FEED).

Table ES-6 Summary of Comparative Analysis of Design / Activity Options

Design/Activity Option	Justification for Selected Option
Talisman field development	**Option 1 – Subsea tieback system:** *Selected* • Requires additional seabed footprint associated with the physical footprint of drilling on location at Talisman (~0.002 km^2); and from installation of subsea infrastructure and tieback components, with a total additional footprint of ~0.055 km^2 (including 50% contingency). • Some additional light emissions and interaction with marine fauna from additional facility and vessel movements. Some additional planned discharges from leak testing of production flowline.

Design/Activity Option	Justification for Selected Option
	• Option carried through into FEED, if Option 2 is proven not technically feasible following geomechanics study. Option 1 used as basis for impact assessment as presents greater potential environmental impact.
	Option 2 – Extended reach deviated wells from MOPU: *Selected* • Incremental additional planned discharges from drilling. • Preferred option, carried through into FEED.
Talisman well intervention methodology	**Option 1 – ISV with well intervention package:** *Selected* • Requires additional seabed disturbance from positioning MODU (~0.002 km^2); and incremental additional planned discharges and accidental release risk, from additional facility and support vessels in field.
	Option 2 – MODU: *Selected* • No additional seabed disturbance or discharges. • No significant environmental differentiator. Both options selected to carry through FEED.
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*

Design/Activity Option	Justification for Selected Option
	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 Amulet 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 Amulet Development was demarcated into three sub-areas that are used to support the impact and risk assessments (as described in Table ES-7).

If the subsea tieback option is selected for Talisman field development, there will potentially be facilities and support vessels undertaking activities above the Talisman field. Therefore, the expected position of the Talisman manifold has been used (in addition to the MOPU at Amulet) as a source of aspects for the relevant buffers.

Table ES-7 Description of Amulet Development EMBA Sub-Areas

Area	Description
Environment that May Be Affected	
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 outer extent of the EMBA for the Amulet 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. Specifically, 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) 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 Sub-Areas	
Project Area	This area has been defined to include the extent of all planned activities, and is the area relevant to the impact and risk assessments for all planned and unplanned aspects, with the exception of light emissions and accidental releases. The Project Area has been defined as a 5 km area extending around the expected position of facilities at Amulet and Talisman[2].

[2] As the position of the MOPU at Amulet and the manifold at Talisman is indicative only at this stage, the identification of values and sensitivities (including an EPBC protected matters search) was completed using an additional 2 km buffer around the defined Project Area (Appendix A).

Area	Description
Light Area	This area has been defined to include the worst-case extent of predicted measurable light based on planned activities, and is the area relevant to the impact assessment for planned light emissions. This Light Area has been defined as a 12.6 km area extending around the expected position of facilities at Amulet and Talisman.
Unplanned Activities Sub-Areas	
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, and is the area relevant to the risk assessment for unplanned accidental releases. This Hydrocarbon Area has been defined based on the outcomes of stochastic modelling (i.e. it is the cumulative extent of 150/300[3] 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.

Physical Environment

Table ES-8 summarises the physical environment relevant to the Amulet Development.

Table ES-8 Summary of Physical Environment Relevant to the Amulet 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 majority of the offshore Pilbara region is relatively remote and therefore air quality is expected to be high. However, anthropogenic sources (e.g. vessels, industry developments) would contribute to local variation in air quality.
Climate	The climate within the Pilbara region is dry tropical, and is characterised by very hot summers, mild winters and low and variable rainfall. It is the most tropical cyclone prone coast in Australia, averaging two cyclones crossing the coast each year.
Ambient light	Natural ambient light within the offshore Pilbara region is expected to predominantly be from solar/lunar luminance. Artificial ambient light sources associated with anthropogenic activities also exist, including both permanent (e.g. onshore/offshore developments) and temporary (e.g. vessels) light sources. However, the Amulet Development is located ~40 km from the nearest petroleum facility and ~7 km from the nearest shipping fairway, and therefore negligible measurable increases in ambient light levels from these sources are expected.
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.

[3] 150 model simulations were run for the subsea release of Amulet 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).

Physical Receptor	Overview
	Anthropogenic noise sources that are also likely to be experienced in the area include low-frequency noise from vessels. The Amulet Development is located between two shipping fairways on the North West Shelf, and therefore is likely to be exposed to the occasional sounds generated by mid to large vessels such as tankers and bulk carriers.

Ecological Environment

Table ES-9 summarises the ecological environment for the Amulet Development.

Threatened and/or migratory seabirds and shorebirds, fish, marine reptiles and marine mammals may be categorised as MNES under the EPBC Act.

Table ES-9 Summary of the Ecological Environment Relevant to the Amulet Development

Ecological Receptor	Overview
Plankton	Primary productivity of the North-west Marine Region is generally low and appears to be largely driven by offshore influences. Phytoplankton biomass is typically variable (spatially and temporally), but greatest in areas of upwelling, or in shallow waters where nutrient levels are high. 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.
Benthic habitats and communities	Previous studies of the Amulet Development area have shown that the seabed is composed of partially exposed cemented carbonates overlain by a fine to coarse grained sedimentary veneer, with sparse populations of filter and deposit-feeding epibenthic fauna, polychaete worms, crustaceans and echinoderms. At the water depth of the Project Area (~85 m), the consequent reduced light levels of this 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 or Hydrocarbon Area. One internationally important Ramsar wetland occurs within the EMBA (Eighty-mile Beach).
Seabirds and Shorebirds	The Protected Matters Search Tool (PMST; EPBC Act) identified the following number of species or species habitat that may occur within the Amulet Development Areas: • 11 within the Project Area • 102 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)
Fish	The PMST identified the number of species or species habitat that may occur within the Amulet Development Areas: • 34 within the Project Area • 68 within the EMBA.

Ecological Receptor	Overview
	BIAs that overlap the sub-areas for planned activities were identified as: • Project Area: Whale Shark (foraging) • Light Area: Whale Shark (foraging).
Marine mammals	The PMST identified the number of species or species habitat that may occur within the Amulet Development Areas: • 24 within the Project Area • 42 within the EMBA. BIAs that overlap the sub-areas for planned activities were identified as: • Project Area: Pygmy Blue Whale (distribution) • Light Area: Pygmy Blue Whale (distribution)
Marine reptiles	The PMST identified the number of species or species habitat that may occur within the Amulet Development Areas: • 19 within the Project Area • 28 within the EMBA BIAs that overlap the sub-areas for planned activities were identified as: • Project Area: None • Light Area: None.

Social, Economic and Cultural Environment

Table ES-10 summarises the social, economic and cultural environment for the Amulet Development.

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

Table ES-10 Summary of the Social, Economic and Cultural Environment Relevant to the Amulet 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 Amulet Development are the Dampier Marine Park and Montebello Marine Park, ~90 km and ~120 km from the expected position of the MOPU respectively. Within the EMBA, 11 AMPs are present—ten within the North-west Marine Region, and one 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. There are no KEFs within the Project Area; the closest are the ‘ancient coastline at 125 m depth contour’ and ‘Glomar Shoals’ (~8 km and 15 km from the expected MOPU position respectively). Within the EMBA, 12 KEFs are present— nine within the North-west Marine Region, and three within the South-west Marine Region.
Commercial Fisheries	The commercial fisheries that intersect the sub-areas for planned activities were identified as: • Project Area:

Social, Economic and Cultural Receptor	Overview
	○ three Commonwealth-managed fisheries; of which none are active ○ 10 State-managed fisheries; of which three are active – Pilbara Fish Trawl (Interim) Managed Fishery, Pilbara Line Fishery and Pilbara Trap Fishery. • Light Area: ○ three Commonwealth-managed fisheries; of which none are active ○ 10 State-managed fisheries; of which four are active – Mackerel Managed Fishery, Pilbara Fish Trawl (Interim) Managed Fishery, Pilbara Line Fishery and Pilbara Trap Fishery.
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 far offshore (~132 km from Dampier).
State Protected Areas – Marine	The Project Area and Light Area do not intersect any State Protected Areas – Marine. The closest State marine protected area is the Montebello Islands Marine Park, ~171 km away. There are five State marine protected areas within the EMBA.
State Protected Areas – Terrestrial	The Project Area and Light Area do not intersect any State Protected Areas – Terrestrial. 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. The closest oil and gas facilities to the Amulet Development are the Woodside-operated Angel platform (~40 km) and Okha FPSO (~57 km). Santos' Mutineer Exeter Development is ~45 km away, but is in cessation and the FPSO has left the field. In 1992, the Talisman field was shut-in, and some production equipment was abandoned by the operator at the time. The T-7 flowline and control umbilical line, an anchor and length of chain, and a tyre weight remain on the seabed, with a designated 1 km buffer (as the location of the latter two items is not known; but are assumed to be buried). If the Talisman subsea tieback option is selected, the expected location of the Talisman manifold is ~140 m inside the buffer. The Amulet Development is located between two shipping fairways for Dampier Port (~9 km west and ~23 km east of the MOPU). However, historic tracking data indicates vessel traffic within the Project Area itself is minimal. The Project Area is not within the Department of Defence's (DoD) North West Exercise Area (NWXA).
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 and Light Area do not intersect any identified heritage and cultural features. 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 (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.

Impacts and risks have been demonstrated to be at an acceptable level if they do not result in a 'significant impact' as described in the Matters of National Environmental Significance – Significant Impact Guidelines (DoE 2013). The level of significant impact is specific to each receptor, and is determined by whether the receptor is listed as an MNES, and whether it is present within the relevant impact area. As such, the levels of significant impact are sourced from:

- Matters of National Environmental Significance– Significant Impact Guidelines 1.1 (DoE 2013)
- OPGGS Act Section 280(2).

ES7. Evaluation of Environmental Impacts and Risks

The OPP has identified potential environmental impacts and risks associated with the Amulet Development. The impacts and risks associated with each aspect of the Amulet Development were determined to be acceptable following implementation of the adopted control measures (Table ES-11 and Table ES-12).

Table ES-11 Summary of Environmental Impacts and Risks Associated with the Amulet Project – Planned

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; Talisman subsea tieback; flowlines; CALM buoy and mooring arrangements; 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	**EPO1:** Undertake the Amulet Development in a manner that prevents a substantial adverse effect on the sustainability of commercial fishing. **EPO2:** Undertake the Amulet Development in a manner that does 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 500 m exclusion and 2 km cautionary zones. **CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction.	Minor
		Industry				Minor
Physical Presence – Seabed Disturbance	*Survey* geotechnical survey *Drilling* MODU positioning; top-hole drilling *Installation, Hook-up and commissioning* MOPU; Talisman subsea tieback;	**Ambient water quality**	Change in water quality	**EPO3:** Undertake the Amulet Development in a manner that does not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO4:** Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact	**CM05**: Mooring analysis will be undertaken, which will include an environmental sensitivity and seabed topography analysis. **CM06**: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below seabed and removed. **CM07**: If any objects are to be left in situ on the seabed, KATO will consult with DAWE to confirm any requirements, and apply for, a Sea Dumping Permit, if required.	Minor

Aspect	Phase and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
	flowlines; CALM buoy and mooring arrangements *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	on marine ecosystem functioning or integrity results. **EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO8:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **EPO10:** Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species. **EPO11:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and communities, including life cycle and spatial distribution.	**CM08**: Locate Talisman subsea tieback infrastructure to avoid any abandoned production equipment discovered during the site survey.	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	**EPO4:** Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. **EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt	**CM09**: Lighting will be sufficient for navigational, safety and emergency requirements (e.g. requirements contained in AMSA Marine Order Part 30 and Facility Safety Cases). **CM010:** An Artificial Light Management Plan will be developed in alignment with the National Light Pollution Guidelines (CoA 2020).	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	the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO6:** Undertake the Amulet Development in a manner that will not result in the displacement of marine turtles from important foraging habitat or from habitat critical during nesting and internesting periods. **EPO7:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population. **EPO8:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **EPO9:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO10:** Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species.		Minor
		Fish				Minor
		Marine reptiles				Minor

<table>
<tr><th>Aspect</th><th>Phase and Activity (source of aspect)</th><th>Receptor</th><th>Impact</th><th>EPO</th><th>Adopted Control Measures</th><th>Consequence</th></tr>
<tr><td rowspan="2">Emissions – Atmospheric</td><td rowspan="2">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</td><td>Ambient air quality</td><td>Change in air quality</td><td rowspan="2">EPO12: Undertake the Amulet Development in a manner that will not result in a substantial change in air quality, which may adversely impact on biodiversity, ecological integrity, social amenity, or human health.
EPO13: Undertake the Amulet Development in a manner that will not significantly contribute to Australia's annual greenhouse gas emissions.
EPO14: KATO will not export oil produced from the Amulet Development to countries that are not signatories to the Paris Agreement.</td><td rowspan="2">CM11: Compliance with AMSA Marine Order 97 (Marine pollution prevention — air pollution).
CM12: 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.
CM13: Maximise the use of associated gas, for example, as fuel gas during operations
CM14: Comply with the requirements of the Safeguard Mechanism, including purchase of Australian Carbon Units (ACCUs) if designated emissions baseline is exceeded, as determined by the Clean Energy Regulator.
CM15: Operations designed to be optimised to enable the safe and economically efficient operation of the facility.
CM16: Develop KATO Greenhouse Gas Management Plan and identify emissions mitigation hierarchy to reduce direct GHG emissions to ALARP during EP development, including consideration of:
• Avoid – as per alternatives assessment (Section 4.3.1)
• Reduce – identify opportunities for reduction of emissions during FEED (i.e. heat and power generation, energy efficiencies); and monitor new technologies for use of excess associated gas and evaluate feasibility for use on the Amulet Development
• Offsets – in alignment with Safeguard Mechanism</td><td>Minor</td></tr>
<tr><td>Climate</td><td>Climate change</td><td>Moderate</td></tr>
</table>

Aspect	Phase and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
					• Monitor – Monitor Australia's and export countries' commitments under the Paris Agreement regarding NDCs, export of oil and Scope 3 emissions. • Mechanisms to ensure adaptive management of these measures for the duration of the Amulet Development via the EP mechanism. **CM17**: Reporting of GHG emissions as per the National Greenhouse and Energy Reporting (NGER) Scheme.	
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;	**Ambient noise**	Change in ambient noise	**EPO4:** Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. **EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO6:** Undertake the Amulet Development in a manner that will not result in the displacement of marine turtles from important foraging habitat or from habitat critical during nesting and internesting periods. **EPO8:** Undertake the Amulet Development in a manner that will not have a substantial	**CM04:** KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM18**: Vessels and aircraft will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the project area. **CM19**: Vertical seismic profiling (VSP) operations will adhere to the EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines. **CM20**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements.	Minor
		Fish	Change in fauna behaviour			Moderate
		Marine mammals	Injury / mortality to fauna			Moderate

Aspect	Phase and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
	helicopter operations		Change in fauna behaviour	adverse effect on a population of fish, or the spatial distribution of the population. **EPO9:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO15:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **EPO16:** Noise emissions are managed such that any Blue Whale continues to utilise the area without injury and is not displaced from a foraging BIA.		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	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO4:** Undertake the Amulet Development in a manner that will 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 results. **EPO11:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and	**CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM22**: 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. **CM23**: Drilling and cementing procedures to standard industry practices will be developed that will describe specific well locations, design and fluid volumes. **CM24:** Whole SBM will not be discharged into the marine environment. **CM25:** Drilling of the conductor section will use seawater and/or WBM only.	Minor
		Ambient sediment quality	Change in sediment quality			Minor
		Benthic habitats and communities	Change in habitat			Minor
			Injury / mortality to fauna			Minor

Aspect	Phase and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
				communities, including life cycle and spatial distribution. **EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		
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	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO4:** Undertake the Amulet Development in a manner that will 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 results. **EPO11:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and communities, including life cycle and spatial distribution. **EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM23**: 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			Minor
			Injury / mortality to fauna			Minor

Aspect	Phase and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
Planned Discharge – Commissioning and Operational Fluids	*Installation, Hook-up and commissioning* Talisman subsea tieback; flowlines; FSO; MOPU *Operations* Hydrocarbon extraction *Decommissioning* disconnection of FSO and MOPU	**Ambient water quality**	Change in water quality	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM21**: 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
Planned Discharge – Produced Formation Water	*Operations* hydrocarbon processing, storage and offloading	**Ambient water quality**	Change in water quality	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO18:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of plankton, including its life cycle and spatial distribution.	**CM26**: A management framework for produced formation water discharges will be developed.	Minor
		Ambient sediment quality	Change in sediment quality			Minor
		Plankton	Injury / mortality to fauna			Minor

Aspect	Phase and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
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	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM20**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM21**: 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	**EPO18:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of plankton, including its life cycle 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	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality, which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM20**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM27:** Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM28**: 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.	Minor
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	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality, which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM20**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide	Minor

Aspect	Phase and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
					technical effectiveness.**CM27:** Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM29:** Compliance with Marine Order 96 (Marine pollution prevention – Sewage) 2013. **CM30:** Compliance with Marine Order 95 (Marine pollution prevention – Garbage) 2013.	

Table ES-12 Summary of Environmental Impacts and Risks Associated with the Amulet Project – Unplanned

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; Talisman subsea tieback; flowlines; CALM buoy and mooring arrangements; FSO *Decommissioning* inspection and cleaning *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Benthic habitats and communities**	Change in ecosystem dynamics	**EPO19:** Undertake the Amulet Development in a manner that will prevent an IMS becoming established in the marine environment.	**CM31**: Requirements of the Australian Ballast Water Management Requirements Version 7 (DAWR 2017) to be met. **CM32**: Requirements of the National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry (DAFF 2009) to be met. **CM33**: 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 of biological material into the water. **CM34**: A Biofouling Management Plan will be developed as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015).	Serious	Unlikely	Medium
		Commercial Fisheries	Changes to the functions, interests or activities of other users			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	**EPO20:** Undertake the Amulet Development in a manner that will prevent a vessel strike with protected marine fauna during project activities.	**CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction.	Minor	Unlikely	Low
		Marine mammals				Minor	Unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
	vessel operations; helicopter operations	**Marine Reptiles**			**CM18**: Vessels and aircraft will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the Project Area. **CM35:** All marine mammal vessel strike incidents will be reported in the National Vessel Strike Database.	Minor	Unlikely	Low
Physical Presence – Unplanned Seabed Disturbance	*Installation, Hook-up and commissioning* MOPU; Talisman subsea tieback; flowlines; CALM buoy and mooring arrangements *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	**EPO21:** Undertake the Amulet Development in a manner that will prevent unplanned seabed disturbance.	**CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM05**: Mooring analysis will be undertaken, which will include an environmental sensitivity and seabed topography analysis. **CM06**: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below the mudline and removed. **CM33**: 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	Minor	Unlikely	Low
		Benthic habitats and communities	Change in habitat Injury / mortality to fauna			Minor	Unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
					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	**EPO22:** Undertake the Amulet Development in a manner that will prevent an unplanned discharge of solid waste to the marine environment.	**CM27**: Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM30**: Compliance with Marine Order 95 (Marine Pollution Prevention – Garbage).	Minor	Very Unlikely	Low
		Seabirds and Shorebirds	Injury / mortality to fauna			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	**EPO23:** Undertake the Amulet Development in a manner that will prevent an unplanned discharge of chemicals or hydrocarbons to the marine environment.	**CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM27**: Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated **CM37**: Compliance with AMSA	Minor	Very unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
					Marine Order Part 91 (Marine Pollution Prevention – Oil) to prevent accidental pollution and pollution from routine operations. **CM28**: 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. **CM36**: 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). **CM37**: Emergency response capability (including equipment) will be maintained in accordance with SOPEPS/SMPEPs; and accepted EPs and OPEPs.			
Accidental Release – Amulet Light Crude Oil	*Drilling* top-hole drilling; bottom-hole drilling; completions; well clean-up and flowback *Operations*	**Ambient water quality**	Change in water quality	**EPO24:** Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC,	**CM03:** Pre-start notifications will be provided to relevant stakeholders at appropriate timing, including presence of 500 m exclusion and 2 km cautionary zones.	Minor	Unlikely	Low
		Ambient sediment quality	Change in sediment quality			Minor	Unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
	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	**Plankton**	Injury / mortality to fauna	or failure of a flowline or bulk tank.	**CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM28**: 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. **CM36**: 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). **CM37**: Emergency response capability (including equipment) will be maintained in accordance with SOPEPS/SMPEPs; and accepted EPs and OPEPs. **CM38:** NOPSEMA-accepted Environment Plans and Oil	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 Injury / mortality to fauna Change in fauna behaviour Change in aesthetic value			Moderate	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

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
		Marine mammals	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		Pollution Emergency Plans will be in place. **CM39:** NOPSEMA-accepted Well Operations Management Plan in place for all wells, in accordance with the OPGGS Act requirements. **CM40**: NOPSEMA-accepted Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken. **CM41**: 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	Moderate	Very unlikely	Low
		Australia Marine Parks				Moderate	Very unlikely	Low
		State protected areas – Marine				Moderate	Very unlikely	Low
		Heritage and cultural 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		• handling of the BOP over existing wells • any drilling clash potential due to new wellbore proximity to an existing production wellbore.	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
Accidental Release –	*Support Activities (all phases)*	**Ambient water quality**	Change in water quality	**EPO25:** Undertake the Amulet Development in a manner that will prevent an	**CM03:** Pre-start notifications will be provided to relevant stakeholders at appropriate	Minor	Very unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
Marine Diesel/Gas Oil	MODU operations; MOPU operations; FSO operations; vessel operations	**Plankton**	Injury / mortality to fauna	accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.	timing, including presence of 500 m exclusion and 2 km cautionary zones. **CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM28**: 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. **CM36:** 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). **CM37**: Emergency response capability (including equipment) will be maintained in accordance with SOPEPS/SMPEPs; and accepted EPs and OPEPs.	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
		Australian Marine Parks	Change in water quality Change in habitat Injury / mortality to fauna			Moderate	Very unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
			Change in fauna behaviour Changes to the functions, interests or activities of other users		**CM38:** NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place. **CM40**: NOPSEMA-accepted Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken.			
		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

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 Amulet Development. Given the low likelihood of unplanned events (e.g. accidental releases) occurring during the Amulet 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 Amulet Development and other actions / projects.

Spatial and Temporal Boundary of the Assessment

The largest potential impact area for any planned aspect is for light emissions (12.6 km radius around the expected position of the MOPU at Amulet and the manifold at Talisman). This is the worst-case extent of predicted measurable change to ambient light based on planned activities from the Amulet Development for the life of the project. All other spatial potential impact extents from planned aspects are within the Project Area (5 km radius around Amulet MOPU and the Talisman manifold locations). Therefore, a conservative spatial extent of 12.6 km was used for the cumulative impact assessment for the Amulet Development.

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

Existing Industries / Projects—Past, Present or Future

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

- commercial fisheries
- marine and coastal industries (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 Environmental Aspects Interactions

Impacts resulting from planned aspects are restricted to the Project Area, which comprises a 5 km buffer around the expected position of the MOPU at Amulet and the manifold at Talisman, except for light, which comprises a 12.6 km buffer around Amulet and Talisman.

The only existing industries / projects within 12.6 km (i.e. spatial boundary for cumulative assessment for these aspects) are:

- commercial fisheries
- marine and coastal industries (commercial shipping)

Cumulative Impact Assessment

This OPP identifies potential cumulative impacts and risks associated with the Amulet Development. The impacts and risks associated with each aspect of the Amulet Development (identified as requiring further assessment) were determined to be acceptable; they are summarised in Table ES-13. 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-13 Summary of Cumulative Impacts Evaluation and Risks Associated with the Amulet 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	**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	Minor

ES9. Implementation Strategy

The Amulet 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-14 summarises the key elements of the KATO IMS relevant to this OPP.

Table ES-14 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 Amulet 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	For the EP stage, as per the OPGGS(E)R, KATO will submit a proposed revision of the accepted EP/s to NOPSEMA: • 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 Amulet 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.

The Corowa Development OPP (KATO 2020j) was published by NOPSEMA for an 8-week public comment period, beginning on 27 February 2020. The OPP was made publicly available on NOSPEMA’s website, and KATO published advertisements in regional, state and nation-wide newspapers, as required.

No public comments were received.

1 Introduction

1.1 Activity Location and Overview

The Amulet Development will be centred on the Amulet and Talisman fields, located within Commonwealth waters on the North West Shelf, offshore of mainland Western Australia (WA), ~132 km north of Dampier (Figure 1-1). The field lies in ~85 m of water within production licence WA-8-L in the North Carnarvon Basin, and contains light crude oil.

KATO plans to develop the Amulet and Talisman fields 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 Amulet field has previously been appraised by Tap (Shelfal) Pty Ltd, with three wells drilled in 2006. The Amulet field is classified as a small field with a short life span and proven contingent resource of 6.9 MMstb (at best estimate). The Talisman field is situated ~5 km to the west of the Amulet field and was initially drilled in 1984 by Marathon Petroleum. A total of six wells were drilled. The field produced from two wells until the field was shut-in in 1992. The field has since been abandoned, with the final well plugged and abandoned (P&A) in 1992. However, due to its proximity to the Amulet field, KATO may choose to reinstate production from the Talisman field.

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

- site survey of the proposed location of subsea infrastructure
- drilling of up to four production wells, allowance for two sidetracks, and one dual-purpose production/water injection well
- 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.

The Talisman oil field is ~3.5 km to the west of Amulet, within WA-8-L, which has been produced but was shut-in in 1992 and since abandoned. Due to its proximity to the Amulet field, KATO may choose to reinstate production from the Talisman field. If the subsea tieback option is selected for development of the adjacent Talisman field, the following additional components covered in this OPP are:

- site survey of the proposed location of subsea infrastructure (at Talisman)
- installation of a production flowline and service umbilical between the MOPU and Talisman field
- installation of associated subsea infrastructure at Talisman, if the subsea tieback option is selected
- operation of the Talisman subsea facilities

- decommissioning and removal of Talisman subsea 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.

KATO's business strategy is to develop multiple small marginal discovered fields which are currently uneconomic and subsequently 'stranded'. KATO will unlock the resource in these fields by using the relocatable honeybee production system to move from one field to the next.

At the time of writing, KATO's portfolio consists of Amulet, and the Corowa Development. The Corowa Development is centred on the Corowa field located within Commonwealth waters on the NWS, which lie in ~90 m of water within production licence WA-41-R, and contains light crude oil. Corowa is ~335 km south-east of the Amulet Development. A separate OPP for Corowa has been submitted to NOPSEMA (KATO 2020j). Future fields will be the subject of separate OPP/s, once identified and acquired/confirmed.

There is potential there may also be exploration targets within the WA-8-L permit area, that are as yet undiscovered and therefore undefined. Whilst on location drilling the Amulet and Talisman wells, KATO may take the opportunity to drill an exploration well into a nearby oil prospect that is within reach of the drill rig.

Exploration activities such as drilling are not within scope of the OPP process; if undertaken, this activity will be covered by a separate Environment Plan (EP).

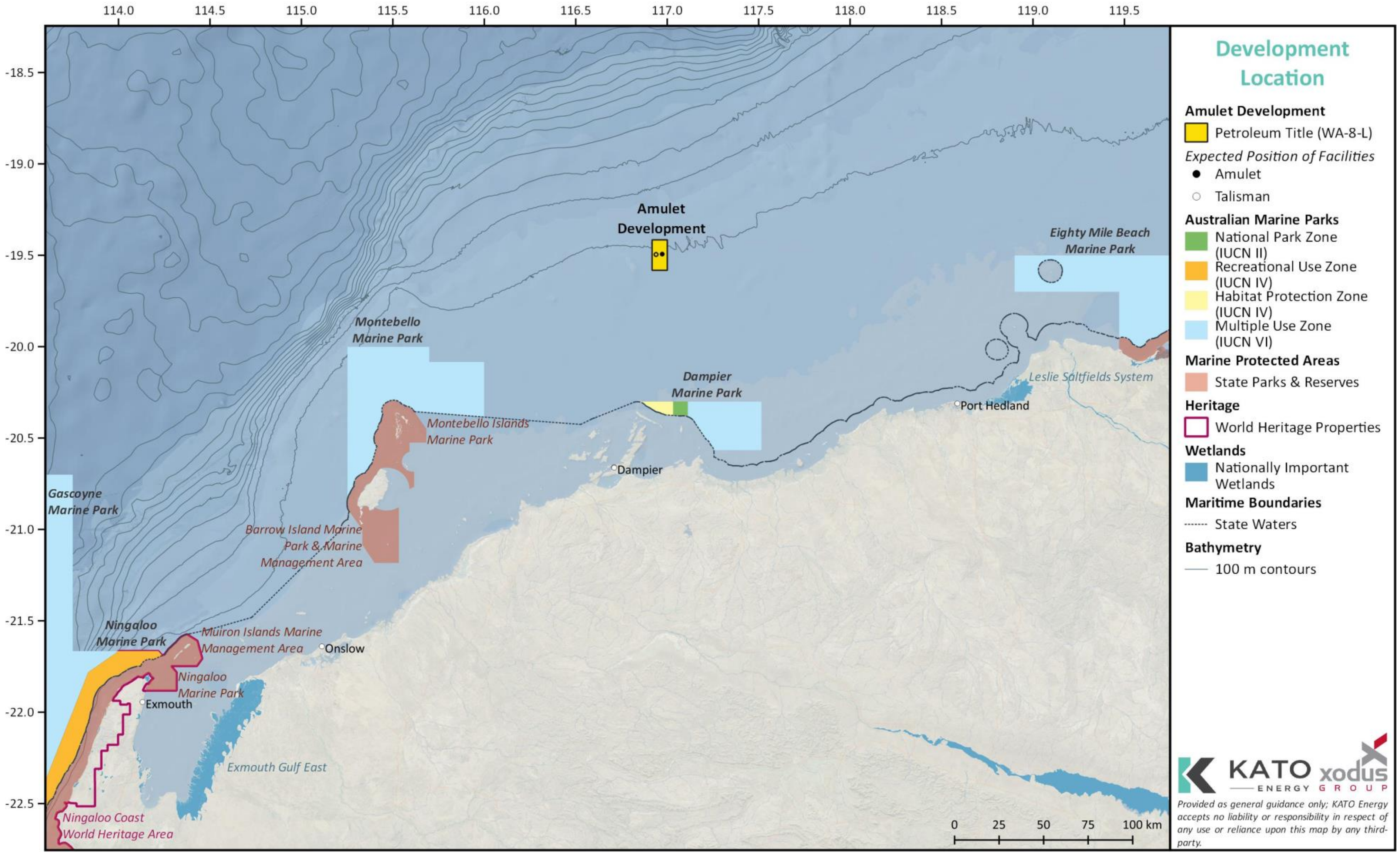


Figure 1-1 Location of Amulet Development

1.2 Titleholder Details

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

KATO is an Australian company that was formed to combine ownership of the Amulet oil discovery, 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). KATO owns the titleholders Tamarind Amulet Pty Ltd and Skye Energy 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-8-L	Amulet	KATO Energy	Tamarind Amulet Pty Ltd Skye Energy 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 Amulet 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, March 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 Amulet 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 Amulet 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 OPPGS(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 Amulet 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 (MNES) 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 MNES
- provide for Commonwealth environmental assessment and approval processes

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

MNES identified as relevant to the Amulet 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 Amulet 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 Amulet Development

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	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	There are four main objectives: • Contribute to the long-term prevention of the incidence of harmful marine debris • Remove existing harmful marine debris from the marine environment • Mitigate the impacts of harmful marine debris on marine species and ecological communities • Monitor the quantities, origins and impacts of marine debris and assess the effectiveness of management arrangements over time for the strategic reduction of 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*	Vulnerable	Noise interference	No explicit relevant objectives	Assess and manage acoustic disturbance.
			Vessel disturbance		Minimising vessel collisions:

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	Relevant Conservation Actions
	borealis Sei Whale (TSSC 2015a)				Develop a national vessel strike strategy that investigates the risk of vessel strikes on Sei Whales and also identifies potential mitigation measures. Ensure all vessel strike incidents are reported in the National Vessel Strike Database
			Climate and oceanographic variability and change		Understanding impacts of climate variability and change: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica
			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	The long-term recovery objective is to minimise anthropogenic threats to allow the conservation status of the southern right whale to improve so that it can be removed from the threatened species list under the EPBC Act.	A2: Assess and address anthropogenic noise: shipping, industrial and seismic noise.
			Vessel disturbance		A5: Addressing vessel collision: Develop a national ship strike strategy that quantifies vessel movements within the distribution ranges of southern right whales and outlines appropriate mitigation measures that reduce impacts from vessel collisions.
			Climate variability and change		Understanding impacts of climate variability and change: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica
Fin Whale	Conservation advice *Balaenoptera*	Vulnerable	Noise interference	No explicit relevant objectives	Once the spatial and temporal distribution (including biologically important areas) of Fin Whales is further defined, assess the impacts of increasing anthropogenic

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	Relevant Conservation Actions
	physalus Fin Whale (TSSC 2015b)				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		Understanding impacts of climate variability and change: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.
			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	No explicit relevant objectives	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).
			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. Maximise the likelihood that all vessel strike incidents are reported in the National Ship Strike Database. All cetaceans are protected in Commonwealth waters and, the EPBC Act requires that all collisions with whales in Commonwealth waters are reported. Vessel collisions

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	Relevant Conservation Actions
					can be submitted to the National Ship Strike Database at https://data.marinemammals.gov.au/report/shipstrike Enhance education programs to inform vessel operators of best practice behaviours and regulations for interacting with humpback whales.
			Climate and Oceanographic Variability and Change		A4: Impacts of climate variability and change: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.
			Entanglement with commercial fisheries or aquaculture equipment, shark safety equipment or marine debris		Reducing commercial fishing entanglements. No explicit management measures for marine debris.
Southern Right Whale	Conservation Management Plan for the Southern Right Whale (DSEWPaC 2011)	Endangered	Noise interference	Long term recovery objective: To minimise anthropogenic threats to allow the conservation status of the southern right whale to improve so that it can be removed from the threatened species list under the EPBC Act Interim Recovery Objective 5:	A2: Assess and address anthropogenic noise: shipping, industrial and seismic noise.
			Vessel disturbance		A5: Address vessel collisions: Develop a national ship strike strategy that quantifies vessel movements within the distribution ranges of southern right whales and outlines appropriate mitigation measures that reduce impacts from vessel collisions
			Climate Variability and Change		A4: Assess impacts of climate variability and change. Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	Relevant Conservation Actions
			Entanglement with commercial fisheries or aquaculture equipment or marine debris	Anthropogenic threats are demonstrably minimised	A3: Reducing commercial fishing entanglements. There are no explicit management actions for marine debris.
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		Long-term recovery objective: Minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list. Interim objective 3: Anthropogenic threats are demonstrably minimised.	A1: Maintain and improve efficacy of legal and management protection • Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival as per section 3.3 Table 6. • Manage anthropogenic activities in Biologically Important Areas to ensure that biologically important behaviour can continue.
					A9. Address the impacts of coastal development/infrastructure and dredging and trawling. • Use up-to-date information regarding nesting, internesting and foraging habitat to inform future development proposals and approval decisions.
			Vessel disturbance		Vessel interactions identified as a threat; no specific management actions in relation to vessels prescribed in the plan.
			Light pollution		A8. Minimise light pollution. • Artificial light within or adjacent to habitat critical to the survival of marine turtles will be managed such that marine turtles are not displaced from these habitats. • Develop and implement best practice light management guidelines for existing and future

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	Relevant Conservation Actions
					developments adjacent to marine turtle nesting beaches. • Identify the cumulative impact on turtles from multiple sources of onshore and offshore light pollution.
			Acute chemical discharge (oil pollution)		A4. Minimise chemical and terrestrial discharge.
			Climate change and variability		A2: Adaptively manage turtle stocks to reduce risk and build resilience to climate change and variability: • Continue to meet Australia's international commitments to address the causes of climate change. • Identify, test and implement climate-based adaptation measures.
			Marine debris		A3. Reduce the impacts from marine debris. • Support the implementation of the EPBC Act Threat Abatement Plan for the impacts of marine debris on vertebrate marine life.
			Noise Interference		B3. Assess and address anthropogenic noise. • Understand the impacts of anthropogenic noise on marine turtle behaviour and biology.
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.
			Climate change		No explicit relevant management actions; climate change identified as a threat.

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	Relevant Conservation Actions
Short-nosed Seasnake	Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Seasnake) (DSEWPaC 2011b)	Critically Endangered	Habitat loss, disturbance and modification	No explicit relevant objectives	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					
Sawfish and river sharks	Sawfish and river shark multispecies recovery plan (CoA 2015b)	N/A	Habitat degradation/ modification	The primary objective of this recovery plan is to assist the recovery of sawfish and river sharks in Australian waters with a view to: • improving the population status leading to the removal of the sawfish and river shark species from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder recovery in the near future, or impact on the conservation status of the species in the future.	Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	Relevant Conservation Actions
				The specific objectives of the recovery plan (relevant to industry) are: Objective 5: Reduce and, where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species. Objective 6: Reduce and, where possible, eliminate any adverse impacts of marine debris on sawfish and river shark species noting the linkages with the Threat Abatement Plan for the Impact of Marine Debris on Vertebrate Marine Life.	
White Shark	Recovery plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013a)	Vulnerable	Climate change	No explicit relevant objectives	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 objectives	No explicit relevant management actions; habitat loss, disturbance and modification identified as threats.

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	Relevant Conservation Actions
Green Sawfish, Dindagubba, Narrowsnout Sawfish	Approved conservation advice for Green Sawfish (TSSC 2008a)	Vulnerable	Habitat degradation/ modification	No explicit relevant objectives	No explicit relevant management actions; habitat loss, disturbance and modification identified as threats.
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	No explicit relevant objectives	Implement measures to reduce adverse impacts of habitat degradation and/or modification.
Whale Shark	Conservation advice *Rhincodon typus* (Whale Shark) (TSSC 2015d) [Note the Recovery plan for the Whale Shark (DEH 2005a) ceased to be in effect from 1 October 2015]	Vulnerable	Vessel disturbance	Objective: To maintain existing levels of protection for the whale shark in Australia while working to increase the level of protection afforded to the whale shark within the Indian Ocean and Southeast Asian region to enable population growth so that the species can be removed from the threatened species list of the EPBC Act.	Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with Whale Shark aggregations (Ningaloo Reef, Christmas Island and the Coral Sea) and along the northward migration route that follows the northern Western Australian coastline along the 200 m isobath (as set out in the Conservation Values Atlas, DotE, 2014).
			Habitat degradation/ modification		Implement measures to reduce adverse impacts of habitat degradation and/or modification.
			Marine debris		No explicit relevant management actions; marine debris identified as a threat.
			Climate change		No explicit relevant management actions; climate change identified as less important threats.
Grey Nurse Shark (west	Recovery Plan for the Grey Nurse Shark	Vulnerable	Pollution and disease	Overarching objective:	No explicit relevant management actions; pollution and disease identified as a threat.

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	Relevant Conservation Actions
coast population)	(*Carcharias taurus*) (DoE 2014b)			To assist the recovery of the grey nurse shark in the wild, throughout its range in Australian waters with a view to: • improving the population status, leading to future removal of the grey nurse shark from the threatened species list of the EPBC Act • ensuring that anthropogenic activities do not hinder the recovery of the grey nurse shark in the near future, or impact on the conservation status of the species in the future.	
Seabirds and shorebirds					
Migratory shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (DoEE 2015)	N/A	Habitat loss / modification	3. Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated	No explicit relevant management actions; identified as a threat.
			Anthropogenic disturbance		3c. Investigate the significance of cumulative impacts on migratory shorebird habitat and populations in Australia. 3f. Ensure all areas important to migratory shorebirds in Australia continue to be considered in development

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	Relevant Conservation Actions
					assessment processes. (specifically for coastal developments).
			Climate change		3b: Investigate the impacts of climate change on migratory shorebird habitat and populations in Australia
Red Knot	Conservation advice *Calidris canutus* (Red Knot) (TSSC 2016a)	Endangered	Habitat degradation/ modification	No explicit relevant objectives	No explicit relevant management actions; oil pollution recognised as a threat.
			Climate change		No explicit relevant management actions; climate change recognised as a threat.
Curlew Sandpiper	Conservation advice *Calidris ferruginea* (Curlew Sandpiper) (DoE 2015a)	Critically Endangered	Habitat degradation/ modification (oil pollution)	Australian Objective: 3. Disturbance at key roosting and feeding sites reduced.	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 objectives	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 objectives	No explicit relevant management actions; oil spills recognised as a threat.
Southern Giant Petrel	National recovery plan for threatened albatrosses and giant	Endangered	Marine Pollution	Overall objective: To ensure the long-term survival and recovery of albatross and giant petrel	No explicit management actions; marine pollution recognised as a threat. .

Species / Sensitivity	Plan	Protection under EPBC Act	Relevant Key threats identified	Relevant Objectives	Relevant Conservation Actions
	petrels 2011–2016 (DSEWPaC 2011)		Climate change	populations breeding and foraging in Australian jurisdiction by reducing or eliminating human related threats at sea and on land. Specific objectives: 2. Land-based threats to the survival and breeding success of albatrosses and giant petrels breeding within areas under Australian jurisdiction are quantified and reduced. 3. Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced.	A3.1: Where climate change is identified as having the potential for significant negative impacts on Australian populations of seabirds: • appropriate monitoring strategies are implemented to fill information gaps • mitigation actions are identified and adopted where feasible and appropriate.
Australian Fairy Tern	Conservation advice for *Sterna nereis* nereis (Fairy Tern) (TSSC 2011b)	Vulnerable	Habitat degradation/ modification (oil pollution)	No explicit relevant objectives	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	Australian Objectives: 3. Reduce disturbance at key roosting and feeding sites	7. 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 Amulet Areas

Australian Marine Park	Distance from Project Area	IUCN Protected Area Category
Carnarvon Canyon*	~718 km	Habitat Protection Zone (IUCN IV)
Gascoyne^	~363 km	National Park Zone (IUCN II) Habitat Protection Zone (IUCN IV) Multiple Use Zone (IUCN VI)
Montebello*	~122 km	Multiple Use Zone (IUCN VI)
Ningaloo*	~374 km	National Park Zone (IUCN II) Recreational Use Zone (IUCN IV)
Dampier*	~90 km	National Park Zone (IUCN II) Habitat Protection Zone (IUCN IV) Multiple Use Zone (IUCN VI)
Shark Bay*	~669 km	Multiple Use Zone (IUCN VI)
Eighty Mile Beach*	~202 km	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace*	~192 km	Multiple Use Zone (IUCN VI) National Park Zone (IUCN II) Special Purpose Zone (Trawl) (IUCN VI)
Mermaid Reef*	~369 km	National Park Zone (IUCN II)
Abrolhos^	~866 km	Recreational Use Zone (IUCN IV) Habitat Protection Zone (IUCN IV) National Park Zone (IUCN II) Special Purpose Zone (IUCN VI)
Jurien^	~1202 km	Special Purpose Zone (IUCN VI)
Two Rocks^	~1350 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.	

Category II: National Park:	Category IV: Habitat/Species Management Area	Category VI: Managed Resource Protected Areas
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 account, including subsistence resource use, to the extent that they do not conflict with these principles.	5.07 If the reserve or zone is declared for the purpose of 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 Amulet 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.

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

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)

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

Legislation	Scope	Application to Activities under the OPGGS(E)R
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.
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. Includes the requirement for an approved Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class) which describes emergency response activities.	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	In the event of removal, damage or interference to shipwrecks, sunken aircraft or relics declared to be

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

Table 2-6 Relevant Commonwealth Policies and Guidelines

Policy / Guideline / Convention	Purpose	Relevance to the Amulet Development
EPBC Policy Statement Staged Developments—Split referrals: Section 74A of the EPBC Act	To help identify whether a referred action is a 'split referral' and, if so, whether the Minister will treat it as part of a larger non-referred action or separately as a component of a larger action. A split referral is where a referred action is part of a larger action that: • has not been referred; • has been referred in separate 'lesser referrals' for commercial or other operational reasons; • will be conducted in progressive stages (also known as 'staged developments'). The making of a section 74A decision in relation to a referral is discretionary rather than mandatory, and a 'split referral' is not automatically rejected.	At the time of writing, KATO's portfolio consists of Amulet, and the Corowa Development in production licence WA-41-R, which is ~335 km south-east of the Amulet Development. A separate OPP for Corowa was submitted to NOPSEMA for the first time in August 2019 (KATO 2020j). The Amulet Development has been referred under the same 'level' of referral as Corowa–i.e. as an OPP under the OPGGS(E)R, as per early discussions with NOPSEMA. The two developments are a substantial distance apart (335 km). There is no geographical overlap of potential impacts, with the exception of accidental release. As the honeybee production system will relocate from the first field to the next, the developments are not undertaken concurrently. It was decided upon a separate OPP for each development due to the physical distance between them and differing environment that may be affected and subsequent impact assessment, and the non-concurrent nature of the developments. KATO considers that having separate OPPs for the developments does not reduce the ability to achieve the objects of the EPBC Act.

Policy / Guideline / Convention	Purpose	Relevance to the Amulet Development
EPBC Policy Statement 2.1 Interaction between offshore seismic exploration and whales	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.
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.

Policy / Guideline / Convention	Purpose	Relevance to the Amulet Development
National Light Pollution Guidelines (CoA 2020)	Aim to raise awareness of the potential impacts of artificial light on wildlife and provide a framework for assessing and managing these impacts around susceptible listed wildlife. Currently applies to marine turtles, seabirds and migratory shorebirds.	Includes requirements for impact assessment, best practice lighting design and an artificial light management plan.
Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)	Provides overarching guidance on determining whether an action is likely to have a significant impact on a matter protected under national environment law — the EPBC Act.	Impacts and risks of the petroleum activity can be demonstrated to be at an acceptable level if they do not result in a 'significant impact' as described in the Matters of National Environmental Significance – Significant Impact Guidelines (DoE 2013).
Environment Factor Guideline: GHG Emissions (EPA 2020)	Communicates how the factor Greenhouse Gas Emissions is considered by the Environmental Protection Authority (EPA) in the environmental impact assessment (EIA) process.	Although the Amulet Development is not subject to State jurisdiction, the guideline has been used in evaluation of Emissions – Atmospheric.
World Bank's 'Zero Routine Flaring by 2030' initiative	The initiative brings together governments, oil companies, and development institutions who recognize routine flaring is unsustainable from a resource management and environmental perspective, and who agree to cooperate to eliminate routine flaring no later than 2030.	The federal government has not endorsed initiative. The West Australian government has indicated that it intends to, via amendments to regulations under the *Petroleum and Geothermal Energy Resources Act* and *the Petroleum (Submerged Lands) Act*. Although the Amulet Development is not subject to State jurisdiction, the guideline has been used in evaluation of Emissions – Atmospheric.
EPBC Policy Statement 'Indirect consequences' of an action: Section 527E of the EPBC Act (DSEWPaC 2013)	Provides guidance on determining whether an event or circumstance is an 'indirect consequence' of an action for the purposes of the EPBC Act. An indirect consequence is frequently referred to as an 'indirect impact'.	Used in evaluation of Emissions – Atmospheric.
NGER (Measurement) Determination 2008 (as amended 2019); API Compendium of GHG Emissions Methodologies (API 2009	Provides methods, criteria and measurement standards for calculating greenhouse gas emissions and energy data under the National Greenhouse and Energy Reporting Act 2007 (NGER Act).	Used to calculate GHG emissions for the Amulet Development.
Antifouling and In-water Cleaning Guidelines (DoA 2015)	Provides best practice approaches to applying, maintaining, removing and disposing of anti-fouling coatings and managing biofouling and invasive aquatic species on vessels and movable	Guidance for evaluation of contamination and biosecurity risk of in-water cleaning; and for in-water cleaning, including suitable coatings, coating service life, methods to ensure minimal release of biological material

Policy / Guideline / Convention	Purpose	Relevance to the Amulet Development
	structures in Australia and New Zealand.	into the water, and appropriate disposal of collected cleaning debris.
National biofouling management guidelines for the petroleum production and exploration industry (DAFF 2009)	Is a voluntary biofouling management guidance document has been developed to assist industry manage biofouling risk.	Guidance for evaluation of biofouling risk of types of structures/facilities; and on biofouling management and decommissioning.
National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (CoA 2017)	Provides guidance on understanding and reducing the risk of vessel collisions and the impacts they may have on marine megafauna.	Guidance to determine risks of vessel strike, and identify mitigation measures. The audience is government agencies.
American Petroleum Institute (API) Recommended Practice 14G: Recommended Practice for Fire Prevention and Control on Open Type Offshore Production Platforms	Presents recommendations for minimizing the likelihood of having an accidental fire, and for designing, inspecting, and maintaining fire control systems on fixed open-type offshore production platforms.	Describes safe handling and storage of materials such as dirty rags, garbage, waste oil, and chemicals.

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 Amulet 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 Amulet and Talisman fields 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.

Whilst the preferred Talisman field development option is to drill extended reach deviated wells through the conductor deck of the MOPU; if the subsea tieback system option is selected, the following additional components will be incorporated specifically for the development of the Talisman field:

9. Talisman subsea trees (production wells) and jumpers to the manifold
10. Talisman manifold to commingle production from nearby Talisman wells
11. Production flowline and service umbilical from Talisman manifold to MOPU

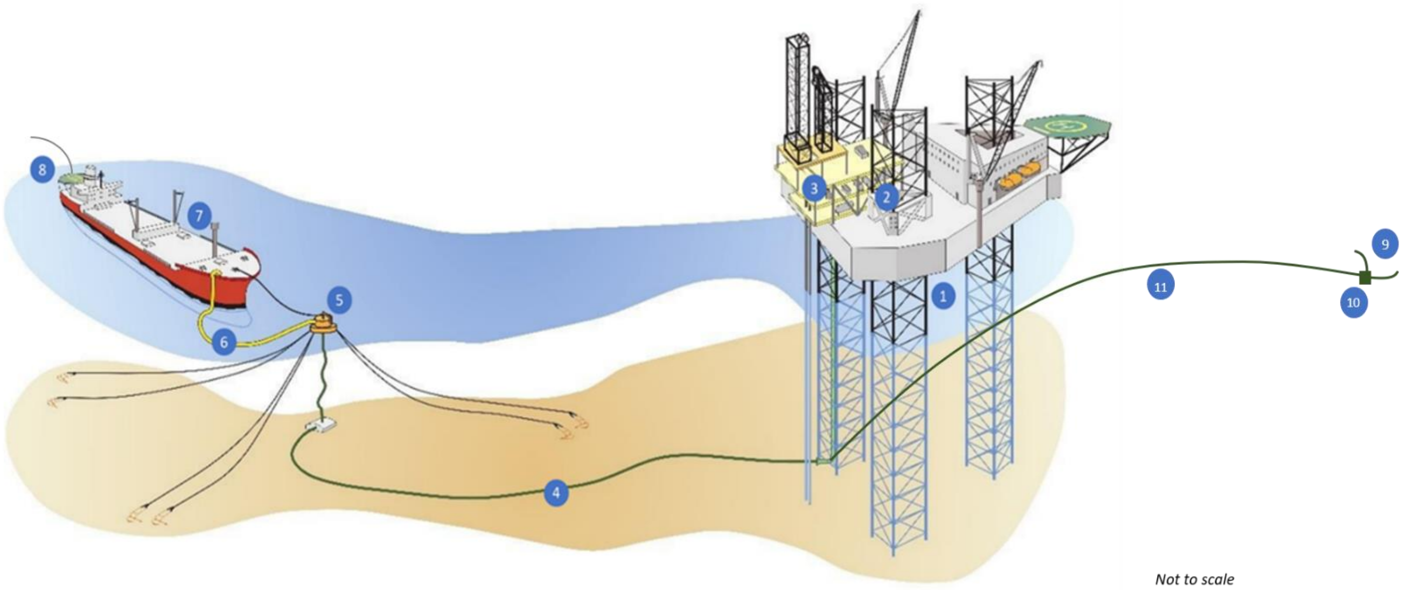


Figure 3-1 Amulet and Talisman Development Infrastructure

The proposed location of the MOPU is optimised for the primary target oil field, Amulet. Amulet is a discovered field, not yet produced. The Talisman field is ~4 km to the west of the Amulet field, in WA-8-L (Figure 3-3). The field has been produced, but in 1992 production was shut-in, and the field has since been abandoned. Due to its proximity to the Amulet field, KATO may choose to reinstate production from the Talisman field.

The preferred Talisman field development option is to drill extended reach deviated well/s through the conductor deck of the MOPU. This will be similar to the development wells drilled into the Amulet reservoir, consisting of 'dry trees' located on the MOPU conductor deck. However, in the event that drilling the wells from the MOPU location is not technically feasible, an alternative will be to reinstate production from the Talisman field using a subsea gathering system tied back to the MOPU via ~3.5 km flowline (see Section 4.3.2). As this subsea option presents the greater potential environmental impact than the preferred option, it has been used as the basis for impact assessment.

KATO's business strategy is to develop multiple small marginal discovered fields which are currently uneconomic and subsequently 'stranded'. KATO will unlock the resource in these fields by using the relocatable honeybee production system to move from one field to the next.

At the time of writing, KATO's portfolio consists of Amulet, and the Corowa Development, which is ~335 km south-east, within production licence WA-41-R. A separate OPP for Corowa has been submitted to NOPSEMA (KATO 2020j). Future fields will be the subject of separate OPP/s, once identified and acquired/confirmed.

There is potential there may also be exploration targets within the WA-8-L permit area, that are as yet undiscovered and therefore undefined. Whilst on location drilling the Amulet and Talisman wells, KATO may take the opportunity to drill an exploration well into a nearby oil prospect that is within reach of the MODU. Exploration drilling is not within scope of this OPP; if undertaken, this activity will be covered by a separate EP.

3.1.1 Location

The Amulet and Talisman fields are located within Commonwealth waters in offshore petroleum permit WA-8-L, located ~132 km north of Dampier in the northwest of Australia in water depths of ~85 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 a sufficient buffer, which has been conservatively designated as a 5 km radius around the expected position of the MOPU at Amulet If the subsea tieback option is selected for Talisman field development, there will potentially be facilities and support vessels undertaking activities above the Talisman field (Section 4.3.2). Therefore, the 5 km buffer for the Project Area has also been extended around the expected position of the Talisman manifold.

The expected location of the Amulet MOPU and Talisman manifold seabed location are shown in

. Note the two Talisman subsea wells will be located with 200 m of the Talisman manifold.

The final position of the infrastructure will be included in the relevant EPs.

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.

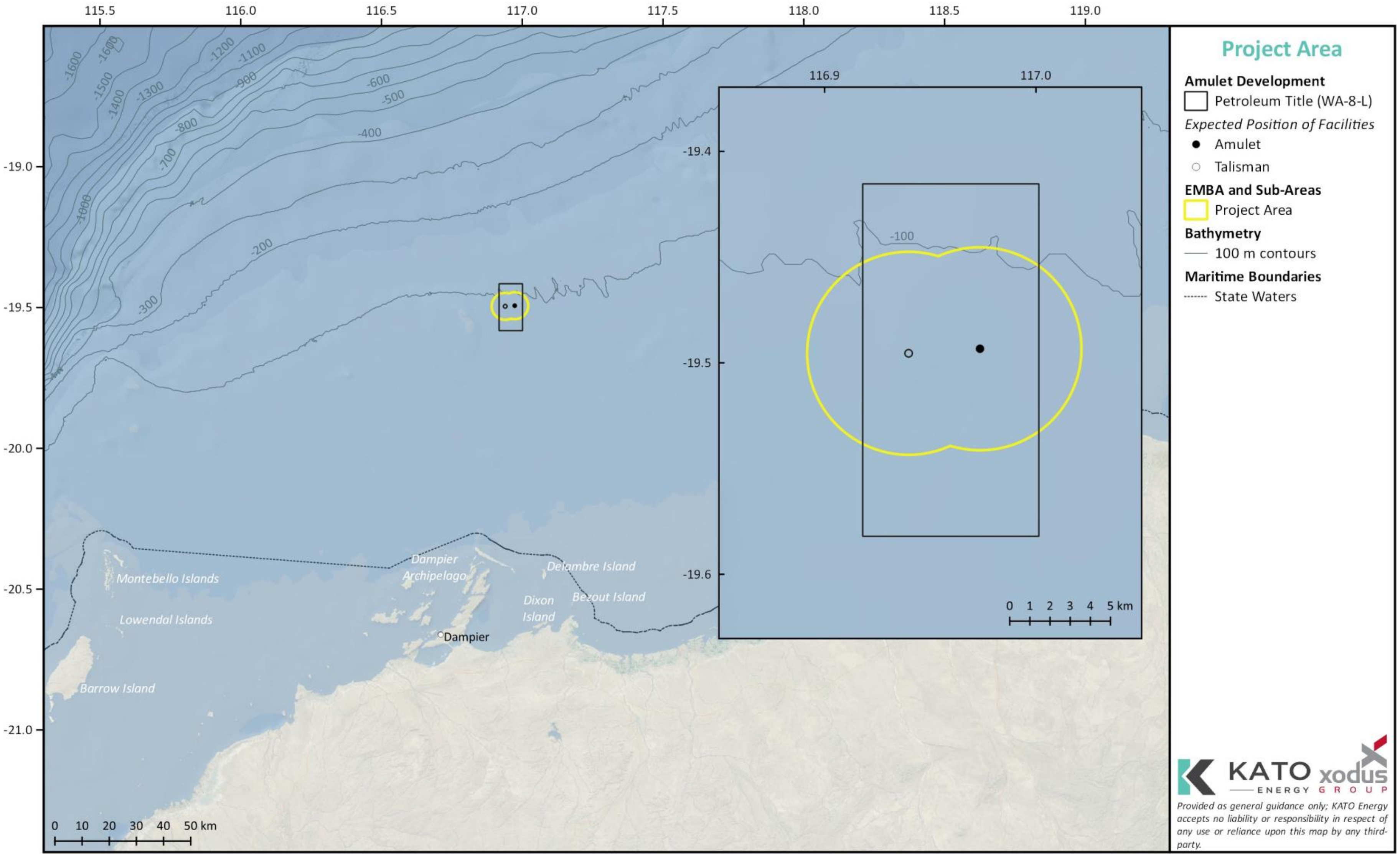


Figure 3-2 Amulet Development Project Area

Table 3-1 Expected Facility Coordinates

Facility	Latitude	Longitude
Amulet (MOPU)	19° 29’ 35.9” South	116° 58’ 24.5” East
Talisman (manifold)	19° 29’ 43.7” South	116° 56’ 22.9” East

3.1.2 Project Schedule

The target schedule for the Amulet Development is detailed in Table 3-2. KATO’s business strategy is to become the titleholder for a number of fields, and with the intent being that, as each field is depleted, it is fully decommissioned and wells P&A’d. The honeybee production system will then relocate to the next field. The order of the fields is not yet decided, and the timing shown in Table 3-2 assumes that the Amulet field will be the first development. If the fields are produced in a different order, the timing of the Amulet Development may be 2–5 years later than shown.

Based on statistical modelling of the production profile, the best estimate of production life is 1.5 years (also known as P50), and the high estimate is 4.5 years (also known as P10; RISC 2014), meaning the duration of the Operations phase is between 1.5–4.5 years.

A contingent infill drilling program is included in the preliminary project schedule for a possible second MODU mobilisation for an infill, well intervention and/or sidetrack program, dependent on reservoir performance in the initial 6–9 months of production.

The conservative project life for the Amulet Development (from mobilisation to decommissioning) is up to 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	Timing*	Indicative Duration
Survey	Q1 2023	1 month
Drilling	Initial campaign – Q2/Q3 2023 Second campaign (if required) – 1 to 2 years after start-up	Initial campaign – 7 months Second campaign (if required) – additional 4 months
Installation, Hook-up and Commissioning	Q3 2023	3 months
Operations	Q4 2023	Between 1.5 and 4.5 years, at best and high estimates of production respectively
Decommissioning	Between 2025 and 2027 (depending on duration of operations)	3 months

**Timing shown is if the Amulet Development is the first field developed using the relocatable honeybee production system of the KATO-owned fields. If the KATO- owned fields are developed in a different order, the timing of Amulet may be later than shown.*

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 Amulet Development, the six 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 are assessed in Section 7.

Table 3-3 Design and Activity Options Carried into FEED

<table>
<tr><th>Activity or Design Option</th><th>Option description</th><th>Implications</th></tr>
<tr><td rowspan="2">Talisman field development</td><td>Subsea well tieback from Talisman to the MOPU.
Talisman well/s drilled in situ by separate MODU/MOPU, and subsea trees, ~3.5 km flowline and umbilical installed to the MOPU.</td><td rowspan="2">The preferred option for development of Talisman is to drill extended reach deviated wells from the MOPU. However, whist KATO have a high confidence that the extended reach Talisman wells can be drilled from the proposed MOPU location, a significant amount of geomechanics study is required to confirm technical & commercial feasibility, which will not be completed until FEED. In the event extended reach wells are proven not technically & commercially feasible, the subsea well tieback option may be developed. This option also presents the greater potential environmental impact, due to the additional seabed footprint from subsea infrastructure, additional support vessels and hydrotesting. The key additional environmental impacts are:
• seabed disturbance
• planned discharges.
Therefore, the option of subsea tieback from Talisman to the MOPU has been assessed and used as the basis for the impact assessment in the OPP.
With the exception that the longer durations and discharges associated with the extended reach drilling option have been considered.</td></tr>
<tr><td>Extended reach deviated well/s from the MOPU. Talisman well/s drilled through the MOPU conductor deck at Amulet, with a ‘dry tree’.</td></tr>
<tr><td rowspan="2">Drilling facility</td><td>Drilling will be undertaken by the MOPU, if the selected facility has drilling capability.</td><td rowspan="2">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.</td></tr>
<tr><td>Drilling will be undertaken by a separate MODU, which is positioned alongside the MOPU.</td></tr>
<tr><td rowspan="2">Talisman well intervention methodology (subsea tieback option only)</td><td>ISV with a well intervention package and appropriate capability.</td><td rowspan="2">Using a MODU for well intervention at Talisman (if required) presents the greater potential environmental impact from:
• seabed disturbance
• light emissions
• accidental release.</td></tr>
<tr><td>Separate MODU towed by 2-3 AHTs, and jack-down on location.</td></tr>
</table>

Activity or Design Option	Option description	Implications
		Therefore, the option of a separate MODU has been assessed and used as the basis for the impact assessment in the OPP.
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). There is no significant environmental (or economic, technical feasibility or safety) differentiator between these options. Therefore, 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

The WA-8-L offshore petroleum permit area covers 161 km^2 across a water depth range of 79–89 m, and contains the Amulet and Talisman oil fields.

Eight surface wells and seven subsurface (sidetracked) wells have previously been drilled within the permit area, which is located in the north-eastern Barrow-Dampier Sub-basin of the Carnarvon Basin, Northwest Shelf of Australia.

Table 3-4 gives an overview of past drilling activities in WA-8-L (Geoscience Australia 2019a). Historical well locations are shown in Figure 3-3.

Table 3-4 Summary of Historical Drilling in WA-8-L

Well	Overview	Status
Alpha 1 North	Drilled in 1989 by Marathon Petroleum. Was plugged and abandoned dry.	Abandoned

Well	Overview	Status
Amulet 1	Drilled in 2006 by Tap (Shelfal) Pty Ltd as an exploration well. Oil was confirmed. Amulet 1 was plugged back and abandoned in 2006, with subsequent operations attributed to Amulet 1 CH1.	Abandoned
Amulet CH1	Drilled in 2006 by Tap (Shelfal) Pty Ltd as an exploration well. Was plugged and abandoned.	Abandoned
Amulet 2	Drilled in 2006 by Tap (Shelfal) Pty Ltd as a sidetrack from Amulet 1 to confirm the oil discovery. Oil was confirmed. Was plugged and abandoned.	Abandoned
Amulet 3	Drilled in 2006 by Tap (Shelfal) Pty Ltd as a deviated appraisal well from Amulet 2. Oil was confirmed. Was plugged and abandoned.	Abandoned
Calypso 1	Drilled in 1985 by Marathon Petroleum. Was plugged and abandoned dry.	Abandoned
Talisman 1	Drilled in 1984 by Marathon Petroleum as an exploration well. Was temporarily suspended as an oil discovery, and operated as the Talisman production facility. Subsequently plugged and abandoned in 1992.	Suspended
Talisman 1 ST1	Drilled in 1984 by Marathon Petroleum as an exploration well.	Abandoned
Talisman 1 ST2	Drilled in 1984 by Marathon Petroleum as an exploration well.	Suspended
Talisman 4	Drilled in 1987 by Marathon Petroleum as an appraisal well. Was plugged and abandoned dry.	Abandoned
Talisman 5	Drilled in 1990 by Marathon Petroleum as an appraisal well. Was plugged and abandoned dry.	Abandoned
Talisman 6	Drilled in 1990 by Marathon Petroleum as a sidetrack from Talisman 5.	Abandoned
Talisman 7	Drilled in 1990 by Marathon Petroleum as a development well, as a sidetrack from Talisman 5. The well was successfully production tested and completed as a production well connected to the Talisman 1 production facility. Was plugged and abandoned in 1992.	Completed Abandoned

Source: Geoscience Australia 2019a

The Talisman field produced 7.7 million bbl of light crude oil between 1989 and 1992 from two production wells (Talisman-1 and Talisman-7; T-1 and T-7). The oil was processed on an FPSO (the *Acqua Blu*), connected to the wells with subsea trees, flowlines and umbilicals (Santos 2018).

Following the termination of production operations, the two wells were plugged and abandoned, and the wellheads were recovered over two stages from September to November 1992. During the decommissioning, all locatable items were recovered from the Talisman field, with the exception of the T-7 flowline and control umbilical line, an anchor and length of chain, and a tyre weight. The flowline and umbilical were clamped together at the time of decommissioning and, together with the other items that could not be recovered, are collectively referred to as the ‘production equipment’ (Santos 2018).

In January 2019, NOPSEMA accepted the WA-8-L Production Equipment Abandonment Environment Plan (Santos 2018), which comprises of leaving the production equipment in situ in perpetuity.

These items remain on the seabed. Santos had defined a ‘production equipment abandonment area’ based on a 1 km radius buffer around the known or assumed coordinates of remaining equipment (Figure 3-3). The flowline and umbilical and T-7 wellhead locations are known; however the position of the anchor and chain and tyre weight are not, but are assumed to be within the buffer area.

The ‘production equipment abandonment area’ is approximately 3.4 km from the expected MOPU location, within the Project Area. The proposed Talisman manifold location is ~140 m inside the 1 km buffer; ~860 m from the abandoned flowline.

The Amulet field was initially discovered in 2006 by Tap (Shelfal) Pty Ltd who drilled a number of exploration wells.

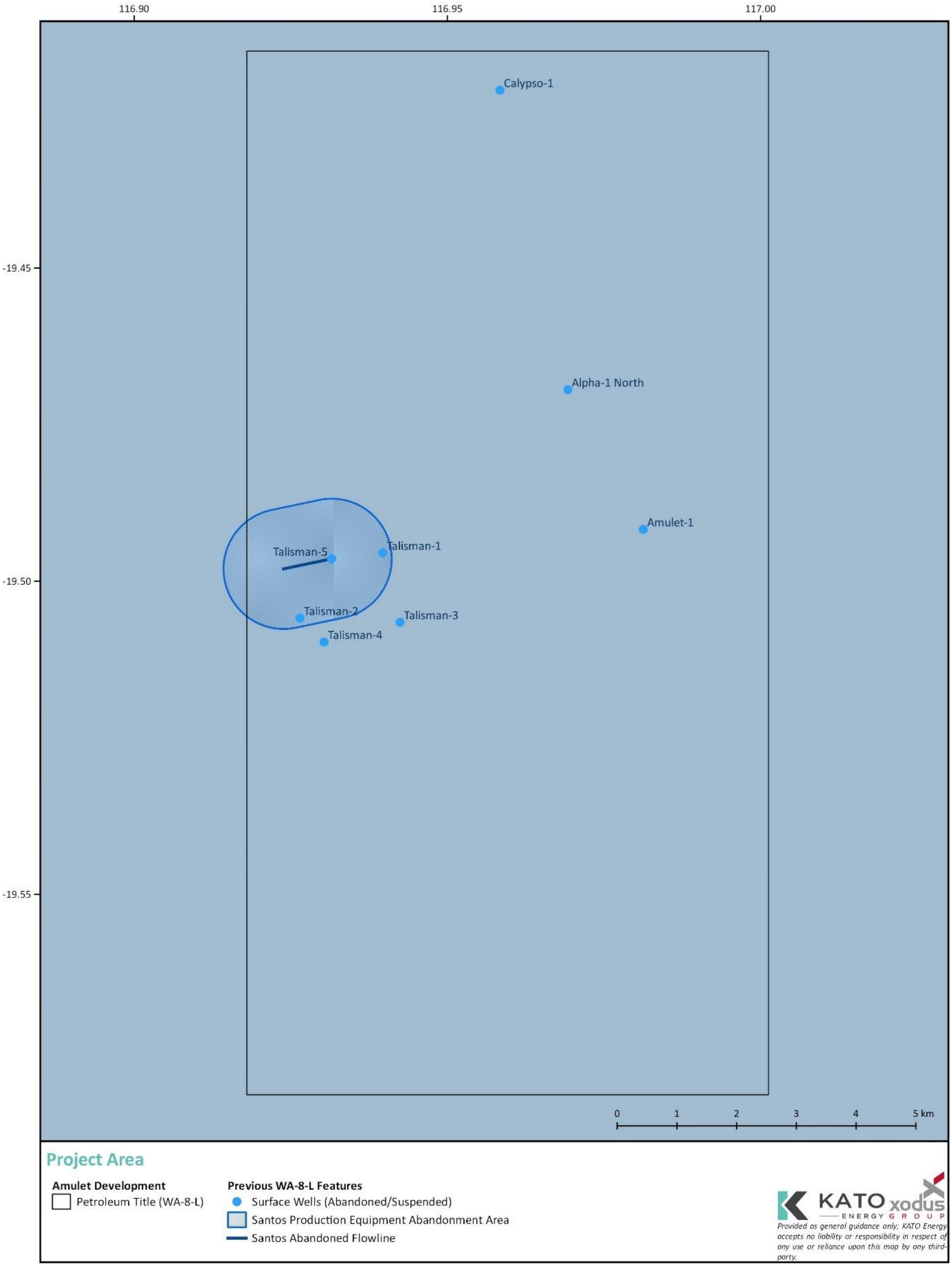


Figure 3-3 Historical Drilling (Surface Wells) and Abandoned Equipment in WA-8-L

3.2.1 Reservoir Characteristics

The Amulet field has a likely resource of 6.9 MMstb. The field has an oil gravity of 45°API with a gas-oil-ratio (GOR) of 65 scf/stb. No significant CO_2 or H_2S has been recorded.

The reservoir fluid and gas composition for the Amulet Field is detailed in Table 3-5.

Table 3-5 Fluid and gas composition for the Amulet Field

Component	Composition range (mol%)	
	Fluid Component	Gas Component
Carbon dioxide	0.84–0.91	9.57
Nitrogen	0.21–0.24	5.12
Methane	2.99–3.16	46.54
Ethane	1.93–2.09	14.04
Propane	3.88–4.24	12.54
Hydrogen Sulphide (H_2S)	0	0

A re-instated Talisman field has a likely remaining resource of 2.5 MMstb. The field has two producing sands containing hydrocarbons with oil gravity 41°–43° API with a gas-oil-ratio (GOR) of 55–75 scf/stb. The records indicate some CO_2, but typically approximately 2% and negligible H_2S.

The reservoir fluid and gas composition for the Talisman Field is detailed in Table 3-6.

Table 3-6 Fluid and gas composition for the Talisman Field

Component	Composition range (mol%)	
	Fluid Component	Gas Component
Carbon dioxide	0.04–0.96	0.00–16.60
Nitrogen	0.18–2.49	0.22–12.14
Methane	2.51–6.47	1.15–66.05
Ethane	0.18–5.94	2.72–12.26
Propane	0.45–18.74	1.17–32.89
Hydrogen Sulphide (H_2S)	Negligible	Negligible

3.3 Description of Infrastructure

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

3.3.1 Wells

Amulet Wells

Up to two production wells and one contingent sidetrack may be drilled at Amulet, potentially over two project drilling campaigns (depending on the initial production outcomes). This may also include a dual-purpose producer/water injection well for reservoir pressure support. Either a separate MODU will be used, or the MOPU selected for use may have drilling capability itself (Section 4.3.5). 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 (approximately 24 m above sea level); and the production tree and the 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 5 if extended reach Talisman wells are technically feasible) 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.

The Amulet reservoir consists of two sands – the Calypso Upper Sand at TVD ~1,760 m and the Calypso Hot Sand at TVD ~1,810 m. The 'Hot Sand' has 95% of the oil resource and is the primary target. Any development of the 'Upper Sand' will be incorporated as part of either a 'Hot Sand' production well or the planned water injection well.

It is also unlikely the Amulet 'Hot Sand' reservoir has a strong aquifer support system, so pressure in the reservoir will deplete quickly as fluids are drained from the formation. A water injection well will be drilled at Amulet to provide supplementary pressure support, replacing the fluids that have been removed from the formation to maintain pressure. The water injection well will be ~100 m deeper than the production wells.

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

Figure 3-4 shows an indicative section view of a potential three well P10 development option.

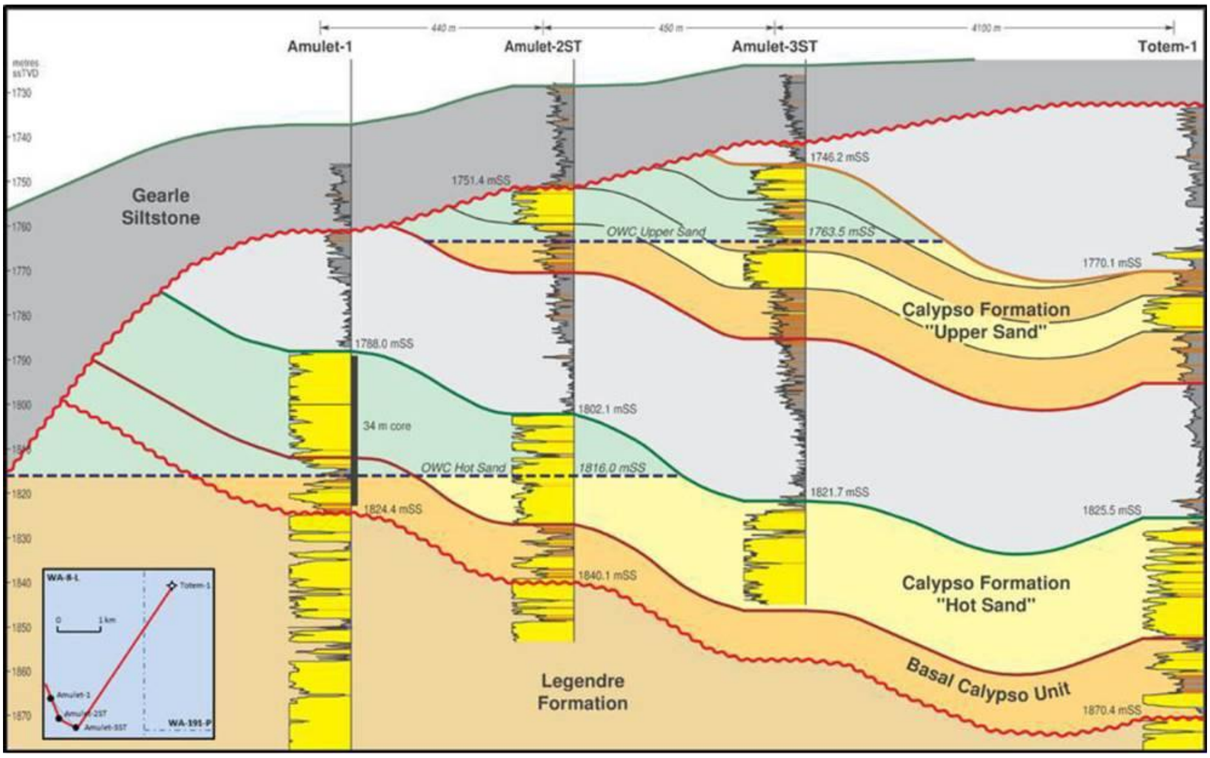


Figure 3-4 Indicative Section View of a Three-well P10 Development Option

The wells may not flow to surface naturally during their production life, and will require artificial lift. Electric submersible pumps (ESPs) will be used for artificial lift of the wells at this time. Final configuration will be confirmed during FEED.

Table 3-7 summarises the key well design characteristics.

Table 3-7 Key Characteristics of the Amulet Wells

Characteristic	Description
Well location (expected MOPU location)	Latitude: 19° 29’35.9” South Longitude: 116° 58’24.5” East
Well depth	Calypso Upper Sand: TVD 1745 m to 1765 m Calypso Hot Sand: TVD 1775 m to 1815 m Water injection well: TVD ~1,910 m
Total area direct seabed disturbance	100 m^2 Including 50% contingency – **150 m^2**

Talisman Wells

Up to two production wells and one contingent sidetrack may be drilled, potentially split over the two Amulet project drilling campaigns (dependent on the initial production outcome). The preferred option will be to drill the Talisman wells through the conductor deck of the MOPU as extended reach wells. However, while KATO have a high confidence that the extended reach Talisman wells can be drilled from the proposed MOPU location, a significant amount of geomechanics study is required to confirm technical and commercial feasibility, which will not be completed until FEED.

If extended reach drilling is proven to not be technically feasible, Talisman may be developed using a subsea alternative, tied back to the MOPU. The subsea tieback alternative poses the greater potential environmental impact, and is used as the basis for impact assessment for the purpose of this OPP (see Section 4.3.2).

For the subsea development option, the MODU will drill each well at independent locations (separate from the MOPU), utilising a riser and subsea BOP. The Talisman production manifold will be installed in the vicinity of the Talisman field, and both subsea wells will be connected to the manifold to convey production fluids, and power and controls. Each Talisman subsea well will be within ~200 m of the manifold.

The subsea well design will be that the main conductor terminates at the seabed (mudline) where a subsea production tree will be installed. Each well will have a separate entry point (approximately <1 m diameter hole). Each well will have a subsea tree installed on the seabed, with a footprint of ~25 m^2, centred in the well main conductor. The wells will not be immediately adjacent to each other and will require a separate move of the MODU, so there will be additional seabed disturbance and spud can footprint at each well site.

The subsea tree will have valves that will likely discharge hydraulic fluid. The hydraulic fluid will be a water-based fluid, and benign to the environment.

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

The wells may not always flow to surface naturally and will require artificial lift. Electric submersible pumps (ESPs) will be used for artificial lift of the wells at this time. Final configuration will be confirmed during FEED.

Table 3-8 summarises the key well design characteristics of the two Talisman target sands.

Table 3-8 Key Characteristics of the Talisman Wells (Subsea Tieback option)

Characteristic	Description
Talisman manifold location	Latitude: 19° 29’52.1” South Longitude: 116° 56’25.8” East
Talisman subsea trees seabed location (expected MODU location when drilling)	Within 200 m of the Talisman manifold
Well depth	Talisman: “B” Sand at TVD 1940 m to 1960 m Talisman: “C” Sand at TVD 1960 m to 1970 m
Total area direct seabed disturbance	25 m^2 per subsea tree Including 50% contingency – **75 m^2**

3.3.2 MOPU

The MOPU will be a jack-up facility that has been modified to include a production unit, and storage for small quantities of processed oil. 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 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 Development is that a separate MODU will drill the wells for Amulet, and then (if required) move to the Talisman well location, to complete as a subsea well. However, there is an option that the MOPU itself may have drilling capability. In this case, a separate MODU would not be required for Amulet, and may not be required for Talisman, should extended reach wells drilled from the MOPU location be feasible (refer to Section 4.3.5).

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. The Talisman subsea completed wells would be tied-back to the MOPU via a subsea production flowline to a J-tube (a tube that runs from the deck of the MOPU to the seafloor and allows a flexible flowline to be pulled up through it from the seafloor) within one of the MOPU legs.

The base case of a separate MOPU and MODU presents the greater potential environmental impact due to having two facilities in the field during drilling; therefore it has been used as the basis for the impact assessment in the OPP.

If an FSO is selected, the MOPU may not be 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 3-9 summarises the key MOPU characteristics.

Table 3-9 Key Characteristics of the MOPU

Characteristic	Description
MOPU type	Jack-up rig or custom-built facility
Deck Dimensions	Hull length: 80 m – 90 m Hull width: ~ 90 m Hull depth: ~ 10 m
Rig feet	Rig feet are attached to the bottom of each leg, and each rig foot sits into the ocean floor supporting the rig, adding stability to the facility during operations. • three rig feet; one for each leg • rig foot diameter: ~ 17 m – 20 m • rig foot area: ~ 250 m^2 – 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 ~ 150.
Crude storage	~ 1000 m^3 (depending on export method - if shuttle tanker option is selected)
Diesel storage	~ 800 m^3
Power consumption	Installed power: 6 MW Diesel generation (normal operations): 6 MW (jacking) for 12 hours, 2 MW Emergency diesel generation: 1 MW Firewater pump/s diesel driven: 300 kW
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 MMscf/d) Maximum PFW discharge rate 185 m^3/hour (4,440 m^3/day)
Total footprint	~ 1,500 m^2 (for all three rig feet) Including 50% contingency – **0.002 km^2**

3.3.3 Talisman Subsea Tieback System

If the Talisman subsea tieback option is selected (see Section 4.3.2), this system will likely consist of:

- up to two subsea trees
- manifold to comingle production fluids from nearby Talisman wells
- production and service jumper connections from the subsea trees to the manifold
- ~3.5 km flexible production flowline from the Talisman manifold to the MOPU
- ~3.5 km service umbilical that will provide power, communications, control fluids and chemicals to the Talisman subsea well/s.

The Talisman production flowline and service umbilical will each have dedicated J-tubes on the MOPU and will be connected to the production system.

The production flowline will be a flexible flowline laid in a 5 m corridor. The service umbilical will include communications, fluid supply lines and likely power cable. It may be bundled with the flowline or laid within a separate 5 m corridor. If the production flowline and service umbilical require stabilisation, this would likely be concrete mattresses and/or grout bags, and would be installed after the flowline and service umbilical are laid.

A manifold will be located in the Talisman Field, which is a gravity based/skirted structure providing a secure termination point. Short ~200 m jumper connectors will connect from the wells to the Talisman manifold, and ~200 m control lines will connect from the manifold to the subsea tree/s.

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

Table 3-10 summarises the key characteristics of the Talisman subsea tieback system. Although this is not the preferred option, it is used as the basis for impact assessment in this OPP. Figure 3-5 shows the key components of the Talisman subsea tieback system.

Table 3-10 Key Characteristics of the Talisman Subsea Tieback System

Characteristic	Description
Talisman production flowline dimensions	~3.5 km long (Talisman to the MOPU) Likely diameter 6” (inventory of ~65 m^3) May be bundled with the service umbilical.
Talisman production flowline footprint	3 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 17,500 m^2.
Service umbilical dimensions	~ 3.5 km long Likely diameter of 5” May be bundled with the production flowline.
Service umbilical footprint	~ 3.5 km long, assuming 5 m wide disturbance corridor. Note if mattresses/ grout bags are used, these will be within the 5 m corridor. Total of 17,500 m^2
Talisman jumper connections dimensions	2 x production jumpers ~200 m long 2 x control jumpers ~200 m long Likely diameter of 4” (inventory of ~ 1.22 m^3 each)
Talisman manifold, subsea tree and jumper footprint	Manifold: ~10 m x 8 m, giving a total area of 80 m^2 Subsea tree: 5m x 5 m giving 25 m^2 per tree. Jumper connections: 200 m long. Assume 3 m wide disturbance corridor each, giving 600 m^2 each. Assume 4 jumper corridors giving a total of 2,400 m^2 Total of 2,505 m^2.
Total Footprint	37,635 m^2 (0.0376 km^2) Including 50% contingency – **0.056 km^2**

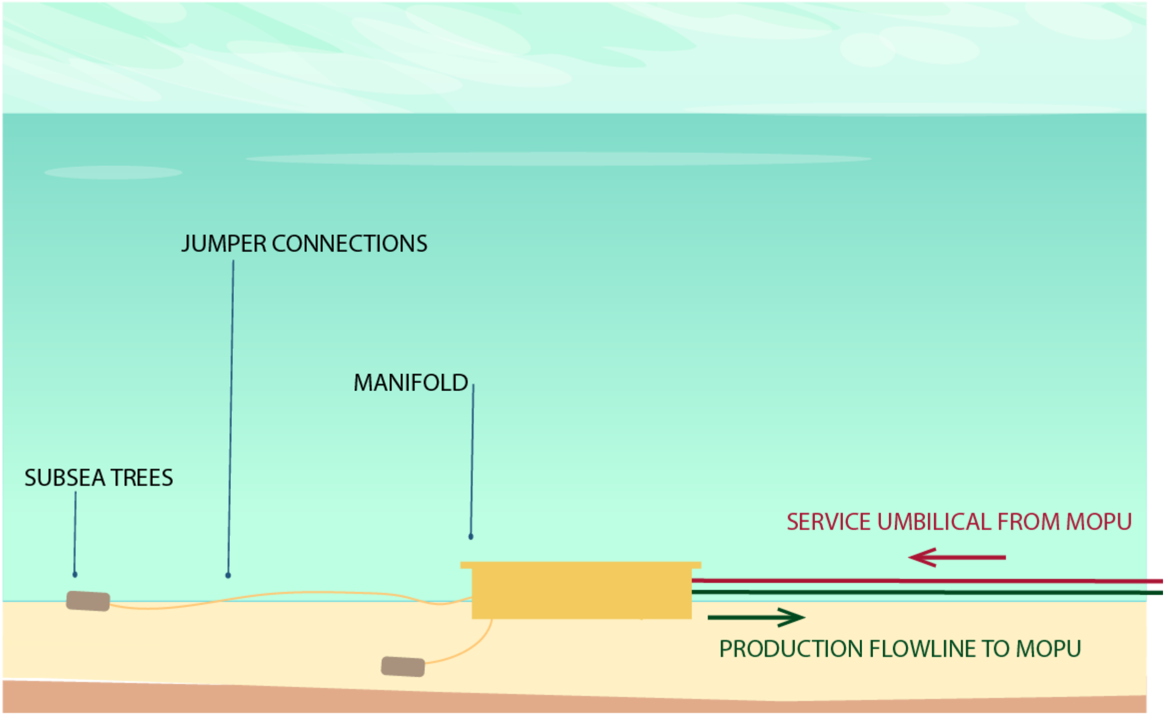


Figure 3-5 Talisman Subsea Tieback infrastructure

3.3.4 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.

If the subsea well tie-in option is selected for Talisman, wellheads, subsea tree/s and a ~4.2 km flowline and service umbilical to the MOPU will be installed.

Table 3-11 summarises the key flowlines characteristics. The flowlines and CALM buoy arrangement are shown in Figure 3-6.

Table 3-11 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.

Characteristic	Description
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 (0.0076 km^2) Including 50% contingency – **0.011 km^2**

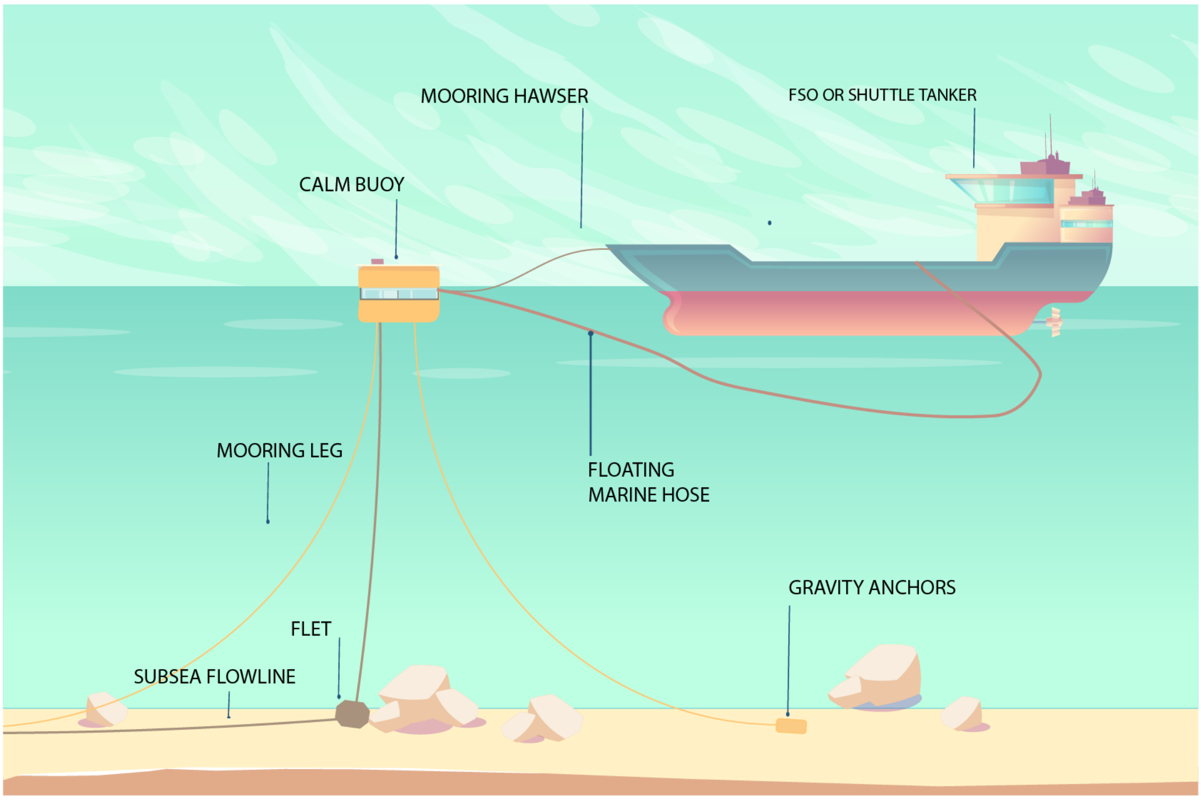


Figure 3-6 FSO, CALM Buoy and mooring arrangement

3.3.5 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 3-6). 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 4.3.8 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).

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 tanker.

Table 3-12 summarises the key characteristics of the CALM buoy and mooring arrangements.

Table 3-12 Key Characteristics of the CALM Buoy and Mooring Arrangements

Characteristic	Description
Mooring radius / method	Mooring leg length approximately <600 m 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, which includes 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 footprint	Steel or concrete structure with a gravity skirt of ~ 20 m x 12 m. Three gravity anchors of 240 m^2 each gives a total of 720 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 (0.0098 km^2) Including 50% contingency – **0.015 km^2**

3.3.6 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 3-13 summarises the key characteristics of the FSO.

Table 3-13 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 360° movement around the buoy. No proposed anchoring.
Nominal POB	17- 30 POB (depending on manning strategy)
Crude storage	Storage 95,392 m^3 – 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 a 24-hour continuous period within the standard 36-hour laycan.
Diesel storage	~ 4,000 m^3

3.3.7 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 3-6). 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).

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 Operations (Section 3.4.6) may be used throughout all phases of the Amulet 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 jack-up MODU, to set-up adjacent to the MOPU for the Amulet wells, and drill the wells through the MOPU's conductor deck (shown in Figure 3-7; refer to Section 4.3.5).

However, there is potential that the selected MOPU could have drilling capability – in this case, a separate MODU may not be required (at least for the initial drilling campaign).

Drilling activities are expected to take approximately 7 months, and an additional 4 months if a second drilling campaign is required.

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.

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).

Amulet

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

- MOPU will be towed into Project Area by 2-3 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 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.

Up to three production wells (one of which may be a dual water injection well) will be drilled at Amulet, to a vertical depth of ~1,800 to 1,900 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. As such, provision for one sidetrack in one of the wells to enable a different final position is included in this OPP.

Well design is described in Section 3.3.1. A more detailed description of expected activities involved in drilling is provided in subsections below.

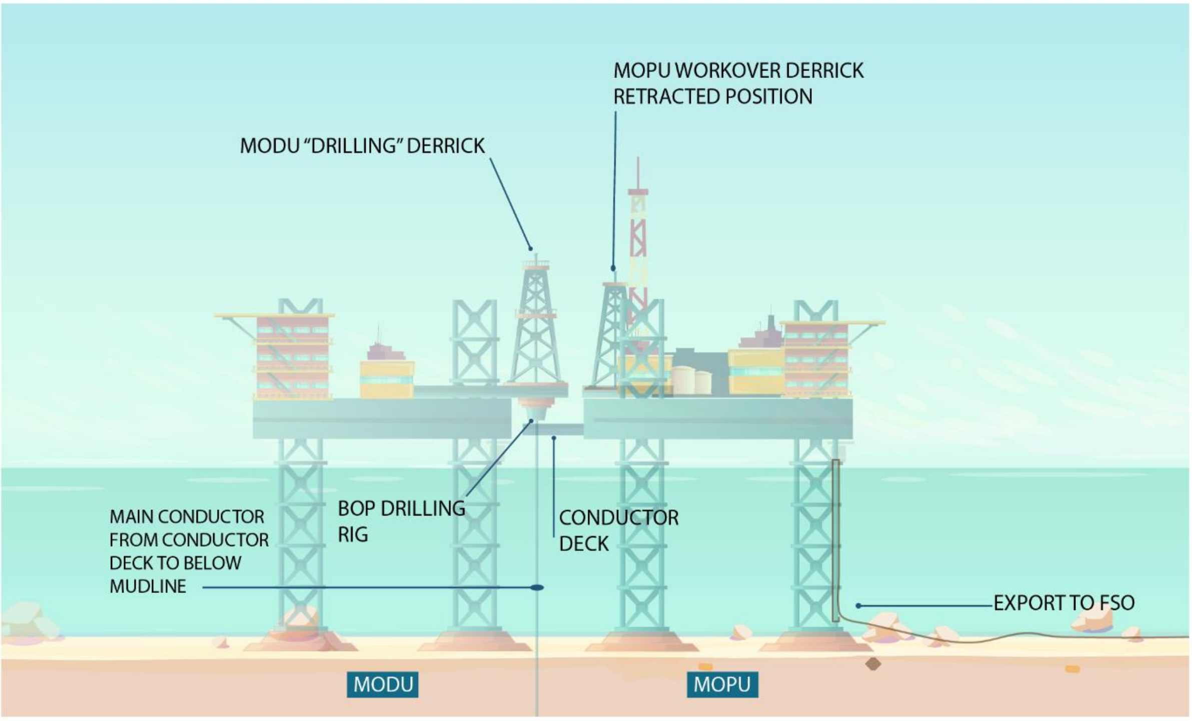


Figure 3-7 MODU and MOPU Set-up during Amulet Drilling

Talisman

The preferred option is extended reach drilling of the Talisman wells from the MOPU location (see Section 4.3.2). These would be drilled concurrent with the Amulet wells.

However if this option is not technically feasible, the subsea tieback system option is for the MODU to be jacked down from drilling at the MOPU location, then towed to each Talisman production well location and jacked up into position, ready for drilling. The Talisman wells are not adjacent to each other, and so the MODU will be moved to each location sequentially. They will be drilled within 200 m of the Talisman manifold to enable simple connection via short production and power/control jumpers.

Up to two production wells will be drilled, to a vertical depth of ~1,920 – 1,970 m. For the subsea tieback system, the wells will be spudded on the seabed; 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 is therefore subject to change. As such, provision for one sidetrack in one of the wells to enable a different final position is included in this OPP. Well design is described in Section 3.3.1.

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 may not be required (see Section 4.3.5).

For Talisman, if the subsea tieback option is selected, the separate MODU will mobilise to the well location, likely towed by 2-3 support vessels (e.g. AHTs). However, if extended reach drilling is feasible, the MODU will not have to move from the Amulet MOPU location (see Section 4.3.2).

The MODU selected to complete the activities will be a jack-up facility. It is expected to have three rig feet with a footprint of approximately 315 m^3 each, giving a conservative total footprint of 1,500 m^3, each time the MODU jacks down to position.

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. If the subsea tieback option is used for Talisman, the MODU will also position above the two Talisman well locations. This assumed four occasions to position the MODU gives a total seabed disturbance footprint of 6,000 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 mandatory 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 3-6).

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 jack-up MODU.

3.4.2.2 Conductor and Top-Hole Drilling

Once the MODU derrick is positioned over the well location (through the conductor deck), drilling will commence with the top-hole section. If the subsea tieback option is used for Talisman, the MODU derrick is positioned over the subsea well location at Talisman. Conductor and top-hole drilling 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 MOPU conductor deck at Amulet; and MODU conductor deck or underside drilling derrick for Talisman subsea tieback option
- 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 vertical depth of ~950 m (for Amulet) and 1,000 m (for Talisman) 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 Amulet Development, conductor casing (a carbon steel pipe) is used from the MOPU conductor deck to the seabed for wells supported at the MOPU. For the Talisman subsea tieback system the conductor casing will support the subsea tree at the mudline. 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 ~600 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. If the subsea tieback system option is used for Talisman, the BOP will be installed just above the seabed, supported on the main conductor.

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 the Amulet wells use a ‘dry’ BOP, it uses a closed-circuit hydraulic system, and doesn’t require any discharge of fluid to the marine environment during testing. If the subsea tieback option is selected for Talisman, control fluid is released from the subsea BOP occasionally to the marine environment.

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):

- for Amulet wells, drill through the BOP to a vertical depth of ~1,800 m, immediately before entering the reservoir (hydrocarbon zone)
- for Talisman wells, drill through the BOP to a vertical depth of approximately ~1,900 m, immediately before entering the reservoir (hydrocarbon zone).
- run the intermediate casing(s) inside
- run cement through the intermediate casing(s), 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. One contingent sidetrack at both Amulet and Talisman is allowed for.

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, which is the term for an assembly of valves, spools, and fittings used to regulate hydrocarbon flow within a well. For the Amulet wells, the tree will be located above the sea surface, on the MOPU conductor deck (known as a ‘dry’ tree). For the Talisman wells, if the wells are drilled through the MOPU conductor deck, dry trees will also be used. However, if the subsea tieback option is selected, subsea trees will be installed just above the seabed, supported on the main conductor.

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 (~60 m^3 per well). If extended reach drilling is used to develop Talisman, the volume may be more (~90 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 mud, 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 4.3.6 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 near 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 ~60 m^3 per well for the top-hole section.

Once the main conductor (riser) of the well is installed, the remainder of the top-hole and bottom-hole well sections will be drilled through the main conductor, allowing the drill cuttings and fluids to be routed back to the MODU, 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 dependent on the well geometry drilled for each well with variations expected depending on the depth of the well. For the base case, it is estimated to be ~395 m^3 per well for the Amulet production wells and ~405 m^3 for the dual-purpose production/water injection well. For the Talisman subsea tieback option, discharge is estimated to be ~380 m^3 per well.

If the extended reach drilling from the MOPU is feasible for Talisman, the estimated volume of cuttings discharged during the remaining top-hole and the bottom-hole section is ~870 m^3 per well, for the two Talisman production wells.

The remaining top-hole and bottom-hole drilling may use SBM or WBM depending on technical feasibility and safety, and drilling technical requirements. If SBM is used, there is no planned discharge of SBM to the marine environment during drilling. If WBM is used, a maximum of 160 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
- if the Talisman subsea tieback option is used, installation of the Talisman subsea tieback system
- hook-up of FSO.

3.4.3.1 MOPU

The MOPU will be a jack-up facility 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 on location at Amulet (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, this hook-up scope will be undertaken on location at Amulet:

- 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 will be installed and leak tested after the tree has been installed
- 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 Amulet Development Area, 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 Talisman Subsea Tieback System

If the Talisman subsea tieback system option is selected, the Talisman production flowline, service umbilical, manifold, subsea trees and jumper connectors will be installed, and then connected once the wells have been drilled and completed.

The Talisman production manifold will be installed in the vicinity of the Talisman field to provide a local structure for subsea wells to transport production fluids to the MOPU, and for receipt of power and controls from the MOPU. Each Talisman subsea well will be within 200 m of the Talisman manifold. The Talisman manifold will be pre-commissioned, and pressure tested prior to arrival on site and installed by an installation vessel (ISV) by lowering and positioning onto the seabed.

A ~3.5 km production flowline will be installed to connect the Talisman wells to the MOPU, and a service umbilical installed for providing control and fluids from the MOPU to the Talisman wells (via the manifold). The flowline and service umbilical will be stored and transported to the Project Area by support vessels (e.g. ISVs, AHTs) on reel assemblies. The flowline and service umbilical will be pre-commissioned, and pressure tested prior to arrival on site.

The Talisman production flowline will be laid directly on the seabed. It may be installed in multiple sections. One end of the flowline will be ‘pulled’ up a dedicated J-tube on the MOPU and connected to the production system. The other end will be laid and secured on the Talisman manifold located adjacent to the Talisman wells, which is a gravity based/skirted structure providing a secure connection point. Short ~200 m 'jumper' connections from the wells will connect from the subsea tree to the manifold.

The service umbilical will include communications, fluid supply lines and power. It may be bundled with the flowline or laid in similar manner to the flowline, within a separate corridor. One end of the service umbilical will be 'pulled' up a dedicated J-tube on the MOPU and connected to the onboard utility systems. The other end will be laid and secured to the Talisman manifold.

If the production flowline and service umbilical require stabilisation, this would likely be concrete mattresses and/or grout bags, and would be installed after the flowline and service umbilical are laid. These would be laid within the 5 m corridor. Table 3-10 shows the dimensions and footprint of the system.

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

- Talisman manifold lowered to seabed, positioned and secured
- production 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 production flowline laid on the seabed
- production flowline stabilisation installed as required (concrete mattress and/or grout bags)
- final end connection of production flowline installed onto Talisman manifold, diver-less connection
- service umbilical 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 service umbilical laid on the seabed
- service umbilical stabilisation installed as required (concrete mattress and/or grout bags)
- final end connection of service umbilical installed onto Talisman manifold, diver-less connection.

After installation, the Talisman subsea tieback system 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 via the MOPU on commencement of production; but it may be discharged to the marine environment. The volume of commissioning fluid is expected to be approximately 130 m^3, allowing for double the total inventory.

3.4.3.3 Flowlines and Marine Hoses

The static flowline and riser that connect the MOPU to the CALM buoy will be stored and transported to the Project Area by support vessels (e.g. ISVs) 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 MOPU export 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 (a 'service umbilical') 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 (via the MOPU), 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 CALM Buoy and Mooring Arrangements

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

There are two options for mooring the CALM buoy—gravity anchors and drilled and grouted anchor piles (refer Section 4.3.8 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 an 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). Once capacity is confirmed, 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.

3.4.3.5 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 Amulet 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. Risks to FSO operation from cyclone will be managed through the implementation of a cyclone management plan, details of this plan will be described further in the future EP.

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.

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 Amulet and Talisman reservoirs 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 trees for Amulet are 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.

If subsea trees are used for Talisman, small quantities of subsea control fluid / hydraulic fluid will be discharged from the trees during routine valve operations.

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 3-14.

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

Table 3-14 Key Process System Overview

Process System	Description
Production and Injection Manifold	The production and injection manifold provides 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	Likely comprising: Crude Heater, Second Stage Separator, Crude Oil Rundown Cooler, and 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 including disposal and injection	This system removes entrained oil from the produced water to achieve the design specification for overboard disposal or injection. Likely comprising: • free water knock out (KO) drum • produced water pumps • de-oiling hydrocyclone • degasser vessel/tank • discharge pipe • produced water injection pumps
Cooling Water System	• Seawater. • 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.

<table>
<tr><th>Process System</th><th>Description</th></tr>
<tr><td></td><td>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.</td></tr>
<tr><td>Fuel Gas System</td><td>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 users include:
gas Engine Generator set [for power generation]
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).</td></tr>
<tr><td>Heat Medium System</td><td>Provides process heating duty which may be required for:
crude oil stabilization
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.</td></tr>
<tr><td>Flare System and Flare Boom</td><td>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 <1.2 MMscf/d (allowing for fuel gas usage) at the commencement of production for 6-9 months, then then decline as the reservoir depletes to end of field life. System capacity rates are described in Table 3-15.</td></tr>
<tr><td>Seawater Injection Water System</td><td>A seawater injection water system may be required for the Amulet field. This will consist of seawater lift pumps, filtration, de-oxygenation and a biocide system. Inject for voidage displacement at maximum 30,000 bwpd.</td></tr>
<tr><td>Talisman subsea tieback system (if used)</td><td>The Talisman subsea tieback system consists of the following additional components:
Talisman subsea trees (production wells)
jumper connections from subsea trees to manifold
Talisman manifold to commingle production from nearby Talisman wells
production flowline from Talisman manifold to MOPU to transport fluids
Talisman service umbilical from MOPU to Talisman manifold for control/power.</td></tr>
<tr><td>Chemical Injection System</td><td>A chemical injection package can inject the following typical chemicals:
demulsifier
corrosion inhibitor
scale inhibitor</td></tr>
</table>

Process System	Description
	• 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 3-15 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 4.3.3 for PFW options.

Table 3-15 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 MMscf/d	Excess gas to be flared
Produced Formation Water	30,000 BWPD	Oil-in-Water of less than 29 mg/L
Injection Water System	30,000 BWPD	Filtered and de-oxygenated

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 subsea trees, 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; and Talisman subsea tieback system (if required). 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 Amulet 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.

For the base case, intervention of the Amulet wells would be undertaken from the MOPU. However, during the production phase, the Talisman wells would require either an ISV with well intervention equipment or a separate MODU to intervene on the subsea trees (Section 4.3.3).

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.

For the base case, P&A of the Amulet wells will be completed by the MOPU (prior to departure from the field). The preferred method to P&A the Talisman wells will be using the MOPU, which will have P&A capability, prior to the MOPU departure to the next field. However, the P&A may also be undertaken by either an ISV with well intervention equipment, or a separate MODU to intervene and P&A the subsea trees.

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 Amulet 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 MOPU export flowline will be inspected and treated onshore, as the spare will be used at the next field. The Talisman subsea tieback subsea infrastructure will be inspected and treated onshore and may be refurbished for future use (e.g. Talisman production flowline). 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 the Project Area, prior to demobilisation and redeployment at the next field. Diving and ROV operations may be required.

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 Amulet 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.

The Talisman subsea tieback infrastructure (if used) is not relocatable. There may be some cleaning of lifting points before recovery, but not to the same extent as for the honeybee production system infrastructure. The Talisman facilities will be recovered to the surface, and removed to shore.

3.4.5.2 Well Plug and Abandonment

The honeybee production system means that all infrastructure can be recovered, and the Amulet wells will be P&A’d before the MOPU demobilises from the field.

If the subsea tieback option is selected for Talisman, the preference is to use the P&A capability of the MOPU to also P&A the Talisman wells, after Amulet. This will involve the MOPU transiting to the Talisman field, positioning over each subsea well sequentially to P&A each well. In summary:

- MOPU will disconnect from the Amulet location as per Section 3.4.5.4 and be towed by 2-3 AHTs to the Talisman location
- MOPU will be positioned at each Talisman subsea well (similar to the MODU as described in Section 3.4.3.1)
- MOPU will P&A Talisman wells as per below overview.

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; or subsea tree (for Talisman tieback option)
- 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.

However, there is also an option for the Talisman well P&A to be undertaken by either an ISV with well intervention equipment; or a separate MODU. If a separate MODU is used to P&A the Talisman wells, it will be towed to the Talisman site and positioned as per Section 3.4.2.1, and P&A as per the overview above.

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

3.4.5.3 Removal of Subsea Infrastructure

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 MOPU export flowline and riser will be 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 will be recovered onto a storage reel on a support vessel, ready for redeployment at the next field or onshore storage.

For the Talisman subsea tieback option, all of the Talisman infrastructure will be recovered from the seabed at cessation of production. The Talisman production flowline will be flushed with inhibited seawater to the FSO (via the MOPU). It will be disconnected from the manifold and MOPU and recovered onto a storage reel on a support vessel, ready for inspection and onshore storage. The Talisman service umbilical will also be disconnected and recovered onto a storage reel on a support vessel, ready for inspection and onshore storage.

The short jumpers will be disconnected from the subsea trees and manifold and recovered to surface. Finally, the Talisman manifold and subsea trees will be lifted to surface, in reverse to the installation methodology by the ISV, MOPU or MODU (depending which is used for P&A of Talisman). The recovered subsea trees, flowline, service umbilicals and manifold will all be inspected and treated onshore.

The CALM buoy, gravity anchors and chains and DMAs will be retrieved, in a reverse of the installation methodology (Sections 3.4.3.4 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.

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.

The base case for decommissioning is complete removal of all above-mudline infrastructure from the Project Area, from both Amulet and Talisman. 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, the removal of subsea infrastructure may include:

- displacement of hydrocarbons in the Talisman production flowline with treated seawater to the FSO (via the MOPU), followed by depressurisation
- displacement of hydrocarbons in the MOPU export flowline with either treated seawater or treated PFW to the FSO, followed by depressurisation
- disconnect all subsea jumpers (between subsea tree and Talisman manifold)

- disconnection, removal and recovery of the MOPU export flowline and the Talisman production flowline from the seabed onto a support vessel
- disconnection, removal and recovery of the Talisman service umbilical from the seabed onto a support vessel
- recovery of the Talisman manifold
- 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
- removal and recovery of Talisman subsea trees (after well P&A).

It is estimated that flushing of the full production system (including Talisman subsea tieback system) to the FSO would take approximately four weeks, and recovery of the subsea infrastructure approximately five 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 3.4.3.5), 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 Amulet wells, and disconnection of all flowlines and service umbilicals, 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.

If the MOPU is used to P&A the Talisman wells, after disconnection from the Amulet site, it will be towed to the Talisman location, and will be positioned as per Section 3.4.2.1, jack down and P&A the wells as per Section 3.4.5.2.

Following P&A of the Talisman wells, the MOPU will disconnect from Talisman as per the above overview, and be demobilised from the Project Area.

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 3-16).

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 3-16 Support Activities for each Project Phase

Support Activity type		Site Survey	Drilling	Installation, hook-up, commissioning	Operations	Decommissioning
MODU			✓		✓ if required[1]	✓ if required[1]
MOPU			✓ if required[2]	✓	✓	✓
FSO				✓	✓	
Support vessels	Survey vessel	✓				
	Supply vessel		✓	✓	✓	✓
	Standby vessel				✓ if required[3]	
	AHT		✓	✓	✓ if required[1]	✓
	ISV			✓	✓ if required[4]	✓
Tankers					✓	
Helicopters			✓	✓	✓	✓
ROVs and Diving		✓	✓	✓	✓	✓
Total POB of facilities during phase[5]		30	160	60	30 +80 if MODU	60 +80 if MODU
Approximate Duration		1 month	7 months 4 months[6]	3 months	1.5–4.5 years	3 months

[1]*if MODU is used for well intervention and/or decommissioning of Talisman*

[2]*if MOPU has drilling capability*

[3]*If FSO is selected, it will have a fast rescue tender, and standby vessel won't be required*

[4]*if an ISV is used for Talisman well intervention, if required*

[5]*doesn't include supply vessels not permanently in Project Area*

[6] *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. If the Talisman subsea tieback option is used, the MODU would be alongside the MOPU at Amulet for approximately four months, and then located in the Talisman field for a further three months during drilling the initial campaign, and four months for the contingent infill campaign (if required). If the extended reach drilling option is selected for Talisman, the MODU would remain adjacent to the MOPU for ~7 months for the whole initial drilling campaign.

If extended reach wells are feasible for the Talisman development from the proposed MOPU location, then the MODU would be alongside the MOPU for approximately seven months during drilling the initial campaign.

A separate MODU may be used for the Talisman wells to conduct well intervention during operations, and/or for P&A during decommissioning.

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 ~five 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 Amulet Development. The expected vessel types, numbers and specifications is provided in Table 3-17. 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 3-17 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

Vessel Type	Purpose	Expected Duration for Relevant Phase	Expected Transit Frequency	Nominal POB
Supply vessel	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 ~1.5–4.5 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 ~1.5–4.5 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. If well intervention is required for Talisman, 2-3 AHTs may be required to tow the MODU	Drilling: • duration 7 months, and additional 4 months if second campaign is required Hook-up, Installation and Commissioning; and Decommissioning: • duration 3 months for each phase. Operations: • duration ~1 month (well intervention)	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) Operations: • 1 x round trip (well intervention)	Typically 12 POB per vessel
ISV	One ISV for commissioning and decommissioning of CALM buoy, gravity anchors and flowline. If well intervention is required for Talisman, one ISV with well intervention package may be required	Hook-up, Installation and Commissioning; and Decommissioning: • duration 3 months for each phase Operations: • duration ~1 month (well intervention)	Hook-up, Installation and Commissioning and Decommissioning phase: • 2 x round trips (mooring system and flowline) Operations • 1 x round trip (well intervention)	Typically 60–80 POB

3.4.6.5 Helicopters

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 northwest of WA.

3.4.6.6 ROVs and Diving

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

Transponders may be used for positioning during ROV activities. Transponders are attached to temporary clump weights and then lowered onto the seabed, which are recovered once the MODU is installed.

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

Diving operations may be conducted throughout all phases of the Amulet Development such as site surveys, installation, hook-up and commissioning, operations (inspections, maintenance and repair), subsea valve operations, recovery of dropped objects 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

Production Licence WA-8-L was granted by the Joint Authority on 8 November 2010 for a period of 21 years to previous title operators. Skye Energy Pty Ltd acquired both the Santos Limited and the Tap (Shelfal) Pty Ltd interests in the Amulet title (WA-8-L) in 2018. Also in 2019, the Kufpec (Perth) Pty Ltd interest in Amulet title (WA-8-L) was sold to Tamarind Amulet Pty Ltd. Subsequently, both titleholders became wholly owned subsidiaries of KATO, meaning KATO owns 100% of WA-8-L.

The Amulet field forms part of a portfolio of small fields that KATO plan to develop via the honeybee production system. A related field in KATO's portfolio is the Corowa field (WA-41-R). The previous titleholder [Hydra Energy (WA) Pty Ltd] had undertaken comprehensive concept select and Front-End Engineering Design (FEED) work on the honeybee production system. KATO took over as titleholder of WA-41-R in 2019, and has further progressed this work. The Corowa Development OPP (KATO 2020j) was submitted to NOPSEMA in August 2019.

Since acquisition of the Amulet field, KATO have reviewed development studies in all disciplines and concurred that the honeybee production system concept represents the best project development solution (Section 3). KATO intends to mature the design 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 Amulet:

- Honeybee production system, including MOPU *(selected)*
- Subsea to shore *(not selected)*[4]*
- Subsea tieback 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 tieback to an existing facility, and tieback to an existing shore-based facility options as they are represented by regional field development analogues and therefore worthy of consideration.

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

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 Amulet. Furthermore, the environmental implications of installing and subsequently removing fixed steel structures at the Amulet location were deemed adequately addressed via the comparative evaluation of the PUQ Platform option.

Talisman Field

The Talisman field is also located within WA-8-L and is less than 5 km to the west of the Amulet field. The Talisman field has been produced, but in 1992 production was shut-in, the field decommissioned and the wells P&A'd. The field has since been abandoned (Section 3.2).

Due to its proximity to the Amulet field, KATO may choose to reinstate production from the Talisman Field (remaining resource between 2.5– 4.0 mmbbls). The Talisman field is not economic as a stand-alone development; however it may provide incremental improvement to the Amulet Development. The comparative assessment of the Amulet Development only considers whether any Talisman development is precluded. The alternatives for Talisman field development are evaluated in Section 4.3.3.

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 Amulet, 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.

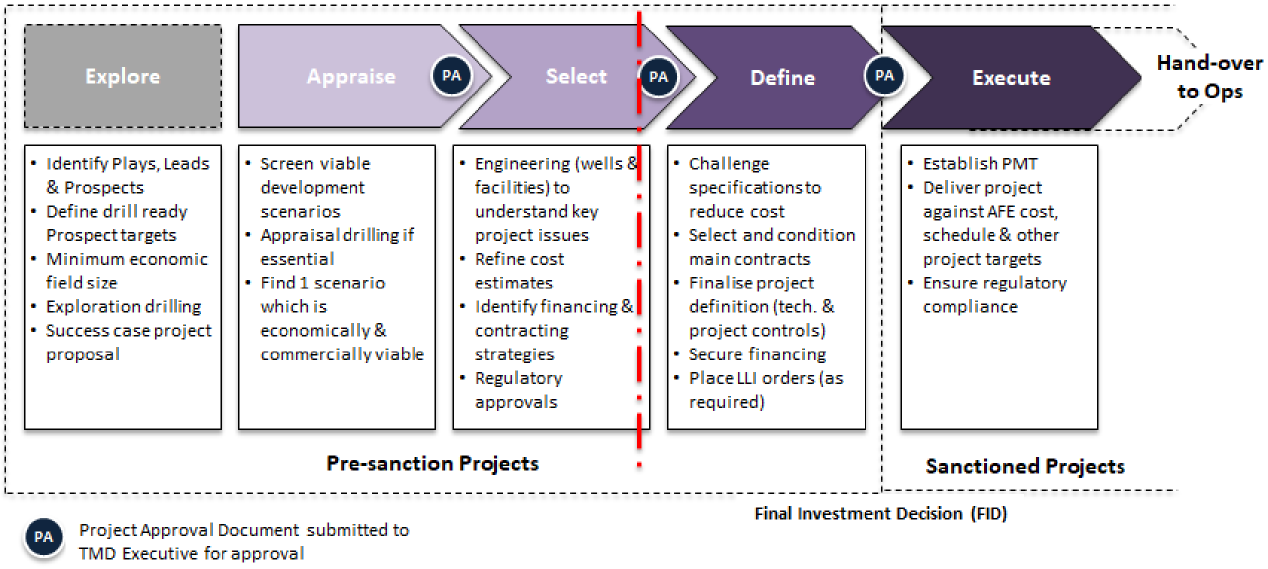


Figure 4-1 KATO JV Partner Tamarind's Development Process

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 Amulet 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)

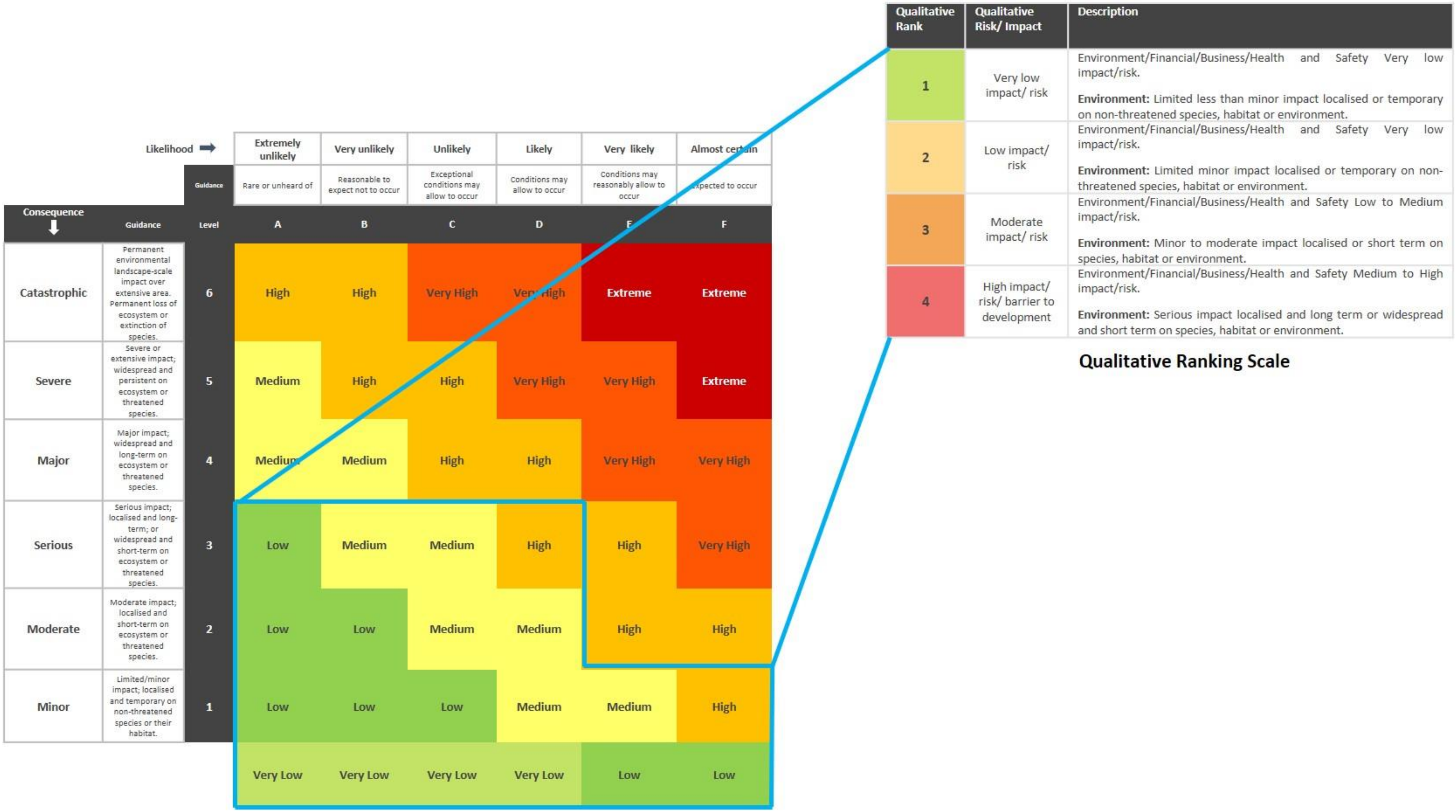
Driver	Criteria
Environmental	
Physical presence	• Seabed disturbance • Interaction with marine fauna (vessel movements)
Emissions	• Underwater sound emissions • Atmospheric emissions • Light emissions
Introduction of IMS	• IMS
Discharges	• Planned liquid and solid discharges and waste • Unplanned discharges 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[1]
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 and Decommissioning Feasibility	• Ability to construct • Ability to relocate and redeploy • 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

[1] *E.g. Subsea tieback 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.

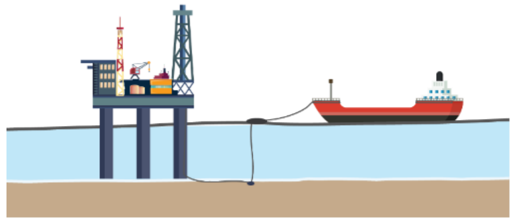
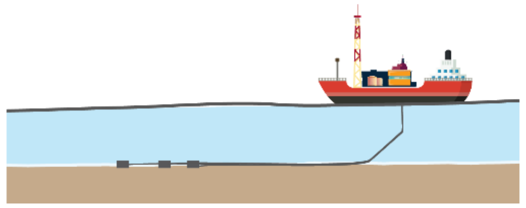
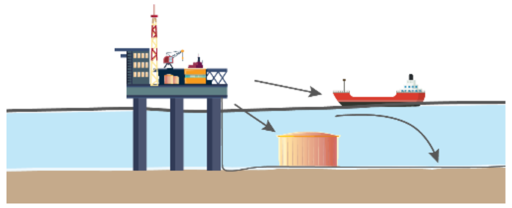
The supporting comparative assessment of the concepts against key criteria is detailed in

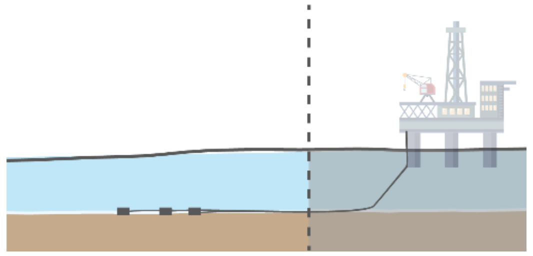
Table 4-1.

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 jack-up MOPU and MODU to drill and support up to four production wells. Oil production, water treatment, water injection, 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. Talisman can be either reached by extended reach drilling or a subsea tieback solution.	Mobilisation and installation of the jack-up MOPU and potentially a separate MODU (Section 4.3.5), interconnecting flowline, CALM buoy, FSO / shuttle tanker (Section 4.3.7). 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 tieback 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. Talisman as increased subsea tieback facilities.	Mobilisation of semi-sub or jack-up 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, ~130 km of subsea, processing, pumping, flowlines, pipelines and umbilicals, and a shore crossing. Incremental increase in onshore processing, storage and export facility. Incremental increase in onshore utilities including water treatment, well control systems, emergency flares, power generation, oil loading facilities for export.
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. Talisman as increased subsea tieback facilities.	Mobilisation of semi-sub or jack-up 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. Talisman can be either reached by extended reach drilling or a subsea tieback solution.	Mobilisation of jack-up 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	Overview	Key Activities
Concept 5 – Subsea tieback 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. Talisman as increased subsea tieback facilities.	As per Concept 2 and 3.
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	Emissions - Noise	Emissions - Atmospheric	Emissions - Light	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*	✓				✓		✓	✓
Offloading of oil (offshore)	1, 3 4 5*		✓	✓	✓				✓

Activity	Related Concept	Physical Presence		IMS Risk	Emissions and Discharges				
		Seabed disturbance	Interaction with marine fauna	IMS	Emissions - Noise	Emissions - Atmospheric	Emissions - Light	Planned Discharges	Unplanned Discharges / Accidental Releases
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 tieback to shore*		*Concept 3 – FPSO*		*Concept 4 – Fixed Platform*		*Concept 5 – Subsea tieback 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 increases footprint.
	Interaction with marine fauna	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	**Emissions - Noise**	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	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	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 discharges**	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
	Unplanned discharges / 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 tieback to existing FSPO/Onshore, with the Concept 1 Honeybee production system ranked second. Concept 1, 2 and 3 are ranked quite closely.

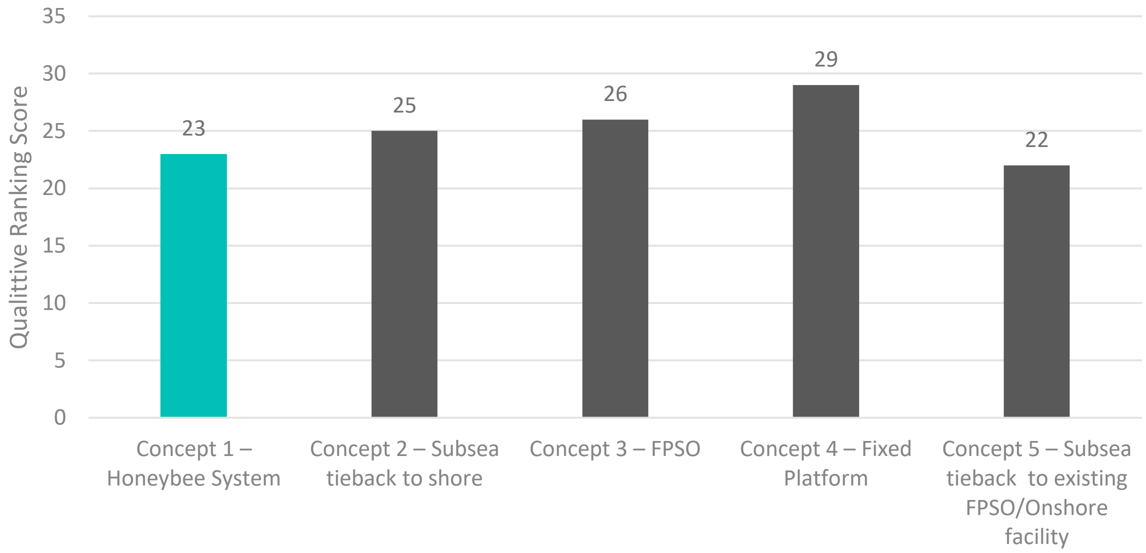


Figure 4-3 Qualitative Ranking of Environmental Criteria for Concept Alternatives

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 1 – Honeybee production system		*Concept 2 – Subsea tieback to shore*		*Concept 3 – FPSO*		*Concept 4 – Fixed Platform*		*Concept 5 – Subsea tieback 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 compared to 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.	1	Lowest safety risk offshore, no offshore manned facilities. Prolonged pipeline installation campaign.	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 and Feasibility Risk	Technically feasible	2	No major feasibility issues. Some topsides weight and space constraints	4	High flow assurance operability risk of long subsea tieback – 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 tieback – 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 ~40-60 km 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 >130 km subsea oil pipeline to existing facility is a technical step change and would require significant CAPEX for flow assurance mitigation and subsea pumping
Constructability, Re-useability, Decommissioning	Feasibility 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.

Criteria		Evaluated Concepts – Qualitative Ranking and Justification									
		Concept 1 – Honeybee production system		*Concept 2 – Subsea tieback to shore*		*Concept 3 – FPSO*		*Concept 4 – Fixed Platform*		*Concept 5 – Subsea tieback to existing facility*	
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 tieback to existing FPSO/Onshore facility has the second-worst score, mainly due to:

- technical feasibly of a very long subsea tieback
- 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.

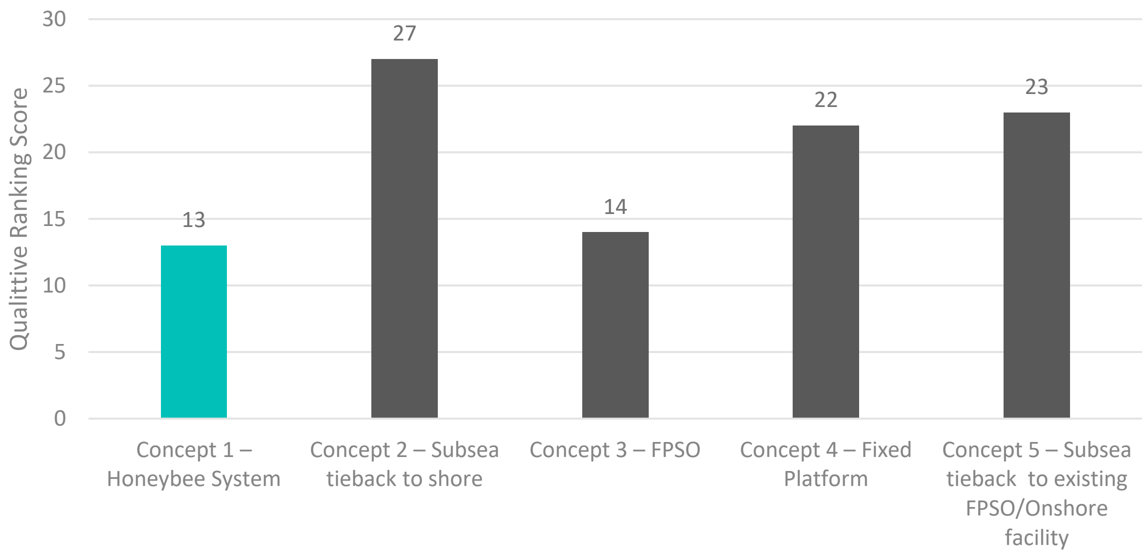


Figure 4-4 Qualitative Ranking of Economic, Technical Feasibility and Safety and Social Criteria for Concept Alternatives

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.

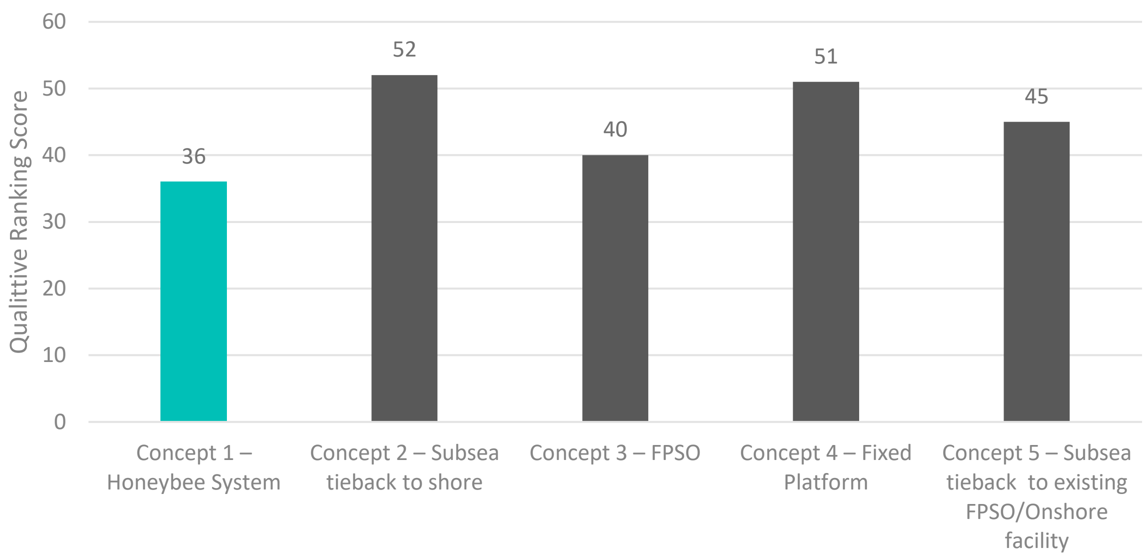


Figure 4-5 Qualitative Ranking of All Criteria for Concept Alternatives

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

- Concept 2 – Subsea tieback to shore was not selected due to the technical step change of the very long tieback 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 tieback to existing FSPO/Onshore facility was not selected due to due to the technical step change of the very long tieback 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 Amulet 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. • Allows for extended reach drilling (if proven feasible) for the Talisman tieback.	
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. • Large development footprint associated with pipeline and onshore facilities.	*X*
3	**FPSO** *Analogue – Pyrenees, Van Gogh (Australia)*	• While re-deployable, the Amulet 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. • Allows for extended reach drilling (if proven feasible) for the Talisman tie-ack.	*X*
5	**Subsea Tieback to Existing Facility** *Analogue – Greater Enfield*	• Distance to existing facility means this option would be technically challenging/not feasible, requiring the deployment of emerging/new 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 Amulet Development that may have potential impacts and risks on the environment include:

- gas strategy
- Talisman field development
- Talisman well intervention methodology
- 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

The Amulet field has a likely resource of 6.9 MMstb. Talisman is an already produced oil field, with some remaining oil in place and Contingent Resource of 2.5 MMstb (best estimate). Combined production is planned to occur for a relatively short period, between 1.5 and 4.5 years (for best and high production estimate respectively). While neither of the reservoir have a gas cap, they will both 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 ~0.65–0.94 Bcf[5] (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 Amulet and Talisman field, at low, high, and best estimates.

[5] Anticipated Gas Oil Ratio (GOR) of 64 scf/stb.

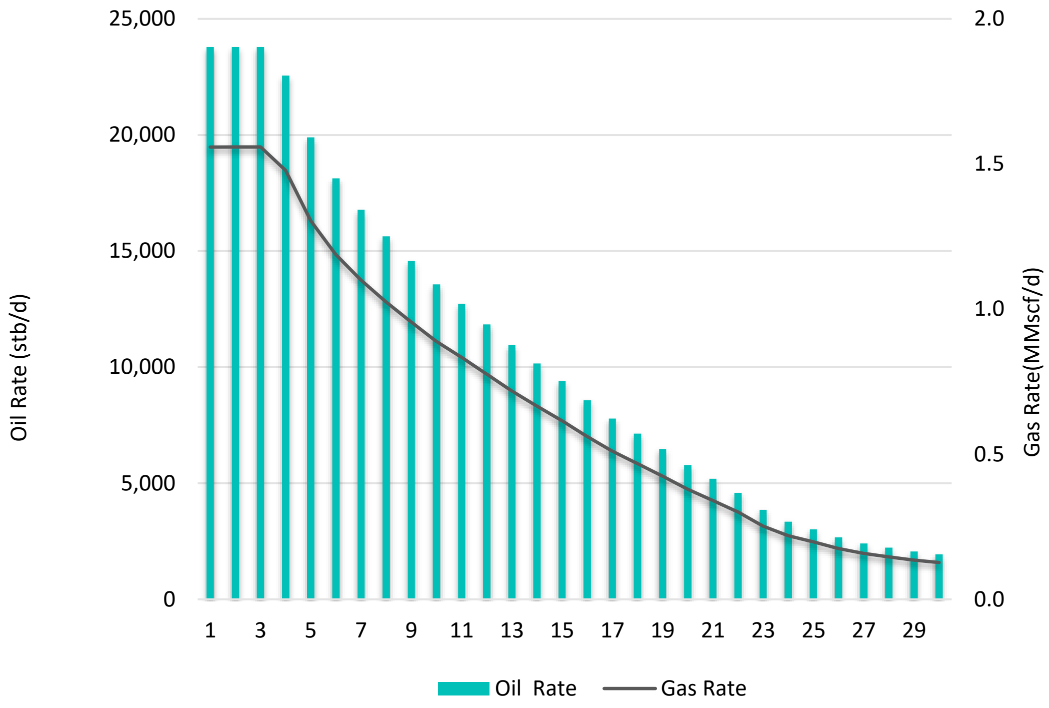


Figure 4-6 Amulet Hydrocarbon Monthly Production Forecast (at the wellhead) – Best Estimate (P50)

Table 4-8 Range of Potential Gas Production

Parameter	Best Estimate (P50)	High Estimate (P10)
Plateau oil production rate (bbl/d)^	25,000	25,000
Gas-Oil-Ratio or GOR (scf/bbl)^	64	64
Peak Gas Production (MMscf/d)	1.6	1.6
Duration of plateau production (months)	6	8
Total Gas Production (Bcf)*	**0.65**	**0.94**
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. All options were considered as standalone and as a possible combination with other options. For ease of understanding and comprehension of the assessment each option is presented here individually.

For ease of understanding and comprehension of the assessment, each option is presented here individually. The net GHG emissions for each option have been calculated using the most conservative P10 basis, shown in Table 4-9. Option 1 – Fuel gas can be combined with all other options and aggregates the GHG reduction – i.e. if used in combination, Option 1 – Fuel gas would provide an additional 0.1 MT CO_2-e reduction for each option.

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). • This option would offset the use of liquid fuels such as diesel and reduce emissions from the facility to a maximum of ~0.1 MT CO_2-e (P10).
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 Amulet to the existing onshore gas treatment facilities near Onslow (~130 km of offshore pipeline) ○ or tieback to an existing trunkline (~40/60 km to the Angel/Okha Facilities). • If feasible, export of associated gas would reduce emission by a maximum of ~0.06 MT CO_2-e (P10).
3	**Reinject gas to reservoir**	• Gas could be reinjected to the producing oil and gas reservoir formation. It would be injected into the underlying Legendre formation. The Legendre is directly below the Amulet reservoir but separated by a reasonable shale so will not communicate with the Amulet wells. It is also very good quality and a large volume. A separate well would be a vertical well, drilled from the MOPU. It would require high compression to push against a reasonably high pressure. • Includes the installation and operation of additional facilities on the MOPU (including power generation, gas treatment, high-pressure gas compression, injection facilities) and construction of a gas injection well. • This option also requires a substantial upgrade to the systems on the MOPU facilities to cope with high-pressure gas injection system on the topsides. • If technically feasible, reinjection of associated gas would reduce emission by a maximum of ~0.06 MT CO_2-e (P10).
4	**Flare**	• Excess 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 54 months. • Flaring would peak at 1.2 MMscf/d (allowing for fuel gas usage) during the initial 6–9 months of production, then decline as the reservoir depletes. Atmospheric emissions of up to 0.1 MT CO_2-e.
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). • The power export requires installing a subsea cable to shore. Onshore switchgear is required to tie into the electricity network.

Option		Description
		• This option would not reduce CO_2 emissions from the MOPU facility, but if feasible may offset a maximum of ~0.06 MT CO_2-e (P10) of emissions from power generation facilities utilising other fuel sources.
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 into an existing natural gas pipeline. • CNG if feasible could reduce CO2 emissions by a maximum of ~0.06 MT CO_2-e over the life of the project (P10). • Mini-LNG (with feed of ~1 MMscf/d) if feasible could reduce emissions by a maximum of ~0.04 MT CO_2-e over the life of the project (P10).
7	**Carbon Capture and Storage (CCS)**	• CCS requires the offshore capture or exhaust gases, removal, treatment, compression and export of compressed separated carbon dioxide gas to a dedicated CO2 pipeline and disposal facilities either at the MOPU or export and disposal to a third party. • If technically feasible CCS could remove emissions from heat and power fired equipment would reduce emission by a maximum of ~0.1 MT CO_2-e (P10).

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 Amulet 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 Amulet gas.
- Recent studies of CNG have identified safety issues which deem the technology currently infeasible for the Amulet project.

Option 7 – Carbon Capture and storage is not considered further for these reasons:

- No technology exists to capture exhaust emissions from a flare system (the main source of carbon emissions from the facility).

- Carbon capture and storage equipment for capturing and treating exhaust emissions from the MOPU fired equipment would require a large amount of process equipment exceeding the weight and space allowance of the MOPU.
- Given the above CCS is not considered technically feasible for the Amulet project.
- Not economic due to short project life, cost of additional CCS infrastructure. The best or low estimate for production profile would have to be assumed, as a worst-case scenario.

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 Amulet Development.

Project drivers were assessed using the process and criteria described in Section 4.1.2.

Table 4-10 provides the comparative assessment of criteria for each option. A subtotal of the qualitative score is given for environmental criteria, all other project drivers, and a total for all drivers; with the lowest score giving the best outcome.

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*	
Environmental										
Seabed disturbance	1	No additional seabed disturbance	3	~40/60 km length 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	~130 km length 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	Minor short-term localised impact associated with additional time for the MODU (and spread) to drill the gas disposal well. 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 injection compressor discharge piping	1	No additional underwater noise	1	No additional underwater noise

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*	
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 MMscf/d. Reduction in emissions of ~0.1 MT CO_2-e compared to flaring 100% of gas.	1	Low level of incremental CO2-e emissions from additional power generation associated with gas compression. Gas utilised via pipeline network. ~0.03 MT CO_2-e embodied emissions in pipeline. Reduction in emissions of ~0.06 MT CO_2-e when compared to flaring 100% of gas.	2	Low level of CO2-e emissions from additional time for the MODU (and spread) to drill the gas disposal well. Low-level incremental CO2-e emissions from additional power generation associated with gas compression. Gas is not used. Reduction in emissions of ~0.06 MT CO_2-e when compared to flaring 100% of gas.	3	Moderate level of CO2-e emissions from burning associated reservoir gas during operations. Atmospheric emissions of up to 0.1 MT CO_2-e. Gas is not used.	2	Some additional power generation associated with gas compression. Gas used via pipeline network. No reduction in emissions compared to flaring 100% of gas. Potential to offset ~0.06 MT CO_2-e of other facility emissions.
Light emissions	1	No additional light emissions	1	No additional light emissions	1	Minor short-term localised impact to light emissions associated with additional time for the MODU (and spread) to drill the gas disposal well.	2	Light emissions associated with continuous flaring. Near field incremental light increase not measurable outside of 8.3 km. Flare visible as a light low on the horizon up to 32.3 km away. (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

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***	
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.
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 additional time for the MODU (and spread) to drill the gas disposal well and the gas compression. Minor localised light 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.
Subtotal - Environment	9		15		15		14		14	
Economic										

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*	
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 Amulet gas is grossly disproportionate to the potential financial reward of processing the gas. 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 (e.g. compression equipment) and modifications required. Additional well required. Schedule delay ~6 months	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 and any offsets required under the Safeguard Mechanism.	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. Reduction in OPEX associated with reduction in offsets required under the Safeguard Mechanism.	4	Not economic due to short project life, cost of additional well and small volumes of gas. Injection well and compression equipment is the majority of the cost. Reduction in OPEX associated with reduction in offsets required under the Safeguard Mechanism.	1	Low capital cost as this option utilises the existing flare. Additional OPEX associated with offsets required under the Safeguard Mechanism.	4	Not economic due to short project life, cost of export cable and small volumes of gas. There is no potential market within range (<100 km). Reduction in OPEX associated with reduction in offsets required under the Safeguard Mechanism.

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*	
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	Relocation 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 (injection pressure)	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.	2	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.
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.	2	Gas injection is a feasible technology. Additional equipment will introduce space and weight demands on MOPU concept, potentially requiring additional strengthening or compromise on other equipment.	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.

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*	
Technical readiness	1	No significant novelty	1	No significant novelty	1	No significant novelty	1	No significant novelty	3	Some novel components for power export and long-distance subsea power cable. Distance is technical stepout.
Constructability **Re-useability** **Decommissioning Feasibility**	1	Re-deployable with MOPU in line with KATO development strategy of honeybee production system.	4	Not re-deployable. Site-specific. More difficult to decommission.	3	Some components re-deployable with MOPU in line with honeybee production system concept. 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 in line with honeybee production system concept. Additional export cable required at each site. More difficult to decommission.
Social										
Socioeconomic impacts	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	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
Subtotal – Other Drivers	11		27		20		11		25	

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*
Total – All Project Drivers	20	42	35	25	39

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

Option 1 – Fuel gas avoids the greatest amount of GHG emissions, in comparison to flaring the entire amount. Option 2 – Export via pipeline and Option 3 – Reinject gas to reservoir avoid are next with 0.06 MT CO_2-e), followed by Option 5 – Gas to wire. In comparison, Option 4 – Flaring of excess associated gas would emit 1.1 MT CO_2-e for project life (Appendix C).

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. However, the qualitative ranking against all other criteria shows that Option 2 – Export via pipeline and Option 5 – Gas to Wire have the 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 is not feasible without installing further infrastructure.

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

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. Construction of a new pipeline is not economic for such a short duration of gas production (between 1.5 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 Amulet gas 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 to pose too great a risk in terms of technical feasibility and safety; due to the addition of high-pressure gas onto the MOPU. Drilling of an additional well introduces substantial increased risks associated with a loss of well control. These impacts and risks are not considered commensurate with the relatively small volumes of gas that may be flared (after fuel gas usage).. The Legendre formation is directly below the Amulet reservoir and separated by a reasonable shale. The well would be a vertical well, drilled from the MOPU. High pressure compression would be necessary to push against a reasonably high pressure, adding complexity and safety hazards. However, more broadly, the increased risks associated with a loss of well control from drilling an additional well is substantial. There are also incremental increased atmospheric and light emissions associated with additional time for the MODU (and spread) and operation of the additional facilities. These impacts and risks are not considered commensurate with the small volumes of gas that may be flared (after fuel gas usage). This option is uneconomic due to short project life, cost of additional well and gas compression equipment.
- 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). No market identified for the electricity within 100 km.

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. 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.

However, gas generated from oil production will exceed 0.5 MMscf/d fuel gas demand in the initial stages of production; 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.

KATO concluded that there were no technically and commercially feasible options for commercialisation of the associated gas, as the volumes are too small.

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 ~0.1 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 60 ML of diesel, which is equivalent to 3.5 days of diesel use emissions from Western Australia (DoEE 2018f).

Flaring during initial peak operations, may be visible on the horizon up to 32.3 km from the MOPU, and is predicted to have no measurable change to ambient light levels beyond 8.3 km from the MOPU (refer to Section 7.1.3). The visible and measurable change in light from flaring reduce over the life of the project as the flare rate decreases (Section 7.1.3).

4.3.2 Talisman Field Development

The Talisman reservoir is located ~3.5 km from the proposed MOPU location, which is adjacent to the Amulet field. Alternatives were considered as to how to tie-in Talisman back to the MOPU. Two options for the tie-in methodology were identified:

- **Option 1 – Subsea tieback system from Talisman to the MOPU:** A MODU or the MOPU with drilling capabilities will drill and install the Talisman subsea production well/s, control system and gathering system. This option involves the mobilisation of the drilling facility to the Talisman field, drilling, and installation of subsea production trees, a manifold and jumper connections, and installation of a ~3.5 km production flowline and service umbilical from Talisman to the MOPU. Well fluids are exported via a flowline and riser system to the MOPU at Amulet where the well fluids are processed as normal.
- **Option 2 – Extended reach deviated well/s from the MOPU:** Extended reach well/s may be drilled through the conductor deck of the MOPU in a similar manner to the Amulet wells. These extended reach wells are drilled on an angle, once they are below the seafloor, and will extend the ~3.5 km from the MOPU to the Talisman reservoir. As per the Amulet wells, these wells will each have a 'dry tree' located on the MOPU conductor deck.

Both options were considered feasible alternatives and carried over into the comparative assessment.

Project drivers were assessed using the process and criteria described in Section 4.1.2. Table 4-11 provides the comparative assessment of criteria for each option. A subtotal of the qualitative score is given for environmental criteria, all other project drivers, and a total for all drivers; with the lowest score giving the best outcome.

Table 4-11 Comparative Assessment Against all Project Drivers for Talisman Field Development Options

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – Subsea tieback system		*Option 2 – Extended reach deviated well/s*	
Environmental				
Seabed Disturbance	3	Additional seabed footprint associated with the physical footprint of drilling on location at Talisman (~1,500 m^2). Additional footprint from installation of subsea infrastructure and tieback components (subsea production trees, manifold, jumpers and ~3.5 km production flowline and service umbilical). Total additional footprint of subsea tieback system ~0.055 km^2 (including 50% contingency).	1	Minimal additional seabed footprint, as there is no additional infrastructure installed on the seabed. Incremental increase in extended reach well drill cuttings.
Interaction with marine fauna	2	Additional MODU and support vessel movements required for drilling of subsea well and installation of subsea equipment.	1	No additional MODU movements, incremental increase in support vessel movements during drilling of additional well.
Emissions - Noise	1	Same duration of noise during drilling, with emissions occurring at the Talisman location, instead of all from Amulet.	1	No additional impacts identified.
Emissions - Atmospheric	1	Minimal additional emissions from short-term additional support vessels.	1	Minimal additional emissions associated with the slightly longer drilling time (extended reach wells).
Emissions - Light	2	Minor offshore impacts associated with physical presence of additional support vessels during installation and decommissioning of subsea infrastructure, and MODU during drilling.	1	No additional impacts identified.
IMS	1	No difference identified between options. MODU and support vessel/s already present in Project Area.	1	No difference identified between options.
Planned discharges	2	Subsea well control system will discharge very small volumes of subsea control fluid/hydraulic fluid. Commissioning of the 3.5 km Talisman production flowline requires an additional ~130 m^3 inhibited seawater discharged to sea; and during decommissioning. Additional source of drilling discharges (fluid, cuttings, cement) at the Talisman location. Installation of the additional subsea infrastructure means additional support vessels are required, with associated vessel discharges.	1	Incremental increase in well drill cuttings associated with extended reach drilling. Using a 'dry tree' on the MOPU means no planned subsea discharges.
Unplanned discharges / Accidental Releases	4	High risk associated with drilling loss of containment. Additional support vessels in field, posing slightly higher risk of vessel loss of containment.	4	High risk associated with drilling loss of containment.

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – Subsea tieback system		*Option 2 – Extended reach deviated well/s*	
Lifecycle environmental impacts	3	Drilling of the wells at Talisman means an additional location of drilling discharges, and greater seabed disturbance from subsea infrastructure. Option has greater environmental impact during installation, and decommissioning; and poorer lifecycle outcomes. Subsea tieback components are not re-useable.	1	No additional risk. No additional infrastructure to install or decommission.
Subtotal - Environment	**19**		**12**	
Economic				
Schedule risk	2	Subsea components to fabricate and install resulting in additional complexity and time	1	No additional impact identified
Economic viability	2	Economic concept. Higher CAPEX option with added components and complexity.	1	Economic concept. Lower CAPEX and less components. Cost risks shifts from infrastructure to drilling risk.
Future flexibility risk	2	Subsea tieback components are not re-useable.	1	No additional impact identified.
Technical Feasibility and Safety				
Safety risk	1	Additional well head located subsea marginally reduces safety risk.	1	Additional well head on MOPU adds incremental safety risk.
Operability and feasibility risk	1	No major feasibility issues. Additional topsides control equipment required for subsea well control systems	1	No major feasibility issues, all systems in place for Amulet wells.
Technical readiness	1	Technically Feasible	3	Technical feasibility of the option to be confirmed during FEED. Likely to be technically feasible.
Constructability **Re-useability** **Decommission-ing Feasibility**	2	Additional components (flowlines, umbilical, risers) may not be required in future development.	1	Fully re-useable
Social				
Socioeconomic impacts	2	There will be an additional exclusion zone and cautionary zone around Talisman during drilling (in addition to around the MOPU).	1	No difference identified between options.
Reputation	1	No difference identified between options.	1	No difference identified between options.
Subtotal – Other Drivers	**14**		**11**	
Total – All Project Drivers	**33**		**23**	

The comparative environmental assessment shows that the most favourable option environmentally is Option 2 – Extended reach deviated well/s. The key differentiators were seabed disturbance, lifecycle environmental impacts and planned discharges.

The comparative assessment of the other project drivers (economic, technical feasibility and safety and social) shows that Option 2 – Extended reach deviated well/s.

The total qualitative ranking score for each concept against the all assessment drivers and criteria (including environmental criteria) shows that Option 2 – Extended reach deviated well/s is ranked significantly better than Option 1 – Subsea tieback system (23 compared to 33).

The preferred option is Option 2 – Extended reach deviation wells from the MOPU. However, whist KATO have a high confidence that the extended reach Talisman wells can be drilled from the proposed MOPU location, a significant amount of geomechanics study is required to confirm technical and commercial feasibility, which will not be completed until FEED.

As such, extended reach drilling may not be proven technically feasible, and Talisman may be developed using the subsea alternative, tied back to the MOPU.

Both options are selected to carry through to FEED. As Option 1 – Subsea tieback system presents the greater potential environmental impact, this has been used as the basis for impact assessment in Section 7.

4.3.3 Talisman Well Intervention Methodology

If the subsea tieback option is selected for Talisman, and if well intervention is required on the Talisman wells during operations, this equipment would be required at the Talisman subsea well locations.

Although the MOPU has well intervention capability, it would be very unlikely to disconnect and relocate to the Talisman location during project life. Therefore, a separate facility would likely be needed to conduct well intervention at Talisman (if this non-routine activity is required).

Two options were considered for Talisman well intervention:

- **Option 1 – ISV with well intervention package:** An ISV with a well intervention package and appropriate capability (e.g. a large moon pool).
- **Option 2 – Separate MODU**: A separate MODU would be towed by 2-3 AHTs, and jack-down on location (described in Section 3.4.2.1).

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

Project drivers were assessed using the process and criteria described in Section 4.1.2. Table 4-13 provides the comparative assessment of criteria for each option. A subtotal of the qualitative score is given for environmental criteria, all other project drivers, and a total for all drivers; with the lowest score giving the best outcome..

Table 4-12 Comparative Assessment Against all Project Drivers for Talisman Well Intervention Options

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – ISV with well intervention package		*Option 2 – MODU*	
Environmental				
Seabed Disturbance	1	No additional seabed disturbance	2	Additional seabed disturbance due to positioning of MODU on seabed (1,500 m^2).
Interaction with marine fauna	1	No real difference identified between options. One additional vessel (ISV).	1	Additional incremental vessel-related movements (MODU and 1-2 AHTs).

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – ISV with well intervention package		*Option 2 – MODU*	
Emissions - Noise	1	No real difference identified between options. One additional vessel (ISV). Short-term (~1 month).	1	Additional incremental noise (MODU and 1-2 AHTs). Short-term (~1 month).
Emissions - Atmospheric	1	No real difference identified between options. One additional vessel (ISV). Short-term (~1 month).	1	Additional incremental atmospheric emissions (MODU and 1-2 AHTs). Short-term (~1 month).
Emissions - Light	1	Height of facility lighting on an ISV is lower than a MODU, and visible for a lesser distance.	2	MODU has the tallest source of light (derrick), extending the visible light area around the Talisman location (~12.6 km). There are no islands or sensitive habitat within this area. Short-term (~1 month).
IMS	1	No difference identified between options.	1	No difference identified between options.
Planned discharges	1	Discharges from one vessel only (60 POB). Short-term (~1 month).	1	Additional incremental vessel-related discharges from the MODU and 1-2 AHTS (total of 160 POB). Short-term (~1 month).
Unplanned discharges / Accidental Releases	1	Only requires one additional vessel in the field.	2	More support vessels in the field and the larger diesel storage capacity on the MODU pose a slightly greater risk from vessel collision.
Lifecycle environmental impacts	1	No difference identified between options.	1	No difference identified between options.
Subtotal - Environment	9		12	
Economic				
Schedule risk	1	Similar availability schedule risk for both options, dependent on availability at time of intervention.	1	Similar availability schedule risk for both options, dependent on availability at time of intervention.
Economic viability	1	Likely lowest cost option, dependent on availability and mobilisation cost.	2	Likely higher cost option, dependent on whether rig of opportunity available (no mobilisation fee).
Future flexibility risk	1	No difference identified between options.	1	No difference identified between options.
Technical Feasibility and Safety				
Safety risk	1	No difference identified between options.	1	No difference identified between options.
Operability and feasibility risk	1	No difference identified between options.	1	No difference identified between options.
Technical readiness	1	No difference identified between options.	1	No difference identified between options.

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – ISV with well intervention package		*Option 2 – MODU*	
Constructability **Re-useability** **Decommission-ing Feasibility**	1	No difference identified between options.	1	No difference identified between options.
Social				
Socioeconomic impacts	1	No difference identified between options.	1	No difference identified between options.
Reputation	1	No difference identified between options.	1	No difference identified between options.
Subtotal – Other Drivers	**9**		**10**	
Total – All Project Drivers	**18**		**22**	

The comparative environmental assessment shows that Option 1 – ISV with well intervention package is ranked slightly better than Option 2 – MODU, due to seabed disturbance, light and accidental release.

The comparative assessment of the other project drivers (economic, technical feasibility and safety and social) shows that there is no real differentiator between the two options.

The total qualitative ranking score for each concept against the all assessment drivers and criteria (including environmental criteria) shows that Option 1 – ISV with well intervention package is ranked slightly better than Option 2.

Further design and engineering work are required to understand the benefits and cost of each option. Therefore, the decision for selection of well intervention methodology will be based on technical feasibility, safety and cost as evaluated at the planning stage for the well intervention (if required).

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

4.3.4 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 PFW 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.

Project drivers were assessed using the process and criteria described in Section 4.1.2. Table 4-13 provides the comparative assessment of criteria for each option. A subtotal of the qualitative score is given for environmental criteria, all other project drivers, and a total for all drivers; with the lowest score giving the best outcome.

Table 4-13 Comparative Assessment Against all Project Drivers for PFW Disposal Options

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – Reinjection		*Option 2 – Discharge to Ocean*	
Environmental				
Seabed Disturbance	1	Minor impact associated with drilling cuttings for additional well.	1	No impact: No subsea infrastructure
Interaction with marine fauna	2	Presence of MODU and support vessel/s for longer duration, to drill additional well.	1	No additional risk.
Emissions - Noise	1	Minor increase in noise emissions from drilling of an additional well, and presence of support vessel/s.	1	No additional risk.
Emissions - Atmospheric	2	Produced water reinjection requires significant additional power generation and associated air emissions.	1	Minimal additional power requirements
Emissions - Light	1	No difference identified between options.	1	No difference identified between options.
IMS	1	No difference identified between options. MODU/MOPU and support vessel/s already present in Project Area.	1	No difference identified between options.
Planned discharges	1	Minor emissions from drilling of a disposal well. No produced formation water discharges.	3	Localised temporary impact associated with discharge of produced formation 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.
Lifecycle environmental impacts	3	Drilling of an additional well means greater environmental impact during installation, and poorer lifecycle outcomes, as well components are not re-useable, and there are additional risks during P&A.	1	No additional risk. No additional infrastructure to install or decommission.
Subtotal - Environment	**16**		**12**	
Economic				
Schedule risk	3	Reinjection poses the potential need for remedial actions including additional topsides treatment facilities, and potentially additional well interventions and/or early cessation of production – all of which have schedule implications.	1	No additional schedule risk identified. does not require additional subsea equipment or wells.

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – Reinjection		*Option 2 – Discharge to Ocean*	
Economic viability	4	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.	1	Has a significantly lower capital cost to reinjection.
Future flexibility risk	3	Injection well is not relocatable, and would have to be decommissioned.	1	No risk to future flexibility. Aligns with the design philosophy of Concept 1 – Honeybee production system, allowing for redeployment at the next field.
Technical Feasibility and Safety				
Safety risk	2	Additional safety risk of drilling an additional well.	1	No additional risk.
Operability and feasibility risk	2	Reinjection of PFW into the production reservoir poses additional risks to reservoir integrity, oil production and the potential need for remedial actions, and risk from drilling an additional well.	1	No additional risk.
Technical readiness	2	Standard practice and readily deployed design in industry.	1	Standard practice and readily deployed design in industry. No additional equipment or wells.
Constructability **Re-useability** **Decommission-ing Feasibility**	3	Injection well is not relocatable, and would have to be decommissioned.	1	No additional risk. Aligns with relocatable honeybee production system concept.
Social				
Socioeconomic impacts	1	No difference identified between options.	1	No difference identified between options.
Reputation	1	No difference identified between options.	2	Public may consider discharge to ocean is the least preferred option due to perceived environmental impacts.
Subtotal – Other Drivers	**21**		**10**	
Total – All Project Drivers	**37**		**22**	

The comparative environmental assessment shows that Option 1 – Reinjection is ranked lower than Option 2 – Discharge to ocean, due to the introduced risks from drilling and P&A'ing an additional well (Table 4-13).

The comparative assessment of the other project drivers (economic, technical feasibility and safety and social) shows that Option 1 – Reinjection is ranked significantly worse than Option 2 – Discharge to ocean (21 compared to 10), due to the economics, increased safety risks, and worse lifecycle outcomes

PFW reinjection eliminates discharge into the marine environment, however 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.

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

The total qualitative ranking score for each concept against the all assessment drivers and criteria (including environmental criteria) shows that Option 2 – Discharge to ocean is ranked significantly better than Option 1 – Reinjection (22 compared to 37).

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.

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

Two options for the drilling facilities were considered:

- **Option 1 – MOPU 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**: 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.

Project drivers were assessed using the process and criteria described in Section 4.1.2. Table 4-14 provides the comparative assessment of criteria for each option. A subtotal of the qualitative score is given for environmental criteria, all other project drivers, and a total for all drivers; with the lowest score giving the best outcome.

Table 4-14 Comparative Assessment Against all Project Drivers for Drilling Facility Options

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – MOPU with Drilling capability		*Option 2 – MOPU and separate MODU*	
Environmental				
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 (~3,000 m^2).
Interaction with marine fauna	1	No additional risk identified.	1	Involves mobilisation of separate MODU and support vessel/s, with potential for fauna interaction; however, as the MODU is under tow, speed is slow.

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – MOPU with Drilling capability		*Option 2 – MOPU and separate MODU*	
Emissions - Noise	1	No additional risk identified.	1	Minor additional noise emissions from the operation of the MODU during drilling (5 to 9 months).
Emissions - Atmospheric	1	No additional risk identified.	1	Minor additional atmospheric emissions from the operation of the MODU during drilling (5 to 9 months).
Emissions - Light	1	No difference identified between options. Height of MOPU and MODU facility lighting are assumed to be the same.	1	No difference identified between options. Height of MOPU and MODU facility lighting are assumed to be the same.
IMS	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.
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 would only be at the Project Area during drilling (~5 months, and possibly an additional 4 months if infill drilling is required).
Unplanned discharges / Accidental Releases	4	High risk associated with drilling loss of containment.	4	High risk associated with drilling loss of containment.
Lifecycle environmental impacts	1	No difference identified between options.	1	No difference identified between options.
Subtotal – Environment	**13**		**14**	
Economic				
Schedule risk	2	No difference identified between options. Schedule risk aligning drilling contractor (for personnel) to operate MOPU rig with MOPU delivery into field and the obtaining associated drilling regulatory documentation (safety case and EP).	2	No difference identified between options. Schedule risk aligning mobilisation of MOPU and MODU to field at the same time. Mitigation using mud-line suspension technology.
Economic viability	2	No difference identified between options. Higher initial cost to customise MODU. Higher risk of increasing costs due infrequent use of the MOPU drilling equipment due to 'downtime' and reduced efficiency.	2	No difference identified between options. Increased cost due to mobilisation of an additional facility, likely offset against a familiar and efficient drilling contractor.
Future flexibility risk	1	No difference identified between options.	1	No difference identified between options.
Technical Feasibility and Safety				

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – MOPU with Drilling capability		*Option 2 – MOPU and separate MODU*	
Safety risk	3	Less conventional methodology and short duration campaign increases likelihood of safety related issues due to the lack of familiarity with the team and equipment.	1	Separate contracted MODU conventional drilling methodology in NWS. No foreseen additional safety risk over normal
Operability and feasibility risk	3	Less conventional methodology. Increased risk obtaining regulatory approvals to proceed (Safety Case) and obtaining competent crew for short duration campaign.	1	Separate contracted MODU, conventional drilling methodology in NWS. No foreseen operability or feasibility risk over normal.
Technical readiness	1	No difference identified between options. MOPU drilling has slight increase in risk since equipment not frequently used.	1	No difference identified between options. MODU drilling equipment more routinely maintained.
Constructability **Re-useability** **Decommission-ing Feasibility**	1	No difference identified between options. MOPU drilling equipment re-used next field. P&A by MOPU both options.	1	No difference identified between options. MODU drilling equipment re-used next customer. P&A by MOPU both options.
Social				
Socioeconomic impacts	1	No difference identified between options.	1	No difference identified between options.
Reputation	1	No difference identified between options.	1	No difference identified between options.
Subtotal – Other Drivers	**15**		**11**	
Total – All Project Drivers	**28**		**25**	

The comparative environmental assessment shows that there is no significant environmental differentiator between the two alternatives. The comparative assessment of the other project drivers (economic, technical feasibility and safety and social) shows that Option 1 is ranked slightly worse than Option 2 (15 compared to 11), primarily due to the less conventional and short duration nature of the drilling campaign associated with Option1, and the associated increased safety risks, operability and feasibility risks.

The total qualitative ranking score for each concept against the all assessment drivers and criteria (including environmental criteria) shows that Option 2 is ranked slightly better than Option 1.

The total qualitative ranking score for each concept against the all assessment drivers and criteria (including environmental criteria) shows that Option 2 is ranked slightly better than Option 1.

Further design and engineering work are required to understand the benefits and cost of each option. The decision for selection of drilling facility will be based on technical feasibility, safety and cost as evaluated in FEED.

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.

4.3.6 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 Amulet and ensuring hole stability when deviated hole drilling.

Project drivers were assessed using the process and criteria described in Section 4.1.2. Table 4-15 provides the comparative assessment of criteria for each option. A subtotal of the qualitative score is given for environmental criteria, all other project drivers, and a total for all drivers; with the lowest score giving the best outcome.

Table 4-15 Comparative Assessment Against all Project Drivers for Drilling Fluid Options

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – WBM		*Option 2 – SBM*	
Environmental				
Seabed Disturbance	2	Cuttings likely to accumulate in piles with local disturbance. Some components of WBMs may have a long half-life in the environment.	3	Cuttings likely to accumulate in piles with local disturbance. Some components of SBMs are known to have a long half-life in the environment.
Interaction with marine fauna	1	No difference identified between options.	1	No difference identified between options.
Emissions - Noise	1	No difference identified between options.	1	No difference identified between options.
Emissions - Atmospheric	1	No difference identified between options.	1	No difference identified between options.
Emissions - Light	1	No difference identified between options.	1	No difference identified between options.
IMS	1	No difference identified between options.	1	No difference identified between options.

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – WBM		*Option 2 – SBM*	
Planned discharges	1	Some components of WBMs likely to be of low to moderate toxicity and persistent in the marine environment.	2	Some components of SBMs likely to be of moderate toxicity and persistent in the marine environment.
Unplanned discharges / Accidental Releases	1	No difference identified between options.	1	No difference identified between options.
Lifecycle environmental impacts	1	No difference identified between options.	1	No difference identified between options.
Subtotal - Environment	**10**		**12**	
Economic				
Schedule risk	1	No difference identified between options.	1	No difference identified between options
Economic viability	1	No difference identified between options.	1	No difference identified between options.
Future flexibility risk	1	No difference identified between options.	1	No difference identified between options.
Technical Feasibility and Safety				
Safety risk	1	No difference identified between options.	1	No difference identified between options.
Operability and feasibility risk	1	Standard practice and readily deployed design in industry. No difference identified between options.	1	Standard practice and readily deployed design in industry. No difference identified between options.
Technical readiness	1	Standard practice and readily deployed design in industry. No difference identified between options.	1	Standard practice and readily deployed design in industry. No difference identified between options.
Constructability **Re-useability** **Decommission-ing Feasibility**	1	No difference identified between options.	1	No difference identified between options.
Social				
Socioeconomic impacts	1	No difference identified between options.	1	No difference identified between options.
Reputation	1	No difference identified between options.	1	No difference identified between options.
Subtotal – Other Drivers	**9**		**9**	

Criteria	Evaluated Options – Qualitative Ranking and Justification	
	Option 1 – WBM	*Option 2 – SBM*
Total – All Project Drivers	**19**	**21**

The comparative assessment shows that there is no significant environmental differentiator between the two alternatives, though Option 1 – WBM have a slightly better ranking.

The comparative assessment of the other project drivers (economic, technical feasibility and safety and social) shows that the ranking of both options is similar (both ranked 9).

The total qualitative ranking score for each concept against the all assessment drivers and criteria (including environmental criteria) shows that Option 1 – WBM is ranked slightly better than Option 2 – SBM (19 compared to 21).

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.

4.3.7 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 from 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 to the second shuttle tanker (including oil in the buffer holding tank) until its cargo tanks are full and the above process is repeated. A shuttle tanker will stay on location for the duration; and will swap out with the next shuttle tanker once full.

As both oil export strategy alternatives are technically feasible a comparative assessment has been undertaken.

Project drivers were assessed using the process and criteria described in Section 4.1.2. Table 4-16 shows the comparative assessment of the alternatives. A subtotal of the qualitative score is given for environmental criteria, all other project drivers, and a total for all drivers; with the lowest score giving the best outcome.

Table 4-16 Comparative Assessment Against all Project Drivers for Oil Export Strategy Options

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – FSO and Export tankers		*Option 2 – Shuttle Tankers*	
Environmental				
Seabed Disturbance	1	No impact: No subsea infrastructure	1	No impact: No subsea infrastructure
Interaction with marine fauna	1	One vessel movement per cargo. No difference identified between options.	1	One vessel movement per cargo. No difference identified between options.

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – FSO and Export tankers		*Option 2 – Shuttle Tankers*	
Emissions - Noise	1	No difference identified between options.	1	No difference identified between options. There will likely always be a shuttle tanker on location.
Emissions - Atmospheric	1	No difference identified between options. The FSO will not be DP, but may be under power to keep tension on the hawser.	1	No difference identified between options. Shuttle tankers won't be DP, but may be under power to keep tension on the hawser, while they are on station.
Emissions - Light	1	No difference identified between options.	1	No difference identified between options. There will likely always be a shuttle tanker on location.
IMS	1	One vessel movement per cargo. No difference identified between options.	1	One vessel movement per cargo. No difference identified between options.
Planned discharges	2	The FSO is permanently on location at Amulet, therefore the usual vessel discharges would occur for the production life of 1.5–4.5 years. POB is only ~17–30, so is not significant.	2	No difference identified between options. There will likely always be a shuttle tanker on location, with typical vessel discharges for the duration of production life.
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.
Lifecycle environmental impacts	1	No difference identified between options.	1	No difference identified between options.
Subtotal - Environment	**11**		**11**	
Economic				
Schedule risk	1	No difference identified between options. Slight operational schedule risk if unable to arrange export tanker prior to FSO tank-tops requiring a production shut-in.	1	No difference identified between options. Slight operational schedule risk if 2nd shuttle delayed and 1st shuttle tanker reaches tank-tops requiring a production shut-in.
Economic viability	1	No difference identified between options. Requires more detailed assessment during FEED.	1	No difference identified between options. Requires more detailed assessment during FEED.
Future flexibility risk	1	No difference identified between options.	1	No difference identified between options.
Technical Feasibility and Safety				
Safety risk	1	Option only requires connection/disconnection from the CALM during cyclone event.	1	Requires connection/disconnection from CALM at each lifting.
Operability and feasibility risk	1	Conventional methodology. Standard on the NWS.	2	Less conventional methodology, introducing some additional operability requirements.
Technical readiness	1	Standard practice and readily deployed design in industry.	1	Whilst less conventional methodology, technically feasibility is similar– just requires more connections and disconnections to/from the CALM.

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 1 – FSO and Export tankers		*Option 2 – Shuttle Tankers*	
Constructability **Re-useability** **Decommission-ing Feasibility**	1	FSO is re-usable	1	Shuttle Tankers is re-usable
Social				
Socioeconomic impacts	1	No difference identified between options.	1	No difference identified between options.
Reputation	1	No difference identified between options.	1	No difference identified between options.
Subtotal – Other Drivers	9		10	
Total – All Project Drivers	20		21	

The comparative assessment shows that there is no significant environmental differentiator between the two alternatives. As a shuttle tanker will be on station until changeover with the next shuttle tanker, there is no real difference between the presence of an FSO or shuttle tanker for the operations phase, and typical vessel-related impacts.

The comparative assessment of the other project drivers (economic, technical feasibility and safety and social) shows that Option 2 is ranked slightly worse than Option 1, due to the less conventional methodology proposed.

The total qualitative ranking score for each option against the all assessment drivers and criteria (including environmental criteria) shows that Option 1 is ranked slightly better than Option 2 (20 compared to 21).

Further design and engineering work are required to understand the benefits of each alternative and, 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 is the base case, this has been used as the basis for impact assessment in Section 7. It is also the base case.

4.3.8 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 Amulet 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.

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

Project drivers were assessed using the process and criteria described in Section 4.1.2. Table 4-17 provides the comparative assessment of criteria for each option. A subtotal of the qualitative score is given for environmental criteria, all other project drivers, and a total for all drivers; with the lowest score giving the best outcome.

Table 4-17 Comparative Assessment Against all Project Drivers for CALM Buoy Mooring Options

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 3 – Drilled and Grouted Anchor Piles		*Option 4 – Gravity Anchors*	
Environmental				
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.
Interaction with marine fauna	1	No difference identified between options.	1	No difference identified between options.
Emissions - Noise	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.
Emissions - Atmospheric	1	No difference identified between options.	1	No difference identified between options.
Emissions - Light	1	No difference identified between options.	1	No difference identified between options.
IMS	1	One vessel movement per cargo	1	One vessel movement per cargo
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.
Unplanned discharges / Accidental Releases	1	No difference identified between options.	1	No difference identified between options.

Criteria	Evaluated Options – Qualitative Ranking and Justification			
	Option 3 – Drilled and Grouted Anchor Piles		*Option 4 – Gravity Anchors*	
Lifecycle environmental impacts	2	Piles are not relocatable, but the mooring chain would be cut off below the mudline. New piles will need to be drilled and grouted at the next field.	1	Can easily be retrieved when decommissioning, cleaned and re-used at the next field.
Subtotal - Environment	**12**		**10**	
Economic				
Schedule risk	2	Drilling and grouting requires additional works which may impact schedule (drilling capability is required on the ISV). However this is not expected to be significant.	1	No additional risk identified.
Economic viability	1	Drilling and grouting required, minor additional cost.	1	No additional risk identified.
Future flexibility risk	2	Piles are not relocatable. New piles will need to be drilled and grouted at the next field.	1	The whole mooring system can be retrieved and relocated – is aligned with the honeybee production system concept.
Technical Feasibility and Safety				
Safety risk	1	No difference identified between options.	1	No difference identified between options.
Operability and feasibility risk	1	No difference identified between options.	1	No difference identified between options.
Technical readiness	1	Standard practice and readily deployed design in industry.	1	Standard practice and readily deployed design in industry.
Constructability **Re-useability** **Decommission-ing Feasibility**	2	Piles are not relocatable; the mooring line would be cut off below the mudline at decommissioning. New piles will need to be drilled and grouted at the next field.	1	Gravity anchors are recoverable and reusable at the end of field life. Aligned with honeybee production system concept.
Social				
Socioeconomic impacts	1	No difference identified between options.	1	No difference identified between options.
Reputation	1	No difference identified between options.	1	No difference identified between options.
Subtotal – Other Drivers	**12**		**10**	
Total – All Project Drivers	**24**		**20**	

The comparative assessment shows there is no significant environmental differentiator between the two alternatives, although Option 4 – Gravity anchors have a slightly better ranking (10 compared to 12). Gravity anchors have a larger area of seabed disturbance, but drilled and grouted anchor piles have additional planned discharge of drilling cuttings and cement, and a worse lifecycle outcome as they are not relocatable.

The comparative assessment of the other project drivers (economic, technical feasibility and safety and social) shows that Option 1 is ranked worse than Option 2, due to the advantages of being able to re-use the gravity anchors on subsequent fields, and less specialised equipment required (i.e. drilling capability).

The total qualitative ranking score for each option against the all assessment drivers and criteria (including environmental criteria) shows that Option 2 is ranked slightly better than Option 1 due to the advantages of being able to re-use the gravity anchors on subsequent fields.

Further design and engineering work are required to understand the benefits of each alternative and as such the decision for selection of oil export strategy will be based on technical feasibility, safety and cost evaluated further in FEED

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 Environment that may be Affected

The environment that may be affected (EMBA) by the Amulet 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. It is noted that 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 Amulet Development extends approximately from north of Kalbarri to Lagrange Bay (south of Broome), and offshore into and beyond the Commonwealth waters boundary (Figure 5-1). For the purposes of the OPP, the EMBA associated with the Amulet Development has been demarcated into three sub-areas that are used to support impact and risk assessments (Table 5-1, Figure 5-1).

If the subsea tieback option is selected for Talisman field development (see Section 4.3.2), there will potentially be facilities and support vessels undertaking activities above the Talisman field. Therefore, the expected position of the Talisman manifold has been used (in addition to the MOPU at Amulet) as a source of aspects for the relevant buffers in Table 5-1.

Table 5-1 Description of EMBA and Sub-Areas for the Amulet Development

Area	Description
Environment that May Be Affected	
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 outer extent of the EMBA for the Amulet 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. Specifically, 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. This modelled area of exposure was then smoothed and simplified (i.e. additional areas were incorporated, including all coastal areas irrespective of modelling results) to define the outer boundary of the EMBA (Figure 5-1).
Planned Activities Sub-Areas	
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 releases. The Project Area has been defined as a 5 km area extending around the expected position of facilities at Amulet and Talisman[6].
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 12.6 km area extending around the expected position of facilities at Amulet and Talisman.

[6] As the position of the MOPU at Amulet and the manifold at Talisman is indicative only at this stage, the identification of values and sensitivities (including an EPBC protected matters search) was completed using an additional 2 km buffer around the defined Project Area (Appendix A).

Area	Description
Unplanned Activities Sub-Areas	
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 (Amulet 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[7] 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.

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 sub-areas, are described in the following sections.

[7] 150 model simulations were run for the subsea release of Amulet 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).

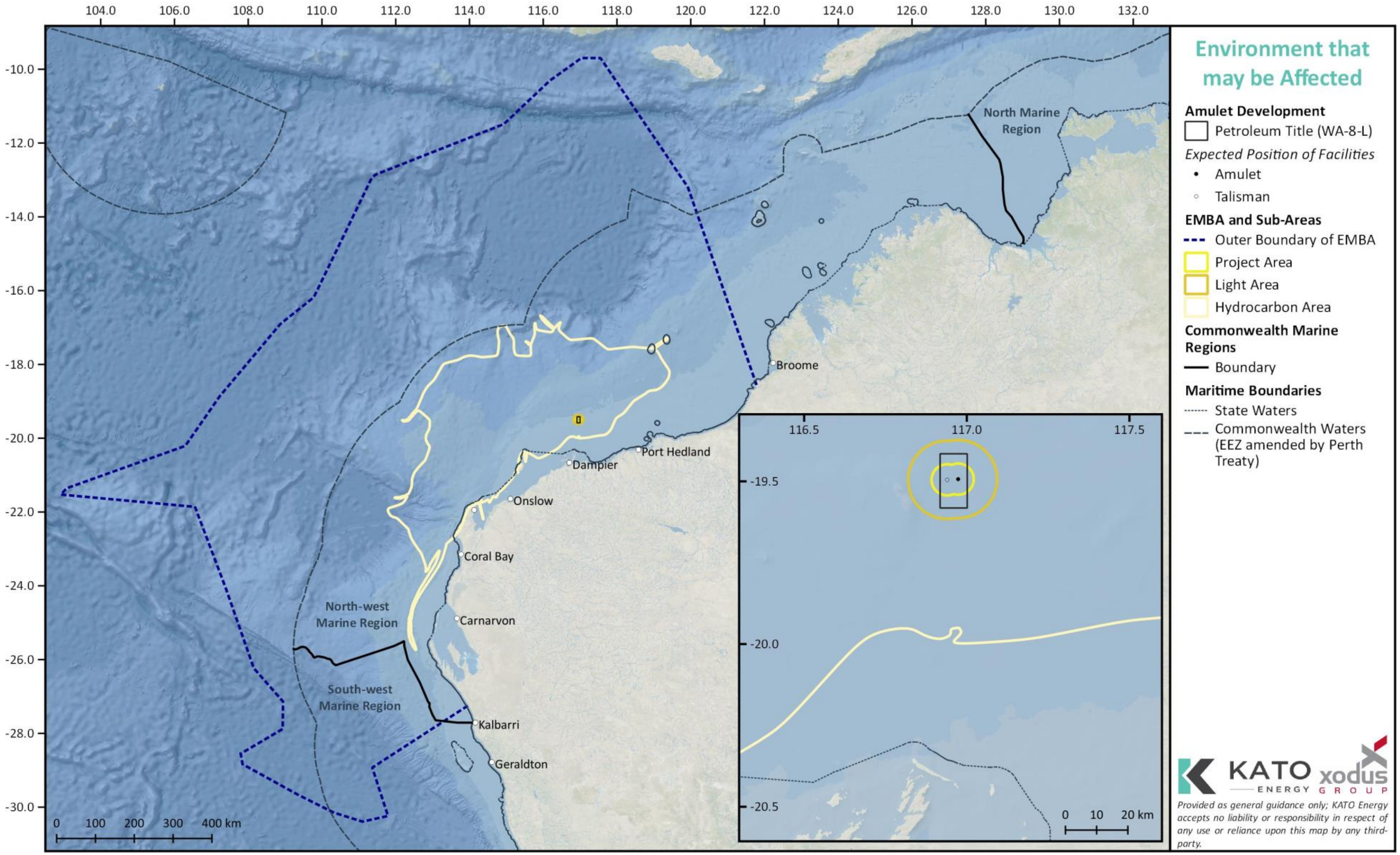


Figure 5-1 Environment that may be Affected (with Sub-Areas) for the Amulet Development

5.2 Regional Context

The Amulet Development occurs in Commonwealth waters within the North-west Marine Region, ~132 km offshore from Dampier on the Pilbara coast, and within the IMCRA Northwest Shelf Province bioregion (Figure 5-2). The EMBA associated with the Amulet Development includes parts of both the North-west and South-west Commonwealth Marine Regions, as well as areas beyond the Commonwealth waters maritime boundary.

5.2.1 North-west Marine Region

The North-west Marine Region comprises Commonwealth waters from the Western Australian – Northern Territory border to Kalbarri (Figure 5-1), covering ~1.07 million km^2 of tropical and subtropical waters (DEWHA 2008).

Those parts of the North-west Marine Region adjacent to the Kimberley and Pilbara include thousands of square kilometres of shallow continental shelf (accounting for ~30% of the total area). The North-west Marine Region also includes Australia's narrowest shelf margin, located at Ningaloo Reef. Over 60% of the seafloor in the North-west Marine Region 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 North-west Marine Region comprise ~10% of the total area.

Overall, the North-west Marine Region 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 North-west Marine Region is characterised by shallow-water tropical marine ecosystems. While in general endemism is not particularly high by Australian standards, the North-west Marine Region 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 and covers much of the area commonly known as the North West Shelf. 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 North West Shelf, 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 North-west Shelf Province 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 North-west Marine Region.

The North-west Shelf Province 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 North-west Marine Region 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 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 South-west Marine Region 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 South-west Marine Region, 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 South-west Marine Region has high biodiversity and large numbers of species native to the region (DEWHA 2008e). Particular hotspots for biodiversity are the Houtman Abrolhos Islands, the Recherche Archipelago and the soft sediment ecosystems in the Great Australian Bight.

The biological productivity of the South-west Marine Region 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 South-west Marine Region. 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 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 (Figure 5-1).

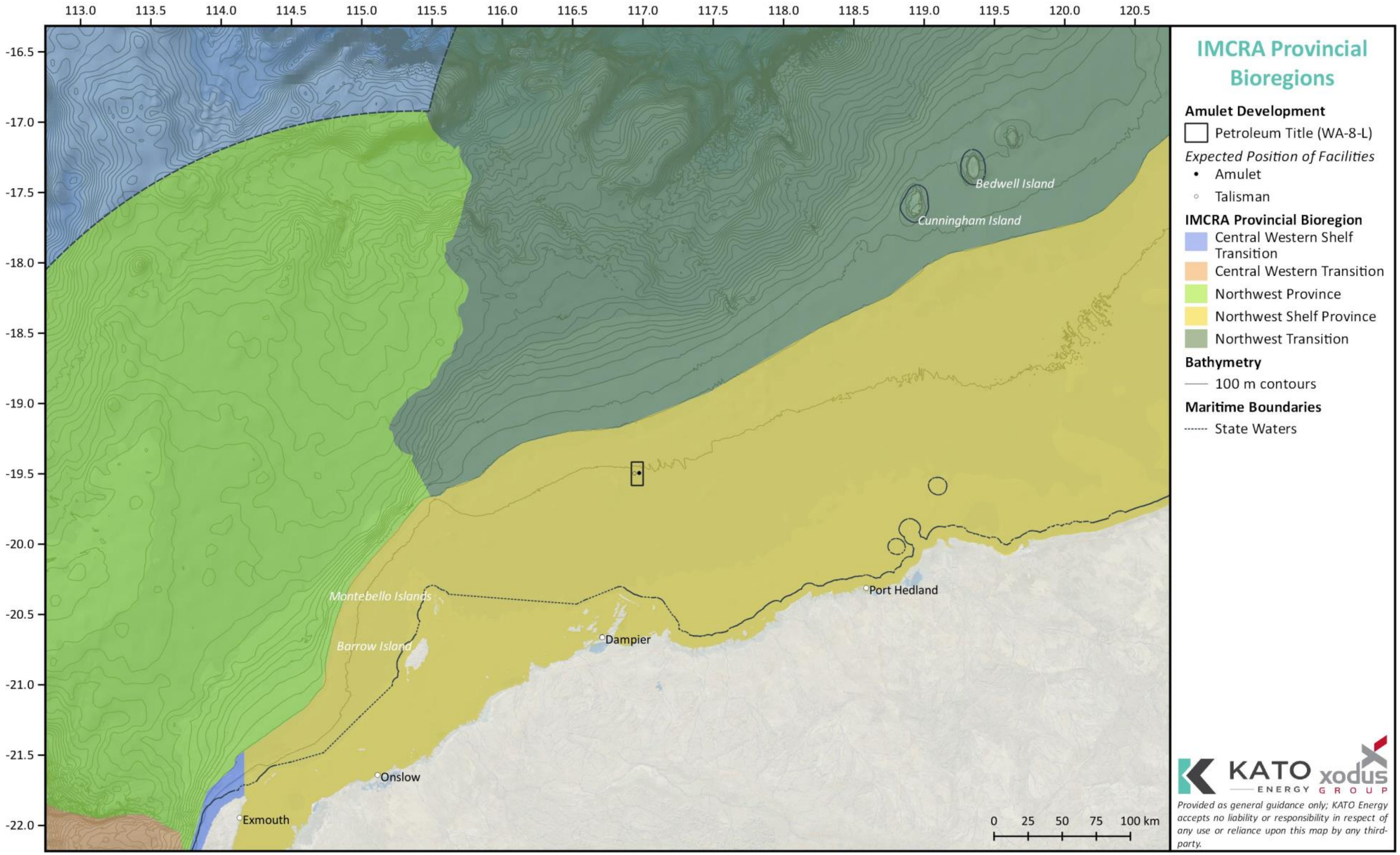


Figure 5-2 IMCRA Provincial Bioregions within the vicinity of the Amulet Development

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 Amulet Development and wider EMBA will be typical of the offshore marine environment on the North West Shelf, 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 within the vicinity of the Amulet Development and wider EMBA will be typical of the offshore marine environment on the North West Shelf, 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. However, anthropogenic sources (e.g. vessels, industry developments) would contribute to local variation in air quality.

Results from the Pilbara Air Quality Study (DoE 2004) showed levels of pollutants (nitrogen dioxide, ozone, sulphur dioxide, carbon monoxide) in Pilbara coastal centres were below NEPM standards. However, it did show that particulate matter measurements were occasionally above NEPM standards at some coastal locations (DoE 2004).

It is expected that air quality within the vicinity of the Amulet Development and wider EMBA will be typical of the offshore marine environment on the North West Shelf (i.e. high).

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 natural light within the offshore Pilbara region is expected to predominantly be from solar/lunar luminance.

Ambient 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 Amulet Development is located ~40 km from the nearest facility and ~7 km from the nearest shipping fairway (Section 5.5.5), and therefore negligible measurable increases in ambient light levels from anthropogenic sources are expected.

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. The Amulet Development is located between two shipping fairways on the North West Shelf, and therefore is likely to be exposed to the occasional sounds generated by mid to large vessels such as tankers and bulk carriers.

5.4 Ecological Environment

5.4.1 Plankton

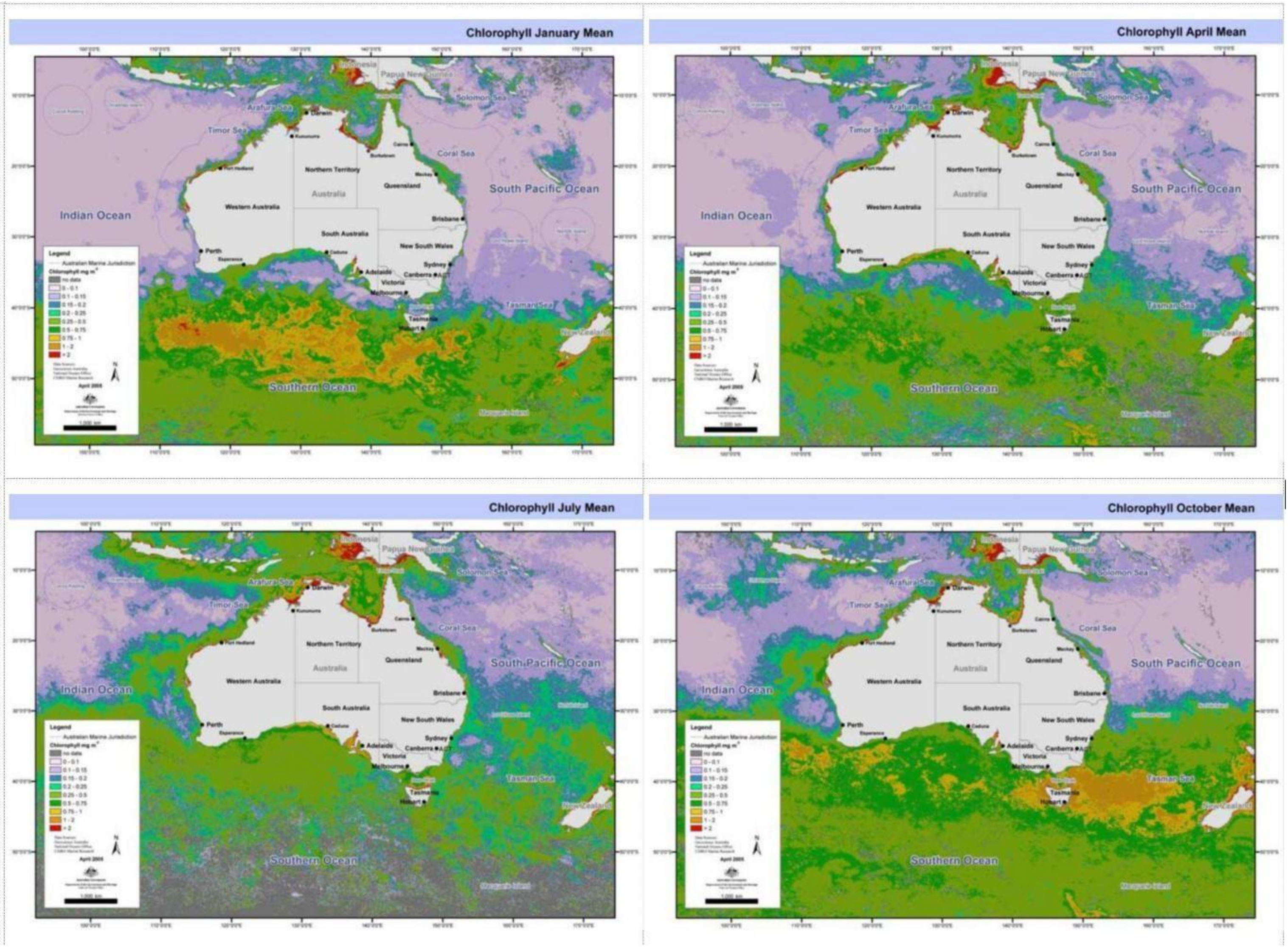
Plankton are microscopic organisms drifting or floating in the sea, consisting chiefly of diatoms, protozoans, small crustaceans, and the eggs and larval stages of larger animals.

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. The inshore ichthyoplankton assemblages are characterised by shallow reef fishes such as blennies (family Blenniidae), damselfish (family Pomacentridae) and northwest 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 Amulet Development is situated in ~85 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 permit area (WA-8-L) is situated in an area characterised by a gently seaward-sloping Pleistocene limestone plain that is relatively flat and dipping gently to the northwest. It consists predominantly of limestone with a sandy covering of varying thickness that rises more or less randomly to form the bases of many cays and islands in the region (Santos 2019a). The seabed topography within the bulk of WA-8-L is expected to be smooth and flat, with a thin layer of silty sand to a maximum of ~2 m thick. The shelf gradually slopes from the coast to the shelf break but displays several distinct seafloor features (e.g. banks/shoals, canyons).

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).

Faunal diversity associated with the EMBA probably shares similarities with the nearby Ancient Coastline KEF (Section 5.5.1.2), with any hard substrates supporting sponges, corals, crinoids, molluscs, echinoderms and other benthic invertebrates representative of hard substrate fauna in the North West Shelf bioregion (Santos 2018). Rhodolith beds are known to occur in the mid shelf sub-system in the Pilbara to depths of ~90 m and Glomar Shoals (Section 5.5.1.2) are also believed to be a site of higher productivity, as evident in high catches of commercial fisheries in this area (Brewer et al. 2007).

The seabed substrate within WA-8-L (i.e. including the Project Area) is expected to typically be sediment covered, with a lack of seabed features (e.g. rocky outcrops), and characterised by sediment infaunal communities and sparsely distributed epibenthic fauna. Previous studies of the Amulet 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. The study also showed the Project Area to have sparse populations of filter and deposit-feeding epibenthic fauna, polychaete worms, crustaceans and echinoderms (Thales 2001).

Apache (2012) states the benthic infauna adjacent to the proposed Hurricane-3 exploration well, which is located ~42 km from the Project Area, consisted of unconsolidated sediments which supports a diverse benthic infauna consisting predominantly of mobile burrowing species which include molluscs, crustaceans (crabs, shrimps and smaller related species), polychaetes, sipunculid and platyhelminth worms, asteroids (sea stars), echinoids (sea urchins) and other small animals. Benthic sampling in the vicinity of Woodside's Goodwyn Alpha facility (located ~111 km from the expected position of the MOPU) detailed a low abundance, high variability and diversity of infauna dominated by polychaetes and crustaceans (RPS 2011).

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, Dampier Archipelago and Rowley Shoals. Corals are also known to occur in shallow areas around some of the Pilbara inshore islands (Figure 5-5).

An assessment of the coral reef systems of Western Australia in a national context indicates that only the offshore atolls such as Scott Reef, Rowley Shoals and Seringapatam approach the species richness and structural complexity of the reefs found off the Queensland coast. For fringing reef systems, the species richness within the Ningaloo Marine Park is greater than that of the Dampier Archipelago and is considered a better example of a fringing reef system than any found along the Pilbara coastline (Osborne et al. 2000).

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).

Coral growth in the inshore waters of the Dampier Archipelago is prolific, particularly on sublittoral rock slopes where species diversity is high, although there is no reef formation in these areas. The best reef development occurs on the seaward slopes of the outer archipelago where the fringing reefs form a deeply dissected reef front sloping to a reef edge zone, with a reef flat behind, shallow back reefs and an occasional lagoon (DoEH 2004).

The Rowley Shoals are a collection of three atoll reefs: Clerke, Imperieuse and Mermaid. The Rowley Shoals contain 214 coral species and the reef system is considered a regionally important (Section 5.5.1.2). There is little connectivity between Rowley Shoals and other outer-shelf reefs, which has led to differences in structure and genetic diversity to other areas.

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).

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).

Known key areas of seagrass habitat within the EMBA are Exmouth Gulf and Shark Bay; both areas providing important habitats for marine fauna. Seagrass is also present in some areas of the Dampier Archipelago, with nine species known to be present (Huisman and Borowitzka 2003). within the Macroalgae habitat is known to occur within the nearshore areas surrounding some of the Pilbara inshore islands, including Barrow Island and the Montebello Islands and the Dampier Archipelago (Figure 5-5).

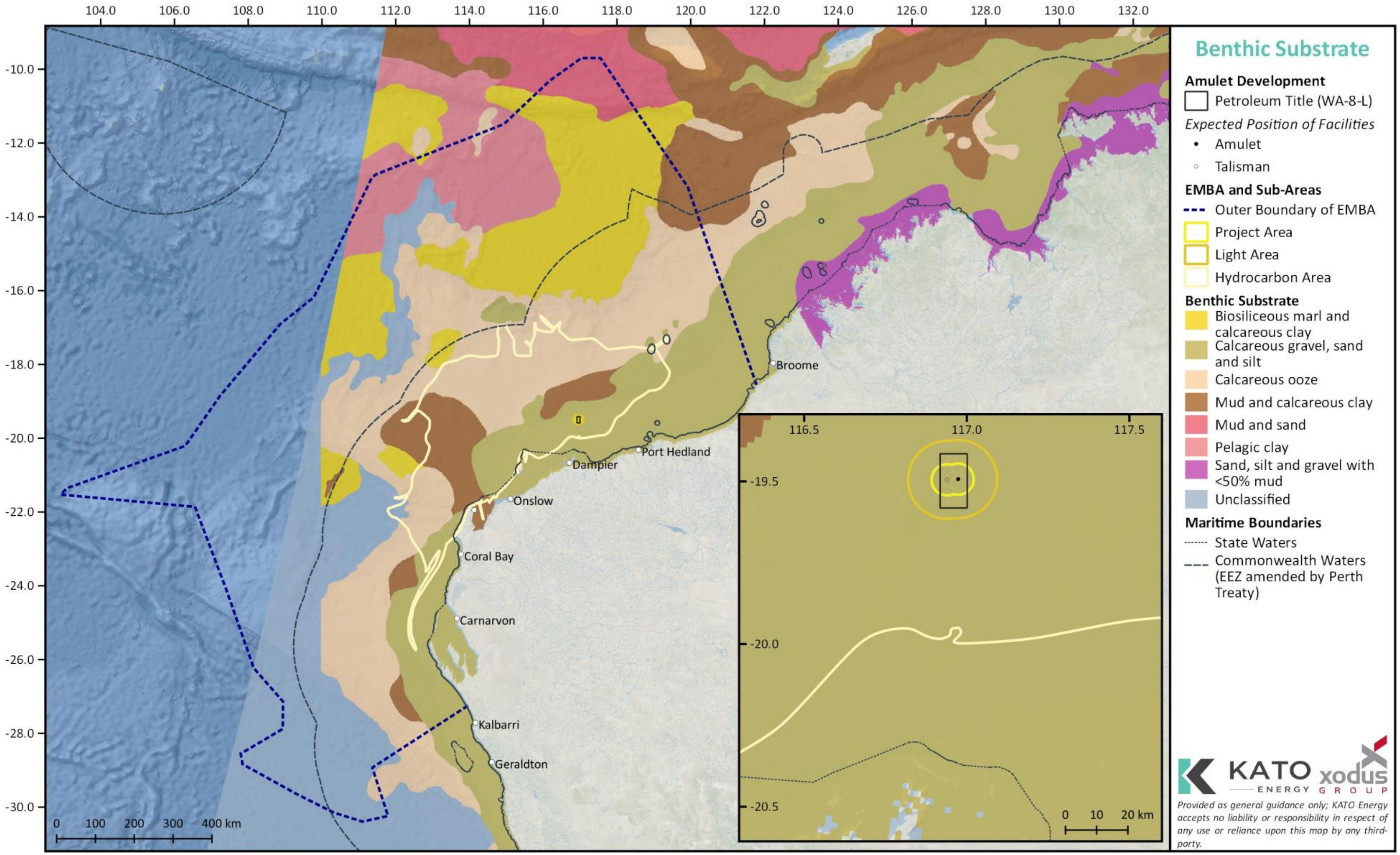


Figure 5-4 Benthic Substrates

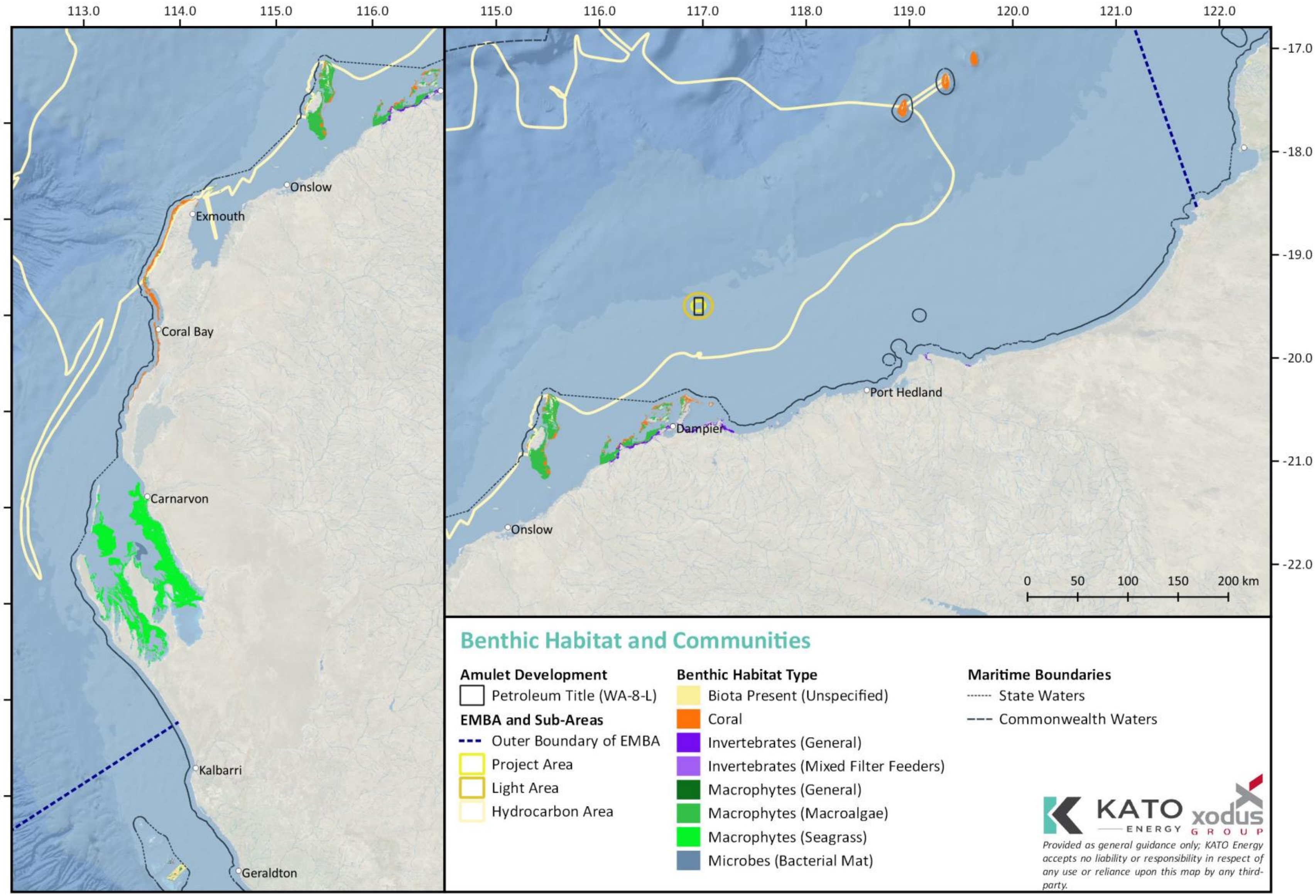


Figure 5-5 Known extents of Benthic Habitats and Communities

5.4.3 Coastal Habitats and 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. Coastal communities are biological communities that live within the coastal zone; these communities include wetlands and other intertidal flora/vegetation such as saltmarsh and mangroves. A variety of fauna (e.g. birds, turtles) also form a part of these coastal communities; however, these are described separately in subsequent sections.

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 typically present on Burrup Peninsular and offshore islands (including Dampier Archipelago, Barrow and Montebello islands), while sandy beaches and tidal flats are the dominant shorelines of the mainland Pilbara coast. 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 Amulet 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	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	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). Seven species of mangroves are widely accepted as occurring along the Pilbara coast: *Avicennia marina*, *Rhizophora stylosa*, *Ceriops australis*, *Aegialitis annulata*, *Aegiceras corniculatum*, *Osbornia octodonta* and *Bruguiera exaristata* (Semeniuk et al. 1978; Semeniuk 1983). *A. marina* is the most widespread mangrove in WA, and it is typically the dominant species present in any mangrove habitat; *R. stylosa* is also relatively widespread in WA and is typically locally dominant or co-dominant in mangrove habitats from the Kimberley to Exmouth Gulf. 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 the widespread tidal flats and wetland habitats along the Pilbara coast. The closest mangrove habitat to the Amulet Development occurs within the Dampier Archipelago, but larger expanses are found around Port Hedland, north of Onslow and within Exmouth Gulf (Figure 5-7). Saltmarsh habitat is widespread along most of 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).

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 2013b).

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). A summary of the ecological character of the Ramsar wetland is provided in Section 5.4.3.3.1.

Nine marine/coastal wetlands of national importance have been identified within the EMBA; the closest to the Amulet Development is the Leslie Saltfields System (north of Port Hedland), ~205 km for the expected position of the MOPU (Table 5-3, Figure 5-9).

None of the marine/coastal wetlands occur within any of the sub-areas (Project, Light or Hydrocarbon) (Table 5-3, Figure 5-9).

Table 5-3 Presence of Wetland Habitats within the Amulet 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*
Lake MacLeod	✓	*X*	*X*	*X*
Learmonth Air Weapons Range – Saline Coastal Flats	✓	*X*	*X*	*X*
Leslie Saltfields System	✓	*X*	*X*	*X*
Mermaid Reef	✓	*X*	*X*	*X*
Shark Bay East	✓	*X*	*X*	*X*

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

5.4.3.3.1 Ecological character of the Eighty-Mile Beach Ramsar wetland

The Eighty-mile Beach Ramsar site is located between Port Headland and Broome (WA) and is made up of Eighty-mile Beach and Mandora Salt Marsh (~40 km to the east).

Eighty-mile Beach is a large (220 km) linear sand coast. The boundary of the Ramsar site along the beach is defined by the tide, extending from Mean Low Water to 40 m above Mean High Water. The intertidal zone is comprised of a large expanse of intertidal mudflats (up to 4 km wide at the lowest tides) and a narrow strip at the landward edge of coarser quartz sands. The site is bounded by coastal dunes to the east. The discontinuous linear floodplain immediately inland of the frontal sand dunes, are predominantly outside the Ramsar boundary. Mandora Salt Marsh includes two large seasonal wetlands and a series of small permanent mound springs.

A summary of ecological character of the Ramsar site (Table 5-4) has been extracted from Hale and Butcher 2009.

Table 5-4 Ecological Character of Ramsar Wetlands

Ramsar Wetlands – Ecosystem Components, Processes and Services
Eighty-mile Beach

Ecosystem components and processes:
• Climate: Semi-arid monsoonal with a prolonged dry period, >80% of rainfall in the wet season (December to March). High inter-annual variability. High occurrence of tropical cyclones.
• The Beach:
  o Geomorphology: Extensive intertidal mudflats comprised of fine-grained sediments. Site is backed by steep dunes comprised of calcareous sand.
  o Hydrology: Macro-tidal regime. No significant surface water inflows. Groundwater interactions unknown (knowledge gap).
  o Primary production and nutrient cycling: Data deficient, but organic material deposited from ocean currents driving the system through bacterial or microphytobenthos driven primary production.
  o Invertebrates: Large numbers and diversity of invertebrates within the intertidal mudflat areas.
  o Fish: Data deficient, but anecdotal evidence of marine fish (including sharks and rays) using inundated mudflats.
  o Waterbirds: Significant site for stop-over and feeding by migratory shorebirds. Regularly supports >200,000 shorebirds during summer and >20,000 during winter. High diversity with 97 species of waterbird recorded from the beach. Regularly supports >1% of the flyway population of 20 species.
  o Marine turtles: Significant breeding site for the Flatback Turtle.
• Mandora Salt Marsh:
  o Geomorphology: Wetland formation dominated by alluvial processes. Wetlands were once a part of an ancient estuary. Freshwater springs have been dated at 7,000 years old.
  o Hydrology: Walyarta, East Lake and the surrounding intermittently inundated paperbark thickets are inundated by rainfall and local runoff. Extensive inundation occurs following large cyclonic events. Salt Creek and the Mound springs are groundwater fed systems through the Broome Sandstone Aquifer.
  o Water quality: Most wetlands are alkaline reflecting the influence of soils and groundwater. Salinity is variable, mound springs are fresh, Salt Creek hyper-saline and Walyarta variable with inundation. Nutrient concentrations in groundwater and groundwater fed systems are high.
  o Primary production and nutrient cycling: Data deficient. However, evidence of boom and bust cycle at Walyarta with seasonal inundation.
  o Vegetation: Inland mangroves (Avicennia marina) lining Salt Creek are one of only two occurrences of inland mangroves in Australia. Paperbark thickets dominated by the saltwater paperbark (*Melaleuca alsophila*) extend across the site on clay soils which retain moisture longer than the surrounding landscape. Samphire (Tecticornia spp.) occurs around the margins of the large lakes.

Ramsar Wetlands – Ecosystem Components, Processes and Services
Freshwater aquatic vegetation occurs at Walyarta when inundated and at the mound spring sites year-round. ○ Invertebrates: Data limited, but potentially unique species. ○ Waterbirds: Significant site for waterbirds and waterbird breeding, particularly during extensive inundation events. 66 waterbirds recorded. Supports >1% of the population of at least two species. Breeding recorded for at least 24 species. **Ecosystem services:** • Provisioning service–Freshwater: The freshwater springs at Mandora Salt Marsh provide drinking water for livestock. • Provisioning service–Genetic resources: Plausible, but as yet no documented uses. • Regulating service– Climate regulation: Plausible, but data deficient. • Regulating service–Biological control of pests: Evidence that many of the shorebirds feed on the adjacent pastoral land and that the incidence of 2.88 million Oriental Pratincole coincided with locusts in almost plague proportions, upon which the birds fed. • Cultural Services–Recreation and tourism: The beach portion of the site is important for recreational fishing, tourism, bird watching and shell collecting. • Cultural Services–Spiritual and inspirational: Spiritually significant for the Karajarri and Nyangumarta and contain a number of specific culturally significant sites. The site has inspirational, aesthetic and existence values at regional, state and national levels. • Cultural Services–Scientific and educational: Mandora Salt Marsh and Eighty-mile Beach have been the site of a number of significant scientific investigations. In addition, Eighty-mile Beach is a significant site for migratory shorebird monitoring and is currently part of the Shorebirds 2020 program. • Supporting services: As evidenced by the listing of the Eighty-mile Beach Ramsar site as a wetland of international importance. The system provides a wide range of biodiversity related ecological services critical for the ecological character of the site including ○ containing a diversity of wetland types ○ supporting significant numbers of migratory shorebirds ○ supporting significant wetland bird breeding ○ supporting Flatback Turtle breeding.

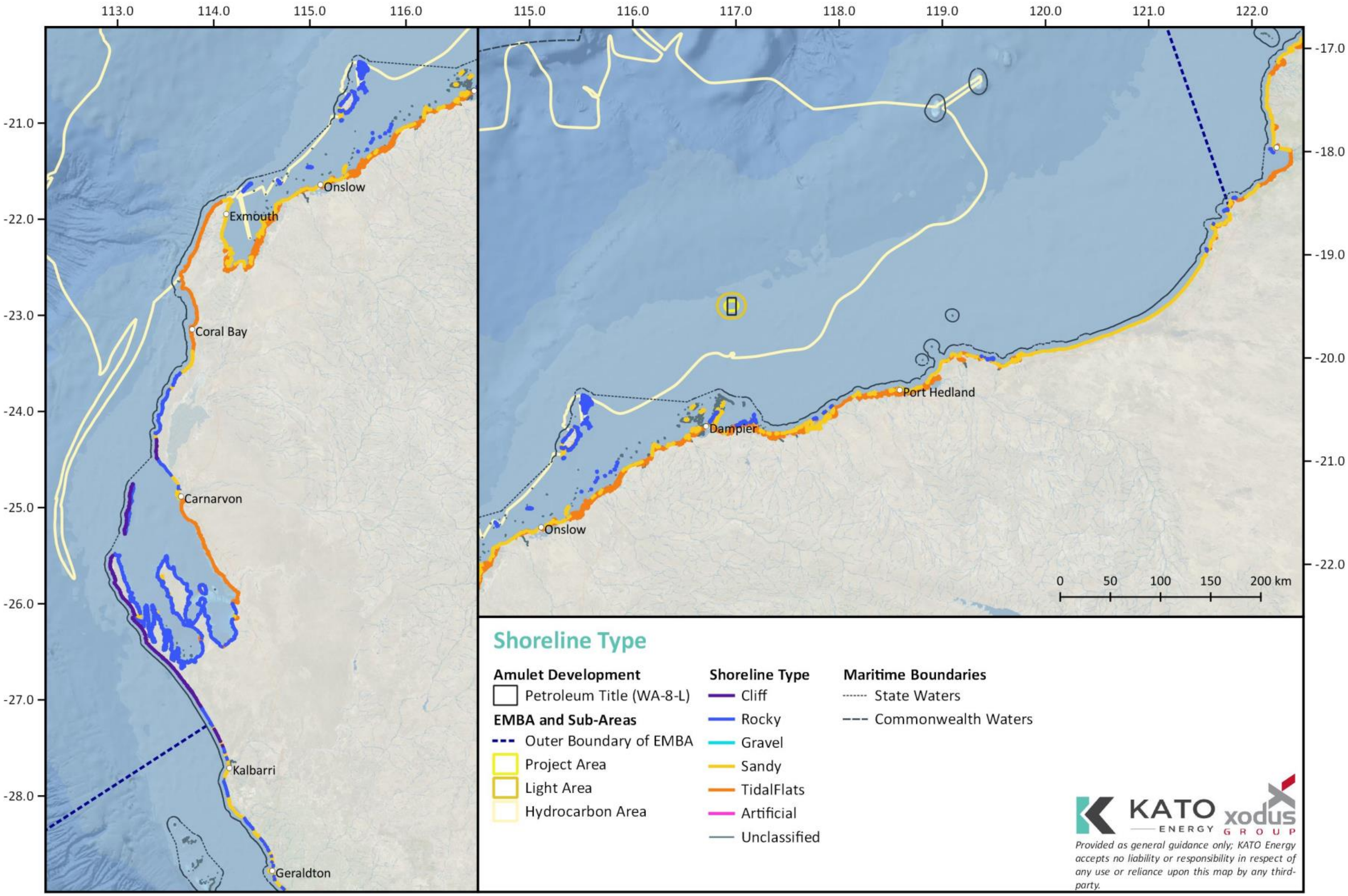


Figure 5-6 Shoreline Types

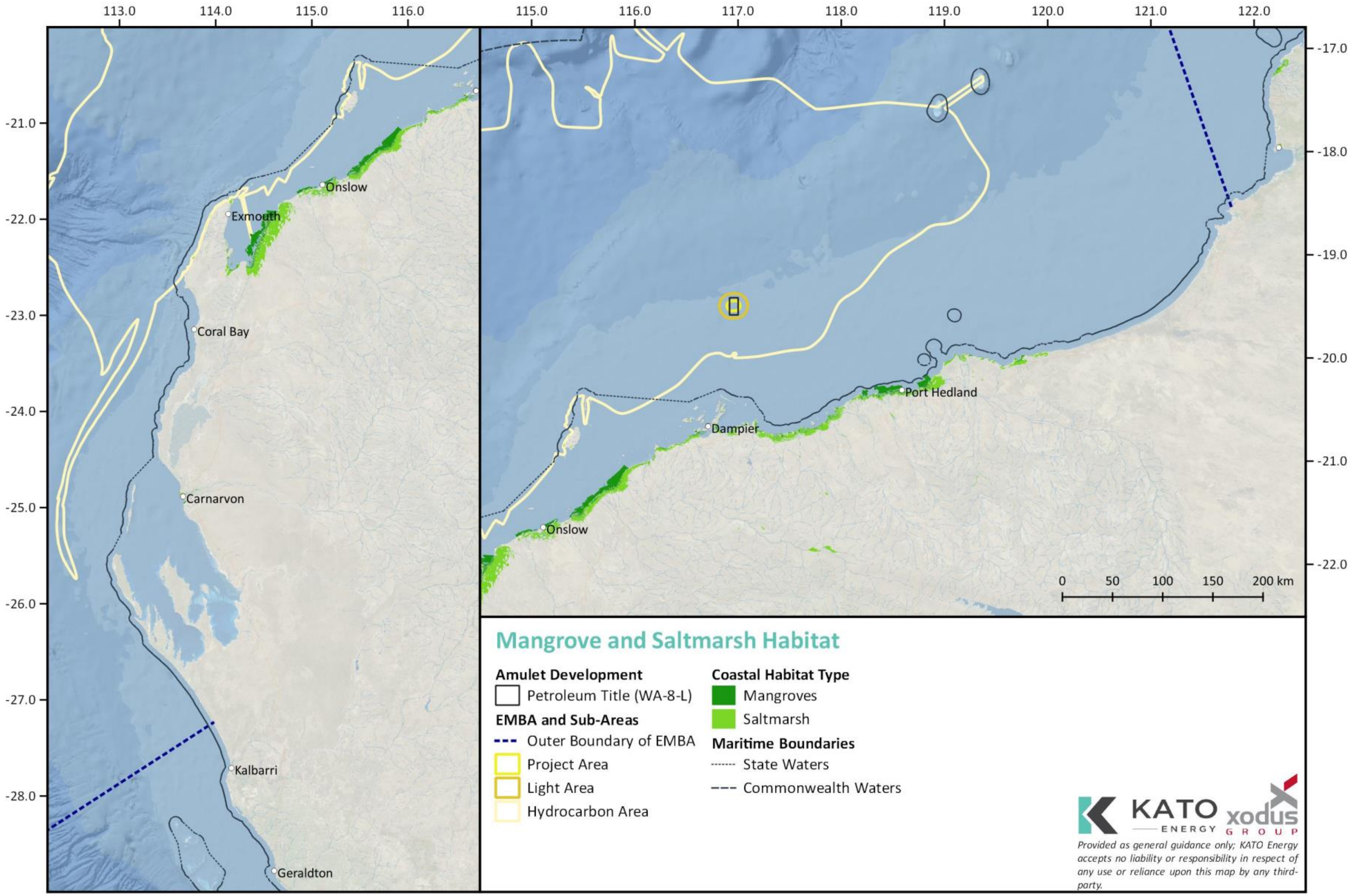


Figure 5-7 Known Mangrove and Saltmarsh Habitat

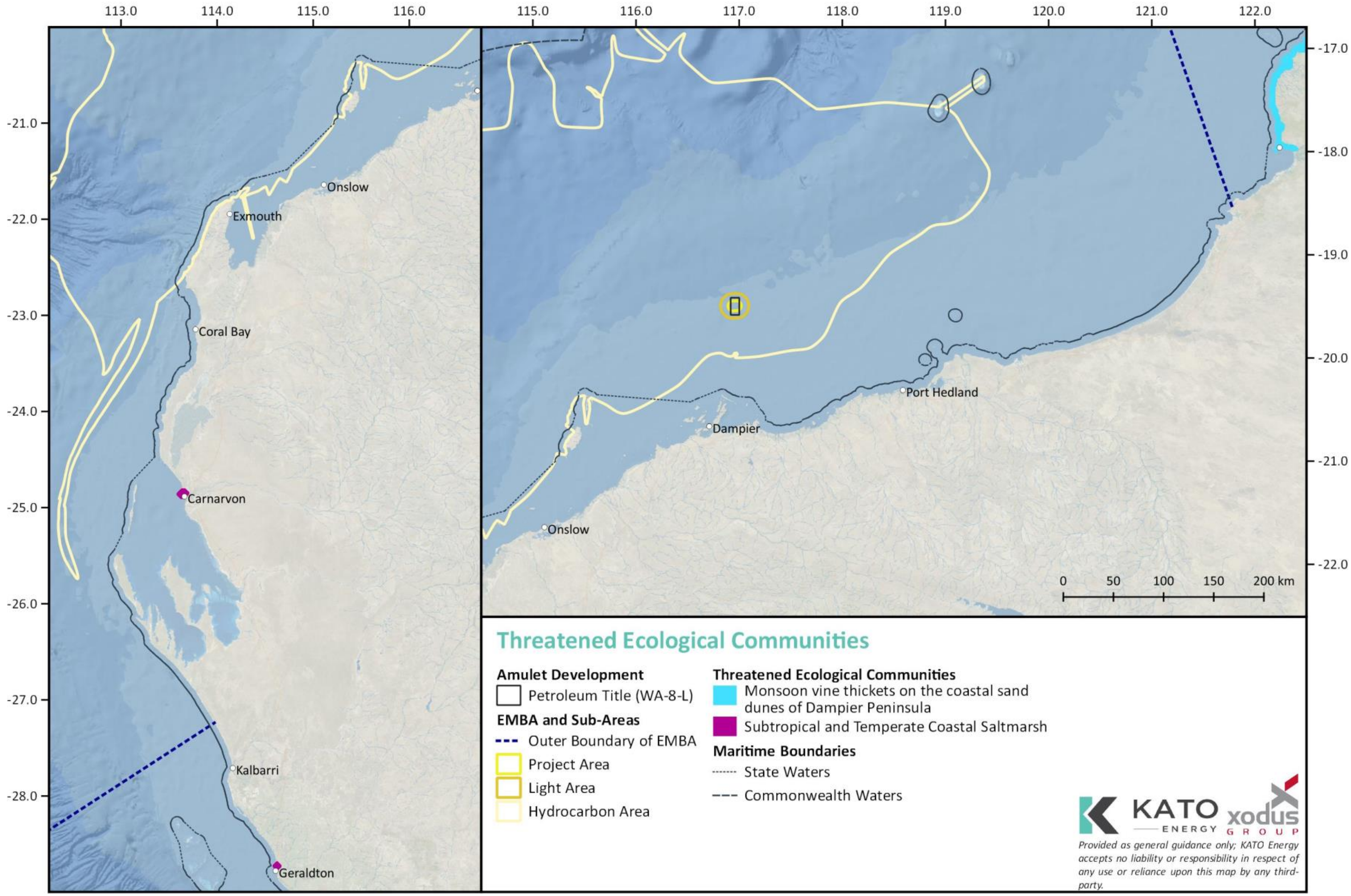


Figure 5-8 Subtropical and Temperate Coastal Saltmarsh Threatened Ecological Community

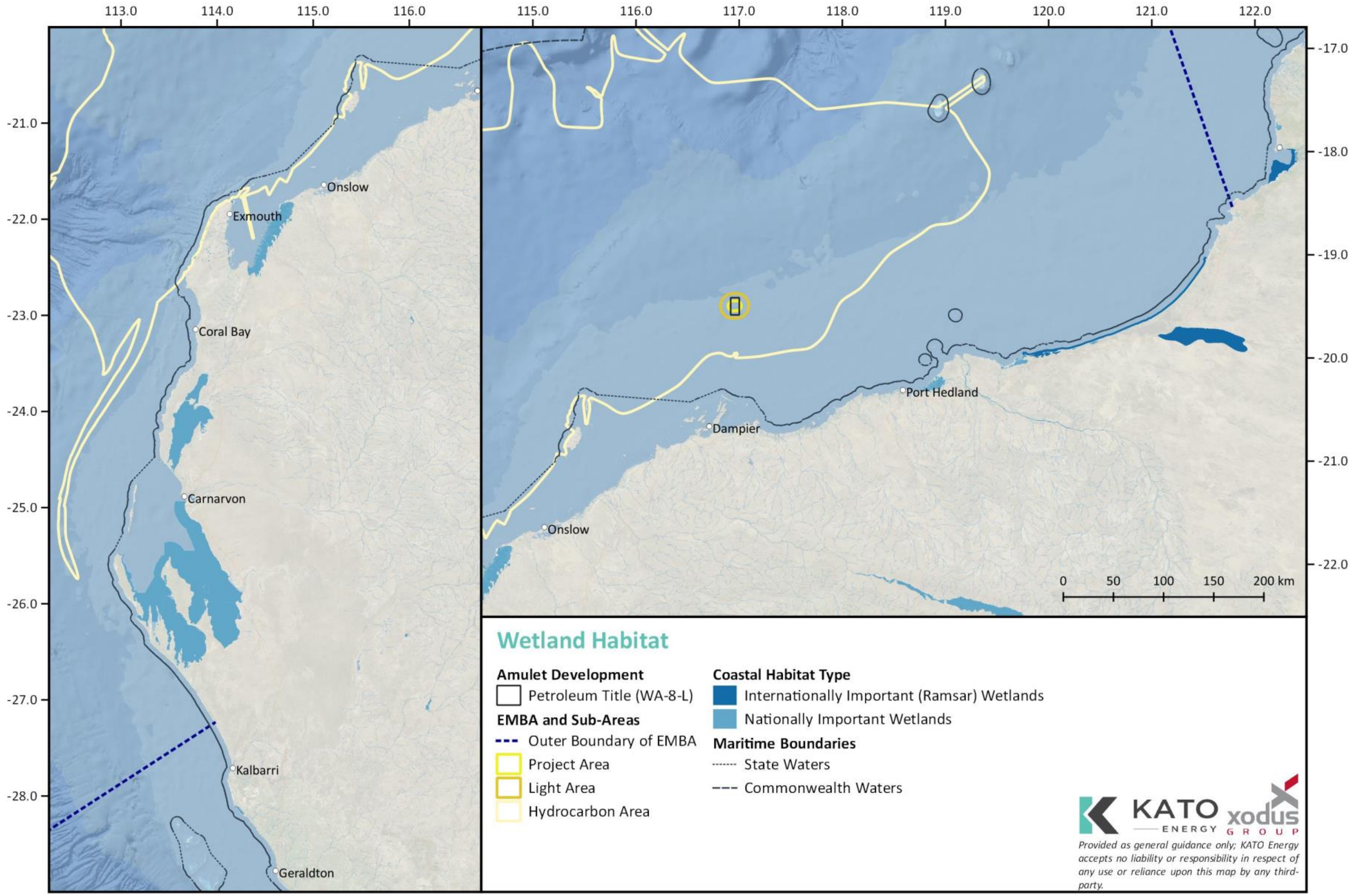


Figure 5-9 Internationally (Ramsar) and Nationally Important Wetlands

5.4.4 Seabirds and Shorebirds

Multiple species (or species habitat) of seabirds and shorebirds may occur within the EMBA (Table 5-5, 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 5-5, 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[8] (BIAs) have also been identified for some bird species (Table 5-6, Figure 5-10, Figure 5-11, Figure 5-12) within the EMBA. Those closest to the Amulet Development are the breeding BIAs for the Wedge-tailed Shearwater (Figure 5-10), Roseate Tern and Fairy Tern (Figure 5-11). Of these, the only one that intersects with the Project Area is the Wedge-tailed Shearwater. The breeding BIA for this species are buffers around islands (such as those of the Dampier Archipelago) that this species is known to nest on (Table 5-6). 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

[8] 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.

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 Roseate, Fairy and Lesser Crested Terns may have 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 5-6). The Lesser Crested Terns breeding will also breed on offshore islands in Pilbara and Gascoyne, with their season typically March to June (Table 5-6). Both the tern species are known to nest within the region of the Ningaloo Marine Park, Muiron and Sunday islands (CALM 2005). The Roseate Tern has breeding grounds on offshore islands in the Gascoyne, Pilbara and Kimberley, with breeding typically mid-March to July (Table 5-6). The Montebello Islands support the largest breeding population of Roseate Terns in WA (DEWHA 2008). The Roseate Terms also have a resting area located around the northern end of Eighty Mile Beach.

Within the North-west Marine Region the Lesser Frigatebird is known to breed on Adele, Bedout and West Lacapede islands (Marchant and Higgins 1990). During the day the Lesser Frigatebird remains out to sea and moves to inshore waters during rough weather or in the late evening (Chatto 2001). 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; Masked Boobies, Lesser Frigatebirds, Roseate Terns and Common Noddies also breed in the area (DEWHA 2008).

Table 5-5 Seabird and Shorebird Species or Species Habitat that may Occur within the Amulet 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			MO
Apus pacificus	Fork-tailed Swift			✓(M)	✓	LO			LO
Ardea alba	Great Egret				✓	BKO			KO
Ardea ibis	Cattle Egret				✓	MO			MO
Ardenna carneipes	Flesh-footed Shearwater			✓(M)	✓	FLO			LO
Ardenna pacifica	Wedge-tailed Shearwater			✓(M)	✓	BKO			BKO
Arenaria interpres	Ruddy Turnstone			✓(W)	✓	RKO			
Calidris acuminata	Sharp-tailed Sandpiper			✓(W)	✓	RKO	MO	MO	KO
Calidris alba	Sanderling			✓(W)	✓	RKO			
Calidris canutus	Red Knot	✓	E	✓(W)	✓	KO	MO	MO	KO
Calidris ferruginea	Curlew Sandpiper	✓	CE	✓(W)	✓	KO			KO
Calidris melanotos	Pectoral Sandpiper			✓(W)	✓	KO	MO	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
Calidris ruficollis	Red-necked Stint			✓(W)	✓	RKO			
Calidris subminuta	Long-toed Stint			✓(W)	✓	KO			
Calidris tenuirostris	Great Knot		CE	✓(W)	✓	RKO			
Calonectris leucomelas	Streaked Shearwater			✓(M)	✓	KO	LO	LO	LO
Catharacta skua	Great Skua				✓	MO			
Charadrius leschenaultii	Greater Sand Plover		V	✓(W)	✓	RKO			
Charadrius mongolus	Lesser Sand Plover		E	✓(W)	✓	RKO			
Charadrius ruficapillus	Red-capped Plover				✓	RKO			
Charadrius veredus	Oriental Plover			✓(W)	✓	RKO			MO
Chrysococcyx osculans	Black-eared Cuckoo				✓	KO			KO
Cuculus optatus	Oriental Cuckoo			✓(T)		MO			
Diomedea amsterdamensis	Amsterdam Albatross		E	✓(M)	✓	LO			
Diomedea epomophora	Southern Royal Albatross		V	✓(M)	✓	LO			
Diomedea exulans	Wandering Albatross		V	✓(M)	✓	LO			
Diomedea sanfordi	Northern Royal Albatross		E	✓(M)	✓	LO			
Fregata ariel	Lesser Frigatebird			✓(M)	✓	BKO	LO	LO	KO
Fregata minor	Great Frigatebird			✓(M)	✓	MO	MO	MO	MO
Gallinago megala	Swinhoe's Snipe			✓(W)	✓	RLO			
Gallinago stenura	Pin-tailed Snipe			✓(W)	✓	RLO			
Glareola maldivarum	Oriental Pratincole			✓(W)	✓	RKO			MO
Haliaeetus leucogaster	White-bellied Sea-Eagle				✓	BKO			KO
Heteroscelus brevipes	Grey-tailed Tattler				✓	RKO			
Himantopus himantopus	Pied Stilt				✓	RKO			

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
Hirundo rustica	Barn Swallow			✓(T)	✓	KO			MO
Hydroprogne caspia	Caspian Tern			✓(M)	✓	BKO			BKO
Larus novaehollandiae	Silver Gull				✓	BKO			BKO
Larus pacificus	Pacific Gull				✓	BKO			
Leipoa ocellata	Malleefowl		V			LO			
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)	✓	V			KO			MO
Limosa lapponica menzbieri	Northern Siberian Bar-tailed Godwit	✓	CE			KO			MO
Limosa limosa	Black-tailed Godwit			✓(W)	✓	RKO			
Macronectes giganteus	Southern Giant Petrel	✓	E	✓(M)	✓	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
Motacilla cinerea	Grey Wagtail			✓(T)	✓	MO			MO
Motacilla flava	Yellow Wagtail			✓(T)	✓	KO			MO
Numenius madagascariensis	Eastern Curlew	✓	CE	✓(W)	✓	KO	MO	MO	KO
Numenius minutus	Little Curlew			✓(W)	✓	RKO			
Numenius phaeopus	Whimbrel			✓(W)	✓	RKO			
Onychoprion anaethetus	Bridled Tern			✓(M)	✓	BKO			BKO
Pandion haliaetus	Osprey			✓(W)	✓	BKO	MO	MO	BKO
Papasula abbotti	Abbott's Booby		E		✓	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
Pezoporus occidentalis	Night Parrot		E			MO			MO
Phaethon lepturus	White-tailed Tropicbird			✓(M)	✓	BLO			BLO
Phaethon rubricauda	Red-tailed Tropicbird			✓(M)	✓	BKO			BKO
Phalaropus lobatus	Red-necked Phalarope			✓(W)	✓	BKO			
Philomachus pugnax	Ruff			✓(W)	✓	RKO			
Phoebetria fusca	Sooty Albatross		V	✓(M)	✓	MO			
Pluvialis fulva	Pacific Golden Plover			✓(W)	✓	RKO			
Pluvialis squatarola	Grey Plover			✓(W)	✓	RKO			
Polytelis alexandrae	Princess Parrot, Alexandra's Parrot		V			KO			
Pterodroma macroptera	Great-winged Petrel				✓	FKO			
Pterodroma mollis	Soft-plumaged Petrel		V		✓	FLO			FLO
Puffinus assimilis	Little Shearwater				✓	BKO			
Recurvirostra novaehollandiae	Red-necked Avocet				✓	BKO			
Rostratula australis	Australian Painted Snipe		E			KO			LO
Rostratula benghalensis (sensu lato)	Painted Snipe		E		✓	KO			
Sterna albifrons	Little Tern				✓	BKO			CKO
Sterna anaethetus	Bridled Tern				✓	BKO			BKO
Sterna bengalensis	Lesser Crested Tern					BKO			BKO
Sterna bergii	Crested Tern				✓	BKO			BKO
Sterna caspia	Caspian Tern				✓	BKO			BKO
Sterna dougallii	Roseate Tern			✓(M)	✓	BKO			BKO
Sterna fuscata	Sooty Tern				✓	BKO			BKO
Sterna nereis	Fairy Tern				✓	BKO			BKO
Sternula albifrons	Little Tern			✓(M)		BKO			
Sternula nereis nereis	Australian Fairy Tern	✓	V			BKO	MO	MO	BKO

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
Stiltia isabella	Australian Pratincole				✓	RKO			
Sula dactylatra	Masked Booby			✓(M)	✓	BKO			
Sula leucogaster	Brown Booby			✓(M)	✓	BKO			
Thalasseus bergii	Crested Tern			✓(W)	✓	BKO			BKO
Thalassarche carteri	Indian Yellow-nosed Albatross		V	✓(M)	✓	FMO			FMO
Thalassarche cauta cauta	Shy Albatross		V	✓(M)	✓	FLO			MO
Thalassarche cauta steadi	White-capped Albatross		V			FLO			LO
Thalassarche impavida	Campbell Albatross		V	✓(M)	✓	MO			MO
Thalassarche melanophris	Black-browed Albatross		V	✓(M)	✓	MO			MO
Thalassarche steadi	White-capped Albatross			✓(M)	✓	FLO			
Tringa brevipes	Grey-tailed Tattler			✓(W)		RKO			
Tringa glareola	Wood Sandpiper			✓(W)	✓	RKO			
Tringa nebularia	Common Greenshank			✓(W)	✓	RKO			LO
Tringa stagnatilis	Marsh Sandpiper			✓(W)	✓	RKO			
Tringa totanus	Common Redshank			✓(W)	✓	RKO			
Xenus cinereus	Terek Sandpiper			✓(W)	✓	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*
RMO	*Roosting may occur within area*
RLO	*Roosting likely to occur within area*
RKO	*Roosting known to occur within area*

*✓ = Present within area; *= Matter of National Environmental Significance*

Table 5-6 Biologically Important Areas for Seabird and Shorebird Species within the Amulet Development EMBA

Scientific Name	Common Name	BIA Presence				Summary Description of BIA
		EMBA	Project Area	Light Area	Hydrocarbon Area	
Ardenna pacifica	Wedge-tailed Shearwater	b,f	b	b	b,f	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).
Fregata ariel	Lesser Frigatebird	b			b	Breeding grounds and buffer area around offshore islands in Pilbara and Kimberley. Breeding season March to September.
Phaethon lepturus	White-tailed Tropicbird	b			b	Breeding grounds and buffer area around offshore islands in Pilbara and Kimberley. Breeding recorded between May and October.
Puffinus assimilis	Little Shearwater	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				Oceanic foraging grounds. Presences is generally driven by breeding season, late September to late February/early May.
Sterna dougallii	Roseate Tern	b,f,r			b	Breeding grounds and buffer area around offshore islands in Gascoyne, 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				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			b	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			r	Breeding grounds and buffer area and resting areas, around offshore

Scientific Name	Common Name	BIA Presence				Summary Description of BIA
		EMBA	Project Area	Light Area	Hydrocarbon Area	
						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	Breeding grounds and buffer area around offshore islands in Gascoyne and Pilbara. Breeding may occur March to June.
Biologically Important Area *b: Breeding; f: Foraging; r: Resting*						

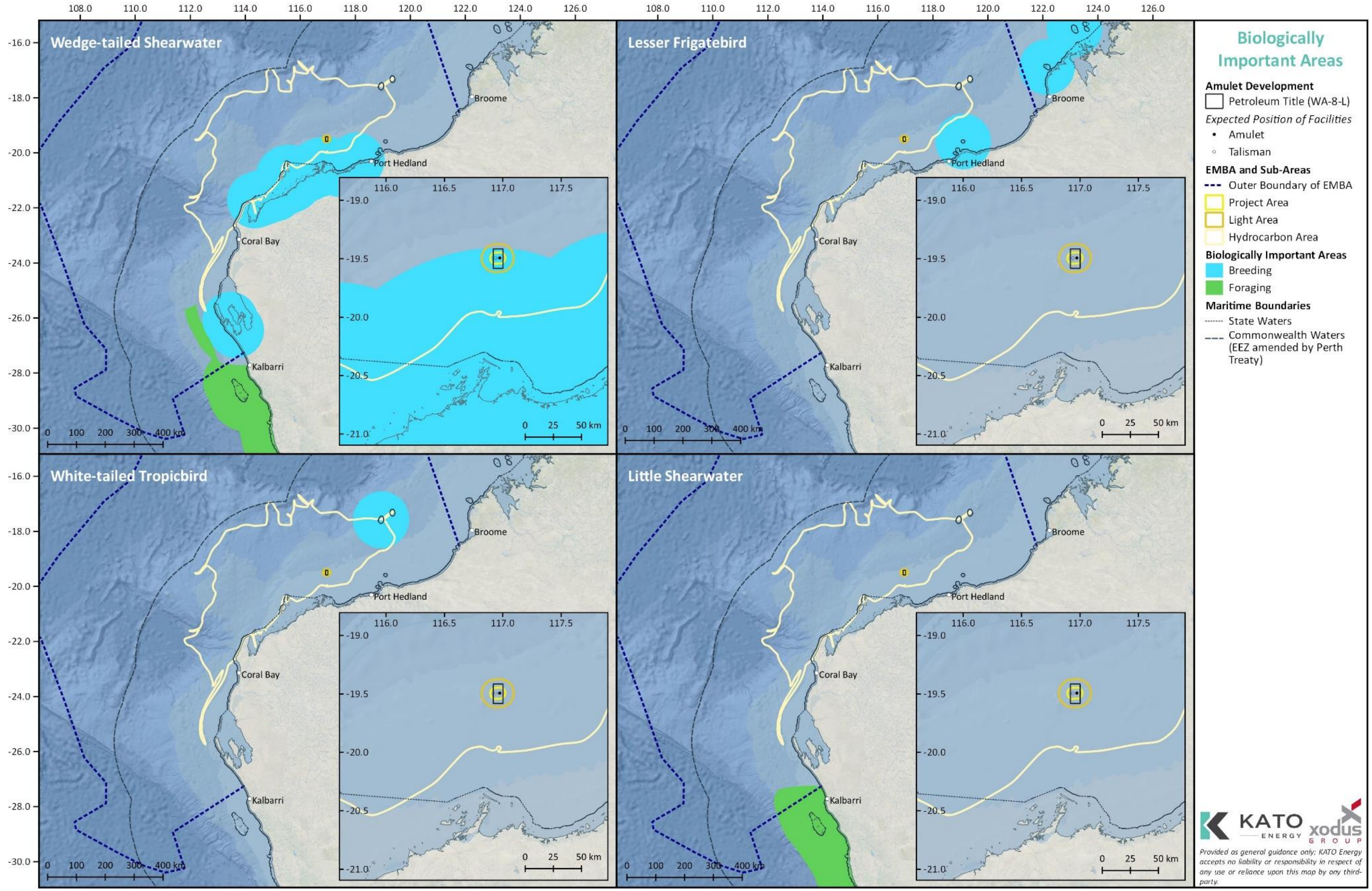


Figure 5-10 Biologically Important Areas for Seabird and Shorebird Species (Wedge-Tailed Shearwater, Lesser Frigatebird, White-tailed Tropicbird, Little Shearwater

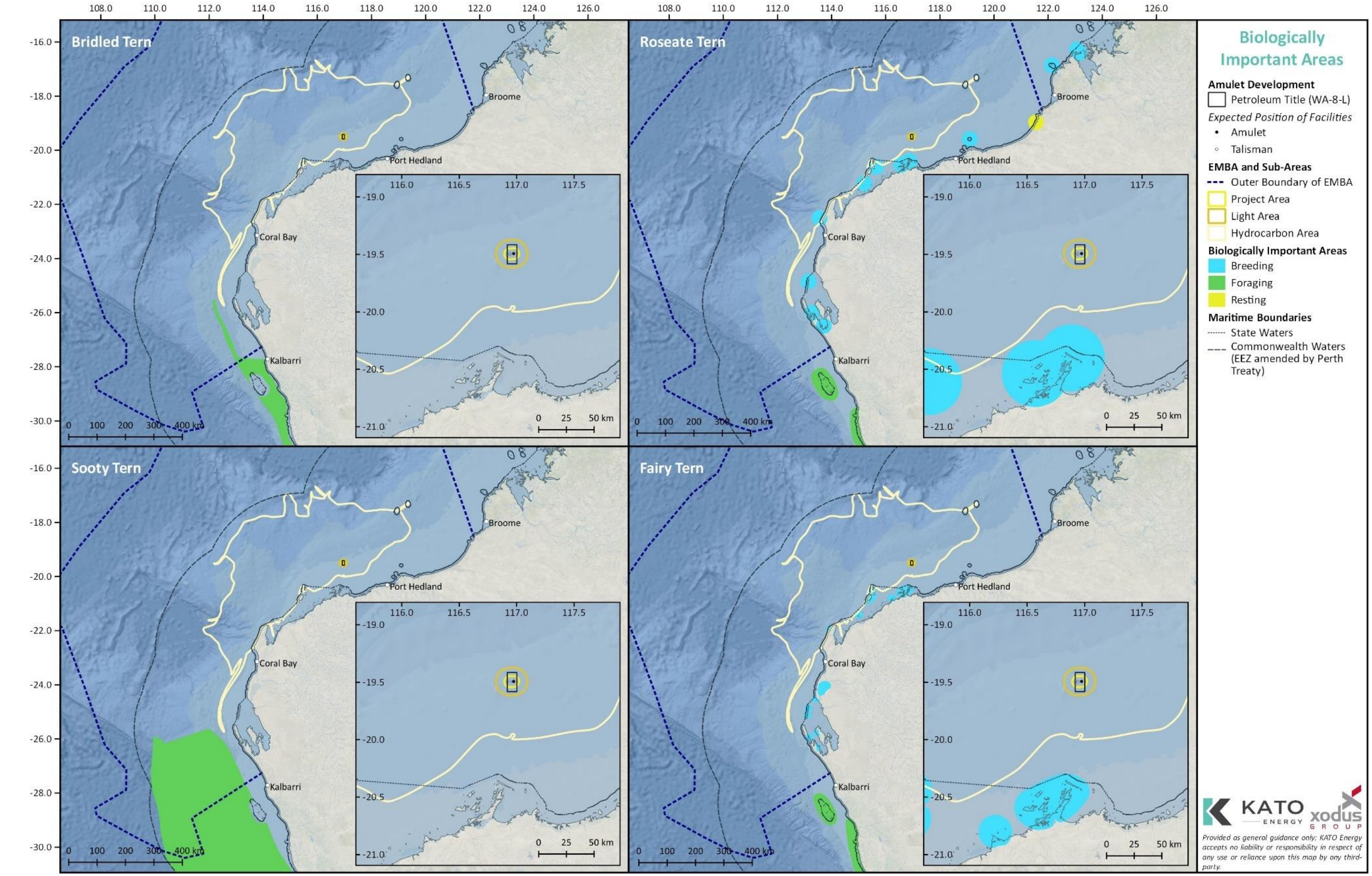


Figure 5-11 Biologically Important Areas for Seabird and Shorebird Species (Bridled Tern, Roseate Tern, Sooty Tern, Fairy Tern)

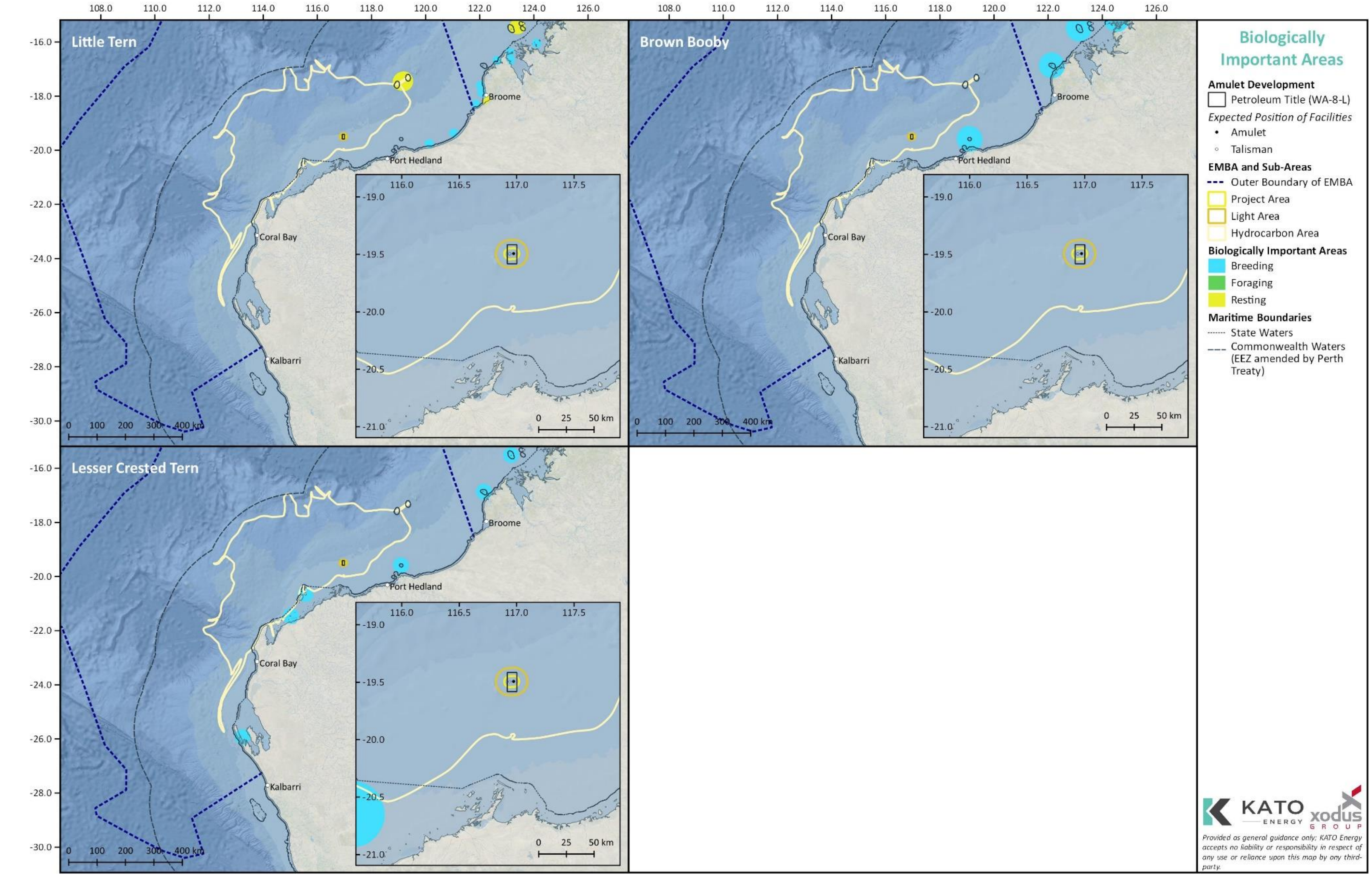


Figure 5-12 Biologically Important Areas for Seabird and Shorebird Species (Little Tern, Brown Booby, Lesser Crested Tern)

5.4.5 Fish

Multiple species (or species habitat) of fish may occur within the EMBA (Table 5-7, 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 5-7, Appendix A).

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). The Glomar Shoals appears to be a particularly important site for fish species within the bioregion, because of increased biological productivity associated with localised upwelling at this location (Brewer et al. 2007). A number of commercial fish species are caught in high numbers in this area, including Rankin cod, brownstripe snapper, red emperor, crimson snapper and the frypan bream (DEWHA 2008).

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). However, limited commercial fishing stocks or activity are expected within the Project Area for the Amulet Development.

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.

BIAs have also been identified for four fish species (Table 5-8) within the EMBA. The Amulet Development Project Area is located within a foraging BIA for the Whale Shark (Figure 5-13). The other species with BIAs (Dwarf, Freshwater and Green Sawfish) occur within the EMBA, but not within any of the sub-areas (Project, Light or Hydrocarbon) (Table 5-8, Figure 5-13).

Whale Sharks have a global distribution in tropical and warm temperate seas, both oceanic and coastal; they are also migratory and undergo seasonal movements. The main aggregation site within Australian waters is at Ningaloo Reef (~380 km southwest of the Amulet Development), between March and July (TSSC 2015d). 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 (Meekan et al. 2006). The Whale Sharks will migrate north from the Ningaloo Reef between July and November, typically centred on the 200 m isobath (~39 km offshore from the Amulet Development) (TSSC 2015d). This migration path coincides with the foraging BIA that extends from Ningaloo through to northern Kimberley waters (Table 5-8). When they depart Ningaloo, satellite tracking has shown that they will generally migrate toward the northeast into Indonesian waters (Meekan et al. 2008). The species is generally encountered as single individuals or occasionally in schools or aggregations of up to hundreds of sharks (DSEWPaC 2012). 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. Around Ningaloo, Whale Sharks spent at least 40% of their time in the upper 15 m of the water column and at least 50% of their time at depths ≥30 m (Wilson et al. 2006; DoEE 2019b); although more recent data suggests that this surface time could be lower, varying between 10–40% (Gleiss et al 2013). Recent survey data also suggests that the most important period of the day for Whale Sharks feeding at Ningaloo was around sunset (Gleiss et al 2013). Off the outer North West

Shelf, Whale Sharks spend much of their time swimming near the seafloor, and can make dives to around 1000 m (DoEE 2019b).

Table 5-7 Fish Species or Species Habitat that may Occur within the Amulet 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
Sharks and Rays									
Anoxypristis cuspidata	Narrow Sawfish			✓		KO	KO	KO	KO
Carcharias taurus	Grey Nurse Shark	✓	V			KO		LO	KO
Carcharodon carcharias	White Shark	✓	V	✓		KO	MO	MO	KO
Isurus oxyrinchus	Shortfin Mako			✓		LO	LO	LO	LO
Isurus paucus	Longfin Mako			✓		LO	LO	LO	LO
Lamna nasus	Porbeagle, Mackerel Shark			✓		MO			MO
Manta alfredi	Reef Manta Ray			✓		KO	MO	MO	KO
Manta birostris	Giant Manta Ray			✓		KO	MO	MO	KO
Pristis clavata	Dwarf Sawfish	✓	V	✓		BKO			KO
Pristis pristis	Freshwater Sawfish	✓	V	✓		KO			KO
Pristis zijsron	Green Sawfish	✓	V	✓		BKO	KO	KO	KO
Rhincodon typus	Whale Shark	✓	V	✓		FKO	FKO	FKO	FKO
Pipefish, Pipehorse, Seahorse and Seadragons									
Acentronura australe	Southern Pygmy Pipehorse				✓	MO			
Acentronura larsonae	Helen's Pygmy Pipehorse				✓	MO			MO
Bhanotia fasciolata	Corrugated Pipefish				✓	MO			MO
Bulbonaricus brauni	Braun's Pughead Pipefish				✓	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

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
Choeroichthys suillus	Pig-snouted Pipefish				✓	MO	MO	MO	MO
Corythoichthys amplexus	Fijian Banded Pipefish				✓	MO			MO
Corythoichthys flavofasciatus	Reticulate Pipefish				✓	MO	MO	MO	MO
Corythoichthys intestinalis	Australian Messmate Pipefish				✓	MO			MO
Corythoichthys schultzi	Schultz's Pipefish				✓	MO			MO
Cosmocampus banneri	Roughridge Pipefish				✓	MO	MO	MO	MO
Doryrhamphus dactyliophorus	Banded Pipefish				✓	MO	MO	MO	MO
Doryrhamphus excisus	Bluestripe Pipefish				✓	MO	MO	MO	MO
Doryrhamphus janssi	Cleaner Pipefish				✓	MO	MO	MO	MO
Doryrhamphus multiannulatus	Many-banded Pipefish				✓	MO			MO
Doryrhamphus negrosensis	Flagtail Pipefish				✓	MO			MO
Festucalex scalaris	Ladder Pipefish				✓	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
Halicampus spinirostris	Spiny-snout Pipefish				✓	MO	MO	MO	MO
Haliichthys taeniophorus	Ribboned Pipehorse				✓	MO	MO	MO	MO
Heraldia nocturna	Upside-down Pipefish				✓	MO			
Hippichthys penicillus	Beady Pipefish				✓	MO	MO	MO	MO
Hippocampus angustus	Western Spiny Seahorse				✓	MO	MO	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 breviceps	Short-head Seahorse				✓	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	MO	MO
Hippocampus subelongatus	West Australian Seahorse				✓	MO			
Hippocampus trimaculatus	Three-spot Seahorse				✓	MO			MO
Lissocampus fatiloquus	Prophet's Pipefish				✓	MO			MO
Maroubra perserrata	Sawtooth Pipefish				✓	MO			
Micrognathus micronotopterus	Tidepool Pipefish				✓	MO	MO	MO	MO
Mitotichthys meraculus	Western Crested Pipefish				✓	MO			
Nannocampus subosseus	Bonyhead Pipefish				✓	MO			MO
Phoxocampus belcheri	Black Rock Pipefish				✓	MO			MO
Phycodurus eques	Leafy Seadragon				✓	MO			
Phyllopteryx taeniolatus	Common Seadragon				✓	MO			
Pugnaso curtirostris	Pugnose Pipefish				✓	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			

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
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			
Vanacampus margaritifer	Mother-of-pearl Pipefish				✓	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

*✓= Present within area; *= Matter of National Environmental Significance*

Table 5-8 Biologically Important Areas for Fish Species within the Amulet Development EMBA

Scientific Name	Common Name	BIA Presence				Summary Description of BIA
		EMBA	Project Area	Light Area	Hydrocarbon Area	
Sharks and Rays						
Pristis clavata	Dwarf Sawfish	f,n,p				Inshore foraging, pupping and nursery area along Eighty Mile Beach.
Pristis pristis	Freshwater Sawfish	f,p				Inshore foraging and pupping area along Eighty Mile Beach. Pupping occurs from January to May.
Pristis zijsron	Green Sawfish	f,n,p				Inshore foraging, pupping and nursery area along Eighty Mile Beach.
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.

Biologically Important Area
f: Foraging; n: Nursing; p: Pupping

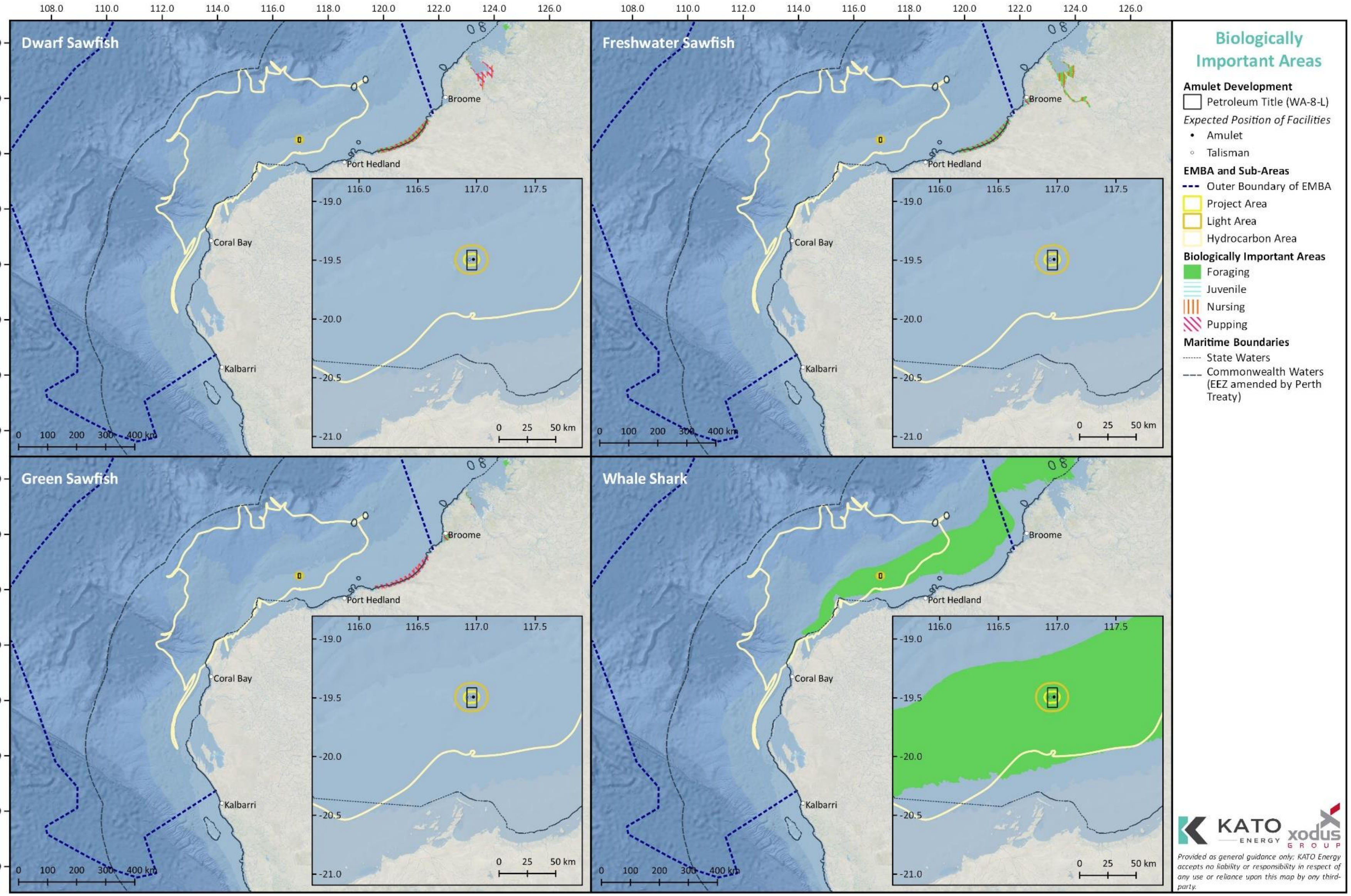


Figure 5-13 Biologically Important Areas for Fish Species (Dwarf Sawfish, Freshwater Sawfish, Green Sawfish, Whale Shark)

5.4.6 Marine Mammals

Multiple species (or species habitat) of marine mammal may occur within the EMBA (Table 5-9, 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 5-9, Appendix A).

BIAs have also been identified for some mammal species (Table 5-10) within the EMBA. The closest to the Amulet Development is the distribution and migration BIAs for the Pygmy Blue and the migration BIA for Humpback Whales (Figure 5-14). Of these, the only one that intersects with the Project Area is the distribution BIA for the Pygmy Blue Whale (Figure 5-14). The migration BIAs are ~65 km (Pygmy Blue Whale) and ~33 km (Humpback Whale) from the expected position of the MOPU. Foraging, breeding, calving and nursing BIAs for the Dugong are also found within the EMBA, but are >345 km from the expected position of the MOPU (Figure 5-14).

Two subspecies of Blue Whales 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). Pygmy Blue Whales migrate along the west coast of Australia in the northern direction to their breeding grounds near the Indonesian Archipelago from mid-February to early-June, and in the southern direction to the feeding grounds in the Southern Ocean from mid-November to early January (McCauley and Jenner 2010; Gavrilov et al. 2018). Pygmy Blue Whales follow the edge of the continental shelf south of North West Cape, on both the north and southbound migratory routes (Gavrilov et al. 2018). It has also been observed that the Pygmy Blue Whales tended to travel much further away from the coast, at distances of up to 400 km, during their southern migration, compared to that observed on their northbound migration (Gavrilov et al. 2018). Two GPS-tagged Pygmy Blue Whales, followed during their northbound migration, gradually moved to a corridor at ~50–100 km west of the continental shelf, when they were tracked north of North West Cape (Double et al. 2014; Gavrilov et al. 2018). McCauley and Jenner (2010) estimated between seven and fifteen hundred Pygmy Blue Whales migrating southward past Exmouth in 2004.

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 (DoEE 2019b). 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.

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 5-14) (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). No known foraging, resting or migratory route for the Humpback Whale exists within the Project Area, and as such any presence would be transitory only.

A significant proportion of the world's Dugong population occurs in coastal waters from Shark Bay (WA) to Moreton Bay (QLD) (DEWHA 2008d). Areas supporting Dugong populations in WA include Shark Bay and the Ningaloo region. 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 northwest to the warmer part of the 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 North West Shelf. 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 5-14; 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 5-9 Marine Mammal Species or Species Habitat that may Occur within the Amulet 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
Balaenoptera bonaerensis	Antarctic Minke Whale			✓	✓	LO			LO
Balaenoptera borealis	Sei Whale	✓	V	✓	✓	FLO	LO	LO	FLO
Balaenoptera edeni	Bryde's Whale			✓	✓	LO	MO	MO	LO
Balaenoptera musculus	Blue Whale	✓	E	✓	✓	MKO	LO	LO	MKO
Balaenoptera physalus	Fin Whale	✓	V	✓	✓	FLO	LO	LO	FLO
Eubalaena australis	Southern Right Whale	✓	E	✓	✓	LO			LO
Globicephala macrorhynchus	Short-finned Pilot Whale				✓	MO		MO	MO
Globicephala melas	Long-finned Pilot Whale				✓	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
Hyperoodon planifrons	Southern Bottlenose Whale				✓	MO			
Kogia breviceps	Pygmy Sperm Whale				✓	MO		MO	MO
Kogia simus	Dwarf Sperm Whale				✓	MO		MO	MO
Indopacetus pacificus	Longman's Beaked Whale				✓	MO			MO
Megaptera novaeangliae	Humpback Whale	✓	V	✓	✓	BKO	BKO	BKO	BKO
Mesoplodon bowdoini	Andrew's Beaked Whale				✓	MO			
Mesoplodon densirostris	Blainville's Beaked Whale				✓	MO			MO
Mesoplodon ginkgodens	Gingko-toothed Beaked Whale				✓	MO			MO
Mesoplodon grayi	Gray's Beaked Whale				✓	MO			
Mesoplodon layardii	Strap-toothed Beaked Whale				✓	MO			
Mesoplodon mirus	True's Beaked Whale				✓	MO			
Peponocephala electra	Melon-headed Whale				✓	MO		MO	MO
Physeter macrocephalus	Sperm Whale			✓	✓	MO		MO	MO
Ziphius cavirostris	Cuvier's Beaked Whale				✓	MO		MO	MO
Sirenians									
Dugong dugon	Dugong			✓	✓	BKO			BKO
Dolphins									
Delphinus delphis	Common Dolphin				✓	MO	MO	MO	MO
Feresa attenuata	Pygmy Killer Whale				✓	MO		MO	MO
Grampus griseus	Risso's Dolphin				✓	MO	MO	MO	MO
Lagenodelphis hosei	Fraser's Dolphin				✓	MO			MO
Lissodelphis peronii	Southern Right Whale Dolphin			✓	✓	MO			
Orcaella brevirostris	Irrawaddy Dolphin				✓	LO			
Orcaella heinsohni	Australian Snubfin Dolphin			✓		LO			

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
Orcinus orca	Killer Whale			✓	✓	MO	MO	MO	MO
Peponocephala electra	Melon-headed Whale				✓	MO			MO
Pseudorca crassidens	False Killer Whale				✓	LO	LO	LO	LO
Sousa chinensis	Indo-Pacific Humpback Dolphin			✓	✓	KO			KO
Stenella attenuata	Spotted Dolphin				✓	MO	MO	MO	MO
Stenella coeruleoalba	Striped Dolphin				✓	MO		MO	MO
Stenella longirostris	Long-snouted Spinner Dolphin				✓	MO		MO	MO
Steno bredanensis	Rough-toothed Dolphin				✓	MO		MO	MO
Tursiops aduncus	Spotted Bottlenose Dolphin			✓	✓	LO	MO	MO	LO
Tursiops aduncus (Arafura/Timor Sea populations)	Indian Ocean Bottlenose Dolphin				✓	LO	MO	MO	KO
Tursiops truncatus s. str.	Bottlenose Dolphin				✓	MO	MO	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*

MKO *Migration route known to occur within area*

FLO *Foraging, feeding or related behaviour likely to occur within area*

BKO *Breeding known to occur within area*

*✓= Present within area; *= Matter of National Environmental Significance*

Table 5-10 Biologically Important Areas for Marine Mammal Species within the Amulet Development EMBA

Scientific Name	Common Name	BIA Presence				Summary Description of BIA
		EMBA	Project Area	Light Area	Hydrocarbon Area	
Whales						
Balaenoptera musculus	Pygmy Blue Whale	d,f,m	d	d	d,f,m	Offshore migration corridor, typically along the shelf edge at depths 500–

Scientific Name	Common Name	BIA Presence: EMBA	Project Area	Light Area	Hydrocarbon Area	Summary Description of BIA
						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.
Megaptera novaeangliae	Humpback Whale	m,r			m,r	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.
Sirenians						
Dugong dugon	Dugong	b,c,f, n			b,c,f, n	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.
Biologically Important Area *b: Breeding; c: Calving; d: Distribution; f: Foraging; m: Migration; n: Nursing; r: Resting*						

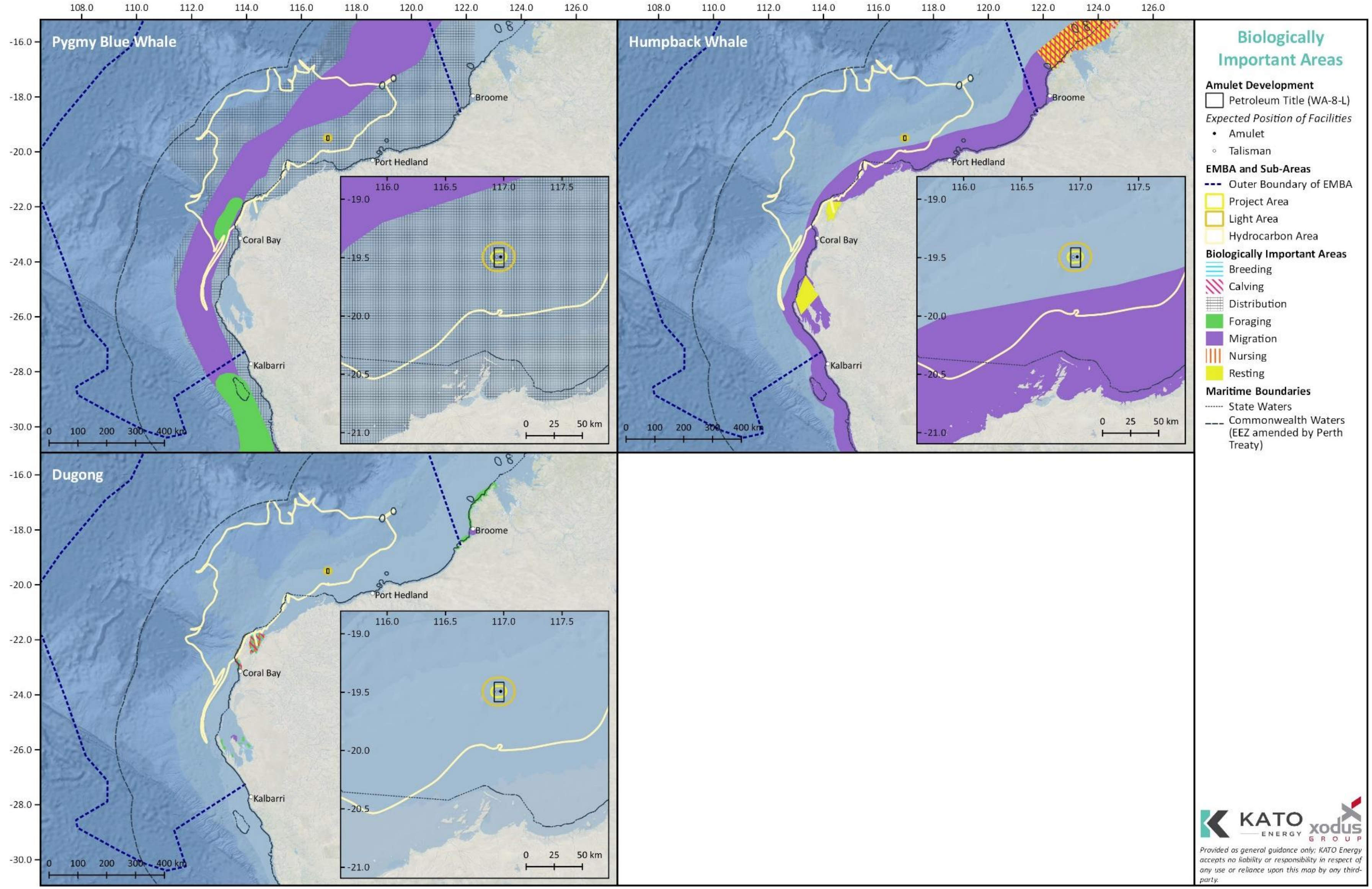


Figure 5-14 Biologically Important Areas for Mammal Species (Pygmy Blue Whale, Humpback Whale, Dugong)

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) (Figure 5-1; Appendix A).

BIAs and critical habitat have also been identified for some turtle species (

Table 5-12) within the EMBA. The closest to the Amulet Development is the internesting BIA and critical habitat for the Flatback Turtle (~18 km and ~36 km south of the expected position of the MOPU (Figure 5-15). Use of internesting areas by turtles is typically for resting or foraging between nesting attempts.

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 (

Table 5-13) (CoA 2017). These important nesting locations include areas inshore of the Amulet Development at the Dampier Archipelago (e.g. Rosemary Island, Delambre Island) and Barrow Island to the west. 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.

Estimates of turtle populations within the entire NWS vary, but are typically largest for the Green and Flatback Turtles. Both species are known to nest in relatively high numbers in Dampier Archipelago, Barrow Island and Montebello Island. The North West Shelf population of Green Turtles is one of the largest in the world, and is likely to be the largest in the Indian Ocean (Seminoff 2002; Limpus 2009). The North West Shelf population of Flatback Turtles is globally significant for the species, which only nests in Australia (Limpus 2009; Pendoley et al. 2014).

The WA Hawksbill Turtle stock is one of the largest in the world and the largest in the Indian Ocean (Limpus 2009). The Dampier Archipelago has the largest nesting aggregation recorded with approximately 1,000 nesting females per year at Rosemary Island (Limpus 2009). Surveys undertaken at Varanus and Rosemary Islands suggest that survivorship of nesting females has remained high (0.95) and constant over the past 20 years (Prince and Chaloupka 2012).

Recently, the Department of Biodiversity, Conservation and Attractions (DBCA) found a high-density Loggerhead foraging site near Point Sampson whilst tracking “Yoshi” a Loggerhead turtle released from Cape Town (RNZ 2020). Numerous Loggerhead turtles were observed at the site, ranging from juveniles to adults.

Table 5-11 Marine Reptile Species or Species Habitat that may Occur within the Amulet Development EMBA

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
Turtles									
Caretta caretta	Loggerhead Turtle	Y	E	✓	✓	BKO	LO	LO	BKO
Chelonia mydas	Green Turtle	Y	V	✓	✓	BKO	LO	LO	BKO
Dermochelys coriacea	Leatherback Turtle	Y	E	✓	✓	FKO	LO	LO	KO
Eretmochelys imbricate	Hawksbill Turtle	Y	V	✓	✓	BKO	LO	LO	BKO
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle	Y	E	✓	✓	LO			
Natator depressus	Flatback Turtle	Y	V	✓	✓	BKO	LO	KO	BKO
Seasnakes									
Acalyptophis peronii	Horned Seasnake				✓	MO	MO	MO	MO
Aipysurus apraefrontalis	Short-nosed Seasnake	Y	CE		✓	KO		MO	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	MO	MO
Astrotia stokesii	Stokes' Seasnake				✓	MO	MO	MO	MO
Disteira kingii	Spectacled Seasnake				✓	MO	MO	MO	MO
Disteira major	Olive-headed Seasnake				✓	MO	MO	MO	MO
Emydocephalus annulatus	Turtle-headed Seasnake				✓	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			

Scientific Name	Common Name	EPBC Status: Recovery Plans / 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
Hydrophis czeblukovi	Fine-spined Seasnake				✓	MO	MO	MO	MO
Hydrophis elegans	Elegant Seasnake				✓	MO	MO	MO	MO
Hydrophis mcdowelli	null				✓	MO	MO	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
Crocodiles									
Crocodylus porosus	Salt-water Crocodile			✓	✓	LO			

Threatened Species:
V Vulnerable
E Endangered
CE Critically 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

*✓= Present within area; *= Matter of National Environmental Significance*

Table 5-12 Biologically Important Areas for Marine Reptile Species within the Amulet 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
Caretta caretta	Loggerhead Turtle	f,i,n			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.

Scientific Name	Common Name	BIA Presence: EMBA	Project Area	Light Area	Hydrocarbon Area	Summary Description of BIA
Chelonia mydas	Green Turtle	a,b,f,i, n,m, mr			b,f,i,n ,m	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, and De Grey River and Bedout Island.
Eretmochelys imbricate	Hawksbill Turtle	f,i,n, m,mr			f,i,n, m	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, and De Grey River and Bedout Island.
Natator depressus	Flatback Turtle	a,f,i,n, m, mr			f,i,n, m	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, and De Grey River and Bedout Island.
<u>Biologically Important Area</u> *a: Aggregation; b: Basking; f: Foraging; i: Internesting; n: Nesting; m: Mating; mr: Migration*						

Table 5-13 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 (North West Shelf)	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

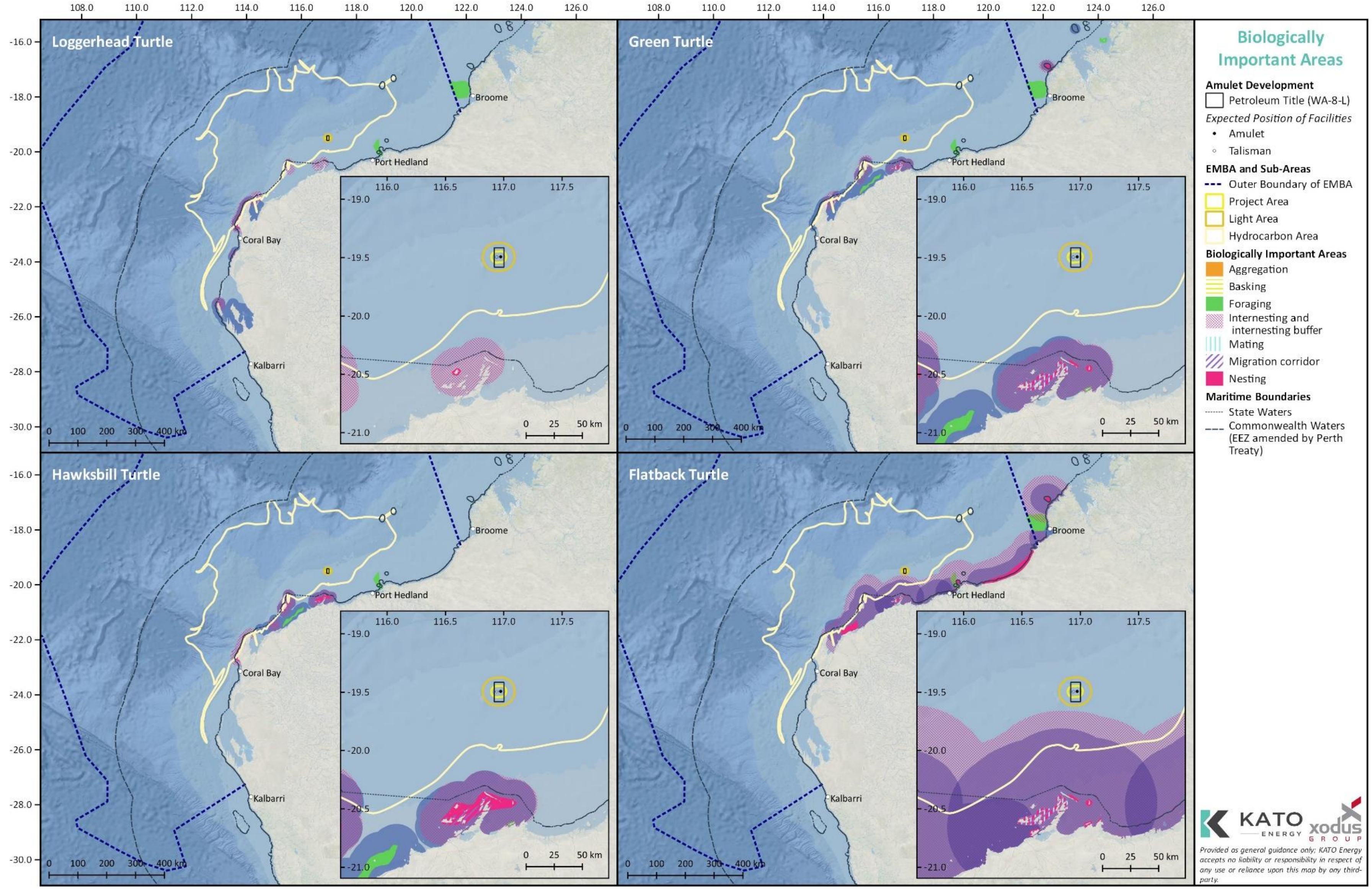


Figure 5-15 Biologically Important Areas and Critical Habitat for Marine Reptile Species (Loggerhead Turtle, Green Turtle, Hawksbill Turtle, Flatback Turtle

5.5 Social, Economic and Cultural Environment

5.5.1 Commonwealth Marine Area

The Commonwealth marine environment is a MNES under the EPBC Act. The EMBA for the Amulet 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 (Section 5.2.1) 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 (Section 5.2.2) 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 have been proclaimed as Commonwealth reserves under the EPBC Act in 2007 and 2013. Within the EMBA, 11 AMPs are present; ten within the North-west Marine Region, and one within the South-west Marine Region (Table 5-14, Figure 5-16). The closest AMPs to the Amulet Development are the Dampier Marine Park and Montebello Marine Park, ~90 km and ~120 km from the expected position of the MOPU respectively (Figure 5-16).

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 5-15:

- 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 5-14 Australian Marine Parks within the Amulet Development EMBA

Australian Marine Park	EMBA	Project Area	Light Area	Hydrocarbon Area
North-west Marine Region				
Argo-Rowley Terrace	✓	X	X	✓
Carnarvon Canyon	✓	X	X	X
Dampier	✓	X	X	X
Eighty Mile Beach	✓	X	X	X
Gascoyne	✓	X	X	✓
Kimberley	✓	X	X	X
Mermaid Reef	✓	X	X	X
Montebello	✓	X	X	✓
Ningaloo	✓	X	X	✓
Shark Bay	✓	X	X	✓
South-west Marine Region				
Abrolhos	✓	X	X	X

✓ = Present within area; X = not present within area

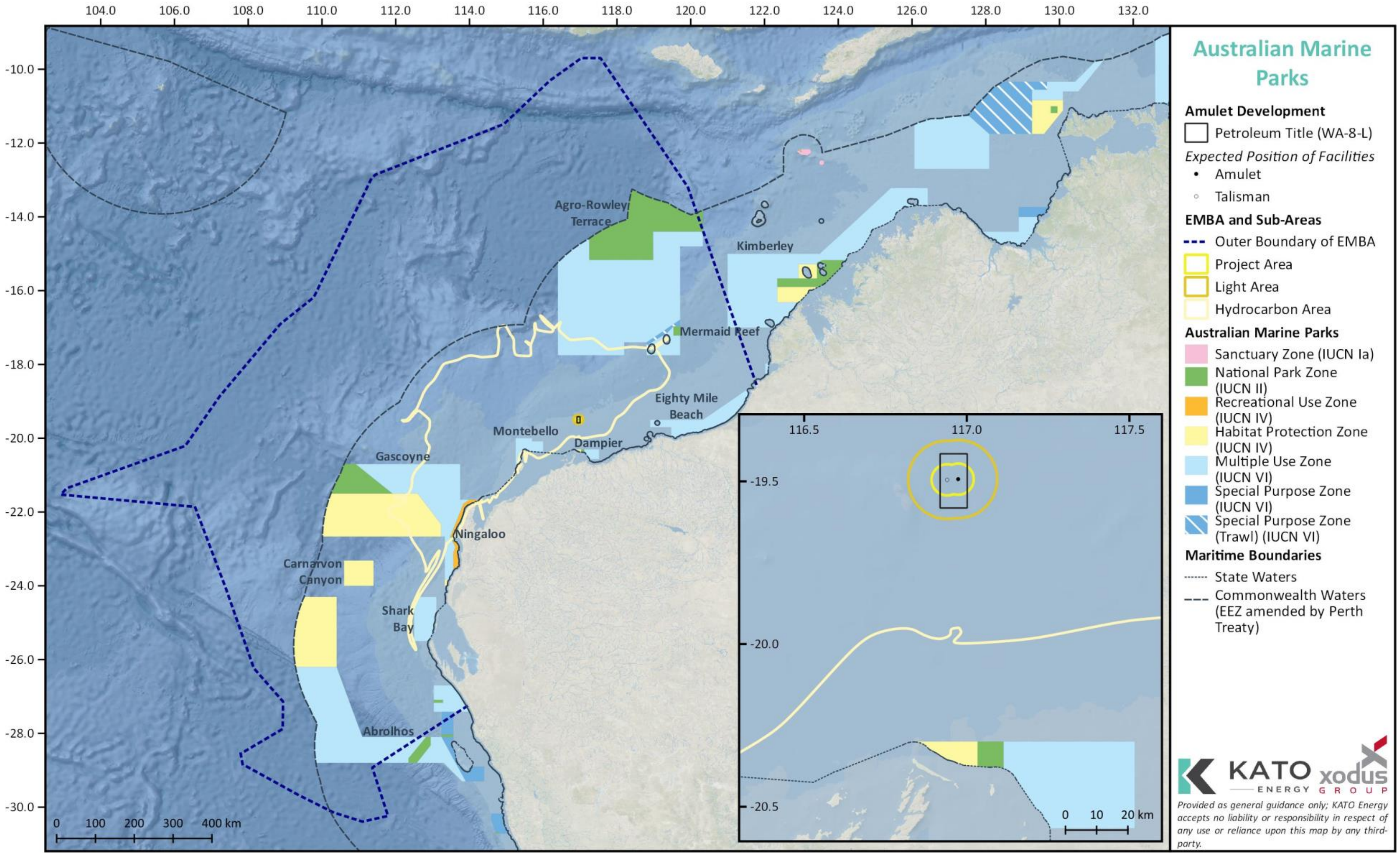


Figure 5-16 Australian Marine Parks

Table 5-15 Significance and Values of Australian Marine Parks

Australian Marine Parks – Significance and Values
North-west Marine Region
Argo-Rowley Terrace Marine Park

The Argo-Rowley Terrace Marine Park is located ~270 km northwest 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:
  o 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.
  o 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.

Carnarvon Canyon Marine Park
The Carnarvon Canyon Marine Park is located ~300 km northwest 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**

Australian Marine Parks – Significance and 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.

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.

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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. • 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.
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

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○ 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.
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.

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• 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 people have responsibilities for sea country in the Marine Park.
• The Wunambal Gaambera people's country includes daagu (deep waters), with ~3,400 km^2 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 warrurru (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.
• 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.

Mermaid Reef Marine Park
The Mermaid Reef Marine Park is located ~280 km northwest 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 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).

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• 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.
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 km^2 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). • 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

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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:
  ○ 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
  ○ 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.
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

Shark Bay Marine Park

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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 km², 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.
- 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:

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○ 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. ○ 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. ○ 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. ○ 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. • 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.

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, 12 KEFs are present; nine within the North-west Marine Region, and three within the South-west Marine Region (Table 5-16, Figure 5-17). The closest KEFs to the Amulet Development are the Ancient coastline at 125 m depth contour and Glomar Shoals, ~8 km and ~15 km from the expected position of the MOPU respectively (Figure 5-17).

The importance and values have been identified for each KEF within the SPRAT database (DoEE 2019b) and are summarised in Table 5-16.

Table 5-16 Key Ecological Features within the Amulet Development EMBA

Key Ecological Feature	EMBA	Project Area	Light Area	Hydrocarbon Area
North-west Marine Region				
Ancient coastline at 125 m depth contour	✓	X	✓	✓
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	X	✓
Commonwealth waters adjacent to Ningaloo Reef	✓	X	X	✓
Continental slope demersal fish communities	✓	X	X	✓
Exmouth Plateau	✓	X	X	✓
Glomar Shoals	✓	X	✓	✓
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	✓	X	X	✓
Wallaby Saddle	✓	X	X	X
South-west Marine Region				
Mesoscale eddies	✓	X	X	X
Perth Canyon and adjacent shelf break, and other west coast canyons	✓	X	X	X
Western demersal slope and associated fish communities	✓	X	X	X

✓ = Present within area; X = not present within area

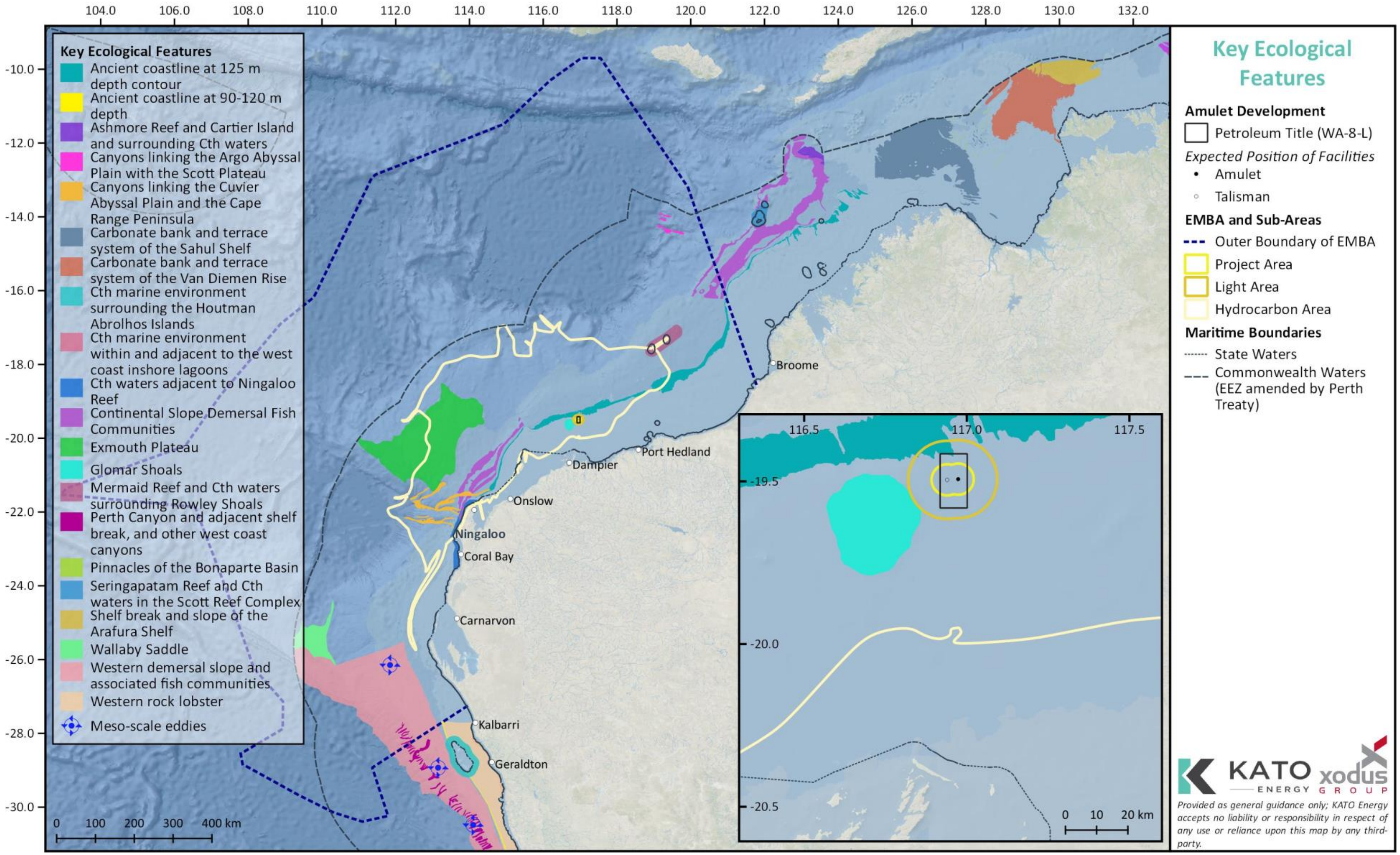


Figure 5-17 Key Ecological Features

Table 5-17 Importance and Values of Key Ecological Features

Key Ecological Features – Importance and Values
North-west Marine Region
Ancient coastline at 125 m 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 North West Shelf 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 North West Shelf 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.

Key Ecological Features – Importance and Values
Whaling records from the 19th century suggest that the Exmouth Plateau may have supported large populations of Sperm Whales.
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 northwest. 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.

Key Ecological Features – Importance and Values
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
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.
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

Key Ecological Features – Importance and Values
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.

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 5-18). However, not all the fisheries are active within the full extents of the management areas. Based on historical fishing effort data (e.g. Patterson et al. 2018, 2019):

- North West Slope Trawl Fishery (NWSTF) is likely to be active in waters offshore from the 200 m isobath off the Pilbara and Kimberley coasts (Figure 5-18)
- 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 5-19)
- Western Deepwater Trawl Fishery (WDTF) is likely to be active in waters offshore from the 200 m isobath off the Gascoyne coast (Figure 5-20)
- 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 5-21).

Therefore, based on previous data, no active fishing effort from Commonwealth-Managed Fisheries is expected to occur within the immediate vicinity of the Amulet Development (i.e. within the Project Area or Light Area) (Table 5-18).

A summary of the three fisheries that may be active within the Hydrocarbon Area and the wider EMBA are summarised in

Table 5-19.

Table 5-18 Management Areas for Commonwealth-managed Fisheries within the Amulet Development EMBA

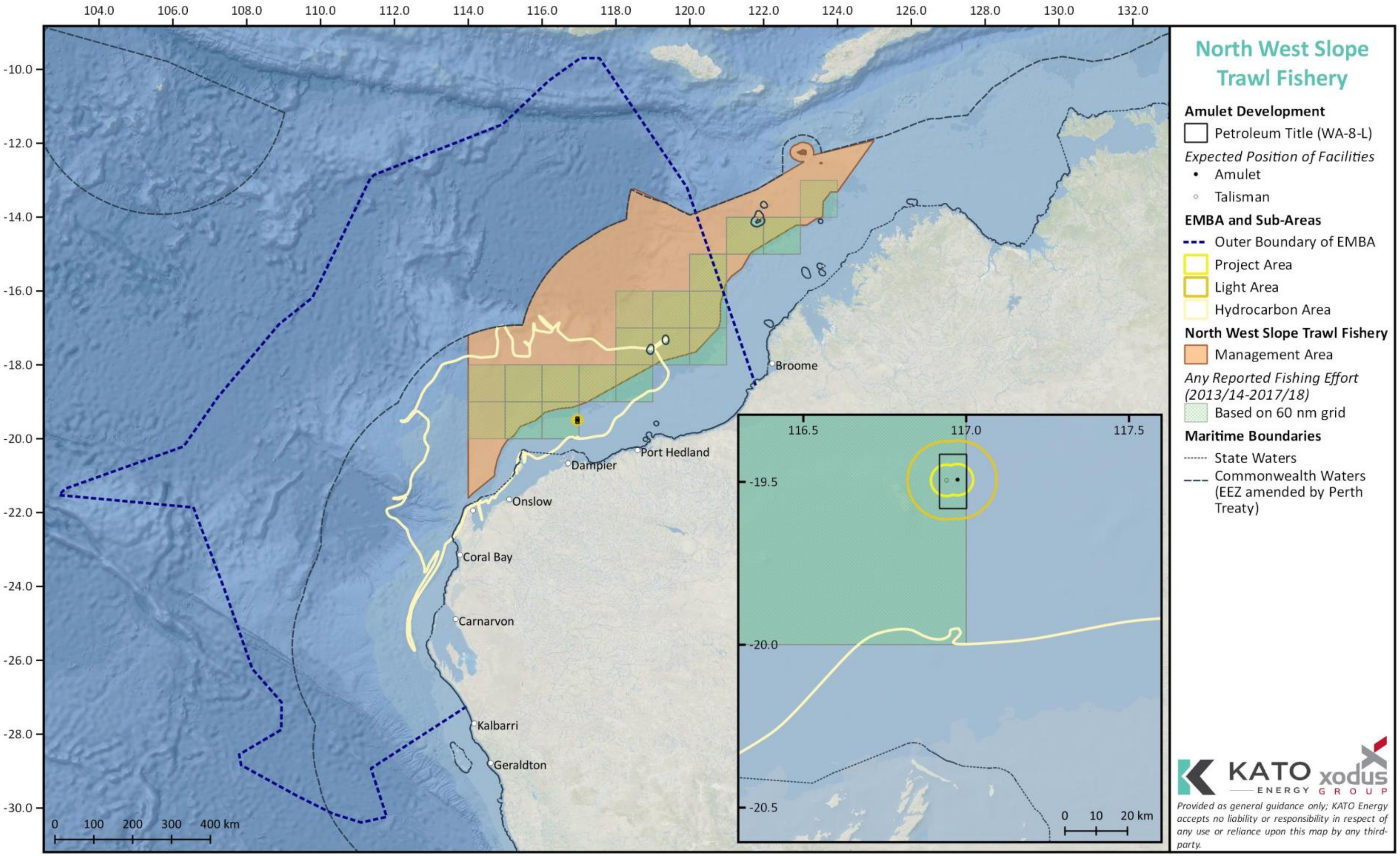
Fishery	EMBA	Project Area	Light Area	Hydrocarbon Area
North West Slope Trawl Fishery	✓ (a)	*X*	*X*	✓ (a)
Southern Bluefin Tuna Fishery	✓ (n)	✓ (n)	✓ (n)	✓ (n)
Western Deepwater Trawl Fishery	✓ (a)	*X*	*X*	✓ (a)
Western Skipjack Tuna Fishery	✓ (n)	✓ (n)	✓ (n)	✓ (n)
Western Tuna and Billfish Fishery	✓ (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

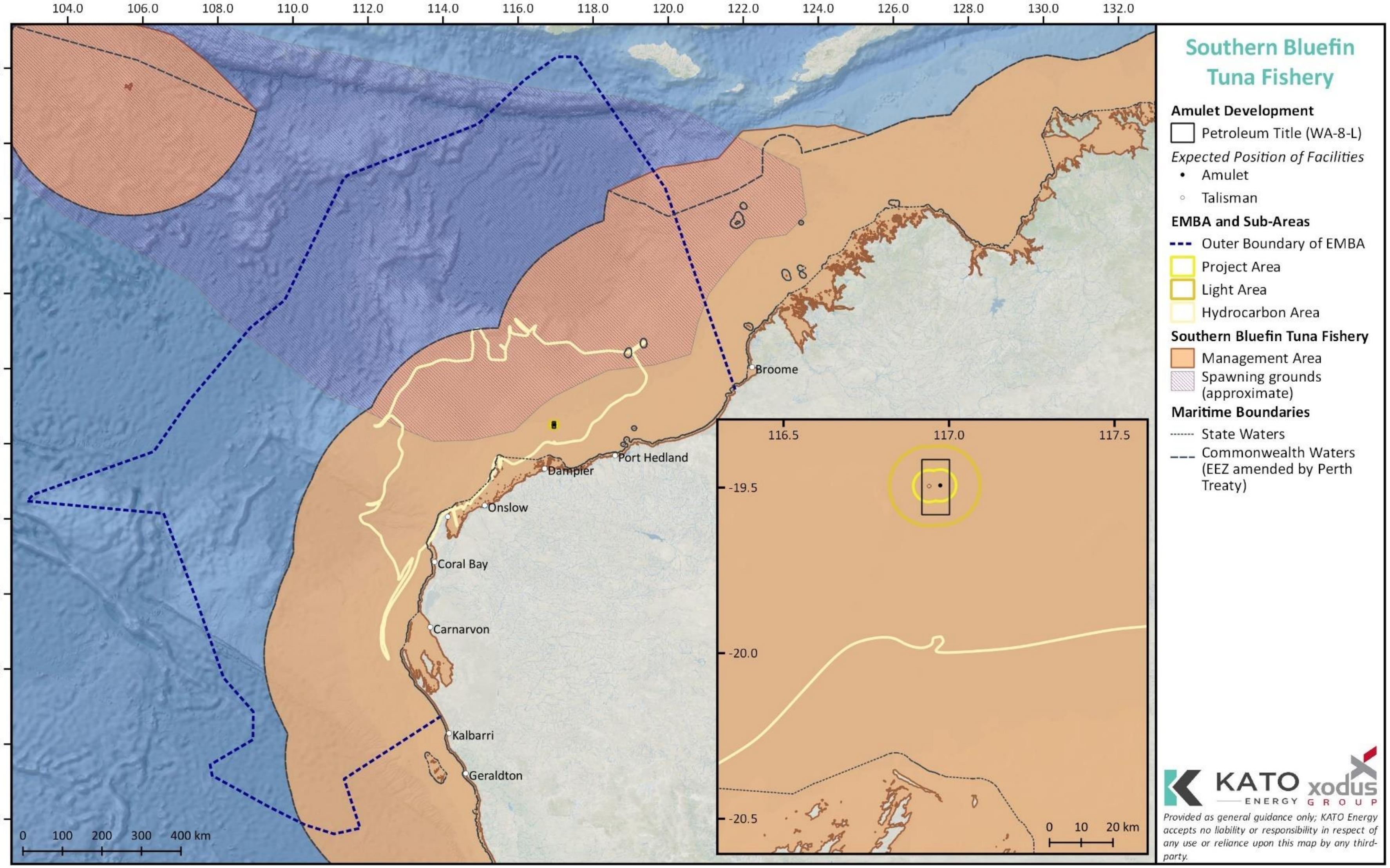
Table 5-19 Commonwealth-managed Fisheries with Active Fishing Effort within the Amulet Development EMBA

Fishery	Fishery Area	Method/s	Season (if specified)	Target Species
North West Slope Trawl Fishery	200 m isobath to AFZ, Exmouth to Mitchell Plateau	Demersal trawl	1 July – 30 June	Scampi (*Metanephrops australiensis, M. boschmai, M. velutinus*)
Western Deepwater Trawl Fishery	200 m isobath to AFZ, Exmouth to Augusta	Demersal trawl	1 July – 30 June	Deepwater Bugs (*Ibacus* spp.) Ruby Snapper (*Etelis* sp.)
Western Tuna and Billfish Fishery	In the AFZ and high seas of the Indian Ocean, from Cape York to SA/VIC border	Pelagic longline, minor line and purse seine	1 February – 31 January	Bigeye Tuna (*Thunnus obesus*) Yellowfin Tuna (*T. albacares*) Broadbill Swordfish (*Xiphias gladius*) Striped marlin (*Tetrapturus audux*)



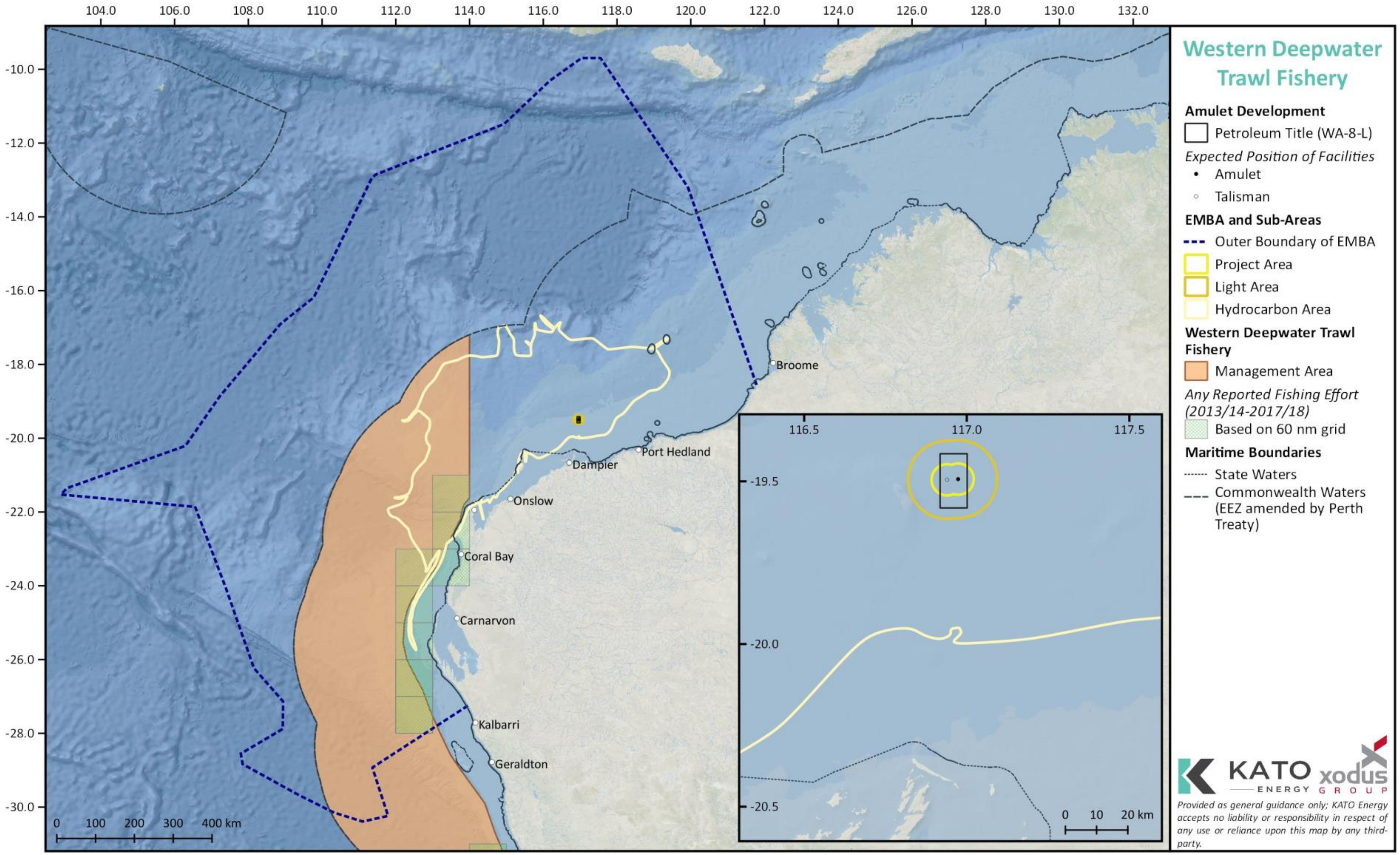
Source: Fisheries data were supplied by the Australian Bureau of Agricultural and Resource Economics and Sciences from data collected by the Australian Fisheries Management Authority

Figure 5-18 Management Area and Reported Active Fishing Areas between 2013/14 and 2017/18 for the North West Slope Trawl Fishery



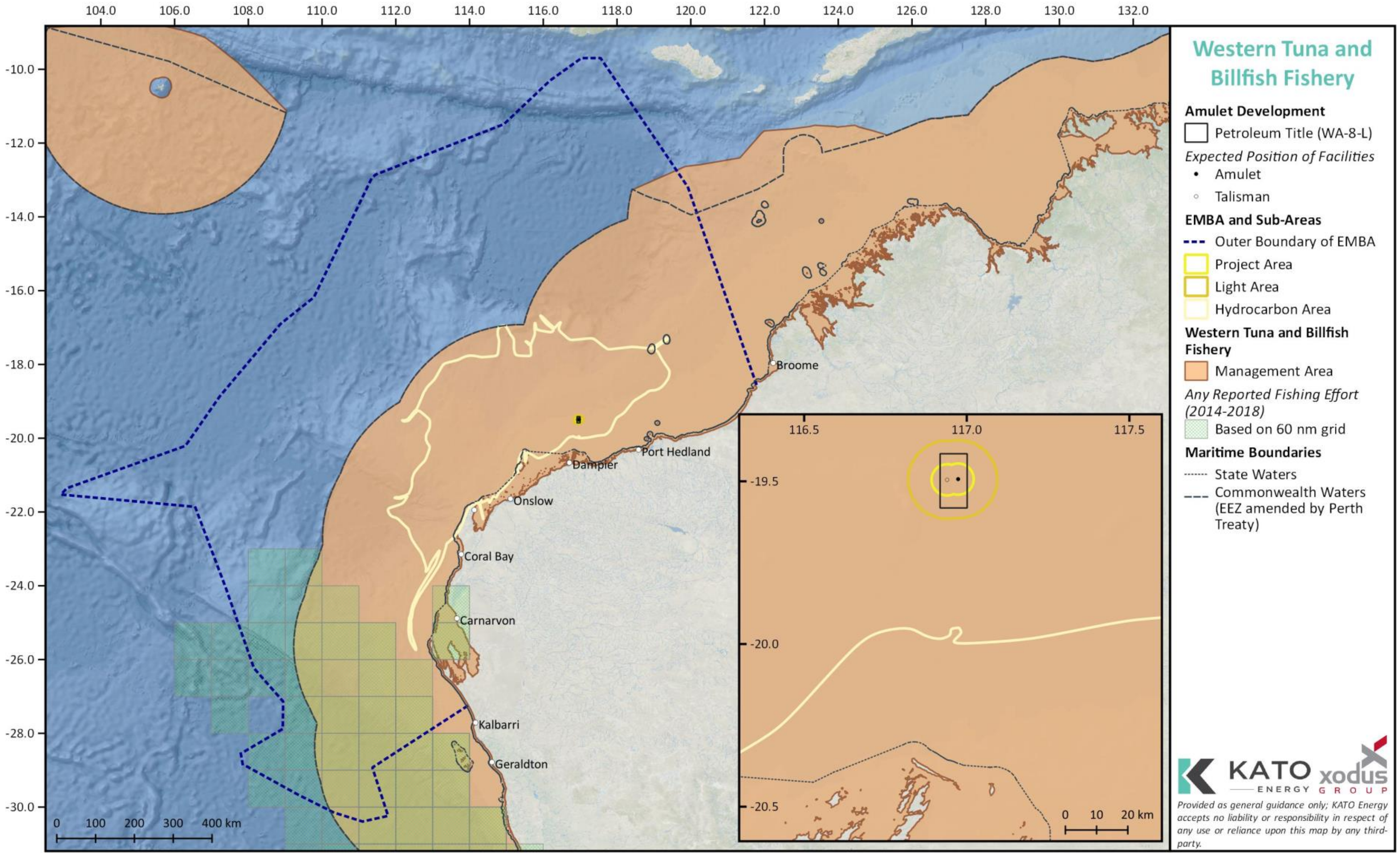
Source: Fisheries data were supplied by the Australian Bureau of Agricultural and Resource Economics and Sciences from data collected by the Australian Fisheries Management Authority

Figure 5-19 Management Area for the Southern Bluefin Tuna Fishery with Indian Ocean Spawning Ground (no active fishing areas in WA)



Source: Fisheries data were supplied by the Australian Bureau of Agricultural and Resource Economics and Sciences from data collected by the Australian Fisheries Management Authority

Figure 5-20 Management Area and Reported Active Fishing Areas between 2013/14 and 2017/18 for the Western Deepwater Trawl Fishery



Source: Fisheries data were supplied by the Australian Bureau of Agricultural and Resource Economics and Sciences from data collected by the Australian Fisheries Management Authority

Figure 5-21 Management Area and Reported Active Fishing Areas between 2014 and 208 for the Western Tuna and Billfish Fishery

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*[9] (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 Amulet Development occurring within the North Coast region (Gaughan and Santoro 2019). Several State-managed commercial fisheries have management areas that intersect with the EMBA (Table 5-20). 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 5-21.

The FishCube database (DPIRD 2019, 2020) indicates four State fisheries may be active within the 60 nm grid block (No. 19160) that directly intersects with the Amulet Development:

- Mackerel Managed Fishery (MMF)
- Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF)
- Pilbara Line Fishery (PLF)
- Pilbara Trap Managed Fishery (PTMF).

However, it is noted that the Amulet Development is located on the eastern boundary of this 60 nm block, and as such fishing effort within the block is not necessarily indicative of fishing activity directly within the planned activity areas (i.e. Project Area and Light Area) for the Amulet Development.

Fishing effort data for this block within the previous five-year period (2014–2018), typically shows low and variable activity from these fisheries:

- Fishing activity for the MMF was recorded for all years during 2014-2018; with typically low vessel numbers (<3 to 4) being active during any month. The MMF typically focusses on coastal areas and around reefs and shoals. Smaller-scale (10 nm grid blocks) activity reporting available in the vicinity of the Amulet Development shows that no activity was recorded within the Project Area and only a small intersect between the Light Area and areas of fishing effort during 2014-2018 (see inset within Figure 5-22).
- Fishing activity for the PFTIMF was recorded for all years during 2014-2018; with typically low vessel numbers (≤3) being active during any month. The Amulet Development is within Zone 2 / Area 2 of the fishery, which is open for fishing. Smaller-scale (10 nm grid blocks) activity reporting available in the vicinity of the Amulet Development shows that activity was recorded within the Project Area and Light Area during 2014-2018 (see inset within Figure 5-23).
- Fishing activity for the PLF was recorded for all years during 2014-2018; with typically low vessel numbers (≤3) being active during any month. The Amulet Development is within an area open for fishing, , and low levels of activity within the Project and Light Areas is possible (Figure 5-24). The PLF is managed under the Prohibition on Fishing by Line from Fishing Boats (Pilbara Waters) Order 2006 with the exemption of nine fishing vessel licences for any nominated five-month block period within the year.
- Fishing activity for the PTMF was recorded for all years during 2014-2018; with typically low vessel numbers (≤3) being active during any month. The Amulet Development is within an

[9] 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)

area open for fishing, and low levels of activity within the Project and Light Areas is possible (Figure 5-25).

Therefore, based on management boundaries and the previous reported fishing effort, low levels of commercial fishing activity is expected to occur within the planned activities areas for the Amulet Development. Any fishing effort that may occur within the Project Area and Light Area is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF); noting some fishing effort from the MMF may also occur within the western extent of the Light Area.

A summary of commercial fishery management areas and fishery status (active/not active) for the EMBA and Sub-Areas is provided in Table 5-20.

Table 5-20 Management Areas for State-managed Fisheries within the Amulet Development EMBA

State-managed Fishery	EMBA	Project Area	Light Area	Hydrocarbon Area
North Coast Bioregion				
Beche-De-Mer (Sea Cucumber) Fishery	✓(a)	X	X	✓(n)
Pearl Oyster Fishery	✓(a)	✓(n)	✓(n)	✓(n)
Mackerel Managed Fishery	✓(a)	✓(n)	✓(a)	✓(a)
North Coast Nearshore and Estuarine Fishery (Kimberley Gillnet and Barramundi Fishery)	✓(a)	X	X	X
North Coast Crab Fisheries				
Kimberley Developing Mud Crab Fishery	✓(a)	X	X	X
Pilbara Developmental Crab Fishery	✓(a)	✓(n)	✓(n)	✓(n)
North Coast Demersal Scalefish Fisheries				
Pilbara Fish Trawl (Interim) Managed Fishery	✓(a)	✓(a)	✓(a)	✓(a)
Pilbara Line Fishery	✓(a)	✓(a)	✓(a)	✓(a)
Pilbara Trap Managed Fishery	✓(a)	✓(a)	✓(a)	✓(a)
North Coast Prawn Fisheries				
Broome Prawn Managed Fishery	✓(a)	X	X	X
Nickol Bay Prawn Managed Fishery	✓(a)	✓(n)	✓(n)	✓(a)
Onslow Prawn Managed Fishery	✓(a)	X	X	✓(a)
Gascoyne Coast Bioregion				
Exmouth Gulf Prawn Fishery	✓(a)	X	X	✓(a)
Gascoyne Demersal Scalefish Fishery	✓(a)	X	X	✓(a)
Inner Shark Bay Scalefish Fishery	✓(a)	X	X	X
Shark Bay Blue Swimmer Crab Fishery	✓(a)	X	X	✓(n)
Shark Bay Prawn and Scallop Managed Fisheries	✓(a)	X	X	✓(n)
West Coast Deep Sea Crustacean Fishery	✓(a)	✓(n)	✓(n)	✓(a)
West Coast Bioregion				
Octopus Fishery	✓(a)	X	X	X
Roe’s Abalone Fishery	✓(a)	X	X	✓(n)

State-managed Fishery	EMBA	Project Area	Light Area	Hydrocarbon Area
West Coast Demersal Scalefish Fishery	✓(a)	X	X	X
West Coast Rock Lobster Fishery	✓(a)	X	X	✓(a)
Statewide Bioregion				
Marine Aquarium Fish Managed Fishery	✓(a)	✓(n)	✓(n)	✓(a)
The Specimen Shell Managed Fishery	✓(a)	✓(n)	✓(n)	✓(a)
Pearling and Aquaculture				
Pearling / Aquaculture Leases	✓(a)	X	X)	✓(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

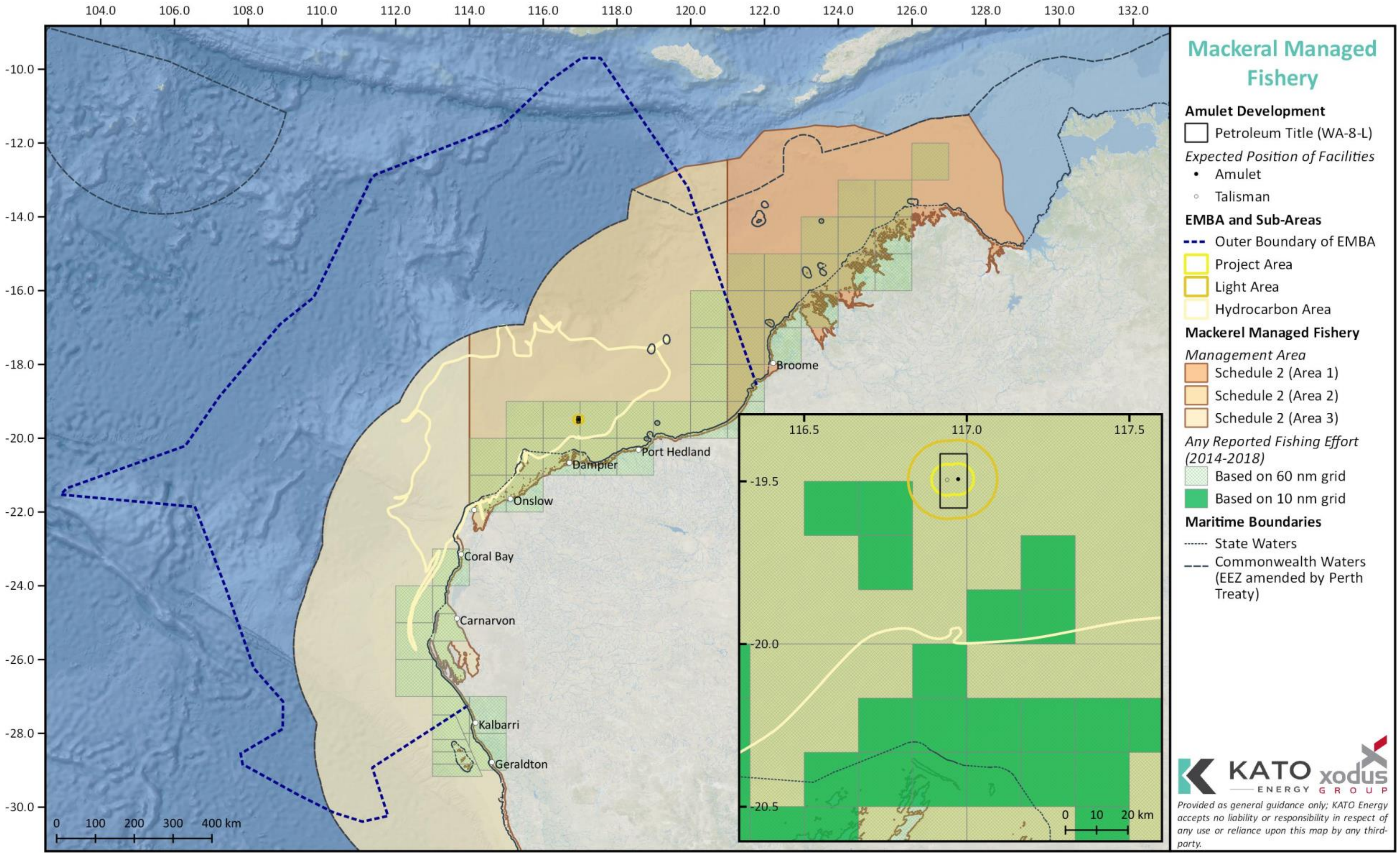


Figure 5-22 Management Area and Reported Active Fishing Areas during 2014-2018 for the Mackerel Managed Fishery

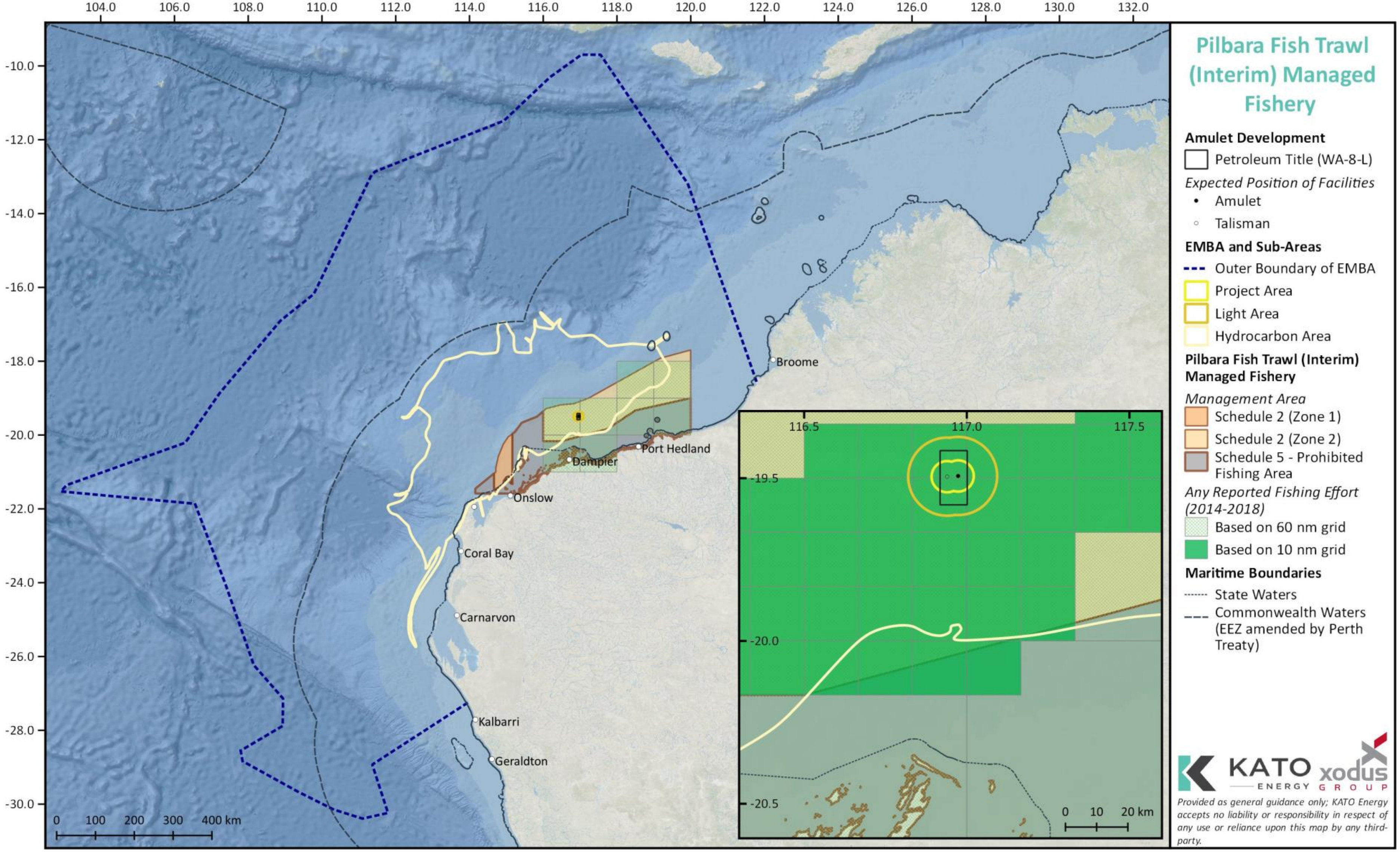


Figure 5-23 Management Area and Reported Active Fishing Areas during 2014-2018 for the Pilbara Fish Trawl (Interim) Managed Fishery

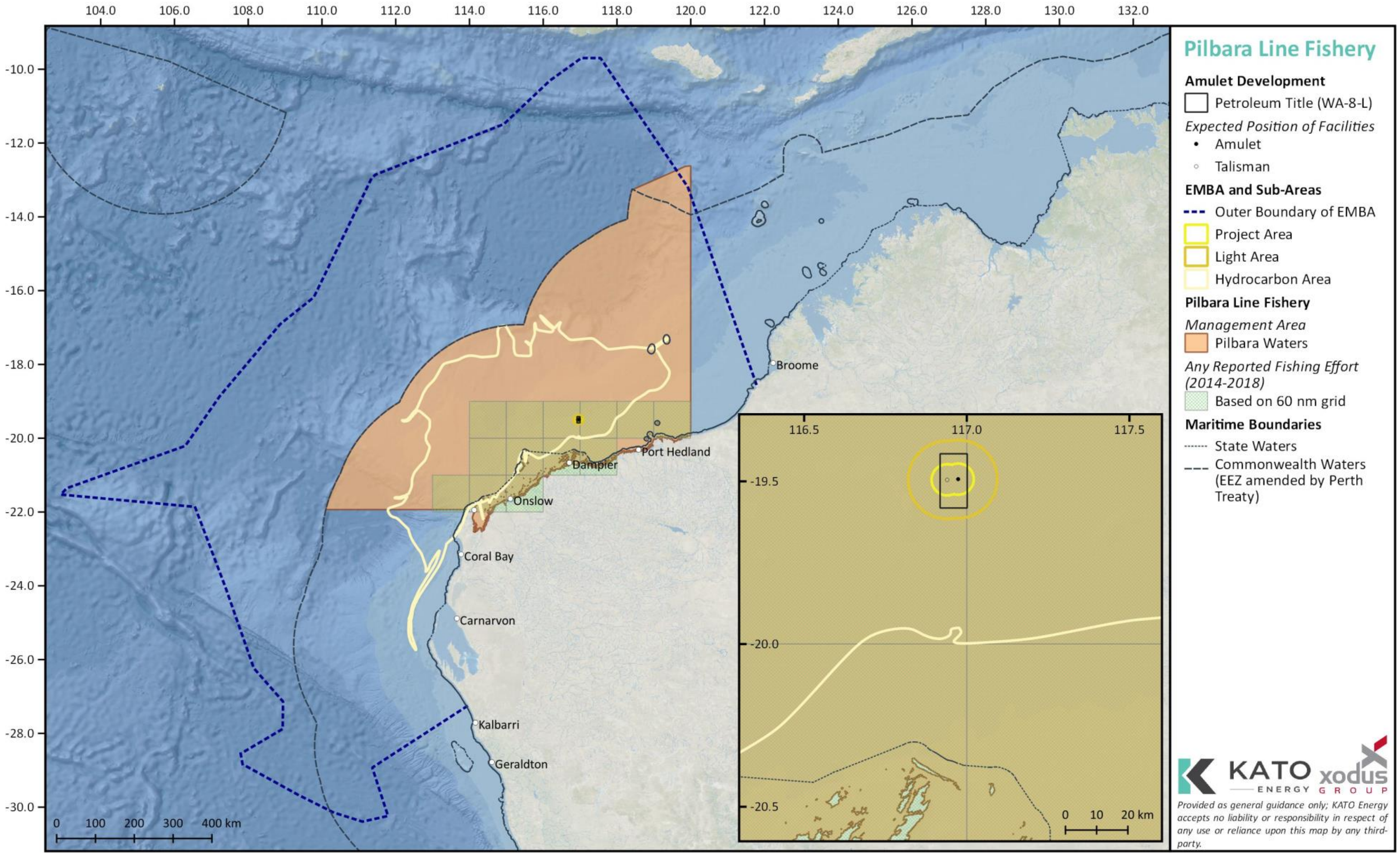


Figure 5-24 Management Area and Reported Active Fishing Areas during 2014-2018 for the Pilbara Line Fishery

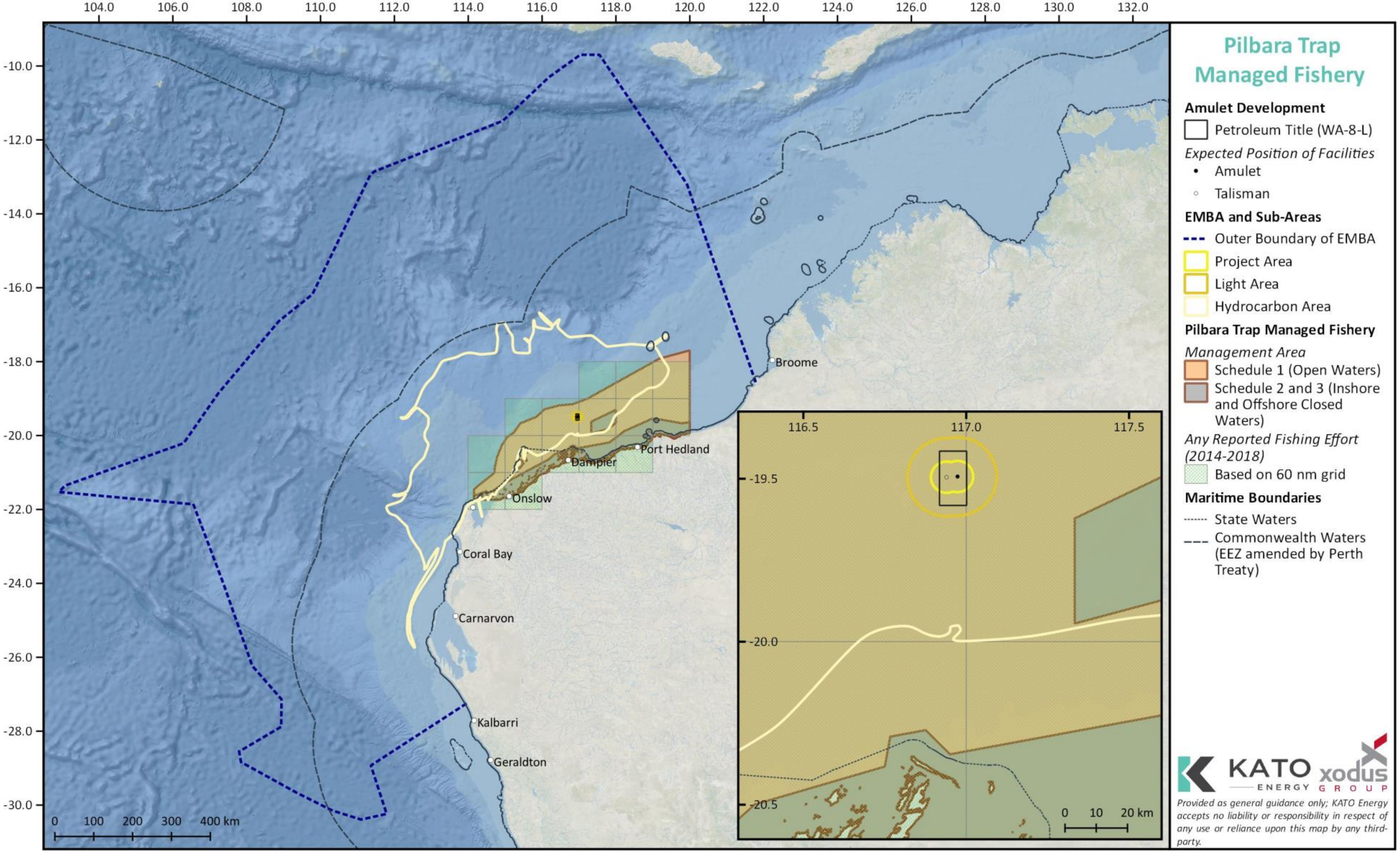


Figure 5-25 Management Area and Reported Active Fishing Areas during 2014-2018 for the Pilbara Trap Managed Fishery

Table 5-21 State-managed Fisheries with Active Fishing Effort within the Amulet Development EMBA

Fishery	Fishery Area	Method/s	Season (if specified)	Target Species
North Coast Bioregion				
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*)
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 Nearshore and Estuarine Fishery (Kimberley Gillnet and Barramundi Fishery)	River and tidal creek systems of the Cambridge Gulf, the Ria coast, King Sound, Roebuck Bay and the northern end of Eighty Mile Beach	Gillnets	Closed 1 December – 31 January (west of Cunningham Point); and closed 1 November – 31 January (east of Cunningham Point)	Barramundi (*Lates calcarifer*) Blue Threadfin (*Eleutheronema tetradactylum*) King Threadfin (*Polydactylus macrochir*)
North Coast Crab Fishery				
Kimberley Developing Mud Crab Fishery	Kimberley coastal areas, most fishing effort concentrated around Cambridge Gulf, Admiralty Gulf, York Sound and King Sound.	Crab traps		Mud Crab (*Scylla* spp.)
Pilbara Developmental Crab Fishery	Pilbara coastal embayments, estuaries and nearshore areas up to 50 m depth. Nickol Bay is often targeted.	Hourglass traps	Hot weather restricts fishing effort between April and November	Blue Swimmer Crabs (*Portunus armatus*)
North Coast Demersal Scalefish Fisheries				
Pilbara Demersal Scale Fisheries includes • Pilbara Fish Trawl (Interim) 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*)

Fishery	Fishery Area	Method/s	Season (if specified)	Target Species
• Pilbara Trap Managed Fishery				
North Coast Prawn Fisheries				
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.)
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*)
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 November	Western King Prawns (*Penaeus latisulcatus*) Brown Tiger Prawns (*Penaeus esculentus*) Endeavour Prawns (*Metapenaeus endeavouri*)
Gascoyne Coast Bioregion				
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*)
Gascoyne Demersal Scalefish Fishery	Continental shelf waters	Mechanised handlines	Year-round (May – Aug for Pink Snapper)	Pink Snapper (*Chrysophrys auratus*) Goldband Snapper (*Pristipomoides multidens*)
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
Shark Bay Blue Swimmer Crab Fishery	Within Shark Bay	Commercial traps and trawls	Trawl season: Mar/April – Sept/Oct	Blue Swimmer Crab (*Portunus armatus*)
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*)
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*)
West Coast Bioregion				
Octopus Fishery	Waters south from Shark Bay	Trigger trap, unbaited / passive pots		Octopus (*Octopus* aff. *tetricus*)
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 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 Snapper (*Chrysophrysauratus*), Redthroat Emperor (*Lethrinus miniatus*), Bight redfish (*Centroberyx gerrardi*) and Baldchin Groper (*Choerodon rubescens*) Offshore species include: Eightbar Grouper (*Hyporthodus*

Fishery	Fishery Area	Method/s	Season (if specified)	Target Species
				octofasciatus), Hapuku (*Polyprion oxygeneios*), Blue-eye Trevalla (*Hyperoglyphe antarctica*) and Ruby Snapper (*Etelis carbunculus*)
West Coast Rock Lobster Fishery	Waters from North West Cape to Cape Leeuwin	Pots	Year-round	Western Rock Lobster (*Panulirus cygnus*)
Statewide Bioregion				
Marine Aquarium Fish Managed Fishery	All State waters between NT border and SA border, typically more active south of Broome and around Capes region	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
The Specimen Shell Managed Fishery	Covers the entire WA coastline, some concentration adjacent to population centres	By hand by divers or by coastal wading		224 different Specimen Shell species
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*)

5.5.3 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 5-22).

Table 5-22 Marine Tourism and Recreation within the Amulet Development EMBA

Activity	EMBA	Project Area	Light Area	Hydrocarbon Area
Charter vessel tours	✓	X	X	✓
Cruises	✓	X	X	✓
Recreational diving, snorkelling, and other nature-based activities	✓	X	X	✓
Recreational fishing	✓	X	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 Amulet 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 and Commonwealth marine reserves. Primary dive locations within the vicinity of the Amulet Development are within the State Ningaloo MP and the Muiron Islands MMA plus the Rowley Shoals including the Commonwealth marine reserve at Mermaid Reef (DEWHA 2008).

Exmouth is occasionally utilised 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 utilise the marina. Port Hedland can accommodate larger vessels (up to 2000 passengers) but only receives vessels of this size approximately once per year.

5.5.4 State Protected Areas

5.5.4.1 Marine

There are nine State marine protected areas within EMBA (Table 5-23, Figure 5-26). The closest State marine protected areas to the Amulet Development are the Montebello Islands Marine Park (MP) and the Barrow Islands MP and Marine Management Area (MMA), ~171 km and ~186 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 5-23 State Marine Protected Areas within the Amulet Development EMBA

State Marine Protected Area	EMBA	Project Area	Light Area	Hydrocarbon Area
Barrow Islands Marine Park and Marine Management Area	✓	X	X	✓
Eighty Mile Beach Marine Park	✓	X	X	X
Hamelin Pool Marine Nature Reserve	✓	X	X	X
Miaboolya Beach Fish Habitat Protection Area	✓	X	X	X
Montebello Islands Marine Park	✓	X	X	✓
Muiron Islands Marine Management Area	✓	X	X	✓

State Marine Protected Area	EMBA	Project Area	Light Area	Hydrocarbon Area
Ningaloo Marine Park	✓	X	X	✓
Rowley Shoals Marine Park	✓	X	X	✓
Shark Bay Marine Park	✓	X	X	X

✓ = Present within area; X = not present within area

5.5.4.1.1 Montebello Islands Marine Park, Barros Island Marine Park and Marine Management Area

The Montebello Islands Marine Park, Barrow Island Marine Park and Barrow Island Marine Management Area was originally gazetted in December 2004. The reserves are located off the northwest coast of Western Australia and cover areas of approximately 58,331 ha, 4,169 ha and 114,693 ha respectively (DoEC 2007).

The Montebello/Barrow islands marine conservation reserves have very complex seabed and island topography including sheltered lagoons, channels, beaches and cliffs. This complexity has resulted in a myriad of different habitats in the reserves supported by high sediment and water quality. These habitats include subtidal coral reefs, macroalgal and seagrass communities, subtidal soft-bottom communities, rocky shores and intertidal reef platforms, which support a rich diversity of invertebrates and finfish (DoEC 2007).

The reserves are important breeding areas for several species of marine turtles and seabirds, which use the undisturbed sandy beaches for nesting. Humpback Whales migrate through the reserves and dugongs occur in the shallow warm waters (DoEC 2007).

The Montebello Islands complex consists of 265 distinct, low lying islands and islets composed of limestone and cross-bedded sandstones. The islands are generally irregular with convoluted coastlines that comprise a mixture of lagoons, channels, intertidal embayments, barrier and fringing reefs, intertidal rocky and occasionally sandy shores and shallow limestone platforms that are exposed to open ocean conditions (DoEC 2007). Barrow Island is the largest island within the reserves with nine smaller islands nearby.

While macroalgae-dominated limestone reef and subtidal reef platform/sand mosaic are the main marine habitat types in the Montebello/Barrow islands region, coral reef, mangroves and subtidal sand and soft-bottom habitats are also common. Five of the six species of marine turtle found in Western Australia have been recorded in the reserves with the Western Australian Hawksbill Turtle population the only large population of this species remaining in the Indian Ocean (DoEC 2007).

Seven species of toothed whale and three species of baleen whale have been recorded from the Montebello/Barrow islands region and is a Humpback Whales resting area. The Montebello/Barrow islands region is also a significant rookery for at least 15 seabird species, with the largest breeding colony of roseate terns in Western Australia found on the Montebello Islands (DoEC 2007).

The Montebello Islands Marine Park, Barrow Island Marine Park and Barrow Island Marine Management Area areas also have a high social significance. The petroleum industry within the area is one of the state’s most valuable industries. The reserves are also a potentially important area for nature-based tourism with a wide variety of wildlife, seascapes, as well as the rich maritime heritage that includes exploration, whaling, fishing for turtles, cultured pearl farming and military use (including atomic testing) (DoEC 2007).

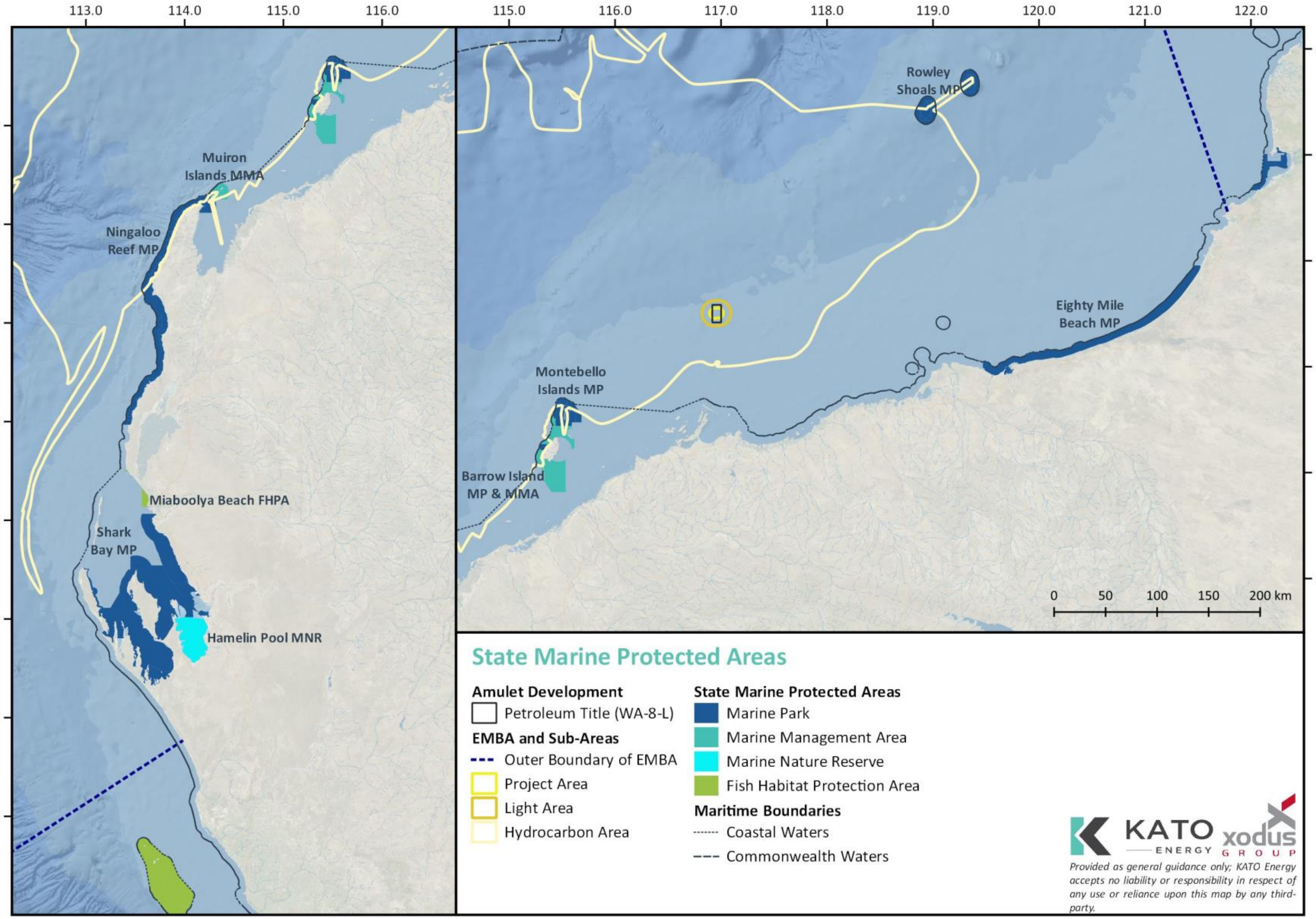


Figure 5-26 State Marine Protected Areas

5.5.4.2 Terrestrial

There are eight State terrestrial protected areas within EMBA (Table 5-24, Figure 5-27). The closest State terrestrial protected areas to the Amulet Development are the Dampier Archipelago Island Reserves, Murujuga National Park and the Pilbara Inshore Islands Nature Reserves, ~99 km, ~115 km and ~157 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 5-24 State Terrestrial Protected Areas within the Amulet Development EMBA

State Marine Protected Area	EMBA	Project Area	Light Area	Hydrocarbon Area
Cape Range National Park	✓	X	X	✓
Dampier Archipelago Island Reserves	✓	X	X	X
Dirk Hartog Island National Park	✓	X	X	X
Francois Peron National Park	✓	X	X	X
Monkey Mia Reserve	✓	X	X	X
Murujuga National Park	✓	X	X	X
Pilbara Inshore Islands Nature Reserves	✓	X	X	✓
Shell Beach Conservation Park	✓	X	X	X

✓ = Present within area; X = not present within area

5.5.4.2.1 Dampier Archipelago Island Reserves

The Dampier Archipelago comprises 42 islands, islets and rocks within a 45 km radius of the town of Dampier; with Eaglehawk Island the western-most and Delambre Island the eastern-most of the archipelago (CALM 1990). Many of the archipelago's islands are reserves managed by DBCA, including some island classified as 'special conservation zones' where no public access is allowed as they provide nesting sites for threatened seabird and/or marine turtle species (DEC 2011). The reserves extent to low water mark (CALM 1990).

The islands range in size from rock islets of less than 1 ha, to Enderby Island at 3,290 ha; Dolphin Island is the highest, rising to 120 m above sea level (CALM 1990). Many of the islands resemble the adjacent mainland and Burrup Peninsula, and are steep and rugged, with coastal cliffs and rocks, sandy beaches and coastal sandplains (CALM 1990).

The archipelago is floristically diverse; 288 species of native terrestrial plants from 60 families are known to occur within the Dampier Archipelago (CALM 1990). However, records of introduced species, including buffel grass, also exist on some of the islands. There is also an abundance and diverse range of fauna on the islands. For example, 102 species of bird have also been recorded in the Dampier Archipelago, with at least 25 of these species known to nest on the islands (CALM 1990). Flatback, Green, Hawksbill and Loggerhead turtles are often seen in the Dampier Archipelago and during the summer will nest on several of the islands (DEC 2011). The Archipelago supports the largest Hawksbill Turtle rookery in the Indo-Pacific region (DEC 2011). The intertidal zone of the Dampier Archipelago is characterised by wide sandflats and mudflats, rocky shores, coral reefs and mangals, all of which support an abundant and diverse invertebrate fauna (CALM 1990).

Many thousands of Aboriginal rock engravings, shell middens, stone arrangements and artefact scatters are located in the Dampier Archipelago (DEC 2011). These outstanding examples of Aboriginal heritage and culture within the ancient landscape have been acknowledged through the National Heritage Listing of the area (Section 5.5.6). The first recorded European to visit to the

Dampier Archipelago was Englishman William Dampier aboard the *Cygnet* in 1688. Relics of later European occupation can be seen on the islands with structures remaining from whaling, pearling and pastoral activities (DEC 2011).

5.5.4.2.2 Murujuga National Park

Murujuga National Park is freehold land on the Burrup Peninsula owned by the Murujuga Aboriginal Corporation (MAC). The Aboriginal freehold land is leased back to the State and is jointly managed by the MAC and the DBCA as the Murujuga National Park and is protected under the CALM Act.

Murujuga National Park covers an area of 4,913 ha within the Burrup Peninsula (Figure 5-27), and is considered as ecologically and biologically diverse (DEC 2013). Habitats include sandy and rocky shores, mangroves, mudflats and sea cliffs (DoEC 2013). The vegetation of the Burrup Peninsula is generally in very good or excellent condition, except in areas of coastal sand. Disturbance from human activity (especially four-wheel drives) and subsequent invasion by buffel grass (*Cenchrus ciliaris*), an introduced weed, has altered the vegetation of these coastal sand dunes (DEC 2013).

Ten species of migratory birds have been recorded on the Burrup Peninsula and are listed under the Biodiversity Conservation Act and Regulations as ‘specially protected fauna’ (i.e. birds protected under international agreement) with many also protected under the EPBC Act (DEC 2013). Although the peninsula possesses no large permanent freshwater wetlands, the salt ponds and the sheltered waters of the mangroves, creeks and small embayments all provide good localities for episodic visits by many waterbirds. Many species normally associated with freshwater habitats are occasionally found as vagrants in such places, particularly in the rich shallows of the salt farm impoundments.

Murujuga is home to one of the largest, densest and most diverse collections of rock art (petroglyphs) in the world, estimated to contain more than one million petroglyphs; these provide an archaeological record of traditional use of the area, possibly dating back more than 30,000 years (ORIC 2019).

Swimming, boating, camping, fishing and other social activities are the current uses of the Park (DEC 2013).

5.5.4.2.3 Pilbara Inshore Islands Nature Reserve

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 Muirons, Locker, Thevenard, Serrurier and Sholl Islands (DBCA, 2017). Around one million Wedge-tailed Shearwaters migrate to the area each year, visiting the islands (particularly the Muirons 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.

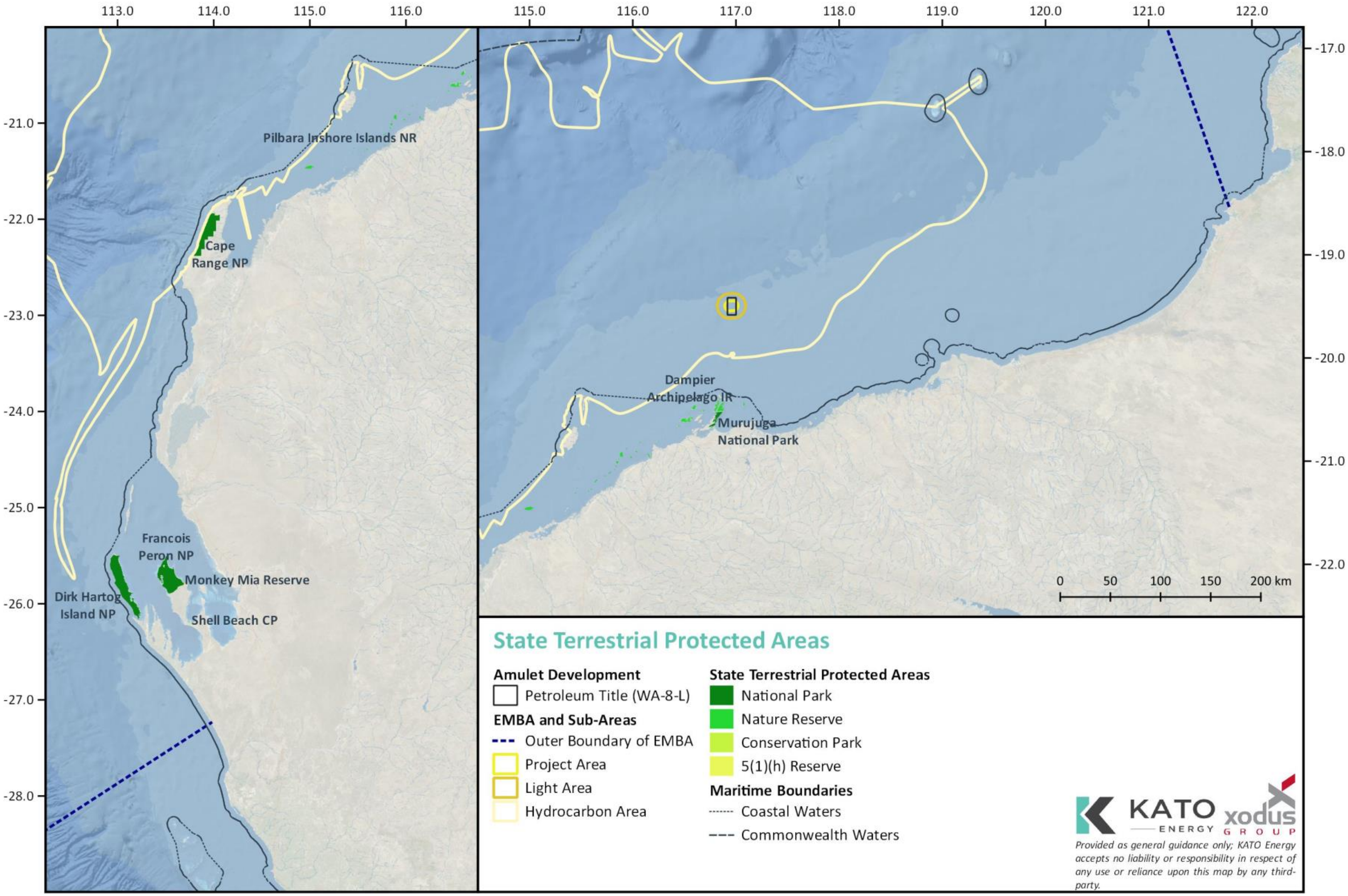


Figure 5-27 State Terrestrial Protected Areas

5.5.5 Marine and Coastal Industries

Several other industries or users may be present within the EMBA (Table 5-25). Commercial fisheries and tourism/recreation have been described separately (Sections 5.5.2 and 5.5.3 respectively).

Table 5-25 Marine and Coastal Industries within the Amulet Development EMBA

Industry or User	EMBA	Project Area	Light Area	Hydrocarbon Area
Commercial shipping	✓	✓	✓	✓
Defence	✓	X	X	✓
Petroleum exploration and production	✓	X	X	✓
Ports	✓	X	X	X
Submarine telecommunication cables	✓	X	X	X

✓ = Present within area; X = not present within area

The Amulet 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).

The Amulet Development is within the WA-8-L offshore petroleum permit. Previous exploration and development wells have been drilled within the Amulet and Talisman oil fields that occur within this permit area (Section 3.2). In 1992, production equipment was abandoned on the seabed by the operator at the time. Following the recent decommissioning operations in the Talisman field by Santos, all locatable items were recovered, with the exception of the T-7 flowline and control umbilical line, an anchor and length of chain, and a tyre weight. In January 2019, NOPSEMA accepted an EP by Santos to leave the equipment on the seabed in perpetuity (Santos 2018).

These items remain on the seabed within a defined 'production equipment abandonment area' based on a 1 km buffer around the known or assumed coordinates of remaining equipment. The 'production equipment abandonment area' is ~3.4 km from the expected position of the MOPU. If the Talisman subsea tieback option is selected, the expected location of the Talisman manifold is ~140 m inside the buffer; and ~860 m from the known location of the abandoned T-7 flowline/umbilical. The location of the anchor and chain and tyre weight is not known; the EP considered that there was a strong likelihood that the equipment has been partially or completely buried in the underlying sediment (Santos 2018).

Oil and gas facilities within the vicinity of the Amulet Development include Woodside's Angel, North Rankin and Goodwyn Alpha platforms (~40 km, ~88 km and ~111 km respectively); Woodside's Okha FPSO (~57 km); Apache's Reindeer platform (~91 km); VOGA's Wandoo platform (~90 km); and Jadestone Energy's Stag platform and Dampier Spirit FSO (~114 km). Santos' Mutineer Exeter Development (~45 km northeast) is currently in cessation and the FPSO has left the field (Figure 5-28). The closest onshore processing site is Woodside's Burrup Hub (including Karratha Gas Plant). There are also several submerged pipelines associated with petroleum fields and facilities with onshore processing hubs (e.g. the TL1 and TL2 export pipelines from the North Rankin Complex to the Karratha Gas Plant; 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 Amulet Development is the Port of Dampier (Figure 5-29).

Commercial shipping traffic is high within the North West Shelf with vessel activities including commercial fisheries, international freight, domestic support and supply, tourism, and oil and gas operations (Figure 5-30). The Australian Maritime Safety Authority (AMSA) has established a network of shipping fairways off the northwest coast of Australia (Marine Notice 15/2012). The fairways are intended to direct large vessels (e.g. bulk carriers) transiting to the major ports into pre-defined routes. The Amulet Development is located between two shipping fairways for Dampier Port (~9 km west and ~23 km east of the expected position of the MOPU). However, historic tracking data indicates vessel traffic within the Project Area itself is minimal (Figure 5-30).

The Royal Australian Air Force (RAAF) have a base located at Learmonth, and there is training and practice areas associated with this base, including the offshore training area known as North West Exercise Area (NWXA) (Figure 5-31). The RAAF base and associated facilities around Learmonth and Exmouth occur on Commonwealth land. The Learmonth Air Weapons Range Facility (on the western coast of the North West Cape) is also listed as a Commonwealth Heritage Place (Section 5.5.6). 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. There are also other defence related facilities (e.g. training depots) located on Commonwealth land in Carnarvon, Geraldton, Greenough and Karratha.

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 active communication cables are distant (>750 km) from the Amulet 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. There are no declared protection zones within the EMBA.

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. The main cable is >190 km from the Amulet Development.

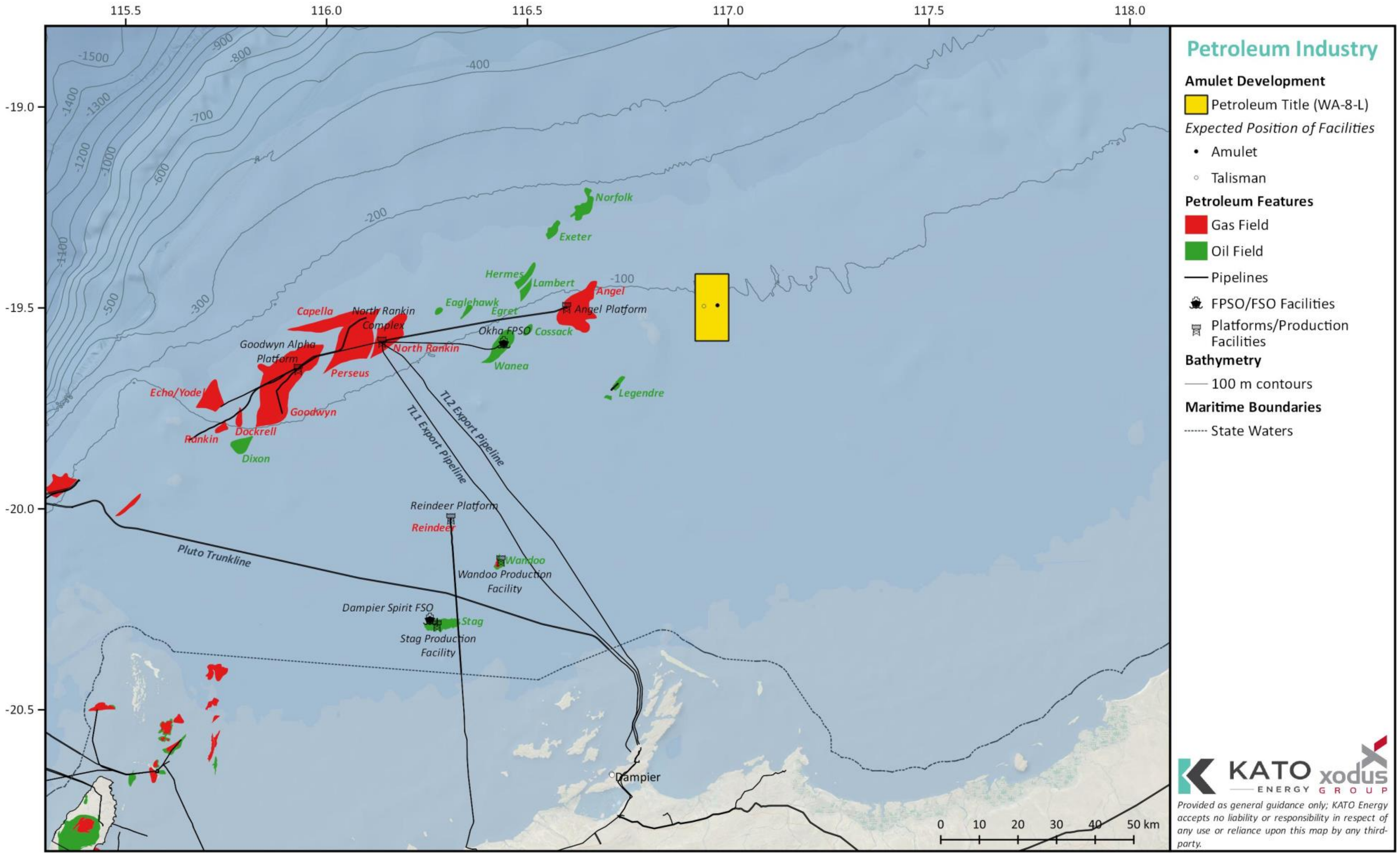


Figure 5-28 Petroleum Industry Facilities and Features

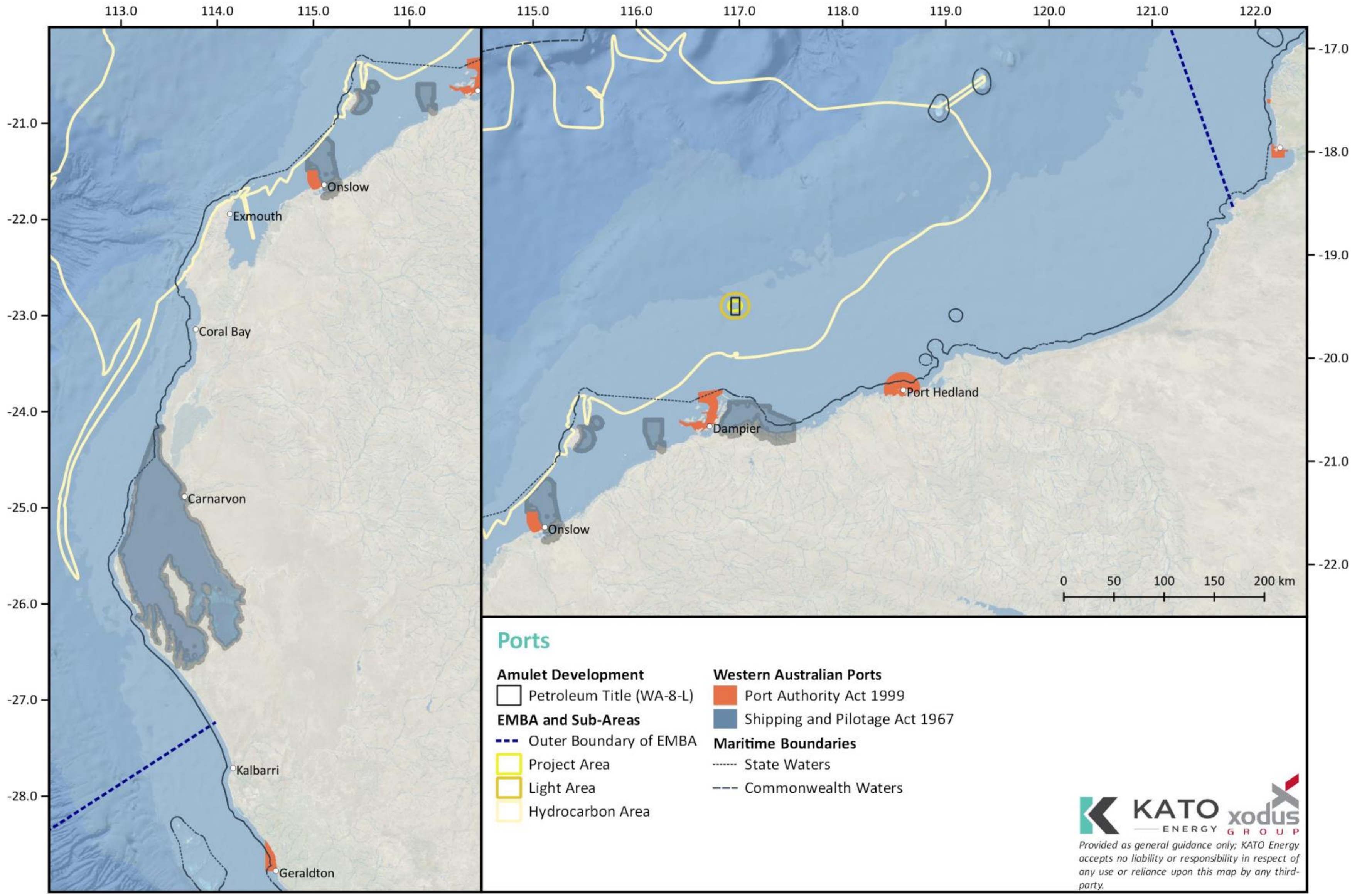


Figure 5-29 Port facilities

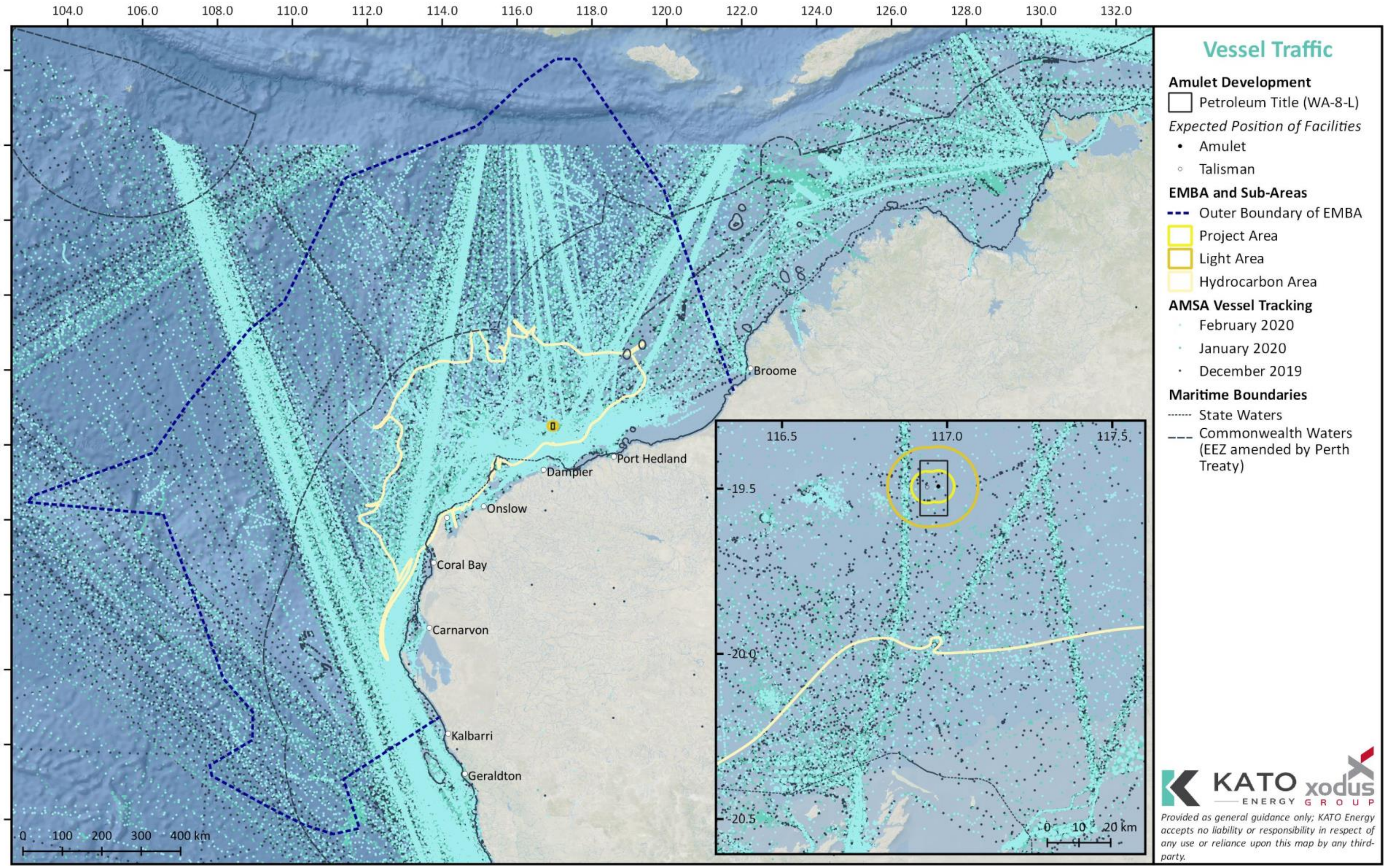


Figure 5-30 Commercial Shipping Traffic

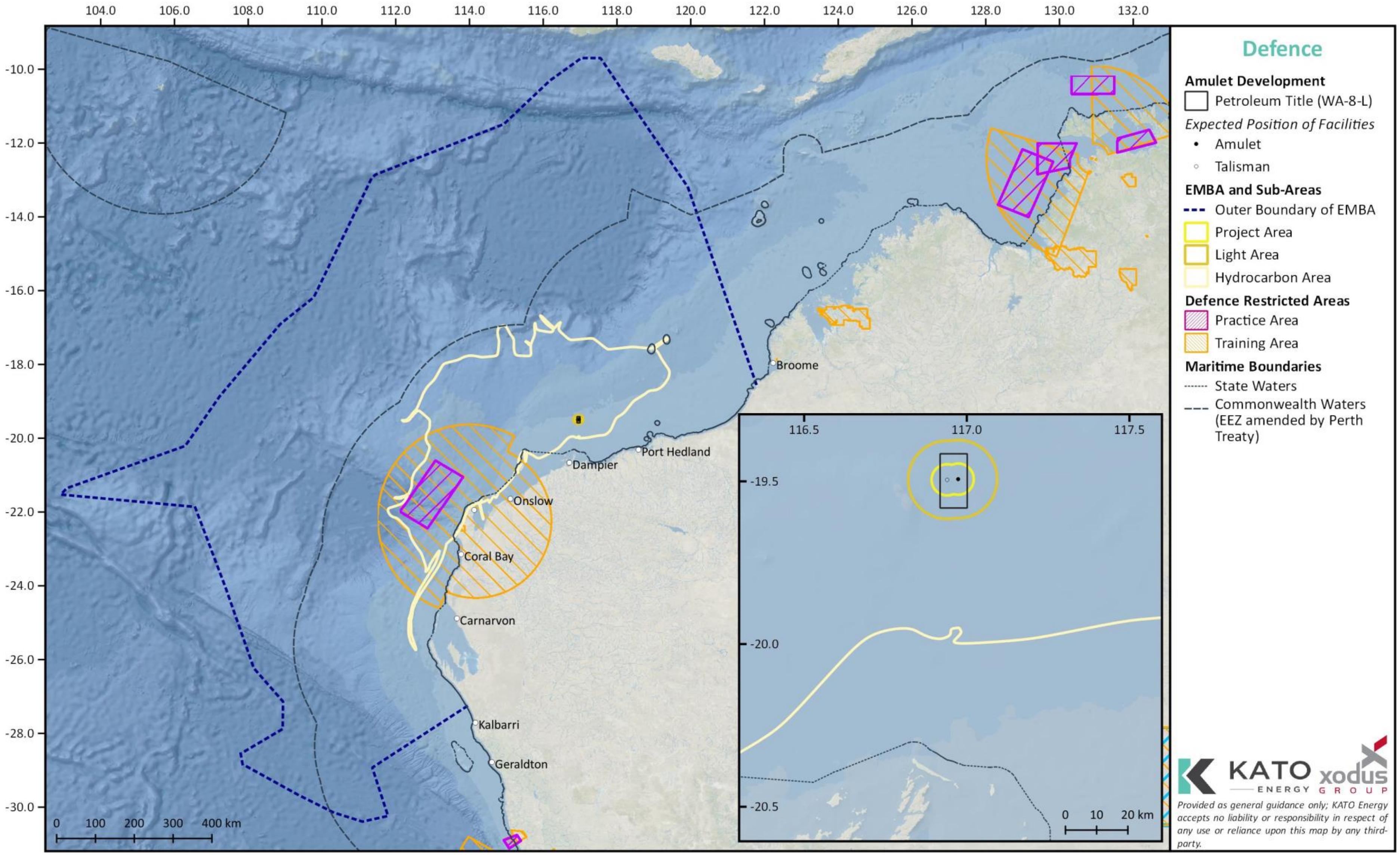


Figure 5-31 Defence Training Areas

5.5.6 Heritage and Cultural Features

Several marine or coastal heritage and cultural places and values may be present within the EMBA (Table 5-26, Appendix A); key features are further described below.

Table 5-26 Heritage and Cultural Features within the Amulet Development EMBA

Feature	EMBA	Project Area	Light Area	Hydrocarbon Area
World Heritage Properties*				
Class: Natural				
Shark Bay	✓	X	X	X
The Ningaloo Coast	✓	X	X	✓
National Heritage Places*				
Class: Natural				
Shark Bay	✓	X	X	X
The Ningaloo Coast	✓	X	X	✓
The West Kimberley	✓	X	X	X
Class: Indigenous				
Dampier Archipelago (including Burrup Peninsula)	✓	X	X	X
Class: Historical				
Cape Inscription (Dirk Hartog Landing Site)	✓	X	X	X
HMAS Sydney II and *HSK Kormoran* Shipwrecks	✓	X	X	X
Commonwealth Heritage Places				
Class: Natural				
Learmonth Air Weapons Range Facility	✓	X	X	✓
Mermaid Reef – Rowley Shoals	✓	X	X	X
Ningaloo Marine Area (Commonwealth waters)	✓	X	X	✓
Class: Historical				
HMAS Sydney II and *HSK Kormoran* Shipwrecks	✓	X	X	X
Aboriginal Heritage Places				
Registered sites	✓	X	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	X	✓
Shipwrecks	✓	X	X	✓

Feature	EMBA	Project Area	Light Area	Hydrocarbon Area
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 areas within the EMBA (Table 5-26, Figure 5-32). The closest National Heritage Place to the Amulet Development is Dampier Archipelago, ~98 km south of the expected position of the MOPU; this area is protected for Indigenous heritage significance. The closest World Heritage Property (and also a National Heritage Place) to the Amulet Development is The Ningaloo Coast, ~353 km southwest of the expected position of the MOPU; this area is protected for natural heritage significance. A summary of the description and values of these heritage areas are provided below (Section 5.5.6.1 and 5.5.6.2 respectively).

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 5-15), the registered site list is land-based sites.

Indigenous Protected Areas (IPAs) 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, IPAs deliver environmental, cultural, social, health and wellbeing and economic benefits to Indigenous communities (DoEE 2019d). The boundary of the Karajarri IPA partially occurs within the extent of the EMBA (Table 5-26, 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 5-26, Figure 5-32). The *HMAS Sydney II* and *HSK Kormoran*, both wrecked in 1941 offshore from Shark Bay, are also listed on the National and Commonwealth heritage lists. 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 5-26). 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 Dampier Archipelago (including Burrup Peninsula)

The Dampier Archipelago (including the Burrup Peninsula) was included in the National Heritage List in July 2007. The area consists of islands, reefs, shoals, channels and straits, and covers a land area of ~400 km^2.

The Dampier Archipelago contains a wide variety of marine habitats, varying from exposed areas subject to high wave energies, clear water and low sedimentation rates in the seaward areas to sheltered habitats with turbid water in the coastal bays. The marine plants and animals of the area are highly diverse and abundant as the warm tropical waters of the Dampier Archipelago provide an ideal habitat for marine life (DoEE 2007).

Coral growth in the inshore waters of the Dampier Archipelago is prolific, particularly on sublittoral rock slopes where species diversity is high, although there is no reef formation in these areas. The area is rich in marine invertebrates, particularly echinoderms, molluscs and sponges with extensive sand and mud flats supporting rich and diverse invertebrate populations (DoEE 2007).

Seagrass beds, although not as well developed as in some other areas, provide important habitat for fauna particularly for dugongs. A total of 650 species of shallow water marine fish have been recorded within the Dampier Archipelago that includes a rich reef assemblage (DoEE 2007).

Marine vertebrate fauna recorded for the place include at least seven species of mammals including the Humpback Whale and dugong. As well as a habitat for a number of seasnake species the Dampier Archipelago is an important area for marine turtles with and four of the five species found in the area nesting there (Green, Loggerhead, Hawksbill and Flatback Turtles) (DoEE 2007).

Over one hundred species of birds have been recorded in the Dampier Archipelago region, including both terrestrial species and sea and shore birds, some of which are migratory. At least ten terrestrial species, and fifteen sea and shore bird species, are known to breed on the islands and many more use the extensive mudflats, intertidal reefs and salt-marshes during their annual migration between Australia and south-east Asia (DoEH 2004).

The Dampier Archipelago (including the Burrup Peninsula) contains one of the densest concentrations of rock engravings in Australia with some sites containing tens of thousands of images. Rock engravings and stone arrangements contain detailed images of water birds, crabs, crayfish, kangaroos, turtles and fish, and schematised human figures with both human and animal features. The area also contains a high density of stone pits, complex circular arrangements, and standing stones ranging from single monoliths through to extensive alignments of three or four hundred stones (DEH 2004).

5.5.6.2 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 2019e). 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).

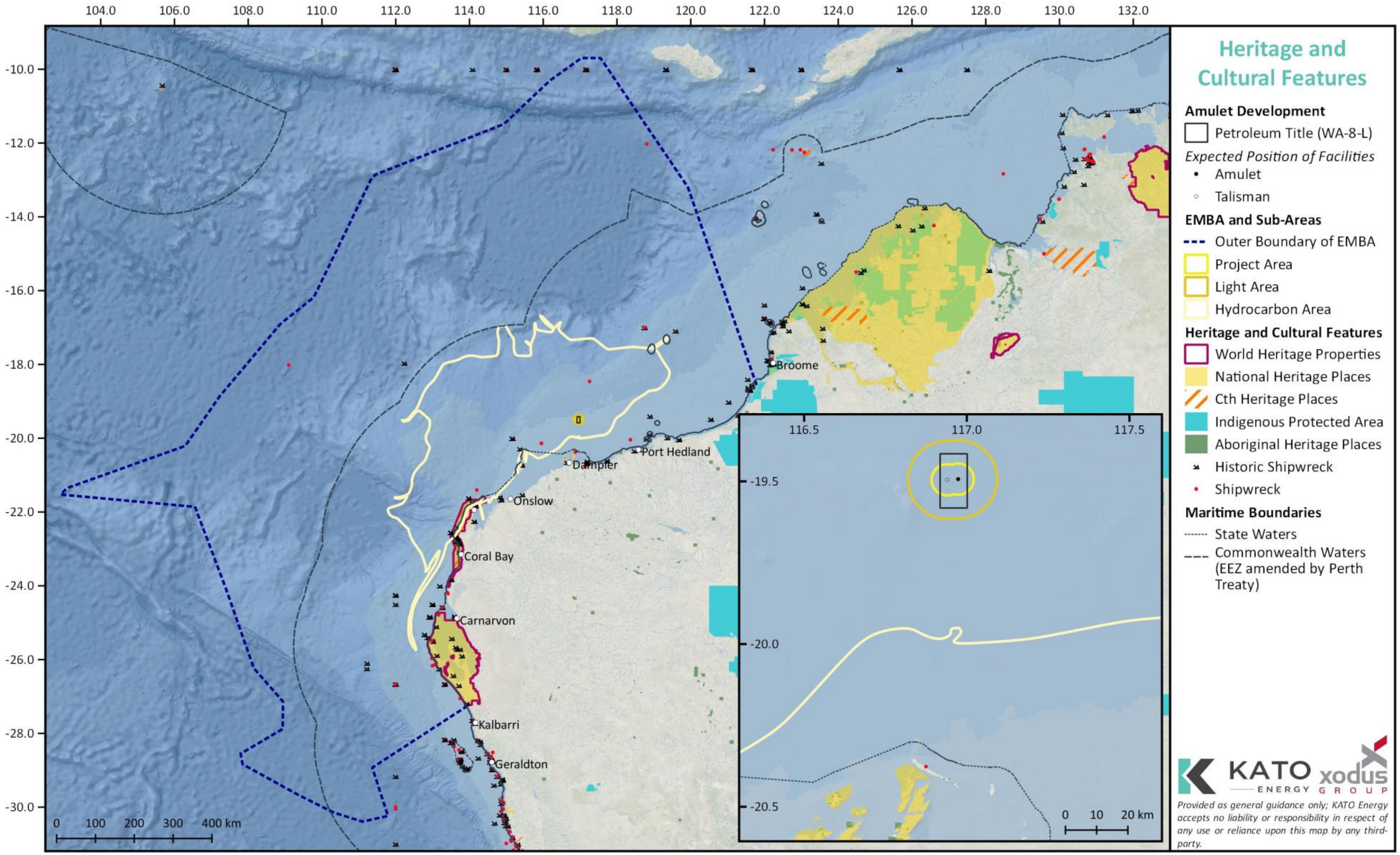
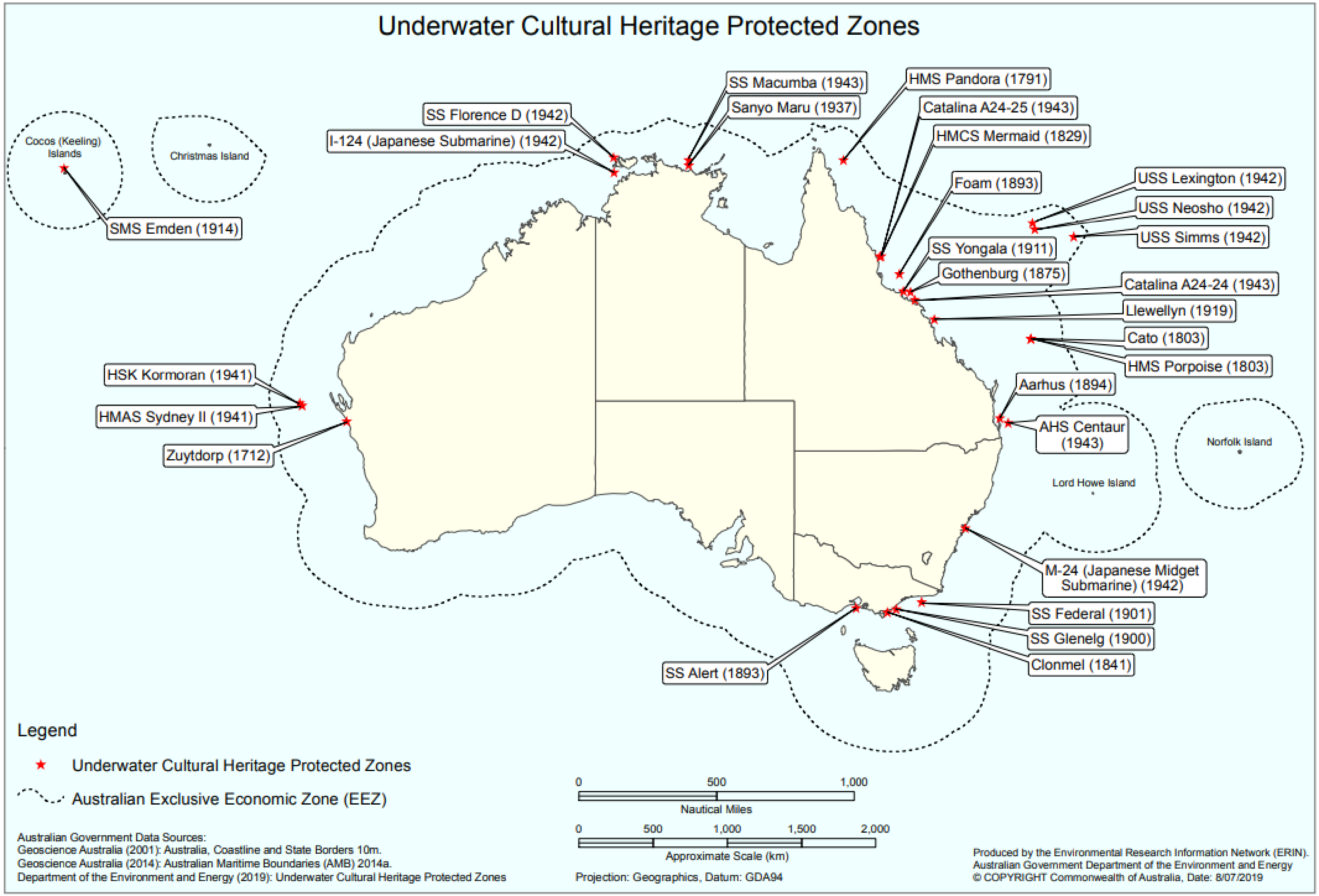


Figure 5-32 Cultural and Heritage Features



Source: DoEE 2019e

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.

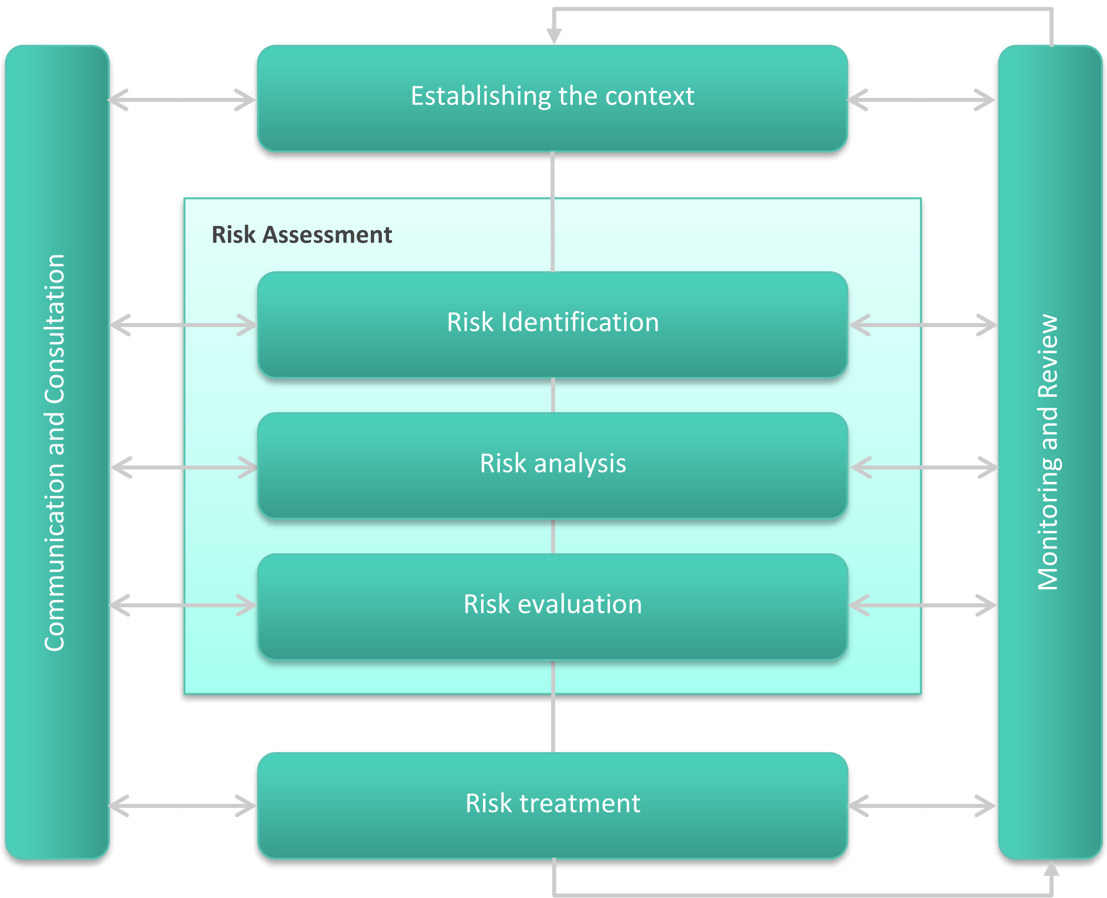


Figure 6-1 Risk Assessment Process

6.2 Establish the Context

6.2.1 Identification and Description of the Petroleum Activity

The activities associated with the Amulet 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 Amulet Development, the environment have 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	Talisman subsea tieback	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 and Operational 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	Talisman Subsea tieback	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 – Amulet 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

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	Industry	Heritage and Cultural features
Physical Presence – Interaction with Other Users	Changes to the functions, interests or activities of other users																✓				✓	
Physical presence – Seabed disturbance	Change in water quality	✓																				
	Change in habitat								✓													
	Injury/mortality to fauna							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					
Emissions – Atmospheric	Change in air quality			✓																		
	Climate change				✓																	

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	Industry	Heritage and Cultural features
	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	✓	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		✓																			
	Change in habitat								✓													
	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	Industry	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								
	Changes to the functions, interests or activities of other users																X					
Planned Discharge – Commissioning and Operational 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					

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	Industry	Heritage and Cultural features
Planned Discharge – Produced Formation Water	Change in water quality	✓																				
	Change in sediment quality		✓																			
	Change in habitat								X													
	Injury/mortality to fauna							✓	X			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		X																			
	Change in habitat								X													
	Injury/mortality to fauna							✓				X	X	X								
	Changes to the functions, interests or activities of other users																X					
Planned Discharge –	Change in water 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	Industry	Heritage and Cultural features
Deck drainage and Bilge	Injury/mortality to fauna							X				X	X	X								
	Changes to the functions, interests or activities of other users																X					
Planned Discharge – Sewage, Greywater and Food waste	Change in water quality	✓																				
	Change in fauna behaviour							X			X	X	X	X								
	Changes to the functions, interests or activities of other users																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	Industry	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: Water quality	Physical: Sediment quality	Physical: Air quality	Physical: Climate	Physical: Ambient light	Physical: Ambient noise	Ecological: Plankton	Ecological: Benthic habitat and communities	Ecological: Coastal habitats and communities	Ecological: Seabirds and shorebirds	Ecological: Fish	Ecological: Marine mammals	Ecological: Marine reptiles	Social, economic and cultural: KEFs	Social, economic and cultural: AMPs	Social, economic and cultural: Commercial Fisheries	Social, economic and cultural: Tourism and Recreation	Social, economic and cultural: State protected area – Marine	Social, economic and cultural: State protected area – Terrestrial	Social, economic and cultural: Industry	Social, economic and cultural: Heritage and Cultural features
	Changes to the functions, interests or activities of other users																X					
Minor LOC – Chemicals and Hydrocarbons	Change in water quality	✓																				
	Change to sediment quality		X																			
	Injury/mortality to fauna							X	X			X	X	X								
	Changes to the functions, interests or activities of other users																X					
Accidental Release – Amulet 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									✓						✓		✓	✓			✓
	Change in water quality	✓													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	Industry	Heritage and Cultural features
Accidental Release – Marine Diesel/Gas Oil	Change in sediment quality		✓												X	X	X		X			X
	Change in habitat								X	X					X	X			X			X
	Injury/mortality to fauna							✓	X	X	✓	✓	✓	✓	X	✓			X	X		X
	Change in fauna behaviour								X	X	✓	✓	✓	✓	X	✓			X	X		X
	Changes to the functions, interests or activities of other users															✓	✓	X	X	X	✓	X
	Change in aesthetic value									X						X		X	X			X

6.3.2 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 (KAT-000-GN-PP-002) (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 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

<table>
<tr><th>Consequence Ranking</th><th>Minor</th><th>Moderate</th><th>Serious</th><th>Major</th><th>Severe</th><th>Catastrophic</th></tr>
<tr><td>Planned Aspects</td><td>Broadly acceptable</td><td colspan="2">Broadly acceptable with additional control measures and management approval / if ALARP</td><td colspan="3">Unacceptable</td></tr>
<tr><td>Risk Ranking</td><td>Low</td><td>Medium</td><td>High</td><td>Very High</td><td colspan="2">Extreme</td></tr>
<tr><td>Unplanned Aspects</td><td colspan="2">Broadly acceptable</td><td colspan="2">Broadly acceptable with additional control measures and management approval / if ALARP</td><td colspan="2">Unacceptable</td></tr>
</table>

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.

Consequence	Guidance	Level	A	B	C	D	E	F
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
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 Regulation 5A of the OPGGS(E)R requires that the Amulet 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 1.1.1.1).

6.6 Significant Impacts

The OPP must demonstrate to NOPSEMA that the Amulet Development is able to be carried out in a manner consistent with the principles of ecologically sustainable development, and that the environmental impacts and risks will be of an acceptable level.

Impacts and risks have been demonstrated to be at an acceptable level if they do not result in a ‘significant impact’ as described in the Matters of National Environmental Significance – Significant Impact Guidelines (DoE 2013). The level of significant impact is specific to each receptor, and is determined by whether the receptor is listed as an MNES, and whether it is present within the relevant impact area.

As such, the levels of significant impact are sourced from:

- OPGGS Act Section 280(2)
- Matters of National Environmental Significance– Significant Impact Guidelines 1.1 (DoE 2013).

Table 6-8 provides the defined level of significant impact used when developing the EPOs for receptors identified as being relevant to this OPP, in order to manage impacts to at or below the defined acceptable level.

Table 6-8 Defined level of Significant Impact for Receptors

Receptor		Description / Regional Context / Sensitivity	Defined level of Significant Impact	Source
Physical	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).	An action is likely to have a significant impact if there is a possibility that it will: • result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	DoE 2013
	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.	An action is likely to have a significant impact if there is a possibility that it will: • result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. • 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.	DoE 2013
	Air quality	The majority of the offshore Pilbara region is relatively remote and therefore air quality is expected to be high. However, anthropogenic sources (e.g. vessels, industry developments) would contribute to local variation in air quality.	An action is likely to have a significant impact if there is a possibility that it will: • result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	DoE 2013
	Climate	The climate within the Pilbara region is dry tropical, and is characterised by very hot summers, mild winters and low and variable rainfall. It is the most tropical cyclone prone coast in Australia, averaging two cyclones crossing the coast each year. 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.	It is important to recognise that anthropogenic climate change impacts cannot be directly attributed to any one development, as they are the result of net global GHG emissions and GHG sinks, that have accumulated in the atmosphere since the industrial revolution. Therefore it is not appropriate to attribute climate change or any particular climate-related impacts to GHG emissions from the Amulet Development. An action is likely to have a significant impact if there is a possibility that it will: • substantially contribute to Australia's annual GHG emissions and directly result in Australia being unable to meet its NDC target under the Paris Agreement to reduce GHG emissions by 26 to 28 per cent below 2005 levels by 2030. • substantially contribute to global annual GHG emissions and directly result in the Paris Agreement aim to keep global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts	Australia's Intended Nationally Determined Contribution to a new Climate Change Agreement August 2015 Paris Agreement 2016 under the United Nations

	Receptor	Description / Regional Context / Sensitivity	Defined level of Significant Impact	Source
			to limit the temperature increase even further to 1.5°C being unable to be met.	Framework Convention on Climate Change
	Ambient light	Ambient light within the offshore Pilbara region is expected to predominantly be from solar/lunar luminance. 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 Amulet Development is located ~40 km from the nearest petroleum facility and ~7 km from the nearest shipping fairway.	An action is likely to have a significant impact if there is a possibility that it will: • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.	DoE 2013
	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. The Amulet Development is located between two shipping fairways on the North West Shelf, and therefore is likely to be exposed to the occasional sounds generated by mid to large vessels such as tankers and bulk carriers.	An action is likely to have a significant impact if there is a possibility that it will: • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.	DoE 2013
Ecological	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. Phytoplankton biomass is typically variable (spatially and temporally), but greatest in areas of upwelling, or in shallow waters where nutrient levels are high.	An action is likely to have a significant impact if there is a possibility that it will: • have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.	DoE 2013
Ecological	Benthic habitat and communities	Benthic infauna adjacent to the proposed Hurricane-3 exploration well, located ~43 km from the MOPU, consists of unconsolidated sediments which supports a diverse benthic infauna consisting predominantly of mobile burrowing species which include molluscs, crustaceans (crabs, shrimps and smaller related species), polychaetes, sipunculid and platyhelminth worms, asteroids (sea stars), echinoids (sea urchins) and other small animals (Apache 2012). At the water depth of the Project Area (~85 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	An action is likely to have a significant impact if there is a possibility that it will: • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.	DoE 2013

Receptor		Description / Regional Context / Sensitivity	Defined level of Significant Impact	Source
Ecological		communities associated with the unconsolidated sediment habitats are of relatively low environmental sensitivity.		
	Coastal habitat 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 or Hydrocarbon Area. One internationally important Ramsar wetland occurs within the EMBA (Eighty-mile Beach).	An action is likely to have a significant impact if there is a possibility that it will: • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.	DoE 2013
	Seabirds and shorebirds	The Protected Matters Search Tool (PMST; EPBC Act) identified the following number of species that may occur within the Amulet Development Areas: • 11 within the Project Area • 102 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).	An action is likely to have a significant impact if there is a possibility that it will: • have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population. • substantially modify, destroy or isolate an area of important habitat for a migratory species. • seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	DoE 2013
	Fish	The PMST identified the number of species that may occur within the Amulet Development Areas: • 34 within the Project Area • 68 within the EMBA. BIAs that overlap the sub-areas for planned activities were identified as: • Project Area: Whale Shark (foraging) • Light Area: Whale Shark (foraging).	An action is likely to have a significant impact if there is a possibility that it will: • have a substantial adverse effect on a population of fish, or the spatial distribution of the population. • substantially modify, destroy or isolate an area of important habitat for a migratory species. • seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	DoE 2013
	Marine mammals	The PMST identified the number of species that may occur within the Amulet Development Areas: • 24 within the Project Area • 42 within the EMBA.	An action is likely to have a significant impact if there is a possibility that it will: • have a substantial adverse effect on a population of fish, or the spatial distribution of the population.	DoE 2013

	Receptor	Description / Regional Context / Sensitivity	Defined level of Significant Impact	Source
		BIAs that overlap the sub-areas for planned activities were identified as: • Project Area: Blue Whale/Pygmy Blue Whale (distribution) • Light Area: Blue Whale/Pygmy Blue Whale (distribution).	• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. • seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	
	Marine reptiles	The PMST identified the number of species that may occur within the Amulet Development Areas: • 19 within the Project Area • 28 within the EMBA BIAs that overlap the sub-areas for planned activities were identified as: • Project Area: None • Light Area: None	An action is likely to have a significant impact if there is a possibility that it will: • have a substantial adverse effect on a population of fish, or the spatial distribution of the population. • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. • seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	DoE 2013
Social, Economic, and Cultural	AMPs	The Project Area and Light Area do not intersect any AMPs. The closest AMPs to the Amulet Development are the Dampier Marine Park and Montebello Marine Park, ~90 km and ~120 km from the expected position of the MOPU respectively. Within the EMBA, 11 AMPs are present—ten within the North-west Marine Region, and one within the South-west Marine Region.	An action is likely to have a significant impact if there is a possibility that it will: • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.	DoE 2013
	KEFs	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. There are no KEFs within the Project Area; the closest are the 'ancient coastline at 125 m depth contour' and 'Glomar Shoals' (~8 km and 15 km from the expected MOPU position respectively). Within the EMBA, 12 KEFs are present— nine within the North-west Marine Region, and three within the South-west Marine Region.	An action is likely to have a significant impact if there is a possibility that it will: • 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 an area defined as a Key Ecological Feature results.	OPGGS Act 2006 DoE 2013
	Commercial Fisheries	The commercial fisheries that intersect the sub-areas for planned activities were identified as: Project Area:	An action is likely to have a significant impact if there is a possibility that it will:	DoE 2013

Receptor		Description / Regional Context / Sensitivity	Defined level of Significant Impact	Source
		• three Commonwealth-managed fisheries (of which none are active) • 10 State-managed fisheries (of which three are active – Pilbara Fish Trawl (Interim) Managed Fishery, Pilbara Line Fishery and Pilbara Trap Fishery). Light Area: • three Commonwealth-managed fisheries (of which none are active); • 10 State-managed fisheries (of which three are active – Pilbara Fish Trawl (Interim) Managed Fishery, Pilbara Line Fishery and Pilbara Trap Fishery).	• have a substantial adverse effect on the sustainability of commercial fishing An activity will contravene the OPGGS Act Section 280(2), and therefore result in a Significant Impact, if it is deemed to: • interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.	
	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 far offshore (~132 km from Dampier).	An activity will contravene the OPGGS Act Section 280(2), and therefore result in a Significant Impact, if it is deemed to: • interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.	DoE 2013
	State Protected Areas	The Project Area and Light Area do not intersect any marine or terrestrial state protected areas. The closest State marine protected area is the Montebello Islands Marine Park, ~171 km away. There are five State marine protected areas within the EMBA. There are eight State terrestrial protected areas within the EMBA.	An action is likely to have a significant impact if there is a possibility that it will: • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.	DoE 2013

Receptor		Description / Regional Context / Sensitivity	Defined level of Significant Impact	Source
Social, Economic, and Cultural	Industries	The closest oil and gas facilities to the Amulet Development are the Woodside-operated Angel platform (~40 km) and Okha FPSO (~57 km). Santos' Mutineer Exeter Development is ~45 km away, but is in cessation and the FPSO has left the field. In 1992, the Talisman field was shut-in and some production equipment was abandoned by the operator at the time. The T-7 flowline and control umbilical line, an anchor and length of chain, and a tyre weight remain on the seabed, with a designated 1 km buffer (as the location of the latter two items is not known; but are assumed to be buried). If the Talisman subsea tieback option is selected, the expected location of the Talisman manifold is ~140 m inside the buffer. The Amulet Development is located between two shipping fairways for Dampier Port (~9 km west and ~23 km east of the MOPU). However, historic tracking data indicates vessel traffic within the Project Area itself is minimal. The Project Area is not within the Department of Defence's (DoD) North West Exercise Area (NWXA).	An activity will contravene the OPGGS Act Section 280(2), and therefore result in a Significant Impact, if it is deemed to: • interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.	OPGGS Act 2006
	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 and Light Area do not intersect any identified heritage and cultural features. 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.	An activity will result in a Significant Impact, if it is deemed to: • cause significant harm to social surroundings.	

7 Environmental Impact and Risk Assessment

Section 7 is organised into aspects as follows:

- planned aspects – Section 7.1
- unplanned aspects – 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 Amulet 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 (unplanned aspects only).

7.1 Planned

7.1.1 Physical Presence – Interaction with Other Users

The physical presence of vessels and facilities associated with Amulet 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 Amulet Development, phases and activities that may interact with other marine users include:

Installation, Hook-up and Commissioning	MOPU; Talisman subsea tieback; flowlines; CALM buoy and mooring arrangements; 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 Amulet Development may interact with other marine users through the displacement of their activities.

A variety of vessels will operate throughout the duration of the Amulet Development, which is expected to be up to five years (shown in Table 3-17). This number will peak during drilling, commissioning and decommissioning at approximately ten support vessels. Throughout normal operations (~1.5–4.5 years), only one to two support vessels are expected. If well intervention is required on Talisman during operations, an ISV, or MODU (towed by AHTs) may be required, for ~1 month.

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 Amulet 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 Amulet 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 Amulet Development. Receptors marked '*X*' are subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-2 Identification of Receptors Potentially Impacted by Physical Presence – Interaction with Other Users

Impacts	Commercial Fisheries	Industry
Changes to the functions, interests or activities of other users	✓	✓

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 Amulet Development:

- commercial fisheries
- industry.

Impacts to the above receptors include:

- changes to the functions, interests or activities of other users.

Table 7-3 provides a detailed evaluation of the impact of interactions with other users as a result of the physical presence to receptors.

Table 7-3 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 Amulet Development has the potential to displace fishers from the Project Area through the implementation of the exclusion zone (i.e. the PSZ), and presence of support vessels. 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 Amulet Development infrastructure (FSO, flowline, CALM buoy) and the Talisman subsea tieback infrastructure (if that option is selected). 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. The FishCube database (DPIRD 2019, 2020) was interrogated for the 60 nm grid block 19160 that intersect with the Project Area. While some Commonwealth and State commercial fisheries have management area boundaries that intersect with the Amulet Development, previous commercial fishing effort has been minimal and intermittent (Sections 5.5.2.1 and 5.5.2.2). Ten state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show minimal and intermittent commercial fishing activity is expected to occur within the planned activities areas for the Amulet Development. Any fishing effort that may occur is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF). 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. 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. 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 Amulet Development may impact shipping activity due to exclusion of vessels from areas designated as a PSZ. Also, the presence of vessels such as support vessels, AHTs, ISVs and shuttle tankers 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.

There is very little shipping activity 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 Dampier (~130 km away). The Port of Dampier is one of the major tonnage ports in Australia, with prime export commodities of iron ore, LNG and salt. The Project Area is ~10 km to the east of the Port of Dampier bulk carrier shipping lane. Port Hedland is the second largest port in Australia, mainly exporting bulk commodities including iron ore and salt. It is situated ~180 km to the south east of the Project Area. 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 (1.5 – 4.5 years), the expected flight frequency is only 5-8 round trips per week. The Amulet Development is not within a Department of Defence exercise area, with the closest being the North West Exercise Area (NWXA) which is ~200 km to the west of the Project Area. In 1992, production equipment was abandoned on the seabed by the operator at the time. This consisted of the T-7 flowline and control umbilical line, an anchor and length of chain, and a tyre weight. This edge of the Talisman 'production equipment abandonment area' is 3.4 km from the expected MOPU location. In January 2019, NOPSEMA accepted an EP by Santos to leave the equipment on the seabed in perpetuity; therefore the there is no activity proposed by any other operator, or KATO to retrieve this equipment. 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 Amulet Development physical infrastructure, and Talisman subsea tieback system (if that option is selected). 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 is considered **acceptable** based on an evaluation against the criteria in Table 7-4.

Table 7-4 Demonstration of Acceptability for Physical Presence – Interaction with Other Users

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="5">Commercial Fisheries</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Physical Presence – Interaction with Other Users, the Amulet Development will not result in significant impacts to commercial fisheries identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on the sustainability of commercial fishing.
In addition, an activity will contravene the OPGGS Act Section 280(2), and therefore result in a significant impact, if it is deemed to:
• interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>The proposed EPO’s for the Amulet Development are consistent with the principles of ESD.
With respect to potential impacts to all receptors from Physical Presence – Interaction with Other Users the relevant principles are:
• Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations
• 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.</td></tr>
<tr><td>Internal context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards.
With respect to potential impacts to all receptors from Physical Presence – Interaction with Other Users, this specifically includes:
• KATO Marine Operations Procedure (KATO 2020b).</td></tr>
<tr><td></td><td>External context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders.
With respect to potential impacts to all receptors from Physical Presence – Interaction with Other Users, this specifically includes:
• Stakeholder engagement to date confirmed that various agencies require notification prior to commencement of activities (Section 10); specifically:
  ○ Notification to AHO to update Navigational Charts and provide Notice to Mariners
  ○ Contact AMSA Joint Rescue Coordination Centre (JRCC) Australia to request an AUSCOAST Warning (radio/navigation warnings)</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="7"></td><td></td><td colspan="3">WAFIC recommended consulting with fisheries when project information is known, during development of the EPs; i.e. project timing, location and exact exclusion/cautionary zones. WAFIC communicated preference to minimise exclusion areas where possible and use of cautionary zones.
The Amulet Development is not within the North West Exercise Area (NWXA) and will not conflict with Defence training.
The proposed Talisman manifold location is ~860 m away from the closest known location of the Santos abandoned production equipment infrastructure (T-7 flowline); however the location of the anchor, chain and tyre weight is not known. NOPSEMA have accepted an EP by Santos to leave the equipment on the seabed in perpetuity; therefore there is no required future activity or responsibility regarding this equipment for Santos, or any other titleholder (including KATO).</td></tr>
<tr><td rowspan="4">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Physical Presence – Interaction with Other Users from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to all receptors from Physical Presence – Interaction with Other Users this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Commonwealth Navigation Act 2012, MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act</td><td>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.</td><td>Adoption of the following control measure:
CM01: Vessels to adhere to the navigation safety requirements including the Commonwealth Navigation Act 2012 and any subsequent Marine Orders.</td></tr>
<tr><td>Chapter 6, Part 6.6 of the OPGGS Act</td><td>A petroleum safety zone (PSZ) <500 m will be set following assessment by NOPSEMA, within which certain vessels are prohibited.</td><td>Section 3.4.2 of this OPP refers to the establishment of a 500 m PSZ under the OPGGS Act.</td></tr>
<tr><td colspan="3">Summary of impact assessment</td><td>Consequence level</td></tr>
<tr><td colspan="3">The impacts on commercial fisheries from Physical Presence – Interaction with Other Users include:
The development will not significantly impact on commercial fishing as it is situated outside areas that have historically been fished.
Tourism and vessel traffic are not expected or low within the Project Area.</td><td>Minor</td></tr>
</table>

Receptor	Demonstration of Acceptability		
	• The exclusion zone will have a 500 m radius, within which third-party vessels may be prohibited. A 2 km radius cautionary zone will be established around the MOPU, (including FSO, flowline, CALM buoy), and the Talisman subsea tieback infrastructure (if that option is selected). • 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).		
	Statement of acceptability		
	Based on an assessment against the defined acceptable levels, the impacts on *commercial fisheries* from Physical Presence – Interaction with Other Users is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO1**: Undertake the Amulet Development in a manner that prevents a substantial adverse effect on the sustainability of commercial fishing.		
Industry	**Acceptable level of impact**		
	With respect to Physical Presence – Interaction with Other Users, the Amulet Development will not result in significant impacts to *Industry* identified as potentially affected, defined as a possibility that it will (Section 6.6): • interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		
	Acceptability assessment		
	Principles of ESD	Refer to details in *commercial fisheries* assessment (above)	
	Internal context	Refer to details in *commercial fisheries* assessment (above)	
	External context	Refer to details in *commercial fisheries* assessment (above)	
	Other requirements	Refer to details in *commercial fisheries* assessment (above)	
	Summary of impact assessment		**Consequence level**

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="3"></td><td>The impacts on industry from Physical Presence – Interaction with Other Users include:
• Tourism and vessel traffic are expected to be negligible to low within the Project Area.
• The exclusion zone will have a 500 m radius, within which third-party vessels may be prohibited. A 2 km radius cautionary zone will be established around the MOPU, (including FSO, flowline, CALM buoy), and the Talisman subsea tieback infrastructure (if that option is selected).
• 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).</td><td>Minor</td></tr>
<tr><td colspan="2">Statement of acceptability</td></tr>
<tr><td colspan="2">Based on an assessment against the defined acceptable levels, the impacts on industry from Physical Presence – Interaction with Other Users is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO2: Undertake the Amulet Development in a manner that does not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.</td></tr>
</table>

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-5.

Table 7-5 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	**EPO1:** Undertake the Amulet Development in a manner that prevents a substantial adverse effect on the sustainability of commercial fishing. **EPO2:** Undertake the Amulet Development in a manner that does 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 500 m exclusion and 2 km cautionary zones. **CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction.	Minor
Industry				Minor

7.1.2 Physical Presence – Seabed Disturbance

Seabed disturbance associated with the Amulet 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 Amulet 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	MOPU; Talisman subsea tieback; flowlines; CALM buoy and mooring arrangements
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 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 7-6). Each facility has three rig feet, totalling 1,500 m^2 for each facility, each time they are jacked-down onto the seabed.

Even if the MODU jacks-down at the same location, the rig feet are unlikely to be in exactly the same place, therefore each time the MODU (or MOPU) positions onto the seabed, a direct disturbance footprint of 1,500 m^2 is assumed. For Talisman, if the subsea tieback option is selected, the separate MODU will mobilise to each expected well location. However, if extended reach drilling is feasible, the MODU will not have to move from the Amulet MOPU location (see Section **4.3.2**).

Therefore, the maximum number of occasions a MODU may need to jack-down onto the seabed to either drill or sidetrack wells at either Amulet and/or Talisman is five, giving a total potential area of 7,500 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 Amulet 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) with an estimated seabed disturbance of 100 m^2.

If the subsea tieback option is used for Talisman, the subsea tree footprint is 25 m^2 per tree.

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.

If the Talisman subsea tieback option is used, a ~3.5 km production flowline and service umbilical will be installed from the expected Talisman location to the MOPU. If the production flowline and service umbilical require stabilisation, this would likely be concrete mattresses and/or grout bags, and will be within the 5 m pipeline corridor.

A manifold will be located in the Talisman field, which is a gravity based/skirted structure providing a secure termination point. Short ~200 m jumper flowlines and control lines (one each per tree) will connect the subsea trees to the Talisman manifold. The total footprint of the whole Talisman subsea tieback system is 0.0376 km^2 (details listed in Table 7-6).

The Amulet 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 7-6).

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 export 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 7-6 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.

If well intervention is required at Talisman during operations, this could be undertaken either by ISV or a MODU. If a MODU is used, the actual configuration will depend on availability of MODU's in Australian waters at the time. For the purposes of impact assessment, a similar seabed disturbance footprint to drilling is assumed (i.e. three rig feet, totalling 1,500 m^2).

Decommissioning

In alignment with Section 572 of the OPGGS Act, the wells will be plugged and abandoned (P&A) following cessation of 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.

If the subsea tieback option is used for Talisman, either a separate MODU, or the MOPU with P&A capability will position at each Talisman well location to conduct P&A. For the purposes of impact assessment, a similar seabed disturbance footprint to drilling is assumed for both locations (i.e. a total of 3,000 m^2).

Support Operations

It may be required that support vessels anchor within the Amulet 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 7-6). 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 7-6, allowing for an overestimation of 50%.

Where multiple options are available, the option posing the greatest seabed disturbance has been used – i.e.:

- Talisman subsea tieback
- Talisman well intervention using a MODU.

Table 7-6 Total Area of Seabed Disturbance from Subsea Infrastructure

Subsea Infrastructure	Total Area Seabed Disturbance
Wells	Total of 100 m^2 *(Talisman subsea trees included under 'Talisman subsea tieback infrastructure')*
MOPU	1,500 m^2
MODU (if separate MODU required)	Total of 12,000 m^2 assuming: • Amulet – 3,000 m^2 assuming two drilling campaigns • Talisman – 4,500 m^2 assuming the MODU moves for each well, and there is a second campaign to sidetrack one well (if subsea tieback option is selected) • Talisman well intervention – 1,500 m^2 if MODU is used (if subsea tieback option is selected) • Talisman subsea well P&A – 3,000 m^2 (by MODU or MOPU), for both well locations

Subsea Infrastructure	Total Area Seabed Disturbance
Talisman subsea tieback infrastructure	Total of 37,530 m^2 assuming: • 3.5 km long production flowline and service umbilical, with a 5 m wide disturbance corridor for each, giving a total of 35,000 m^2. Mattresses/grout bags will be within the 5 m corridor • 80 m^2 manifold • 2 x subsea trees of 25 m^2 each • 4 x Jumper connections: 200 m long, 3 m wide disturbance corridor each, giving a total of 2,400 m^2
MOPU Export Flowline (subsea)	Total of 7,530 m^2 assuming: • 1.5 km long flowline, with a 5 m wide disturbance corridor. A service umbilical and any 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	**68,455 m^2 (0.0684 km^2)** Including 50% contingency – **0.103 km^2**

7.1.2.2 Impact Analysis and Evaluation

Seabed disturbances generated by the Amulet 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 7-7 identifies the potential impacts to receptors as a result of seabed disturbance from the physical presence of the Amulet Development. Receptors marked '*X*' are subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-8 provides a summary and justification for those receptors not evaluated further.

Table 7-7 Receptors Potentially Impacted by Physical Presence – Seabed Disturbance

Impacts	Ambient water quality	Plankton	Benthic habitat and communities	Fish	Marine mammals	Marine reptiles	Commercial Fisheries
Change in water quality	✓						
Change in habitat			✓				

Impacts	Ambient water quality	Plankton	Benthic habitat and communities	Fish	Marine mammals	Marine reptiles	Commercial Fisheries
Injury / mortality to fauna		X	✓	✓	X	X	
Changes to the functions, interests or activities of other users							X

Table 7-8 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). Due to regionally low nutrient levels (DEWHA 2007) and the naturally decreased light levels at the ~85–90 m depth, phytoplankton production at the seabed at the Amulet Development are likely to be low. 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.	
Marine Mammals and Marine Reptiles	***X***
Injury/mortality to fauna Marine mammals and marine reptiles include species that may feed on the seabed, but they are not demersal species and can occur and transit vertically through the entire water column. As such the installation of subsea infrastructure is not expected to result in injury or mortality. Marine mammals and reptiles are highly mobile and are expected to exhibit avoidance behaviours. In addition, while a reduction in food source may have an indirect effect on mammals and reptiles, there is no significant source benthic habitat and communities (e.g. seagrass) within the Project Area. Therefore, no impacts to marine mammals or marine reptiles 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 is 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 North West Shelf. 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 Amulet Development is conservatively estimated as 0.103 km^2 (including 50% contingency) – well within the 5 km radius of the Project Area (~121 km^2). This assumes the Talisman subsea tieback option is used, and a separate MODU if well intervention is required – neither of which are the preferred option. This is an insignificant area compared to the size and scale of commercial fisheries. Four state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show minimal and intermittent commercial fishing activity is expected to	

occur within the planned activities areas for the Amulet Development. Any fishing effort that may occur is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF).

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 7-9 provides a detailed evaluation of the impact of seabed disturbance from the physical presence of the activities to physical receptors.

Table 7-9 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, the CALM buoy anchors and chains, 1.5 km flowline and the Talisman subsea tieback system (if selected). 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 Amulet 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 North West Shelf is subject to natural variability. Tropical cyclones in the North West Shelf 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.

Ambient Water Quality ✓
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 7-10 provides a detailed evaluation of the impact of seabed disturbance to ecological receptors.

Table 7-10 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 Amulet Development will result in a change in habitat due to the localised and small-scale seabed disturbance. The continental shelf areas which 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 5.4.2). There are no KEFs which intersect the Project Area. A benthic survey undertaken by Apache (2012) ~50 km from the Project Area found unconsolidated sediments which support a diverse benthic infauna consisting predominantly of mobile burrowing species which include molluscs, crustaceans (crabs, shrimps and smaller related species), polychaetes, sipunculid and platyhelminth worms, asteroids (sea stars), echinoids (sea urchins) and other small animals. 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. In 1992, production equipment was abandoned on the seabed by the operator at the time. In January 2019, NOPSEMA accepted an EP by Santos to leave the equipment on the seabed in perpetuity. The EP considered that there was a strong likelihood that the equipment has been partially or completely buried in the underlying sediment (Santos 2018). The expected Amulet MOPU location is ~3.4 km from the edge of the 1 km buffer used around the equipment. If the Talisman subsea tieback option is selected, the expected location of the Talisman manifold is ~140 m inside the buffer; and ~860 m from the abandoned flowline. It is not expected that the Talisman infrastructure would interact with any abandoned equipment, but the location of the anchor and chain and tyre weight is not known (Section 3.2; Santos 2018). Therefore, during the site survey, KATO will locate any abandoned production equipment in the vicinity of the proposed Talisman manifold. The Talisman location will be relocated to avoid abandoned equipment if necessary.

The MOPU rig feet, flowlines plus the CALM buoy and mooring arrangements and the Talisman subsea tieback system (if selected) will be present throughout the project life of the Amulet Development, and may result in injury or mortality to epifauna and infauna through loss of habitat, smothering or decreased water quality. Temporary disturbance may also be caused by the MODU if this separate unit option is selected.

The total area of direct seabed disturbance from subsea infrastructure and installation is 0.103 km^2 (including 50% contingency). This assumes the Talisman subsea tieback option is used, and a separate MODU if well intervention is required – neither of which are the preferred option. In comparison, Woodside's proposed Scarborough Development has an expected footprint of 12.9 km^2 in Commonwealth waters (Woodside 2019) with a predicted 30-year operational period. Chevron's Jansz–Io gas field (Chevron 2018a) also predicts benthic disturbance of 13 km^2 by subsea infrastructure during the 30-year operational period of the Gorgon Gas Development. Due to the short project life of the Amulet Development (~5 years), the disturbance is much shorter-term compared to the projected project life for the Scarborough and Jansz–Io gas field developments.

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>

Seabed surveys undertaken ~50 km and ~112 km from the Project Area (Apache 2012 and RPS 2011 respectively) found that there was a low abundance, high variability and diversity of infauna dominated by polychaetes and crustaceans. Santos' WAS-8-L Production Equipment Abandonment EP (2018) stated that the macrobenthos of the permit area most likely consist of sponges, polychaete worms, bivalves and echinoderms, and microorganisms. Subsea surveys and fauna reviews within the North West Shelf 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.

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 Amulet 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.

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 approximately 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 2014 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 are not proposed as part of the Amulet 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 form subsea infrastructure and installation is 0.103 km^2 (including 50% contingency), making it relatively localised. The disturbance is also temporary, due to the short project life of the Amulet 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.

When considering the disturbance footprint of the Amulet 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. 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 ✓
Injury / mortality to fauna. Installed subsea infrastructure will be present throughout the operational life of the Amulet 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 North West Shelf. 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 Amulet Project Area, which is situated within a foraging BIA for the Whale Shark. The Project Area including 5 km buffer is ~121 km^2, and the direct area of seabed disturbance is 0.103 km^2 (including 50% contingency), which is insignificant when compared to the size of the BIA (218,911 km^2). Within the North West Shelf, 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). While the species is generally encountered close to or at the surface, it will regularly dive and move through the water column. Around Ningaloo, Whale Sharks spend 10-40% of their time in surface waters (Gleiss et al. 2013). Off the outer North West Shelf, they spend much of their time swimming near the seafloor and make dives to over 1000 m depth (DoEE 2019b). 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 where foraging activity is centred on the 200 m isobath from July to November. The 200 m isobath is situated ~39 km to the north of the Amulet Project Area. The approved Conservation Advice (TSSC 2015d) states that the main threat to the Whale Shark occurs outside Australian waters, which is commercial harvest by a number of other range states. Habitat disruption from mineral exploration, production and transportation is listed as a threat. 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 7-11.

Table 7-11 Demonstration of Acceptability for Physical Presence – Seabed Disturbance

Receptor	Demonstration of Acceptability	
Water quality	**Acceptable level of impact**	
	With respect to Physical Presence - Seabed Disturbance, the Amulet Development will not result in significant impacts to *water quality* identified as potentially affected, defined as a possibility that it will (Section 6.6): • result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	
	Acceptability assessment	
	Principles of ESD	The proposed EPO's for the Amulet Development are consistent with the principles of ESD. With respect to potential impacts to *all receptors* from Physical Presence - Seabed Disturbance the relevant principles are: • Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. • 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.
	Internal context	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards. With respect to potential impacts to *all receptors* from Physical Presence - Seabed Disturbance, there are no specific KATO internal requirements with respect to seabed disturbance or potentially impacted receptors.
	External context	The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders. With respect to potential impacts to *all receptors* from Physical Presence - Seabed Disturbance, no specific concerns were raised during stakeholder consultation with relevant persons. • The proposed Talisman manifold location is ~860 m away from the closest known location of the Santos abandoned production equipment infrastructure (T-7 flowline); however the location of the anchor, chain and tyre weight is not known. NOPSEMA have accepted an EP by Santos to leave the equipment on the seabed in perpetuity; therefore there is no future activity or responsibility regarding this equipment for Santos, or any other operator (including KATO). • If the Talisman subsea tieback option is selection, consideration will be given to location of the Santos abandoned production equipment, when selecting the site location for Talisman infrastructure during the site survey

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="7"></td><td rowspan="3">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Physical Presence - Seabed Disturbance from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to water quality from Physical Presence - Seabed Disturbance, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Commonwealth Environment Protection (Sea Dumping) Act 1981</td><td>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</td><td>Adoption of the following control measures:
CM06: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below the mudline and removed
CM07: If any objects are to be left in situ on the seabed, KATO will consult with DAWE to confirm any requirements, and apply for, a Sea Dumping Permit, if required</td></tr>
<tr><td colspan="3">Summary of impact assessment</td><td>Consequence level</td></tr>
<tr><td colspan="3">The impacts on water quality from Physical Presence - Seabed Disturbance include:
The impacts of seabed disturbance from the Amulet Development will be comparable with existing facilities on the North West Shelf and will not result in a notable change to the localised level of water quality.
The total area of direct seabed disturbance from subsea infrastructure and installation is 0.103 km^2 (including 50% contingency) which includes the Talisman subsea tieback option – making it localised.
A reduction in water quality will be highly localised and very brief.</td><td>Minor</td></tr>
<tr><td colspan="4">Statement of acceptability</td></tr>
<tr><td colspan="4">Based on an assessment against the defined acceptable levels, the impacts on water quality from Physical Presence - Seabed Disturbance is considered acceptable, given that:
the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
the predicted level of impact is at or below the defined acceptable level</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="4">To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO3: Undertake the Amulet Development in a manner that does not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health</td></tr>
<tr><td rowspan="10">Benthic habitats and communities</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td colspan="4">With respect to Physical Presence - Seabed Disturbance, the Amulet Development will not result in significant impacts to benthic habitats and communities identified as potentially affected, defined as a possibility that it will (Section 6.6):
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
<tr><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td rowspan="3">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Physical Presence - Seabed Disturbance from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to benthic habitats and communities from Physical Presence - Seabed Disturbance, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Commonwealth Environment Protection (Sea Dumping) Act 1981</td><td>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</td><td>Adoption of the following control measures:
CM06: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below the mudline and removed
CM07: If any objects are to be left in situ on the seabed, KATO will consult with DAWE to confirm any requirements, and apply for, a Sea Dumping Permit, if required.</td></tr>
<tr><td colspan="3">Summary of impact assessment</td><td>Consequence level</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="3"></td><td colspan="2">The impacts on benthic habitats and communities from Physical Presence - Seabed Disturbance include:
• Benthic habitat and communities within the Project Area are expected to be sparse, with no impacts on any MNES or KEFs
• The total area of direct seabed disturbance from subsea infrastructure and installation is 0.103 km² (including 50% contingency) which includes the Talisman subsea tieback option – making it localised.
• Seabed disturbance is temporary, due to the short project life of the Amulet Development (~5 years).
• Recolonisation is expected to be rapid following any disturbance.

Minor</td></tr>
<tr><td colspan="2">Statement of acceptability</td></tr>
<tr><td colspan="2">Based on an assessment against the defined acceptable levels, the impacts on benthic habitats and communities from Physical Presence - Seabed Disturbance is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO4: Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
• EPO11: Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and communities, including life cycle and spatial distribution.</td></tr>
<tr><td rowspan="5">Fish</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Physical Presence - Seabed Disturbance, the Amulet Development will not result in significant impacts to fish identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
• substantially modify, destroy or isolate an area of important habitat for a migratory species.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td>Refer to details in water quality assessment (above)</td></tr>
</table>

Receptor	Demonstration of Acceptability			
	External context	Refer to details in *water quality* assessment (above)		
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Physical Presence - Seabed Disturbance from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. With respect to potential impacts to *fish* from Physical Presence - Seabed Disturbance, this specifically includes:		
		Requirement	*Relevant Item/Objective/Action*	*Addressed/Managed by Amulet Development*
		Recovery plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013a)	Identifies ecosystem effects as a result of habitat modification as a threat. No explicit relevant objectives or management actions.	Environmental impact assessment for seabed disturbance on fish has been completed in this OPP (Section 7.1.2.2.2).
		Sawfish and river shark multispecies recovery plan (CoA 2015b)	Identifies habitat degradation and modification as a principal threat. Objective 5: Reduce and, where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species. Relevant management actions: • 5c: Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.	
		Approved conservation advice for *Pristis clavata* (Dwarf Sawfish) (TSSC 2009b)	Identifies habitat degradation due to increasing human development in northern Australia as a potential threat. No explicit relevant objectives or management actions.	
		Approved conservation advice for Green Sawfish (TSSC 2008a)	Identifies habitat degradation through coastal development as a potential threat. No explicit relevant objectives or management actions.	
		Approved Conservation Advice for *Pristis pristis*	Identifies habitat degradation and modification as a main threat. No explicit relevant objectives.	

Receptor	Demonstration of Acceptability			
		(Largetooth Sawfish) (DoE 2014a).	Relevant management action: • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	
		Conservation advice Rhincodon typus (Whale Shark) (TSSC 2015d)	Identifies habitat disruption from mineral exploration, production and transportation as a threat. No explicit relevant objectives or management actions.	
	Summary of impact assessment			**Consequence level**
	The impacts on *fish* from Physical Presence - Seabed Disturbance include: • The total area of direct seabed disturbance from subsea infrastructure and installation is 0.103 km^2 (including 50% contingency) which includes the Talisman subsea tieback option – making it localised. • Seabed disturbance is temporary, due to the short project life of the Amulet Development (~5 years). • Impacts on Whale Shark BIA foraging areas are not predicted and are insignificant.			Minor
	Statement of acceptability			
	Based on an assessment against the defined acceptable levels, the impacts on *fish* from Physical Presence - Seabed Disturbance is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. • **EPO8:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. • **EPO10:** Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species.			

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-12.

Table 7-12 Summary of Impact Assessment for Physical Presence – Seabed Disturbance

<table>
<tr><th>Receptor</th><th>Impacts</th><th>EPOs</th><th>Adopted control measures</th><th>Consequence</th></tr>
<tr><td>Ambient water quality</td><td>Change in water quality</td><td rowspan="3">EPO3: Undertake the Amulet Development in a manner that does not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.

EPO4: Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.

EPO5: Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

EPO8: Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.

EPO10: Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species.

EPO11: Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and communities, including life cycle and spatial distribution.</td><td rowspan="3">CM05: Mooring analysis will be undertaken, which will include an environmental sensitivity and seabed topography analysis.

CM06: Wells will be plugged and abandoned during decommissioning activities, with wellheads cut below the mudline and removed.

CM07: If any objects are to be left in situ on the seabed, KATO will consult with DAWE to confirm any requirements, and apply for, a Sea Dumping Permit, if required.

CM08: The Talisman subsea tieback infrastructure will be located to avoid any existing abandoned production equipment discovered during the site survey.</td><td>Minor</td></tr>
<tr><td>Benthic habitats and communities</td><td>Change in habitat

Injury / mortality to fauna</td><td>Minor</td></tr>
<tr><td>Fish</td><td>Injury / mortality to fauna</td><td>Minor</td></tr>
</table>

7.1.3 Emissions – Light

The operations of vessels and facilities associated with the Amulet 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 2020); 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 Amulet 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 during this process flaring of hydrocarbon gas may be required either form the MOPU or MODU. 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.

If the subsea tieback option is used for Talisman, these wells will be drilled on location by a MODU (or the MOPU with drilling capability).

Operations

During the production phase of the Amulet Development, continuous flaring of excess gas may be required to allow for hydrocarbon production and processing, depending on the high and best production estimates (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˚ to 60˚ to the horizontal cantilevered structure, external to the MOPU hull perimeter, extending 30–40 m from the hull. An analogous facility (Galoc) has a flare tower tip height of 80 m, which is the height used for the purposes of the visible light exposure assessment (Section 7.1.3.2.2).

Operations are expected to occur over a relatively short period of 1.5–4.5 years, with an estimated peak flaring rate of 1.2 MMscf/d during the initial 6–9 months (P50–P10 estimates) of operations, and then declining rapidly as the reservoir is depleted (Figure 7-1; Section 4.3.1).

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 2 m above the MOPU flare tower tip in calm conditions. Therefore, the height of the flame during this flaring rate is ~82 m above sea level.

Final design for flaring will be determined during FEED, including investigations of best practice design and assessments to reduce light emissions to ALARP.

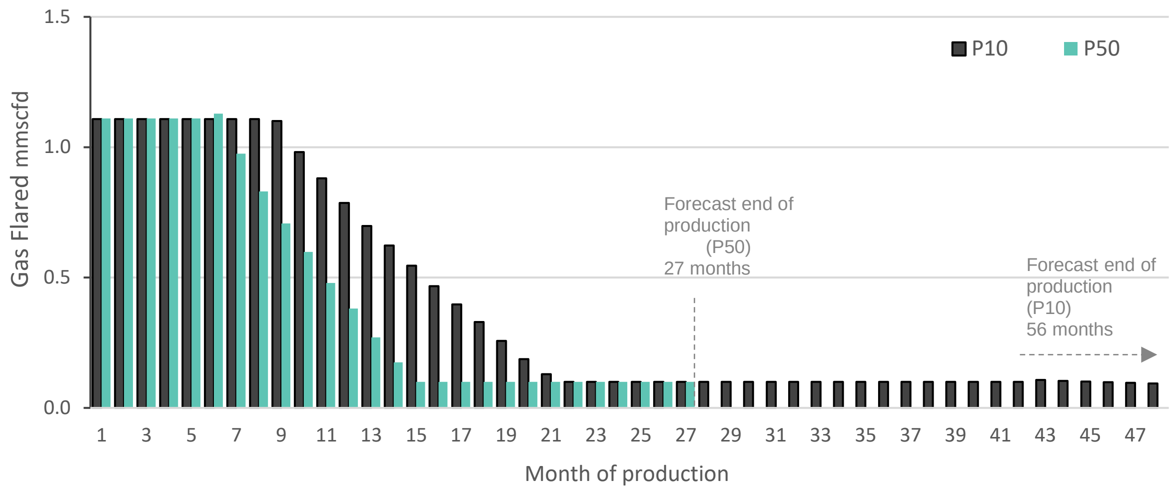


Figure 7-1 Expected Flaring Profiles (P10 and P50) for the Amulet Development

Support Activities

Throughout the Amulet 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.

As the MOPU, MODU, and support vessels may all undertake activities at both the Amulet location, and the Talisman location (~3.5 km from Amulet), both locations and the flowline route in between are sources of light emissions, within the Project Area.

7.1.3.2 Modelling and Exposure Assessment

Two areas have been defined for describing artificial light emissions for the Amulet Development, a Visible Light Exposure Area and a Potential Impact Area (Table 7-13). Desktop modelling of visible light and light intensity has been undertaken (Xodus Group 2020a; 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 National Light Pollution Guidelines (CoA 2020) 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 2020). 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 7-13 Description of Amulet Development Artificial Light Exposure and Potential Impact Areas

Amulet 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 Amulet 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 Amulet 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 Amulet 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 Amulet 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

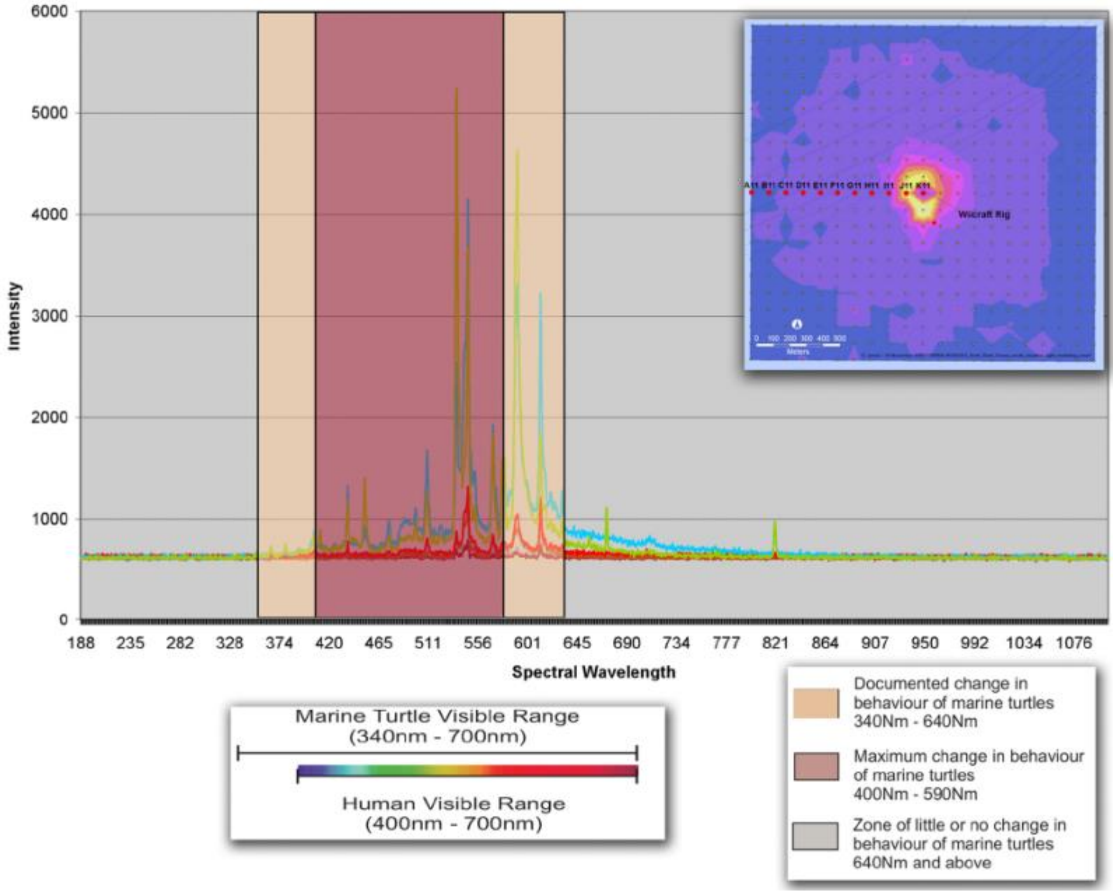
As described in Section 7.1.3.1, two main sources of light emissions are associated with the Amulet Development:

- 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.

Amulet Development Light Characteristics

Light emissions due to facility lighting from the MODU and MOPU for the Amulet 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 7-2) (SKM 2008; Woodside 2014).



Source: SKM 2008; Woodside 2014

Figure 7-2 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 7-3) 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 Amulet Development.

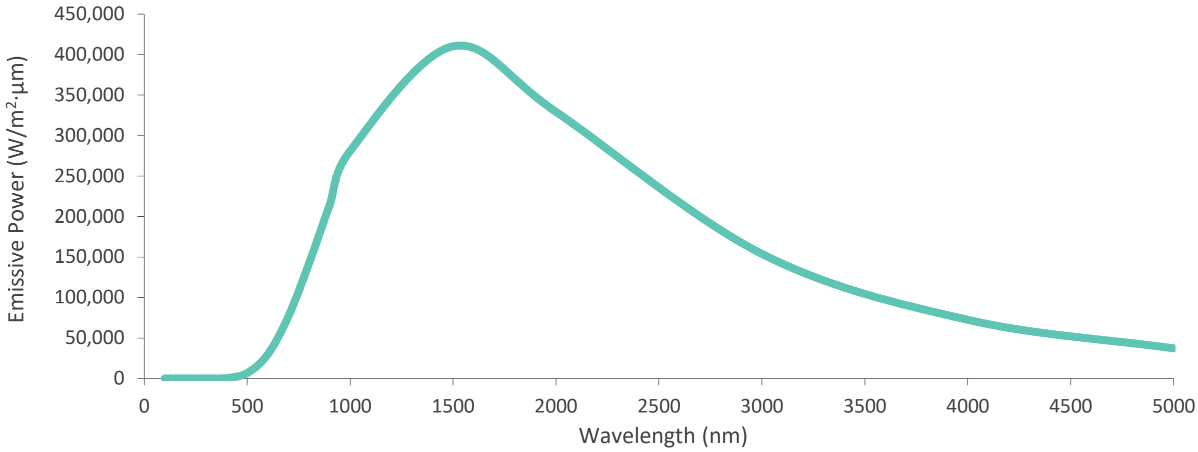
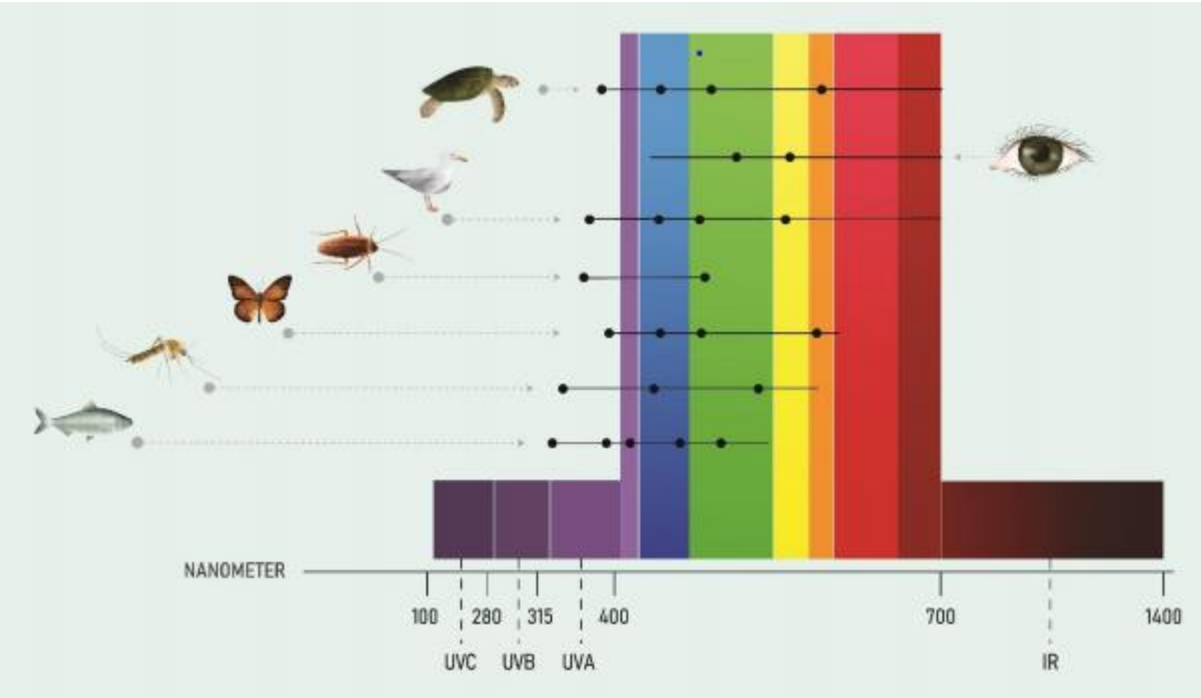


Figure 7-3 Spectral Signature Predicted from the Gas Flare (according to Planks equation at 2,000 Kelvin)

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 7-4; CoA 2020). Fauna perceive light differently to humans, with most sensitive to the ultraviolet, violet and blue light wavelengths (Figure 7-4; CoA 2020). 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 2020. Ability to perceive different wavelengths of light in humans and wildlife is shown by horizontal lines. Black dots represent reported peak sensitivities. Figure adapted from Campos (2017)

Figure 7-4 Different Fauna Groups' Ability to Perceive Different Wavelengths of Light

7.1.3.2.2 Visible Light Exposure Area

Light from the Amulet 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 2020a; 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 small navigation light/s on the derrick is the tallest source of facility lighting present throughout the whole Amulet Development, and is estimated to be visible to a distance of 35.5 km (Table 7-14).

The flare flame height reduces over time as the field is depleted (Figure 7-1; Section 4.3.1), the initial visible distance of 32.3 km will decrease towards 32.0 km, which is associated with the small pilot flare (~0.5 m height). This is close to the height of the flare tower, therefore is visible for a similar distance (31.9 km) (Table 7-14).

The line of sight assessment indicates that the MOPU and MODU will not be visible from mainland WA, but may be visible from some adjacent facilities (Figure 7-5). As the MOPU, MODU, and support vessels may all undertake activities at both the Amulet and Talisman locations (~3.5 km apart), both locations have been used as the source location for the line of sight distance.

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).

Table 7-14 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		
2 m high flame from the flare (~1.2 MMscf/d)	82 m	32.3 km
0.5 m high flame from the flare (pilot flare)	80.5 m	32.0 km

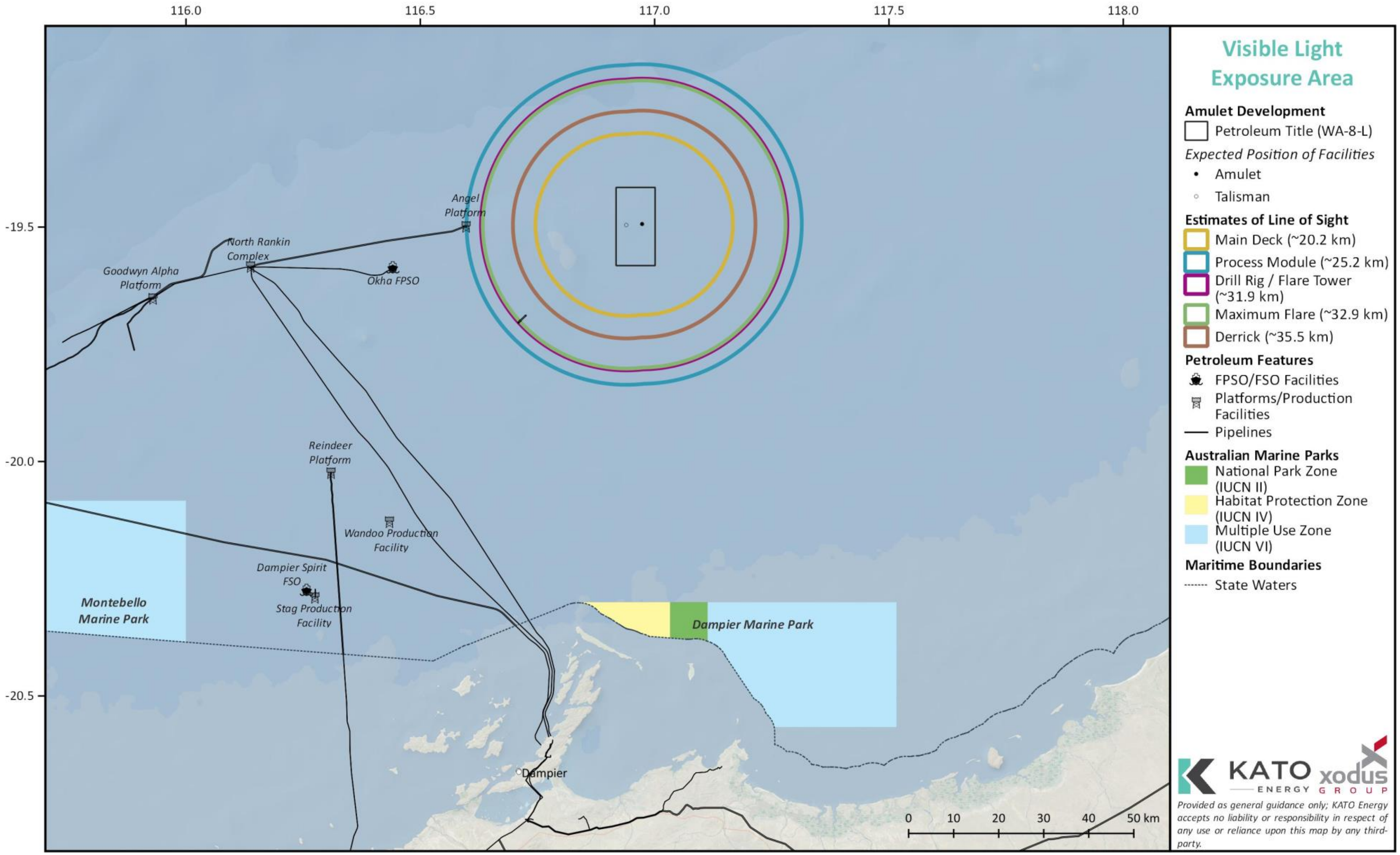


Figure 7-5 Visible Light Exposure Area for the Amulet Development

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[10]. 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[11] (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 7-4).

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 7-15; these are considered to be representative of ambient light levels in the vicinity of the Amulet Development and wider North West Shelf region.

Table 7-15 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

[10] 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).

[11] 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[12]	0.001
Moonless overcast night sky	0.0001

Source: ERM 2010

The two sources of light emissions associated with the Amulet Development (facility lighting and the gas flare) will have differing areas of potential impact over the life of the project.

Two scenarios were modelled to quantify the potential impact area from facility lighting and the flare (Xodus Group 2020a; Appendix B):

- flare light emissions for a 1.2 MMscf/d gas flare rate (representing peak flaring during initial period of operations)
- 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 2020a; Appendix B).

Light Illuminance Estimates for the Gas Flare and Facility Lighting

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.

A flare light assessment was conducted by Xodus Group (Appendix B), utilising scaling of light intensity and flaring rates measured at other facilities. 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.

Modelled light intensity (illuminance) levels for the Amulet Development during peak flaring conditions (i.e. 1.2 MMscf/d) predicted (Xodus Group 2020a; Appendix B):

- Light intensity levels greater than 0.1 Lux up to 0.9 km from the MOPU, comparable to ambient light levels during full moon to twilight
- Between 0.9 km and 2.7 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 2.7 km and 8.3 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 8.3 km there was no measurable change to the ambient light intensity levels.

[12] Impact threshold used in this impact assessment is 0.001 lux; beyond this threshold no impact to light-sensitive fauna is assumed.

This measurable change in light from the gas flare does not extend over adjacent facilities or to any island or mainland areas. This modelled light intensity curve for peak flaring for the Amulet Development is shown graphically in Figure 7-6; and the predicted radii is shown in Figure 7-7.

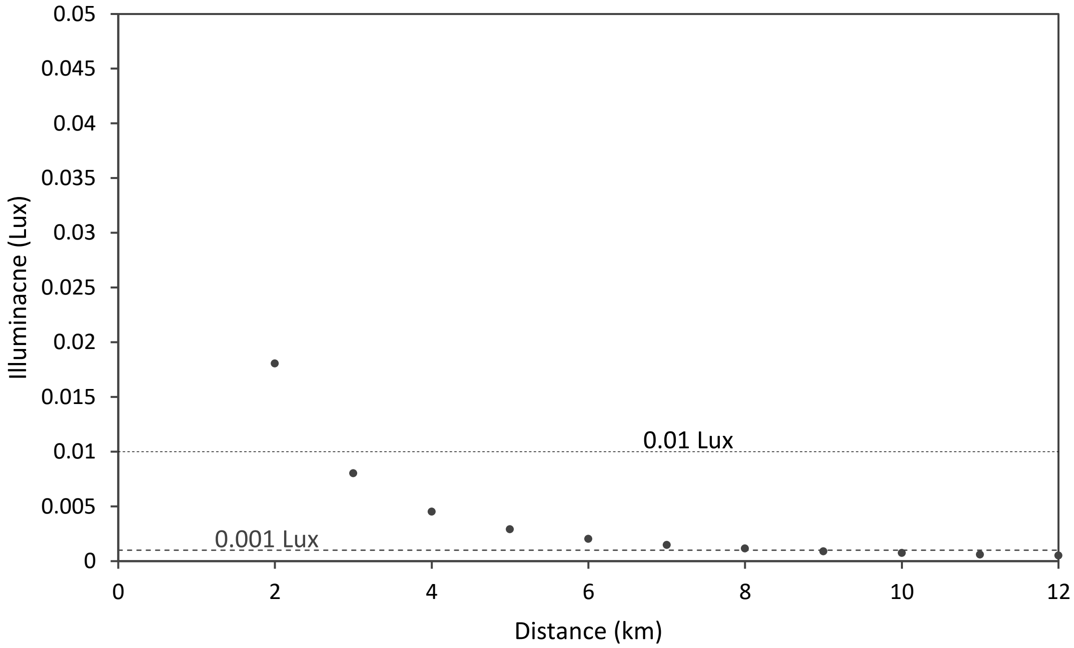


Figure 7-6 Modelling Light Intensity (Illuminance) for Peak Flaring (1.2 MMscf/d) during Operations for the Amulet Development

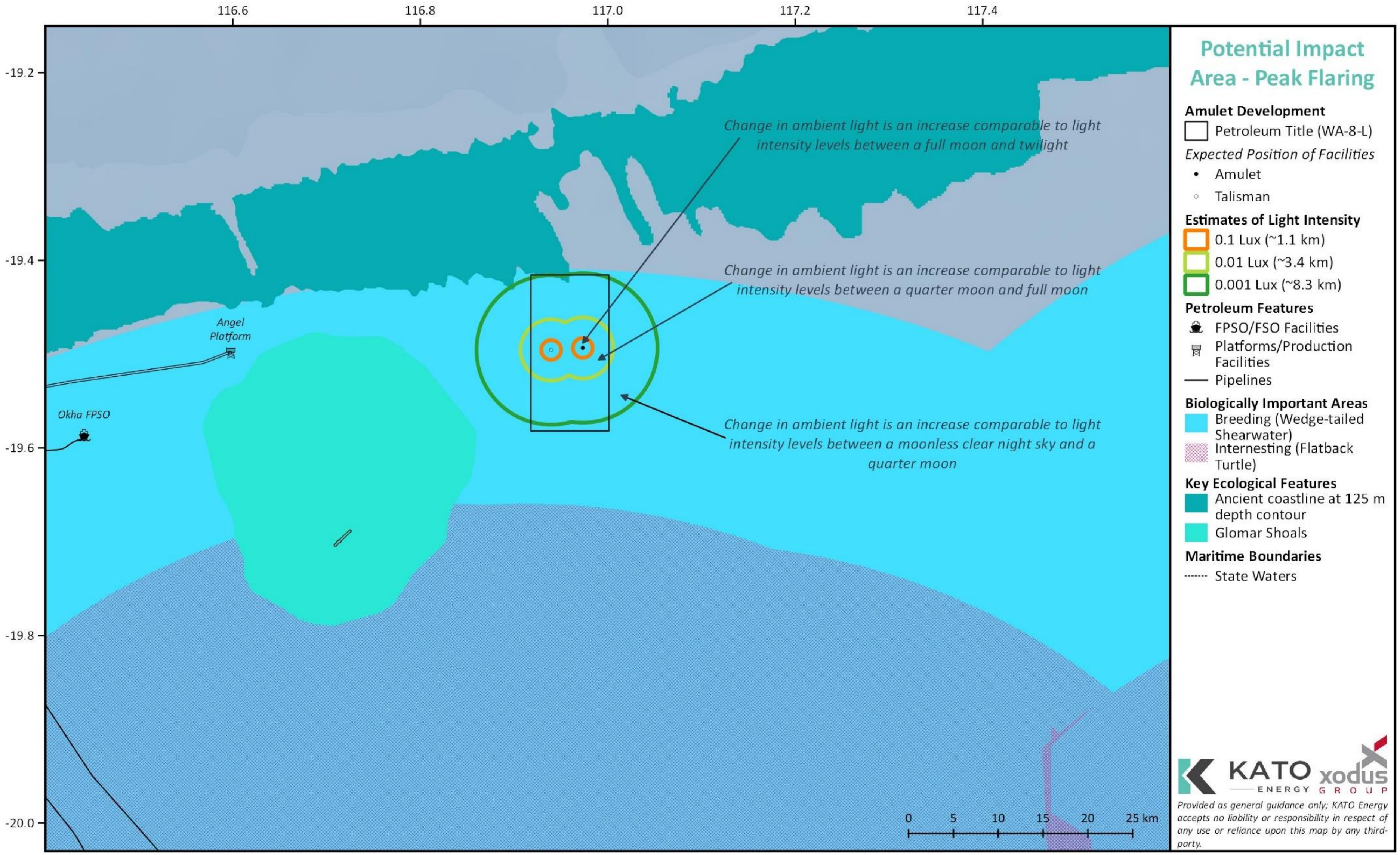


Figure 7-7 Potential Impact Area – Modelled Light Intensity Levels during Peak Flaring at Amulet and Talisman locations

Light Intensity Estimates for Facility Lighting

Light emissions from the facility lighting from the MODU and MOPU for the Amulet Development is expected to be comparable to that of the Torosa drilling rig used during previous light intensity modelling completed by ERM (2010). As both are drilling rigs with requirements for functional and navigational lighting, the MODU and MOPU is expected to 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).

This measurable change in light from the gas flare does not extend over adjacent facilities or to any island or mainland areas. This modelled light intensity predicted radii for facility lighting for the Amulet Development is shown in Figure 7-8.

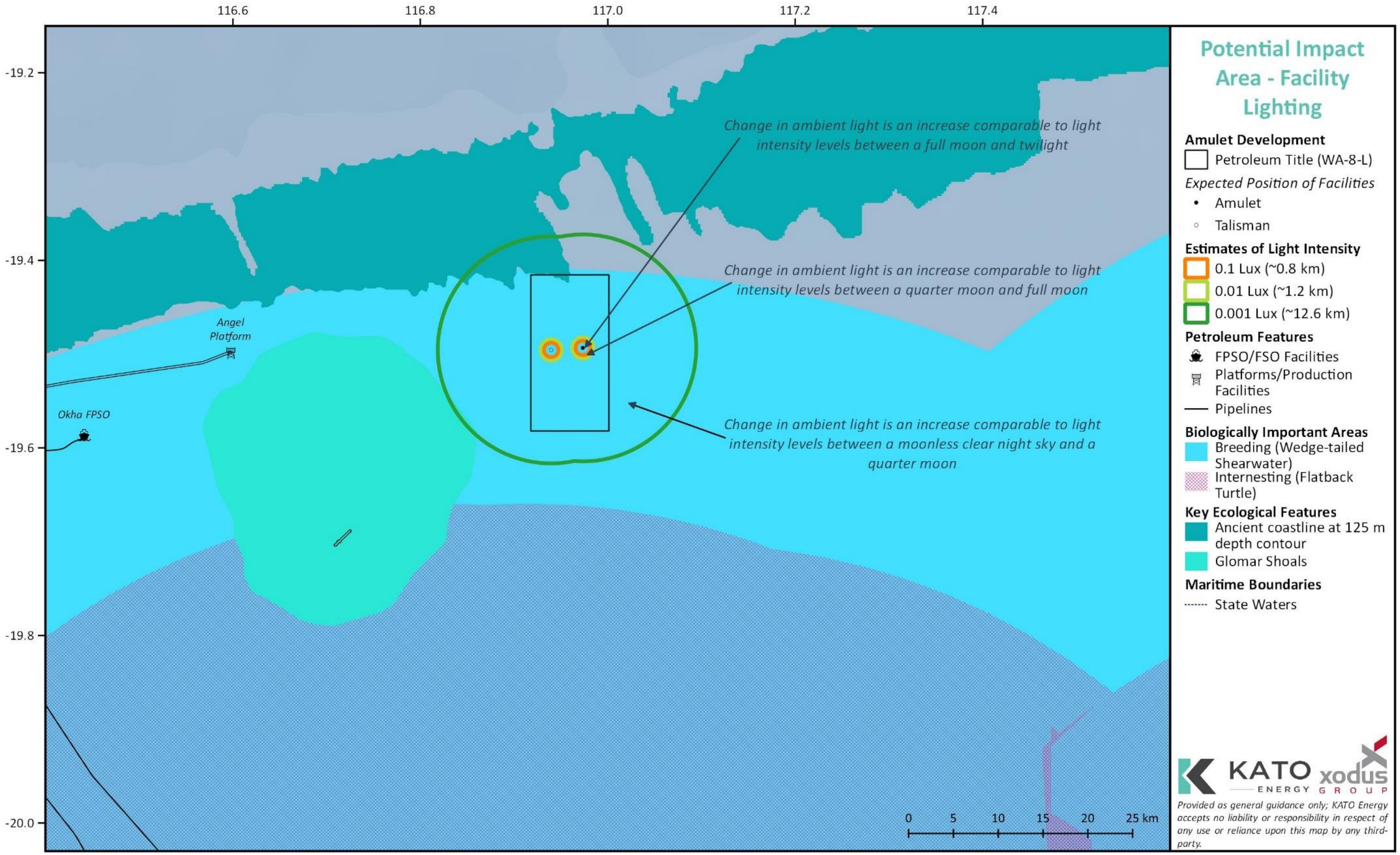


Figure 7-8 Potential Impact Area – Modelled Light Intensity Levels for Facility Lighting from the MOPU and MODU at Amulet and Talisman locations

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 Amulet Development are:

- Flaring:
  - ~8.3 km during peak (1.2 MMscf/d) operational flaring (first 6–9 months)
- Facility:
  - ~12.6 km over the life of the project.

Therefore, over the life of the project the maximum distance of the potential impact area for artificial light emissions from the Amulet Development is from facility lighting at ~12.6 km.

It is also noted that the 20 km distance indicated within the National Light Pollution Guidelines (CoA 2020) falls beyond the estimated extent of measurable changes to ambient conditions (that was defined as <0.001 Lux) from peak flaring (8.3 km) and facility lighting (12.6 km) (Figure 7-9).

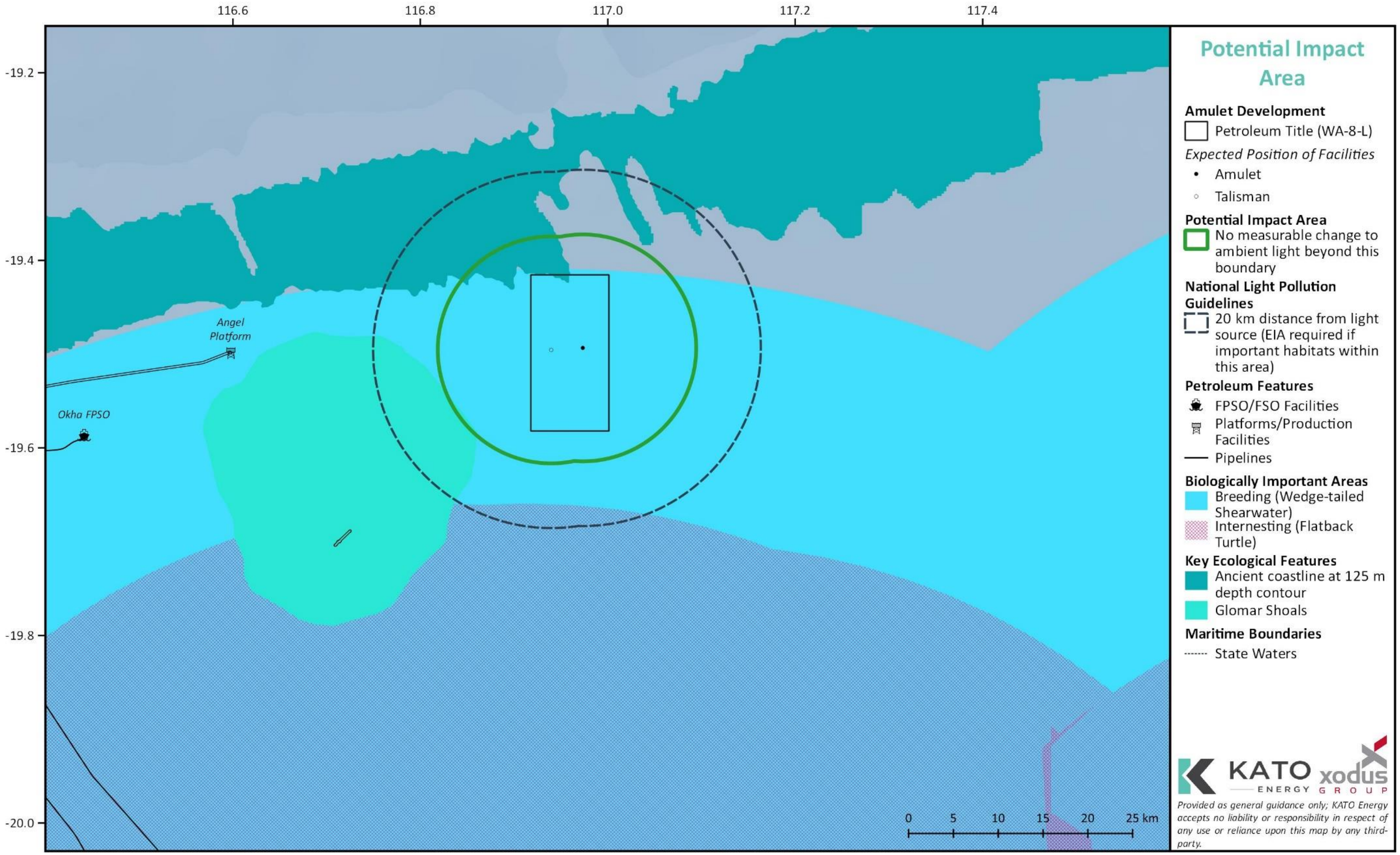


Figure 7-9 Potential Impact Area for Light Emissions from the Amulet Development

7.1.3.3 Impact Analysis and Evaluation

Light emissions generated by the Amulet 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 7-16 identifies the potential impacts to receptors as a result of light emissions from the Amulet Development. Receptors marked '*X*' are subject to impacts that are predicted to have a consequence considered as negligible (i.e. less than Minor).

Table 7-17 provides a summary and justification for those receptors not evaluated further.

Table 7-16 Receptors Potentially Impacted by Emissions – Light

Impacts	Ambient light	Seabirds and shorebirds	Fish	Marine mammals	Marine reptiles	Commercial Fisheries
Change in ambient light	✓					
Change in fauna behaviour		✓	✓	*X*	✓	
Injury/mortality to fauna		✓				
Changes to the functions, interests or activities of other users						*X*

Table 7-17 Justification for Receptors Not Evaluated Further for Emissions – Light

Marine Mammals	***X***
<u>Change in fauna behaviour</u> Artificial light has not been reported to cause a significant behavioural disturbance to marine mammals, despite their often-higher activity levels at night. Results from a previous independent review and risk assessment of the sensitivity of marine mammals to mining and exploration activities in the Great Australian Bight Marine Park indicate that the consequence of light pollution impacts to marine mammals were insignificant (defined as occasional short-term attraction and/or disruption to marine mammals) (Pidcock, Burton and Lunney 2003). Therefore, impacts to marine mammals from light emissions are not expected, and have not been evaluated further.	
Commercial Fisheries	***X***
As outlined above, a measurable change in light from ambient conditions may occur up to a maximum distance of ~12.6 km from the Amulet Development during the life of the project. 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 7-18 provides a detailed evaluation of the impact or risk of light emissions to physical receptors.

Table 7-18 Impact and Risk Assessment for Physical Receptors from Emissions – Light

Ambient Light ✓
Change in ambient light The operations of vessels and facilities associated with the Amulet Development will generate artificial light emissions, which will result in a change in the ambient light environment within the immediate vicinity of the sources. As outlined above, artificial lighting from the Amulet Development is expected to be visible for a maximum distance of 35.5 km for the tallest lighting source (i.e. navigational lighting on the derrick). The flare itself would be visible for a maximum of 32.3 km (during peak flaring in the initial 6-9 months). Although the light may be visible at the above distances, the intensity of the light and any associated sky glow rapidly decrease as distance from the source increases. 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. From a previous modelling assessment, facility lighting had no measurable effect on ambient light conditions beyond 12.6 km from the light source (ERM 2010; Woodside 2014). The artificial light from the Amulet Development is not predicted to be visible, or measurable, from the mainland, or from any offshore islands. There are no Management Plans related specifically to ambient light. While a change in ambient light conditions within the vicinity of the Amulet Development is predicted to occur, 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 7-19 provides a detailed evaluation of the impact of light emissions to ecological receptors.

Table 7-19 Impact and Risk Assessment for Ecological Receptors from Emissions – Light

Seabirds and Shorebirds ✓
Change in fauna behaviour 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 2020). Fledgling seabirds may also not take their first flight if their nesting habitat never becomes dark (CoA 2020). Emergence during darkness is believed to be a predator-avoidance strategy and artificial lighting may make the fledglings more vulnerable to predation (CoA 2020). 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 2020).

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 2020). 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 2020). The eyes of the Wedge-tailed Shearwater are characterised by a high proportion of cones that a sensitive to shorter wavelengths (CoA 2020). For the Amulet 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 2020).

A measurable change in light from ambient conditions may occur up to a maximum distance of ~12.6 km from the Amulet Development over the life of the project. This potential area of impact does not intersect any area of mainland or offshore island. In addition, there is no mainland or islands that intersect with the 20 km distance from an artificial light source, as referenced in the National Light Pollution Guidelines (CoA 2020; Figure 7-9). It is noted that a breeding BIA for the Wedge-tailed Shearwaters would intersect with the potential impact area; however, this intersection is with the buffer extending from the islands (e.g. within Dampier Archipelago) that are used for nesting (i.e. and not with a nesting location itself). Therefore, the potential area of impact does not directly intersect with any nesting habitat for seabirds or shorebirds; and as such changes to nesting and fledgling emergence are not expected.

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).

<u>Fauna injury/mortality</u>

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 2020). 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.

<u>Summary</u>

Given the details above, the consequence of light emissions causing a change in the behaviour of seabird and shorebird species has been assessed as **Minor (1)**, due to expected impacts to be localised to within ~12.6 km of the Amulet Development. Impacts are also predicted to be short-term, with 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 2020). As there is no significant benthic habitat within the immediate vicinity of the Amulet 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 Amulet Development is located within a foraging BIA for Whale Sharks. Foraging activity in the Pilbara occurs from July to November, however it is typically centred on the 200 m isobath, which is ~39 km further offshore than the MOPU (which is in ~85 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 Amulet Development area but at significantly lower numbers. It is not expected that Whale Sharks could be directly impacted by light emissions.

The National Light Pollution Guidelines does not specifically address light impacts to fish species, although it is recognised that light can cause changes in fish assemblages (CoA 2020).

Given the details above, the consequence of light emissions causing a change in the behaviour of fish species has been assessed as **Minor (1)**, due to expected impacts to be localised to within ~12.6 km of the Amulet Development. Impacts are also predicted to be short-term, with a project life of ~5 years.

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 2020; 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 2020).

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 2020). Hatchlings have been observed to respond to artificial light up to 18 km away during sea finding (CoA 2020).

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 2020). 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 2020). 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 2020).

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 2020). As there is no coastal or nearshore artificial lighting associated with the Amulet 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 ~12.6 km from the Amulet Development for the life of the project. This potential area of impact does not intersect any area of mainland or offshore island. In addition, there is no mainland or islands that intersect with the 20 km distance from an artificial light source, as referenced in the National Light Pollution Guidelines (CoA 2020; Figure 7-9). Therefore, the potential area of impact does not directly intersect with any nesting habitat for marine turtles; and as such changes to nesting and hatchling behaviour are not expected. The potential impact area for light associated with the Amulet Development does intersect with a small portion of an internesting BIA for the Flatback Turtle. Internesting areas for Flatback Turtles can be up to ~60 km from a nesting beach. 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). In addition, it is also noted that the peak wavelengths of light emissions from the Amulet 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 National Light Pollution Guidelines currently apply to marine turtles, seabirds and migratory shorebirds (CoA 2020). Given the details above, the consequence of light emissions causing a change in the behaviour of reptile species has been assessed as **Minor (1)**, due to expected impacts to be localised to within ~12.6 km of the Amulet Development. Impacts are also predicted to be short-term, with a project life of ~5 years.

7.1.3.4 Consequence and Acceptability Summary

The worst-case consequence of light emissions from the Amulet Development has been evaluated as **Minor (2)**, which was for seabirds and shorebirds and is considered **acceptable** when assessed against the criteria in Table 7-20.

Table 7-20 Demonstration of Acceptability for Emissions – Light

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="7">Ambient light</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Emissions – Light, the Amulet Development will not result in significant impacts to ambient light identified as potentially affected, defined as a possibility that it will (Section 6.6):
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>The proposed EPO's for the Amulet Development are consistent with the principles of ESD.
With respect to potential impacts to all receptors from Emissions – Light the relevant principles are:
• Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
• 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.</td></tr>
<tr><td>Internal context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards.
With respect to potential impacts to all receptors from Emissions – Light, this specifically includes:
• KATO Artificial Light Management Plan KAT-000-PO-PP-102 (KATO 2020g).</td></tr>
<tr><td>External context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders.
With respect to potential impacts to all receptors from Emissions – Light, no specific concerns were raised during stakeholder consultation with relevant persons.</td></tr>
<tr><td>Other requirements</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions – Light from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to ambient light from Emissions – Light, this specifically includes:
Requirement   Relevant Item/Objective/Action   Addressed/Managed by Amulet Development</td></tr>
</table>

Receptor	Demonstration of Acceptability			
		Commonwealth *Navigation Act 2012* and the various Marine Orders (as appropriate to vessel class) enacted under 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.	Adoption of the following control measure: **CM09:** Lighting will be sufficient for navigational, safety and emergency requirements (e.g. requirements contained in AMSA Marine Order Part 30 and Facility Safety Cases).
		Facility Safety Cases, required by OPGGS Act 2006	A safety case is a document produced by the operator of a facility, and assessed by NOPSEMA, which: • Identifies the hazards and risks • Describes how the risks are controlled • Describes the safety management system in place to ensure the controls are effectively and consistently applied.	
		National Light Pollution Guidelines (CoA 2020)	The Guidelines recommend: • Always using best practice lighting design to reduce light pollution and minimise the effect on wildlife	Adoption of the following control measures: **CM10**: An Artificial Light Management Plan will be developed in alignment with the National Light Pollution Guidelines (CoA 2020).
	Summary of impact assessment			**Consequence level**
	The impacts on *ambient light* from Emissions - Light include: • The maximum distances of the potential impact area for artificial light emissions from the Amulet Development is ~12.6 km for the life of the project. • The generation of light emissions will be relatively short-term, due to the short project life of the Amulet Development (~5 years) and with operational flaring only expected for the first 6-9 months.			Minor
	Statement of acceptability			
	Based on an assessment against the defined acceptable levels, the impacts on *ambient light* from Emissions - Light is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)			

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="4">

- the predicted level of impact is at or below the defined acceptable level

To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:

- **EPO4:** Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results**.**

</td></tr>
<tr><td rowspan="9">Seabirds and shorebirds</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td colspan="4">

With respect to Emissions - Light, the Amulet Development will not result in significant impacts to *seabirds and shorebirds* identified as potentially affected, defined as a possibility that it will (Section 6.6):

- have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population.
- substantially modify, destroy or isolate an area of important habitat for a migratory species.
- seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

</td></tr>
<tr><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in ambient light assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in ambient light assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in ambient light assessment (above)</td></tr>
<tr><td rowspan="3">Other requirements</td><td colspan="3">

The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions - Light from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.

With respect to potential impacts to *seabirds and shorebirds* from Emissions - Light, this specifically includes:

</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>National Light Pollution Guidelines (CoA 2020)</td><td>

The aim of the Guidelines is that artificial light will be managed so wildlife is:

- Not disrupted within, nor displaced from, important habitat
- Able to undertake critical behaviours such as foraging, reproduction and dispersal.

</td><td>

Environmental impact assessment for light emissions on seabirds and shorebirds has been completed in this OPP (Section 7.1.3.3.2).

Adoption of the following control measures:

</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="5">Demonstration of Acceptability</th></tr>
<tr><td rowspan="6"></td><td></td><td></td><td>The Guidelines recommend:
• Always using best practice lighting design to reduce light pollution and minimise the effect on wildlife
• Undertaking environmental impact assessment for effects of artificial light on listed species for which artificial light has been demonstrated to affect behaviour, survivorship or reproduction.</td><td colspan="2">CM010: An Artificial Light Management Plan will be developed in alignment with the National Light Pollution Guidelines (CoA 2020).</td></tr>
<tr><td colspan="4">Summary of impact assessment</td><td>Consequence level</td></tr>
<tr><td colspan="4">The impacts on seabirds and shorebirds from Emissions - Light include:
• Behavioural disturbance to migratory or nocturnally active birds due to light emissions is expected to be localised (e.g. up to 5 km) and temporary (~5 years project life) 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 is not predicted to occur over any island or mainland coastal areas.</td><td>Minor</td></tr>
<tr><td colspan="5">Statement of acceptability</td></tr>
<tr><td colspan="5">Based on an assessment against the defined acceptable levels, the impacts on seabirds and shorebirds from Emissions - Light is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO5: Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.
• EPO7: Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population.
• EPO10: Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species.</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="9">Fish</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td colspan="4">With respect to Emissions - Light, the Amulet Development will not result in significant impacts to fish identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
• substantially modify, destroy or isolate an area of important habitat for a migratory species.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in ambient light assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in ambient light assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in ambient light assessment (above)</td></tr>
<tr><td rowspan="3">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions - Light from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
None of the Recovery Plans / Conservation Advices light as a key threat for fish species (Section 2.2.1)
With respect to potential impacts to fish from Emissions - Light, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>National Light Pollution Guidelines (CoA 2020)</td><td>The aim of the Guidelines is that artificial light will be managed so wildlife is:
• Not disrupted within, nor displaced from, important habitat
• Able to undertake critical behaviours such as foraging, reproduction and dispersal.
The Guidelines recommend:</td><td>Environmental impact assessment for light emissions on fish has been completed in this OPP (Section 7.1.3.3.2).
Adoption of the following control measures:
CM010: An Artificial Light Management Plan will be developed in alignment with the National Light Pollution Guidelines (CoA 2020).</td></tr>
</table>

Receptor	Demonstration of Acceptability				
			• Always using best practice lighting design to reduce light pollution and minimise the effect on wildlife. • Undertaking an environmental impact assessment for effects of artificial light on listed species for which artificial light has been demonstrated to affect behaviour, survivorship or reproduction.		
	Summary of impact assessment				**Consequence level**
	The impacts on *fish* from Emissions - Light include: • No significant benthic habitat occurs within the immediate vicinity of the Amulet Development; therefore it is not expected that aggregation of adults or abundant fish spawning would occur in the area. • Behavioural disturbance to fish is expected to occur only within the immediate vicinity of the facilities and be temporary due to the relatively short project life (~5 years) of the Amulet Development.				Minor
	Statement of acceptability				
	Based on an assessment against the defined acceptable levels, the impacts on *fish* from Emissions - Light is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. • **EPO8:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. • **EPO10:** Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species**.**				
	Acceptable level of impact				

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="8">Marine reptiles</td><td colspan="4">With respect to Emissions - Light, the Amulet Development will not result in significant impacts to marine reptiles identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in ambient light assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in ambient light assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in ambient light assessment (above)</td></tr>
<tr><td rowspan="3">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions - Light from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to marine reptiles from Emissions - Light, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>National Light Pollution Guidelines (CoA 2020)</td><td>The aim of the Guidelines is that artificial light will be managed so wildlife is:
• Not disrupted within, nor displaced from, important habitat
• Able to undertake critical behaviours such as foraging, reproduction and dispersal.
The Guidelines recommend:
• Always using best practice lighting design to reduce light pollution and minimise the effect on wildlife.</td><td>Environmental impact assessment for light emissions on marine reptiles has been completed in this OPP (Section 7.1.3.3.2).
Cumulative environmental impact assessment for light emissions on marine reptiles has been completed in this OPP (Section 8).
Adoption of the following control measures:
CM010: An Artificial Light Management Plan will be developed in alignment with the National Light Pollution Guidelines (CoA 2020).</td></tr>
</table>

Receptor	Demonstration of Acceptability			
			• Undertaking an environmental impact assessment for effects of artificial light on listed species for which artificial light has been demonstrated to affect behaviour, survivorship or reproduction.	
		Recovery plan for Marine Turtles in Australia (CoA 2017)	Identifies light pollution as a threat. Action Area A8 (minimise light pollution) relevant management 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	
	Summary of impact assessment			**Consequence level**
	The impacts on *marine reptiles* from Emissions - Light include: • The maximum distances of the potential impact area for artificial light emissions from the Amulet Development is ~12.6 km for the life of the project. This potential impact area does not intersect any island or mainland coastal areas. As such, no adverse impacts the nesting of adult turtles, or the orientation cues for emerging hatchlings, is predicted to occur.			Minor
	Statement of acceptability			
	Based on an assessment against the defined acceptable levels, the impacts on *marine reptiles* from Emissions - Light is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above			

Receptor	Demonstration of Acceptability
	• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. • **EPO6:** Undertake the Amulet Development in a manner that will not result in the displacement of marine turtles from important foraging habitat or from habitat critical during nesting and internesting periods. • **EPO9:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. • **EPO10:** Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-21.

Table 7-21 Summary of Impact Assessment for Emission – Light

<table>
<tr><th>Receptor</th><th>Impacts</th><th>EPOs</th><th>Adopted Control Measures</th><th>Consequence</th></tr>
<tr><td>Ambient light</td><td>Change in ambient light</td><td>EPO4: Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td><td rowspan="4">CM09: Lighting will be sufficient for navigational, safety and emergency requirements (e.g. requirements contained in AMSA Marine Order Part 30 and Facility Safety Cases).

CM010: An Artificial Light Management Plan will be developed in alignment with the National Light Pollution Guidelines (CoA 2020).</td><td>Minor</td></tr>
<tr><td>Seabirds and shorebirds</td><td rowspan="3">Change in fauna behaviour</td><td rowspan="3">EPO5: Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

EPO6: Undertake the Amulet Development in a manner that will not result in the displacement of marine turtles from important foraging habitat or from habitat critical during nesting and internesting periods.

EPO7: Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population.

EPO8: Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.

EPO9: Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.

EPO10: Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species.</td><td>Minor</td></tr>
<tr><td>Fish</td><td>Minor</td></tr>
<tr><td>Marine Reptiles</td><td>Minor</td></tr>
</table>

7.1.4 Emissions – Atmospheric Emissions

Atmospheric emissions produced during the Amulet Development can be classified into two categories:

- atmospheric pollutants (non-greenhouse gas emissions)
- greenhouse gas (GHG) 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}).

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 Amulet 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 reservoirs are expected to produce associated gas at a ratio of gas to oil of approximately 65 standard cubic feet per storage tank barrel of oil produced. This associated gas will be used as much as practical in supporting the operation as fuel gas, with the excess 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 of gas may also occur on board the FSO during storage and offloading activities, via routing of accumulated gas in the storage tanks to onboard vents.

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 Amulet 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 Amulet 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.

7.1.4.2 Atmospheric Pollutant Emissions – Modelling and Exposure Assessment

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, *National Greenhouse and Energy Reporting (Measurement) Determination 2008* for greenhouse gases and emissions factors 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 BP (2013) for an offshore oil and gas production facility with comparable emissions characteristics to the Amulet development. NO_x is considered the primary pollutant of interest due to the large volume of pollutant emitted compared to other pollutants for the Amulet Development. The NEPM Ambient Air Quality Measures relevant to NO_x emissions state an annual maximum concentration exposure standard of 56 µg/m^3 and a maximum one-hour concentration of 226 µg/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 µg/m^3 annual mean.

The BP study considered the WHO guideline and demonstrated no exceedances of NOx criteria. Similarly, no exceedance of NOx criteria is expected from Amulet.

The BP study shows a maximum one-hour ground level concentration increase NOx concentrations up to approximately 10% of the NEPM criteria during upset conditions within 2km of the facility. Amulet NOx emissions will be one quarter of the BP emissions rate as such no exceedances of short-term criteria are expected. Far field long term modelling shows that within 40 km of the source background annual average NO_x levels are increased by approximately 0.1 µg/m^3. This represents an increase of 2% over typical background levels and well below NOx criteria. Levels in the immediate vicinity of the facility may increase by up an annual average of up to 0.3 µg/m³ NOx.

The volume of atmospheric pollutants emitted from the facilities noted in BP study is comparable to those from the Amulet Development. Given the nature and scale of these emissions it is considered appropriate to use this study to predict atmospheric pollutant NO_x emission attenuation of the aggregated emissions from the MOPU, MODU, FSO and support vessels.

7.1.4.3 Greenhouse Gas Emissions – Modelling and Exposure Assessment

The assessment of greenhouse gas (GHG) emissions from the Amulet Development requires the evaluation of direct GHG emissions, and indirect GHG emissions from third party consumption of Amulet light crude oil. This assessment includes the contribution to global GHG emissions and the potential impacts of climate change on sensitive receptors, including matters of national environmental significance, within Australian jurisdictions.

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 1.

The direct (Scope 1) and indirect (Scope 2 and 3) GHG emissions have been calculated for the Amulet 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 2020b). 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 Amulet Development. This Commonwealth guidance has been used as the basis for the calculation of GHG emissions from the Amulet 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.

7.1.4.3.1 Direct Emissions – 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 North West Shelf (i.e. Macedon, Gorgon, Vincent and Greater Enfield), Amulet 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 will not be emitted by the Amulet 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 Amulet Greenhouse Gas Assessment Report details the calculation methodology, calculation inputs and results of greenhouse gas estimates for the Amulet Development (Xodus Group 2020b, Appendix C).

Results from the study are summarised in Table 7-22 which provides the calculation of direct GHG emissions (Scope 1) for the life of the Amulet Development including all phases of development described in Section 3.

Table 7-22 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	100,475	96	819	101,390
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	1,143	0	10	1,153
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	75,061	21,446	804	104,264
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	Diesel oil	100,003	130	286	100,432
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	Diesel oil	42,513	61	122	42,695
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	Oil Throughput	Fixed Roof Tank Offshore Oil Production		14,744		14,744

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
	Average Emission Factors Approach						
Approximate Total Direct Emissions							**400,500 (0.4 MT CO2-e)**

Assumptions:

- *Assumed four and a half years of production for P10 outcome.*
- *Flaring emissions assumed to be P10 reservoir outcome.*
- *Flaring reduced by 0.5 MMscf/d month 1-21 due to fuel gas use. 0.1 MMscf/d flare purge maintained for rest of field life.*
- *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)*

The calculated direct (Scope 1) emissions from the Amulet Development total 0.4 MT CO_2-e for the total field life of all phases of the project, with the most optimistic reservoir outcome (P10) assuming four and a half 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 (i.e. most optimistic) estimate reservoir outcome (P10) is 0.11 MT CO_2-e/year for the first year, falling to 0.07 T CO_2-e/year in the second year of operation, and further reduction beyond. Annual Scope 1 emissions from the Amulet Development comprise 0.001% of global annual CO_2-e emissions (for the year 2017; UN Environment 2018)

Figure 7-10 shows the breakdown of GHG emissions by project phase for the Amulet Development.

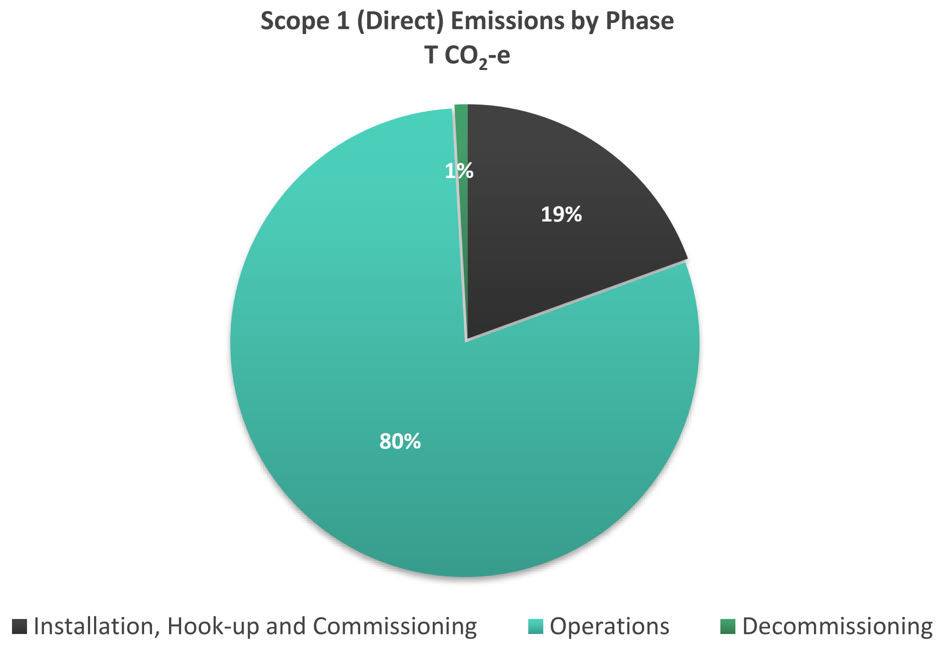


Figure 7-10 Direct (Scope 1) Emissions Calculations by Amulet Development Phase

As the operations phase presents the largest source of GHG emissions (0.30 MT CO_2-e), Figure 7-11 shows the breakdown of emissions by source. The greatest contributor is from flaring, which comprises 32% of GHG emissions during the operations phase (0.10 MT CO_2-e).

Peak operational flaring (1.2 MMscf/d) will only occur within the first 6-9 months of operation, and continuing to decrease below this as the reservoir continues to deplete and flaring rates reduces further.

KATO undertook a robust assessment to identify all feasible alternatives for the Amulet Development gas strategy, as it was recognised as a key project risk. Section 4.3.1 shows that the only viable option to develop the Amulet resource is to flare the excess associated gas (after fuel gas usage). All other feasible alternatives options show an analogous or worse environmental outcome – the infrastructure-heavy alternatives (Export, Gas to wire) show a worse environmental outcome due to significant additional seabed and ground disturbance and support activities; and/or introduce new risks (Reinject gas, hot tap). These options have a worse lifecycle outcome as these gas components are not re-usable. Due to the relatively small volumes of gas and short project life, there is no market for the resource.

KATO's strategy is to develop discovered 'stranded' oil by utilising the relocatable honeybee production system. This oil would otherwise be unable to be developed. The oil from these fields include small volumes of associated gas, which are too small to effectively get to market using current technology. Notwithstanding, KATO will monitor their development and production plans, and coincident with the technology of the time, endeavour to meet the Zero Routine Flaring by 2030 for our developments. KATO will maximise the use of the associated gas within their facilities, aligned with the intent to not waste the gas resource whilst enabling the utilisation of the 'stranded' oil resource.

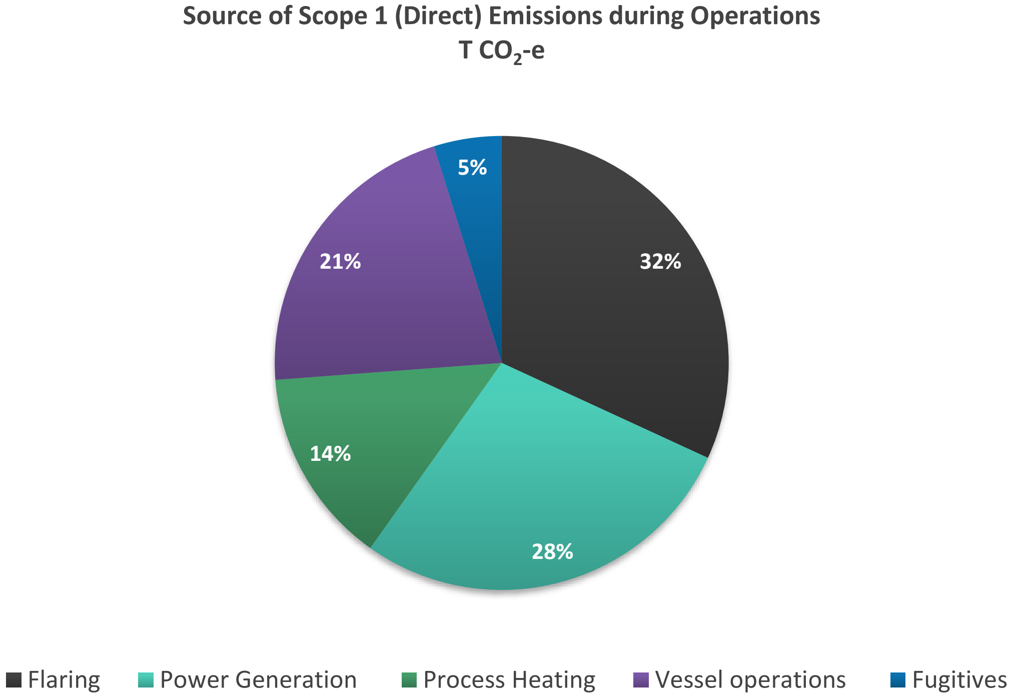


Figure 7-11 Source of Direct (Scope 1) Emissions during Operations Phase

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 7-23 provides a comparison between Amulet Development direct (Scope 1) emissions against the total GHG inventory for WA and Australia.

Table 7-23 Comparison of Amulet 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 Amulet Development*	0.13%	0.02%
Maximum emissions of total field life of Amulet Development#	0.46%	0.07%
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)*		

7.1.4.3.2 Indirect Emissions – Scope 2

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 Amulet Development, as KATO will not purchase power from an external provider, instead generating all its power requirements directly.

7.1.4.3.3 Indirect Emissions – Scope 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 2020b).

Scope 3 emissions are indirect GHG emissions, other than Scope 2 emissions, that are generated in the wider economy. They occur as a result of the activities of a facility, but from sources not owned or controlled by that facility's business. Relevant to Amulet, this is the transportation of exported oil, and the subsequent burning of that oil for energy by the customer.

A large portion of Australia’s crude oil production is exported into Asia-Pacific, mainly to Thailand, followed by Singapore and the People’s Republic of China. These key trading partners for oil have commitments under the Paris Agreement Nationally Determined Contributions. At this early project phase, KATO do not yet have sales agreements for the Amulet (or Corowa) oil; however, Amulet oil will most likely be exported into the Asia Pacific region.

Scope 3 greenhouse gas emissions are not reported under the NGER Scheme but have been estimated using Australia's National Greenhouse Accounts. For Amulet, oil will most likely be exported to international markets.

Table 7-24 provides the calculation of indirect GHG emissions (Scope 3) for the life of the Amulet 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 5.7 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 Amulet Development has been estimated to emit 3.8 g CO_2-e/MJ of product, or 20 kg CO_2-e/stb.

Table 7-24 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	NGA Factors – July 2018: Crude oil transport	Oil Throughput	Crude oil transport	1,554
Oil Refining	NGA Factors – July 2018: Crude oil refining	Oil Throughput	Crude oil refining	1,518
Oil Storage	NGA Factors – July 2018: Crude oil refining	Oil Throughput	Fixed roof tank	267
Consumer Use	NGA Factors – July 2018: Appendix 4 Scope 3 emission factors	Oil Throughput	Crude oil including crude oil condensates	5,656,998
TOTAL Indirect (Scope 3) Emissions				**5,660,339 (5.7 MT CO_2-e)**
Assumptions:				

Emissions Source	Calculation			GHG Emissions for Project Life
Activity	Estimation Methodology	Inputs	Emission Factor Used	Total (t CO_2-e)
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.).				

7.1.4.3.4 Total Emissions

The total emissions (Scope 1 and Scope 3) for the Amulet Development are calculated as 6.1 MT CO_2-e; shown in Table 7-25. Of this total, 93% are indirect (Scope 3).

Table 7-25 Summary of Total GHG Emissions

GHG Emissions Scope	Total Project life MT CO_2-e
Scope 1	0.4
Scope 2	0
Scope 3	5.7
Total	6.1
Assumptions: *# <4.5 years for high estimate (P10 profile)* *^ Source: National Inventory Report 2017 Volume 1 (DoEE 2019c)*	

The total GHG emissions from both direct (Scope 1) and indirect (Scope 3) for the whole project life of the Amulet Development is equivalent to 0.011% of global annual CO_2-e emissions in 2017 (for the year 2017; UN Environment 2018).

Amulet's total recoverable oil is equivalent to 0.03% – 0.04% of annual global oil production (best and high estimate respectively; US Energy Information Administration 2019).

7.1.4.3.5 GHG Benchmarking

GHG intensity is an indicator of GHG emissions released in energy consumption for production of the product, energy consumption, transport and emissions released from the production process. This indicator principally combines:

- Scope 1 (all direct GHG emissions)
- Scope 2 (indirect GHG emissions from consumption of purchased electricity, heat or steam); which is not relevant for the Amulet Development (OECD 2020).

The unit of measure is tonnes CO_2-e/normalisation factor; which for Amulet, barrel of oil equivalent (boe) of production has been used.

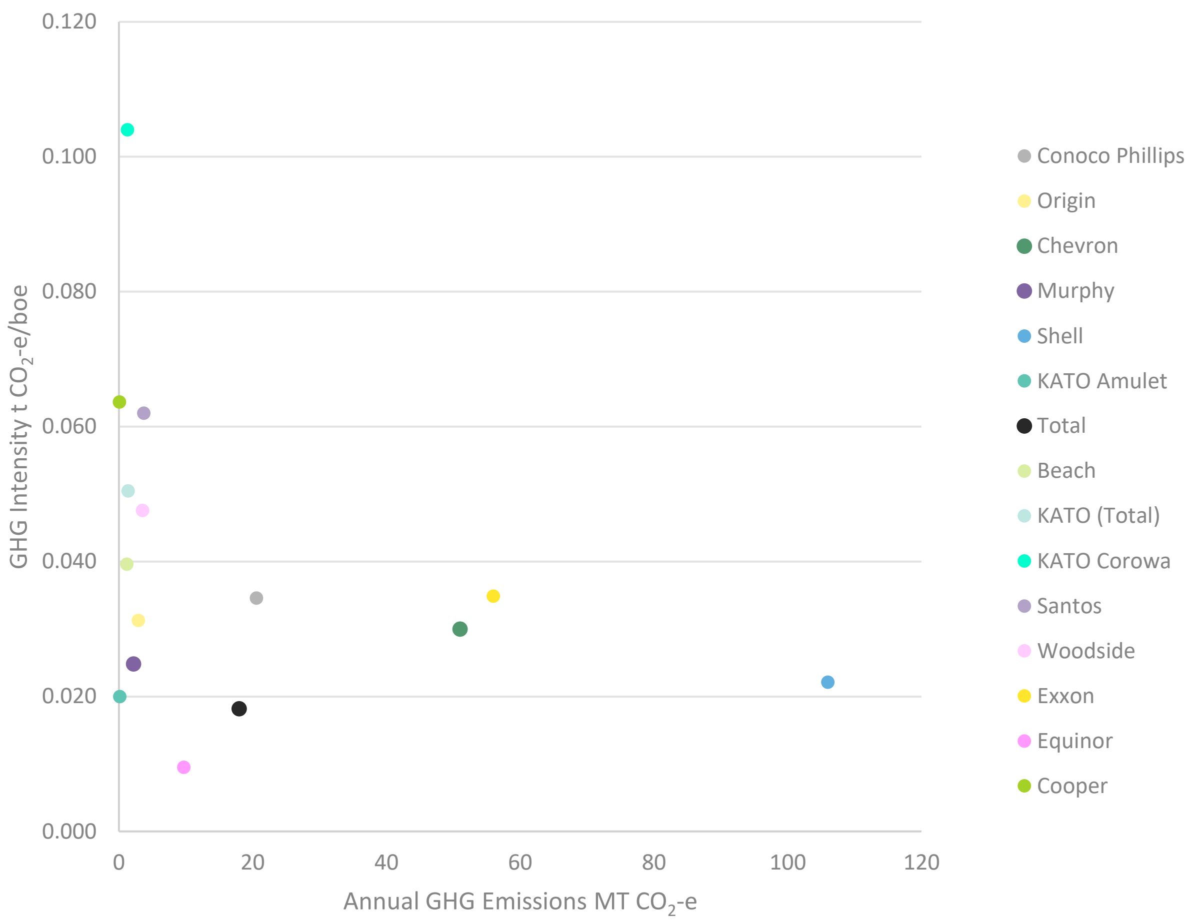
KATO undertook a benchmarking exercise of GHG intensity and annual GHG emissions of upstream oil and gas production (for the years 2017 or 2018), using publicly available data for total upstream oil and gas emissions, for operators who are active in Australia. All data was sourced from publicly available information in company annual reports, sustainability reports, climate change reports, or published in response to the CDP's Climate Change Questionnaire, which is a global voluntary disclosure of emissions data by publicly traded companies. Links to these published reports can be found in the References section (Beach Energy 2019; Chevron 2018; ConocoPhillips 2018; Cooper Energy 2019a; Cooper Energy 2019b; Equinor 2019; ExxonMobil 2019; Murphy Oil 2017; Origin 2019; Shell 2019; Santos 2019; Total 2019; Woodside 2019).

Figure 7-12 shows the total annual Scope 1 and 2 GHG emissions for the whole global upstream portfolio of each operator (i.e. the Shell data includes both international and Australian developments); whereas the smaller companies which only have Australian operations (e.g. Origin) only includes Australian emissions data. Note that 'upstream' production refers to the process of constructing, operating and decommissioning the facilities required to extract and transport hydrocarbons, including processing to a saleable product. For example, a gas facility includes producing the gas and processing it into LNG in an LNG plant prior to export; and an oil facility includes stabilising crude oil on an FPSO prior to export. For companies with significant construction and limited production in the benchmarked year, GHG intensity may be higher than in subsequent years (e.g. Cooper in 2018).

The GHG intensity (y axis of Figure 7-12) was either provided directly in the above reports; or was calculated by dividing total upstream GHG emissions by total upstream hydrocarbons production (which were sourced from the publicly available data). If different units were used, data was converted to boe.

The Amulet Development has a relatively low GHG intensity of 0.02 t CO2-e/boe, due to a relatively low GOR (64 scf/bbl); and has low annual GHG emissions (0.1 MT CO2-e/year). Figure 7-12 shows that KATO's portfolio (currently the Corowa and Amulet Developments) benchmarks at average upstream oil and gas GHG intensity of the small players in Australia on a CO_2-e/boe basis and is in line with the estimated average GHG intensity of global upstream oil (~0.055 t CO_2-e/boe) for 2015 (Masnadi et al. 2018). Amulet has a below average GHG intensity.

The accumulated total project GHG emissions for Amulet is relatively low in comparison to other benchmarked oil and gas producers. This is primarily due to the short-term nature of the project and the small total volume of associated gas; and the low GHG intensity. In addition, Figure 7-12 uses the worst-case first year of annual GHG emissions for Amulet (P10), which decreases significantly in subsequent years of production.



Source: Beach Energy Ltd 2019; Chevron 2018; ConocoPhillips 2018; Cooper Energy 2019a; Cooper Energy 2019b; Equinor 2019; ExxonMobil 2019; Murphy Oil 2017; Origin 2019; Santos 2019; Shell 2019; Total 2019; Woodside 2019.

Figure 7-12 GHG Intensity and GHG annual emission (2017or2018) benchmarking of upstream oil and gas production

Woodside's proposed Scarborough Development has undergone the OPP approval process just prior to the Amulet Development. For comparison, Scarborough will have annual Scope 1 emissions of 0.47 MT CO_2-e, and an averaged annual total emissions (Scope 1 + Scope 3) of 28.4 MT CO_2-e (Woodside 2020).

Total emissions for the whole Scarborough Development project life are 878.02 MT CO_2-e, compared to 6.1 MT CO_2-e for Amulet. The Scarborough Development has a much longer project life and involves downstream processing and reservoir CO_2 venting, but it does provide some perspective of the relatively minor nature of the Amulet Development emissions.

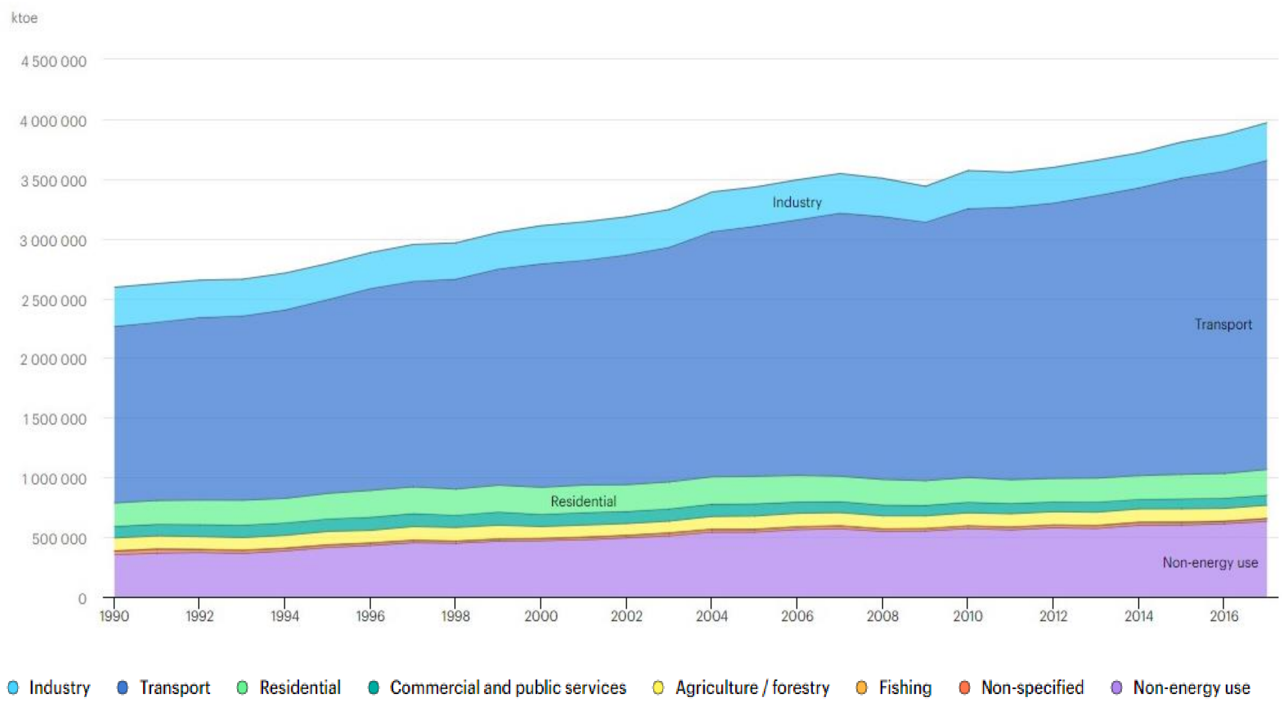
7.1.4.3.6 Oil Demand

According to the International Energy Agency Sustainable Development Scenarios, oil plays a major role in the energy mix for a sustainable energy future, and provides the main source of energy for transport for the foreseeable future. Two global energy study references were reviewed to identify the role of oil in a sustainable energy future meeting the requirements of the Paris Agreement. These studies were the International Energy Agency (IEA) World Energy Outlook, including the Sustainable Development Scenario (SDS) (IEA 2019a) and the BP Energy Outlook including the Rapid Transition Scenario (BP 2020).

The World Energy Outlook series is a leading source of strategic insight on the future of energy and energy-related emissions, providing detailed scenarios that map out the consequences of different energy policy and investment choices. The World Energy Outlook 2019 sets out a number of pathways that represent climate, energy access and air quality goals while maintaining a strong focus on the reliability and affordability of energy for a growing global population (IEA 2019a).

The IEA's Sustainable Development Scenario (SDS) outlines a major transformation of the global energy system, mapping an energy transition that delivers the objectives of the Paris Agreement. The scenario indicates the majority of emissions reductions required to meet the Paris Agreement will be achieved through a doubling in electrification, investment in renewable energy for grid connected consumers, carbon capture and storage and efficiency gains (IEA 2019a). The Stated Policies Scenario is the IEA's scenario for current stated policies and aims to provide a view on the gap between current policy and the SDS.

The IEA has highlighted the role that oil plays in providing an energy source for transport now and for the future 20 years. The IEA notes the difficulty in achieving CO_2 reductions in this area and the limited ability to switch from oil as the primary fuel to meet these demands. Currently oil is the main source of fuel for the transport industry. Energy for transport is the key source of oil demand in the world (Figure 7-13).

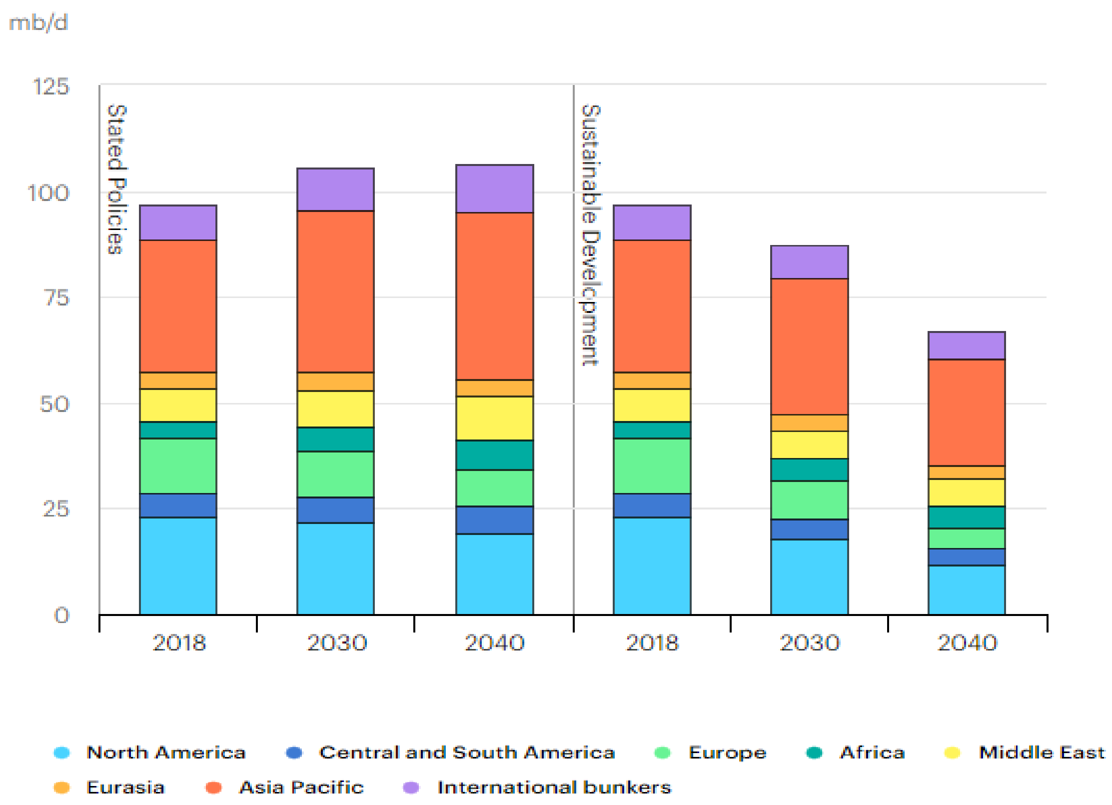


Source: IEA 2019b

Figure 7-13 Oil Products final consumption by sector, World 1990 – 2017

In all scenarios including the SDS oil remains the predominant source of energy for transport. Oil demand grows significantly in the Stated Policies Scenario (which reflects the impacts of existing policy frameworks) and is reduced by ~25% in the SDS (Figure 7-14). In all scenarios, oil demand for long-distance freight, shipping and aviation, and petrochemicals continues to grow. While there is a significant reduction in demand from passenger car use due to fuel switching and increased efficiency.

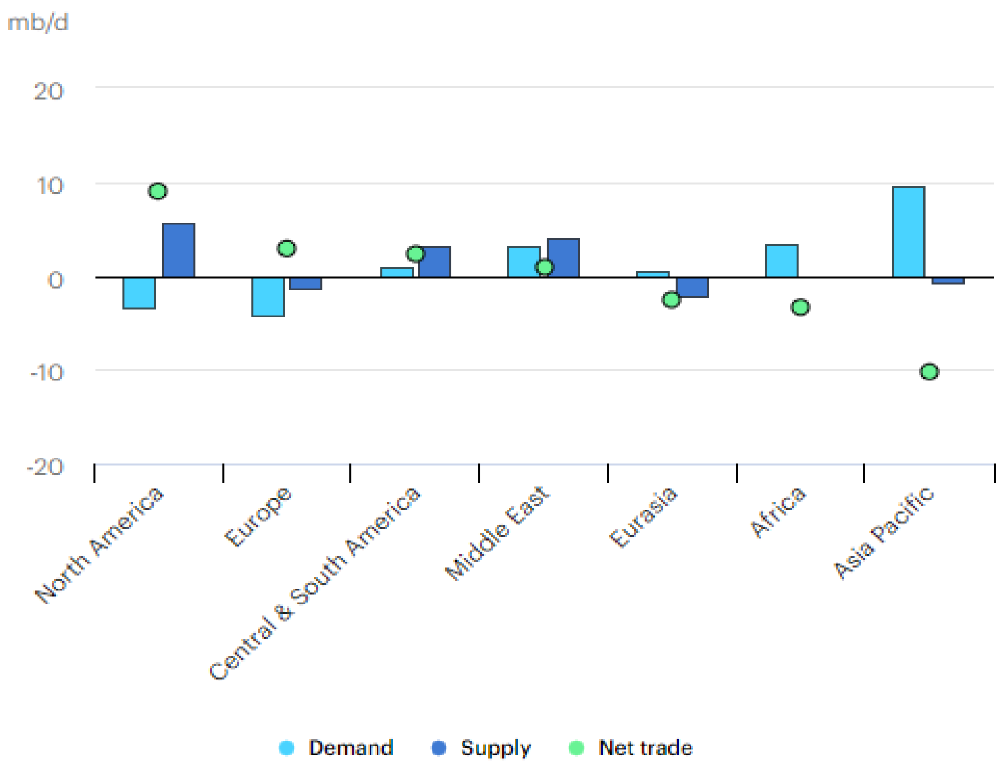
In the Stated Policies Scenario for oil, demand growth is robust to 2025, but growth slows to a crawl thereafter and demand reaches 106 Mb/d in 2040. In the SDS, the scale, scope and speed of changes in the energy landscape means that demand soon peaks and drops to under 67 Mb/d in 2040 (IEA 2019b).



Source: IEA 2019b

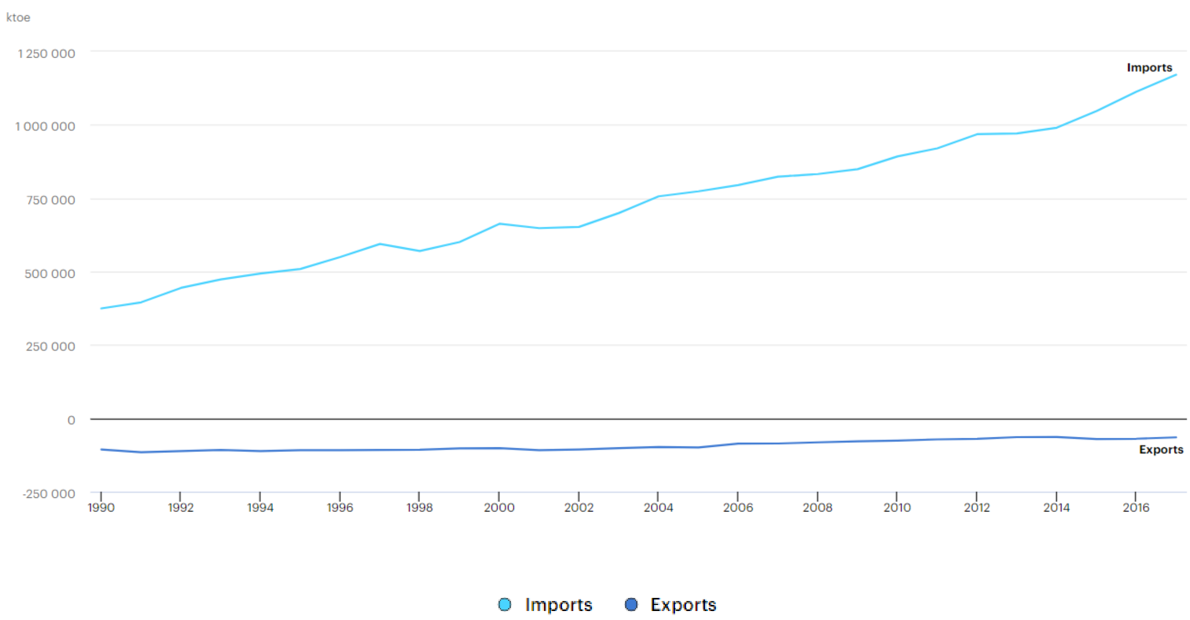
Figure 7-14 Oil production and demand by region and scenario, 2018-2040

Under the Stated Policies Scenario, the Asia Pacific region is predicted to take an increasing share of global imports, increasing towards 2040 (Figure 7-16). Demand predicted to increase to 9 million barrels (Mb)/day, and supply at -1 Mb/day (Figure 7-15; IEA 2019c). Therefore, the Asia Pacific region is expected to be a net importer of oil. To meet this continued demand for oil, significant investment is required in existing and new projects to meet the demands for transport fuels.



Source: IEA 2019c

Figure 7-15 Change in oil demand, supply and net trade position in the Stated Policies Scenario, 2018-2040



Source: IEA 2019c

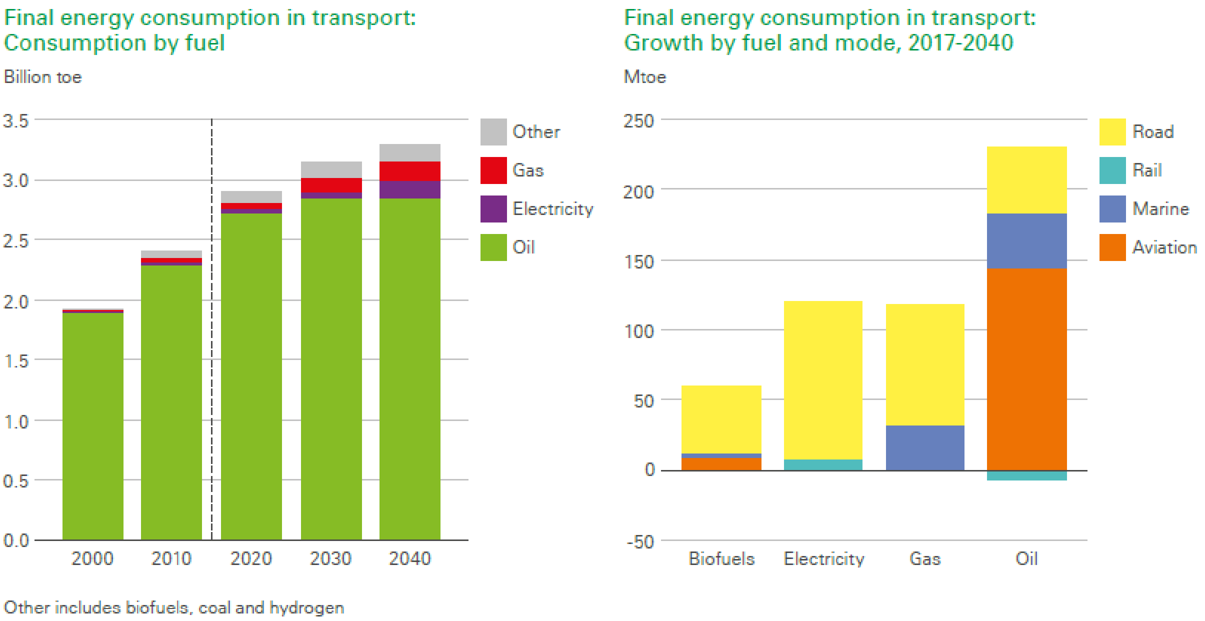
Figure 7-16 Asia Pacific Oil Imports vs Exports

At this early project phase, KATO do not yet have any sales agreements for the Amulet (or Corowa) oil. However, the Amulet Development will most likely supply oil products largely into the Asia Pacific region. Interpretation of IEA data suggests the product split would be >50% for transport, and the remainder spread between non-combusted (including petrochemicals), building, industry and power (IEA 2019a).

The BP Energy Outlook (BP 2019) provides an industry view to the expected energy demands of the future mapped against the IEA and other scenarios including the SDS. It predicts that the non-combusted use of oil, gas and coal (e.g. as feedstocks for petrochemicals, lubricants and bitumen) will grow; with the use of oil as a feedstock comprising the largest source of oil demand growth over the study (7 Mb/d). Allowing for assumed tighter restrictions on single-use plastics in the future, the non-combusted use of oil accounts for around 18% of total liquids consumption by 2040.

The GHG emissions estimated for the Amulet Development have assumed that 100% of oil sold will be combusted; which is a very conservative approach, given the BP study predicts oil used as feedstock in manufacturing will account for the largest growth in oil demand.

In alignment with the IEA study (IEA 2019a), the BP Energy Outlook also predicts that the transport sector continues to be dominated by oil, despite increasing penetration of alternative fuels (particularly electricity and natural gas). The share of oil within the transport sector is predicted to decline by 2040 (from 94% to 85%) (Figure 7-17). Oil used in transport increases 4 Mb/d, with the majority of that demand stemming from increased use in aviation and marine, rather than road transportation (BP 2019).



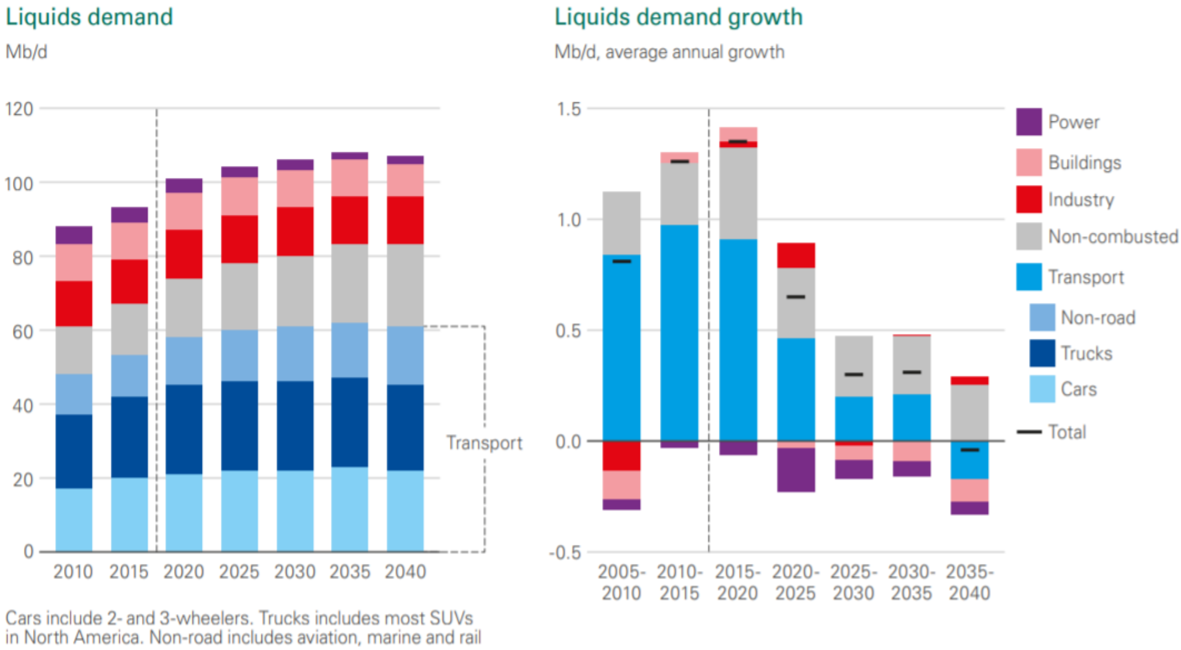
Source: BP 2019

Figure 7-17 Fuel consumption by fuel and mode for transportation: 2000-2040

The demand for liquid fuels is predicted to continue to be dominated by the transport sector, with its share of liquids consumption remaining around 55% (Figure X; BP 2019). The BP study aligns with the IEA analysis indicating the main source of oil demand is the transport sector, an area where electrification and the further material efficiency gains are difficult to achieve:

> *'The demand for liquid fuels increases from 56 Mb/d to 61 Mb/d by 2040, with this expansion split between road (2 Mb/d) (divided broadly equally between cars, trucks, and 2/3 wheelers) and aviation/marine (3 Mb/d).'*

Transport demand is predicted to plateau, as energy efficiencies increase, and alternative fuels penetrate the transport market. However, efficiency gains are limited when using oil for non-combusted purposes (i.e. feedstock). Therefore, the non-combusted use of oil overtakes transport as the largest source of demand growth by 2040 (increasing from 7 Mb/d to 22 Mb/d) (Figure 7-18).

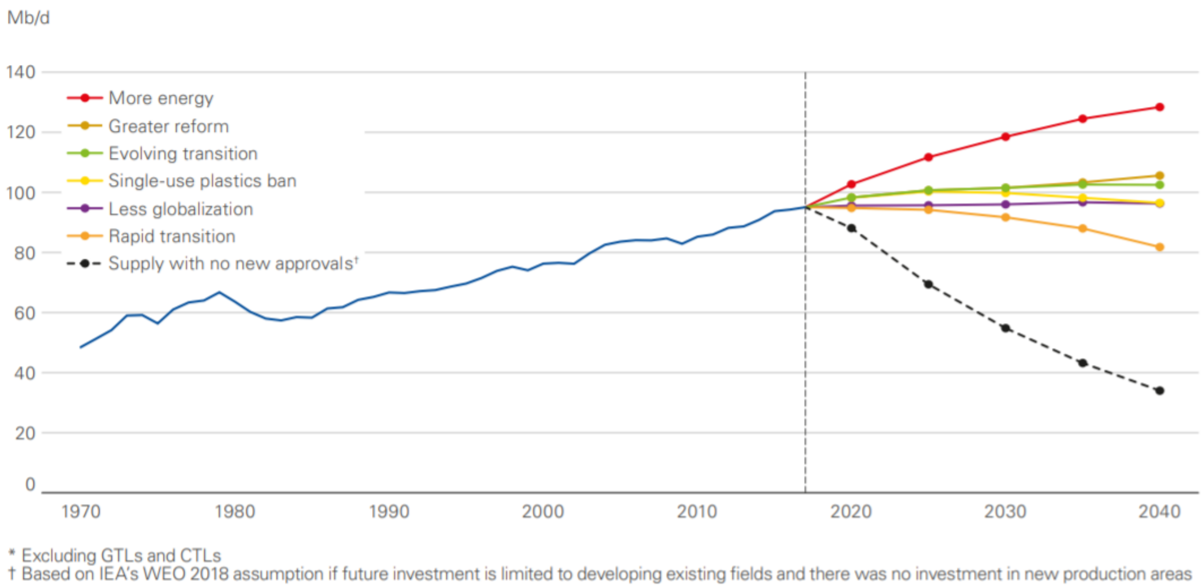


Source: BP 2019

Figure 7-18 Oil (liquids) demand, and oil (liquids) demand growth: 2010-2040

The BP Energy Outlook study concludes the following regarding oil (Figure 7-19; BP 2019):

> *'Although the precise outlook is uncertain, the world looks set to consume significant amounts of oil (crude plus NGLs) for several decades, requiring substantial investment.*
>
> *This year's Energy Outlook considers a range of scenarios for oil demand, with the timing of the peak in demand varying from the next few years to beyond 2040. Despite these differences, the scenarios share two common features.*
>
> *First, all the scenarios suggest that oil will continue to play a significant role in the global energy system in 2040, with the level of oil demand in 2040 ranging from around 80 Mb/d to 130 Mb/d.*
>
> *Second, significant levels of investment are required for there to be sufficient supplies of oil to meet demand in 2040. If future investment was limited to developing existing fields and there was no investment in new production areas, global production would decline at an average rate of around 4.5% p.a. (based on IEA's estimates), implying global oil supply would be only around 35 Mb/d in 2040.*
>
> *Closing the gap between this supply profile and any of the demand scenarios in the Outlook would require many trillions of dollars of investment over the next 20 years.'*



Source: BP 2019

Figure 7-19 Demand and Supply of oil to 2040

Summary

These two studies show that oil fulfils a future demand, in particular for the transportation sector, and has a place in energy transition.

KATO's development concept, the relocatable honeybee production system and short production life, provides an adaptable response to the world oil demand; without committing to large GHG emissions of large-scale, long-term megaprojects. The honeybee production system is able to exploit a local resource that would otherwise remain undeveloped, supply to the local regional market, and then relocate to the next field. KATO's strategy to develop small but prolific oil fields (i.e. Amulet) means the individual projects are of a short-term nature, so no pre-investment in long-term high volume GHG emissions typical with mega-projects.

KATO's development concept of a mobile re-usable MOPU and infrastructure means the facilities are re-cycled on subsequent fields, eliminating facility materials and fabrication emissions for the future fields. The concept also avoids significant embodied emissions of large-scale infrastructure (i.e. long trunklines, shore crossings, onshore processing facilities).

Furthermore, KATO's strategy is to develop discovered 'stranded' oil, making effective use of the already emitted GHGs associated with finding and appraising oil fields. The exploration and appraisal drilling has already been undertaken for the Amulet Development, eliminating the need for further exploration and appraisal activity and the associated impacts and risks to environmental aspects. The Talisman field has already been discovered, developed and now is abandoned. KATO have identified a remaining oil resource within this Talisman reservoir, so also do not require for further exploration and appraisal activity and the associated impacts and risks to environmental aspects.

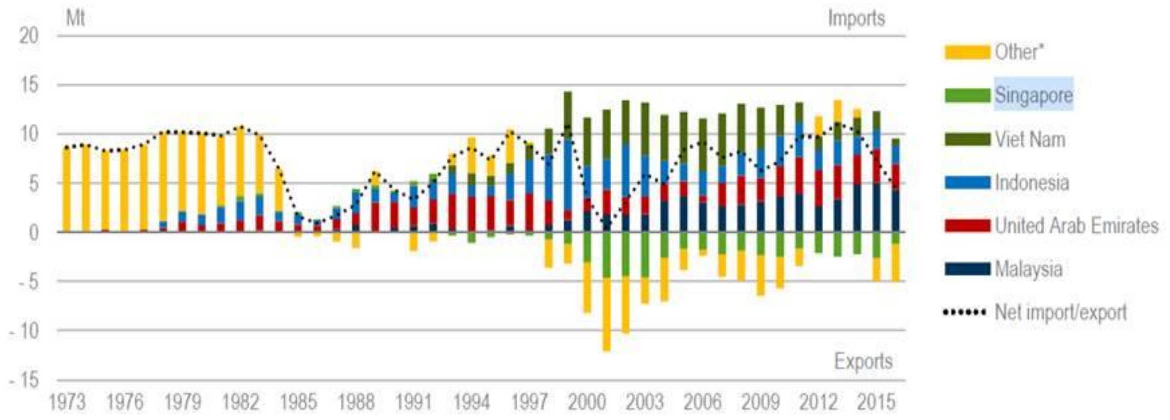
KATO notes that the Asia Pacific Region including Australia is oil deficient in terms of supply and imports and it is predicted for this trend to continue. The IEA prediction of Asia Pacific being a net importer of oil to 2040 (9 Mb/day) under the Stated Policies Scenario means that the Amulet Development helps to address this local shortfall. By supplying oil within the region, the need to import oil from the rest of the world is avoided – i.e. results in a net reduction in Scope 3 emissions from the long-distance transport of oil.

7.1.4.3.7 International Markets and Scope 3 Frameworks

The Department of Industry, Science, Energy and Resources compiles the Australian Petroleum Statistics each year. The destination of crude oil and other refinery feedstocks is shown in Table 7-29 for Australia's largest crude oil export markets for 2018-2019 (Department of Industry, Science, Energy and Resources 2020).

Australia's historical exports since 1973 are shown in Figure 7-22, showing Thailand as the main trading partner, followed by Singapore and the People's Republic of China (hereafter 'China'), which is included under 'Other'.

The emissions arising from the consumption of Amulet oil in those markets are managed under domestic and international emissions control frameworks.



Source: IEA 2017

Figure 7-20 Crude oil imports and exports by country (net), 1973-2016

*Note: *Other includes exporting countries, e.g. New Zealand and Gabon, and importing countries, e.g. China and Thailand.*

Note: Crude oil including natural gas liquids and feedstock. Data are provisional for 2016.

All likely customers for Amulet Development oil are in countries that have ratified the Paris Agreement. Under the Paris Agreement and global GHG accounting conventions, each country is responsible for accounting for reporting and reducing emissions that physically occur in its jurisdiction–i.e. the Paris Agreement is the framework which manages Scope 3 emissions associated with customer consumption of Amulet oil.

The Paris Agreement requires each signatory to put forward their best efforts through Nationally Determined Contributions (NDCs). The NDCs committed to by Australia's key trading partners for crude oil are summarised in Table 7-26, relevant to the consideration of Scope 3 emissions from Australian exports (United Nations Framework Convention on Climate Change 2020).

Table 7-26 Summary of Australian oil export trading partners' Paris Agreement Nationally Determined Contributions

Country	Volume crude oil and other refinery feedstocks imported from Australia (ML) 2018-2019 [1]	Summary of the Nationally Determined Contributions[2]
Singapore	3175	Singapore communicates that it intends to reduce its Emissions Intensity by 36% from 2005 levels by 2030 and stabilise its emissions with the aim of peaking around 2030 at 65Mt CO_2e. (Updated 1st NDC)

Country	Volume crude oil and other refinery feedstocks imported from Australia (ML) 2018-2019 [1]	Summary of the Nationally Determined Contributions[2]
Malaysia	2626.8	Malaysia intends to reduce its GHG emissions intensity of GDP by 45% by 2030 relative to the emissions intensity of GDP in 2005. This consist of 35% on an unconditional basis and a further 10% is condition upon receipt of climate finance, technology transfer and capacity building from developed countries.
Thailand	1775	An unconditional 20% reduction in emissions by 2030, compared to business-as-usual levels. This could increase to 25%, conditional upon the provision of international support. Includes section on adaptation.
China (excluding Taiwan)	1501.2	A peak in carbon dioxide emissions by 2030, with best efforts to peak earlier. China has also pledged to source 20% of its energy from low-carbon sources by 2030 and to cut emissions per unit of GDP by 60-65% of 2005 levels by 2030, potentially putting it on course to peak by 2027.
Republic of South Korea	1138.5	Korea plans to reduce its greenhouse gas emissions by 37% from the business-as-usual (BAU, 850.6 MT CO_2q) level by 2030 across all economic sectors.
Indonesia	1034.5	In 2010 the Government of Indonesia pledged to reduce emissions by 26% (41% with international support) against the business as usual scenario by 2020. Post 2020, Indonesia envisions a progression beyond its existing commitment to emission reductions. Based on the country's most recent emissions level assessment, Indonesia has set unconditional reduction target of 29% and conditional reduction target up to 41 % of the business as usual scenario by 2030.

[1]*Source: Department of Industry, Science, Energy and Resources 2020*

[2]*Source: United Nations Framework Convention on Climate Change 2020.*

7.1.4.3.8 KATO GHG Strategy

KATO are developing the Greenhouse Gas Management Plan (GHGMP; KATO 2020j). The following mitigations have been considered and proposed in hierarchy of control. These mitigations will be further evaluated during FEED, and will be reduced to ALARP during EP development, as required by the OPGGS(E)R.

Avoid – Complete avoidance of GHG emissions for KATO operations is not considered feasible. As described in Section 7.1.4.3, GHG emissions will result from all phases of the project, and from transport, distribution and consumption of KATO's hydrocarbon products.

Reduce – KATO reduce emissions to ALARP through best practice design and operation. The current design includes the following ALARP/best practice GHG mitigations:

- Redeployable mobile production facility
- Opportunity to utilise an existing facility as the mobile production facility
- Zero cold venting target
- Maximise fuel gas usage over diesel

Further design consideration are reviewed during the design process such as:

- Heat and power system integration
- Efficiency of fired equipment
- Efficiency of rotating equipment
- Operational control to maximise efficiency
- Equipment selection to minimise fugitive emissions

Further direct GHG emission optimisation will continue during the design / FEED phase.

KATO will monitor applicability of new technologies for use of excess associated gas and evaluate their feasibility for use on the Amulet Development, and other KATO projects.

Offset – KATO will comply with the requirements of the Safeguard Mechanism, including purchase of Australian Carbon Units (ACCUs) if the designated emissions baseline is exceeded, as determined by the Clean Energy Regulator.

Substitute – None identified to date (e.g. solar, hydrogen). A proportion of the associated gas is utilised as fuel gas, therefore there is no benefit to substituting this as a fuel source.

Advocate – Monitor Australia's commitments under the Paris Agreement regarding export of oil and Scope 3 emissions.

KATO is a small Australian-owned company, which will operate within Australia. It has limited capability for advocacy, and limited influence over Australian and global energy and climate change policy. KATO acknowledge Australia is committed to taking strong domestic and international action to reduce emissions and build resilience to the impacts of climate change, as documented in the 2017 Foreign Policy White Paper (CoA 2017b).

The GHGMP will include mechanisms to ensure adaptive management of these mitigations for the duration of the Amulet Development, via the EP mechanism.

7.1.4.4 Impact Analysis and Evaluation

Atmospheric emissions generated throughout the Amulet 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 Amulet 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***
<u>Injury /mortality to fauna; Change in ecosystem dynamics</u>	
Climate change is caused by the concentration of GHG emissions in the global atmosphere. 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).	
For terrestrial ecosystems, the results of climate change such as altering temperature, rainfall patterns and fire regimes, are likely to lead to changes in vegetation structure within Australia (Dunlop et al. 2012). Increases in fire regimes will impact Australian ecosystems by altering composition structure, habitat heterogeneity and ecosystem processes; for native and invasive species (Dunlop et al. 2012). Climate change could result in significant ecosystem shifts, as well as alterations to species ranges and abundances within those ecosystems (Hoegh-Guldberg et al. 2018).	

A report by Australia's Biodiversity and Climate Change Advisory Group (Steffen et al. 2009) in 2009 gives a summary of potential impacts to marine and terrestrial species, habitats and ecosystems across Australia. The impacts to taxa are and ecosystems are summarised in the tables below (as modified from Steffen et al. 2009).

Taxa	Potential impacts
Mammals	• Narrow-ranged endemics susceptible to rapid climate change in situ (Williams et al., 2003); • changes in competition between grazing macropods in tropical savannas mediated by changes in fire regimes and water availability (Ritchie and Bolitho, 2008); • herbivores affected by decreasing nutritional quality of foliage as a result of CO2 fertilisation.
Birds	• Changes in phenology of migration and egg-laying; • increased competition of resident species; • breeding of waterbirds susceptible to reduction; • top predators vulnerable to changes in food supply; • rising sea levels affecting birds that nest on sandy and muddy shores, saltmarshes, intertidal zones, coastal wetlands and low-lying islands; • saltwater intrusion into freshwater wetlands affecting breeding habitat.
Reptiles	• Warming temperatures may alter sex ratios of species with environmental sex determination to cope with warming in situ.
Amphibians	• Frogs may be the most at-risk terrestrial taxa. • Amphibians may experience altered interactions between; pathogens, predators and fires.
Fish	• Freshwater species vulnerable to reduction in water flows and water quality; limited capacity for freshwater species to migrate to new waterways; • all species susceptible to flow-on effects of warming on the phytoplankton base of food webs.
Invertebrates	• Expected to be more responsive than vertebrates due to short generation times, High reproduction rates and sensitivity to climatic variables. • Flying insects may be able to adapt by shifting ranges as long as they are not limited by host plant distributions • Nonflying species with narrow ranges are susceptible to rapid change in situ
Plants	• Climate change may impact various functional dynamics of plants such as water use efficiency, photosynthesis rates, productivity, pollination and dispersal and plant phenology due to increasing CO2, changing fire regimes and increased evaporation from soil and higher temperatures.

Source: Modified after Steffen et al 2009

Key component of environmental change	Projected impacts
Coral reefs	
CO_2 increases leading to increased ocean acidity	• Coral reefs are among the most vulnerable ecosystems to climate change. Reduction in ability of calcifying organisms, such as corals, to build and maintain skeletons.
Sea surface temperature increases leading to coral bleaching	• Extensive coral bleaching can occur when sea temperatures exceed the long-term summer maximum by 1-1.5oC for six weeks. If frequency of bleaching events exceeds recovery time,

	reefs will be maintained in an early successional state or be replaced by communities dominated by macroalgae.
Increase in cyclones and storm surges	• Increase in physical damage to reef structure
Rising sea levels	• Change in structure and composition of reefs as fast growing coral species are advantaged over slow growing species.
Oceanic systems (including planktonic systems, fisheries, sea mounts and offshore islands)	
Ocean warming	• Many marine organisms are highly sensitive to small changes in average temperature (1–2 degrees), leading to effects on growth rates, survival, dispersal, reproduction and susceptibility to disease. • Warm water assemblages may replace cold water assemblages
Changed circulation patterns, including increase in temperature stratification and decrease in mixing depth and strengthening of the East Australian Current	• Distribution and productivity of marine ecosystems is heavily influenced by the timing and location of ocean currents; currents transfer the reproductive phase of many organisms. • Climate change may suppress upwelling in some areas and increase it in others, leading to shifts in location and extent of productivity zones.
Changes in ocean chemistry	• Increasing CO2 in the atmosphere is leading to increased ocean acidity and a concomitant decrease in the availability of carbonate ions.
Alteration in cloud cover and ozone levels which alter solar radiation	• Potential negative impacts on phytoplankton production
Changes in timing of major climatic events such as El Nino	• Changes in seasonal cycles of plankton abundance
Estuaries and coastal fringe (including benthic, mangrove, saltmarsh, rocky shore and seagrass communities)	
Sea level rise	• Landward movement of some species as inundation provides suitable habitat, changes to upstream freshwater habitats will have flow-on effects to species.
Increased storm surges	• Physical damage to coastal zone including beaches and rocky shores, changes to timing and magnitude of wrack (decaying plant material) washing up on estuarine and ocean shores
Increase in water temperature	• Impacts on phytoplankton production will affect secondary production in benthic communities.
Savannas and grasslands	
Elevated CO_2	• Shifts in competitive relationships between woody and grass species due to differential responses.
Increased rainfall in north and northwest region	• Increased plant growth will lead to higher fuel loads, in turn leading to fires that are more intense, frequent and occur over large areas
Tropical rainforests	
Warming and changes in rainfall patterns	• Increased probability of fires penetrating into rainforest vegetation resulting in shift from fire-sensitive vegetation to communities dominated by fire-tolerant species.
Changes in length of dry season	• Altered patterns of flowering, fruiting and leaf flush will affect resources for animals.

Rising atmospheric CO_2	• Differential response of different growth forms to enhanced CO2 may alter structure of vegetation.
Temperate forests	
Potential increases in frequency and intensity of fires	• Changes in structure and species composition of communities with obligate seeders may be disadvantaged compared with vegetative resprouters.
Warming and changes in rainfall patterns	• Potential increases in productivity in areas where rainfall is not limiting; reduced forest cover associated with soil drying projected for some Australian forests.
Increasing atmospheric CO_2	• Overall increase in productivity and vegetation thickening
Inland waterways and wetlands	
Reductions in precipitation, increased frequency and intensity of drought	• Reduced river flows and changes in seasonality of flows • More intense rainfall events will increase flooding, affecting movements of nutrients, pollutants and sediments, riparian vegetation and erosion • Groundwater dependant ecosystems may be negatively affected
Changes in water quality, including changes in nutrient flows, sediment, oxygen and CO_2 concentration	• May affect eutrophication levels, incidence of blue-green algal outbreaks.
Sea level rise	• Saltwater intrusion into low-lying floodplains, freshwater swamps and groundwater; replacement of existing riparian vegetation by mangroves.
Arid and semi-arid regions	
Increasing CO_2 couples with drying in some regions	• Interaction between CO2 and water supply critical, as 90% of the variance in primary production can be accounted for by annual precipitation.
Shifts in seasonality or intensity of rainfall events	• Any enhanced runoff redistribution will intensify vegetation patterning and erosion cell mosaic structure in degraded areas. • Changes in rainfall variability and amount will also impacts on fire frequency. Dryland salinity could be affected by changes in the timing and intensity of rainfall.
Warming and drying leading to increased frequency and intensity of fires	• Reduction in patches of fire-sensitive mulga in spinifex grasslands potentially leading to landscape-wide dominance of spinifex.
Alpine areas	
Reduction in snow cover, depth and duration	• Potential loss of species dependent on adequate snow cover for hibernation and protection from predators; increased establishment of plant species at higher elevations as snowpack is reduced.

Source: Modified after Steffen et al 2009

Anthropogenic climate change impacts cannot be directly attributed to any one development, as they are the result of net global GHG emissions, minus GHG sinks, that have accumulated in the atmosphere since the industrial revolution. Therefore, there is no direct link between GHG emissions from the Amulet Development and climate change impacts to specific ecological receptors.

The maximum annual direct Scope 1 emissions from the Amulet Development represents 0.02% of Australia's annual GHG emissions (as reported for the year 2017; DoEE 2019c), which is a very low contribution.

Amulet 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 the Amulet Development to oil refinery products and the global oil market is a small proportion of supply. Amulet's total recoverable oil is equivalent to 0.03% – 0.04% 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 Amulet Development is equivalent to 0.011% of global annual CO_2-e emissions in 2017 (UN Environment 2018). This is a negligible contribution to 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 Amulet Development are not substantial on a national or international scale; and 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***
Change in ecosystem dynamics; Injury / mortality to fauna; Changes to the functions, interests or activities of other users 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. Anthropogenic climate change impacts cannot be directly attributed to any one development, as they are the result of net global GHG emissions, minus GHG sinks, that have accumulated in the atmosphere since the industrial revolution. Therefore, there is no direct link between GHG emissions from the Amulet Development and climate change impacts to specific ecological receptors. The proportion of the maximum annual direct GHG emissions from the Amulet Development compared to even one nation (Australia, at 0.02%) is very low. The total GHG emissions from both direct (Scope 1) and indirect (Scope 3) for the whole project life of the Amulet Development is equivalent to 0.011% of global annual CO2-e emissions in 2017 (UN Environment 2018). Amulet's total recoverable oil is equivalent to 0.03% – 0.04% of annual global oil production (best and high estimate respectively; US Energy Information Administration 2019). This is a negligible contribution to a complex, global phenomena. The duration of emissions is also relatively short term (~5 years for whole project life). Therefore, any changes to climate as a result of the GHG emissions from the whole project life of the Amulet Development are not substantial on a national or international scale; and 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. Therefore impacts to social, economic and cultural receptors have not been evaluated further.	

Impacts to receptors are assessed below, by receptor type.

7.1.4.4.1 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 Amulet 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 Amulet Development through combustion and flaring will contribute to the overall concentration of GHGs in the Earth's atmosphere. Total GHG emissions generated during the Amulet 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). Anthropogenic climate change impacts cannot be directly attributed to any one development, as they are the result of net global GHG emissions, minus GHG sinks, that have accumulated in the atmosphere since the industrial revolution. Therefore, there is no direct link between GHG emissions from the Amulet Development and climate change impacts to specific ecological receptors. Direct (Scope 1) GHG Emissions The calculated direct (Scope 1) emissions from the Amulet Development total 0.4 MT CO_2-e for the total field life of all phases of the project, with the most optimistic reservoir outcome (P10), assuming 4.5 years of operation. Direct (Scope 1) annual emissions for the best estimate reservoir outcome (P50) is 0.11 MT CO_2-e/year for the first year, falling to 0.07 MT CO_2-e/year in the second year of operation. The maximum annual direct emissions from the Amulet Development presents 0.02% of Australia's annual GHG emissions, or 0.001% of global annual CO_2-e emissions for 2017 (UN Environment 2018). This is a very small contribution, due to the small absolute volumes of GHG emissions and short duration of project life. The alternatives analysis undertaken in Section 4.3.1 shows that the only viable option to develop the Amulet resource is to flare the excess associated gas (after fuel gas usage). All other feasible alternatives options show an analogous or worse environmental outcome – from significant additional seabed and ground disturbance and support activities; and/or introduce new risks (from drilling of additional wells or a hot tap into a live pipeline). These options have a worse lifecycle outcome, as these gas strategy components are not re-usable. Flaring of excess gas for the Amulet Development comprises 32% of emissions during operations. Indirect (Scope 3) GHG Emissions Scope 3 emissions are indirect GHG emissions generated by third-parties that occur as a result of the activities of a facility, but from sources not owned or controlled by that facility's business. Relevant to

Amulet, this is the transportation of exported oil and the subsequent use of that oil by the customer, most likely in Asia. The total Scope 3 GHG emissions for the whole project life are 5.7 MT CO_2-e. Scope 3 emissions comprise 93% of the total GHG emissions for the Amulet Development.

The contribution of the Amulet Development to oil refinery products and the global oil market is a small proportion of supply. Amulet's total recoverable oil is equivalent to 0.03% – 0.04% of annual global oil production (best and high estimate respectively; US Energy Information Administration 2019).

Total GHG Emissions

The total emissions (Scope 1 and Scope 3) for the Amulet Development are calculated as 6.1 MT CO_2-e (Table 7-25), of which 93% are indirect (Scope 3). For comparison, Woodside's gas Scarborough Development is predicted to have total emissions for the whole project life of 878.02 MT CO_2-e, due to much larger production, longer project life and downstream processing and venting (Woodside 2020).

The total GHG emissions from both direct (Scope 1) and indirect (Scope 3) for the whole project life of the Amulet Development is equivalent to 0.011% of global annual CO_2-e emissions in 2017 (UN Environment 2018).

The Amulet Development has a relatively low GHG intensity of 0.02 t CO_2-e/boe, due to a relatively low GOR (64 scf/bbl) (Source: Beach Energy Ltd 2019; Chevron 2018; ConocoPhillips 2018; Cooper Energy 2019a; Cooper Energy 2019b; Equinor 2019; ExxonMobil 2019; Murphy Oil 2017; Origin 2019; Santos 2019; Shell 2019; Total 2019; Woodside 2019.

Figure 7-12). KATO undertook a benchmarking exercise of GHG intensity and annual GHG emissions of upstream oil and gas production (for the year 2018-2019), using publicly available data for total upstream oil and gas emissions, for operators who are active in Australia. Amulet has a below-average GHG intensity (compared to ~0.055 t CO_2-e).

KATO's overall portfolio (currently the Corowa and Amulet Developments) benchmarks towards the average upstream oil and gas GHG intensity of the small players in Australia on a CO_2-e/boe basis. The accumulated total GHG volume of Amulet against other operator portfolios is very low, largely due to short term project duration and small total volumes of associated gas.

According to the International Energy Agency Sustainable Development Scenarios, oil plays a major role in the energy mix for a sustainable energy future. In all scenarios, oil demand for long-distance freight, shipping and aviation, and petrochemicals continues to grow, and provides the main source of energy for the transport sector for the foreseeable future (IEA 2019; BP 2019). The Asia Pacific region has historically been, and is predicted to grow as a net importer of oil. The Amulet Development provides 'local' oil in this supply deficient market to reduce demand for the importation of oil into the Asia Pacific region – which would lead to an increase in net emissions from transportation of oil from outside the region.

The IEA (2018) notes that consideration should be made to avoiding 'lock-in' from existing infrastructure. KATO's development concept meets this requirement allowing for short term projects to meet the oil demand gap without locking in long-term emissions associated with megaprojects and coal projects. The honeybee production system allows for the economy and market to be adaptative to GHG and energy policy in the short term. The KATO development strategy of using mobile facilities designed to produce from a string of small fields, results in short production durations at each site (2-4.5 years), with small individual project GHG emission volume footprints.

Scope 3 emissions are outside the scope of relevant Commonwealth legislation (NGER Act, Safeguard Mechanism) and international agreements (targets under the Paris Agreement 2016).Summary

The contribution of annual direct GHG emissions from the Amulet Development compared to even one nation's annual emissions (0.02% of Australia's annual inventory) is very low.

The total GHG emissions from both direct (Scope 1) and indirect (Scope 3) for the whole project life of the Amulet Development is equivalent to 0.011% of global annual CO_2-e emissions in 2017 (UN Environment 2018). Amulet's total recoverable oil is equivalent to 0.03% – 0.04% of annual global oil production (best and high estimate respectively; US Energy Information Administration 2019). This is a negligible contribution to a complex, global phenomena. The time frame of emissions is also relatively short, at ~5 years for whole project life.

Therefore, any changes to climate as a result of the GHG emissions from the whole project life of the Amulet Development are not substantial on a national or international scale.

Climate change is an accumulated global GHG emission impact. As such, it is not appropriate to attribute any particular climate-related impacts to GHG emissions from the Amulet Development, due to:

- net global GHG concentrations cause climate change and climate-related impacts
- Scope 1 and Scope 3 emissions calculated for the Amulet Development are negligible in the context of existing and future predicted global GHG concentrations; due to the relatively small absolute volumes of GHG emissions, scale, small proportion of Australia's total emissions, and short duration of the development (~5 years).
- inability to precisely predict the amount of total future global GHG emissions
- inability to predict future national and international initiatives on climate change and the impact they will have on total future global GHG emissions, including Amulet emissions.

Given the details above, the consequence of atmospheric emissions causing climate change has been assessed as **Moderate (2)**, due to the relatively low accumulated volume contribution of GHGs' to the atmosphere from planned activities and the short duration of emissions, while recognising this small contribution to a global, long-term phenomena.

7.1.4.5 Consequence and Acceptability

The consequence of Emissions – Atmospheric Emissions has been evaluated as **Moderate (2)** for the worst-case receptor (climate) and is considered **acceptable** when assessed against the criteria in Table 7-30.

Table 7-30 Demonstration of Acceptability for Emissions – Atmospheric Emissions

Receptor				
Ambient Air Quality	**Acceptable level of impact**			
	With respect to Emissions - Atmospheric, the Amulet Development will not result in significant impacts to ambient air quality identified as potentially affected, defined as a possibility that it will (Section 6.6): • result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.			
	Acceptability assessment			
	Principles of ESD	The proposed EPO's for the Amulet Development are consistent with the principles of ESD. With respect to potential impacts to ambient air quality from Emissions - Atmospheric the relevant principles are: • Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. • 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.		
	Internal context	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards. With respect to potential impacts to ambient air quality from Emissions – Atmospheric, there are no specific KATO internal requirements.		
	External context	The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders. With respect to potential impacts to ambient air quality from Emissions - Atmospheric no specific concerns were raised during stakeholder consultation with relevant persons.		
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions - Atmospheric from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. With respect to potential impacts to ambient air quality from Emissions - Atmospheric this specifically includes:		
		Requirement	*Relevant Item/Objective/Action*	*Addressed/Managed by* Amulet *Development*

Receptor				
		AMSA Marine Order 97 (Marine pollution prevention — air pollution)	Sets out the requirements for the prevention of air pollution by vessels including certification requirements, reporting requirements, incineration on board a vessel, energy efficiency, servicing and record keeping.	Adoption of the following control measure: **CM11**: Compliance with AMSA Marine Order 97 (Marine pollution prevention — air pollution).
		Commonwealth *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*	Restrictions on import and use of Ozone Depleting Substances (ODS) for refrigeration and air conditioning systems	Adoption of the following control measure: **CM12**: 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*.
	Summary of impact assessment			**Consequence level**
	The impacts on air quality from Emissions - Atmospheric include: • 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, including NOx, CO, SO2, VOC's (benzene, xylenes, toluene, ethylbenzene), non-VOC's, particulate matter, CO2, N2O, CH4, SF6, HFCs and PFCs. • Released emissions will dissipate quickly through wind action. Concentrations of NO2 not expected to be above NEPM levels at any point throughout the development. • Approximately 2,000 sm3 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.			Minor
	Statement of acceptability			
	Based on an assessment against the defined acceptable levels, the impacts on air quality from Emissions - Atmospheric is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level			

<table>
<tr><th>Receptor</th><th colspan="2"></th></tr>
<tr><td></td><td colspan="2">To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
EPO12: Undertake the Amulet Development in a manner that will not result in a substantial change in air quality, which may adversely impact on biodiversity, ecological integrity, social amenity, or human health.</td></tr>
<tr><td rowspan="6">Climate</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Emissions - Atmospheric the Amulet Development will not result in significant impacts to climate as potentially affected, defined as a possibility that it will (Section 6.6):
It is important to recognise that anthropogenic climate change impacts cannot be directly attributed to any one development, as they are the result of net global GHG emissions and GHG sinks, that have accumulated in the atmosphere since the industrial revolution. Therefore it is not appropriate to attribute climate change or any particular climate-related impacts to GHG emissions from the Amulet Development.
An action is likely to have a significant impact if there is a possibility that it will:
substantially contribute to Australia’s annual GHG emissions and directly result in Australia being unable to meet its NDC target under the Paris Agreement to reduce GHG emissions by 26 to 28% below 2005 levels by 2030.
substantially contribute to global annual GHG emissions and directly result in the Paris Agreement aim to keep global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C being unable to be met.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>The proposed EPO’s for the Amulet Development are consistent with the principles of ESD.
With respect to potential impacts to climate from Emissions - Atmospheric the relevant principles are:
Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
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.</td></tr>
<tr><td>Internal context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards.
With respect to potential impacts to climate from Emissions – Atmospheric, this specifically includes:
KATO Greenhouse Gas Management Plan KAT-000-EN-PP-003 (KATO 2020j)</td></tr>
<tr><td>External context</td><td>During stakeholder consultation with relevant persons, no specific concerns were raised with respect to potentially impacted receptors from Emissions – Atmospheric.</td></tr>
</table>

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<tr><th>Receptor</th><th colspan="2"></th></tr>
<tr><td rowspan="2"></td><td></td><td>

Discussion on KATO’s proposed gas strategy for the honeybee production system, and estimated greenhouse gas emissions were held with the National Inventory Systems and International Reporting Branch of DoEE (July 2019). Feedback was:

suggested KATO confirm appropriate emissions factors were used to calculate emissions
provision of contact person within Clean Energy Regulator (CER) for detailed discussions on calculations and reporting.

Discussion on KATO’s proposed gas strategy for the honeybee production system, and estimated greenhouse gas emissions (specifically for the Amulet Development) were held with the CER (July 2019). Feedback was:

ensuring KATO understood whether Amulet and KATO as a whole triggered the values for reporting under the NGERs act and whether KATO was considered a controlling corporation for reporting purposes.
suggested future engagement to clarify further how the facility baseline would be set.

Discussion with NOPTA on KATO field development concept and status, associated gas strategy and flaring (May 2020).
Emails exchanged with the CER – NGER and CER – Safeguard Baseline Branch (May 2020) requesting clarification on how baseline will be calculated and Scope 3 emissions. Feedback was:

A calculated baseline may be applied for, to start on 1 July 2020. For a production variable, a site-specific emissions intensity can be used, or the default selected.
A calculated baseline is the sum of each of the forecast site-specific emissions intensity (or the default for a prescribed production variable) multiplied by the forecast quantity of that production variable. Each figure is using the baseline setting year for that baseline application, which will be the year of highest production of the primary production variable, depending on the date that the calculated baseline application is submitted.
Refer to the ‘Using ACCUs to offset emissions’ section of the CER’s Managing excess emissions webpage. This includes a link to further guidance to purchase ACCUs from other businesses. Purchasing greenhouse gas offsets has no bearing on the figures that are reported under the NGER scheme. Some eligible carbon units can be used to acquit excess emissions under safeguard. However, this only becomes relevant if the safeguard baseline is exceeded.
There are currently no obligations under the NGER scheme (or any scheme administered by the CER) to report and manage scope 3 emissions. There is no requirement to report scope 3 emissions now or in the future.

</td></tr>
<tr><td>Other requirements</td><td>
The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions - Atmospheric from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to climate from Emissions - Atmospheric this specifically includes:
<table>
<tr><th>Requirement</th><th>Relevant Item/Objective/Action</th><th>Addressed/Managed by Amulet Development</th></tr>
</table>
</td></tr>
</table>

Receptor				
		Paris Agreement	Australia has ratified the Paris Agreement and the Doha Amendment to the Kyoto Protocol, set a target to reduce emissions by 26-28% below 2005 levels by 2030. To date, there are 195 signatories to the Paris Agreement, including Australia's key oil export markets in the Asia Pacific region, including Singapore, China, Thailand and Indonesia. In 2017, the Government reviewed its climate policies to ensure they remain effective in achieving Australia's 2030 target and Paris Agreement commitments. The primary policy mechanisms to implement Australia's current commitments under the Paris Agreement, are the National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 (Cth) (Safeguard Mechanism) made under the National Greenhouse and Energy Reporting Act 2007 (Cth) (NGERS).	Adoption of the following control measures: **CM13**: Maximise the use of associated gas, for example, as fuel gas during operations. **CM14**: Comply with the requirements of the Safeguard Mechanism, including purchase of Australian Carbon Units (ACCUs) if designated emissions baseline is exceeded, as determined by the Clean Energy Regulator. **CM15**: Operations designed to be optimised to enable the safe and economically efficient operation of the facility. **CM16:** Develop KATO Greenhouse Gas Management Plan and identify emissions mitigation hierarchy to reduce direct GHG emissions to ALARP during EP development, including consideration of: • Avoid – as per alternatives assessment (Section 4.3.1) • Reduce – identify opportunities for reduction of emissions during FEED (i.e. heat and power generation, energy efficiencies); and monitor new technologies for use of excess associated gas and evaluate feasibility for use on the Amulet Development • Offsets – in alignment with Safeguard Mechanism • Monitor – Monitor Australia's and export countries' commitments under the Paris Agreement regarding NDCs, export of oil and Scope 3 emissions.

Receptor				
				• Mechanisms to ensure adaptive management of these measures for the duration of the Amulet Development via the EP mechanism.
		National Greenhouse and Energy Reporting (NGER) Act 2007 and National Greenhouse and Energy Reporting Regulations 2008	Provides methods and criteria for calculating greenhouse gas emissions and energy data under the NGER Act. This supports DAWE's National Greenhouse Gas Inventory Program and underpins Australian emission reduction policies including the Emission Reduction Fund, Safeguard Mechanism and Renewable Energy Target. It provides a national framework for corporations to report on greenhouse gas emissions, energy consumption and energy production data.	Used to calculate Amulet Development emissions in Section 7.1.4.1.2. Adoption of the following control measure: **CM17**: Reporting of GHG emissions are required as per the National Greenhouse and Energy Reporting (NGER) Scheme.
		National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 (Safeguard Mechanism)	Primary mechanism to implement Australia's commitments under the Paris Agreement. It is administered by the Clean Energy Regulator (CER). It was developed to ensure that emission reductions implemented through the Emissions Reduction Fund (ERF) are not offset or exceeded by significant GHG emissions (above 'business-as-usual levels') emanating from other industrial or economic sectors. The purpose of the Safeguard Mechanism has more recently been communicated to measure, report and manage greenhouse gas emissions for industrial facilities. It currently applies to direct emissions (Scope 1), including direct emissions from energy production, where a facility's emissions are above 0.1 MT CO_2-e/year. Large facilities are required to keep net emissions at or below a designated baseline emissions	Adoption of the following control measures: **CM13**: Maximise the use of associated gas, for example, as fuel gas during operations. **CM14**: Comply with the requirements of the Safeguard Mechanism, including purchase of Australian Carbon Units (ACCUs) if designated emissions baseline is exceeded, as determined by the Clean Energy Regulator. **CM15**: Operations designed to be optimised to enable the safe and economically efficient operation of the facility. **CM16:** Develop KATO Greenhouse Gas Management Plan and identify emissions mitigation hierarchy to reduce direct GHG emissions to ALARP during EP development, including consideration of: • Avoid – as per alternatives assessment (Section 4.3.1)

Receptor				
			level. Options for managing excess emissions provided by the Safeguard Mechanism include: • A 'net emissions' approach, which allows facilities to use Australian Carbon Credit Units to reduce net emissions. • A 'multi-year monitoring' approach, which allows a facility to average its net emissions over an extended two- or three-year multi-year period.	• Reduce – identify opportunities for reduction of emissions during FEED (i.e. heat and power generation, energy efficiencies); and monitor new technologies for use of excess associated gas and evaluate feasibility for use on the Amulet Development • Offsets – in alignment with Safeguard Mechanism • Monitor – Monitor Australia's and export countries' commitments under the Paris Agreement regarding NDCs, export of oil and Scope 3 emissions. • Mechanisms to ensure adaptive management of these measures for the duration of the Amulet Development via the EP mechanism.
		National Greenhouse and Energy Reporting (Measurement) Determination 2008	Provides methods and criteria for calculating greenhouse gas emissions and energy data under the NGER Act.	Used to calculate Amulet Development emissions in Section 7.1.4.1.2.
		World Bank's 'Zero Routine Flaring by 2030' initiative.	The WA government have announced they are signing up to the World Bank's 'Zero Routine Flaring by 2030' initiative. Although KATO plans to produce both Amulet and Amulet Developments prior to 2030, there is a chance that one of the fields may be still producing post-2030.	Although the Amulet Development is exclusively within Commonwealth waters and is not subject to Western Australian jurisdiction, KATO will monitor their development and production plans, and coincident with the technology of the time, endeavour to meet the Zero Routine Flaring by 2030 for both these developments.
		Production licence WA-8-L	WA-41-R requires that: *'the licensee shall continue to explore and appraise the production licence area to*	KATO have an obligation to develop the Amulet field under the title conditions of

Receptor				
			determine whether additional recoverable petroleum exists in the area and exploit such petroleum where commercially viable'	production licence WA-8-L, which is the purpose of this OPP.
		North-west Marine Parks Network Management Plan 2018 (DNP 2018)	Identifies climate change as a pressure. No relevant objectives or management actions.	Management action to continue to meet Australia's international commitments to reduce greenhouse gas emissions is addressed by adoption of the following control measures: Adoption of the following control measures: **CM13**: Maximise the use of associated gas, for example, as fuel gas during operations. **CM14**: Comply with the requirements of the Safeguard Mechanism, including purchase of Australian Carbon Units (ACCUs) if designated emissions baseline is exceeded, as determined by the Clean Energy Regulator. **CM15**: Operations designed to be optimised to enable the safe and economically efficient operation of the facility. **CM16:** Develop KATO Greenhouse Gas Management Plan and identify emissions mitigation hierarchy to reduce direct GHG emissions to ALARP during EP development, including consideration of: • Avoid – as per alternatives assessment (Section 4.3.1) • Reduce – identify opportunities for reduction of emissions during FEED (i.e. heat and power generation, energy efficiencies); and monitor new
		Conservation advice *Balaenoptera borealis* Sei Whale (TSSC 2015a)	Identifies climate and oceanographic variability and change as a key threat. No explicit relevant objectives. Management action to understand impacts of climate variability and change: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.	
		Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 2015–2025 (CoA 2015a)	Identifies climate variability and change as a key threat. No explicit relevant objectives. Management action to understand impacts of climate variability and change: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.	
		Conservation advice *Balaenoptera physalus* Fin Whale (TSSC 2015b)	Identifies climate and oceanographic variability and change as a key threat. No explicit relevant objectives. Management action to understand impacts of climate variability and change: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.	

Receptor				
		Conservation Advice for Humpback Whales (TSSC 2015c)	Identifies climate and oceanographic variability and change as a key threat. No explicit relevant objectives. Management action to understand impacts of climate variability and change: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.	technologies for use of excess associated gas and evaluate feasibility for use on the Amulet Development • Offsets – in alignment with Safeguard Mechanism • Monitor – Monitor Australia's and export countries' commitments under the Paris Agreement regarding NDCs, export of oil and Scope 3 emissions. • Mechanisms to ensure adaptive management of these measures for the duration of the Amulet Development via the EP mechanism.
		Conservation Management Plan for the Southern Right Whale (DSEWPaC 2012a)	Identifies climate variability and change as a key threat. No explicit relevant objectives. Management action to understand impacts of climate variability and change: Continue to meet Australia's international commitments to reduce greenhouse gas emissions and regulate the krill fishery in Antarctica.	
		Recovery plan for marine turtles in Australia (CoA 2017)	Identifies climate change and variability as a threat. Interim Recovery Objective 3: Anthropogenic threats are demonstrably minimised. Management action A2: Adaptively manage turtle stocks to reduce risk and build resilience to climate change and variability: • Continue to meet Australia's international commitments to address the causes of climate change. • Identify, test and implement climate-based adaptation measures	
		Conservation advice for *Dermochelys coriacea* (Leatherback Turtle) (TSSC 2009a)	Identifies climate change as a threat. No explicit relevant objectives or management actions.	

Receptor				
		Recovery plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013a)	Identifies climate change and variability as a threat. No explicit relevant objectives or management actions.	
		Conservation advice *Rhincodon typus* (Whale Shark) (TSSC 2001)	Identifies climate change as a threat. No explicit relevant objectives or management actions.	
		Conservation advice *Calidris canutus* (Red Knot) (TSSC 2016a)	Identifies climate change as a threat. No explicit relevant objectives or management actions.	
		National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011a)	Identifies climate change as a threat. No explicit relevant objectives. Management action A3.1: Where climate change is identified as having the potential for significant negative impacts on Australian populations of seabirds: • appropriate monitoring strategies are implemented to fill information gaps • mitigation actions are identified and adopted where feasible and appropriate.	
		Wildlife Conservation Plan for Migratory Shorebirds (DoEE 2015)	Identifies climate change as a threat. Objective 4: Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	
	Summary of impact assessment			**Consequence level**
	The impacts on climate from Emissions - Atmospheric include: • GHG emissions generated during the Amulet Development will contribute to the overall concentration of GHGs in the Earth's atmosphere. • Anthropogenic climate change impacts cannot be directly attributed to any one development, as they are the result of net global GHG emissions, minus GHG sinks, that have accumulated in the atmosphere since the industrial revolution.			Moderate

Receptor		
	Therefore, there is no direct link between GHG emissions from the Amulet Development and climate change impacts to specific ecological receptors. • The calculated direct (Scope 1) emissions from the Amulet Development total 0.4 MT CO_2-e for the total field life of all phases of the project, with the most optimistic reservoir outcome (P10), assuming 4.5 years of operation. • The maximum annual direct (Scope 1) emissions from the Amulet Development represents 0.02% of Australia's annual GHG emissions (DoEE 2019c); and 0.001% of global annual CO_2-e emissions for 2017 (UN Environment 2018). This is a very small contribution. • The Amulet Development has a relatively low GHG intensity of 0.02 t CO_2-e/boe, due to a relatively low GOR (64 scf/bbl) (Source: Beach Energy Ltd 2019; Chevron 2018; ConocoPhillips 2018; Cooper Energy 2019a; Cooper Energy 2019b; Equinor 2019; ExxonMobil 2019; Murphy Oil 2017; Origin 2019; Santos 2019; Shell 2019; Total 2019; Woodside 2019. • Figure 7-12). KATO undertook a benchmarking exercise of GHG intensity and annual GHG emissions of upstream oil and gas production for operators who are active in Australia. Amulet has a below-average GHG intensity (compared to ~0.055 t CO_2-e). • The accumulated total project GHG emissions for Amulet is relatively low in comparison to other benchmarked oil and gas producers. This is primarily due to the short-term nature of the project and the small total volume of associated gas, and low GHG intensity. • The comparative volume of Amulet against other operator portfolios is very low, largely due to short term project duration and relatively small volumes of associated gas. • The total Scope 3 GHG emissions for the whole project life are 5.7 MT CO_2-e. Amulet's total recoverable oil is equivalent to 0.03% – 0.04% of annual global oil production. The contribution of the Amulet Development to oil refinery products and the global oil market is a small proportion of supply. • Total emissions (Scope 1 and Scope 3) for the Amulet Development are 6.1 MT CO_2-e, of which 93% are indirect (Scope 3). For the for the whole project life, this is equivalent to 0.011% of global annual CO_2-e emissions in 2017. This is a very small contribution to a complex, global phenomena. • The time frame of emissions is also relatively short, at ~5 years for whole project life. Therefore, any changes to climate as a result of the GHG emissions from the whole project life of the Amulet Development are not substantial on a national or international scale. • It is not appropriate to attribute climate change or any particular climate-related impacts to GHG emissions from the Amulet Development, due to: ○ net global GHG concentrations cause climate change and climate-related impacts	

Receptor		
	- Scope 1 and Scope 3 emissions calculated for the Amulet Development are negligible in the context of existing and future predicted global GHG concentrations; due to the relatively small absolute volumes of GHG emissions, scale, small proportion of Australia's total emissions, and short duration of the development (~5 years). - inability to precisely predict the amount of total future global GHG emissions - inability to predict future national and international initiatives on climate change and the impact they will have on total future global GHG emissions, including Amulet emissions. - In addition, oil plays a major role in the energy mix for a sustainable energy future has a place in energy transition, and provides the main source of energy for the transport sector for the foreseeable future (IEA 2019; BP 2019). The Asia Pacific Region (including Australia) is oil deficient in terms of supply and imports and it is predicted for this trend to continue. The Amulet Development will help address this local shortfall. By supplying oil within the region, the need to import oil from the rest of the world is reduced – i.e. results in a net reduction in Scope 3 emissions from the long-distance transport of oil. - KATO's development concept–the relocatable honeybee production system and short production life–provides an adaptable response to the world oil demand; without committing to large GHG emissions of large-scale, long-term megaprojects. The honeybee production system is able to exploit a local resource that would otherwise remain undeveloped, supply to the local regional market, and relocate to the next field. KATO's strategy to develop small but prolific oil fields (i.e. Amulet) means the individual projects are of a short-term nature, so no pre-investment in long-term high volume GHG emissions typical with mega-projects. - Due to the short project life of the Amulet Development, there is a lesser degree of uncertainty regarding oil demand and future market, and international climate change policies. There is also less uncertainty regarding available technology for reducing emissions.	
	Statement of acceptability	
	Based on an assessment against the defined acceptable levels, the impacts on plankton from Emissions - Atmospheric is considered acceptable, given that: - the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above - the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) - the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. - the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: **EPO13**: Undertake the Amulet Development in a manner that will not significantly contribute to Australia's annual greenhouse gas emissions.	

Receptor	
	• **EPO14**: KATO will not export oil produced from the Amulet Development to countries that are not signatories to the Paris Agreement.

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">EPO12: Undertake the Amulet Development in a manner that will not result in a substantial change in air quality, which may adversely impact on biodiversity, ecological integrity, social amenity, or human health.
EPO13: Undertake the Amulet Development in a manner that will not significantly contribute to Australia's annual greenhouse gas emissions.
EPO14: KATO will not export oil produced from the Amulet Development to countries that are not signatories to the Paris Agreement.</td><td rowspan="2">CM11: Compliance with AMSA Marine Order 97 (Marine pollution prevention — air pollution).
CM12: 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.
CM13: Maximise the use of associated gas, for example, as fuel gas during operations.
CM14: Comply with the requirements of the Safeguard Mechanism, including purchase of Australian Carbon Units (ACCUs) if designated emissions baseline is exceeded, as determined by the Clean Energy Regulator.
CM15: Operations designed to be optimised to enable the safe and economically efficient operation of the facility.
CM16: Develop KATO Greenhouse Gas Management Plan and identify emissions mitigation hierarchy to reduce direct GHG emissions to ALARP during EP development, including consideration of:
• Avoid – as per alternatives assessment (Section 4.3.1)
• Reduce – identify opportunities for reduction of emissions during FEED (i.e. heat and power generation, energy efficiencies); and monitor new technologies for use of excess associated gas and evaluate feasibility for use on the Amulet Development
• Offsets – in alignment with Safeguard Mechanism
• Monitor – Monitor Australia’s and export countries’ commitments under the Paris Agreement regarding NDCs, export of oil and Scope 3 emissions.
• Mechanisms to ensure adaptive management of these measures for the duration of the Amulet Development via the EP mechanism.
CM17: Reporting of GHG emissions as per the National Greenhouse and Energy Reporting (NGER) Scheme.</td><td>Minor</td></tr>
<tr><td>Climate</td><td>Climate change</td><td>Moderate</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 (e.g. wind, waves, rain) and biological (e.g. 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. The decibel scale 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.

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 Amulet 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 Amulet 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.

Underwater noise emissions from MODUs primarily originate from on-board equipment vibrations, although some emissions are transmitted directly into the water through vibration of the drill string and potentially also from interaction between the drill bits and the seafloor (Austin et al. 2018). Underwater sounds produced by drilling units were characterised by Austin et al. (2018), with ranges shown in Table 7-32. Up to four wells may be drilled over approximately seven 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 decommissioning of the Amulet 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 is 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 (~11 months if two drilling campaigns are required); the MOPU will emit acoustic emissions for the entire duration of the Amulet Development.

Various vessels (listed in Table 3-17) will operate throughout the duration (~5 years) of the Amulet Development. This number will peak with up to ten support vessels during drilling, commissioning and decommissioning. During normal operations (~1.5–4.5 years), only one to two support vessels are expected. Table 7-32 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. 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 Amulet 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.

Noise emissions from ROV thrusters and propulsion are of lower frequency, however they are intermittent and minimal (when compared to other sound sources for the Amulet Development) 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 is 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 7-32 Typical Sound Pressure Source Levels and Frequencies of Survey and Positional Equipment for Various Offshore Activities

Phase	Activity	Sound Pressure Level	Reference
Impulsive Noises			
Survey	SSS	~229 dB re 1 µPa RMS @ 1 m	Geoscience Australia 2019b Tritech 2019 MacGillivray et al. 2013
	SBP	~200 dB re 1 µPa RMS @ 1 m	Geoscience Australia 2019b MacGillivray et al. 2013
	MBES	~218 dB re 1 µPa RMS @ 1 m	MacGillivray et al. 2013
Drilling	Transponders	183–202 dB re 1 µPa @ 1 m	Sonardyne 2019a,b,c
	VSP	~228 dB re 1 µPa RMS @ 1 m[13]	Mathews 2012 McCauley and Kent 2008 SLR 2017 Green 1997
Continuous Noises			
Drilling	MODU (drilling)	169–175 dB re 1 µPa RMS @ 1 m	Austin et al. 2018
Support Activities	MODU (non-drilling)	85–135 dB re 1 µPa RMS @ 1 m	McCauley 1998 WDCS 2004 Gales 1982
	Vessels, FSO	165–192 dB re 1 µPa RMS @ 1 m	Hannay et al. 2004 Richardson et al. 1995
	Helicopter	149–162 dB re 1 µPa RMS @ 1 m	Richardson et al. 1995 WDCS 2004

7.1.5.2 Modelling and Exposure Assessment

Noise modelling has been used to predict the potential spatial extent of noise emissions from the Amulet Development. An un-weighted spherical spreading model (Richardson et al. 1995) has been used to predict distances to noise effect thresholds for different marine fauna.

It is acknowledged that the spherical spreading model is highly simplified, and does not consider directionality, reflection, refraction, or absorption of sound at the seabed. However, it is considered to provide a conservative indication of distances at which received sound levels from are likely to decrease to below relevant threshold values, and therefore is appropriate for use in impact analysis.

7.1.5.2.1 Scenario

As described above (Section 7.1.5.1), noise emissions from the Amulet Development include both impulsive and continuous sources. For the purposes of impact assessment, the highest source of both impulsive and continuous has been selected for modelling, as these are considered to represent the greatest spatial extent of potential impacts for each noise type. The two noise levels modelled are:

- Impulsive: 229 dB re 1 µPa RMS @ 1 m

[13] 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.

- Continuous: 192 dB re 1 µPa RMS @ 1 m.

7.1.5.2.2 Environmental Thresholds

Southall et al. (2019) has assigned species of marine mammals (cetaceans, pinnipeds, sirenians) to one of six functional hearing groups based on behavioural psychophysics, evoked potential audiometry and auditory morphology. Pinnipeds and sirenians are not expected within the Amulet Development Project Area and therefore these are not discussed further. Cetacean species have been grouped as low frequency (LF), high frequency (HF), and very high frequency (VHF).

Different species groups perceive and respond to noise differently, and so a variety of thresholds for the different types of impacts and species groups are considered. KATO have selected the following noise effect thresholds, based on current best available science, for use in the impact assessment:

- Frequency-weighted SEL_{cum} (24 hours) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in marine mammals for impulsive and continuous noise (NMFS 2019; Southall et al. 2019)
- Un-weighted SPL for behavioural threshold for marine mammals for impulsive and continuous noise (NOAA 2019)
- Frequency-weighted SEL_{cum} (24 hours) for the onset of PTS and TTS in marine turtles for impulsive and continuous noise (Finneran et al. 2017)
- Un-weighted SPL for behavioural threshold for marine turtles for impulsive noise (McCauley et al. 2000)
- Sound exposure guidelines for fish, eggs and larvae (Popper et al. 2014).

The selected noise effect thresholds are shown in Table 7-33.

Table 7-33 Noise Effect Thresholds for Different Types of Impacts and Species Groups

Receptor	Threshold Type					
	Mortal or potential mortal injury	Recoverable injury	Permanent threshold shift (PTS)	Temporary threshold shift (TTS)	Masking	Behavioural
Impulsive Noise						
LF cetaceans	—	—	SEL_{cum}: 183 dB re 1 μPa^2s SPL: 219 dB re 1 µPa PK	SEL_{cum}: 168 dB re 1 μPa^2s SPL: 213 dB re 1 µPa PK	—	SPL: 160 dB re 1 µPa
HF cetaceans	—	—	SEL_{cum}: 185dB re 1 μPa^2s SPL: 230 dB re 1 µPa PK	SEL_{cum}: 170 dB re 1 μPa^2s SPL: 224 dB re 1 µPa PK	—	
VHF cetaceans	—	—	SEL_{cum}: 155 dB re 1 μPa^2s SPL: 202 dB re 1 µPa PK	SEL_{cum}: 140 dB re 1 μPa^2s SPL: 196 dB re 1 µPa PK	—	
Turtles	—	—	SEL_{cum}: 204 dB re 1 μPa^2s SPL: 232 dB re 1 µPa PK	SEL_{cum}: 189 dB re 1 μPa^2s SPL: 226 dB re 1 µPa PK	—	SPL: 175 dB re 1 µPa
Fish (no swim bladder)	SEL_{cum}: 219 dB re 1 μPa^2s SPL: 213 dB re 1 µPa PK	SEL_{cum}: 216 dB re 1 μPa^2s SPL: 213 dB re 1 µPa PK	—	SEL_{cum}: 186 dB re 1 μPa^2s	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish (swim bladder not involved in hearing)	SEL_{cum}: 210 dB re 1 μPa^2s SPL: 207 dB re 1 µPa PK	SEL_{cum}: 203 dB re 1 μPa^2s SPL: 207 dB re 1 µPa PK	—	SEL_{cum}: 186 dB re 1 μPa^2s	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish (swim bladder involved in hearing)	SEL_{cum}: 207 dB re 1 μPa^2s SPL: 207 dB re 1 µPa PK	SEL_{cum}: 203 dB re 1 μPa^2s SPL: 207 dB re 1 µPa PK	—	SEL_{cum}: 186 dB re 1 μPa^2s	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate
Eggs and larvae	SEL_{cum}: 210 dB re 1 μPa^2s SPL: 207 dB re 1 µPa PK	—	—	—	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low

Receptor	Threshold Type					
	Mortal or potential mortal injury	Recoverable injury	Permanent threshold shift (PTS)	Temporary threshold shift (TTS)	Masking	Behavioural
Continuous Noise						
LF cetaceans	—	—	SEL_{cum}: 199 dB re 1 µPa²s	SEL_{cum}: 179 dB re 1 µPa²s	—	SPL: 120 dB re 1 µPa
HF cetaceans	—	—	SEL_{cum}: 198 dB re 1 µPa²s	SEL_{cum}: 178 dB re 1 µPa²s	—	
VHF cetaceans	—	—	SEL_{cum}: 173 dB re 1 µPa²s	SEL_{cum}: 153 dB re 1 µPa²s	—	
Turtles	—	—	SEL_{cum}: 220 dB re 1 µPa²s	SEL_{cum}: 200 dB re 1 µPa²s	—	—
Fish (no swim bladder)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	—	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish (swim bladder not involved in hearing)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	—	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish (swim bladder involved in hearing)	(N) Low (I) Low (F) Low	SPL: 170 dB re 1 µPa (48 hours)	—	SPL: 158 dB re 1 µPa (12 hours)	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Eggs and larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	—	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) High (I) Moderate (F) Low

Dash [—] = threshold type not relevant

Relative risk (high, moderate, low) is given for fauna at three distances from the source (near [N], intermediate [I] and far [F])

7.1.5.2.3 Predicted Exposure

The results from the spherical modelling of the highest impulsive (229 dB re 1 µPa RMS @ 1 m) and continuous (192 dB re 1 µPa RMS @ 1 m) noise emissions from the Amulet Development are shown in Table 7-34. Conversions have then been applied to convert SPL RMS to unweighted SEL for impulsive sound (Green 1997 cited in Richardson 1997; McCauley et al. 2000).

Table 7-34 Predicted Sound Levels for highest Impulsive and Continuous Noise Emissions from Amulet Development

Distance (m)	Impulsive SPL (dB re 1 µPa RMS)	Impulsive SEL^ (dB re 1 μPa^2s)	Continuous SPL (dB re 1 µPa RMS)
1	229	216	192
50	195	182	158
100	189	176	152
200	183	170	146
300	179	166	142
400	177	164	140
500	175	162	138
1,000	169	156	132
2,000	163	150	126
3,000	159	146	122
4,000	157	144	120
5,000	155	142	118

^ The converted SEL values are unweighted per pulse (i.e. not cumulative over 24 hours).

To confirm the estimated distances derived from the spherical spreading modelling for the Amulet Development is not significantly underestimating distance to sound threshold values, a comparison was made to the following publicly available noise modelling studies: Browse to North West Shelf Project (McPherson et al. 2019a), Woodside 4-D Marine Seismic Survey (specifically sites in <200 m water depth within survey Area A [Pluto and Harmony fields]) (McPherson et al. 2019b), a multi-client seismic survey on North West Shelf (Schlumberger 2016), and the Otway Offshore Drilling Program (Koessler et al. 2020). Comparisons of predicted distances to reach marine mammal behaviour criteria show:

- Modelling in McPherson et al. (2019a) for VSP predicted being below the marine mammal behaviour threshold for impulsive noise (160 dB re 1 µPa) at a maximum distance of ~1.6 km from the source. Modelling in McPherson et al. (2019b) for a single-pulse seismic airgun, for sites in <200 m water depth within survey Area A, predicted being below the marine mammal behaviour threshold for impulsive noise at ~2.3-2.6 km. Modelling in Schlumberger (2016) for seismic airgun predicted being below the marine mammal behaviour threshold for impulsive noise at a distance of ~0.5-1.2 km. The spherical modelling for impulsive noise from the Amulet Development predicts being below this threshold by ~3 km.
- Modelling in McPherson et al. (2019a) for vessel noise (support vessel, FPSO without DP) predicted being below the marine mammal behaviour threshold for continuous noise (120 dB re 1 µPa) at a maximum distance of 0.6-2.2 km from the source. Modelling in Koessler et al. (2020) for vessel noise (MODU, support vessel) predicted being below the marine mammal behaviour threshold for continuous noise at a maximum distance of 4.4-4.6 km from the source. The spherical modelling for continuous noise from the Amulet Development predicts being below this threshold by ~4 km.

It is acknowledged that the modelling studies were completed for facilities in different water depths: Torosa (within McPherson et al. 2019a) is in ~391 m, Pluto/Harmony (within McPherson et al. 2019b) is in ~100-177 m, Thylacine (within Koessler et at. 2020) is in ~99 m, and the modelled location (within Schlumberger 2016) is ~50 m off the North West Cape, compared to the Amulet Development in ~85 m. These difference in depths and locations, as well as some differences in sound source levels or types, would likely influence modelling results. However, it is still considered that the simplified spherical modelling results are not significantly dissimilar or significantly underestimating sound field results and is therefore appropriate for use in the following impact assessment.

7.1.5.3 Impact Analysis and Evaluation

Underwater noise emissions generated by the Amulet 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 7-35 identifies the potential impacts to receptors as a result of underwater sound from the Amulet 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 7-36 provides a summary and justification for those receptors not evaluated further.

Table 7-35 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 noise	✓						
Change in fauna behaviour		*X*	*X*	✓	✓	✓	
Injury/mortality to fauna		*X*	*X*	*X*	✓	*X*	
Changes to the functions, interests or activities of other users							*X*

Table 7-36 Justification for Receptors Not Evaluated Further for Emissions – Underwater Noise

Plankton	***X***
Injury/mortality to marine fauna Plankton is a collective term for all marine organisms that are unable to swim against a current. This group is diverse and includes phytoplankton (plants) and zooplankton (animals), as well as fish and invertebrate eggs and larvae. There is no scientific information on the potential for noise-induced effect in phytoplankton and no functional cause-effect relationship has been established. Continuous noise sources have been identified as low risk of causing injury or mortality to plankton (Table 7-33), and as such are not discussed further. Impulsive noise emissions from the Amulet Development that may cause injury/mortality in plankton will be from acoustic sources during the geophysical survey or from VSP during the drilling phase (Table 7-32). Both of these activities will result in short-term noise emissions, occurring from a few hours to a few days.	

Results from spherical modelling estimate that noise levels would be below the mortal or potential mortal injury threshold for eggs and larvae (Table 7-33) within 50 m of the sound source (Table 7-34).

Any mortality or mortal injury effects to plankton resulting from sound emissions is expected to be inconsequential compared to natural mortality rates. Natural mortality estimates for zooplankton are generally high and variable. Tang et al. (2014) reviewed available research and reported zooplankton daily mortality rates of 11.6% (average minimum) to 59.8% (average maximum), but in some instances these authors found that 100% of samples died within a day. Similarly, Saetre and Ona (1996 cited in Popper et al. 2014) concluded that mortality rates caused by exposure to seismic sounds are so low compared to natural mortality that the impact from seismic surveys must be regarded as insignificant. Based upon the understanding that:

- natural mortality of plankton (including fish larvae) is quite high, in the order of 21.3% per day (Houde and Zastrow 1993), and
- fast growth rates of zooplankton, and the dispersal and mixing of zooplankton from both inside and outside of the impacted region and therefore expected to rapidly recover (Richardson et al. 2017).

Primary productivity of the North-west Marine Region is generally low (Brewer et al. 2007); and the Project Area for the Amulet Development does not intersect with any known aggregation or foraging areas for species (e.g. cetaceans) that have krill as a main component of their diet.

Therefore, while it is possible that localised injury to plankton may occur directly around the an impulsive sound source, change in numbers will be insignificant when compared to natural mortality, and as such changes 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

Continuous noise sources have been identified as high risk of causing masking or behavioural changes to plankton for any fauna in close proximity to the sound source; this risk decreases with increasing distance from the source (Table 7-33). Impulsive noise sources have been identified as moderate risk of causing behavioural changes to plankton in close proximity to the sound source; and there is low risk of causing behavioural change beyond this close proximity, and low risk of masking at all distances from the sound source (Table 7-33).

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). Noise 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; Change in fauna behaviour

There are currently no defined noise effect thresholds for invertebrates; however, several experimental studies and reviews investigating the impact of seismic sound on marine invertebrates have been conducted (e.g. Carroll et al. 2017). The types of impacts of seismic noise on marine invertebrates include mortality, auditory damage, organ damage and behavioural changes (Webster et al. 2018).

A risk assessment facilitated by the Department of Primary Industries and Regional Development (DPIRD) was undertaken (Webster et al. 2018). This assessment determined that the risk to mobile invertebrates (e.g. crabs, prawns, lobsters) from a small (<2,000 in^3) air gun array in 100 m water depth was low (Webster et al. 2018). The risk rankings on mobile invertebrates were mainly based on the experimental studies which examined impacts of seismic surveys on the Southern Rock Lobster (*Jasus edwardsii*) (Day et al. 2016). A risk ranking of low was determined to be acceptable and that no assessment of impacts at the population level for key species was required (Webster et al. 2018).

This assessment determined that the risk to immobile invertebrates (e.g. oysters, scallops, trochus, sea cucumbers) from a small (<2,000 in^3) air gun array in 100 m water depth was high (Webster et al. 2018). The risk rankings on immobile invertebrates were mainly based on the results of research on seismic impacts to the commercial scallop (*Pecten fumatus*) (Day et al. 2016). A risk ranking of high was determined as below

acceptable, and assessment of impacts at the population level for key species is required (Webster et al. 2018). There are no important or substantial areas of benthic habitats and communities identified within the Project Area. The majority of substrate within the WA-8-L permit area is expected to be characterised by sediment infaunal communities and sparsely distributed epibenthic fauna; and not support significant or diverse populations of immobile invertebrates. This is supported by benthic studies from other operations in the region (e.g. Apache 2012, RPS 2011), which showed unconsolidated sediments and varied infauna species. It is also noted that while scallops are found on sandy substrates, they are more often located within sheltered environments. No commercial fisheries targeting benthic invertebrates (e.g. lobster, scallop, prawn, oyster etc) is within the Project Area Therefore, as a significant population of immobile invertebrates is not expected to occur within the Project Area, and the short-duration (hours for VSP or days for SSS) of any impulsive noise, any potential impact to benthic habitats and communities is not expected and therefore is not evaluated further.	
Fish	***X***
<u>Injury/mortality to fauna</u> Continuous noise sources have been identified as low risk of causing injury or mortality to fish with no swim bladders, or those with bladders not involved in hearing (Table 7-33). For fish species with a swim bladder involved in hearing, a numerical threshold has been defined, but would be met within 50 m of the sound source (Table 7-33, Table 7-34). Impulsive noise emissions from the Amulet Development that may cause injury/mortality in plankton will be from acoustic sources during the geophysical survey or from VSP during the drilling phase (Table 7-32). Both of these activities will result in short-term noise emissions, occurring from a few hours to a few days. Results from spherical modelling estimate that noise levels would be below the mortal or potential mortal injury threshold and the recoverable injury threshold for all fish groups (Table 7-33) within 50 m of the sound source (Table 7-34). Any presence of fish within the Project Area is expected to be of a transitory nature only, with no sensitive or significant benthic features known to be present that would cause an aggregation of fauna. In addition, it is expected that any fauna within the immediate vicinity of the sound source would likely exhibit avoidance behaviour. Therefore, noise emissions are unlikely to cause a significant impact to fish species at a population level, and impacts from noise emissions to the injury or mortality of fish are not evaluated further.	
Marine reptiles	***X***
<u>Injury/mortality to fauna</u> Continuous noise sources from the Amulet Development are not at a level to result in an injury or mortality to marine reptiles (based on thresholds for turtles), and as such are not discussed further. Impulsive noise emissions from the Amulet Development that may cause injury/mortality in marine reptiles will be from acoustic sources during the geophysical survey or from VSP during the drilling phase (Table 7-32). Both of these activities will result in short-term noise emissions, occurring from a few hours to a few days. Results from spherical modelling estimate that noise levels would be below the TTS and PTS thresholds for marine turtles (Table 7-33) within 50 m of the sound source (Table 7-34). Any presence of turtles or other reptiles within the Project Area is expected to be of a transitory nature only, with no sensitive or significant benthic features known to be present that would cause an aggregation of fauna. In addition, it is expected that any fauna within the immediate vicinity of the sound source would likely exhibit avoidance behaviour. Therefore, noise emissions are unlikely to cause a significant impact to marine reptiles at a population level, and impacts from noise emissions to the injury or mortality of marine reptiles are not evaluated further.	
Commercial Fisheries	***X***
<u>Changes to the functions, interests or activities of other users</u> Ten state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show low levels of commercial fishing activity is expected to occur	

within the Project Area. Any fishing effort that may occur is expected to be from one of the WA North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF). The impact assessment of underwater noise on fish is described in Section 7.1.5.3.2, and determined as a minor consequence to the potential impacts for behavioural change; it was also assessed above that the potential for injury/mortality to fish was negligible. In addition, negligible impacts are expected to plankton (i.e. including fish eggs and larvae) or benthic habitats and communities (as described in evaluations above). Therefore, given that noise emissions are unlikely to significantly impact fish populations, their larvae or habitat, negligible indirect impacts to commercial fisheries are expected, and are not evaluated further.

Impacts to receptors are assessed below, by receptor type.

7.1.5.3.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of sound emissions include:

- ambient noise.

Table 7-37 provides a detailed evaluation of the impact of noise emissions from the physical presence of the activities to physical receptors.

Table 7-37 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 Amulet 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 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 Amulet Development area are expected to be similar to other Pilbara development areas, which have been recorded as 90–110 dB re 1 µPa, representing the typical range for calm to windy conditions (Shell 2018). Acoustic sources detailed in Table 7-32 represent the range of anthropogenic sound levels during the Amulet 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. 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 drill units at 169–175 dB re 1 µPa RMS @ 1 m (Austin et al. 2018). Noise emissions from the MODU during non-drilling periods will reduce to 85–135 dB re 1 µPa RMS @ 1 m once drilling and commissioning are complete (Table 7-32). 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. Amulet Development drilling operations are expected to take approximately seven months to complete (with an additional four months if infill drilling is required). 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 Amulet Development Project Area. The commissioning and decommissioning phases are expected to each take approximately one month. As the Amulet Development enters the operational phase, noise levels will reduce with fewer support vessels on site and these will generally be running at idle, or at

anchor. Broadband levels ranging from 165–192 dB re 1µPa RMS @ 1 m have previously been reported for vessels involved in marine exploration activities (Table 7-32). Information on underwater noise 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. 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. 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.

7.1.5.3.2 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>Change in fauna behaviour</u> A change in ambient noise generated by the Amulet Development has the possibility to change the behaviour of fish species. Impulsive noise sources have been identified as a high risk causing behavioural changes within the near vicinity of a sound source for all fish with no swim bladder or a bladder not involved in hearing; and high at both near and intermediate vicinity for fish that use their swim bladder for hearing (Table 7-33). There is a low risk of causing masking behaviours for all fish groups from impulsive noise sources (Table 7-33). Impulsive noise emissions from the Amulet Development that may cause behavioural changes will be from acoustic sources during the geophysical survey or from VSP during the drilling phase (Table 7-32). Both of these activities will result in short-term noise emissions, occurring from a few hours to a few days. Potential behavioural impacts to finfish from seismic sounds include temporary stunning, changes in position in the water, displacement from area and effects on breeding behaviours (Webster et al. 2018). However, due to the short duration of impulsive noise emission, 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. A risk assessment facilitated by DPIRD was undertaken (Webster et al. 2018). This assessment determined that the risk to demersal finfish (e.g. Goldband Snapper, Red Emperor, Pink Snapper) from a small (<2,000 in^3) air gun array in 100 m water depth was low (Webster et al. 2018). A risk ranking of low was determined to be acceptable and that no assessment of impacts at the population level for key species was required (Webster et al. 2018). Continuous noise sources have been identified as a moderate risk of causing behavioural changes, a high risk of causing masking changes, within the near and intermediate vicinity of a sound source for all fish	

groups (Table 7-33). Continuous noise sources will be present throughout the operational phases of the project (~1.5-4.5 years).

Continuous noise of any level that is detectable by fishes can mask signal detection, and thus may have a pervasive effect on fish behaviour. However, the consequences of this masking and any attendant behavioural changes for the survival of fishes are unknown (Popper et al. 2014). It is expected that most fish (including sharks and rays) will exhibit avoidance behaviour from a sound source if it reaches levels that may cause behavioural or physiological effects.

The Amulet Development Project Area overlaps with the foraging BIA for the EPBC listed Whale Shark. However, the approved EPBC Conservation Advice for Whale Sharks does not list underwater noise as a threat (TSSC 2015d). 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 noise will be the same as for other fish. Whale Sharks do not have swim bladders, so at close range to a sound source they may be at moderate to high risk of a behavioural response.

Given the details above, the consequence of underwater noise causing a change in fish behaviour has been assessed as **Moderate (2)**, due to the localised and short-term (< 5 years) nature of the noise emissions and potential presences of threatened species.

Marine Mammals	✓

Injury/ mortality to fauna

Impulsive noise emissions from the Amulet Development that may cause injury/mortality in marine mammals will be from acoustic sources during the geophysical survey or from VSP during the drilling phase (Table 7-32). Both of these activities will result in short-term noise emissions, occurring from a few hours to a few days. Continuous noise emissions from the Amulet Development that may cause injury/mortality in marine mammals will be from general vessels and facilities operations (Table 7-32). Continuous noise sources will be present throughout the operational phases of the project (~1.5-4.5 years).

Permanent threshold shift (PTS) and temporary threshold shift (TTS) are 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 TTS onset levels and assumed growth functions (Southall et al. 2007, 2019; NMFS 2018).

Southall et al. (2019) has assigned species of marine mammals (cetaceans, pinnipeds, sirenians) to one of six functional hearing groups based on behavioural psychophysics, evoked potential audiometry, auditory morphology. Pinnipeds and sirenians are not expected within the Amulet Development Project Area and therefore these are not discussed further. Cetacean species have been grouped as low frequency (LF), high frequency (HF), and very high frequency (VHF).

The LF cetacean 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, Humpback Whale, Bryde's Whale, Sei Whale and Fin Whale). The Project Area also overlaps with the Blue Whale distribution BIA. Results from spherical modelling estimates that impulsive noise levels would be below the TTS or PTS thresholds for LF cetaceans (Table 7-33) within 300 m of the sound source (Table 7-34); and that continuous noise levels would be below TTS and PTS thresholds within 50 m (Table 7-34). Incidental occurrences of marine mammals near the Amulet Development 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 Project Area does intersect with a distribution BIA;

however, any change of use in this area due to hearing effects are expected to typically be restricted to within 50 m of a continuous sound source, and within 300 m from an impulsive sound source.

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.

The high-frequency and very high frequency group includes toothed whales and dolphins. Results from spherical modelling estimates that impulsive noise levels would be below the TTS or PTS thresholds for HF cetaceans within 200 m of the sound source, and for VHF cetaceans within ~5 km of the sound source (Table 7-34). Continuous noise levels are estimated to be below TTS and PTS thresholds within 50 m for both HF and VHF cetaceans (Table 7-34). The Project Area does not intersect with any BIAs for EPBC-listed HF or VHF cetaceans.

Given the details above, the consequence of underwater noise causing injury or mortality to marine mammals has been assessed as **Moderate (2)**, due to the localised (<5 km) and short-term (< 5 years) nature of the noise emissions and potential presences of threatened species.

Change in fauna behaviour

A change in ambient noise levels generated by the Amulet Development has the potential to change the behaviour of 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.

Impulsive noise emissions from the Amulet Development that may cause behavioural changes in marine mammals will be from acoustic sources during the geophysical survey or from VSP during the drilling phase (Table 7-32). Both of these activities will result in short-term noise emissions, occurring from a few hours to a few days. Results from spherical modelling estimate that noise levels would be below the behavioural threshold for marine mammals (160 dB re 1 µPa; Table 7-33) within 3 km of the sound source (Table 7-34). . Continuous noise emissions from the Amulet Development that may cause behavioural changes in marine mammals will be from general vessels and facilities operations (Table 7-32). Continuous noise sources will be present throughout the operational phases of the project (~2.5-4 years). Results from spherical modelling estimate that noise levels would be below the behavioural threshold for marine mammals (120 dB re 1 µPa; Table 7-33) within 4 km of the sound source (Table 7-34).

As per discussions above cetaceans may be present within the Project Area but are expected to be of a transient nature only.

Cetaceans are not likely to be significantly affected by noise from the Amulet Development, although it may induce some avoidance behaviour and minor route alterations. However, as noted previously, noise emissions will not result in displacement of a Blue Whale from foraging areas (requirement in accordance with the Conservation Management Plan) as this does not occur within the Project Area.

Given the details above, the consequence of underwater noise causing a change in marine mammal behaviour has been assessed as **Moderate (2)**, due to the localised (<4 km) and short-term (< 5 years) nature of the noise emissions and potential presences of threatened species.

Marine Reptiles ✓

Change in fauna behaviour

A change in ambient noise generated by the Amulet Development has the possibility to change the behaviour of marine reptile species.

Impulsive noise emissions from the Amulet Development that may cause behavioural changes in marine reptiles will be from acoustic sources during the geophysical survey or from VSP during the drilling phase (Table 7-32). Both of these activities will result in short-term noise emissions, occurring from a few hours to a few days. Results from spherical modelling estimate that noise levels would be below the behavioural threshold for marine turtles (175 dB re 1 µPa ; Table 7-33) within 500 m of the sound source (Table 7-34). The EPBC PMST report shows that five species of turtle listed as either Endangered (Loggerhead Turtle, Leatherback Turtle) or Vulnerable (Green Turtle, Hawksbill Turtle, Flatback Turtle) and Migratory may occur within the Project Area. However, the Project Area does not intercept with any BIA for turtle species; the closest being the internesting BIA for the Flatback Turtle ~12.5 km to the south of the Project Area boundary. The Australian Government Recovery Plan for Marine Turtles in Australia (CoA 2017) identifies noise interference as a potential threat to marine turtles.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 ~85 m; nor was it identified as present within the EPBC PMST report (Table 5-11). Impulsive 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 kHz and 675 kHz with favoured ranges around 325 kHz and 675 kHz (Tritech 2019) and MBES ranging between 30 kHz and 100 kHz. These frequencies are outside the normal hearing range of turtles (50–1200 Hz; Lavender et al. 2012) 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. Given the details above, the consequence of underwater noise causing a change in marine reptiles behaviour has been assessed as **Moderate (2)**, due to the localised (<500 m) and temporary (hours to days) nature of the noise emissions, but with the potential presences of threatened species.

7.1.5.4 Consequence and Acceptability Summary

The worst-case consequence of Emissions – Underwater Noise from the Amulet 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 7-39.

Table 7-39 Demonstration of Acceptability for Emissions – Underwater Noise

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="7">Ambient noise</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Emissions - Noise, the Amulet Development will not result in significant impacts to ambient noise identified as potentially affected, defined as a possibility that it will (Section 6.6):
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>The proposed EPO’s for the Amulet Development are consistent with the principles of ESD.
With respect to potential impacts to all receptors from Emissions - Noise the relevant principles are:
• Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
• 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.</td></tr>
<tr><td>Internal context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards.
With respect to potential impacts to all receptors from Emissions - Noise, there are no specific KATO internal requirements with respect to noise emissions or potentially impacted receptors.</td></tr>
<tr><td>External context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders.
With respect to potential impacts to all receptors from Emissions - Noise, no specific concerns were raised during stakeholder consultation with relevant persons.</td></tr>
<tr><td>Other requirements</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions - Noise from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to ambient noise from Emissions - Noise, no explicit relevant requirements or actions were identified.</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="4"></td><td colspan="2">Summary of impact assessment</td><td>Consequence level</td></tr>
<tr><td colspan="2">The impacts on ambient noise from Emissions - Noise include:
• Noise emissions from the Amulet Development will be highly localised and temporary (project life ~5 years)
• Activities generating impulsive noise are of short duration (SSS <1 week, VSP for <24 hours per well; drilling for ~7 months, and an additional 4 months if an infill drilling campaign is required)
• Activities generating continuous noise sources will be present throughout the operational phases of the project (~1.5-4.5 years).</td><td>Minor</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on ambient noise from Emissions - Noise is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO4: Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
<tr><td rowspan="6">Fish</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Emissions - Noise, the Amulet Development will not result in significant impacts to fish identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
• substantially modify, destroy or isolate an area of important habitat for a migratory species.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in ambient noise assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in ambient noise assessment (above)</td></tr>
</table>

Receptor	Demonstration of Acceptability		
	External context	Refer to details in *ambient noise* assessment (above)	
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions - Noise from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. With respect to potential impacts to *fish* from Emissions - Noise, no explicit relevant requirements or actions were identified. None of the Recovery Plans/Conservation Advices identify noise as a key threat for fish species (Section 2.2.1).	
	Summary of impact assessment		**Consequence level**
	The impacts on *fish* from Emissions - Noise include: • The potential for continuous or impulsive noise to result in injury/mortality to fish is considered negligible. • Impulsive noise emissions from the Amulet Development that may cause behavioural changes will be from acoustic sources (e.g. SSS) during the geophysical survey or from VSP during the drilling phase; both of these activities will result in short-term noise emissions, occurring from a few hours to a few days. • A published risk assessment (Webster et al. 2018) determined that the risk to demersal fish from a small (<2,000 in^3) air gun array in 100 m water depth was low. A risk ranking of low was determined to be acceptable and that no assessment of impacts at the population level for key species was required. • Continuous noise sources have been identified as a moderate risk of causing behavioural changes, a high risk of causing masking changes, within the near and intermediate vicinity of a sound source for all fish groups. Continuous noise sources will be present throughout the operational phases of the project (~1.5-4.5 years).		Moderate
	Statement of acceptability		
	Based on an assessment against the defined acceptable levels, the impacts on *fish* from Emissions - Noise is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="3">EPO8: Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
EPO10: Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species.</td></tr>
<tr><td rowspan="8">Marine mammals</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Emissions - Noise, the Amulet Development will not result in significant impacts to marine mammals identified as potentially affected, defined as a possibility that it will (Section 6.6):
have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in ambient noise assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in ambient noise assessment (above)</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in ambient noise assessment (above)</td></tr>
<tr><td rowspan="2">Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions - Noise from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to marine mammals from Emissions - Noise, this specifically includes:
<table>
<tr><th>Requirement</th><th>Relevant Item/Objective/Action</th><th>Addressed/Managed by Amulet Development</th></tr>
<tr><td>EPBC Regulations 2000</td><td>Part 8, Division 8.1 – Interacting with cetaceans
Regulation 8.04:
A prohibited vessel must not approach closer than 300 m to a cetacean.
A prohibited vessel must move, at a constant speed of <6 knots, away from a cetacean</td><td>The Amulet Development is not within known calving, resting, feeding or migratory areas for marine mammal species (Section 5.4.6).
Environmental impact assessment for noise emissions on marine mammals has been completed in this OPP (Section 7.1.5.3.2),</td></tr>
</table></td></tr>
</table>

Receptor	Demonstration of Acceptability			
			that is approaching so that the vessel remains at least 300 m away from the cetacean.	including noise modelling assessment (Section 7.1.5.2). Adoption of the following control measures: • **CM18**: Vessels will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the Project Area • **CM19**: Vertical seismic profiling (VSP) operations will adhere to the EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines.
		EPBC Act Policy Statement 2.1 - Interaction between offshore seismic exploration and whales	Identifies management measures for vessels conducting seismic surveys in Australian waters, including the use of precaution zones and management procedures.	
		Conservation advice *Balaenoptera borealis* Sei Whale (TSSC 2015a)	Identified anthropogenic noise and acoustic disturbance as a threat. No explicit relevant objectives. Relevant management action: • Once the spatial and temporal distribution (including biologically important areas) of Sei Whales is further defined an assessment of the impacts of increasing anthropogenic noise (including from seismic surveys, port expansion, and coastal development) should be undertaken on this species	
		Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 2015–2025 (CoA 2015a)	Identified noise interference as a threat. No explicit relevant objectives. Management action A.2 (assessing and addressing anthropogenic noise): • Improved management and understanding of what impact anthropogenic noise may have on Blue Whales by: ○ Assessing the effect of anthropogenic noise on blue whale behaviour ○ 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.	

Receptor	Demonstration of Acceptability			
			○ EPBC Act Policy Statement 2.1—Interaction between offshore seismic exploration and whales is applied to all seismic surveys.	
		Conservation advice *Balaenoptera physalus* Fin Whale (TSSC 2015b)	Identifies anthropogenic noise and acoustic disturbance as a threat. No explicit relevant objectives. Relevant management action: • Once the spatial and temporal distribution (including biologically important areas) of Fin Whales is further defined an assessment of the impacts of increasing anthropogenic noise (including from seismic surveys, port expansion, and coastal development) should be undertaken on this species	

Receptor	Demonstration of Acceptability			
		Approved Conservation Advice for *Megaptera novaeangliae* (Humpback Whale) (TSSC 2015c)	Identified noise interference a threat. No explicit relevant objectives. Relevant management action: • All seismic surveys must be undertaken consistently with the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales. Should a survey be undertaken in or near a calving, resting, foraging area, or a confined migratory pathway then Part B. Additional Management Procedures must also be applied. • For actions involving acoustic impacts (example pile driving, explosives) on humpback whale calving, resting, feeding areas, or confined migratory pathways site specific acoustic modelling should be undertaken (including cumulative noise impacts). • Should acoustic impacts on Humpback calving, resting, foraging areas, or confined migratory pathways be identified a noise management plan should be developed.	
	Summary of impact assessment			**Consequence level**
	The impacts on *marine mammals* from Emissions - Noise include: • Impulsive noise emissions from the Amulet Development will be from acoustic sources (e.g. SSS) during the geophysical survey or from VSP during the drilling phase; both of these activities will result in short-term noise emissions, occurring from a few hours to a few days. Results from spherical modelling estimates that noise would be below TTS and PTS thresholds for impulsive noise for both the LF and HF cetacean groups within ~300 m of the sound source, and up to ~5 km for the VHF cetaceans; and below the behavioural threshold for marine mammals within ~3 km of the sound source. • Continuous noise sources will be present throughout the operational phases of the project (~1.5-4.5 years). Results from spherical modelling estimates that noise would be below TTS and PTS thresholds for continuous noise for all cetacean			Moderate

Receptor	Demonstration of Acceptability
	groups and sirenians within ~50 m of the sound source; and below the behavioural threshold for marine mammals within ~4 km of the sound source. • The Project Area does not overlap with a foraging area for Blue Whales (a LF cetacean) and therefore, there will be no displacement of Blue Whales from a foraging area. The Project Area does intersect with a distribution BIA for Blue Whales; however, any change of use in this area due to hearing effects (i.e. TTS, PTS) are expected to typically be restricted to within 50 m of a continuous sound source, and 300 m from an impulsive noise source.
	Statement of acceptability
	Based on an assessment against the defined acceptable levels, the impacts on *marine mammals* from Emissions - Noise is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. • **EPO10:** Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species**.** • **EPO15**: Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. • **EPO16**: Noise emissions are managed such that any Blue Whale continues to utilise the area without injury and is not displaced from a foraging BIA.
Marine reptiles	**Acceptable level of impact**
	With respect to Emissions - Noise, the Amulet Development will not result in significant impacts to *marine reptiles* identified as potentially affected, defined as a possibility that it will (Section 6.6): • have a substantial adverse effect on a population of fish, or the spatial distribution of the population. • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. • seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="12"></td><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in ambient noise assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in ambient noise assessment (above)</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in ambient noise assessment (above)</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions - Noise from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to marine reptiles from Emissions - Noise, no explicit relevant requirements or actions were identified. None of the Recovery Plans/Conservation Advices identify noise as a key threat for marine reptile species (Section 2.2.1).</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Consequence level</td></tr>
<tr><td colspan="2">The impacts on marine reptiles from Emissions - Noise include:
• The potential for continuous or impulsive noise to result in injury/mortality to marine reptiles is considered negligible. Results from spherical modelling estimate that impulsive noise levels would be below the TTS and PTS thresholds for marine turtles within 50 m of the sound source. Continuous noise sources are not at a level above TTS or PTS thresholds.
• Impulsive noise emissions from the Amulet Development that may cause behavioural changes in marine reptiles will be from acoustic sources (e.g. SSS) during the geophysical survey or from VSP during the drilling phase; both of these activities will result in short-term noise emissions, occurring from a few hours to a few days. Results from spherical modelling estimate that noise levels would be below the behavioural threshold for marine turtles (175 dB re 1 µPa) within 500 m of the sound source.</td><td>Moderate</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on marine reptiles from Emissions - Noise is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level</td></tr>
</table>

Receptor	Demonstration of Acceptability
	To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. • **EPO6:** Undertake the Amulet Development in a manner that will not result in the displacement of marine turtles from important foraging habitat or from habitat critical during nesting and internesting periods. • **EPO9:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. • **EPO10:** Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species.

A summary of the impact analysis and evaluation, including adopted control measures adopted and EPOs, is provided in Table 7-40.

Table 7-40 Summary of Impact Assessment for Emissions – Underwater Noise

<table>
<tr><th>Receptor</th><th>Impacts</th><th>EPOs</th><th>Adopted Control Measures</th><th>Consequence</th></tr>
<tr><td>Ambient noise</td><td>Change in ambient noise</td><td rowspan="5">EPO4: Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.

EPO5: Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

EPO6: Undertake the Amulet Development in a manner that will not result in the displacement of marine turtles from important foraging habitat or from habitat critical during nesting and internesting periods.

EPO8: Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.

EPO9: Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.

EPO15: Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.

EPO16: Noise emissions are managed such that any Blue Whale continues to utilise the area without injury and is not displaced from a foraging BIA.</td><td rowspan="5">CM04: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction.

CM18: Vessels will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the Project Area.

CM19: VSP operations will adhere to the EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines.

CM20: Equipment will be maintained in accordance with the manufacturer's specifications, facility planned maintenance system and regulatory requirements.</td><td>Minor</td></tr>
<tr><td>Fish</td><td>Change in fauna behaviour</td><td>Moderate</td></tr>
<tr><td rowspan="2">Marine mammals</td><td>Injury / mortality to fauna</td><td>Moderate</td></tr>
<tr><td>Change in fauna behaviour</td><td>Moderate</td></tr>
<tr><td>Marine reptiles</td><td>Change in fauna behaviour</td><td>Moderate</td></tr>
</table>

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 Amulet 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 production wells (including allowance for two sidetracks) and one water injection well (potentially drilled as a dual-purpose producer/injector) may be drilled during the development. The initial drilling campaign will take ~7 months, and an additional four months if an infill drilling campaign is required. If Talisman is drilled through the conductor deck at the MOPU, the drill fluids and cuttings discharge will be at the well entry location at Amulet. If this is not feasible and the subsea tieback option is used, the MODU will drill on location at Talisman, meaning cuttings and fluids will be discharged at a second location.

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 are 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, 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 remaining top-hole and the bottom-hole section are dependent on the well geometry drilled for each well with variations expected depending on the depth of the well. For the base case, it is estimated to be ~395 m^3 per well for the two Amulet production wells and ~405 m^3 for the dual-purpose Amulet production/injection well. For the Talisman tieback option, is estimated to be ~380 m^3 per well for the two Talisman production wells.

In the event an extended reach well is feasible from the proposed MOPU position for the Talisman production wells, is estimated the volumes of cutting discharged during the remaining top-hole and the bottom-hole section for this option to be ~870 m^3 per well for the two Talisman production wells.

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 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 4.3.6). If SBM is used, there is no planned discharge of SBM to the marine environment during drilling. If WBM is used, a maximum of 160 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 Amulet 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 1.5–4.5 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 (similar to during drilling)
- control fluids (refer to Section 7.1.8).

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 per well.

7.1.6.2 Impact Analysis and Evaluation

Drilling cuttings and fluids discharged to the marine environment during the Amulet 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 7-41 identifies the potential impacts to receptors as a result of a planned discharge of drilling cuttings and fluids at the Amulet 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 7-42 provides a summary and justification for those receptors not evaluated further.

Table 7-41 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		✓						
Change in habitat				✓				
Injury/mortality to fauna			*X*	✓	*X*	*X*	*X*	
Changes to the functions, interests or activities of other users								*X*

Table 7-42 Justification for Receptors Not Evaluated Further for Planned Discharge – Drilling cuttings and Fluids

Plankton	***X***
<u>Injury/mortality to fauna</u> 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 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 three species of shark as Vulnerable/Migratory (Green Sawfish, White Shark and Whale Shark) that may occur within the Project Area. The Green Sawfish species is not likely to occur at the site of the Amulet Development given its habitat preference of shallow coastal and estuarine areas.; and it intersects with a BIA foraging area for the Whale Shark. Within the North West Shelf, 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). 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 where foraging activity is centered on the 200 m isobath from July to November. The 200 m isobath is situated ~39 km to the north of the Amulet Project Area. The approved Conservation Advice for Whale Sharks (TSSC 2015d) states that the main threat to the species occurs outside Australian waters. Within Australian waters, habitat disruption from mineral exploration, production and transportation is listed as a threat. 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 one species listed as Endangered (Blue Whale) that are likely to occur within the Project Area.

The Amulet Development intercepts with the Pygmy Blue Whale distribution BIA however, this area is not considered particularly important for the conservation of the species compared to migration or foraging BIAs. The Conservation Management Plan for the Blue Whale does not list pollution as a threat to the Pygmy Blue Whale. Pygmy Blue Whales tend to pass along the shelf edge at depths between 500 m to 1000m during their migration (DoE 2015b). As the 500 m isobath is situated ~90 km north of the Amulet Project Area and the southern boundary of the migration BIA is ~60 km to the north of the Amulet Project Area, occurrences of the Pygmy Blue Whale within the Project Area are expected to be extremely unlikely.

The Amulet Development is situated ~32 km north of the Humpback Whale migration BIA. Humpback Whales migrate between May and November each year; with peak northern migration occurring during June and July, and no noted peak for the southern migration (TSSC 2015c). The approved Conservation Advice for the Humpback Whale does not list pollution as a threat (TSSC 2015c).

The EPBC PMST also shows that five species of turtle listed as either Vulnerable (Green Turtle, Hawksbill Turtle and Flatback Turtle) or Endangered (Loggerhead Turtle and Leatherback Turtle) are known or are likely to occur within the Project Area; however, there are no BIAs for turtle species within the Project Area. Although the Recovery Plan for Marine Turtles in Australia, (DOEE, 2017a) identifies chemical and terrestrial discharge as a threat, this mostly in relation to pollution from agricultural, terrestrial industrial and domestic sources.

All species listed are highly mobile, therefore, none are expected to be affected by negligible increases in toxicity and short-term turbidity increases. In addition, there is no known significant benthic habitat or

benthic features within the Project Area that would result in the aggregation of, or occurrence of site-attached, marine fauna within the area. Because drilling cuttings and fluid discharges within the Amulet 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. Therefore, impacts are not 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 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 around the well entry point, well within the 5 km radius of the Project Area. This is an insignificant area compared to the size and scale of commercial fisheries. Three Commonwealth and ten state-managed fisheries intersect with the Project Area. However, historical fishing effort data shows limited activity with only four of these state managed fisheries 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.

Impacts to receptors are assessed below, by receptor type.

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 7-43 provides a detailed evaluation of the impact of discharges of drilling cuttings and fluids to physical receptors.

Table 7-43 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 Amulet 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 three wells that may be drilled at Amulet are very close together (all wells within a 10 m x 10 m footprint); therefore the cuttings piles from each one will overlap. If the extended reach option is used to drill Talisman, the cuttings piles from the two potential Talisman wells will also overlap. However, if the subsea tieback option is used, the MODU will also discharge drill cuttings and fluids at each Talisman well location.

A conservative maximum impact radius of 200 m around the well footprint at the MOPU is assumed, giving a footprint of 0.125 km^2 for Amulet, plus a total of 0.25 km^2 for each Talisman well (if the subsea tieback option is selected). The total footprint is 0.375 km^2, which 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)** as discharges are expected to be limited to close to the discharge source, the highest concentrations are 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 7-44 provides a detailed evaluation of the impact of a planned discharge of drilling cuttings and fluids to ecological receptors.

Table 7-44 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 three wells that may be drilled at Amulet are very close together (all wells within a 10 m x 10 m footprint); therefore the cuttings piles from each one will overlap. If the extended reach option is used to drill Talisman, the cuttings piles from the two potential Talisman wells will also overlap. However, if the subsea tieback option is used, the MODU will also discharge drill cuttings and fluids at each Talisman well location. A conservative maximum impact radius of 200 m around the well footprint at the MOPU is assumed, giving a footprint of 0.125 km^2 for Amulet, plus a 0.25 km^2 impact footprint for each Talisman well (if the subsea tieback option is selected). The total impact footprint is 0.375 km^2, which is well within the 5 km buffer that comprises the Project Area. Impact to benthic habitat from drilling cuttings will be limited to within this ~200 m radius around the Amulet and Talisman well footprints, which is considered negligible considering the extent of the sparse seabed communities within the North West Shelf. 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 Amulet Development area will be representative of the North West Shelf 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 Amulet 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; andwould be 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 7-45.

Table 7-45 Demonstration of Acceptability for Planned Discharge – Drilling cuttings and Fluids

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="8">Water quality</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Planned Discharge – Drilling Cuttings and Fluids, the Amulet Development will not result in significant impacts to water quality identified as potentially affected, defined as a possibility that it will (Section 6.6):
• result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.</td></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">The proposed EPO's for the Amulet Development are consistent with the principles of ESD.
With respect to potential impacts to all receptors from Planned Discharge – Drilling Cuttings and Fluids the relevant principles are:
• Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
• 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.</td></tr>
<tr><td>Internal context</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards.
With respect to potential impacts to all receptors from Planned Discharge – Drilling Cuttings and Fluids, this specifically includes:
• KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)</td></tr>
<tr><td>External context</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders.
With respect to potential impacts to all receptors from Planned Discharge – Drilling Cuttings and Fluids, no specific concerns were raised during stakeholder consultation with relevant persons.</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Drilling Cuttings and Fluids from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to water quality from Planned Discharge – Drilling Cuttings and Fluids, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Consequence level</td></tr>
</table>

Receptor	Demonstration of Acceptability		
	The impacts on *water quality* from Planned Discharge – Drilling Cuttings and Fluids include: • 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 Amulet Development within the high-energy offshore marine environment means that impacts will be localised.		Minor
	Statement of acceptability		
	Based on an assessment against the defined acceptable levels, the impacts on *water quality* from Planned Discharge – Drilling Cuttings and Fluids is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO3:** Undertake the Amulet Development in a manner that does not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health		
Sediment quality	**Acceptable level of impact**		
	With respect to Planned Discharge – Drilling Cuttings and Fluids, the Amulet Development will not result in significant impacts to *sediment quality* identified as potentially affected, defined as a possibility that it will (Section 6.6): • result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. • 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.		
	Acceptability assessment		
	Principles of ESD	Refer to details in *water quality* assessment (above)	
	Internal context	Refer to details in *water quality* assessment (above)	
	External context	Refer to details in *water quality* assessment (above)	
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be	

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="6"></td><td colspan="2">managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Drilling Cuttings and Fluids from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to sediment quality from Planned Discharge – Drilling Cuttings and Fluids, no specific other requirements have been identified as relevant.</td></tr>
<tr><td>Summary of impact assessment</td><td>Consequence level</td></tr>
<tr><td>The impacts on sediment quality from Planned Discharge – Drilling Cuttings and Fluids include:
• the predominantly dispersive nature and low toxicity of drilling cuttings and fluids discharges and the location of the Amulet 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.
• a conservative direct disturbance radius of 200 m has been assumed to , giving a footprint of 0.375 km^2 (allowing for Talisman to be drilled on location by a separate MODU), which is within the Project Area 5 km buffer.</td><td>Minor</td></tr>
<tr><td colspan="2">Statement of acceptability</td></tr>
<tr><td colspan="2">Based on an assessment against the defined acceptable levels, the impacts on sediment quality from Planned Discharge – Drilling Cuttings and Fluids is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO17: Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="2">Benthic habitats and communities</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Planned Discharge – Drilling Cuttings and Fluids, the Amulet Development will not result in significant impacts to benthic habitat and communities identified as potentially affected, defined as a possibility that it will (Section 6.6):
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
</table>

Receptor	Demonstration of Acceptability		
	Acceptability assessment		
	Principles of ESD	Refer to details in *water quality* assessment (above)	
	Internal context	Refer to details in *water quality* assessment (above)	
	External context	Refer to details in *water quality* assessment (above)	
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Drilling Cuttings and Fluids from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. With respect to potential impacts to *benthic habitats and communities* from Planned Discharge – Drilling Cuttings and Fluids, no specific other requirements have been identified as relevant.	
	Summary of impact assessment		**Consequence level**
	The impacts on benthic habitat and communities from Planned Discharge – Drilling Cuttings and Fluids include: • 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 0.375 km^2 (allowing for Talisman to be drilled on location by a separate MODU), which is within the Project Area 5 km buffer. • impacts to mobile benthic fauna (e.g. crabs, shrimps) are not expected given their ability to avoid effected areas.		Minor
	Statement of acceptability		
	Based on an assessment against the defined acceptable levels, the impacts on benthic habitat and communities from Planned Discharge – Drilling Cuttings and Fluids is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO4:** Undertake the Amulet Development in a manner that will 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 results.		

Receptor	Demonstration of Acceptability
	• **EPO11:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and communities, including life cycle and spatial distribution.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-46.

Table 7-46 Summary of Impact Assessment for Planned Discharge – Drilling cuttings and Fluids

<table>
<tr><th>Receptor</th><th>Impact</th><th>EPOs</th><th>Adopted Control Measures</th><th>Consequence</th></tr>
<tr><td>Ambient water quality</td><td>Change in water quality</td><td rowspan="4">EPO3: Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.

EPO4: Undertake the Amulet Development in a manner that will 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 results.

EPO11: Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and communities, including life cycle and spatial distribution.

EPO17: Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.</td><td rowspan="4">CM21: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness.

CM22: Solids 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.

CM23: Drilling and cementing procedures to standard industry practices will be developed that will describe specific well locations, design and fluid volumes.

CM24: Whole SBM will not be discharged into the marine environment.

CM25: Drilling of the conductor section will use seawater and/or WBM only.</td><td>Minor</td></tr>
<tr><td>Ambient sediment quality</td><td>Change in sediment quality</td><td>Minor</td></tr>
<tr><td rowspan="2">Benthic habitats and communities</td><td>Change in habitat</td><td>Minor</td></tr>
<tr><td>Injury / mortality to fauna</td><td>Minor</td></tr>
</table>

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 Amulet 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 per well). Once the main conductor has been installed, all further displaced fluids will be returned to the MODU.

Upon completion of 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).

If extended reach wells are feasible for Talisman, and the wells are drilled through the conductor deck at the MOPU, the cement discharge during drilling will be at the well entry location adjacent to the proposed MOPU location. If the subsea tieback option is used, the MODU will drill on location at each Talisman well, meaning cement will be discharged at each Talisman well location.

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 MOPU (or MODU).

7.1.7.2 Impact Analysis and Evaluation

Activities involving cement at the Amulet 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 7-47 identifies the potential impacts to receptors as a result of a planned discharge of cement at the Amulet 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 7-48 provides a summary and justification for those receptors not evaluated further.

Table 7-47 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 7-48 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 Amulet 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 per well (see Table 7-50). Allowing for the 10 m x 10 m Amulet well footprint, this gives a footprint of 0.011 km^2 for the Amulet wells, and another 0.008 km^2 for each Talisman well (if the subsea tieback option is selected). Using the same assumptions for cement overspill, this gives a total footprint of 0.027 km^2. 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. Ten state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show minimal and intermittent commercial fishing activity is expected to occur within the planned activities areas for the Amulet Development. Any fishing effort that may occur is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF). 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 7-49 provides a detailed evaluation of the impact of planned discharges of cement to physical receptors.

Table 7-49 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 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 three Amulet 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. If the subsea tieback option is used for Talisman, there will also be cement discharged at that location during drilling, giving another 0.008 km^2 for each Talisman well. Using the same assumptions for cement overspill, this gives a total footprint of 0.027 km^2. This is well within the 5 km radius of 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 7-50 provides a detailed evaluation of the impact of a planned discharge of cement to ecological receptors.

Table 7-50 Impact and Risk Assessment for Ecological Receptors from a Planned Discharge of Cement

Benthic Habitats and Communities ✓
<u>Change in habitat</u> Activities associated with the Amulet Development will result in a change in habitat due to the localised and small-scale overspill of cement. The majority of seabed substrates within WA-8-L are expected to be characterised by sediment infaunal communities and sparsely distributed epibenthic fauna (Santos 2018). The extents of smothering are discussed above in *Change in sediment quality*, with affects localised to within ~60 m of the drilling site (including well separation), giving a total footprint of 0.011 km^2 for the Amulet wells, and potentially another 0.008 km^2 for each Talisman well (if the subsea tieback option is selected). 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)**. <u>Injury / mortality to fauna</u>

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). There are no EPBC listed threatened benthic communities or species present within the Project Area. Seabed surveys undertaken ~50 km and ~112 km from the Project Area (Apache 2012 and RPS 2011 respectively) found that there was a low abundance, high variability and diversity of infauna dominated by polychaetes and crustaceans. Santos' WAS-8-L Production Equipment Abandonment EP (2018) stated that the macrobenthos of the permit area most likely consist of sponges, polychaete worms, bivalves and echinoderms, and microorganisms. A lack of seabed features within the Amulet Development also suggests sparse benthic assemblages. The extents of smothering have been discussed above, with affects localised to within ~60 m of the drilling site, giving a total footprint of 0.011 km^2 for the Amulet wells (including the 10 m separation), and potentially another 0.008 km^2 for each Talisman well (if the subsea tieback option is selected). 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 and is considered **acceptable** when assessed against the criteria in Table 7-51.

Table 7-51 Demonstration of Acceptability for Planned Discharge – Cement

Receptor	Demonstration of Acceptability		
Water quality	**Acceptable level of impact**		
	With respect to Planned Discharge – Cement, the Amulet Development will not result in significant impacts to water quality identified as potentially affected, defined as a possibility that it will (Section 6.6): • result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		
	Acceptability assessment		
	Principles of ESD	The proposed EPO's for the Amulet Development are consistent with the principles of ESD. With respect to potential impacts to *all receptors* from Planned Discharge – Cement the relevant principles are: • Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. • 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.	
	Internal context	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards. With respect to potential impacts to *all receptors* from Planned Discharge – Cement, this specifically includes: • KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)	
	External context	The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders. With respect to potential impacts to *all receptors* from Planned Discharge – Cement, no specific concerns were raised during stakeholder consultation with relevant persons.	
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Cement from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. With respect to potential impacts to *water quality* from Planned Discharge – Cement, no specific other requirements have been identified as relevant.	
	Summary of impact assessment		**Consequence level**

Receptor	Demonstration of Acceptability		
	The impacts on *water quality* from Planned Discharge – Cement include: • The risk of chemical toxicity is most likely to occur at the seabed as part of overspill of mixed cement during drilling operations, however additives to the dry cement mix are of low toxicity. • Discharges of cement are highly localised and temporary based on rapid deposition rates, and once hardened, cement is inert.		Minor
	Statement of acceptability		
	Based on an assessment against the defined acceptable levels, the impacts on *water quality* from Planned Discharge – Cement is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO3:** Undertake the Amulet Development in a manner that does not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health		
Sediment quality	**Acceptable level of impact**		
	With respect to Planned Discharge – Cement, the Amulet Development will not result in significant impacts to *sediment quality* identified as potentially affected, defined as a possibility that it will (Section 6.6): • result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. • 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.		
	Acceptability assessment		
	Principles of ESD	Refer to details in *water quality* assessment	
	Internal context	Refer to details in *water quality* assessment	
	External context	Refer to details in *water quality* assessment	
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be	

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="6"></td><td></td><td colspan="2">managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Cement from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to sediment quality from Planned Discharge – Cement, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Consequence level</td></tr>
<tr><td colspan="2">The impacts on sediment quality from Planned Discharge – Cement include:
• planned cement discharges from overflow during drilling operations may affect the seabed around the well to a radius of ~10 m–50 m
• the seabed entry point of all the three Amulet wells will be within an ~10 m by 10 m footprint. Assuming a conservative maximum impact radius of 50 m this gives a footprint of 0.011 km^2. If the subsea tieback option is used for Talisman, there will also be cement discharged at that location during drilling, giving another 0.008 km^2 for each Talisman, giving a total footprint of 0.027 km^2. This is well within the 5 km buffer of 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, with no potential for chronic exposure.</td><td>Minor</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on sediment quality from Planned Discharge – Cement is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO17: Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">Benthic habitats and</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Planned Discharge – Cement, the Amulet Development will not result in significant impacts to benthic habitat and communities identified as potentially affected, defined as a possibility that it will (Section 6.6):</td></tr>
</table>

Receptor	Demonstration of Acceptability		
communities	• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		
	Acceptability assessment		
	Principles of ESD	Refer to details in *water quality* assessment	
	Internal context	Refer to details in *water quality* assessment	
	External context	Refer to details in *water quality* assessment	
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions – Light from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.	
	Summary of impact assessment		**Consequence level**
	The impacts on benthic habitat and communities from Planned Discharge – Cement include: • 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, the direct disturbance footprint around the Amulet wells is 0.011 km^2. If the subsea tieback option is used for Talisman, there will also be cement discharged at that location during drilling, giving another 0.008 km^2 for each Talisman, giving a total footprint of 0.027 km^2. This is well within the 5 km buffer of the Project Area. • 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.		Minor
	Statement of acceptability		
	Based on an assessment against the defined acceptable levels, the impacts on benthic habitat and communities from Planned Discharge – Cement is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.		

Receptor	Demonstration of Acceptability
	• the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO4:** Undertake the Amulet Development in a manner that will 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 results. • **EPO11:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and communities, including life cycle and spatial distribution.

A summary of the impact analysis and evaluation, including adopted control measures adopted and EPOs, is provided in Table 7-52.

Table 7-52 Summary of Impact Assessment for Planned Discharge – Cement

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM23**: 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	**EPO4:** Undertake the Amulet Development in a manner that will 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 results.		Minor
Benthic habitats and communities	Change in habitat	**EPO11:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and communities, including life cycle and spatial distribution.		Minor
	Injury / mortality to fauna	**EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Minor

7.1.8 Planned Discharge – Commissioning and Operational Fluids

7.1.8.1 Aspect Source

Throughout the Amulet Development, commissioning and operational fluids will be discharged to the marine environment during these activities:

Installation, hook-up and commissioning	Talisman subsea tieback; flowlines; FSO; MOPU
Operations	hydrocarbon extraction
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 MOPU export 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).

If the subsea tieback option is used for Talisman, the 3.5 km production flowline and jumper connections will also be leak tested after installation. Commissioning of the Talisman subsea tieback system would involve a planned discharge of ~130 m^3 of commissioning fluids (allowing for double the inventory). The base case is for commissioning fluid to be displaced to the FSO via the MOPU for processing on commencement of production, but it may be discharged to the marine environment in a single event.

Operations

If the Talisman subsea tieback option is used, there will be up to two subsea trees and a manifold located at the Talisman site. Subsea control fluids are supplied via the umbilicals and are used for functioning of the choke valves, providing lubrication and corrosion protection. During routine valve operations, small quantities of hydraulic fluid are discharged to the marine environment, at or near the seabed. Volumes are estimated at about 2 L per valve actuation, occurring several times per day (i.e. not continuous).

The Amulet wells use 'dry' trees, above the MOPU conductor deck, which do not release any fluid to the marine environment. If the extended reach drilling option is used for Talisman, there won't be any discharge of operational fluids to the marine environment during operations.

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 MOPU flowline, marine hose and export hose respectively).

If the Talisman subsea tieback option is selected, ~135 m^3 commissioning fluid discharged (allowing for double the inventory) from the Talisman production flowline and jumpers.

7.1.8.2 Impact Analysis and Evaluation

Planned discharges of commissioning and operational fluids during the Amulet 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 7-53 identifies the potential impacts to receptors as a result of a discharge of commissioning and operational fluids from the Amulet 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 7-54 provides a summary and justification for those receptors not evaluated further.

Table 7-53 Receptors Potentially Impacted by Planned Discharge – Commissioning and Operational 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*	*X*	
Changes to the functions, interests or activities of other users								*X*

Table 7-54 Justification for Receptors Not Evaluated Further

Plankton	***X***
<u>Injury/mortality to fauna</u> 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 Amulet 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 and operational 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***
<u>Injury/mortality to fauna</u> 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 and operational fluid discharges. There are also no Management Plans, Recovery Plans or Conservation Advice related to benthic habitats and communities within the Project Area. The majority of seabed substrates within WA-8-L are expected to be characterised by sediment infaunal communities and sparsely distributed epibenthic fauna. Seabed surveys undertaken ~50 km and ~112 km from the Project Area (Apache 2012 and RPS 2011 respectively) found that there was a low abundance, high variability and diversity of infauna dominated by polychaetes and crustaceans. Santos' WA-8-L Production Equipment Abandonment EP (2018) stated that the macrobenthos of the permit area most likely consist of sponges, polychaete worms, bivalves and echinoderms, and microorganisms.	

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 and operational 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***
<u>Injury/mortality to fauna</u> Potential impacts to fish, marine mammals and marine reptiles from commissioning and operational fluid discharges are expected to be limited to avoidance of the discharge plume, which will be localised to the flowline and risers, and Talisman subsea trees and manifold. The EPBC PMST lists three species of shark as Vulnerable/Migratory (Green Sawfish, White Shark and Whale Shark) that are likely to occur within the Project Area which is also situated within a BIA foraging area for the Whale Shark. The approved Conservation Advice for Whale Sharks (TSSC 2015d) states that the main threat to the species occurs outside Australian waters. Within Australian waters, habitat disruption from mineral exploration, production and transportation is listed as a 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. 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 and operational fluid discharges within the Amulet Project Area will be localised and rapidly diluted, and fish, marine mammals and marine reptile species will be transitory in nature, impacts from these discharges are not expected, and are not evaluated further.	
Commercial Fisheries	***X***
<u>Changes to the functions, interests or activities of other users</u> As impacts to fish have not been expected from planned discharges of commissioning and operational fluids, indirect impacts to commercial fisheries are not expected. Marine fauna found in the water column, including commercial fishing species, are expected to actively avoid discharge plumes and associated turbidity and toxicity within the water column. Ten state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show minimal and intermittent commercial fishing activity is expected to occur within the planned activities areas for the Amulet Development. Any fishing effort that may occur is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF). Commissioning and operational 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 and operational fluids are not expected, and have not been evaluated further.	

Impacts to receptors are assessed below, by receptor type.

7.1.8.2.1 Physical Receptors

Physical receptors with the potential to be impacted as a result of discharges of commissioning and operational fluids include:

- Ambient water quality
- Ambient sediment quality.

Table 7-55 provides a detailed evaluation of the impact or risk of commissioning and operational fluids to physical receptors.

Table 7-55 Impact and Risk Assessment for Physical Receptors from Planned Discharges – Commissioning and Operational Fluids

Ambient Water Quality ✓
<u>Change in water quality</u> A planned release of commissioning and operational fluids may result in an impact on ambient water quality, as discharges may include hydraulic fluid, 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 Amulet Development are insignificant compared to these modelled studies. Flowline specifications are still in the design stage. The volume of commissioning fluid is expected to be ~70 m^3, allowing for double the total inventory. If the subsea tieback option is used for Talisman, there would be an additional ~135 m^3 commissioning fluid discharged (allowing for double the inventory) from the Talisman production flowline and jumpers. 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. If the Talisman subsea tieback option is selected, operational fluids (i.e. hydraulic fluid, subsea control fluids) will be discharged at small volumes (2 L) several times per day from during valve actuations, for the duration of the operations phase (1.5-4.5 years). Although relatively frequent, the very small volumes represent a negligible change in water quality. Given the details above, the consequence of commissioning and operational fluids causing a change in ambient water quality has been assessed as **Minor (1)**, as single event discharges during commissioning and decommissioning phases, and very small discharges during operations, combined with rapid mixing by ocean currents will ensure discharges are localised and temporary.
Ambient Sediment Quality ✓
A planned release of commissioning and operational 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 and operational fluids causing a change in ambient sediment quality has been assessed as **Minor (1)**, given that discharges will be localised, infrequent or of very small volumes, and will be rapidly diluted.

7.1.8.3 Consequence and Acceptability

The consequence of Planned Discharge – Commissioning and Operational Fluids has been evaluated as **Minor (1)** for all potentially impacted receptors and is considered **acceptable** when assessed against the criteria in Table 7-56.

Table 7-56 Demonstration of Acceptability for Planned Discharge – Commissioning and Operational Fluids

Receptor	Demonstration of Acceptability	
Water quality	**Acceptable level of impact**	
	With respect to Planned Discharge – Commissioning and Operational Fluids, the Amulet Development will not result in significant impacts to water quality identified as potentially affected, defined as a possibility that it will (Section 6.6): • result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	
	Acceptability assessment	
	Principles of ESD	The proposed EPO's for the Amulet Development are consistent with the principles of ESD. With respect to potential impacts to *all receptors* from Planned Discharge – Commissioning and Operational Fluids the relevant principles are: • Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. • 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.
	Internal context	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards. With respect to potential impacts to *all receptors* from Planned Discharge – Commissioning and Operational Fluids, this specifically includes: • KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)
	External context	The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders. With respect to potential impacts to *all receptors* from Planned Discharge – Commissioning and Operational Fluids, no specific concerns were raised during stakeholder consultation with relevant persons.
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Commissioning and Operational Fluids from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="4"></td><td colspan="2">With respect to potential impacts to water quality from Planned Discharge – Commissioning Fluids, no specific other requirements have been identified as relevant.</td></tr>
<tr><td>Summary of impact assessment</td><td>Consequence level</td></tr>
<tr><td>The impacts on water quality from Planned Discharge – Commissioning and Operational Fluids include:
discharges of commissioning fluids will be of much smaller volumes (~70 m³ and an additional 130 m³ if the Talisman subsea tieback option is selected) compared to other pipelines within the North West Shelf of significantly longer length.
the biocides routinely used in the oil and gas industry for commissioning do not bioaccumulate and are expected to consumed by microorganisms once discharged.
discharges of operational fluids will be of very small volumes (2 L), although relatively frequent, for the duration of operations (1.5-4.5 years).
discharges will cause a localised and temporary reduction in water quality.</td><td>Minor</td></tr>
<tr><td colspan="2">Statement of acceptability
Based on an assessment against the defined acceptable levels, the impacts on water quality from Planned Discharge – Commissioning and Operational Fluids is considered acceptable, given that:
the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
EPO3: Undertake the Amulet Development in a manner that does not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health</td></tr>
<tr><td>Sediment quality</td><td colspan="2">Acceptable level of impact
With respect to Planned Discharge – Commissioning and Operational Fluids, the Amulet Development will not result in significant impacts to sediment quality identified as potentially affected, defined as a possibility that it will (Section 6.6):
result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
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></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="12"></td><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in water quality assessment</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in water quality assessment</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in water quality assessment</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Commissioning Fluids from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to sediment quality from Planned Discharge – Commissioning and Operational Fluids, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Consequence level</td></tr>
<tr><td colspan="2">The impacts on sediment quality from Planned Discharge – Commissioning and Operational Fluids include:
• discharges of commissioning fluids will be of much smaller volumes (~70 m^3 and an additional 130 m^3 if the Talisman subsea tieback option is selected) compared to other pipelines within the North West Shelf of significantly longer length.
• the biocides routinely used in the oil and gas industry for commissioning do not bioaccumulate and are expected to consumed by microorganisms once discharged.
• discharges of operational fluids will be of very small volumes (2 L), although relatively frequent, for the duration of operations (1.5-4.5 years).
• 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.
• discharges will cause a localised and temporary reduction in sediment quality.</td><td>Minor</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on sediment quality from Planned Discharge – Commissioning and Operational Fluids is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)</td></tr>
</table>

Receptor	Demonstration of Acceptability
	• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.

A summary of the impact analysis and evaluation, including adopted control measures adopted and EPOs, is provided in Table 7-57.

Table 7-57 Summary of Impact Assessment for Planned Discharge – Commissioning Fluids

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM21**: 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	**EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		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 Amulet 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 Amulet 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 Amulet Development is 185 m^3/hr and corresponds to when production is concurrent from both the Amulet and Talisman fields.

There is only a single discharge of PFW for the Amulet Development, as all fluids from the subsea wells at Talisman will be transferred to the MOPU at Amulet for processing and discharge. The discharge point will be at or below sea level, from a pipe within one of the support legs of the MOPU. The depth depends on the final design of the MOPU.

The maximum temperature of the PFW discharge would be 65°C. Residual hydrocarbon (Oil-in-Water [OIW]) will be discharged as part of the PFW discharge stream. For the purpose of impact assessment, OIW of ≤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 2020c; 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 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 residual hydrocarbons and any temperature differential. The following 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.

Model simulations were run for the worst-case discharge (185 m^3/hr at 65 °C) using variations in discharge depth (from near-surface to near-seabed alternatives) and ambient current conditions to evaluate the differences in plume mixing behaviour and spatial extent to reach environmental thresholds (Table 7-58). Final configuration of the PFW discharge (including volume, temperature and discharge depth) from the MOPU will occur during the FEED phase.

Table 7-58 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	0 m	30 m	75 m
Water depth	85 m		
Discharge characteristics			
Flow type	Continuous		
Flow rate	185 m^3/hour (0.051 m^3/s)		
Temperature	65 °C		
Salinity	37		
Oil-in-Water (OIW)	29 mg/L		

Source: Xodus Group 2020c

The discharge modelling (Xodus Group 2020c) showed these mixing behaviours for PFW from the MOPU:

- The horizontal extent of the near-field mixing zone (i.e. the initial dilution phase) varies between ~3 m (Table 7-59) to ~261 m (Table 7-61) from the release location, depending on the combination of discharge and ambient conditions.
- The PFW discharge is initially buoyant compared to ambient seawater, but for discharges at depths (e.g. ≥30 m) the discharged PFW plume is not always 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 10 m above seabed).
- The distance required to meet the hydrocarbon threshold varies between ~22 m (Table 7-59) and ~1,215 m (Table 7-61) from the release location. The width of the PFW plume varies between ~7 m (Table 7-61) to ~67 m (Table 7-60). The hydrocarbon threshold is

met under either near-field or far-field mixing depending on the combination of discharge and ambient conditions.

- The distance required to meet the temperature threshold is <1 m (Table 7-59, Table 7-60, Table 7-61). The temperature threshold is met under near-field mixing for all combinations of discharge and ambient conditions.

Therefore, the maximum horizontal mixing zone predicted to be needed for the PFW discharge from the MOPU for the Amulet Development is 1,215 m (Figure 7-21).

Table 7-59 Mixing Behaviour of PFW Discharge Under Weak (0.05 m/s) Ambient Currents

Discharge depth (below sea level)	0 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~34	~455	~350
Approximate horizontal extent of near-field mixing	~3 m	~23 m	~23 m
Hydrocarbon threshold			
Approximate horizontal distance to reach hydrocarbon (70.5 µg/L) threshold	~295 m	~22 m	~75 m
Approximate width of plume at this horizontal distance	~67 m	~22 m	~30 m
Type of mixing required to dilute PFW to meet the hydrocarbon threshold	NF + FF	NF	NF + FF
Temperatures threshold			
Approximate horizontal distance to reach temperature (≤3 °C) threshold	<1 m	<1 m	<1 m
Temperature (≤3 °C) threshold met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes
Type of mixing required to dilute PFW to meet the temperature threshold	NF	NF	NF

NF = near-field, FF = far-field

Table 7-60 Mixing Behaviour of PFW Discharge Under Average (0.2 m/s) Ambient Currents

Discharge depth (below sea level)	0 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~69	~223	~962
Approximate horizontal extent of near-field mixing	~12 m	~36 m	~107 m
Hydrocarbon threshold			
Approximate horizontal distance to reach hydrocarbon (70.5 µg/L) threshold	~735 m	~340 m	~38 m
Approximate width of plume at this horizontal distance	~39 m	~22 m	~12 m
Type of mixing required to dilute PFW to meet the hydrocarbon threshold	NF + FF	NF + FF	NF
Temperatures threshold			
Approximate horizontal distance to reach temperature (≤3 °C) threshold	<1 m	<1 m	<1 m
Temperature (≤3 °C) threshold met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes

Discharge depth (below sea level)	0 m	30 m	75 m
Type of mixing required to dilute PFW to meet the temperature threshold	NF	NF	NF

NF = near-field, FF = far-field

Table 7-61 Mixing Behaviour of PFW Discharge Under Strong (0.5 /s) Ambient Currents

Discharge depth (below sea level)	0 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~85	~310	~1,253
Approximate horizontal extent of near-field mixing	~26 m	~96 m	~261 m
Hydrocarbon threshold			
Approximate horizontal distance to reach hydrocarbon (70.5 µg/L) threshold	~1,215 m	~440 m	~75 m
Approximate width of plume at this horizontal distance	~22 m	~11 m	~7 m
Type of mixing required to dilute PFW to meet the hydrocarbon threshold	NF + FF	NF + FF	NF
Temperatures threshold			
Approximate horizontal distance to reach temperature (≤3 °C) threshold	<1 m	<1 m	<1 m
Temperature (≤3 °C) threshold met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes
Type of mixing required to dilute PFW to meet the temperature threshold	NF	NF	NF

NF = near-field, FF = far-field

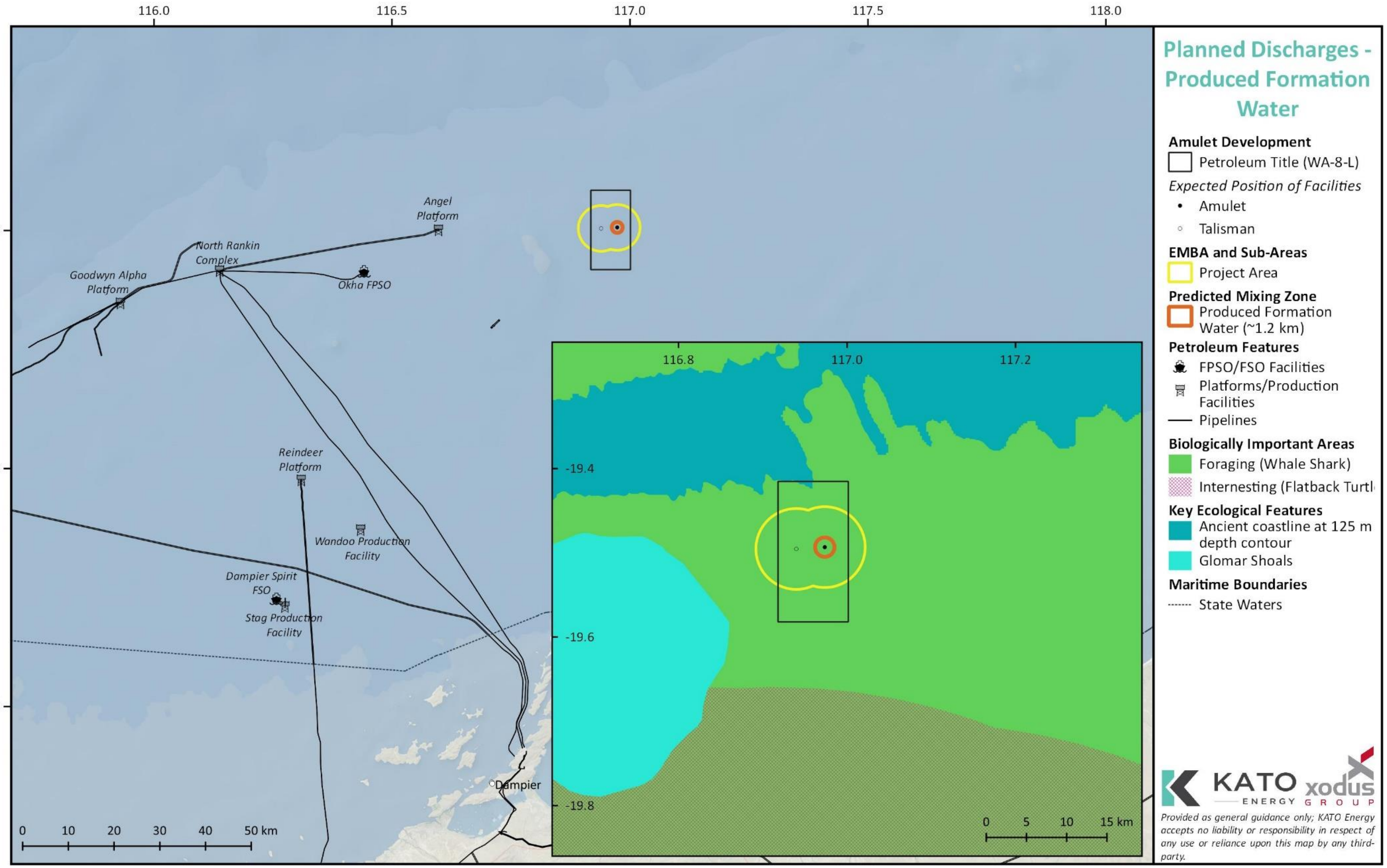


Figure 7-21 Predicted Mixing Zone for Produced Formation Water Discharge from the Amulet Development

7.1.9.2 Impact Analysis and Evaluation

PFW discharged to the marine environment during the Amulet Development has the potential to result in these impacts:

- change in water quality
- change in habitat
- change in sediment quality.

As a result of a change in water quality, further impacts may occur including:

- injury/mortality to fauna.

Table 7-62 identifies the potential impacts to receptors as a result of discharges of PFW from the Amulet 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 7-63 provides a summary and justification for those receptors not evaluated further.

Table 7-62 Receptors Potentially Impacted by Planned Discharge – Produced Formation Water

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				*X*				
Injury / mortality to fauna			✓	*X*	*X*	*X*	*X*	
Changes to the functions, interests or activities of other users								*X*

Table 7-63 Justification for Receptors Not Evaluated Further

Fish, Marine Mammals and Marine Reptiles	***X***
<u>Injury/mortality to fauna</u> 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) • 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, mammals and reptiles found in either surface waters or the water column. Impacts to pelagic fish are likely to be caused by exposure to dissolved hydrocarbons (e.g. BTEX, PAHs etc.) 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.

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 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 planned discharges of PFW predicted a maximum horizontal distance of ~1,215 m and a maximum plume width of ~67 m until the hydrocarbon threshold is reached; the temperature threshold was typically met at very low (<1 m) distances (Table 7-59, Table 7-60,

Table 7-61). Therefore, the predicted area of exposure and mixing zone for the PFW discharge is well within the defined Project Area for the Amulet Development.

Given the results of the modelling, any potential impacts to water quality are expected to be spatially limited. Marine fauna (fish, marine mammals and marine reptiles) are all highly mobile and as such, any interaction with this relatively thin plume of PFW discharge is expected to be a transitory nature only. Therefore, impacts to fish, marine mammals and marine reptiles from PFW discharges are not expected, and have not been evaluated further.

Benthic habitats and communities	***X***

Change in habitat

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. Based on regional presence, 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 benthic habitats and communities that are within the mixing zone for the PFW discharge are widely distributed in the region and are not considered to be of high conservation value.

The discharge of PFW will not physically modify, destroy, fragment, isolate or disturb benthic habitats and communities.

There are no Management Plans, Recovery Plans or Conservation Advice related to benthic habitats and communities within the Project Area.

Injury/mortality to fauna

As a result of a change in sediment quality, there is potential for further impacts to benthic receptors resulting from the accumulation of potential contaminants in the sediment; or from a change in water quality.

Modelling of the PFW discharge predicts that the plume from the deepest discharge point (i.e. 10 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 (evaluated in Table 7-64).

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. Given the results of the modelling and that only inert contaminants are expected to settle out of the water column to the seabed, impacts to benthic habitats and communities are not expected, and have not been evaluated further. Summary PFW discharges will not result in a change to, and are unlikely to result in 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 PFW are not expected, and have not been evaluated further.
Commercial Fisheries ***X***
<u>Changes to the functions, interests or activities of other users</u> While there are multiple commercial fisheries with management areas that overlap the Amulet Development, records of fishing effort (for both Commonwealth and State managed fisheries) indicate little to no fishing activity is expected to occur within the Project Area of the Amulet Development (Sections 5.5.2.1, 1.1.1.1). Any potential impacts to water quality are expected to be limited to within ~1,215 m of the discharge source, and within a plume of a maximum width of ~67 m. This area of exposure is well within the defined Project Area for the Amulet Development. However, as impacts to fish are not expected from planned discharges of PFW, indirect impacts to commercial fisheries are not expected. 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 PFW include:

- ambient water quality.

Table 7-64 provides a detailed evaluation of the impact of PFW discharge activities to physical receptors.

Table 7-64 Impact and Risk Assessment for Physical Receptors from Planned Discharge – Produced Formation Water

Ambient Water Quality ✓
<u>Change in water quality</u> 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 point. 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). 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 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 planned discharges of PFW predicted a maximum horizontal distance of ~1,215 m and a maximum plume width of ~67 m until the hydrocarbon threshold is reached; the temperature threshold was typically met at very low (<1 m) distances (Table 7-59, Table 7-60, Table 7-61). Therefore, the predicted area of exposure and mixing zone for the PFW discharge is well within the defined Project Area for the Amulet Development. Therefore, any potential impacts to water quality are expected to be limited to within ~1,215 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 **Minor (1)**, 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 ✓
<u>Change in sediment quality</u> Modelling of the PFW discharge predicts that the plume from the deepest discharge point (i.e. 10 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 relatively high despite previous petroleum activities within the area. Sediment condition is 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 7-65 provides a detailed evaluation of the impact of PFW on ecological receptors.

Table 7-65 Impact and Risk Assessment for Ecological Receptors from Planned Discharge – Produced Formation Water

Plankton ✓
<u>Injury/mortality to fauna</u> 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 discharge location. 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 planned discharges of PFW predicted a maximum horizontal distance of ~1,215 m and a maximum plume width of ~67 m until the hydrocarbon threshold is reached (Table 7-59, Table 7-60,

Table 7-61). Therefore, it is expected that 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 of planned discharges of PFW predicted the temperature threshold was typically met at very low (<1 m) distances (Table 7-59, Table 7-60,

Table 7-61). Therefore, impacts to plankton species by temperature variations are expected to be negligible and are not discussed further.

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 **Minor (1)**, 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 **Minor (1)** for all receptors and is considered **acceptable** when assessed against the criteria in Table 7-66.

Table 7-66 Demonstration of Acceptability for Planned Discharge – Produced Formation Water

Receptor	Demonstration of Acceptability		
Water quality	**Acceptable level of impact**		
	With respect to Planned Discharge – Produced Formation Water, the Amulet Development will not result in significant impacts to water quality identified as potentially affected, defined as a possibility that it will (Section 6.6): • result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		
	Acceptability assessment		
	Principles of ESD	The proposed EPO's for the Amulet Development are consistent with the principles of ESD. With respect to potential impacts to *all receptors* from Planned Discharge – Produced Formation Water the relevant principles are: • Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. • 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.	
	Internal context	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards. With respect to potential impacts to *all receptors* from Planned Discharge – Produced Formation Water, this specifically includes: • KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)	
	External context	The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders. With respect to potential impacts to *all receptors* from Planned Discharge – Produced Formation Water, no specific concerns were raised during stakeholder consultation with relevant persons.	
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Produced Formation Water from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. With respect to potential impacts to *water quality* from Planned Discharge – Produced Formation Water, no specific other requirements have been identified as relevant.	
	Summary of impact assessment		**Consequence level**

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="3"></td><td colspan="2">The impacts on water quality from Planned Discharge – Produced Formation Water include:
• modelling of planned discharges of PFW predicted a maximum horizontal distance of 1,215 m and a maximum plume width of 67 m until the hydrocarbon threshold is reached; the temperature threshold was typically met at very low (<1 m) distances. This is within the 5 km Project Area defined for all 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 Amulet 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.</td><td>Minor</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on water quality from Planned Discharge – Produced Formation Water is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO3: Undertake the Amulet Development in a manner that does not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health</td></tr>
<tr><td rowspan="6">Sediment quality</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Planned Discharge – Produced Formation Water, the Amulet Development will not result in significant impacts to sediment quality identified as potentially affected, defined as a possibility that it will (Section 6.6):
• result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
• 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></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in water quality assessment</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in water quality assessment</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in water quality assessment</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="7"></td><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Produced Formation Water from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to sediment quality from Planned Discharge – Produced Formation Water, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Consequence level</td></tr>
<tr><td colspan="2">The impacts on sediment quality from Planned Discharge – Produced Formation Water include:
• modelling of planned discharges of PFW predicted a maximum horizontal distance of 1,215 m and a maximum plume width of 67 m until the hydrocarbon threshold is reached; the temperature threshold was typically met at very low (<1 m) distances. This is within the 5 km Project Area.
• 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.</td><td>Minor</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on sediment quality from Planned Discharge – Produced Formation Water is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO17: Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.</td></tr>
<tr><td rowspan="2">Plankton</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Planned Discharge – Produced Formation Water, the Amulet Development will not result in significant impacts to plankton identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.</td></tr>
</table>

Receptor	Demonstration of Acceptability		
	Acceptability assessment		
	Principles of ESD	Refer to details in *water quality* assessment	
	Internal context	Refer to details in *water quality* assessment	
	External context	Refer to details in *water quality* assessment	
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Emissions – Light from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.	
	Summary of impact assessment		**Consequence level**
	The impacts on benthic habitat and communities from Planned Discharge – Produced Formation Water include: • 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.		Minor
	Statement of acceptability		
	Based on an assessment against the defined acceptable levels, the impacts on benthic habitat and communities from Planned Discharge – Produced Formation Water is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO18:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of plankton, including its life cycle and spatial distribution.		

A summary of the impact analysis and evaluation, including adopted control measures adopted and EPOs, is provided in Table 7-67.

Table 7-67 Summary of Impact Assessment for Planned Discharge – Produced Formation Water

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM26**: A management framework for produced formation water discharges will be developed.	Minor
Ambient sediment quality	Change in sediment quality	**EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Minor
Plankton	Injury / mortality to fauna	**EPO18:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of plankton, including its life cycle and spatial distribution.		Minor

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 Amulet 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 Amulet 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 duration of the Amulet 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 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.

If the subsea tieback option is selected for Talisman, a MODU may drill up to two Talisman wells at that location (Section 3.3.3, 4.3.2). Therefore, there may also be a CW discharge from this location, for the duration of drilling only.

The maximum temperature of the CW discharge would be 65 °C. Residual chlorine will be discharged as part of the CW discharge stream. For the purpose of impact assessment, a residual chlorine content of 2,000 ppb has been assumed (actual discharge concentrations will be reduced to ALARP and will be determined during FEED).

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 Amulet Development.

7.1.10.1.1 Cooling Water – Modelling and Exposure Assessment

VPLUMES is a set of mixing zone models developed by the 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 2020c; 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 the CW discharge, the critical parameters that have the potential to impact the marine environment are the residual chlorine (from treatment to prevent biofouling of pipework) and the temperature differential (i.e. heat). 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 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.

Model simulations were run for the worst-case discharge (170 m^3/hr at 65 °C) using variations in discharge depth (from near-surface to near-seabed alternatives) and ambient current conditions to evaluate the differences in plume mixing behaviour and spatial extent to reach environmental thresholds (Table 7-68). Final configuration of the CW discharge (including volume, temperature and discharge depth) from the MOPU will occur during the FEED phase.

Table 7-68 CW Discharge Modelling Parameters

Parameter	Description / Value		
Outlet characteristics			
Number of ports	1		
Port orientation	Vertical down		
Port diameter	10" (0.25 m)		
Port depth	2 m	30 m	75 m
Water depth	85 m		
Discharge characteristics			
Flow type	Continuous		
Flow rate	170 m^3/hour (0.047 m^3/s)		
Temperature	65 °C		
Salinity	35		
Residual Chlorine	2,000 ppb		

The discharge modelling (Xodus Group 2020c) showed these mixing behaviours for CW from the MOPU:

- The horizontal extent of the near-field mixing zone (i.e. the initial dilution phase) varies between ~1 m (Table 7-69) to ~760 m (Table 7-71) from the release location, depending on the combination of discharge and ambient conditions.
- The CW discharge is initially buoyant compared to ambient seawater, but for discharges at depths (e.g. ≥30 m) the discharged CW plume is not always 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 10 m above seabed).

- The distance required to meet the chlorine threshold varies between ~44 m (Table 7-70) and ~1,960 m (Table 7-71) from the release location. The width of the CW plume varies between ~9 m (Table 7-71) to ~149 m (Table 7-69). The chlorine threshold is met under either near-field or far-field mixing depending on the combination of discharge and ambient conditions.
- The distance required to meet the temperature threshold varies between <2 m and ~15 m (Table 7-69). The temperature threshold is predominantly met under near-field mixing. One simulation required some far-field mixing to occur to meet the temperature threshold (Table 7-69), however the threshold was still met well within the default 100 m distance defined in the EHS Guidelines (IFC 2015). This default part of the guideline is considered appropriate for this simulation 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 mixing zone predicted to be needed for the CW discharge from the MOPU for the Amulet Development is 1,960 m (Figure 7-22).

If the subsea tieback option is selected for Talisman, a MODU may drill up to two Talisman wells at that location (Section 3.3.3, 4.3.2). A MODU only discharges CW from its machinery cooling system; there is no process CW discharge, since all processing will be done on the MOPU. Therefore the discharge volume at Talisman would be less than that modelled for the MOPU at Amulet. However, the same predicted mixing zone (i.e. 1,960 m) has been applied at Talisman for the purposes of conservative impact assessment (Figure 7-22).

Table 7-69 Mixing Behaviour of CW Discharge Under Weak (0.05 m/s) Ambient Currents

Discharge depth (below sea level)	2 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~11	~289	~277
Approximate horizontal extent of near-field mixing	~1 m	~11 m	~18 m
Chlorine threshold			
Approximate horizontal distance to reach chlorine (3 ppb) threshold	~555 m	~150 m	~180 m
Approximate width of plume at this horizontal distance	~149 m	~43 m	~53 m
Type of mixing required to dilute CW to meet the chlorine threshold	NF + FF	NF	NF + FF
Temperatures threshold			
Approximate horizontal distance to reach temperature (≤3 °C) threshold	~15 m	<2 m	<2 m
Temperature (≤3 °C) threshold met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes
Type of mixing required to dilute CW to meet the temperature threshold	NF + FF	NF	NF

NF = near-field, FF = far-field

Table 7-70 Mixing Behaviour of CW Discharge Under Average (0.2 m/s) Ambient Currents

Discharge depth (below sea level)	2 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~34	~2,064	~906
Approximate horizontal extent of near-field mixing	~5 m	~110 m	~99 m
Chlorine threshold			

Discharge depth (below sea level)	2 m	30 m	75 m
Approximate horizontal distance to reach chlorine (3 ppb) threshold	~1,440 m	~44 m	~58 m
Approximate width of plume at this horizontal distance	~85 m	~14 m	~14 m
Type of mixing required to dilute CW to meet the chlorine threshold	NF + FF	NF	NF
Temperatures threshold			
Approximate horizontal distance to reach temperature (≤3 °C) threshold	<3 m	<3 m	<3 m
Temperature (≤3 °C) threshold met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes
Type of mixing required to dilute CW to meet the temperature threshold	NF	NF	NF

NF = near-field, FF = far-field

Table 7-71 Mixing Behaviour of CW Discharge Strong (0.5 m/s) Ambient Currents

Discharge depth (below sea level)	2 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~70	~5,446	~1,230
Approximate horizontal extent of near-field mixing	~17 m	~760 m	~247 m
Chlorine threshold			
Approximate horizontal distance to reach chlorine (3 ppb) threshold	~1,960 m	~86 m	~96 m
Approximate width of plume at this horizontal distance	~38 m	~9 m	~9 m
Type of mixing required to dilute CW to meet the chlorine threshold	NF + FF	NF	NF
Temperatures threshold			
Approximate horizontal distance to reach temperature (≤3 °C) threshold	<5 m	<8 m	<5 m
Temperature (≤3 °C) threshold met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes
Type of mixing required to dilute CW to meet the temperature threshold	NF	NF	NF

NF = near-field, FF = far-field

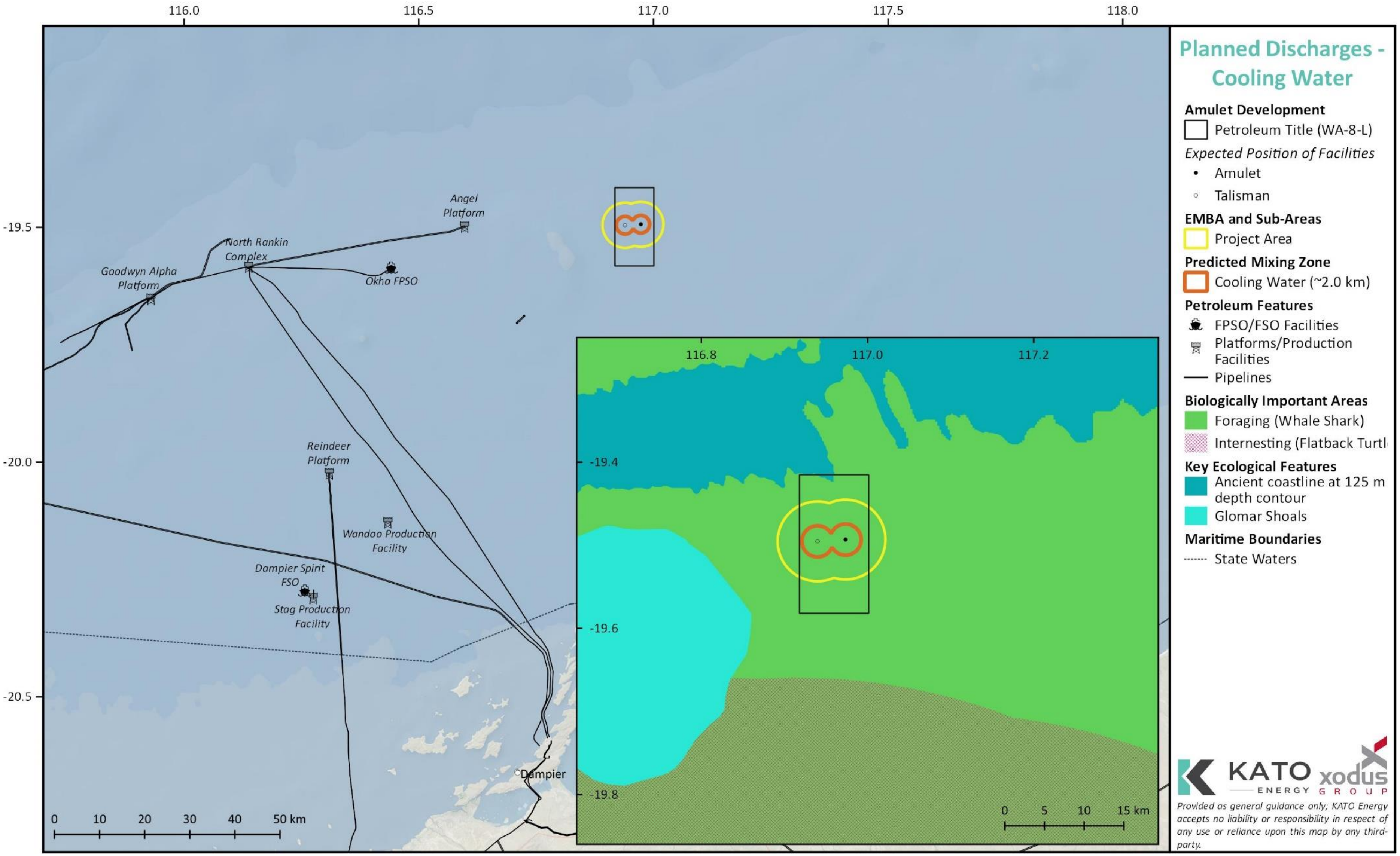


Figure 7-22 Predicted Mixing Zone for Cooling Water Discharge from the Amulet Development

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 Amulet Development can be estimated based on expected POB (not including support vessels not permanently in Project Area; Table 3-16).

Table 7-72 summarises estimated brine discharge volumes by project phase.

Table 7-72 Estimated Total Daily Brine Discharges

Phase	Max Indicative POB	Approx. total brine discharge (m^3/day)	Duration of phase
Drilling	160	168	Initial campaign – 7 months Infill drilling (if required) – additional 4 months
Operations	30	31.5	1.5–4.5 years
Operations – well intervention (if required)	60-160*	63-168	~1 month
Installation, Hook-up and Commissioning; Decommissioning	60	63	~3 months per phase

**If an ISV is used for well intervention, POB is ~60; if a MODU is used, POB is ~160 (including support vessels).*

The daily brine discharges in Table 7-72 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 1,700–2,550 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 Amulet 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 7-73 identifies the potential impacts to receptors as a result of discharges of CW and brine from the Amulet 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 7-74 provides a summary and justification for those receptors not evaluated further.

Table 7-73 Receptors Potentially Impacted by Planned Discharge – CW and Brine

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*						
Change in habitat				*X*				
Injury / mortality to fauna			✓	*X*	*X*	*X*	*X*	
Changes to the functions, interests or activities of other users								*X*

Table 7-74 Justification for Receptors Not Evaluated Further

Ambient Sediment Quality	***X***
Change in sediment quality Brine is discharged in relatively small volumes near the water surface; given the expected rapid dilution and water depths of ~85 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 (i.e. 75 m, or 10 m above seabed) will not intersect with the seabed. Therefore, a change in 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.	
Benthic habitats and communities	***X***
Change in habitat 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. Based on regional presence, 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 benthic habitats and communities that are within the mixing zone for the CW discharge are widely distributed in the region and are not considered to be of high conservation value. The discharge of CW will not physically modify, destroy, fragment, isolate or disturb benthic habitats and communities. There are no Management Plans, Recovery Plans or Conservation Advice related to benthic habitats and communities within the Project Area. Injury/mortality to fauna	

Biota within the benthic environment may experience injury or mortality due to potential toxic effects from the CW discharge.

Modelling of the CW discharge predicts that the plume from the deepest discharge point (i.e. 15 m above the seabed) will not intersect with the seabed. Therefore, changes to water or sediment quality within the benthic environment are not expected to occur, and as such toxicity effects to fauna in the benthic environment is not expected to occur.

Injury/mortality to fauna

As a result of a change in sediment quality, there is potential for further impacts to benthic receptors resulting from the accumulation of potential contaminants in the sediment; or from a change in water quality.

Modelling of CW discharge predicts that the plume from the scenario with the deepest discharge point (10 m above the seabed) will not intersect with the seabed. Brine is discharged near the water surface, and will also not intersect with the seabed. Therefore, changes to water or sediment quality within the benthic environment are not expected to occur, and as such toxicity effects to fauna in the benthic environment is not expected to occur.

Summary

CW and brine discharges will not result in a change to, or result in injury or mortality to, 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 CW are not expected, and have 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.

Potential receptors to changes in water quality resulting from toxic effects of CW discharges are likely to be transient marine fauna, including fish, mammals and reptiles found in either surface waters or the water column. Hypochlorite generation systems are commonly used 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. Sublethal impacts to fish as a result of chlorine exposure 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. 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. It has also been suggested (Abarno an Miossec 1992) that mobile organisms can detect low-level concentrations of chlorine and actively avoid such areas.

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). 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). 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%. Modelling of planned discharges of CW predicted a maximum horizontal distance of ~1,960 m and a maximum plume width of ~149 m until the chlorine threshold is reached; the temperature threshold was typically met at very low (<2 m to ~15 m) distances (Table 7-69, Table 7-70, Table 7-71). Therefore, the predicted area of exposure and mixing zone for the CW discharge is well within the defined Project Area for the Amulet Development. Given the results of the modelling, any potential impacts to water quality are expected to be spatially limited. Marine fauna (fish, marine mammals and marine reptiles) are all highly mobile and as such, any interaction with this relatively thin plume of CW discharge is expected to be a transitory nature only. Therefore, impacts to fish, marine mammals and marine reptiles from CW discharges are not expected, and have not been evaluated further.
Commercial Fisheries ***X***
Changes to the functions, interests or activities of other users While there are multiple commercial fisheries with management areas that overlap the Amulet Development, records of fishing effort (for both Commonwealth and State managed fisheries) indicate little to no fishing activity is expected to occur within the Project Area of the Amulet Development (Sections 5.5.2.1, 1.1.1.1). Any potential impacts to water quality are expected to be limited to within ~1,960 m of the discharge source, and within a plume of a maximum width of ~149 m. This area of exposure is well within the defined Project Area for the Amulet Development. However, as impacts to fish are not expected from planned discharges of CW, indirect impacts to commercial fisheries are not expected. Therefore, impacts to commercial fisheries from planned discharge of CW 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 7-75 provides a detailed evaluation of the impact of CW and brine on physical receptors.

Table 7-75 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, plus increased salinity levels and increased water temperature within the vicinity of the discharge points. Chemical additives such as biocides and scale inhibitors 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 ~1,960 m for chlorine to be below the defined DGV (ANZG 2018). Given the volume of brine discharge is similar, it is also expected to be well mixed 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 Amulet 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). Brine dispersion modelling for the Gorgon Gas Development (discharges 1,700–2,550 m^3/day during construction) predicted that salinity and chemicals would be rapidly diluted to near ambient levels within 10–20 m of the outfall (RPS 2009; Chevron 2015). Modelling undertaken for Woodside's (2019) Scarborough Development suggests that the salinity levels from RO discharges will fall below impact threshold levels within 4 m of the discharge point confirming localised impacts.

Modelling of planned discharges of CW predicted a maximum horizontal distance of ~1,960 m and a maximum plume width of ~149 m until the chlorine threshold is reached; the temperature threshold was typically met at very low (<2 m to ~15 m) distances (Table 7-69, Table 7-70, Table 7-71). Therefore, the predicted area of exposure and mixing zone for the CW discharge is well within the defined Project Area for the Amulet Development.

Therefore, any potential impacts to water quality are expected to be limited to within ~1,960 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 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 7-76 provides a detailed evaluation of the impact of CW and brine discharges to ecological receptors.

Table 7-76 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 water temperatures. Early life stages of fish (embryos, larvae) and other plankton would be most susceptible to the toxic exposure from chemicals in CW and brine discharges, as they are less mobile and therefore can become exposed to the plume at the discharge location. 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. The maximum residual chlorine for the CW discharge is 2,000 ppb (i.e. 2 ppm). As such, any potential impacts are expected to be limited to the source of the discharge where concentrations are highest. Modelling of planned discharges of CW predicted a maximum horizontal distance of ~1,960 m and a maximum plume width of ~149 m until the chlorine threshold is reached (Table 7-69, Table 7-70, Table 7-71). Therefore, the predicted area of exposure and mixing zone for the CW discharge is well within the defined Project Area for the Amulet Development. 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 of planned discharges of CW predicted the temperature threshold was typically met at very low (<2 m to ~15 m) distances (Table 7-69, Tabl 7-70, Table 7-71). Therefore, impacts to plankton species by temperature variations are expected to be negligible and are not discussed further. As planktonic productivity within the permit area is low and given the relatively small area of impact as a result of CW 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 has been evaluated as **Minor (1)** for all receptors and is considered **acceptable** when assessed against the criteria in Table 7-77.

Table 7-77 Demonstration of Acceptability for Planned Discharge – Cooling Water and Brine

Receptor	Demonstration of Acceptability		
Water quality	**Acceptable level of impact**		
	With respect to Planned Discharge – Cooling Water and Brine, the Amulet Development will not result in significant impacts to *water quality* identified as potentially affected, defined as a possibility that it will (Section 6.6): • result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		
	Acceptability assessment		
	Principles of ESD	The proposed EPO's for the Amulet Development are consistent with the principles of ESD. With respect to potential impacts to all receptors from Planned Discharge – Cooling Water and Brine, the relevant principles are: • Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. • 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.	
	Internal context	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards. With respect to potential impacts to all receptors from Planned Discharge – Cooling Water and Brine, this specifically includes: • KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)	
	External context	The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders. With respect to potential impacts to all receptors from Planned Discharge – Cooling Water and Brine, no specific concerns were raised during stakeholder consultation with relevant persons.	
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Cooling Water and Brine from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. With respect to potential impacts to water quality from Planned Discharge – Cooling Water and Brine, no specific other requirements have been identified as relevant.	
	Summary of impact assessment		**Consequence level**

Receptor	Demonstration of Acceptability		
	The impacts on *water quality* from Planned Discharge – Cooling Water and Brine include: • modelling of planned discharges of CW predicted a maximum horizontal distance of 1,960 m and a maximum plume width of 149 m until the chlorine threshold is reached; the temperature threshold was typically met at very low (<2 m to ~15 m) distances. This is within the 5km Project Area. • 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. • CW and brine discharge volumes during the Amulet 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.		Minor
	Statement of acceptability		
	Based on an assessment against the defined acceptable levels, the impacts on *water quality* from Planned Discharge – Cooling Water and Brine is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO3:** Undertake the Amulet Development in a manner that does not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health		
Plankton	**Acceptable level of impact**		
	With respect to Planned Discharge – Cooling Water and Brine, the Amulet Development will not result in significant impacts to plankton identified as potentially affected, defined as a possibility that it will (Section 6.6): • have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		
	Acceptability assessment		
	Principles of ESD	Refer to details in *water quality* assessment	
	Internal context	Refer to details in *water quality* assessment	

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="8"></td><td>External context</td><td colspan="2">Refer to details in water quality assessment</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Cooling Water and Brine include from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Consequence level</td></tr>
<tr><td colspan="2">The impacts on benthic habitat and communities from Planned Discharge – Cooling Water and Brine include:
modelling of planned discharges of CW predicted a maximum horizontal distance of 1,960 m and a maximum plume width of 149 m until the chlorine threshold is reached; the temperature threshold was typically met at very low (<2 m to ~15 m) distances.
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.
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.</td><td>Minor</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on benthic habitat and communities from Planned Discharge – Cooling Water and Brine is considered acceptable, given that:
the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
EPO18: Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of plankton, including its life cycle and spatial distribution.</td></tr>
</table>

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-78.

Table 7-78 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	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO18:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of plankton, including its life cycle and spatial distribution.	**CM20**: Equipment will be maintained in accordance with the manufacturer's specifications, facility planned maintenance system and regulatory requirements. **CM21**: 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			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 Amulet 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 Amulet 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 7-79 identifies the potential impacts to receptors as a result of deck drainage and bilge discharges from the Amulet 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 7-80 provides a summary and justification for those receptors not evaluated further.

Table 7-79 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 7-80 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 three species of shark as Vulnerable/Migratory (Green Sawfish, White Shark, Whale Shark) that may occur within the Project Area. The Green Sawfish is not likely to occur at the site of the Amulet Development given their habitat preference of shallow coastal and estuarine areas. The Amulet Project Area is situated within a foraging BIA for the Whale Shark. The approved Conservation Advice for Whale Sharks (TSSC 2015d) states that the main threat to the species occurs outside Australian waters. Within Australian waters, habitat disruption from mineral exploration, production and transportation is listed as a threat. However, planned discharges are not expected to result in a change in habitat due to the highly dispersive nature of such discharge plumes. 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 one species listed as Endangered (Blue Whale) that are known or may occur within the Project Area. The Project Area sits within a distribution BIA for Blue Whales. The recovery plan (CoA 2015a) lists pollution as a threat although this is primarily in relation to runoff from land-based agriculture, oil spills and outputs from aquaculture.

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 likely to occur within the Project Area. The Project Area does not intersect any BIAs for marine turtle species.

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***

Changes to the functions, interests or activities of other users

As impacts to fish are not expected from planned discharges of deck drainage and bilge, indirect impacts to commercial fisheries are not expected.

Ten state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show minimal and intermittent commercial fishing activity is expected to occur within the planned activities areas for the Amulet Development. Any fishing effort that may occur is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF).

As these discharges within the Amulet 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 7-81 provides a detailed evaluation of the impact or risk of deck drainage and bilge to physical receptors.

Table 7-81 Impact and Risk Assessment for Physical Receptors from Planned Discharge – Deck Drainage and Bilge

Ambient Water Quality ✓
Change in water quality 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 North West Shelf 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. The impact ranking has been calculated as **Low** and is considered **acceptable** when assessed against the criteria in Table 7-82.

Table 7-82 Demonstration of Acceptability for Planned Discharge – Deck Drainage and Bilge

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="8">Water quality</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Planned Discharge – Deck Drainage and Bilge, the Amulet Development will not result in significant impacts to water quality identified as potentially affected, defined as a possibility that it will (Section 6.6):
• result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>The proposed EPO’s for the Amulet Development are consistent with the principles of ESD.
With respect to potential impacts to all receptors from Planned Discharge – Deck Drainage and Bilge the relevant principles are:
• Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
• 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.</td></tr>
<tr><td>Internal context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards.
With respect to potential impacts to all receptors from Planned Discharge – Deck Drainage and Bilge, this specifically includes:
• KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)</td></tr>
<tr><td>External context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders.
With respect to potential impacts to all receptors from Planned Discharge – Deck Drainage and Bilge, no specific concerns were raised during stakeholder consultation with relevant persons.</td></tr>
<tr><td rowspan="2">Other requirements</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Deck Drainage and Bilge from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to water quality from Planned Discharge – Deck Drainage and Bilge, this specifically includes:</td></tr>
<tr><td>Requirement | Relevant Item/Objective/Action | Addressed/Managed by Amulet Development</td></tr>
</table>

Receptor	Demonstration of Acceptability			
		Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* – Section 26F (implements MARPOL Annex I).	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.	Adoption of the following control measures: **CM20**: Equipment will be maintained in accordance with the manufacturer's specifications, facility planned maintenance system and regulatory requirements. **CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM27:** Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated.
		Commonwealth *Navigation Act 2012* – Chapter 4 (Prevention of Pollution).	Gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).	
		AMSA Marine Orders Part 91 (Marine Pollution Prevention – Oil) 2014.	Sets out the requirements of the prevention of pollution of the environment by oil for regulated Australian vessels, domestic commercial vessels and Australian recreation vessels.	Adoption of the following control measure: **CM28**: 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.
	Summary of impact assessment			**Consequence level**
	The impacts on water quality from Planned Discharge – Deck Drainage and Bilge include: • discharge of deck drainage and bilge from vessels and other facilities is well understood, controlled by standard industry practices. Discharges will be comparable to existing projects and developments within the North West Shelf area			Minor

Receptor	Demonstration of Acceptability	
	• 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 only highly localised and temporary effects on water quality.	
	Statement of acceptability	
	Based on an assessment against the defined acceptable levels, the impacts on *water quality* from Planned Discharge – Deck Drainage and Bilge is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO3:** Undertake the Amulet Development in a manner that does not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health	

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 – Deck Drainage and Bilge

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality, which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM20**: Equipment will be maintained in accordance with the manufacturer's specifications, facility planned maintenance system and regulatory requirements. **CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM27:** Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM28**: 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.	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 Amulet 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 (Table 3-16) would equate to treated discharges of 72 m^3 and 13.5 m^3 per day respectively. Note, if a MODU is required at Talisman for well intervention and/or decommissioning activities, these discharge rates may increase during that period to account for the additional POB required.

If the subsea tieback option is selected for Talisman, there would be additional discharges from a separate MODU drilling the Talisman wells, and potentially during well intervention (if required) from an ISV or MODU and support vessels; and if a separate MODU is used to P&A Talisman.

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 Amulet 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 7-84 identifies the potential impacts to receptors as a result of seabed disturbance from the sewage, greywater and food waste discharges from the Amulet 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 Receptors Potentially Impacted by Planned Discharge – Sewage, Greywater and Food Waste

Impacts	Water quality	Plankton	Seabirds and shorebirds	Fish	Marine mammals	Marine reptiles	Commercial fisheries
Change in water quality	✓						
Change in fauna behaviour		*X*	*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 – 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.

Seabirds and Shorebirds, Fish, Marine Mammals and Marine Reptiles	***X***

Change in fauna behaviour

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 lists three species of bird as Critically Endangered (Eastern Curlew), Endangered (Red Knot) and Vulnerable (Australian Fairy Tern) that may occur within the Project Area. A breeding BIA for the Wedge-Tailed Shearwater intersects with the Project Area, which are listed as migratory, though a PMST search does not list them in the Project Area. The Amulet Development area is within the breeding and foraging BIA for the Wedge-tailed shearwater (Figure 5-10). Bird species are likely to forage in the waters surrounding the islands during nesting seasons. Known breeding locations in the region include Forestier Island (Sable Island), Bedout Island and the Dampier Archipelago. The nesting sites at the Dampier Archipelago are the closest to the Project Area with a distance of ~90 km. With high dilution rates, any potential change to scavenging behaviour from seabirds is expected to be incidental.

The EPBC PMST lists three species of shark as Vulnerable/Migratory (Green Sawfish, White Shark, Whale Shark) that are likely to occur within the Project Area. The Green Sawfish is not likely to occur at the Project Area given their habitat preference of shallow coastal and estuarine areas. The approved Conservation Advice for Whale Sharks (TSSC 2015d) states that the main threat to the species occurs outside Australian waters. Within Australian waters, habitat disruption from mineral exploration, production and transportation is listed as a threat. However, planned discharges are not expected to result in a change in habitat due to the highly dispersive nature of such discharge plumes. The EPBC PMST shows that three species of marine mammal listed as either Vulnerable (Sei Whale, Fin Whale and Humpback Whale) and one species listed as Endangered (Blue Whale) that are known or may occur within the Project Area. The Project Area sits within a distribution BIA for Blue Whales. The recovery plan (CoA 2015a) lists pollution as a threat although this is primarily in relation to runoff from land-based agriculture, oil spills and outputs from aquaculture. 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 likely to occur within the Project Area.

All species listed are highly mobile, therefore, none are expected to be affected by minor sewage, greywater or food discharges.

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 from minor sewage, greywater or food 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 sewage, greywater and food waste, indirect impacts to commercial fisheries are not expected. Ten state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show minimal and intermittent commercial fishing activity is expected to occur within the planned activities areas for the

Amulet Development. Any fishing effort that may occur is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF). 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.

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 7-86 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 7-86 Impact and Risk Assessment for Physical Receptors from Planned Discharge – Sewage, Greywater and Food Waste

Ambient Water Quality ✓
<u>Change in water quality</u> 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 Amulet 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 in Table 7-87.

Table 7-87 Demonstration of Acceptability for Planned Discharge – Sewage, Greywater and Food Waste

Receptor	Demonstration of Acceptability	
Water quality	**Acceptable level of impact**	
	With respect to Planned Discharge – Sewage, Greywater and Food Waste, the Amulet Development will not result in significant impacts to water quality identified as potentially affected, defined as a possibility that it will (Section 6.6): • result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	
	Acceptability assessment	
	Principles of ESD	The proposed EPO's for the Amulet Development are consistent with the principles of ESD. With respect to potential impacts to *all receptors* from Planned Discharge – Sewage, Greywater and Food Waste the relevant principles are: • Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. • 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.
	Internal context	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards. With respect to potential impacts to *all receptors* from Planned Discharge – Sewage, Greywater and Food Waste, this specifically includes: • KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h)
	External context	The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders. With respect to potential impacts to *all receptors* from Planned Discharge – Sewage, Greywater and Food Waste, no specific concerns were raised during stakeholder consultation with relevant persons.
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Planned Discharge – Sewage, Greywater and Food Waste from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.

Receptor	Demonstration of Acceptability		
	With respect to potential impacts to *water quality* from Planned Discharge – Sewage, Greywater and Food Waste, this specifically includes:		
	Requirement	*Relevant Item/Objective/Action*	*Addressed/Managed by Amulet Development*
	Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* – Section 26F (implements MARPOL Annex I).	Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution. It also invokes certain requirements of the MARPOL Convention including those relating to discharge of noxious liquid substances, sewage, garbage and air pollution. This Act requires ships greater than 400 gross tonnes to have in place pollution emergency plans, and also provides for emergency discharges from ships.	Adoption of the following control measures: **CM20**: Equipment will be maintained in accordance with the manufacturer's specifications, facility planned maintenance system and regulatory requirements. **CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM27:** Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM29:** Compliance with Marine Order 96 (Marine pollution prevention – sewage) 2013. **CM30:** Compliance with Marine Order 95 (Marine pollution prevention – garbage) 2013.
	Commonwealth *Navigation Act 2012* – Chapter 4 (Prevention of Pollution).	Gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).	
	AMSA Marine Orders Part 91 (Marine Pollution Prevention – Oil) 2014.	Sets out the requirements of the prevention of pollution of the environment by oil for regulated Australian vessels, domestic commercial vessels and Australian recreation vessels	

	Summary of impact assessment	**Consequence level**
	The impacts on *water quality* from Planned Discharge – Sewage, Greywater and Food Waste include: • discharge of sewage, greywater and food waste from vessels and other facilities is well understood, controlled by standard industry practices. Discharges will be comparable to existing projects and developments within the North West Shelf area	**Minor**

Receptor	Demonstration of Acceptability	
	• 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.	
	Statement of acceptability	
	Based on an assessment against the defined acceptable levels, the impacts on *water quality* from Planned Discharge – Sewage, Greywater and Food Waste is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO3:** Undertake the Amulet Development in a manner that does not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health	

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 – Sewage, Greywater and Food Waste

Receptor	Impacts	EPOs	Adopted Control Measures	Consequence
Ambient water quality	Change in water quality	**EPO3:** Undertake the Amulet Development in a manner that does not result in a substantial change in water quality, which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM20**: Equipment will be maintained in accordance with the manufacturer's specifications, facility planned maintenance system and regulatory requirements. **CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM27:** Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM29:** Compliance with Marine Order 96 (Marine pollution prevention – sewage) 2013. **CM30:** 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 Amulet Development, these phases and activities have the potential to introduce an IMS:

Drilling	MODU positioning
Installation, Hook-up and Commissioning	MOPU; Talisman subsea tieback; flowlines; 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 Amulet 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 northwest 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 Amulet 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 Amulet 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 Amulet directly from international waters, or from a previous KATO development (in the northwest region of WA). Following completion of the Amulet 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 Amulet 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 Amulet 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).

The Talisman subsea tieback infrastructure (if used) is not relocatable. There may be some cleaning of lifting points before recovery, but not to the same extent as for the honeybee production system infrastructure. The Talisman facilities will be recovered to the surface, and removed to shore.

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 ~50 nm from shore and ~68 nm from the Port of Dampier.

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 Amulet 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 7-89 identifies the potential impacts to receptors as a result of an IMS from the Amulet 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 7-89 Receptors Potentially Impacted by the Introduction of an IMS

Impacts	Benthic 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.

The above receptors may be impacted from:

- change in ecosystem dynamics.

Table 7-90 provides a detailed evaluation of the impact of an IMS to ecological receptors.

Table 7-90 Impact and Risk Assessment for Ecological Receptors from Introduction of IMS

Benthic Habitats and Communities ✓
Change in ecosystem dynamics Only a small proportion of introduced marine species become invasive (Wells 2018) with relatively few introductions of marine species 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). 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 Amulet Development either from: • an international fabrication yard after refurbishment and pre-commissioning (i.e. from international waters) • from the previous field, in the northwest 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 Amulet Development is in waters of ~85 m and therefore low light levels are expected at the seabed. IMS typically require light to survive and thrive, which will be minimal at the seabed within the Amulet Development area. Previous studies of the Amulet 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 North West Shelf 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 Amulet Development area also suggests sparse benthic assemblages as areas of hard substrate generally supporting a more diverse epibenthic population (Heyward et al. 2001). Additionally, due to the sparse nature of the benthic habitats and lack of nutrients in the waters of the North West Shelf, if an IMS did establish it would be very unlikely to be able to translocate from the Project Area to an adjacent marine area or further distances to coastal areas naturally.

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 ~50 nm from shore, and is also in ~85 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 (Bridgewood 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. The closest KEFs to the Amulet Development are the ‘ancient coastline at 125 m depth contour’ and the ‘Glomar Shoals’, approx. 8 km and 16 km from the expected position of the MOPU respectively.

The closest land masses to the Amulet Development are the Dampier Archipelago and Burrup Peninsula, ~96 km and ~115 km from the expected positions of the MOPU. It is therefore 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).

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:

- commercial fisheries
- industry.

Impacts to the above receptors include:

- changes to the functions, interests or activities of other users.

Table 7-91 provides a detailed evaluation of the impact of an IMS to social, economic and cultural receptors.

Table 7-91 Impact and Risk Assessment for Social, Economic and Cultural Receptors from Introduction of IMS

Commercial fisheries ✓
Changes to the functions, interests or activities of other users

The introduction of an IMS in the Amulet Development is unlikely to impact on fisheries within the region. Ten state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show minimal and intermittent commercial fishing activity is expected to occur within the planned activities areas for the Amulet Development. Any fishing effort that may occur is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF).

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 ✓

Changes to the functions, interests or activities of other users

The most significant industry within the vicinity of the Project Area is petroleum exploration and production. Oil and gas facilities within the vicinity of the Amulet Development include Woodside’s Angel, North Rankin and Goodwyn Alpha platforms (~40 km, 90 km and 112 km respectively); Woodside’s Okha FPSO (~58 km); Apache’s Reindeer platform (~92 km) and VOGA’s Wandoo platform (~91 km). Santos’ Mutineer Exeter Development (~45 km northeast) is currently in cessation and the FPSO has left the field.

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 Amulet Development area has been evaluated as **Serious (3)**, which was for benthic habitats and communities. The impact ranking has been calculated as **Medium** and is considered **acceptable** when assessed against the criteria in Table 7-92.

Table 7-92 Demonstration of Acceptability for the Unplanned Introduction of IMS

Receptor	Demonstration of Acceptability	
Benthic habitats and communities	**Acceptable level of impact**	
	With respect to Unplanned Introduction of IMS, the Amulet Development will not result in significant impacts to *benthic habitats and communities* identified as potentially affected, defined as a possibility that it will (Section 6.6): • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.	
	Acceptability assessment	
	Principles of ESD	The proposed EPO's for the Amulet Development are consistent with the principles of ESD. With respect to potential impacts to *all receptors* from Unplanned Introduction of IMS, the relevant principles are: • Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. • 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.
	Internal context	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards. With respect to potential impacts to *all receptors* from Unplanned introduction of IMS, this specifically includes: • KATO Introduced Marine Pest Management (KAT-000-EN-PP-002) (KATO 2020i) (including Biofouling Management Plan/s).

	External context	The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders.
		With respect to potential impacts to *all receptors* from Unplanned Introduction of IMS, the following specific concerns were raised during stakeholder consultation with relevant persons:
		• Comments received from Marine and Aquatic Biosecurity Animal Biosecurity Branch, Animal Division, Australian Government Department of Agriculture (dated 1 July 2019) that:
		  ○ Biosecurity considerations should be included in future planning
		  ○ 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.

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="4"></td><td></td><td colspan="3">DAWE (formerly DoA) responded to the Corowa Development OPP public comment phase with the following comments relevant to the Amulet Development:
Provision of DAWE Questionnaire for Biosecurity Exemptions for Biosecurity Control Determination, to be submitted to DAWE at least one month prior to project commencement
Reminder to review DAWE’s Offshore Installations webpage and associated biosecurity guide; and contact seaports@agriculture.gov.au for an assessment
Reminder to review Australian ballast water and biofouling requirements and pre-arrival reporting using MARS; and biosecurity reporting requirements for aircraft.</td></tr>
<tr><td rowspan="3">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Unplanned introduction of IMS from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to all receptors from Unplanned Introduction of IMS, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Australian Ballast Water Management Requirements Version 7 (DAWR 2017)</td><td>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
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).</td><td>Adoption of the following control measures:
CM31: Requirements of the Australian Ballast Water Management Requirements Version 7 (DAWR 2017) to be met.
CM32: Requirements of the National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry (DAFF 2009) to be met.
CM33: 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,</td></tr>
</table>

Receptor	Demonstration of Acceptability			
		Commonwealth *Biosecurity Act 2015*	Biosecurity obligations administered by the Department of Agriculture include ballast water and biofouling requirements, specifically: • pre-arrival information must be reported through MARS before arriving in Australian waters • biofouling management plan and record book • 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 • antifouling system certification for vessels is current and in accordance with AMSA Marine Order Part 98 (Antifouling systems)	including methods to ensure minimal release of biological material into the water. **CM34**: A Biofouling Management Plan will be developed as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015).
		Antifouling and In-water Cleaning Guidelines (DoA 2015	• 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)	Includes: • evaluation of biofouling risk of types of structures/facilities • guidance on biofouling management and decommissioning.	

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="4"></td><td>Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td>The impacts on benthic habitats and communities from Unplanned Introduction of IMS include:
• 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 Amulet 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 60 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 85 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.</td><td>Medium</td></tr>
<tr><td colspan="2">Statement of acceptability</td></tr>
<tr><td colspan="2">Based on an assessment against the defined acceptable levels, the impacts on benthic habitats and communities from Unplanned Introduction of IMS is considered acceptable, given that:
• the activity is not inconsistent with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO19: Undertake the Amulet Development in a manner that will prevent an IMS becoming established in the marine environment.</td></tr>
<tr><td rowspan="3">Commercial Fisheries</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Unplanned Introduction of IMS, the Amulet Development will not result in significant impacts to commercial fisheries identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on the sustainability of commercial fishing
An activity will contravene the OPGGS Act Section 280(2), and therefore result in a Significant Impact, if it is deemed to:
• interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
</table>

	Principles of ESD	Refer to details in *benthic habitats and communities* assessment	
	Internal context	Refer to details in *benthic habitats and communities* assessment	
	External context	Refer to details in *benthic habitats and communities* assessment	
	Other requirements	Refer to details in *benthic habitats and communities* assessment	
	Summary of impact assessment		**Risk level**
	The impacts on *commercial fisheries* from Unplanned Introduction of IMS include: • if an IMS is able to establish itself at the Project Area (which is unlikely due to the sparse nature of benthic habitats and communities), it is very unlikely to be able to spread due to the fragmented and sparse habitat. • management areas for ten State- and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data shows that only the WA North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF) may be active in the Project Area. • 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.		Low
	Statement of acceptability		
	Based on an assessment against the defined acceptable levels, the impacts on *commercial fisheries* from Unplanned Introduction of IMS is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO19:** Undertake the Amulet Development in a manner that will prevent an IMS becoming established in the marine environment.		
Industry	**Acceptable level of impact**		

With respect to Unplanned Introduction of IMS, the Amulet Development will not result in significant impacts to *industry* identified as potentially affected, defined as a possibility that it will (Section 6.6): • interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		
Acceptability assessment		
Principles of ESD	Refer to details in *benthic habitats and communities* assessment	
Internal context	Refer to details in *benthic habitats and communities* assessment	
External context	Refer to details in *benthic habitats and communities* assessment	
Other requirements	Refer to details in *benthic habitats and communities* assessment	
Summary of impact assessment		**Risk level**
The impacts on *industry* from Unplanned Introduction of IMS include: • 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. • 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. 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.		Low
Statement of acceptability		
Based on an assessment against the defined acceptable levels, the impacts on industry from Unplanned Introduction of IMS is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:		

	• **EPO19:** Undertake the Amulet Development in a manner that will prevent an IMS becoming established in the marine environment.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-94.

Table 7-93 Summary of Impact Assessment for Unplanned Introduction of IMS

<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>Benthic habitats and communities</td><td>Change in ecosystem dynamics</td><td rowspan="3">EPO19: Undertake the Amulet Development in a manner that will prevent an IMS becoming established in the marine environment.</td><td rowspan="3">CM31: Requirements of the Australian Ballast Water Management Requirements Version 7 (DAWR 2017) to be met.
CM32: Requirements of the National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry (DAFF 2009) to be met.
CM33: 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.
CM34: A Biofouling Management Plan will be developed as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015).</td><td>Serious</td><td>Unlikely</td><td>Medium</td></tr>
<tr><td>Commercial Fisheries</td><td rowspan="2">Changes to the functions, interests or activities of other users</td><td>Moderate</td><td>Very unlikely</td><td>Low</td></tr>
<tr><td>Industry</td><td>Moderate</td><td>Very unlikely</td><td>Low</td></tr>
</table>

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 Amulet Development has the potential to result in an unplanned interaction with marine fauna.

7.2.2.1 Aspect Source

Throughout the Amulet 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 Amulet 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 (~7 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 Amulet Development, which is expected to be ~5 years (with estimated transit frequency shown in Table 3-17). This number will peak during drilling, commissioning and decommissioning at approximately <10 support vessels. Throughout normal operations (~1.5–4.5 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 and Aframax-sized vessels. The FSO will remain stationary during operations, moored to the CALM buoy.

If the Talisman subsea tieback option is selected, there will be potentially multiple additional mobilisations of a MODU, and additional ISV/s and support vessels for drilling, installation, well intervention (if required) and decommissioning.

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 Amulet Development has the potential to result in this impact:

- injury/mortality to fauna.

Table 7-94 identifies the potential impacts to receptors as a result of interactions with marine fauna at the Amulet 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 7-97 provides a summary and justification for those receptors not evaluated further.

Table 7-94 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 7-95 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 0). This evaluation has focused on the large species, such as sharks and Whale Sharks, which are not the commercial species targeted in the North West Shelf. The 5 km radius of the Project Area (121 km^2) is an insignificant area compared to the size and scale of commercial fisheries. Ten state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show minimal and intermittent commercial fishing activity is expected to occur within the planned activities areas for the Amulet Development. Any fishing effort that may occur is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF). Therefore, impacts to commercial fisheries from physical presence – interaction with marine fauna are not expected, and have not been evaluated further.	

Impacts to receptors are assessed 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 7-96 provides a detailed evaluation of the impact of interaction with marine fauna to ecological receptors.

Table 7-96 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 (typically ~10 knots transit speeds; ~2 knots during installation phases) 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 three species of shark as Vulnerable/Migratory (Green Sawfish, White Shark and Whale Shark) that may or are known to occur within the area. The Green Sawfish is unlikely to occur at the Project Area given their habitat preference of shallow coastal and estuarine areas.

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 where foraging activity is centered on the 200 m isobath from July to November. The 200 m isobath is situated ~39 km to the north of the Amulet Project Area. The foraging BIA for Whale Sharks is 218,911 km^2 which is significantly larger compared to the 154.5 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.

While the species is generally encountered close to or at the surface, it will regularly dive and move through the water column. Around Ningaloo, Whale Sharks spend 10-40% of their time in surface waters (Gleiss et al. 2013). . Off the outer North West Shelf, they spend much of their time swimming near the seafloor and make dives to over 1000 m depth (2012DoEE 2019b). 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.

The approved Conservation Advice (TSSC 2015d) states that the main threat to the Whale Shark occurs outside Australian waters, which is from intentional and unintentional mortality from fishing. Within Australian waters, habitat disruption from mineral exploration, production and transportation is listed as a threat.

All EPBC PMST listed fish species are highly mobile, therefore, none are expected to be subject to vessel collision. It is expected that most fish (including sharks and rays) will exhibit avoidance behaviour from a sound source if it reaches levels that may cause behavioural or physiological effects,, thus the likelihood of getting close enough for a collision is very low. Vessel movements in the Amulet Project Area will be slow, and the total number of vessels relatively small (expected maximum of 10 during peak times). During the operations phase (1.5 – 4.5 years), only 1-2 support vessels are expected to be required, making a trip to the Project Area only approximately 2-3 times per month.

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).

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 ✓

Injury/mortality to fauna

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 northwest 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 Amulet Development area will be at slow speeds during most operations (typically ~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 listed as either Vulnerable (Sei Whale, Fin Whale and Humpback Whale) and one species listed as Endangered (Blue Whale) that are likely or may occur within the Project Area. The Amulet Development intercepts with the Pygmy Blue Whale distribution BIA however, this area is not considered particularly important for the conservation of the species compared to migration or foraging BIAs. Pygmy Blue Whales migrate north from the Perth Canyon / Naturaliste Plateau region in March and April reaching Indonesia by June where they remain until at least September. The southern migration from Indonesia may occur from September and finish by December in the subtropical frontal zone after which the animals may make their way slowly northwards towards the Perth Canyon by March or April (DoE 2015b). Pygmy Blue Whales tend to pass along the shelf edge at depths between 500 m to 1000 m during their migration (DoE 2015b). As the 500 m isobath is situated ~90 km north of the Amulet Project Area and the southern boundary of the migration BIA is ~60 km to the north of the Amulet Project Area, occurrences of the Pygmy Blue Whale within the Project Area are expected to be extremely unlikely.

The Department of Environment EPBC Act (1999) Conservation Management Plan for the Pygmy Blue Whale lists vessel disturbance and vessel collision as a threat. However, the presence of Pygmy Blue Whales within the Project Area is unlikely. Since 2006 there have been two records of likely ship strikes of Blue Whales in Australia.

The Amulet Development is situated ~30 km to the north of the Humpback Whale migration BIA with peak migration in the area between June and October. 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 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 approximately 120 m depth as a possible migratory pathway during their northern migration which would take individuals north of the Project Area. The 120 m contour is ~20 to the north of the Project Area which is situated in water depths of approximately 85 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 approximately 115 km from the coastline in 85 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 movements and distributions of Sei Whales are unpredictable and not well documented (Cth Of Australia 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 (Cth Of Australia, 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 (Cth Of Australia 2005), therefore their presence in the Project Area is extremely unlikely.

No dolphin species were identified in the PMST search for the Project Area with no BIAs for small cetaceans identified. 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 within Dampier Archipelago (~96 km from the expected position of the MOPU). However, it is the seagrass meadows in Exmouth Gulf and Shark Bay that are known for supporting aggregations of Dugongs.

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 North West Shelf 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 Amulet Project Area will be slow, and the total number of vessels relatively small (expected maximum of ten during peak times). During the operations phase (~1.5–4.5 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, congregation or congregation likely to occur within the Project Area. The Project Area does not intersect any BIAs for marine turtle species. 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.

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 Amulet Project Area will be slow, and the total number of vessels relatively small (expected maximum of ten during peak times). During the operations phase (~1.5–4.5 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 7-97.

Table 7-97 Demonstration of Acceptability for Physical Presence – Interaction with Marine Fauna

Receptor	Demonstration of acceptability	
Fish	**Acceptable level of impact**	
	With respect to Physical Presence - Interaction with Marine Fauna, the Amulet Development will not result in significant impacts to fish identified as potentially affected, defined as a possibility that it will (Section 6.6): • have a substantial adverse effect on a population of fish, or the spatial distribution of the population. • substantially modify, destroy or isolate an area of important habitat for a migratory species. • seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	
	Acceptability assessment	
	Principles of ESD	The proposed EPO's for the Amulet Development are consistent with the principles of ESD. With respect to potential impacts to *all receptors* from Physical Presence - Interaction with Marine Fauna the relevant principles are: • Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. • 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.
	Internal context	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards. With respect to potential impacts to *all receptors* from Physical Presence - Interaction with Marine Fauna, there are no specific KATO internal requirements with respect to seabed disturbance or potentially impacted receptors.
	External context	The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders. With respect to potential impacts to *all receptors* from Physical Presence - Interaction with Marine Fauna, no specific concerns were raised during stakeholder consultation with relevant persons.
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Physical Presence - Interaction with Marine Fauna from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.

Receptor	Demonstration of acceptability			
		With respect to potential impacts to fish from Physical Presence - Interaction with Marine Fauna, this specifically includes:		
		Requirement	*Relevant Item/Objective/Action*	*Addressed/Managed by Amulet Development*
		Conservation advice *Rhincodon typus* (Whale Shark) (TSSC 2015d)	Identifies vessel disturbance as a key threat. No explicit relevant objectives. Management action to: Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with Whale Shark aggregations (Ningaloo Reef, Christmas Island and the Coral Sea) and along the northward migration route that follows the northern Western Australian coastline along the 200 m isobath (as set out in the Conservation Values Atlas, DoE, 2014).	The Amulet Development is not close to marine features likely to correlate with whale shark aggregation areas, or the 200 m isobath (Section 7.2.2.2.1). Adoption of the following control measures: **CM04:** KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM18**: Vessels and aircraft will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the Project Area.
	Summary of impact assessment			**Risk level**
	The impacts on *fish* from Physical Presence - Interaction with Marine Fauna include: • the Project Area is within a Whale Shark foraging BIA; however, interactions are unlikely due to its distance from the preferred foraging areas around Ningaloo and the 200 m isobath. • it is expected that most fish (including sharks and rays) will exhibit avoidance behaviour from a sound source if it reaches levels that may cause behavioural or physiological effects, thus the likelihood of getting close enough for a collision is very low. • vessel movements in the Project Area will be slow, and the total number of vessels relatively small (expected maximum of ten during peak times). During the operations phase (~1.5–4.5 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.			Low
	Statement of acceptability			
	Based on an assessment against the defined acceptable levels, the impacts on *fish* from Physical Presence - Interaction with Marine Fauna is considered acceptable, given that:			

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of acceptability</th></tr>
<tr><td></td><td colspan="2">• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
EPO20: Undertake the Amulet Development in a manner that will prevent a vessel strike with protected marine fauna during project activities.</td></tr>
<tr><td rowspan="6">Marine Mammals</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Physical Presence - Interaction with Marine Fauna, the Amulet Development will not result in significant impacts to water quality identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>The proposed EPO’s for the Amulet Development are consistent with the principles of ESD.
With respect to potential impacts to all receptors from Physical Presence - Interaction with Marine Fauna the relevant principles are:
• Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
• 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.</td></tr>
<tr><td>Internal context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards.
With respect to potential impacts to all receptors from Physical Presence - Interaction with Marine Fauna, there are no specific KATO internal requirements with respect to seabed disturbance or potentially impacted receptors.</td></tr>
<tr><td>External context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders.</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of acceptability</th></tr>
<tr><td rowspan="6"></td><td></td><td colspan="3">With respect to potential impacts to all receptors from Physical Presence - Interaction with Marine Fauna, no specific concerns were raised during stakeholder consultation with relevant persons.</td></tr>
<tr><td rowspan="5">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Physical Presence - Interaction with Marine Fauna from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to marine mammals from Physical Presence - Interaction with Marine Fauna, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans</td><td>Provides for the protection and conservation of cetaceans, including:
• Exclusion and cautions zones around cetaceans and calves
• Speed restrictions
• Avoidance actions
• Posting a lookout
• Aircraft heights.</td><td rowspan="3">Adoption of the following control measures:
CM04: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction.
CM18: Vessels and aircraft will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the Project Area.
CM35: All marine mammal vessel strike incidents will be reported in the National Vessel Strike Database.</td></tr>
<tr><td>National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (CoA 2017)</td><td>Objectives is to acquire data, determine risks of vessel strike, and identify mitigation measures, with the target audience being government agencies.</td></tr>
<tr><td>Conservation Advice for Humpback Whales (TSSC 2015c)</td><td>Identifies vessel collision as a key threat. No explicit relevant objectives.
Management action to Minimise vessel collisions:
• 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.</td></tr>
</table>

Receptor	Demonstration of acceptability			
			• Maximise the likelihood that all vessel strike incidents are reported in the National Ship Strike Database. All cetaceans are protected in Commonwealth waters and, the EPBC Act requires that all collisions with whales in Commonwealth waters are reported. Vessel collisions can be submitted to the National Ship Strike Database at https://data.marinemammals.gov.au/report/shipstrike • Enhance education programs to inform vessel operators of best practice behaviours and regulations for interacting with humpback whales.	
		Conservation Management Plan for the Blue Whale (DoE 2015b)	Identifies vessel collision as a key threat. No explicit relevant objectives. Management action A5: addressing vessel collisions: • Develop a national ship strike strategy that quantifies vessel movements within the distribution ranges of southern right whales and outlines appropriate mitigation measures that reduce impacts from vessel collisions.	
		Conservation Management Plan for the Southern Right Whale 2011–2021 (DSEWPaC 2012a)	Identifies vessel collision as a key threat. The long-term recovery objective is to minimise anthropogenic threats to allow the conservation status of the southern right whale to improve so that it can be removed from the threatened species list under the EPBC Act. Management action A5: addressing vessel collisions:	

Receptor	Demonstration of acceptability			
			• Develop a national ship strike strategy that quantifies vessel movements within the distribution ranges of southern right whales and outlines appropriate mitigation measures that reduce impacts from vessel collisions.	
		Conservation Advice for Balaenoptera borealis (Sei Whale) (TSSC 2015a)	Identifies vessel strike as a key threat. No explicit relevant objectives. Management action: Minimising vessel collisions: • Develop a national vessel strike strategy that investigates the risk of vessel strikes on Sei Whales and also identifies potential mitigation measures. • Ensure all vessel strike incidents are reported in the National Vessel Strike Database	
		Conservation Advice for *Balaenoptera physalus* (Fin Whale) (TSSC 2015b)	Identifies vessel collision as a key threat. No explicit relevant objectives. Management action: Minimising vessel collisions: • Develop a national vessel strike strategy that investigates the risk of vessel strikes on Sei Whales and also identifies potential mitigation measures. • Ensure all vessel strike incidents are reported in the National Vessel Strike Database	
	Summary of impact assessment			**Risk level**
	The impacts on *marine mammals* from Physical Presence - Interaction with Marine Fauna include: • the Project Area intercepts with the Pygmy Blue Whale distribution BIA however, this area is not considered particularly important for the conservation of the species compared to migration or foraging BIAs • species potentially at risk have a wide distribution and have a relatively low-density presence within the Project Area resulting in unlikely interactions with activities.			Low

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of acceptability</th></tr>
<tr><td rowspan="5"></td><td colspan="2">• vessel movements in the Project Area will be slow, and the total number of vessels relatively small (expected maximum of ten during peak times). During the operations phase (~1.5–4.5 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.</td></tr>
<tr><td colspan="2">Statement of acceptability</td></tr>
<tr><td colspan="2">Based on an assessment against the defined acceptable levels, the impacts on marine mammals from Physical Presence - Interaction with Marine Fauna is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO20: Undertake the Amulet Development in a manner that will prevent a vessel strike with protected marine fauna during project activities.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="8">Marine Reptiles</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Physical Presence - Interaction with Marine Fauna, the Amulet Development will not result in significant impacts to marine reptiles identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>Refer to details in fish assessment</td></tr>
<tr><td>Internal context</td><td>Refer to details in fish assessment</td></tr>
<tr><td>External context</td><td>Refer to details in fish assessment</td></tr>
<tr><td>Other requirements</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Physical Presence - Interaction with Marine Fauna from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.</td></tr>
</table>

Receptor	Demonstration of acceptability
	With respect to potential impacts to *marine reptiles* from Physical Presence - Interaction with Marine Fauna, this specifically includes:

Requirement	*Relevant Item/Objective/Action*	*Addressed/Managed by Amulet Development*
Recovery Plan for Marine Turtles in Australia, (CoA 2017)	Identifies vessel collision as a key threat. No explicit relevant objectives or management actions.	Adoption of the following control measures: **CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM18**: Vessels and aircraft will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the Project Area. **CM35:** All marine mammal vessel strike incidents will be reported in the National Vessel Strike Database.
National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (CoA 2017)	Objectives is to acquire data, determine risks of vessel strike, and identify mitigation measures, with the target audience being government agencies.	

Summary of impact assessment	Risk level
The impacts on *marine reptiles* from Physical Presence - Interaction with Marine Fauna include: • The Project Area does not intersect any BIAs for marine turtle species. It is unlikely that turtles will be feeding within the Project Area due to the sparse nature of the seabed. • 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. • Vessel movements in the Project Area will be slow, and the total number of vessels relatively small (expected maximum of ten during peak times). During the operations phase (~1.5–4.5 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.	Low

Statement of acceptability

Based on an assessment against the defined acceptable levels, the impacts on *marine reptiles* from Physical Presence - Interaction with Marine Fauna is considered acceptable, given that:

- the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above

Receptor	Demonstration of acceptability
	• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO20:** Undertake the Amulet Development in a manner that will prevent a vessel strike with protected marine fauna during project activities.

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 Physical Presence – Interaction with Marine Fauna

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
Fish	Injury / mortality to fauna	**EPO20:** Undertake the Amulet Development in a manner that will prevent a vessel strike with protected marine fauna during project activities.	**CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM18**: Vessels and aircraft will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the Project Area. **CM35:** All marine mammal vessel strike incidents will be reported in the National Vessel Strike Database.	Minor	Unlikely	Low
Marine mammals				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 Amulet 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 Amulet Development, unplanned seabed disturbance may occur through the result of these activities:

Installation, Hook-up and commissioning	MOPU; Talisman subsea tieback; flowlines; CALM buoy and mooring arrangements
Decommissioning	Inspection and cleaning; well P&A; removal of subsea infrastructure; disconnection of MOPU/FSO
Support Activities (all phases)	MODU 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; and the Talisman subsea tieback system (if selected), 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 (Section 3.4.5.1. If the Talisman subsea tieback option is selected, the lifting points of this infrastructure may be cleaned before retrieval also. 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 Amulet 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 7-99 identifies the potential impacts to receptors as a result of unplanned seabed disturbance from the physical presence of the Amulet 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 7-100 provides a summary and justification for those receptors not evaluated further.

Table 7-99 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 7-100 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 Amulet 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 Amulet 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 Amulet 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. Ten state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show minimal and intermittent commercial fishing activity is expected to occur within the planned activities areas for the Amulet Development. Any fishing effort that may occur is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF). The 5 km radius of the Project Area (121 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 7-101 provides a detailed evaluation of the impact of unplanned seabed disturbance to physical receptors.

Table 7-101 Impact and Risk Assessment for Physical Receptors from Unplanned 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. 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 Amulet facilities (MODU, MOPU, FSO), infrastructure (CALM buoy anchors, flowlines, Talisman subsea tieback system), 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 7-102 provides a detailed evaluation of the impact of unplanned seabed disturbance to ecological receptors.

Table 7-102 Impact and Risk Assessment for Ecological Receptors from Unplanned Seabed Disturbance

Benthic habitats and communities ✓
<u>Change to habitat</u> Unplanned seabed disturbance, such as a dropped object or dragged 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. The majority of seabed substrates within WA-8-L are expected to be characterised by sediment infaunal communities and sparsely distributed epibenthic fauna (Santos 2018). Seabed surveys undertaken approximately 50 km and 112 km from the Project Area (Apache 2012 and RPS 2011 respectively) found that there was a low abundance, high variability and diversity of infauna dominated by polychaetes and crustaceans. A lack of seabed features within the Amulet Development also suggests sparse benthic assemblages.

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 will therefore 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 North West Shelf. 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. <u>Injury / mortality to fauna</u> 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 7-103.

Table 7-103 Demonstration of Acceptability for Physical Presence – Unplanned Seabed Disturbance

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="7">Water quality</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Physical Presence – Unplanned Seabed Disturbance, the Amulet Development will not result in significant impacts to water quality identified as potentially affected, defined as a possibility that it will (Section 6.6):
• result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>The proposed EPO's for the Amulet Development are consistent with the principles of ESD.
With respect to potential impacts to all receptors from Physical Presence – Unplanned Seabed Disturbance the relevant principles are:
• Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
• 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.</td></tr>
<tr><td>Internal context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards.
With respect to potential impacts to all receptors from Physical Presence – Unplanned Seabed Disturbance, there are no specific KATO internal requirements with respect to seabed disturbance or potentially impacted receptors.</td></tr>
<tr><td>External context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders.
With respect to potential impacts to all receptors from Physical Presence – Unplanned Seabed Disturbance, no specific concerns were raised during stakeholder consultation with relevant persons.</td></tr>
<tr><td>Other requirements</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Physical Presence – Unplanned Seabed Disturbance from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to water quality from Physical Presence – Unplanned Seabed Disturbance, this specifically includes:</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="7"></td><td></td><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td></td><td>Anti-fouling and In-water Cleaning Guidelines (DoA 2015)</td><td>Requires that methods are used to ensure minimal release of biological material into the water during in-water cleaning.</td><td>Adoption of the following control measure:
CM33: 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.</td></tr>
<tr><td colspan="3">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="3">The impacts on water quality from Physical Presence – Unplanned Seabed Disturbance include:
The impacts of seabed disturbance from Amulet 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.
A reduction in water quality will be highly localised and very brief.</td><td>Low</td></tr>
<tr><td colspan="4">Statement of acceptability</td></tr>
<tr><td colspan="4">Based on an assessment against the defined acceptable levels, the impacts on water quality from Physical Presence – Unplanned Seabed Disturbance is considered acceptable, given that:
the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
EPO21: Undertake the Amulet Development in a manner that will prevent unplanned seabed disturbance.</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td rowspan="2">Benthic habitats and communities</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td colspan="4">With respect to Physical Presence – Unplanned Seabed Disturbance, the Amulet Development will not result in significant impacts to benthic habitats and communities identified as potentially affected, defined as a possibility that it will (Section 6.6):
modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="10"></td><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in water quality assessment</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in water quality assessment</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in water quality assessment</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Physical Presence – Unplanned Seabed Disturbance from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to benthic habitats and communities from Physical Presence – Unplanned Seabed Disturbance, no explicit relevant requirements or actions were identified.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="2">The impacts on benthic habitats and communities from Physical Presence – Unplanned Seabed Disturbance include:
• seabed substrates within WA-8-L are expected to be characterised by sediment infaunal communities and sparsely distributed epibenthic fauna, with seabed surveys in the region showing low abundance, high variability and diversity of infauna dominated by polychaetes and crustaceans.
• 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.
• Epifauna and infauna within mobile soft sediments are adapted to minor seabed disturbance and can recover relatively quickly from any smothering or seabed disturbance.
• 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 North West Shelf.</td><td>Low</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on benthic habitats and communities from Physical Presence – Unplanned Seabed Disturbance is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)</td></tr>
</table>

Receptor	Demonstration of Acceptability
	• the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO21**: Undertake the Amulet Development in a manner that will prevent unplanned seabed disturbance.

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-104.

Table 7-104 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	**EPO21:** Undertake the Amulet Development in a manner that will prevent unplanned seabed disturbance.	**CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM05**: Mooring analysis will be undertaken that will include an environmental sensitivity and seabed topography analysis. **CM06**: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below the mudline and removed. **CM33**: 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			Minor	Unlikely	Low

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 Amulet 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 Amulet Development.

7.2.4.2 Risk Evaluation

Unplanned discharges of solid waste during the Amulet 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 7-105 identifies the potential impacts to receptors as a result of unplanned discharges of solid waste from the Amulet 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 7-106 provides a summary and justification for those receptors not evaluated further.

Table 7-105 Receptors Potentially Impacted by Unplanned Discharge – Solid Waste

Impacts	Ambient water quality	Seabirds and shorebirds	Fish	Marine mammals	Marine reptiles	Commercial fisheries
Change in water quality	✓					
Injury/mortality to fauna		✓	✓	✓	✓	
Change in aesthetic value						
Changes to the functions, interests or						*X*

activities of other users						

Table 7-106 Justification for Receptors Not Evaluated Further for Unplanned Discharge – Solid Waste

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. Ten state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show minimal and intermittent commercial fishing activity is expected to occur within the planned activities areas for the Amulet Development. Any fishing effort that may occur is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF). The 5 km radius of the Project Area (~121 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.	

Impacts to receptors are assessed below, by receptor type.

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 7-107 provides a detailed evaluation of the impact of unplanned discharges of solid waste from the physical presence of the activities to physical receptors.

Table 7-107 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 7-108 provides a detailed evaluation of the impact or risk of an unplanned discharge of solid waste on ecological receptors.

Table 7-108 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). It is recognised that fishing gear (ropes and nets made from synthetic fibres), balloons and plastic bags are the biggest entanglement threat to marine fauna, and plastic bags and utensils are the biggest ingestion risk for seabirds, turtles and marine mammals (Wilcox et al. 2016, cited in DoEE 2018a). EPBC listed species identified in the PMST for the Amulet Project Area which may be impacted by a discharge of solid waste include 11 species of birds (e.g. sandpipers, frigatebirds, osprey). This includes one species listed as Vulnerable (Australian Fairy Tern), one as Endangered (Red knot) and one as Critically Endangered (Eastern Curlew). None of the threatened bird species listed within the PMST for the Project Area have been identified as being sensitive to interactions with marine debris. The closest land masses to the Amulet Development are the Dampier Archipelago and Burrup Peninsula, ~96 km and ~115 km from the expected position of the MOPU. A breeding BIA for the Wedge-Tailed Shearwater intersects with the Project Area, which are listed as migratory, though a PMST search does not list them in the Project Area. The Amulet Development area is within the breeding and foraging BIA for the Wedge-tailed Shearwater (Figure 5-10). The breeding BIAs for this species are buffers around islands that this species is known to nest on (Table 5-6). Bird species are likely to forage in the waters surrounding the islands during nesting seasons. Known breeding locations in the region include Forestier Island (Sable Island), Bedout Island and the Dampier Archipelago. The nesting sites at the Dampier Archipelago are the closest to the Project Area with a distance of ~90 km. Given the distance of the activities from the nesting sites any presence of seabirds and shorebirds within the Project Area is expected to be of a transitory and incidental nature only. The EPBC PMST lists three species of shark as Vulnerable/Migratory (Green Sawfish, White Shark and Whale Shark) that are likely to occur within the area. The Amulet Project Area is situated within a BIA foraging area for the Whale Shark. The approved Conservation Advice for Whale Sharks (TSSC 2015d) stated that the main threat to the species occurs outside Australian waters (which is from intentional and unintentional mortality from fishing). Within Australian waters, marine debris is listed as a less important threat. However, at present, this does not have an impact on the numbers of Whale Sharks visiting Australian waters (DEH 2005a). Foraging activity centres on the 200 m isobath, which is ~39 km from the Project Area (TSSC 2015d). The EPBC PMST shows that three species of marine mammal listed as either Vulnerable (Sei Whale, Fin Whale and Humpback Whale) and one species listed as Endangered (Blue Whale) that are likely, known or may occur within the Project Area. All four 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 Amulet Development intercepts with the Pygmy Blue Whale distribution BIA however, this area is not considered particularly important for the conservation of the species compared to migration or foraging BIAs. Pygmy Blue Whales migrate north from the Perth Canyon / Naturaliste Plateau region in March and April reaching Indonesia by June where they remain until at least September. The southern migration from

Indonesia may occur from September and finish by December in the subtropical frontal zone after which the animals may make their way slowly northwards towards the Perth Canyon by March or April (DoE 2015b). Pygmy Blue Whales tend to pass along the shelf edge at depths between 500 m to 1000 m during their migration (DoE 2015b). As the 500 m isobath is situated ~90 km north of the Amulet Project Area and the southern boundary of the migration BIA is ~60 km to the north of the Amulet Project Area, occurrences of the Pygmy Blue Whale within the Project Area are expected to be extremely unlikely.

The Amulet Development is situated ~32 km to the north of the Humpback Whale migration BIA. Humpback Whales migrate between May and November each year; with peak northern migration occurring during June and July, and no noted peak for the southern migration (TSSC 2015c). The population estimate of Humpback Whales on the west coast of Australia is ~28,800 (Salgado Kent et al. 2012). It has been suggested that Humpback Whales may use the ancient coastline at 125 m depth contour KEF as a guide as they migrate through the region (DEWHA 2008); this KEF is located ~8 km north of the Project Area. However, the Conservation Advice notes that Humpback Whales will migrate predominantly within 50 km of the coast (TSSC 2015c); that is, in areas inshore from the Project Area. In addition, 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 coast of WA of <25 km and therefore the whales were frequently in very shallow water of <40 m. The Project Area is situated >90 km from the Burrup Peninsula (closest coastal region), and is located in a water depth of ~85 m; therefore, based on this study (Double et al. 2010) it is likely that many Humpbacks will travel south of the Project Area during their return migration. The approved Conservation Advice (TSSC 2015c) identifies entanglement and marine debris as a threat.

The EPBC PMST shows that five species of turtle listed as either Vulnerable (Green Turtle, Hawksbill Turtle and Flatback Turtle) or Endangered (Loggerhead Turtle and Leatherback Turtle) are known or are likely to occur within the Project Area. The Project Area does not contain any BIAs for turtle species. 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 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 consists of 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 to prevent solid waste entering the marine environment, impacts from solid waste on marine fauna 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 7-109.

Table 7-109 Demonstration of Acceptability for Unplanned Discharge – Solid Waste

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="8">Water quality</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td colspan="4">With respect to Unplanned Discharge – Solid Waste, the Amulet Development will not result in significant impacts to water quality identified as potentially affected, defined as a possibility that it will (Section 6.6):
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
<tr><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">The proposed EPO’s for the Amulet Development are consistent with the principles of ESD.
With respect to potential impacts to all receptors from Unplanned Discharge – Solid Waste the relevant principles are:
• Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
• 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.</td></tr>
<tr><td>Internal context</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards.
With respect to potential impacts to all receptors from Unplanned Discharge – Solid Waste, there are no specific KATO internal requirements with respect to Unplanned Discharge – Solid Waste or potentially impacted receptors.</td></tr>
<tr><td>External context</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders.
With respect to potential impacts to all receptors from Unplanned Discharge – Solid Waste, no specific concerns were raised during stakeholder consultation with relevant persons.</td></tr>
<tr><td rowspan="2">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Unplanned Discharge – Solid Waste from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to water quality from Unplanned Discharge – Solid Waste, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td></td><td></td><td>AMSA Marine Orders Part 91 (Marine Pollution Prevention – Oil) 2014</td><td>Sets out the requirements of the prevention of pollution of the environment by oil for regulated Australian vessels, domestic commercial vessels and Australian recreation vessels.</td><td>Adoption of the following control measure:
CM30: Compliance with AMSA Marine Order 95 (Marine Pollution Prevention – Garbage).</td></tr>
<tr><td></td><td colspan="3">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td></td><td colspan="3">The impacts on water quality from Unplanned Discharge – Solid Waste include:
• 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.</td><td>Low</td></tr>
<tr><td></td><td colspan="4">Statement of acceptability</td></tr>
<tr><td></td><td colspan="4">Based on an assessment against the defined acceptable levels, the impacts on water quality from Unplanned Discharge – Solid Waste is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO22: Undertake the Amulet Development in a manner that will prevent an unplanned discharge of solid waste to the marine environment.</td></tr>
<tr><td>Seabirds and Shorebirds</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td></td><td colspan="4">With respect to Unplanned Discharge – Solid Waste, the Amulet Development will not result in significant impacts to seabirds and shorebirds identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of seabirds and shorebirds, or the spatial distribution of the population.
• substantially modify, destroy or isolate an area of important habitat for a migratory species
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="9"></td><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td rowspan="3">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Unplanned Discharge – Solid Waste from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to seabirds and shorebirds from Unplanned Discharge – Solid Waste, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (DoEE 2018a)</td><td>Identified marine debris as a key threat. No explicit relevant objectives or management actions for industries that are non-commercial fisheries related industries.</td><td>Adoption of the following control measure:
CM27: Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated.</td></tr>
<tr><td colspan="3">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="3">The impacts on seabirds and shorebirds from Unplanned Discharge – Solid Waste include:
Turtles and seabirds in particular are often subject to physical harm from solid waste, with entanglement being a relatively common occurrence and plastic waste being mistaken as food (i.e. plastic bags as jellyfish).
None of the threatened bird species listed within the PMST for the Project Area have been identified as being sensitive to interactions with marine debris.
Unplanned discharges of solid waste usually comprise items such as oily rags and residue from paint cans lost overboard and therefore are of relatively low levels. Given the low occurrence of unplanned discharges of solid waste with impacts considered on an individual basis, there is no population or ecosystem level impacts expected.</td><td>Low</td></tr>
<tr><td></td><td colspan="4">Statement of acceptability</td></tr>
<tr><td></td><td colspan="4">Based on an assessment against the defined acceptable levels, the impacts on seabirds and shorebirds from Unplanned Discharge – Solid Waste is considered acceptable, given that:
the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above</td></tr>
</table>

Receptor	Demonstration of Acceptability		
	• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO22:** Undertake the Amulet Development in a manner that will prevent an unplanned discharge of solid waste to the marine environment.		
Fish	**Acceptable level of impact**		
	With respect to Unplanned Discharge – Solid Waste, the Amulet Development will not result in significant impacts to *fish* identified as potentially affected, defined as a possibility that it will (Section 6.6): • have a substantial adverse effect on a population of fish, or the spatial distribution of the population. • substantially modify, destroy or isolate an area of important habitat for a migratory species. • seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		
	Acceptability assessment		
	Principles of ESD	Refer to details in *water quality* assessment (above)	
	Internal context	Refer to details in *water quality* assessment (above)	
	External context	Refer to details in *water quality* assessment (above)	
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Unplanned Discharge – Solid Waste from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. Marine debris is identified as key threat for all vertebrate fauna in the Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (DoEE 2018a); however there are no explicit management actions for industries that are non-commercial fisheries related industries. With respect to potential impacts to *fish* from Unplanned Discharge – Solid Waste, this specifically includes:	

Requirement	*Relevant Item/Objective/Action*	*Addressed/Managed by Amulet Development*
Threat abatement plan for the impacts of marine debris on the	Identified marine debris as a key threat. No explicit relevant objectives or management	Adoption of the following control measure:

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td></td><td></td><td>vertebrate wildlife of Australia's coasts and oceans (DoEE 2018a)</td><td>actions for industries that are non-commercial fisheries related industries.</td><td rowspan="2">CM27: Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated.</td></tr>
<tr><td></td><td></td><td>Conservation advice Rhincodon typus (Whale Shark) (TSSC 2015d)</td><td>Identified marine debris as a threat. No explicit relevant objectives or management actions.</td></tr>
<tr><td></td><td colspan="3">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td></td><td colspan="3">The impacts on fish from Unplanned Discharge – Solid Waste include:
• The Project Area intersects a Whale Shark foraging BIA. Within Australian waters, marine debris is listed as a less important threat; however foraging activity is centred on the 200 m isobath, which is ~39 km away.
• Given the low occurrence of unplanned discharges of solid waste with impacts considered on an individual basis, there is no population or ecosystem level impacts expected.</td><td>Low</td></tr>
<tr><td></td><td colspan="4">Statement of acceptability</td></tr>
<tr><td></td><td colspan="4">Based on an assessment against the defined acceptable levels, the impacts on fish from Unplanned Discharge – Solid Waste is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO22: Undertake the Amulet Development in a manner that will prevent an unplanned discharge of solid waste to the marine environment.</td></tr>
<tr><td>Marine mammals</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td></td><td colspan="4">With respect to Unplanned Discharge – Solid Waste, the Amulet Development will not result in significant impacts to marine mammals identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="12"></td><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td rowspan="4">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Unplanned Discharge – Solid Waste from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to marine mammals from Unplanned Discharge – Solid Waste, With respect to potential impacts to fish from Unplanned Discharge – Solid Waste, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia’s coasts and oceans (DoEE 2018a)</td><td>Identified marine debris as a key threat. No explicit relevant objectives or management actions for industries that are non-commercial fisheries related industries.</td><td rowspan="2">Adoption of the following control measure:
CM27: Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated.</td></tr>
<tr><td>Conservation Advice Megaptera novaeangliae Humpback Whale (TSSC 2015c)</td><td>Identifies entanglement from marine debris as a threat. No explicit relevant objectives or management actions.</td></tr>
<tr><td colspan="3">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="3">The impacts on marine mammals from Unplanned Discharge – Solid Waste include:
• All four 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).
• Given the low occurrence of unplanned discharges of solid waste with impacts considered on an individual basis, and sensitivity of marine mammals generally low, there is no population or ecosystem level impacts expected.</td><td>Low</td></tr>
<tr><td colspan="4">Statement of acceptability</td></tr>
<tr><td colspan="4">Based on an assessment against the defined acceptable levels, the impacts on marine mammals from Unplanned Discharge – Solid Waste is considered acceptable, given that:</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="3">• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO22: Undertake the Amulet Development in a manner that will prevent an unplanned discharge of solid waste to the marine environment.</td></tr>
<tr><td rowspan="7">Marine reptiles</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Unplanned Discharge – Solid Waste, the Amulet Development will not result in significant impacts to marine reptiles identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Unplanned Discharge – Solid Waste from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to marine reptiles from Unplanned Discharge – Solid Waste, no explicit relevant requirements or actions were identified.
Marine debris is identified as key threat for all vertebrate fauna in the Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia’s coasts and oceans (DoEE 2018a); however there are no explicit management actions for industries that are non-commercial fisheries related industries.
Requirement | Relevant Item/Objective/Action | Addressed/Managed by Amulet Development</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="6"></td><td rowspan="2"></td><td>Approved conservation advice for Dermochelys coriacea (Leatherback Turtle) (TSSC 2009a)</td><td>Identified marine debris as a threat. No explicit relevant objectives or management actions.</td><td rowspan="2">Adoption of the following control measure:
CM27: Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated.</td></tr>
<tr><td>Recovery plan for marine turtles in Australia (DoEE 2017a)</td><td>A3. Reduce the impacts from marine debris:
Support the implementation of the EPBC Act Threat Abatement Plan for the impacts of marine debris on vertebrate marine life.</td></tr>
<tr><td colspan="3">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="3">The impacts on marine reptiles from Unplanned Discharge – Solid Waste include:
• Turtles and seabirds in particular are often subject to physical harm from solid waste, with entanglement being a relatively common occurrence and plastic waste being mistaken as food (i.e. plastic bags as jellyfish).
• All five turtle species listed within the EPBC PMST report 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 does not contain any BIAs for turtle species.
• Given the low occurrence of unplanned discharges of solid waste with impacts considered on an individual basis, there is no population or ecosystem level impacts expected.</td><td>Low</td></tr>
<tr><td colspan="4">Statement of acceptability</td></tr>
<tr><td colspan="4">Based on an assessment against the defined acceptable levels, the impacts on marine reptiles from Unplanned Discharge – Solid Waste is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO22: Undertake the Amulet Development in a manner that will prevent an unplanned discharge of solid waste to the marine environment.</td></tr>
</table>

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-110.

Table 7-110 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	**EPO22:** Undertake the Amulet Development in a manner that will prevent an unplanned discharge of solid waste to the marine environment.	**CM27**: Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM30**: Compliance with AMSA Marine Order 95 (Marine Pollution Prevention – Garbage).	Minor	Very Unlikely	Low
Seabirds and shorebirds	Injury / mortality to fauna			Minor	Very Unlikely	Low
Fish				Minor	Very Unlikely	Low
Marine mammals				Minor	Very Unlikely	Low
Marine reptiles				Minor	Very Unlikely	Low

C=Consequence L=Likelihood RL=Risk Level

7.2.5 Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons)

During activities associated with the Amulet 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 Amulet 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 7-111.

Types of fluids that may be present on the facilities and vessels associated with the Amulet Development include:

- non-process chemicals
- non-process hydrocarbons
- process chemicals.

Details of the hydrocarbons and chemicals that may be present during the Amulet Development are outlined in Table 7-111.

Table 7-111 Potential MLOC Hydrocarbons and Chemicals at the Amulet 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	Drilling Operations Cementing	~25 m^3 of chemicals during bulk transfer,	Storage in ISO tanks: • tank rupture • corrosion

Chemical Type	Chemical Material	Chemical Use	Credible MLOC Volume	Potential Cause of MLOC
	(WBM/ SBM) MEG Cement		based on largest isotainer size	Bulk transfer and bunkering: • partial or total failure of bulk transfer hose or fittings • failure of dry-break couplings

As detailed in Table 7-111, 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 Amulet 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 Impact and 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 7-112 identifies the potential impacts to receptors as a result of an unplanned minor loss of containment from the Amulet 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 7-113 provides a summary and justification for those receptors not evaluated further.

Table 7-112 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 7-113 Justification for Receptors Not Evaluated Further for Unplanned Discharge – Minor Loss of Containment

Ambient Sediment Quality	***X***
Change in sediment quality 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 (~85 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 North West Shelf (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. The approved Conservation Advice for Whale Sharks (TSSC 2015d) stated that the main threat to the species occurs outside Australian waters (which is from intentional and unintentional mortality from fishing). Within Australian waters, habitat disruption from mineral exploration, production and transportation is listed as a threat. However, foraging activity is centred on the 200 m isobath, which is ~39 km from the Project Area (TSSC 2015d).. 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 Amulet 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***
<u>Changes to the functions, interests or activities of other users</u> 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. Ten state and three Commonwealth-managed fisheries intersect with the Project Area, but historical fishing effort data (Sections 5.5.2.1 and 5.5.2.2) show minimal and intermittent commercial fishing activity is expected to occur within the planned activities areas for the Amulet Development. Any fishing effort that may occur is expected to be from one of the North Coast Demersal Scalefish Fisheries (PFTIMF, PLF, PTMF).	

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 7-114 provides a detailed evaluation of the impact of an unplanned minor loss of containment to physical receptors.

Table 7-114 Impact and Risk Assessment for Physical Receptors 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 7-115.

Table 7-115 Demonstration of Acceptability for an Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons)

Receptor	Demonstration of Acceptability	
Water quality	**Acceptable level of impact**	
	With respect to Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons), the Amulet Development will not result in significant impacts to water quality identified as potentially affected, defined as a possibility that it will (Section 6.6): • result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	
	Acceptability assessment	
	Principles of ESD	The proposed EPO's for the Amulet Development are consistent with the principles of ESD. With respect to potential impacts to *all receptors* from Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons), the relevant principles are: • Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. • 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.
	Internal context	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards. With respect to potential impacts to *all receptors* from Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons), this specifically includes: • KATO Chemical Management Procedure (KAT-000-EN-PP-001) (KATO 2020h) • KATO Marine Operations Procedure (KAT-000-PO-PP-101) (KATO 2020b)
	External context	The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders. With respect to potential impacts to *all receptors* from Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons), no specific concerns were raised during stakeholder consultation with relevant persons.
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Unplanned Discharge – Minor Loss of

Receptor	Demonstration of Acceptability			
		Containment (Chemicals and Hydrocarbons) from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. With respect to potential impacts to *water quality* from Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons), this specifically includes:		
		Requirement	*Relevant Item/Objective/Action*	*Addressed/Managed by Amulet Development*
		Protection of the Sea (Prevention of Pollution from Ships) Act 1983 – Section 26F (implements MARPOL Annex I).	Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution. It also invokes certain requirements of the MARPOL Convention including those relating to discharge of noxious liquid substances, sewage, garbage and air pollution. Includes the requirement for an approved Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class) which describes emergency response activities.	Adoption of the following control measures: **CM04:** KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM21:** Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM27:** Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM28:** 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. **CM36:** 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).
		Navigation Act 2012 – Chapter 4 (Prevention of Pollution).	Gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).	
		AMSA Marine Orders Part 91 (Marine Pollution Prevention – Oil) 2014.	Sets out the requirements of the prevention of pollution of the environment by oil for regulated Australian vessels, domestic commercial vessels and Australian recreation vessels.	

Receptor	Demonstration of Acceptability			
				CM37: Emergency response capability (including equipment) will be maintained in accordance with SOPEPS/SMPEPs; and accepted EPs and OPEPs.
	Summary of impact assessment			**Risk level**
	The impacts on *water quality* from Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons) include: • 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). • 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. • 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.			Minor
	Statement of acceptability			
	Based on an assessment against the defined acceptable levels, the impacts on *water quality* from Unplanned Discharge – Minor Loss of Containment (Chemicals and Hydrocarbons) is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO23**: Undertake the Amulet Development in a manner that will prevent an unplanned discharge of chemicals or hydrocarbons to the marine environment.			

A summary of the impact analysis and evaluation, including adopted control measures and EPOs, is provided in Table 7-116.

Table 7-116 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	**EPO23:** Undertake the Amulet Development in a manner that will prevent an unplanned discharge of chemicals or hydrocarbons to the marine environment.	**CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM27**: Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM28**: 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. **CM36:** 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). **CM37**: Emergency response capability (including equipment) will be maintained in accordance with SOPEPS/SMPEPs; and accepted EPs and OPEPs.	Minor	Very unlikely	Low

C=Consequence L=Likelihood RL=Risk Level

7.2.6 Accidental Release – Amulet Light Crude Oil

During activities associated with the Amulet Development, an accidental release of Amulet crude (a light crude oil) may occur.

7.2.6.1 Aspect Source

Throughout the Amulet 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 Amulet 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 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; and the Talisman production flowline and jumper connection (if selected). 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 Amulet light crude oil.

Decommissioning

At the end of a well's lifetime, it must be permanently 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 Amulet light crude oil.

Support Activities (all phases)

A variety of vessels will be used during all phases of the Amulet 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 bulk storage tank on the MOPU, FSO or export tanker could be the source of an accidental release of Amulet light crude oil.

Guidance on the 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 Amulet light crude oil. There are three potential sources of an accidental release of Amulet light crude oil:

- 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 7-117.

Table 7-117 Potential Maximum Credible Spill Scenarios for Accidental Release – Amulet 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
Rupture of Talisman production flowline	Inventory of entire flowline = 65 m^3.	Offshore Pipeline / Rupture. Based on ability to detect major faults but absence of block valves.	65 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 (~85 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 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	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. The guidance for a 100,000DWT vessel gives 5,500 m^3.	6,425 m^3 released over 1 hour

Cause	Description	AMSA Basis of Credible Volume	Maximum Credible Volume and Duration
	largest tanker to be used for the conversion will be an Aframax Tanker, between 80,000–120,000 DWT.	Pro-rata up to 120,000 DWT gives ~6,425 m^3.	
LOWC	Predicted flow rates from the Amulet^ 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 Amulet 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 Amulet is south-west of Montara, so an extra 3 days were allowed for to account for the longer steam to site. Figure 7-23 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 69,801 m^3 released over 80 days. A variable rate of 967–797 m^3/day was used to simulate depressurisation of the reservoir.

^ A LOWC from Talisman was not considered as the maximum credible spill scenario. The Talisman reservoir has already been produced, and as such both initial reservoir volume and pressure have been significantly depleted. Using conservative estimates of remaining oil volume, and also conservatively allowing for a full reservoir recharge to initial conditions and an aquifer drive, the forecast LOWC release from Talisman would result in ~0.36 MMbbls of oil (i.e. less than the ~0.44 MMbbls of oil at Amulet).

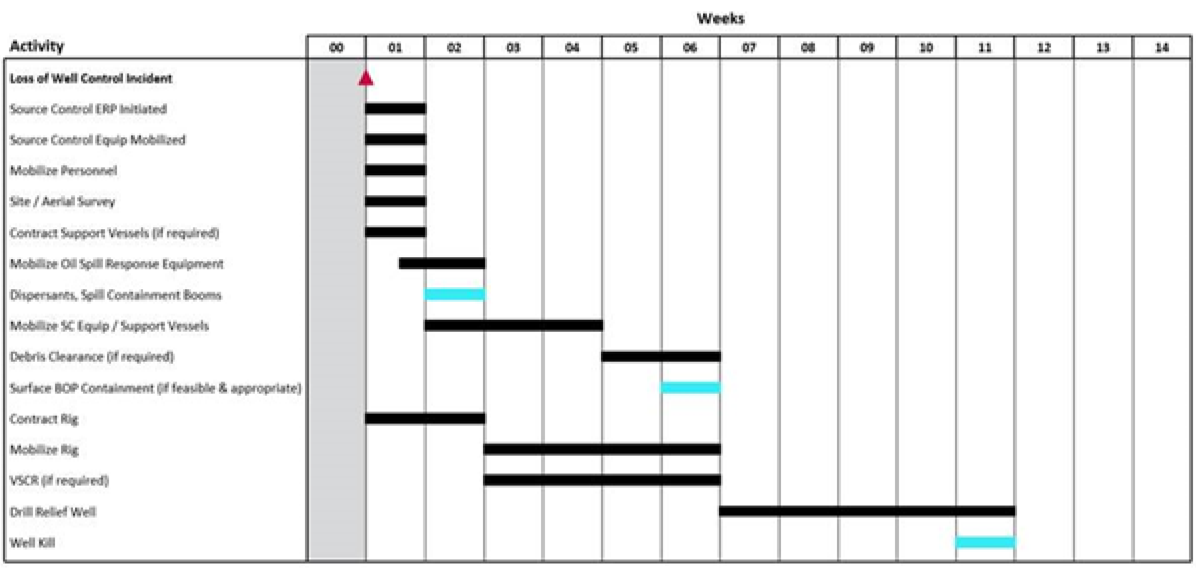


Figure 7-23 Indicative Schedule to Drill a Relief Well in the Event of a LOWC

The LOWC scenario poses the worst-case impact for Accidental Release – Amulet Light Crude Oil out of all the scenarios identified in

Table 7-117. 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 Amulet 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 Amulet light crude oil following a LOWC (

Table 7-118). This is considered the worst-case scenario for potential Amulet light crude oil releases and therefore is representative of the greatest spatial extent of potential impacts.

Table 7-118 Loss of Well Control Event used for Spill Modelling

Scenario Description	Subsea release after loss of well control event
Spill Location	Amulet-1 (~800 m from the expected position of the MOPU)
Oil Released	Amulet light crude oil
Spill Duration	80 days
Total Volume Released	69,801 m^3
Flow Rate ^	967–797 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 Amulet light crude is a light persistent oil, with a low dynamic viscosity and low pour point (Table 7-119). The oil has relatively low (5.0%) residual component (i.e. the component that tends not to evaporate and that may persist in the marine environment) and a relatively low (11.0%) aromatics component (i.e. the component that may dissolve into water).

Table 7-119 Characteristics of Amulet Crude Oil

Classification	Group II, Light persistent oil
API Gravity	43.7 °API
Density	0.80 g/cm^3 at 15 °C

Viscosity	2.35 cP at 15 °C				
Pour Point	9 °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	57.0	22.0	16.0	5.0	11.0
Percentage of Aromatic component only	7.0	3.0	1.0	0	N/A

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 Amulet light crude are:

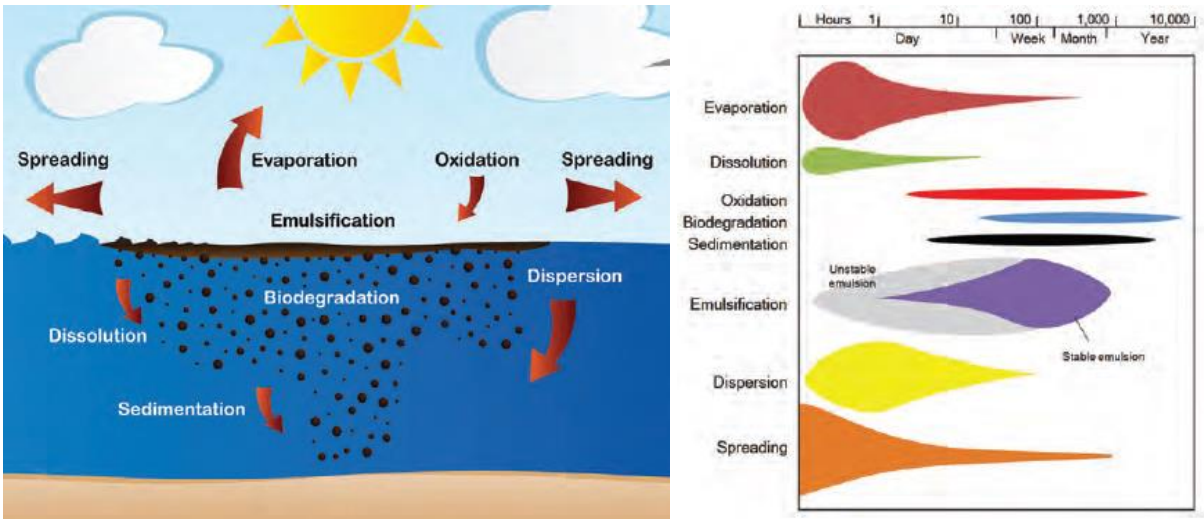
- *Specific gravity* – The Amulet crude has a specific gravity less than seawater and therefore will have the tendency to float.
- *Distillation characteristics (Volatility)* – The Amulet light crude has a high proportion (95%) of volatile components that once on the surface will readily evaporate. Typical 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 (5.0%) 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 Amulet crude has a low viscosity and will tend to flow and spread on the sea surface and may be readily broken up into droplets and entrained into the water column.
- *Pour point* – The Amulet crude has a pour point 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 relatively low proportion (11.0%) of the total Amulet light crude oil by mass. 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 7-24). 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.

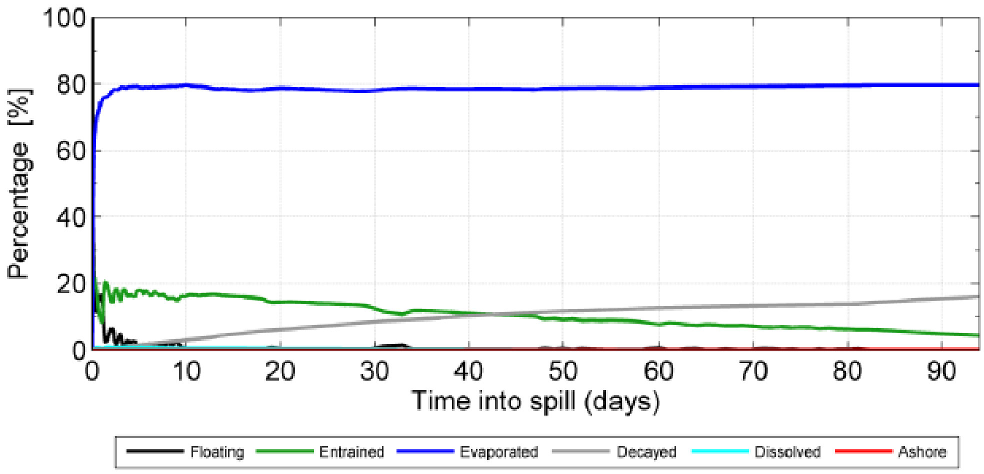
As oil weathers, its composition changes (French-McCay 2018). When oil is floating, the volatile components evaporate rapidly, and the remaining floating oil becomes more viscous and therefore spreading rates also reduce. Floating oil may also be entrained into the water column by breaking waves, or 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 7-24 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

An example of predicted weathering during the modelled 80-day subsurface release of Amulet light crude is shown in Figure 7-25. This example shows that the oil would initially build up in the water column in entrained form, but this would steadily decrease from ~17% of the volume 12-hours after the spill commencement to ~4% by the end of the simulation (94 days). Evaporation rates are predicted to increase very quickly following the commencement of the spill and remain ~79% for the duration of the simulation. A low volume of oil is expected to remain on the surface over time (<6% after day-2), due to the high evaporation rates. Degradation is predicted to slowly increase throughout the simulation, reaching ~16% by the end of the simulation.



Source: RPS 2019

Figure 7-25 Predicted Weathering for a Subsea Release of 69,801 m^3 Amulet Crude under Variable Environmental 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:

- floating (surface)
- 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).

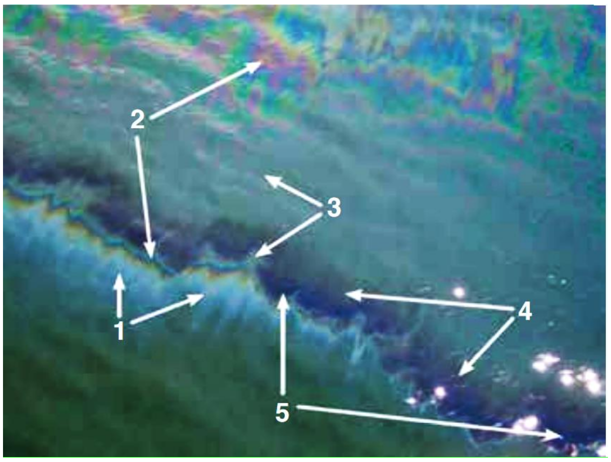
The exposure values used in the spill modelling and impact assessment are described in Table 7-120 and are based on available guidance (e.g. NOPSEMA 2019) and literature (e.g. French-McCay 2018; 2016).

Table 7-120 Exposure Values used in Modelling and Impact Assessments for Accidental Hydrocarbon Release

Exposure Values	Qualitative Description	Environmental Relevance
Floating (surface)		
Low 1 g/m^2	1 ml within 1 m^2 (~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 form 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.
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	

Exposure Values	Qualitative Description	Environmental Relevance
	appearance (BAOAC Code 3)	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) 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.
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-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) 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.
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	
High 400 ppb (instantaneous)	0.4 ml within 1 m^3 (<1/10th of a teaspoon within 1 m^3)	
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.

Exposure Values	Qualitative Description	Environmental Relevance
Moderate 100 ppb (instantaneous)	0.1 ml within 1 m^3 (~1/50th of a teaspoon within 1 m^3)	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) 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.
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) Visible on surface with a metallic appearance (BAOAC Code 3)	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 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). 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). 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) 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.
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)	
High 1,000 g/m^2	1 L within 1 m^2 BAOAC Code 5 – continuous true colour	

Exposure Values	Qualitative Description	Environmental Relevance
<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 Amulet light 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 ~11 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 7-26 shows a schematic 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 150 model runs, and do not represent the actual exposure that would occur from a single individual event.

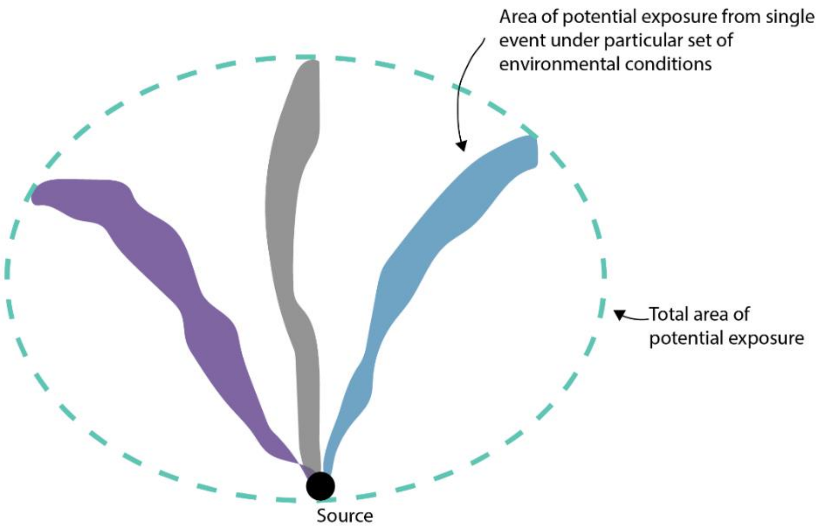


Figure 7-26 Deterministic and Stochastic Modelling

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 7-27). Note that for the Amulet light crude, this residual component represents a very small proportion (5.0%) 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 7-27). The Amulet light crude has a relatively low proportion of aromatics (11.0%).

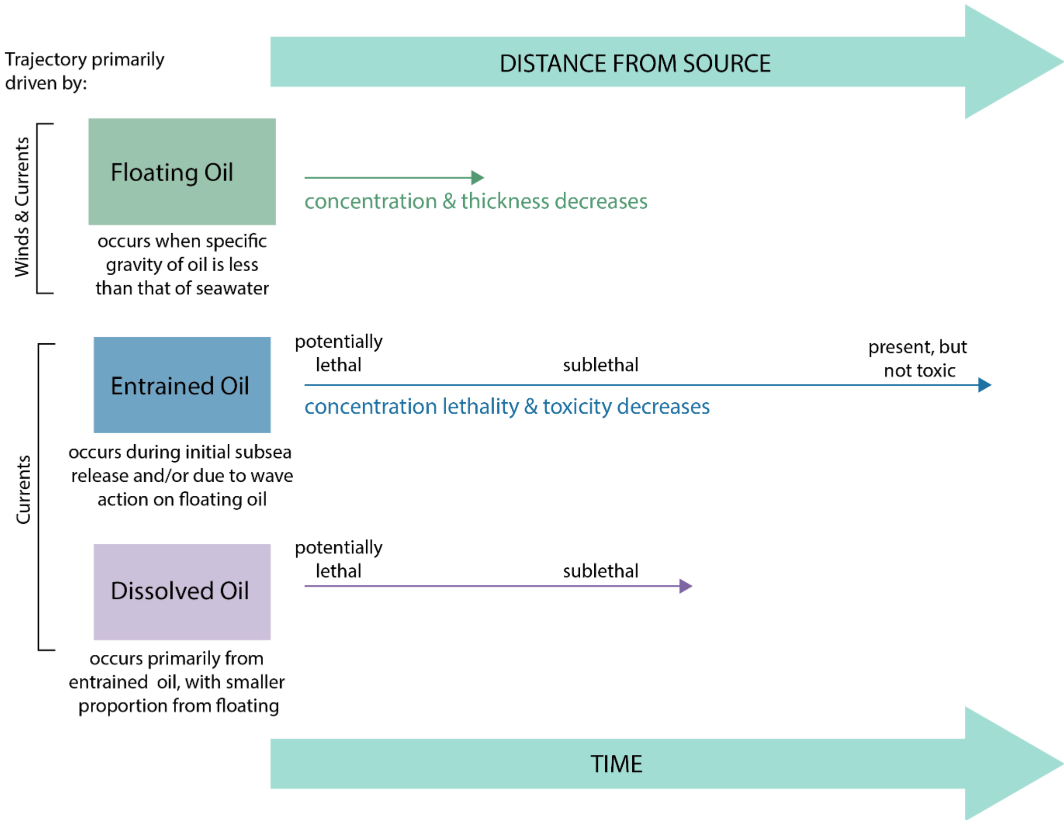


Figure 7-27 Oil Components and Typical Exposure Extent and Type of Impacts

The results of the stochastic modelling undertaken using SIMAP (RPS 2019) is presented in Table 7-121, Figure 7-28, Figure 7-30, Figure 7-32 and Figure 7-34 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 7-29, Figure 7-31, Figure 7-33, Figure 7-35).

Table 7-121 Summary of Stochastic Modelling Results for a LOWC (Accidental Release – Amulet Crude Oil)

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
Floating (surface)																		
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 State waters or over the shallow continental shelf area (Figure 7-28). • 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 393 km.	✓									✓		X		X	✓	✓	X
Moderate 10 g/m^2	• Floating oil above 10 g/m^2 generally remains within close proximity to the spill source, with a slight extension in a NE/SW direction (Figure 7-28). • Maximum distance from the source predicted for floating oil above 10 g/m^2 is 58 km. • Would intersect with BIAs for seabirds, sharks and whales. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack, with a low probability (<%2%) of intersecting the North-West Slope Trawl fishery.	✓					✓		✓	✓	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
High 25 g/m^2	• Floating oil above 25 g/m^2 generally remains within the immediate vicinity of spill source (Figure 7-28). • Maximum distance from the source predicted for floating oil above 25 g/m^2 is 19 km. • May intersect with BIAs for seabirds, sharks and whales (~56–66% probability). • May intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack (~56–66% probability), with a low probability (<2%) of intersecting the North-West Slope Trawl fishery.	✓					✓		✓	✓	X	X	X		X			X
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 within State waters or over the shallow continental shelf area (Figure 7-30). • Maximum distance from the source predicted for dissolved oil above 50 ppb is 584 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 typically remaining with surface layers.	✓				✓		✓	✓	✓	✓	✓	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
	• Probability of exposure to Australian Marine Parks was highest at 8% for Montebello Marine Park during summer. • Would intersect with BIAs for turtles, seabirds, sharks and whales. • 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)	• Dissolved hydrocarbons above the time-integrated threshold (i.e. 4,800 ppb.hr) are predicted to occur only in the immediate vicinity (up to ~15 km) of the spill source (Figure 7-30). • Limited benthic interaction is predicted to occur, with dissolved typically remaining with surface layers.					✓		✓	✓	✓	X	X	X		X		✓	
High 400 ppb (instantaneous)	• Dissolved hydrocarbons above 400 ppb are predicted to occur in a patchy distribution around the spill source (Figure 7-30). • Maximum distance from the source predicted for dissolved hydrocarbons above 400 ppb is 54 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.	✓				✓		✓	✓	✓	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
	• Limited benthic interaction is predicted to occur, with dissolved typically remaining with surface layers. In shallower and nearshore areas some benthic interaction from entrained oil may potentially occur. • Relatively low probability (≤2%) of contact is predicted with BIAs for seabirds, sharks and whales. • Relatively low probability (≤2%) of contact with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack and North-west Slope Trawl 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 (Figure 7-32). • Maximum distance from the source predicted for entrained hydrocarbons above 100 ppb is 832 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.	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓		✓		✓	

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
	• Limited benthic interaction is predicted to occur. Entrained oil concentrations in the vicinity of the release site >100 ppb are not expected to exceed depths of ~25 m. In shallower and nearshore areas some benthic interaction from entrained oil may potentially occur. • Probability of exposure to Australian Marine Parks was highest at 58% for Montebello Marine Park during summer. • Would intersect with BIAs for turtles, seabirds, sharks and whales. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack, and North-West Slope Trawl fishery.																	
Moderate 100 ppb (time-integrated)	• Maximum distance from the source predicted for entrained hydrocarbons above the time-integrated threshold (9,600 ppb.hr) is 483 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 dissolved typically remaining with surface layers. • Would intersect with BIAs for seabirds, sharks and whales. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack, and North-West Slope Trawl fishery.				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
High 1,000 ppb (instantaneous)	• Entrained oil above 1,000 ppb may extend NE/SW and offshore from the spill source (Figure 7-32). • Maximum distance from the source predicted for entrained hydrocarbons above 1,000 ppb is 212 km. • Limited benthic interaction is predicted to occur. Entrained oil concentrations in the vicinity of the release site >1,000 ppb are not expected to exceed depths of ~35 m. No exposure in shallow and nearshore areas is predicted. • Would intersect with BIAs for seabirds, sharks and whales. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish, Western Skipjack; and low probability (~2%) of exposure to North-West Slope Trawl fishery.	✓	X		X	✓		✓	✓	✓	X	✓	X		X		✓	
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 40 km; however this occurs as an individual patch and not a continuous cover from the spill source (Figure 7-32). • No benthic interaction is predicted to occur, with entrained hydrocarbons typically remaining with surface layers (<10 m).				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
Shoreline																		
Low 10 g/m^2	• Shoreline accumulation above 10 g/m^2 may along some offshore islands (e.g. Montebello, Barrow, southern Pilbara islands) and the western coast of North West Cape (Figure 7-34). • Probability of shoreline exposure is low, typically <4%. The highest predicted was 16% during summer for the North West Cape. • The worst-case maximum length of shoreline with concentrations >10 g/m^2 was 28 km along the western coast of North West Cape.		✓										✓	X	✓			✓
Moderate 100 g/m^2	• Negligible shoreline accumulation above 100 g/m^2 was predicted to occur; four individual model cells on the west coast of North West Cape registered at this exposure level at a probability of 4% during summer only (Figure 7-34). • The worst-case maximum length of shoreline with concentrations >100 g/m^2 was 3 km along the western coast of North West Cape. • The maximum total volume of oil onshore during any of the simulations was 18 m^3.		✓	✓	✓		✓		✓					X				
High 1,000 g/m^2	• Shoreline accumulation above this exposure value is not predicted to occur.		X	X	X		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.

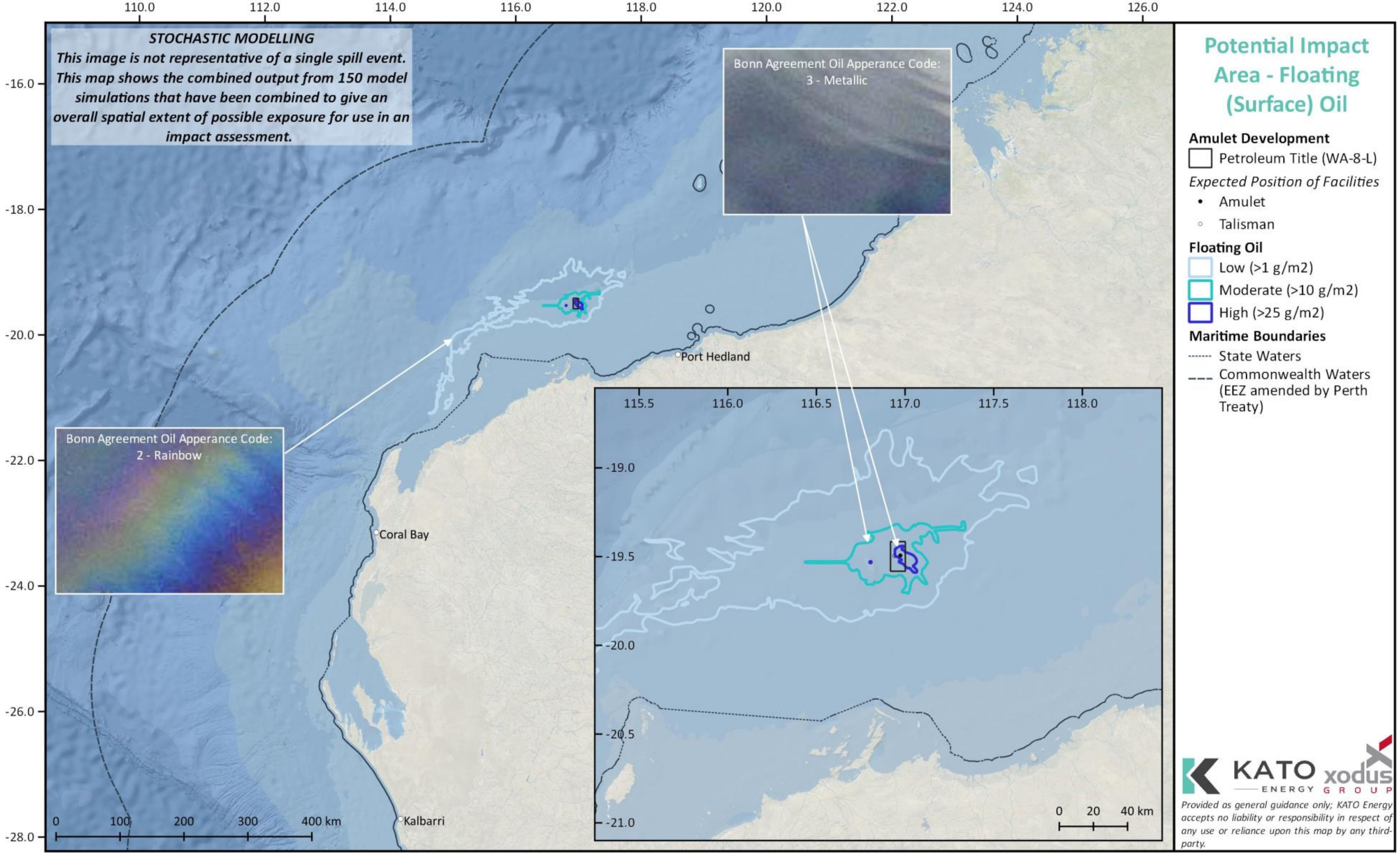


Figure 7-28 Potential Impact Area (stochastic modelling output) for Floating Oil from a Subsea Release of Amulet Light Crude

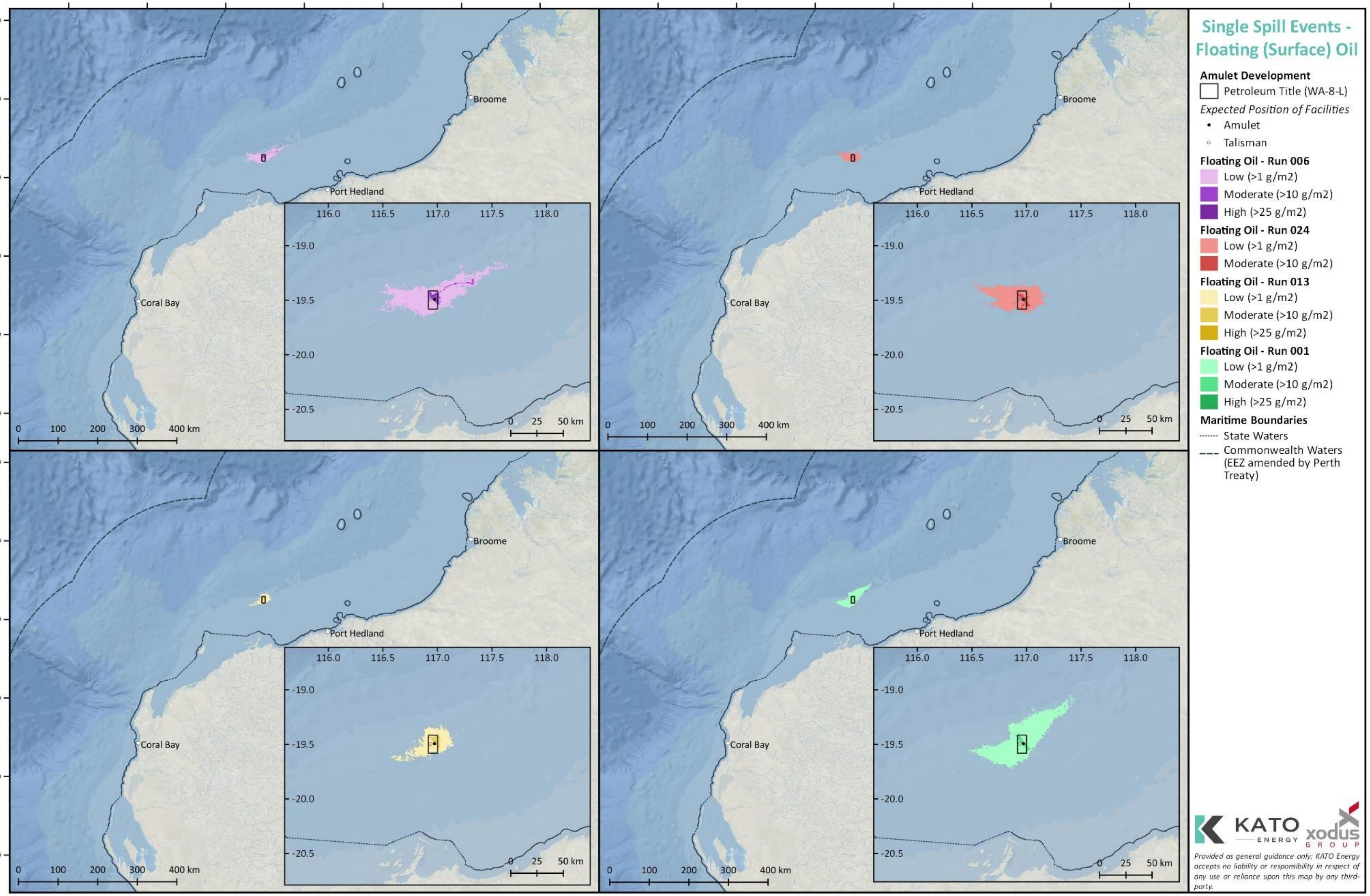


Figure 7-29 Examples of an Individual Spill Event (deterministic modelling output) for Floating Oil from a Subsea Release of Amulet Light Crude

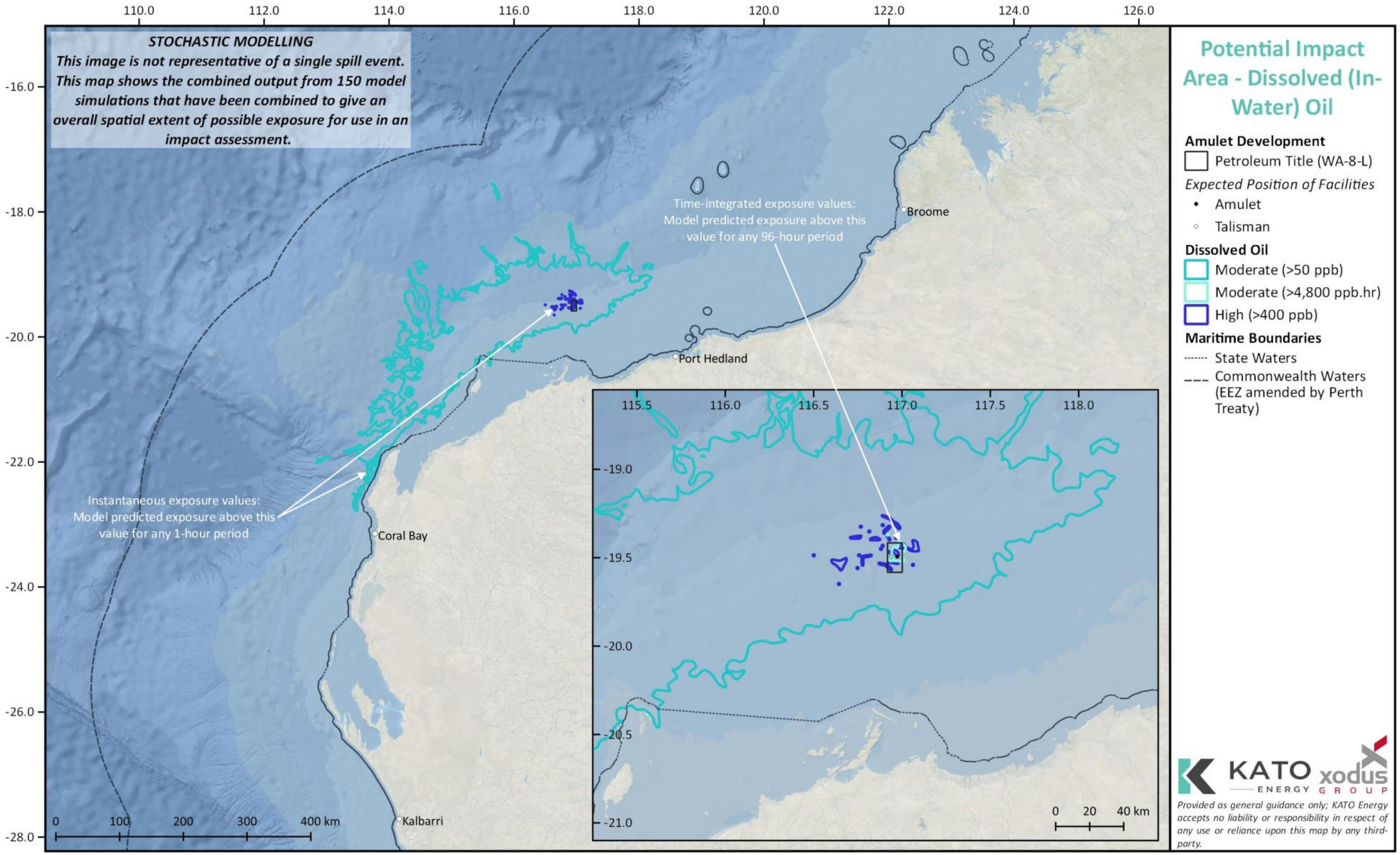


Figure 7-30 Potential Impact Area (stochastic modelling output) for Dissolved Oil from a Subsea Release of Amulet Light Crude

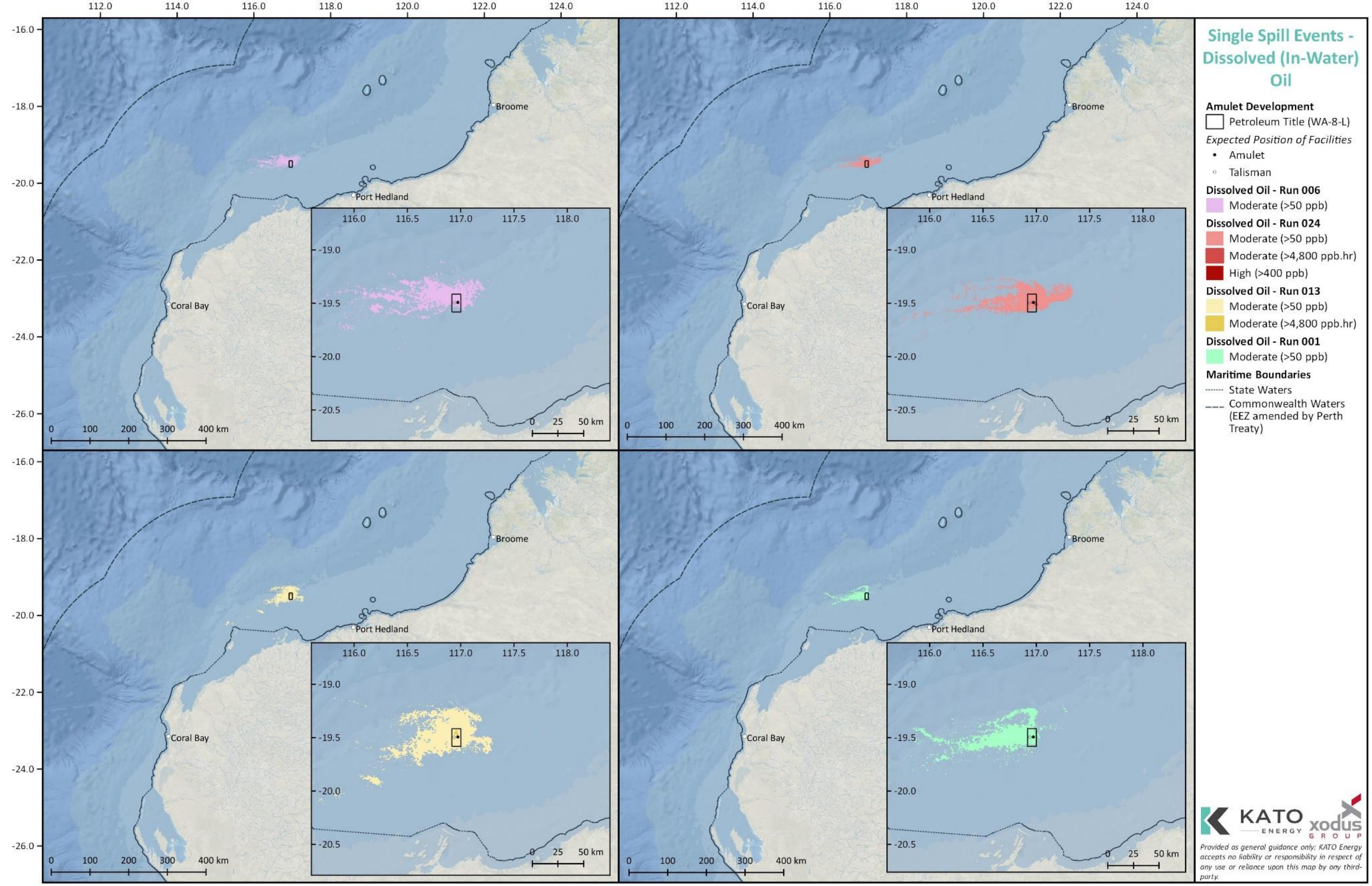


Figure 7-31 Examples of an Individual Spill Event (deterministic modelling output) for Dissolved Oil from a Subsea Release of Amulet Light Crude

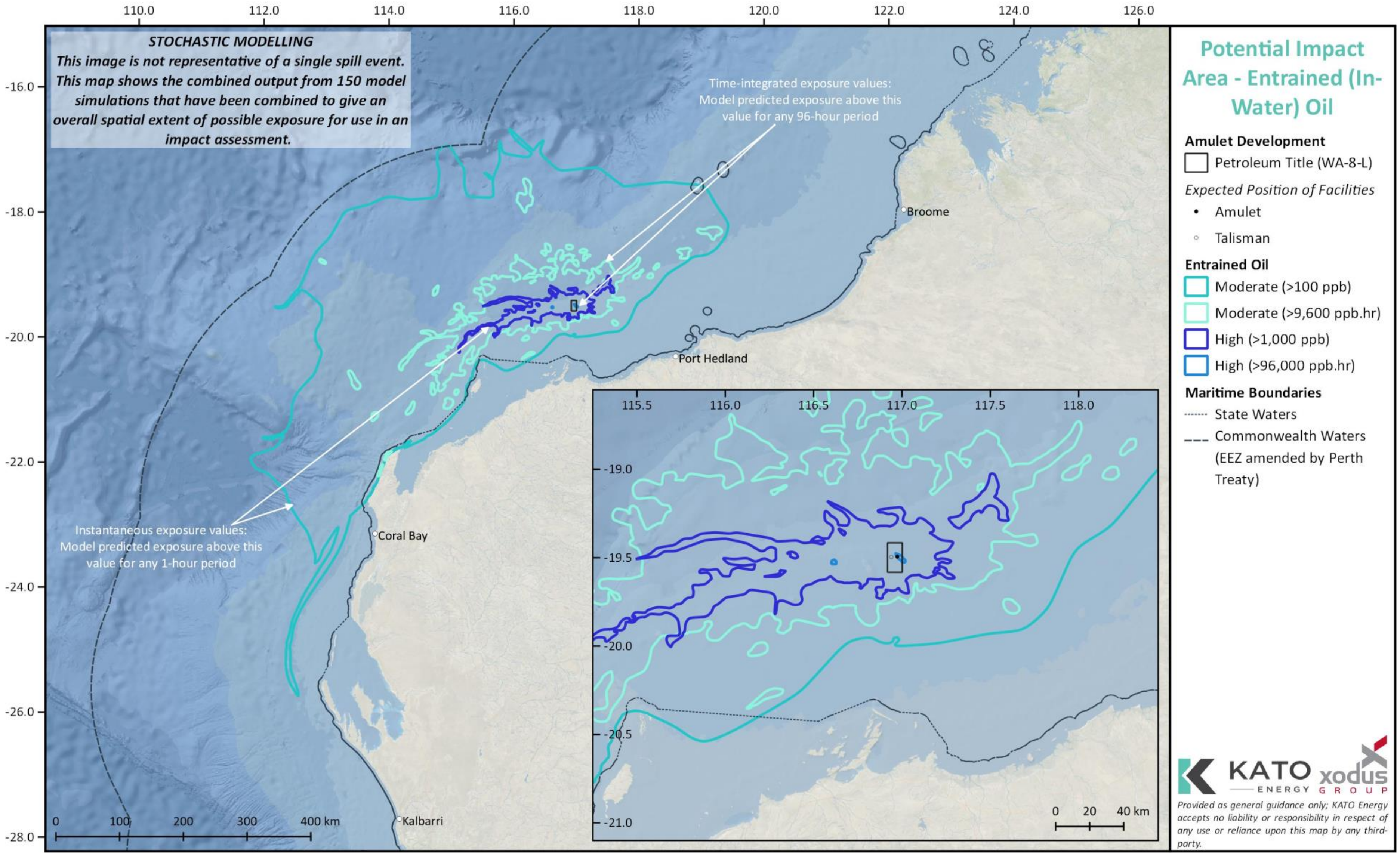


Figure 7-32 Potential Impact Area (stochastic modelling output) for Entrained Oil from a Subsea Release of Amulet Light Crude

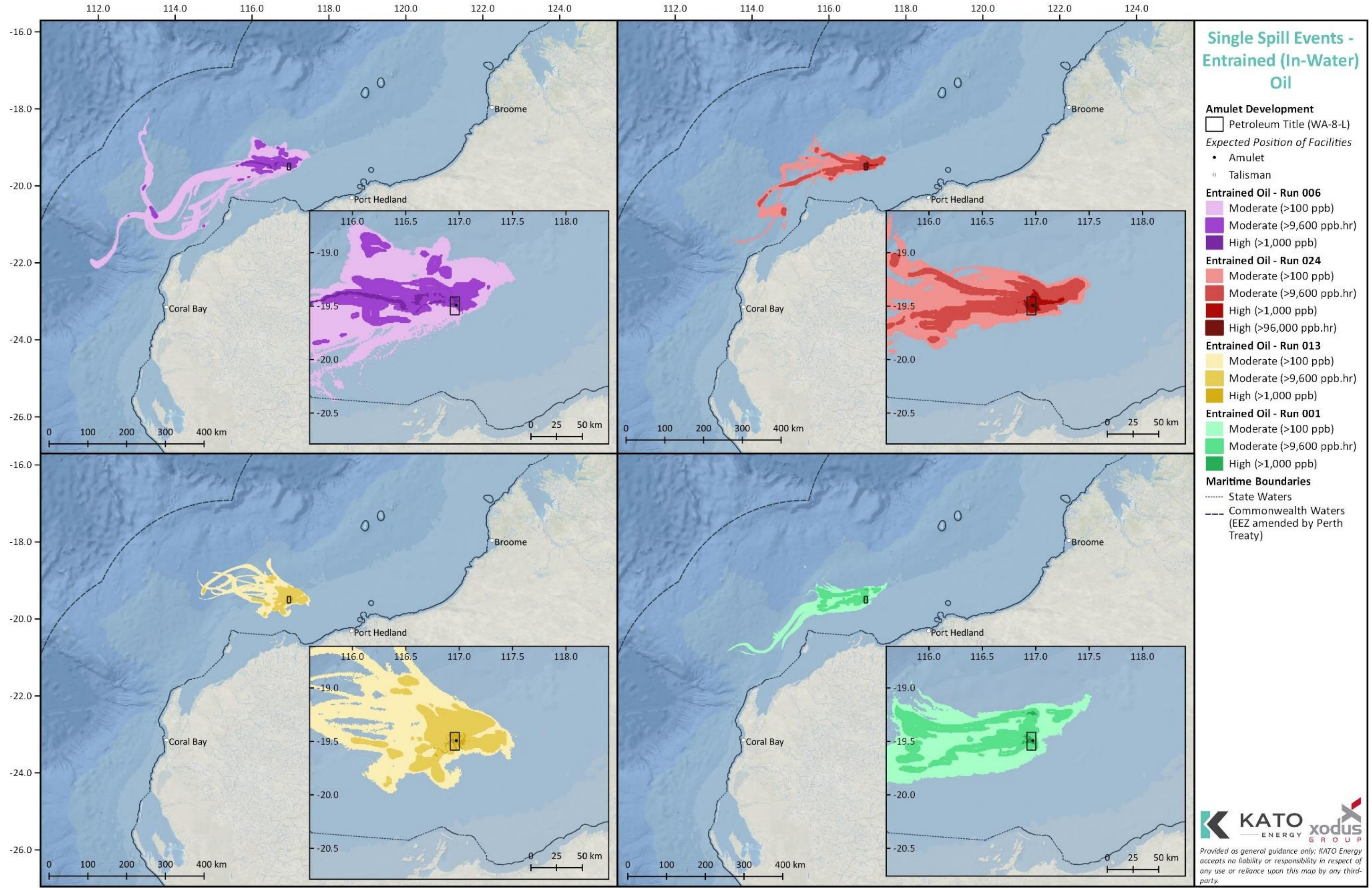


Figure 7-33 Examples of an Individual Spill Event (deterministic modelling output) for Entrained Oil from a Subsea Release of Amulet Light Crude

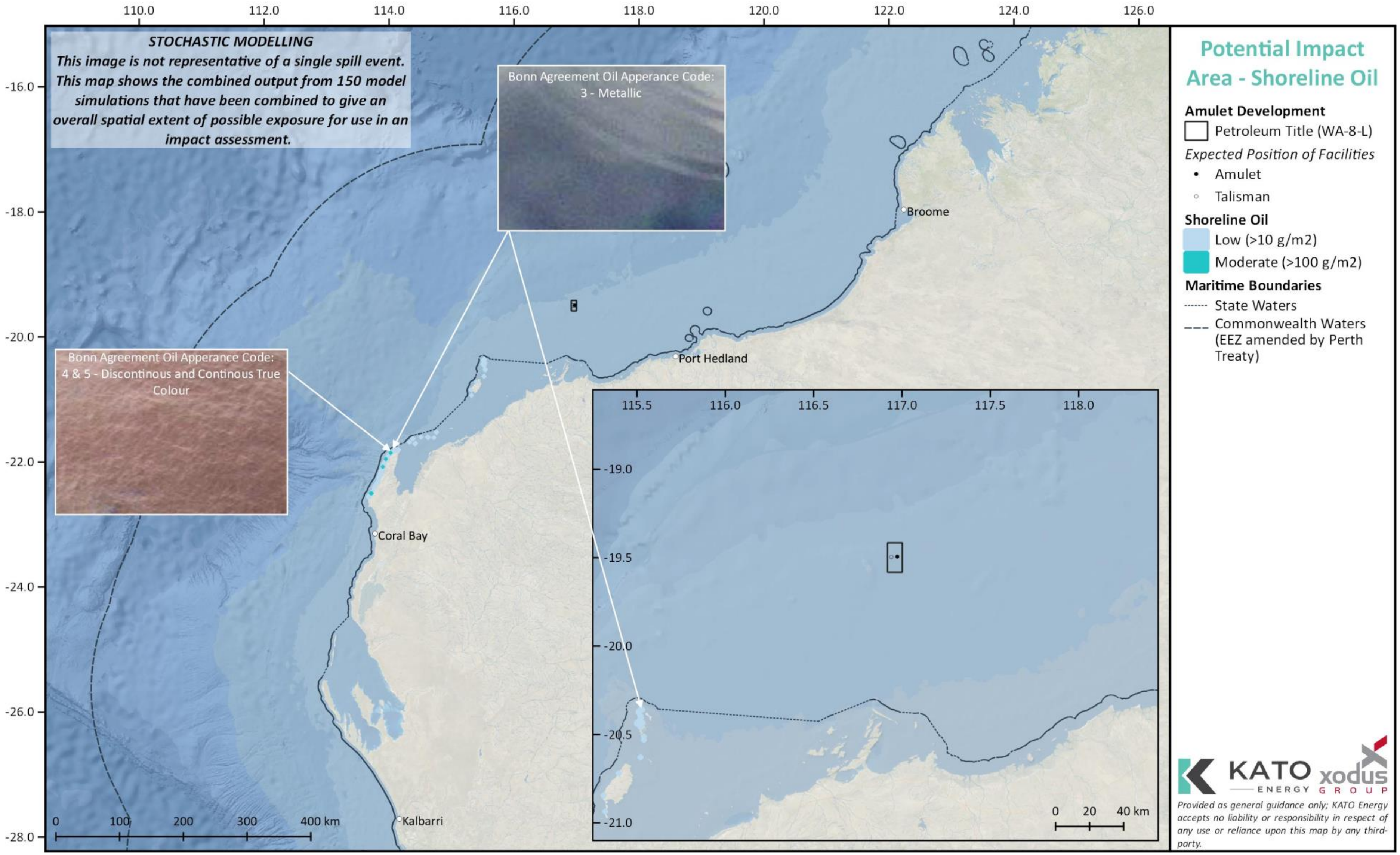


Figure 7-34 Potential Impact Area (stochastic modelling output) for Shoreline Oil from a Subsea Release of Amulet Light Crude

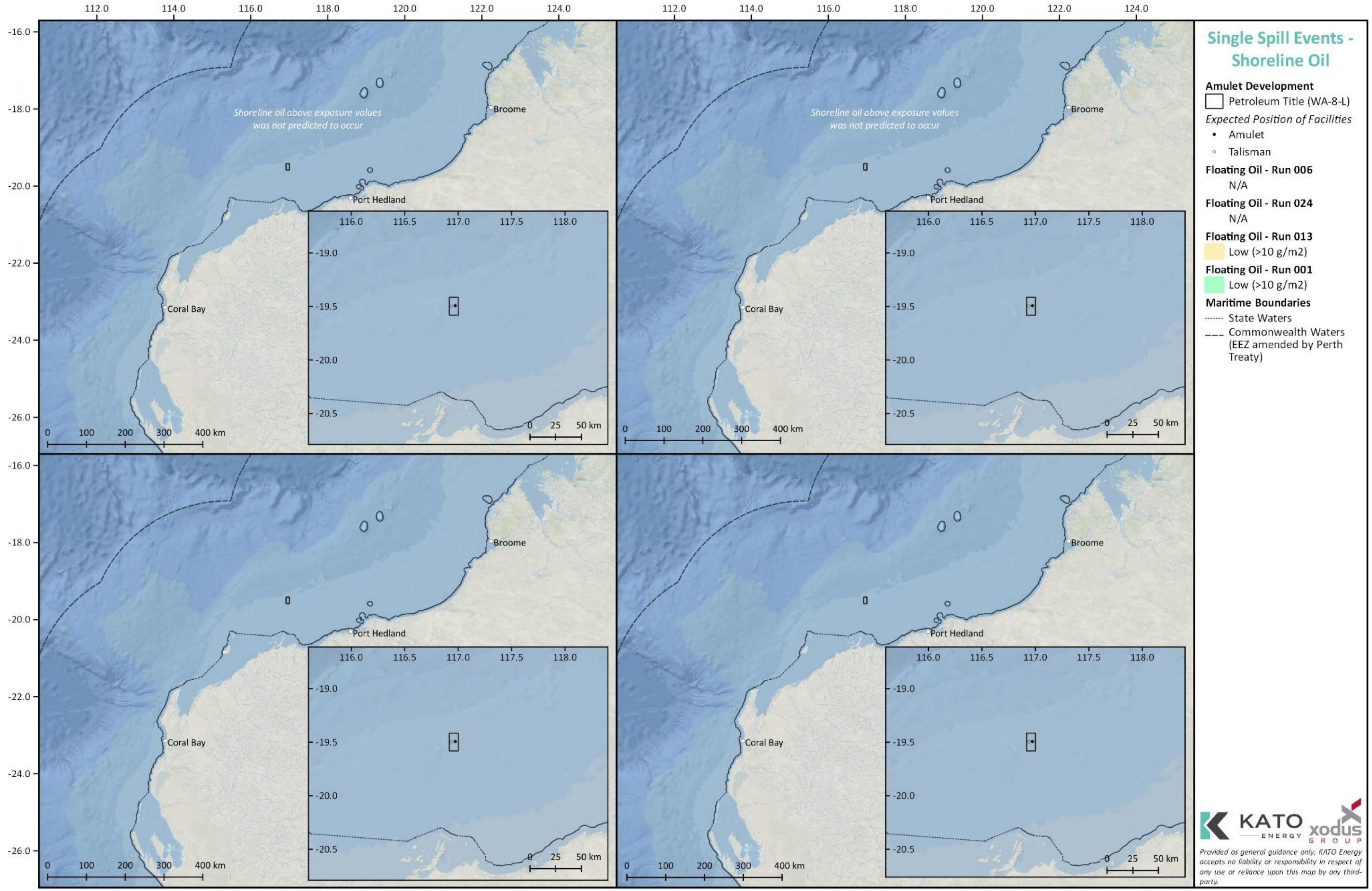


Figure 7-35 Examples of an Individual Spill Event (deterministic modelling output) for Shoreline Oil from a Subsea Release of Amulet Light Crude

7.2.6.3 Risk Evaluation

An accidental release of light crude oil generated by the Amulet 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 7-122 identifies the potential impacts to receptors as a result of an accidental release of light crude oil from the Amulet 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 7-123 provides a summary and justification for those receptors not evaluated further.

Table 7-122 Receptors Potentially Impacted by Accidental Release – Amulet 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	✓	X	✓	✓
Change in aesthetic value					✓						✓		✓	✓			✓

Table 7-123 Justification for Receptors not Evaluated Further for Accidental Release – Amulet 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 7-124 provides a detailed evaluation of the impact of an accidental release of Amulet light crude to physical receptors.

Table 7-124 Impact and Risk Assessment for Physical Receptors from Accidental Release – Amulet Light Crude Oil

Ambient Water Quality	✓
<u>Change in water quality</u> 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 Amulet 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 (~95%) of volatile components and only a small (5%) residual component. Due to this volatility, once on the water surface most of this oil will evaporate 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. 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. Stochastic modelling undertaken for the subsea release of the Amulet crude indicated that if/when entrained or dissolved oil did occur it remained in the surface layers. No benthic interaction was predicted to occur, with the exception of any in-water oil being present in shallow or nearshore areas. 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 Amulet 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	✓
<u>Change in sediment quality</u> An accidental release has the potential to result in a change in sediment quality. The Amulet field is in water ~85 m deep and the stochastic modelling did not indicate that benthic interaction from the released Amulet crude would occur. The only potential exposure to sediments would be from in-water (entrained, dissolved) oil in shallow and nearshore areas; or in areas of 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. Any oil that is on the surface would be subject to evaporation due to the high volatility of the Amulet 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 Amulet 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 7-125 provides a detailed evaluation of the impact of an accidental release of light crude oil to ecological receptors.

Table 7-125 Impact and Risk Assessment for Ecological Receptors from Accidental Release – Amulet Light Crude Oil

Coastal Habitat 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 Amulet crude indicated that shoreline accumulation of oil >100 g/m^2 was predicted to occur in four individual (discontinuous) model cells along the western coast of North West Cape. No exposure above >1,000 g/m^2 was predicted. The western coast along North West Cape is predominantly classified as tidal flats (Section 5.4.3.1). These typically sheltered habitats can provide a nursery ground for many species of fish and crustacean, and provide shelter or nesting areas for birds. Oil penetration into sediments varies with particle size (i.e. greater penetration in coarser materials) and oil viscosity (the Amulet 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 typically have fine sediments, so penetration is not expected to occur deep into the profile. 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. 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. The Amulet crude is classified as a non-persistent oil and has a high proportion (~95%) of volatile components and only a small (5%) 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 Amulet light crude oil 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 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 Amulet 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 of North West Cape, and some of the Pilbara 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 Amulet crude is classified as a non-persistent oil and has a high proportion (~95%) of volatile components and only a small (5%) 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 Amulet light crude oil causing any permanent and/or significant impacts to benthic habitats and communities has been assessed as **Minor (1)**, 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 ✓

<u>Injury / mortality to fauna.</u>

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 North West Shelf 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 Amulet 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 Amulet crude is classified as a light persistent oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~95%) of volatile components and only a small (5%) residual component. Due to this volatility, once on the water surface most of this oil will evaporate within several days of release (Section 7.2.6.2.3).

Modelling undertaken for the subsea release of Amulet crude indicated that floating oil >10 g/m^2 may extend around spill site for up to 58 km. Noting that 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. Negligible shoreline accumulation above 100 g/m^2 was predicted to occur; four individual (discontinuous) model cells on the west coast of North West Cape registered at this exposure level at a probability of 4% during summer only. Therefore, exposure to nesting is expected to be negligible. The area potentially at risk from floating exposure includes a breeding BIA for the Wedge-tailed Shearwater. The BIA is a buffer extending around islands/mainland coastal areas (e.g. Dampier Archipelago) that is used for nesting.

Given the details above, the consequence of an accidental release of Amulet light crude oil causing injury / mortality to fauna or a change in fauna behaviour in seabirds and shorebirds has been assessed as **Minor (1)**, 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 Amulet 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 Amulet 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.

The Amulet crude is classified as a light persistent oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~95%) of volatile components and only a small (5%) residual component. Due to this volatility, once on the water surface most of this oil will evaporate within several days of release (Section 7.2.6.2.3).

Modelling undertaken for the subsea release of Amulet crude indicated that floating oil >10 g/m^2 may extend around spill site for up to 58 km. Noting that 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. Negligible shoreline accumulation above 100 g/m^2 was predicted to occur; four individual (discontinuous) model cells on the west coast of North West Cape registered at this exposure level at a probability of 4% during summer only. Therefore, exposure to nesting habitat is expected to be negligible. The area potentially at risk from floating exposure is also beyond the internesting BIAs for marine turtles.

Given the details above, the consequence of an accidental release of Amulet light crude oil causing injury / mortality to fauna or a change in fauna behaviour in marine reptile species has been assessed as **Minor (1)**, 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) 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 Amulet 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. No surface oil is predicted to occur in this area, and the probability of entrained exposure (only on the western coast of North West Cape) to this BIA is <1%.

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 Amulet 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 7-126 provides a detailed evaluation of the impact of an accidental release of Amulet light crude oil to social, economic and cultural receptors.

Table 7-126 Impact and Risk Assessment for Social, Economic and Cultural Receptors from Accidental Release – Amulet Light Crude Oil

Australian Marine Parks; State Protected Areas – Marine; Heritage Features ✓
An accidental hydrocarbon release of Amulet 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** AMPs may be exposed to entrained or dissolved oil components; and State marine protected areas to entrained and shoreline oil components. The probability of exposure was higher for entrained than dissolved (e.g. 58% and 8% respectively at Montebello Marine Park). Both these oil components are predicted to remain within the surface layers ; therefore, impacts to pelagic values (e.g. marine fauna) are restricted to those in surface waters only. No floating/surface oil was predicted to intersect with any marine protected area. **Heritage Features** The Ningaloo Coast WHA may be exposed to entrained, dissolved and shoreline oil components in the event of a spill of Amulet crude. Potential impacts range from a temporary decrease in aesthetic values toxicity effects associated with the values of the WHA (e.g. marine fauna). There are also known shipwrecks within the predicted area of entrained and dissolved oil exposure. However, stochastic modelling undertaken for the subsea release of the Amulet crude indicated that in-water hydrocarbons typically remain in surface layers, therefore no impacts to shipwrecks is expected to occur. **Summary** Given the details above, the consequence of an accidental release of Amulet light crude oil causing any permanent and/or significant impacts to AMPs, State Protected Areas – Marine and/or Heritage Features has been assessed as **Minor (1)**, 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 Amulet 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 Amulet crude is classified as a light persistent oil, has a low specific gravity (and therefore will tend to remain afloat) and has a high proportion (~95%) of volatile components and only a small (5%) residual component. Due to this volatility, once on the water surface most of this oil is expected to evaporate within several days. Entrained and dissolved oil may persist for longer (compared to floating oil); however, hydrocarbons are predicted to remain within the surface layers.

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 Amulet crude.

However, for those KEFs where values include marine waters and/or pelagic fauna (e.g. Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula etc.), these may be vulnerable to a spill of Amulet crude. It is noted that the probability of exposure to these KEFs was relatively low (≤8%).

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 Amulet 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 ✓

An accidental hydrocarbon release of Amulet light crude has the potential to result in:

- changes to the functions, interests or activities of other users.

Marine and coastal industries in the Hydrocarbon Area mainly comprise petroleum activities, commercial shipping and defence activities (Section 5.5.5). 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 the crude is subject to rapid evaporation the exclusion zone is likely to be temporary minimising the impacts to other marine users.

Offshore petroleum activities in the region include Woodside-operated Angel, North Rankin, Goodwyn Alpha platforms and the Okha FPSO (Section 5.5.5). Stochastic modelling has predicted that some of these facilities may be exposed to in-water (entrained, dissolved) hydrocarbons. No floating oil (including the low-level visual threshold) was predicted to intersect adjacent facilities.

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 Amulet 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 Amulet crude and rapid evaporation so any exclusion zone is likely to be temporary.

Commercial Fisheries ✓

An accidental hydrocarbon release of Amulet light crude has the potential to result in:

- 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 Amulet crude, this would only be expected for in the immediate vicinity of the wells, as the crude weathers rapidly with time and distance.

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 Amulet light crude is Group 2, lighter and disperses and evaporates more rapidly, and has a much lower pour point and will not form solid residues.

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, Kleisner, Sumaila, Swartz, Watson, Zeller, and Pauly (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, Doke, Dzigobodi, Tipre, Lederm and Fitzgerald 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, Doke, Dzigobodi, Tipre, Leder, Fitzgerald 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, Doke, Dzigobodi, Tipre, Leder and Fitzgerald 2011).

Based on historical fishing effort, no activity from Commonwealth and low levels of activity from State fisheries is expected within the immediate vicinity of the Amulet Development, but additional activity may occur within the wider Hydrocarbon Area (Section 5.5.2).

Results from stochastic modelling predicted visible floating oil up to 393 km from the spill source; this threshold is not expected to have biological effects but can alter the use of an area. In-water (entrained, dissolved) are predicted to extend further (e.g. up to 832 km for 100 ppb entrained). 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.

Tourism and Recreation ✓

An accidental hydrocarbon release of Amulet light crude oil has the potential to result in:

- change in aesthetic value.

The Amulet field is located ~132 km offshore from Dampier, and as such minimal tourism and recreational activities are expected within this vicinity (Section 5.5.3). Therefore, any reduced aesthetic from visible floating oil is unlikely to have a significant effect on these activities.

Stochastic modelling did predict the potential for visible (>10 g/m^2) shoreline oil along some offshore islands (e.g. Montebello, Barrow, southern Pilbara islands) and the western coast of North West Cape. However, the probability of shoreline exposure is low, typically <4%; the highest predicted was 16% during summer for the North West Cape. 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). Given the details above, the consequence of an accidental release of Amulet 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 Amulet 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 due to the cautionary and exclusion zones. These would approach at a slow speed for safety reasons. Non-project vessels would remain outside the PSZ. The worst-case likelihood was assessed as **Unlikely (C).**

Risk Level for all receptors is **Low** and considered **acceptable** based on an evaluation against the criteria in Table 7-127.

Table 7-127 Demonstration of Acceptability for Accidental Release – Amulet Light Crude Oil

Receptor	Demonstration of Acceptability	
Ambient water quality	**Acceptable level of impact**	
	With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to *ambient water quality* identified as potentially affected, defined as a possibility that it will (Section 6.6): • result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	
	Acceptability assessment	
	Principles of ESD	The proposed EPO's for the Amulet Development are consistent with the principles of ESD. With respect to potential impacts to *all receptors* from Accidental Release - Amulet Light Crude Oil the relevant principles are: • Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. • 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.
	Internal context	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards. With respect to potential impacts to *all receptors* from Accidental Release - Amulet Light Crude Oil, this specifically includes: • KATO Marine Operations Procedure (KAT-000-PO-PP-101) (KATO 2020b)
	External context	The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders. With respect to potential impacts to *all receptors* from Accidental Release - Amulet Light Crude Oil, no specific concerns were raised during stakeholder consultation with relevant persons.
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. With respect to potential impacts to *ambient water quality* from Accidental Release - Amulet Light Crude Oil, this specifically includes:

Requirement	*Relevant Item/Objective/Action*	*Addressed/Managed by Amulet Development*

Receptor	Demonstration of Acceptability			
		OPPGS(E) Regulations	An Environmental Plan, including oil spill contingency and emergency response arrangements, must be place for any petroleum activity prior to activities commencing.	EPs, Safety Cases, and associated documents (e.g. Oil Pollution Emergency Plans (OPEPs), WOMPs) will be developed as part of the subsequent approvals process. Adoption of the following control measures: **CM37**: Emergency response capability (including equipment) will be maintained in accordance with SOPEPS/SMPEPs; and accepted EPs and OPEPs. **CM38**: NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place. **CM39**: NOPSEMA-accepted Well Operations Management Plan in place for all wells, in accordance with the *Offshore Petroleum and Greenhouse Gas Storage Act* requirements. **CM40:** NOPSEMA-accepted Safety Cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken. **CM41**: 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.
		OPGGS Act	A Well Operations Management Plan (WOMP) must be in place for all wells, which describes well integrity risk management process and well control measures.	

Receptor	Demonstration of Acceptability			
		Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* – Section 26F (implements MARPOL Annex I).	Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution. Includes the requirement for an approved Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class) which describes emergency response activities.	Adoption of the following control measures: **CM03:** Pre-start notifications will be provided to relevant stakeholders at appropriate timing, including presence of 500 m exclusion and 2 km cautionary zones. **CM04:** KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM28**: 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 **CM36:** 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). **CM37**: Emergency response capability (including equipment) will be maintained in accordance with SOPEPS/SMPEPs; and accepted EPs and OPEPs.
		Commonwealth *Navigation Act 2012*– Chapter 4 (Prevention of Pollution)	Gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).	
	Summary of impact assessment			**Risk level**
	The impacts on *ambient water quality* from Accidental Release - Amulet Light Crude Oil include: • Amulet Light Crude is classified as a light persistent oil, with a high proportion (~95%) of volatile components and only a small (~5%) residual component. Due to this volatility, once on the water surface most of this oil will evaporate within several days of release			Low

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="4"></td><td colspan="2">• Stochastic modelling indicated that if/when entrained or dissolved oil did occur it remained in the surface layers. The highest occurrence of entrained or dissolved oil is generally expected to occur within the surface layer (0–10 m), with probabilities of exposure reducing with depth.</td></tr>
<tr><td colspan="2">Statement of acceptability</td></tr>
<tr><td colspan="2">Based on an assessment against the defined acceptable levels, the impacts on ambient water quality from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the predicted level of impact is at or below the defined acceptable level
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO24: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="7">Ambient sediment quality</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to ambient sediment quality identified as potentially affected, defined as a possibility that it will (Section 6.6):
• result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
• 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></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.</td></tr>
</table>

Receptor	Demonstration of Acceptability		
		With respect to potential impacts to *ambient sediment quality* from Accidental Release - Amulet Light Crude Oil, no specific other requirements have been identified as relevant.	
	Summary of impact assessment		**Risk level**
	The impacts on *ambient sediment quality* from Accidental Release - Amulet Light Crude Oil include: • The Amulet field is in water ~85 m deep and the stochastic modelling did not indicate that benthic interaction from the released Amulet light crude would occur. However, it may be possible that some sediment interaction may occur within the intertidal zone adjacent to coasts where shoreline accumulation was predicted to occur.		Low
	Statement of acceptability		
	Based on an assessment against the defined acceptable levels, the impacts on *ambient sediment quality* from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO24:** Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.		
Plankton	**Acceptable level of impact**		
	With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to *plankton* as potentially affected, defined as a possibility that it will (Section 6.6): • have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		
	Acceptability assessment		
	Principles of ESD	Refer to details in *water quality* assessment (above)	
	Internal context	Refer to details in *water quality* assessment (above)	
	External context	Refer to details in *water quality* assessment (above)	

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="6"></td><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to plankton from Accidental Release - Amulet Light Crude Oil, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="2">The impacts on plankton from Accidental Release - Amulet Light Crude Oil include:
• Results from the stochastic modelling 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.
• Once background water quality is re-established, plankton takes weeks to months to recover.</td><td>Low</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on plankton from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO24: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">Benthic habitats and communities</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to benthic habitat and communities identified as potentially affected, defined as a possibility that it will (Section 6.6):</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="12"></td><td colspan="3">• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to benthic habitats and communities from Accidental Release - Amulet Light Crude Oil, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="2">The impacts on benthic habitat and communities from Accidental Release - Amulet Light Crude Oil include:
• The Amulet field is in water ~85 m deep and the stochastic modelling did not indicate that benthic interaction from the released Amulet light crude would occur. However, it may be possible that some interaction with benthic habitats and communities may occur within the intertidal zone adjacent to coasts where shoreline accumulation was predicted to occur.</td><td>Low</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on benthic habitat and communities from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="3">• EPO24: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.</td></tr>
<tr><td rowspan="14">Coastal habitats and communities</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to coastal habitat and communities identified as potentially affected, defined as a possibility that it will (Section 6.6):
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to coastal habitats and communities from Accidental Release - Amulet Light Crude Oil, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="2">The impacts on coastal habitat and communities from Accidental Release - Amulet Light Crude Oil include:
• Stochastic modelling indicated that negligible shoreline accumulation >100 g/m^2 was predicted to occur; only four individual model cells on the west coast of North West Cape registered at or above this exposure level at a probability of 4% during summer only</td><td>Low</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on coastal habitat and communities from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="4">• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO24: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.</td></tr>
<tr><td rowspan="9">Seabirds and shorebirds</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td colspan="4">With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to seabirds and shorebirds identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population.
• substantially modify, destroy or isolate an area of important habitat for a migratory species.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td rowspan="3">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to seabirds and shorebirds from Accidental Release - Amulet Light Crude Oil, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Wildlife Conservation Plan for Migratory Shorebirds (DoEE 2015)</td><td>Identified habitat modification as a threat. No explicit relevant objectives.
Relevant management action:</td><td>Environmental risk assessment for Accidental Release - Amulet Light Crude Oil on seabirds</td></tr>
</table>

Receptor	Demonstration of Acceptability			
			• 3f: Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes.	and shorebirds has been completed in this OPP (Section 7.2.6.3.2). EPs and associated documents (e.g. OPEPs, Oil Spill Monitoring Programs (OSMPs) will be developed as part of the subsequent approvals process. Adoption of the following control measures: **CM38**: NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place.
		Conservation advice *Calidris canutus* (Red Knot) (TSSC 2016a)	Identifies habitat loss and habitat degradation (e.g. through environmental pollution), pollution/contamination impacts and direct mortality as threats. No explicit relevant objectives or management actions.	
		Conservation advice *Calidris ferruginea* (Curlew Sandpiper) (DoE 2015a)	Identifies habitat loss and degradation from pollution as a threat. No explicit relevant objectives or management actions.	
		Conservation advice *Limosa lapponica baueri* [Bar-tailed Godwit (Western Alaskan)] (TSSC 2016b)	Identifies habitat loss and habitat degradation (e.g. through environmental pollution), pollution/contamination impacts and direct mortality as threats. No explicit relevant objectives or management actions.	
		Conservation advice *Limosa lapponica menzbieri* (Bar-tailed Godwit (Northern Siberian)) (TSSC 2016c)	Identifies habitat loss and habitat degradation (e.g. through environmental pollution), pollution/contamination impacts and direct mortality as threats. No explicit relevant objectives or management actions.	
		National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011)	Identifies marine pollution as a key threat. Objective 3: Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced. Relevant management action:	

Receptor	Demonstration of Acceptability		
			• C11.1: Where feasible, population monitoring programs also monitor, in a standardised manner, the incidence of: ○ oiled birds at the nest ○ marine debris egestion/entanglement at the nests ○ eggshell thinning.
		Conservation advice for *Sterna nereis nereis* (Fairy Tern) (TSSC 2011b)	Identifies oil spills, particularly in Victoria, where the close proximity of oil facilities poses a risk of oil spills that may affect the species' breeding habitat as a potential threat. No explicit relevant objectives. Relevant management action: • Ensure appropriate oil-spill contingency plans are in place for the subspecies' breeding sites which are vulnerable to oil spills, such as the breeding colonies in Victoria
		Conservation Advice for *Numenius madagascariensis* (Eastern Curlew) (DoE 2015c)	Identifies habitat loss and degradation from pollution as a threat. No explicit relevant objectives or management actions.
	Summary of impact assessment		**Risk level**
	The impacts on *seabirds and shorebirds* from Accidental Release - Amulet Light Crude Oil include: • Stochastic modelling indicated that surface oil >10 g/m^2 generally remained within close proximity to the spill source, with a slight extension in a NE/SW direction; with a maximum distance from the source predicted at 58 Km. However, due to the high volatility of the oil, most of the oil is expected to evaporate within several days. • Stochastic modelling indicated that negligible shoreline accumulation >100 g/m^2 was predicted to occur; only four individual model cells on the west coast of North West Cape registered at or above this exposure level at a probability of 4% during summer only. Therefore, it is considered there is minimal risk to nesting or roosting habitat for bird species.		Low
	Statement of acceptability		

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="2">Based on an assessment against the defined acceptable levels, the impacts on seabirds and shorebirds from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO24: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.</td></tr>
<tr><td rowspan="8">Fish</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to fish identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
• substantially modify, destroy or isolate an area of important habitat for a migratory species.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to fish from Accidental Release - Amulet Light Crude Oil, this specifically includes:</td></tr>
</table>

Receptor	Demonstration of Acceptability		
	Requirement	*Relevant Item/Objective/Action*	*Addressed/Managed by Amulet Development*
	Recovery plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013a)	Identifies habitat modification as a potential threat. No explicit relevant objectives or management actions.	Environmental risk assessment for Accidental Release - Amulet Light Crude Oil on fish has been completed in this OPP (Section 7.2.6.3.2).
	Sawfish and river shark multispecies recovery plan (CoA 2015b)	Identifies habitat degradation and modification as a principal threat. Objective 5: Reduce and, where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species. Relevant management action: • 5c. Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.	
	Approved conservation advice for *Pristis clavata* (Dwarf Sawfish) (TSSC 2009b)	Identifies habitat degradation due to increasing human development in northern Australia as a threat. No explicit relevant objectives or management actions.	
	Approved conservation advice for Green Sawfish (TSSC 2008a)	Identifies habitat degradation through coastal development as a potential threat. No explicit relevant objectives or management actions.	
	Approved Conservation Advice for *Pristis pristis* (Largetooth Sawfish) (DoE 2014a).	Identifies habitat degradation and modification as a main threat. No explicit relevant objectives. Relevant management action: • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	

Receptor	Demonstration of Acceptability			
		Conservation advice *Rhincodon typus* (Whale Shark) (TSSC 2015d)	Identifies habitat disruption from mineral exploration, production and transportation as a threat. No explicit relevant objectives or management actions.	
		Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (DoE 2014b)	Identifies ecosystem effects as a result of habitat modification as a threat. No explicit relevant objectives or management actions.	
	Summary of impact assessment			**Risk level**
	The impacts on *fish* from Accidental Release - Amulet Light Crude Oil include: • 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 highly mobile and as such are not likely to suffer extended exposure (e.g. >96 hours) at concentrations that would lead to chronic effects. • A foraging BIA has been identified within the area at risk of potential exposure from a release of Amulet light crude oil. Whale Sharks do not spend all their time in surface waters—they routinely move between surface and to depths of >30 m, and as such would not be continually exposed to dispersed or entrained oil within the surface layers, or the surface slick itself.			Low
	Statement of acceptability			
	Based on an assessment against the defined acceptable levels, the impacts on *fish* from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:			

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="4">• EPO24: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.</td></tr>
<tr><td rowspan="9">Marine reptiles</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td colspan="4">With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to marine reptiles identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td rowspan="3">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to marine reptiles from Accidental Release - Amulet Light Crude Oil, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Recovery plan for Marine Turtles in Australia (CoA 2017)</td><td>Identifies chemical and terrestrial discharge as a threat.
Action Area A4 (minimise chemical and terrestrial discharge) relevant management actions:
• Ensure spill risk strategies and response programs adequately include management for marine</td><td>Environmental risk assessment for Accidental Release - Amulet Light Crude Oil on marine reptiles has been completed in this OPP (Section 7.2.6.3.2).
EPs and associated documents (e.g. OPEPs, OSMPs will be developed as part of the subsequent approvals process.</td></tr>
</table>

Receptor	Demonstration of Acceptability			
			turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs • Quantify the impacts of decreased water quality on stock viability • Quantify the accumulation and effects of anthropogenic toxins in marine turtles, their foraging habitats and subsequent stock viability.	Adoption of the following control measures: **CM38**: NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place.
		Approved conservation advice for Dermochelys coriacea (Leatherback Turtle) (TSSC 2009a)	Identification of foraging areas and changes to breeding sites as a main threat. No explicit relevant objectives or management actions.	
		Approved Conservation Advice for Aipysurus apraefrontalis (Short-nosed Seasnake) (TSSC 2011b)	Identifies oil and gas exploration, including seismic surveys and exploration drilling as a threat. No explicit relevant objectives or management actions.	
	Summary of impact assessment			**Risk level**
	The impacts on marine reptiles from Accidental Release - Amulet Light Crude Oil include: • Negligible shoreline accumulation >100 g/m^2 was predicted to occur; four individual (discontinuous) model cells on the west coast of North West Cape registered at this exposure level at a probability of 4% during summer only. Therefore, exposure to nesting habitat is expected to be negligible. The area potentially at risk from floating exposure is also beyond the internesting BIAs for marine turtles.			Low
	Statement of acceptability			
	Based on an assessment against the defined acceptable levels, the impacts on *marine reptiles* from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)			

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="4">• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO24: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.</td></tr>
<tr><td rowspan="9">Marine mammals</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td colspan="4">With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to marine mammals as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td rowspan="3">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to marine mammals from Accidental Release - Amulet Light Crude Oil, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Conservation advice Balaenoptera borealis Sei Whale (TSSC 2015a)</td><td>Identifies habitat degradation including pollution as a threat. No explicit relevant objectives or management actions.</td><td>Environmental risk assessment for Accidental Release - Amulet Light Crude Oil on marine</td></tr>
</table>

Receptor	Demonstration of Acceptability			
		Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 2015–2025 (CoA 2015a)	Identifies habitat modification as a threat. No explicit relevant objectives or management actions.	reptiles has been completed in this OPP (Section 7.2.6.3.2).
		Conservation advice *Balaenoptera physalus* Fin Whale (TSSC 2015b)	Identifies pollution (persistent toxic pollutants) as a threat. No explicit relevant objectives or management actions.	
		Approved Conservation Advice for *Megaptera novaeangliae* (Humpback Whale) (TSSC 2015c)	Identifies habitat degradation including coastal development and port expansion as a threat. No explicit relevant objectives or management actions.	
		Conservation Management Plan for the Southern Right Whale (DSEWPaC 2011)	Identifies habitat modification as a threat. No explicit relevant objectives or management actions.	

Summary of impact assessment	Risk level
The impacts on marine mammals from Accidental Release - Amulet Light Crude Oil include: • Due to the high volatility of the Amulet light crude, once on the surface most of the oil is expected to evaporate within several days. Stochastic modelling indicated that if/when entrained or dissolved oil did occur it remained in the surface layers (predominantly within the 0–10 m depth). • Migratory BIAs for the Pygmy Blue Whale and Humpback Whale occur within the area that may be exposed from an oil spill from the Amulet Development. There is also a BIA for foraging, breeding, nursing and calving extending around the North West Cape region for Dugongs. • As highly mobile species, in general it is unlikely that these animals will be consistently (e.g. >96 hours) exposed to concentrations of oils in the water column that would lead to chronic effects.	Low

Statement of acceptability

Based on an assessment against the defined acceptable levels, the impacts on marine mammals from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that:

- the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="3">

- the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
- the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
- the predicted level of impact is at or below the defined acceptable levels.

To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:

- **EPO24**: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.

</td></tr>
<tr><td rowspan="10">Key Ecological Features</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">

With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to *KEFs* identified as potentially affected, defined as a possibility that it will (Section 6.6):

- 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 an area defined as a Key Ecological Feature results.

</td></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to KEFs from Accidental Release - Amulet Light Crude Oil, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="2">

The impacts on *KEFs* from Accidental Release - Amulet Light Crude Oil include:

- 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 Amulet crude.

</td><td>Low</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="3"></td><td colspan="2">Those KEFs where values include marine waters and/or pelagic fauna (e.g. Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula etc.), these may be exposed in the event of a spill of Amulet light crude. However, this exposure is expected to be limited to the surface layers only.</td></tr>
<tr><td colspan="2">Statement of acceptability</td></tr>
<tr><td colspan="2">Based on an assessment against the defined acceptable levels, the impacts on KEFs from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that:
the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
EPO24: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.</td></tr>
<tr><td rowspan="7">Australian Marine Parks</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to AMPs identified as potentially affected, defined as a possibility that it will (Section 6.6):
modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.</td></tr>
</table>

Receptor	Demonstration of Acceptability			
		With respect to potential impacts to *AMPs* from Accidental Release - Amulet Light Crude Oil, this specifically includes:		
		Requirement	*Relevant Item/Objective/Action*	*Addressed/Managed by Amulet Development*
		North-west Marine Parks Network Management Plan	Identifies marine pollution as a pressure. No explicit relevant objectives or management actions.	Environmental risk assessment for Accidental Release - Amulet Light Crude Oil on AMPs has been completed in this OPP (Section 7.2.6.3.3).
	Summary of impact assessment			**Risk level**
	The impacts on *AMPs* from Accidental Release - Amulet Light Crude Oil include: • AMPs may be exposed to entrained or dissolved oil components. The closest AMP, the Montebello Marine Park, showed 58% probability to entrained oil >100 ppb and 8% probably of exposure to dissolved oil >50 ppb. Both these oil components are predicted to remain within the surface layers; therefore, impacts to pelagic values (e.g. marine fauna) are restricted to those in surface waters only. • No floating/surface oil was predicted to intersect with any marine protected area, therefore no temporary reduction in aesthetic values is expected to occur.			Low
	Statement of acceptability			
	Based on an assessment against the defined acceptable levels, the impacts on *AMPs* from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO24**: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.			
	Acceptable level of impact			

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="12">Commercial fisheries</td><td colspan="3">With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to commercial fisheries identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on the sustainability of commercial fishing
An activity will contravene the OPGGS Act Section 280(2), and therefore result in a significant impact, if it is deemed to:
• interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.</td></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to commercial fisheries from Accidental Release - Amulet Light Crude Oil, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="2">The impacts on commercial fisheries from Accidental Release - Amulet Light Crude Oil include:
• Any exclusion zones around the spill location is expected to be relatively small and temporary given the nature and behaviour of the Amulet light crude after release, as such any interruption to fishery access is expected to be minor.
• Given the volatility and predicted weathering of the Amulet light crude, significant amounts of tainting or toxicity impacts to commercial fish species are not expected.</td><td>Low</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on commercial fisheries from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="3">

- the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
- the predicted level of impact is at or below the defined acceptable levels.

To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:

- **EPO24**: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.
</td></tr>
<tr><td rowspan="10">Tourism and recreation</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Accidental Release - Amulet Light Crude Oil, an activity will contravene the OPGGS Act Section 280(2), and therefore result in a significant impact to tourism and recreation, if it is deemed to (Section 6.6):
• interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.</td></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to tourism and recreation from Accidental Release - Amulet Light Crude Oil, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="2">The impacts on tourism and recreation from Accidental Release - Amulet Light Crude Oil include:
• Any exclusion zones around the spill location is expected to be relatively small given the nature and behaviour of the Amulet light crude after release, and as such any interruptions to marine-based tourism and recreational activities is expected to be minor. In addition, due to the distance from mainland (~132 km to Dampier), minimal tourism and recreational activities are expected within the immediate vicinity of the Amulet Development.
• It is noted that surface oil at low thresholds may cause a temporary reduction in aesthetic values; however due to the high volatility of the Amulet light crude, most of the oil is expected to evaporate within several days.</td><td>Low</td></tr>
</table>

Receptor	Demonstration of Acceptability	
	Statement of acceptability	
	Based on an assessment against the defined acceptable levels, the impacts on *tourism and recreation* from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO24**: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.	
State Protected Areas - Marine	**Acceptable level of impact**	
	With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to *State protected areas – marine* identified as potentially affected, defined as a possibility that it will (Section 6.6): • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.	
	Acceptability assessment	
	Principles of ESD	Refer to details in *water quality* assessment (above)
	Internal context	Refer to details in *water quality* assessment (above)
	External context	Refer to details in *water quality* assessment (above)
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. With respect to potential impacts to *State protected areas – marine* from Accidental Release - Amulet Light Crude Oil, this specifically includes:

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td></td><td></td><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td></td><td></td><td>Management Plan for the Montebello/Barrow Islands Marine Conservation Reserves, 2007-2017 (DoEC 2007)</td><td>Identifies discharge of toxicants and accidental spillage of petroleum products as pressures.
Relevant objectives:
• To ensure coral reef communities are not significantly impacted by accidental spillage of petroleum products or physical disturbance from development activities.
No explicit relevant management actions.</td><td>Environmental risk assessment for Accidental Release - Amulet Light Crude Oil on State protected areas - marine has been completed in this OPP (Section 7.2.6.3.3).</td></tr>
<tr><td></td><td colspan="3">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td></td><td colspan="3">The impacts on State protected areas – marine from Accidental Release - Amulet Light Crude Oil include:
• The closest marine protected areas within the predicted areas of exposure from the stochastic modelling are the Montebello and Barrow Island marine reserves. These protected areas may be exposed to entrained oil in the event of an accidental release of Amulet light crude.
• No floating/surface oil was predicted to intersect with any marine protected area, therefore no temporary reduction in aesthetic values is expected to occur.</td><td>Low</td></tr>
<tr><td></td><td colspan="4">Statement of acceptability</td></tr>
<tr><td></td><td colspan="4">Based on an assessment against the defined acceptable levels, the impacts on State protected areas - marine from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="3">EPO24: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.</td></tr>
<tr><td rowspan="12">Industry</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to industry identified as potentially affected, defined as a possibility that it will (Section 6.6):
interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.</td></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to industry from Accidental Release - Amulet Light Crude Oil, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="2">The impacts on industry from Accidental Release - Amulet Light Crude Oil include:
Any exclusion zones around the spill location is expected to be relatively small and temporary given the nature and behaviour of the Amulet light crude after release, as such any interruption to other industry users in the area is expected to be minor.</td><td>Low</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on industry from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that:
the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="4">• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO24: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.</td></tr>
<tr><td rowspan="11">Heritage and cultural features</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td colspan="4">With respect to Accidental Release - Amulet Light Crude Oil, the Amulet Development will not result in significant impacts to heritage and cultural features identified as potentially affected, defined as a possibility that it will (Section 6.6):
• cause significant harm to social surroundings.</td></tr>
<tr><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td rowspan="3">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - Amulet Light Crude Oil from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to heritage and cultural features from Accidental Release - Amulet Light Crude Oil, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Ningaloo Coast Strategic Management Framework (CoA 2011)</td><td>Identifies resource development as a major potential threat. No explicit relevant management objectives or actions.</td><td>Environmental risk assessment for Accidental Release - Amulet Light Crude Oil on heritage and cultural features has been completed in this OPP (Section 7.2.6.3.3).</td></tr>
<tr><td colspan="3">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="3">The impacts on heritage and cultural features from Accidental Release - Amulet Light Crude Oil include:</td><td>Low</td></tr>
</table>

Receptor	Demonstration of Acceptability	
	• The closest WHA within the predicted areas of exposure from the stochastic modelling is the Ningaloo Coast WHA; this area may be exposed to both in-water (entrained or dissolved) and shoreline oil in the event of an accidental release of Amulet light crude. However, it is noted that the shoreline accumulation predicted from the stochastic modelling at >100 m/^{2} was negligible. • No floating/surface oil was predicted to intersect with any marine protected area, therefore no temporary reduction in aesthetic values is expected to occur. • There are also known shipwrecks within the predicted area of entrained and dissolved oil exposure. However, stochastic modelling indicated that if/when entrained oil did occur it remained in the surface layers (up to 30 m depth). Therefore, no impact to shipwrecks is expected to occur.	
	Statement of acceptability	
	Based on an assessment against the defined acceptable levels, the impacts on *heritage and cultural features* from Accidental Release - Amulet Light Crude Oil is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO24**: Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.	

A summary of the impact analysis and evaluation, including control measures adopted and EPOs, is provided in Table 7-128.

Table 7-128 Summary of Impact Assessment for Accidental Release – Amulet Light Crude Oil

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
Ambient water quality	Change in water quality	**EPO24:** Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.	**CM03:** Pre-start notifications will be provided to relevant stakeholders at appropriate timing, including presence of 500 m exclusion and 2 km cautionary zones. **CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM28**: 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. **CM36:** 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). **CM37**: Emergency response capability (including equipment) will be maintained in accordance with SOPEPS/SMPEPs; and accepted EPs and OPEPs. **CM38:** NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place. **CM39:** NOPSEMA-accepted Well Operations Management Plan in place for all wells, in accordance with the *Offshore Petroleum*	Minor	Unlikely	Low
Ambient sediment quality	Change in sediment quality			Minor	Unlikely	Low
Plankton	Injury / mortality to fauna			Minor	Very unlikely	Low
Benthic habitat and communities	Change in habitat Injury / mortality to fauna Change in fauna behaviour			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			Minor	Very unlikely	Low
Fish				Moderate	Very unlikely	Low
Marine reptiles				Minor	Very unlikely	Low
Marine mammals				Moderate	Very unlikely	Low
Australian Marine Parks	Change in water quality Change in sediment quality			Minor	Very unlikely	Low

Receptor	Impacts	EPOs	Adopted Control Measures	C	L	RL
State Protected Areas – Marine	Change in habitat Injury / mortality to fauna Change in fauna behaviour		*and Greenhouse Gas Storage* Act requirements. **CM40**: NOPSEMA-accepted Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken. **CM41**: 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.	Minor	Very unlikely	Low
Heritage Features	Changes to the functions, interests or activities of other users Change in aesthetic value			Minor	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 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	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 Amulet Development, an accidental release of marine fuel may occur.

7.2.7.1 Aspect Source

Throughout the Amulet 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 Amulet 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 7-129. 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 7-129. Therefore, this scenario is used for the purposes of impact assessment and is carried through into spill modelling.

Table 7-129 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, 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 7-130). This is considered the worst-case scenario for potential fuel releases and therefore is representative of the greatest spatial extent of potential impacts.

Table 7-130 Vessel Collision Event used for Spill Modelling

Scenario Description	Surface release after rupture of a vessel fuel tank
Spill Location	Amulet-1 (~800 m from the expected position of the MOPU)
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 7-131). 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 7-131).

Table 7-131 Characteristics of MGO

Classification	Group II, Light persistent oil				
API Gravity	34.9 °API				
Density	0.83 g/cm^3 at 15 °C				
Viscosity	2.5 cP at 40 °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:

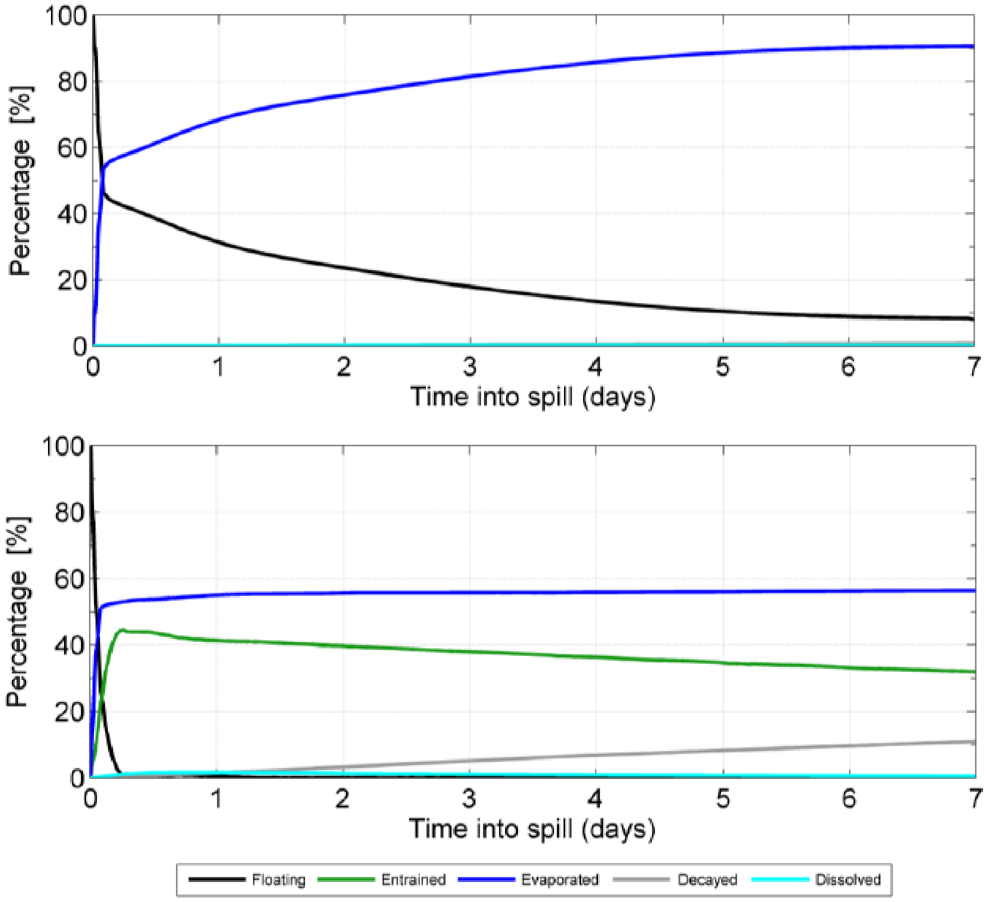
- *Specific gravity* – The MGO has a specific gravity less than seawater and therefore will have the tendency to float.
- *Distillation characteristics (Volatility)* – The MGO has a high proportion (97.3%) of volatile components that once on the surface will readily evaporate. Typical evaporation times 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, ~8% of the oil remained on the sea surface, ~91% had evaporated, a negligible amount had entrained, and ~1% undergoing degradation (Figure 7-36). Under the variable wind conditions, <1% was predicted to remain on the sea surface, with ~56% evaporating, ~30% being entrained into the water column, ~2% dissolving and ~11% undergoing degradation (Figure 7-36). 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 (~0.1–1.6% per day) rates, which would likely increase any area of exposure (RPS 2019).



Source: RPS 2019X

Figure 7-36 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:

- floating (surface)
- 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 7-26).

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 7-27). 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 7-27). The MGO has a low proportion (4.6%) of aromatics.

The results of the stochastic modelling undertaken using SIMAP is presented in Table 7-132, Figure 7-37, Figure 7-39, Figure 7-41 and Figure 7-43 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 7-38, Figure 7-40, Figure 7-42). No figure for shoreline has been shown as none of the example scenarios had shoreline accumulation above the low (10 g/m^2) threshold.

Table 7-132 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
Floating (surface)																		
Low 1 g/m^2	• Floating oil above 1 g/m^2 generally extends in all directions from the spill source (Figure 7-37). Maximum distance from the source predicted for floating oil above 1 g/m^2 is 217 km. • Floating oil at this level is expected to be visually detectable but not have biological effects. • No predicted exposure to protected areas (marine parks, heritage listed sites etc.) • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack; very low (≤1%) probability of intersection North-West Slope Trawl fishery.	✓									X		X		X	✓	✓	X
Moderate 10 g/m^2	• Floating oil above 10 g/m^2 generally extends in all directions from the spill source (Figure 7-37). Maximum distance from the source predicted for floating oil above 10 g/m^2 is 17 km. • No predicted exposure to protected areas (marine parks, heritage listed sites etc.) • Would intersect with BIAs for seabirds, sharks and whales.	✓					✓		✓	✓	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
	• Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack.																	
High 25 g/m²	• Floating oil above 25 g/m² generally extends in NW/SE direction from the spill source (Figure 7-37). Maximum distance from the source predicted for floating oil above 25 g/m² is 14 km. • No predicted exposure to protected areas (marine parks, heritage listed sites etc.) • Would intersect with BIAs for seabirds, sharks and whales. • Would intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack.	✓					✓		✓	✓	X	X	X		X		✓	X
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 7-39). Maximum distance from the source predicted for dissolved hydrocarbons above 50 ppb is 234 km. • No predicted exposure to protected areas (marine parks, heritage listed sites etc.)	✓				✓		✓	✓	✓	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
	• 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 typically remaining with surface layers. No exposure in shallow and nearshore areas is predicted. • May intersect with BIAs for seabirds, sharks and whales (probability ~19–32%). • May intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack (probability ~19–32%).																	
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*	

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
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, with no entrained oil above this exposure value predicted to occur within State waters or over the shallow continental shelf area (Figure 7-41). Maximum distance from the source predicted for entrained hydrocarbons above 100 ppb is 376 km. • Limited benthic interaction is predicted to occur, with entrained typically remaining with surface layers. No exposure in shallow and nearshore areas is predicted. • Probability of exposure to Montebello Marine Park is very low during all seasons (≤3%). • May intersect with BIAs for seabirds, sharks and whales (probability ~79–89%); with lower probability of exposure to BIAs for turtles (~3–13%).	✓	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
	• May intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack (probability ~79–89%); with lower probability (~8–9%) to the North-west Slope Trawl Fishery.																	
Moderate 100 ppb (time-integrated)	• Maximum distance from the source predicted for entrained hydrocarbons above the time-integrated threshold (9,600 ppb.hr) is 198 km. • No predicted exposure to protected areas (marine parks, heritage listed sites etc.) • Limited benthic interaction is predicted to occur, with entrained typically remaining with surface layers. No exposure in shallow and nearshore areas is predicted. • May intersect with BIAs for seabirds, sharks and whales (probability ~14–19%). • May intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack (probability ~14–19%).				X	✓		✓	✓	✓	X	X	X		X		✓	
High 1,000 ppb (instantaneous)	• Entrained hydrocarbons above 100 ppb generally extends in an E/W direction from the spill source (Figure 7-41). Maximum distance from the source predicted for entrained hydrocarbons above 100 ppb is 76 km. • No predicted exposure to protected areas (marine parks, heritage listed sites etc.)	✓	X		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
	• Limited benthic interaction is predicted to occur, with entrained typically remaining with surface layers. No exposure in shallow and nearshore areas is predicted. • May intersect with BIAs for seabirds, sharks and whales (probability ~34–63%) • May intersect with fishery management areas for Southern Bluefin Tuna, Western Tuna and Billfish and Western Skipjack (probability ~34–63%).																	
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 west coast of Barrow Island and on some of the southern Pilbara Islands (Figure 7-43). • Probability of any shoreline exposure is very low, ≤1%. • Shoreline accumulation at this level is expected to be visual detectable but not have biological effects.		✓											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
	• The maximum total volume of oil onshore during any of the simulations was 1 m^3.																	
Moderate 100 g/m^2	• Shoreline accumulation above this exposure value is not predicted to occur.		*X*	*X*	*X*		*X*		*X*					*X*				
High 1,000 g/m^2	• Shoreline accumulation above this exposure value is not predicted to occur.		*X*	*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.

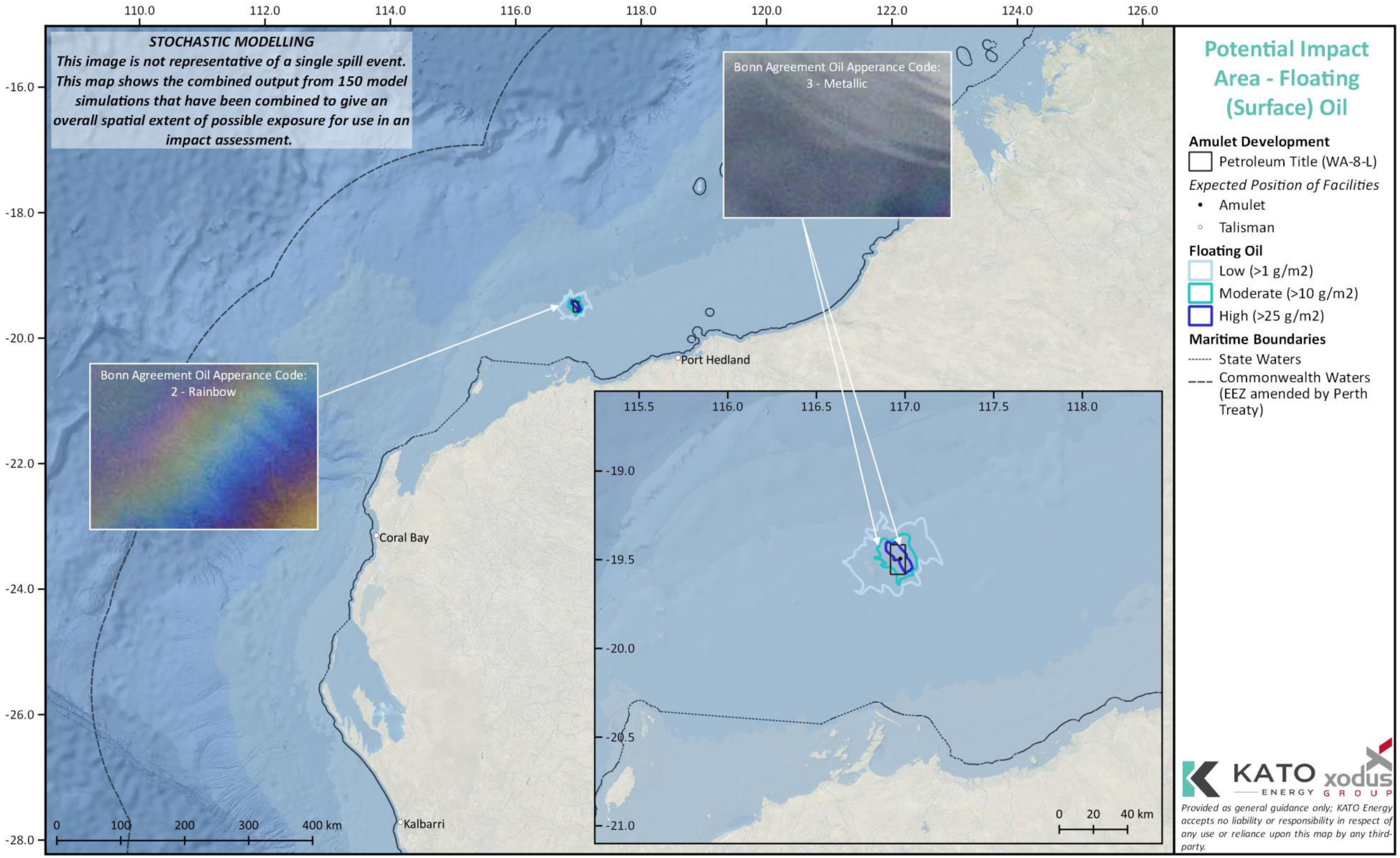


Figure 7-37 Potential Impact Area (stochastic modelling output) for Floating Oil from a Surface Release of MDO/MGO

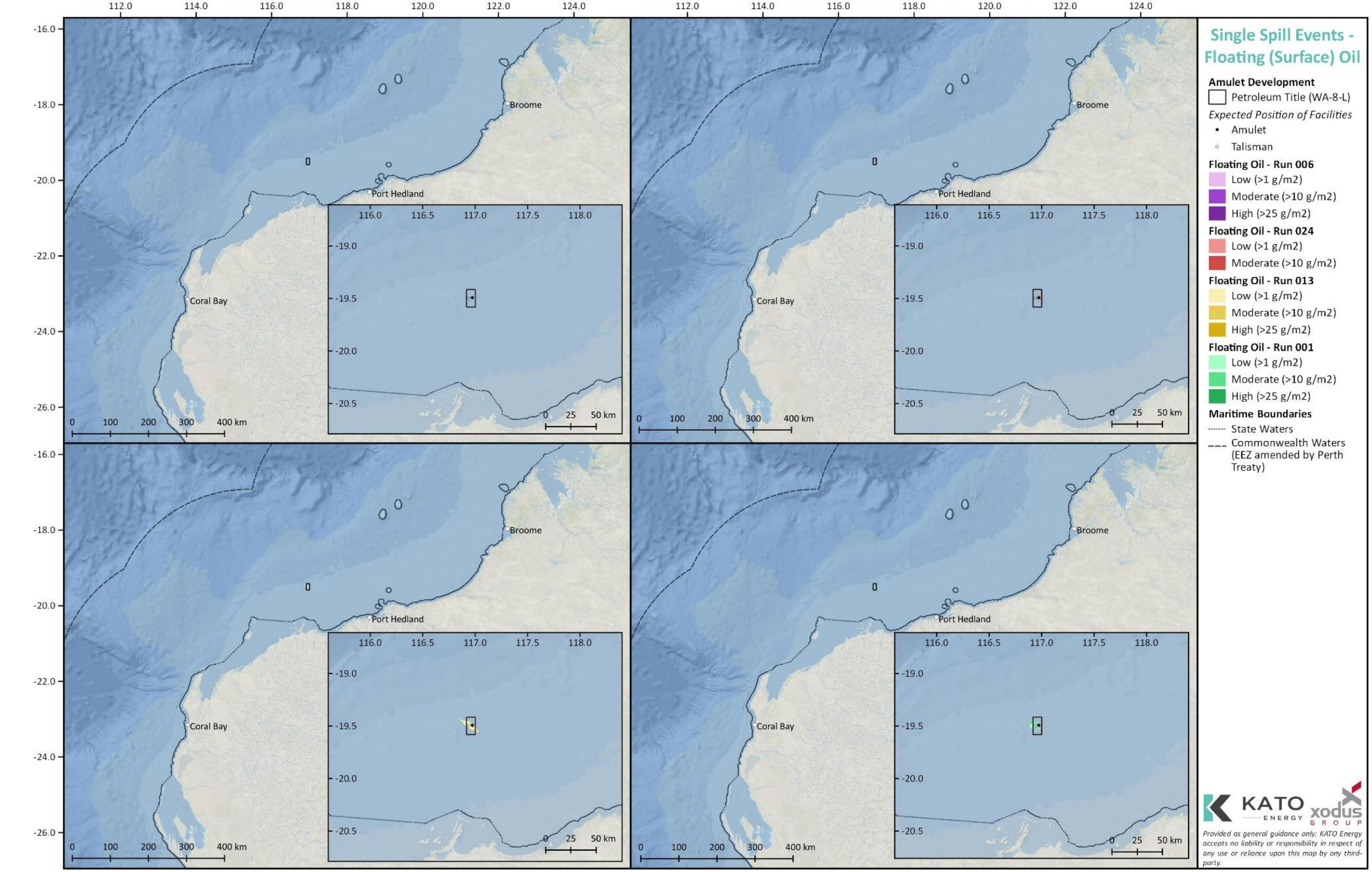


Figure 7-38 Examples of an Individual Spill Event (deterministic modelling output) for Floating Oil from a Surface Release of MDO/MGO

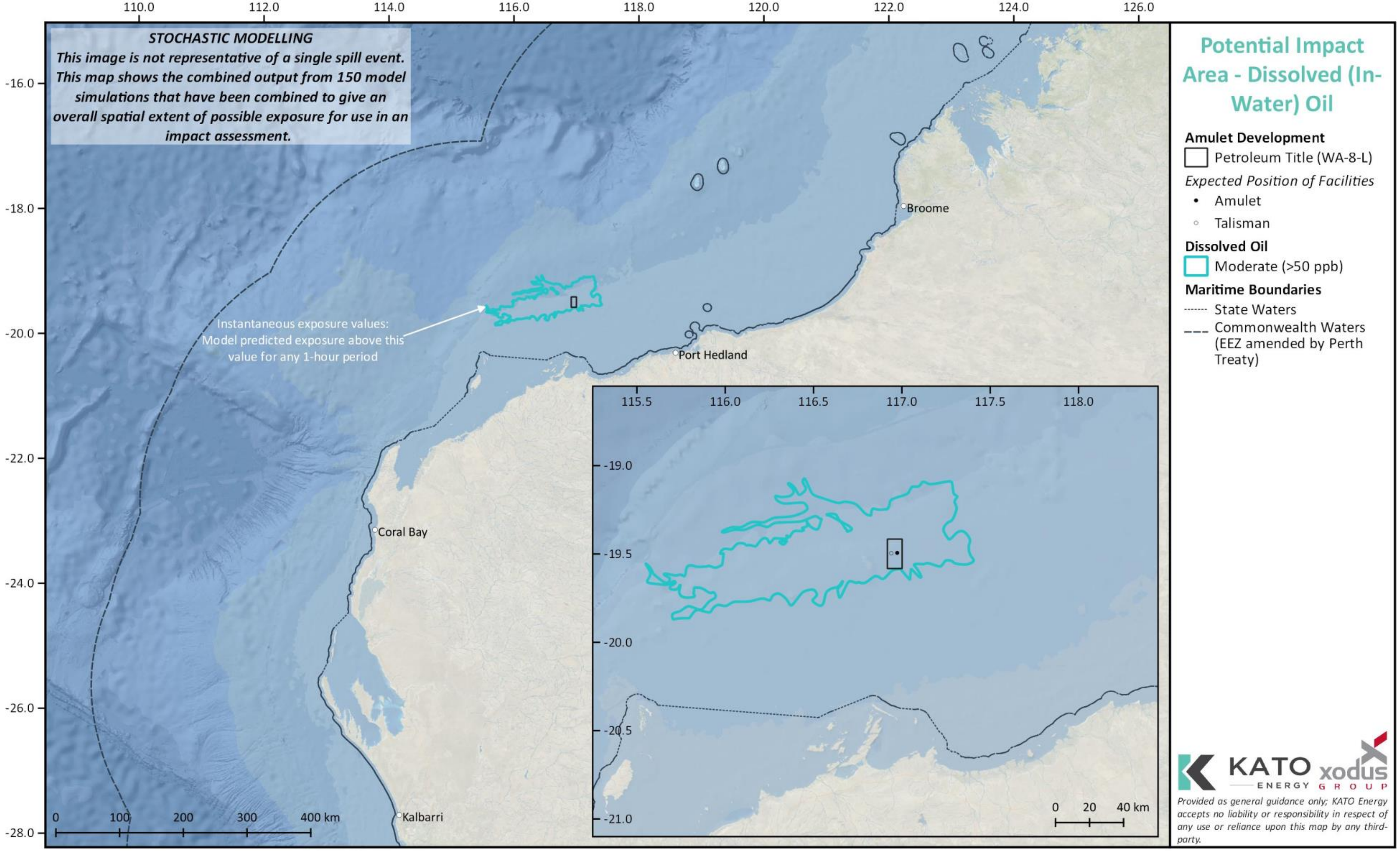


Figure 7-39 Potential Impact Area (stochastic modelling output) for Dissolved Oil from a Surface Release of MDO/MGO

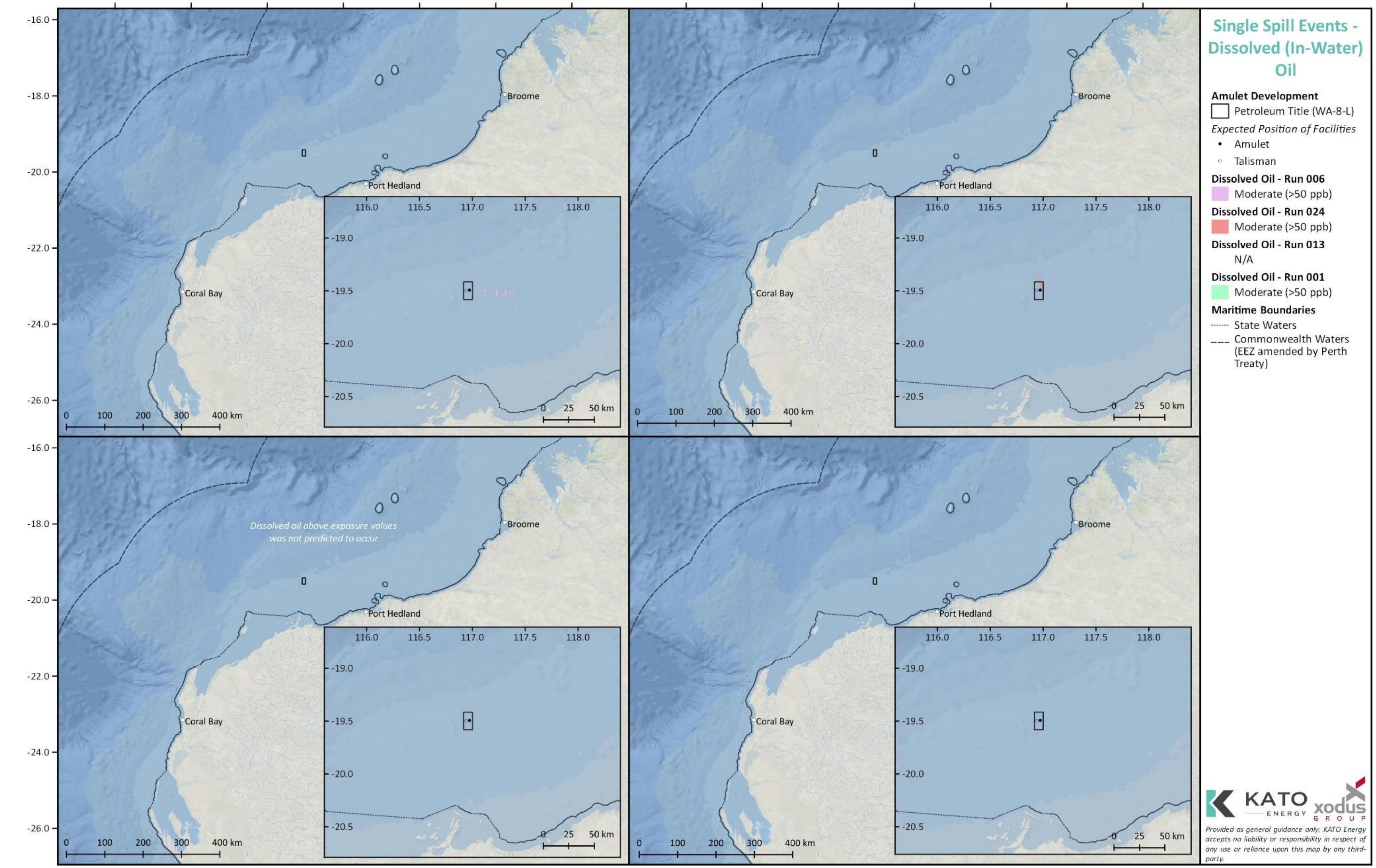


Figure 7-40 Examples of an Individual Spill Event (deterministic modelling output) for Dissolved Oil from a Surface Release of MDO/MGO

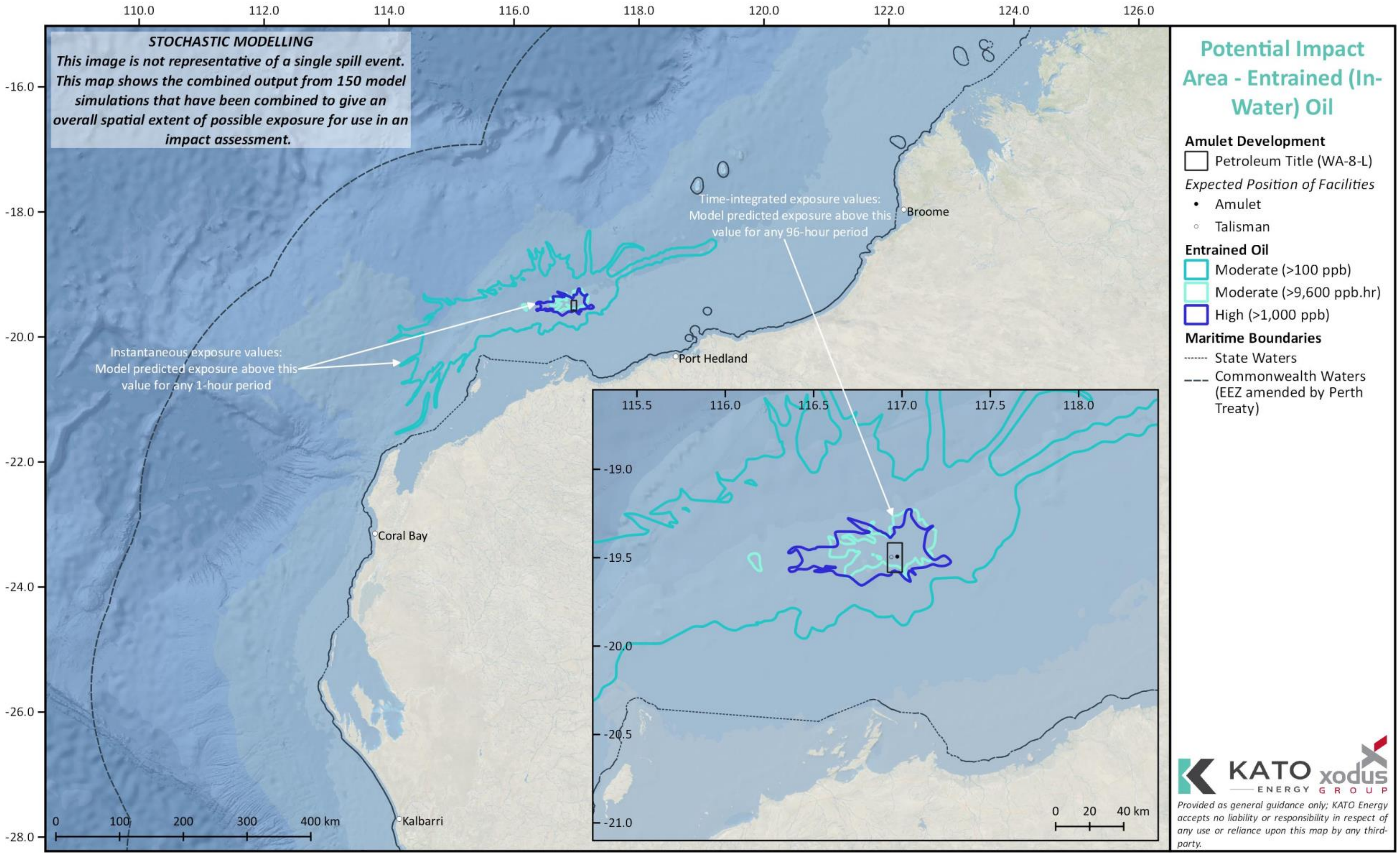


Figure 7-41 Potential Impact Area (stochastic modelling output) for Entrained Oil from a Surface Release of MDO/MGO

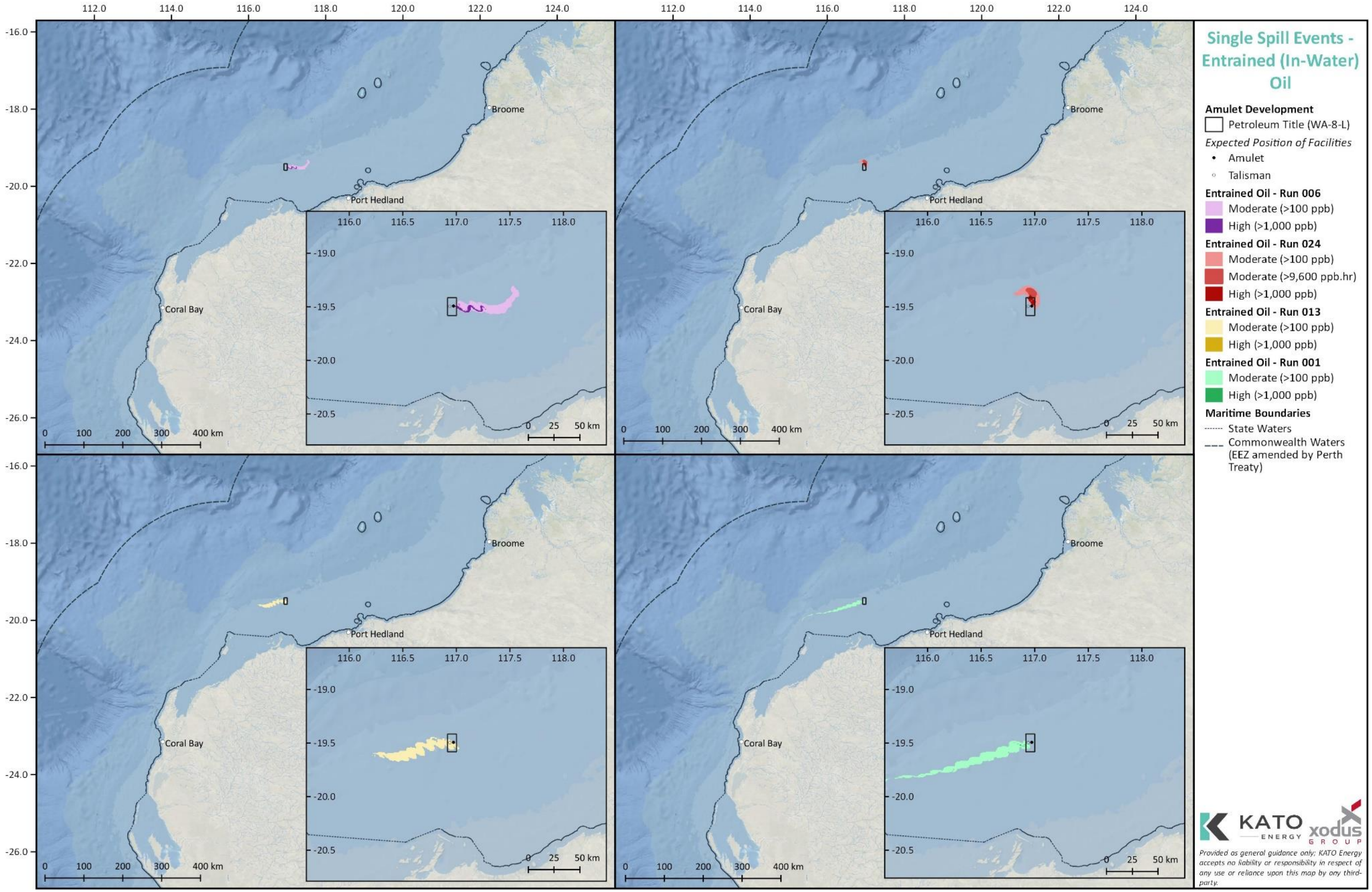


Figure 7-42 Examples of an Individual Spill Event (deterministic modelling output) for Entrained Oil from a Surface Release of MDO/MGO

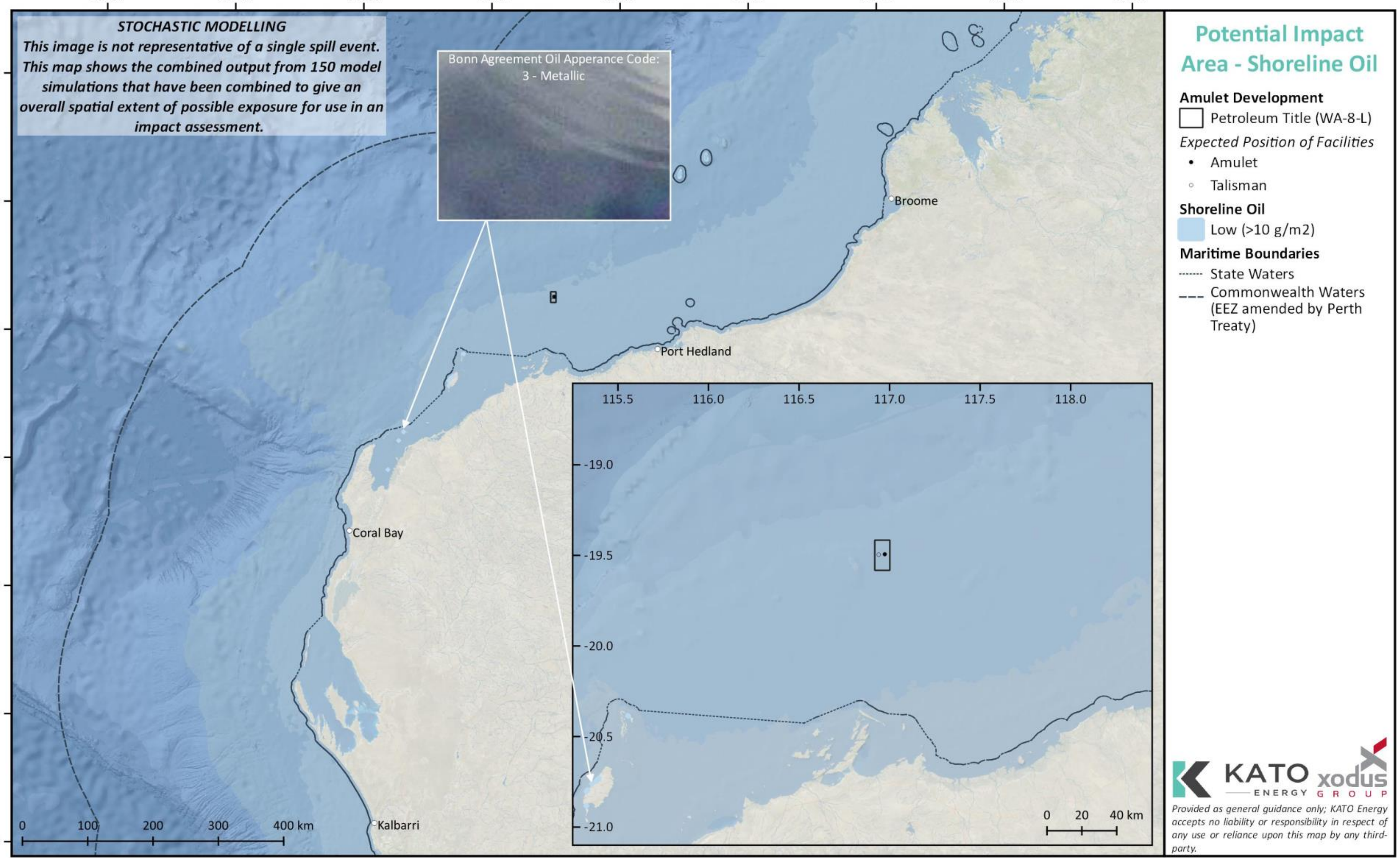


Figure 7-43 Potential Impact Area (stochastic modelling output) for Shoreline Oil from a Surface Release of MDO/MGO

7.2.7.3 Risk Evaluation

An accidental release of MDO/MGO generated by the Amulet 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 7-133 identifies the potential impacts to receptors as a result of an accidental release of MDO/MGO from the Amulet 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-7-134 provides a summary and justification for those receptors not evaluated further.

Table 7-133 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	✓									X	✓	X		X			
Change in sediment quality		X								X	X	X		X			
Change in habitat				X	X					X	X	X		X			
Injury / mortality to fauna			✓	X	X	✓	✓	✓	✓	X	✓	X	X	X			
Change in fauna behaviour				X	X	✓	✓	✓	✓	X	✓	X	X	X			
Changes to the functions, interests or activities of other users											✓	X	X	X	✓	✓	X
Change in aesthetic value					X						X	X		X			X

Table-7-134 Justification for Receptors Not Evaluated Further for Accidental Release – MDO/MGO

Sediment Quality	***X***
The Amulet field is in water ~85 m deep and the stochastic modelling did not indicate any benthic interaction from the released MGO within the vicinity. No in-water exposure (entrained, dissolved) extended into shallow or nearshore areas. The probability of shoreline accumulation is very low (≤1%), with the maximum ashore value of 1 m^3; i.e. negligible oil would be present within an intertidal or beach. 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. Therefore, the risk of any impact to sediment quality is negligible and is not evaluated further.	
Benthic Habitat and Communities	***X***
Benthic habitats and communities may be vulnerable to hydrocarbon exposure from an oil spill. The stochastic modelling did not indicate any benthic interaction from the released MGO within the vicinity of the Amulet Development. No in-water exposure (entrained, dissolved) extended into shallow or nearshore areas. The probability of shoreline accumulation is very low (≤1%), with the maximum ashore value of 1 m^3; i.e. negligible oil would be present within an intertidal area. Therefore, the risk of any impact to benthic habitat and communities is negligible and is not evaluated further.	
Coastal Habitat and Communities	***X***
Coastal habitats and communities may be vulnerable to hydrocarbon exposure from an oil spill. The stochastic modelling did not indicate any shoreline accumulation >100 g/m^2 under any seasonal conditions. Therefore, the risk of any impact to coastal habitat and communities is negligible and is not evaluated further.	
Key Ecological Features	***X***
The KEFs that are within the spatial extent of potential hydrocarbon exposure are all associated with seafloor features and/or benthic and demersal fauna and flora (e.g. ancient coastline at 125 m, continental slope demersal fish communities etc). The stochastic modelling did not indicate any benthic interaction from the released MGO within offshore waters. Therefore, the risk of any impact to KEFs is negligible and is not evaluated further.	
State Protected Areas – Marine; Heritage	***X***
No State marine protected areas or listed heritage features are predicted to be exposed to floating or in-water hydrocarbons. The probability of any shoreline accumulation is very low (≤1%), with volumes ashore being visible (>10 g/m^2) but not predicted to results in impacts (>100 g/m^2). Therefore, the risk of any impact to these receptors is negligible and is not evaluated further.	
State Protected Areas – Terrestrial	***X***
Terrestrial protected areas (e.g. Pilbara Inshore Islands Nature Reserves) occur within the area predicted to be exposed to shoreline accumulation. The probability of shoreline accumulation is very low (≤1%), with the maximum ashore value of 1 m^3. 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.	
Tourism and Recreation	***X***
The Amulet field is located ~132 km offshore from Dampier, and as such minimal tourism and recreational activities are expected within this vicinity (Section 5.5.3). Therefore, any reduced aesthetic from visual oil is unlikely to have a significant effect on these activities. Therefore, the risk of any impact to tourism and recreation is negligible and is 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 7-135 provides a detailed evaluation of the impacts of an accidental release of MDO/MGO to physical receptors.

Table 7-135 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 within several days of release (Section 7.2.7.2.3). Depending on wind conditions, oil may also entrain into the water column. Entrained oil can persist for extended periods of time, however if it refloats it is subject to evaporation; it is also subject to dissolution and natural degradation within the water column. 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 fauna behaviour
- injury / mortality to fauna.

Table 7-136 provides a detailed evaluation of the impact of an accidental release of MDO/MGO to ecological receptors.

Table 7-136 Impact and Risk Assessment for Ecological Receptors from Accidental Release – MDO/MGO

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 North West Shelf 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 within several days of release (Section 7.2.7.2.3).

Modelling undertaken for the surface release of MGO indicated that floating oil >10 g/m^2 may extend around spill site for up to 17 km. Noting that 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. No shoreline accumulation above impact levels (>100 g/m2) was predicted to occur. Therefore, no nesting habitats (islands etc.) are predicted to be exposed.

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 **Minor (1)** 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 Amulet 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.

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 within several days of release (Section 7.2.7.2.3).

Modelling undertaken for the surface release of MGO indicated that floating oil >10 g/m^2 may extend around spill site for up to 17 km. Noting that 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. No shoreline accumulation above impact levels (>100 g/m2) was predicted to occur. Therefore, no nesting habitats (islands etc.) are predicted to be exposed.

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 **Minor (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) 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 Amulet 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.

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
- injury / mortality to fauna

- change in fauna behaviour
- changes to the functions, interests or activities of other users.

Table 7-137 provides a detailed evaluation of the impact of an accidental release of MDO/MGO to social receptors.

Table 7-137 Impact and Risk Assessment for Social, Economic and Cultural Receptors from Accidental Release – MDO/MGO

Australian Marine Parks ✓
An accidental hydrocarbon release of MDO/MGO has the potential to result in: • change in water quality • injury / mortality to fauna • change in fauna behaviour • changes to the functions, interests or activities of other users. Australian Marine Parks 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 and marine fauna. Modelling predicted a low probability of exposure (≤3%) to the Montebello Marine Park. No other oil component (floating, dissolved, shoreline) was predicted to occur within an AMP. The entrained oil component was predicted to remain within surface layers of the ocean; therefore, impacts to pelagic values (e.g. marine fauna) are restricted to those in surface waters only Given the details above, the consequence of an accidental release of MDO/MGO causing any permanent and/or significant impacts to AMPs has been assessed as **Minor (1)** with the impact assessed as **Very unlikely (B)** to occur given effects will be temporary and spatially restricted.
Industry ✓
An accidental hydrocarbon release of MDO/MGO has the potential to result in: • changes to the functions, interests or activities of other users. Marine and coastal industries in the Hydrocarbon Area mainly comprise petroleum activities, commercial shipping and defence activities (Section 5.5.5). 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 MGO is subject to rapid evaporation the exclusion zone is likely to be temporary minimising the impacts to other marine users. Offshore petroleum activities in the region include Woodside-operated Angel, North Rankin, Goodwyn Alpha platforms and the Okha FPSO (Section 5.5.5). Stochastic modelling has predicted that some of these facilities may be exposed to in-water (entrained, dissolved) hydrocarbons. No floating oil (including the low-level visual threshold) was predicted to intersect adjacent facilities. 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 effects being temporary and spatially restricted, and so any exclusion zone is likely to be temporary.
Commercial Fisheries ✓
An accidental hydrocarbon release of MDO/MGO has the potential to result in: • 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, no activity from Commonwealth and low levels of activity from State fisheries is expected within the immediate vicinity of the Amulet Development, but additional activity may occur within the wider Hydrocarbon Area (Section 5.5.2). Results from stochastic modelling predicted visible floating oil up to 217 km from the spill source; this threshold is not expected to have biological effects but can alter the use of an area. In-water (entrained, dissolved) are predicted to extend further (e.g. up to 376 km for 100 ppb entrained). 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 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.

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 1,200 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 due to the cautionary and exclusion zones. These would approach at a slow speed for safety reasons. Non-project vessels would remain outside the PSZ. The worst-case likelihood was assessed as **Unlikely (C)** (for water quality).

Risk Level for all receptors is **Low** and considered **acceptable** based on an evaluation against the criteria in Table 7-138.

Table 7-138 Demonstration of Acceptability for Accidental Release – MDO/MGO

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="7">Ambient water quality</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Accidental Release – MDO/MGO, the Amulet Development will not result in significant impacts to ambient water quality identified as potentially affected, defined as a possibility that it will (Section 6.6):
• result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>The proposed EPO’s for the Amulet Development are consistent with the principles of ESD.
With respect to potential impacts to all receptors from Accidental Release - MDO/MGO the relevant principles are:
• Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
• 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.</td></tr>
<tr><td>Internal context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with KATO internal requirements, including policies, procedures and standards.
With respect to potential impacts to all receptors from Accidental Release - MDO/MGO, this specifically includes:
• KATO Marine Operations Procedure (KAT-000-PO-PP-101) (KATO 2020b)</td></tr>
<tr><td>External context</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development have taken into consideration relevant feedback from stakeholders.
With respect to potential impacts to all receptors from Accidental Release - MDO/MGO, no specific concerns were raised during stakeholder consultation with relevant persons.</td></tr>
<tr><td>Other requirements</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - MDO/MGO from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to ambient water quality from Accidental Release - MDO/MGO, this specifically includes:
Requirement | Relevant Item/Objective/Action | Addressed/Managed by Amulet Development</td></tr>
</table>

Receptor	Demonstration of Acceptability			
		OPPGS(E) Regulations	An Environmental Plan, including oil spill contingency and emergency response arrangements, must be place for any petroleum activity prior to activities commencing.	EPs and associated documents (e.g. OPEPs) will be developed as part of the subsequent approvals process. Adoption of the following control measures: **CM03:** Pre-start notifications will be provided to relevant stakeholders at appropriate timing, including presence of 500 m exclusion and 2 km cautionary zones. **CM04:** KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM28**: 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. **CM36:** 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). **CM37**: Emergency response capability (including equipment) will be maintained in accordance with SOPEPS/SMPEPs; and accepted EPs and OPEPs. **CM38**: NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place.
		Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* – Section 26F (implements MARPOL Annex I).	Aims at protecting the marine environment from discharges associated with ships within Australian waters that may result in pollution to the marine environment. This also includes oil pollution. Includes the requirement for an approved Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) (or equivalent, according to class) which describes emergency response activities.	
		Commonwealth *Navigation Act 2012*– Chapter 4 (Prevention of Pollution)	Gives effect to international conventions for maritime issues where Australia is a signatory, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).	

Receptor	Demonstration of Acceptability				
				CM40: NOPSEMA-accepted Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken.	
	Summary of impact assessment				**Risk level**
	The impacts on *ambient water quality* from Accidental Release - MDO/MGO include: • MGO is classified as a light persistent oil, with 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 will evaporate within several days of release • Stochastic modelling indicated that if/when entrained or dissolved oil did occur it remained in the surface layers (<10 m depth).				Low
	Statement of acceptability				
	Based on an assessment against the defined acceptable levels, the impacts on *ambient water quality* from Accidental Release - MDO/MGO is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the predicted level of impact is at or below the defined acceptable level To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO25:** Undertake the Amulet Development in a manner that will prevent an accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.				
Plankton	**Acceptable level of impact**				
	With respect to Accidental Release - MDO/MGO, the Amulet Development will not result in significant impacts to *plankton* as potentially affected, defined as a possibility that it will (Section 6.6): • have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.				
	Acceptability assessment				
	Principles of ESD	Refer to details in *water quality* assessment (above)			
	Internal context	Refer to details in *water quality* assessment (above)			

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="8"></td><td>External context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - MDO/MGO from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to plankton from Accidental Release - MDO/MGO, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="2">The impacts on plankton from Accidental Release - MDO/MGO include:
• Results from the stochastic modelling 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.
• Once background water quality is re-established, plankton takes weeks to months to recover.</td><td>Low</td></tr>
<tr><td colspan="3">Statement of acceptability</td></tr>
<tr><td colspan="3">Based on an assessment against the defined acceptable levels, the impacts on plankton from Accidental Release - MDO/MGO is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO25: Undertake the Amulet Development in a manner that will prevent an accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.</td></tr>
<tr><td rowspan="2">Seabirds and shorebirds</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Accidental Release - MDO/MGO, the Amulet Development will not result in significant impacts to seabirds and shorebirds identified as potentially affected, defined as a possibility that it will (Section 6.6):</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="10"></td><td colspan="4">• have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population.
• substantially modify, destroy or isolate an area of important habitat for a migratory species.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td rowspan="5">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - MDO/MGO from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to seabirds and shorebirds from Accidental Release - MDO/MGO, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Wildlife Conservation Plan for Migratory Shorebirds (DoEE 2015)</td><td>Identified habitat modification as a threat. No explicit relevant objectives.
Relevant management action:
• 3f: Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes.</td><td rowspan="3">Environmental risk assessment for Accidental Release - MDO/MGO on seabirds and shorebirds has been completed in this OPP (Section 7.2.7.3.2).
EPs and associated documents (e.g. OPEPs, Oil Spill Monitoring Programs (OSMPs) will be developed as part of the subsequent approvals process.
Adoption of the following control measures:
CM38: NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place.</td></tr>
<tr><td>Conservation advice Calidris canutus (Red Knot) (TSSC 2016a)</td><td>Identifies habitat loss and habitat degradation (e.g. through environmental pollution), pollution/contamination impacts and direct mortality as threats. No explicit relevant objectives or management actions.</td></tr>
<tr><td>Conservation advice Calidris ferruginea (Curlew Sandpiper) (DoE 2015a)</td><td>Identifies habitat loss and degradation from pollution as a threat. No explicit relevant objectives or management actions.</td></tr>
</table>

Receptor	Demonstration of Acceptability			
		Conservation advice *Limosa lapponica baueri* [Bar-tailed Godwit (Western Alaskan)] (TSSC 2016b)	Identifies habitat loss and habitat degradation (e.g. through environmental pollution), pollution/contamination impacts and direct mortality as threats. No explicit relevant objectives or management actions.	
		Conservation advice *Limosa lapponica menzbieri* (Bar-tailed Godwit (Northern Siberian)) (TSSC 2016c)	Identifies habitat loss and habitat degradation (e.g. through environmental pollution), pollution/contamination impacts and direct mortality as threats. No explicit relevant objectives or management actions.	
		National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011)	Identifies marine pollution as a key threat. Objective 3: Marine-based threats to the survival and breeding success of albatrosses and giant petrels foraging in waters under Australian jurisdiction are quantified and reduced. Relevant management action: • C11.1: Where feasible, population monitoring programs also monitor, in a standardised manner, the incidence of: ○ oiled birds at the nest ○ marine debris egestion/entanglement at the nests ○ eggshell thinning.	
		Conservation advice for *Sterna nereis nereis* (Fairy Tern) (TSSC 2011b)	Identifies oil spills, particularly in Victoria, where the close proximity of oil facilities poses a risk of oil spills that may affect the species' breeding habitat as a potential threat. No explicit relevant objectives. Relevant management action:	

Receptor	Demonstration of Acceptability			
			• Ensure appropriate oil-spill contingency plans are in place for the subspecies' breeding sites which are vulnerable to oil spills, such as the breeding colonies in Victoria	
		Conservation Advice for *Numenius madagascariensis* (Eastern Curlew) (DoE 2015c)	Identifies habitat loss and degradation from pollution as a threat. No explicit relevant objectives or management actions.	
	Summary of impact assessment			**Risk level**
	The impacts on *seabirds and shorebirds* from Accidental Release - MDO/MGO include: • Stochastic modelling indicated that surface oil >10 g/m^2 may extend up to a maximum of 17 km. Due to the high volatility of MDO/MGO, most of the oil is expected to evaporate within several days once on the water surface. This relatively small (spatially and temporally) area of exposure is expected to have minimal impact on birds at sea. • Stochastic modelling indicated no shoreline accumulation of >100 g/m^2, therefore no risk to nesting or roosting habitat for bird species.			Low
	Statement of acceptability			
	Based on an assessment against the defined acceptable levels, the impacts on *seabirds and shorebirds* from Accidental Release - MDO/MGO is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO25:** Undertake the Amulet Development in a manner that will prevent an accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.			
Fish	**Acceptable level of impact**			

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="9"></td><td colspan="4">With respect to Accidental Release - MDO/MGO, the Amulet Development will not result in significant impacts to fish identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
• substantially modify, destroy or isolate an area of important habitat for a migratory species.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.</td></tr>
<tr><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td rowspan="4">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - MDO/MGO from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to fish from Accidental Release - MDO/MGO, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Recovery plan for the White Shark (Carcharodon carcharias) (DSEWPaC 2013a)</td><td>Identifies habitat modification as a potential threat. No explicit relevant objectives or management actions.</td><td rowspan="2">Environmental risk assessment for Accidental Release - MDO/MGO on fish has been completed in this OPP (Section 7.2.7.3.2).</td></tr>
<tr><td>Sawfish and river shark multispecies recovery plan (CoA 2015b)</td><td>Identifies habitat degradation and modification as a principal threat.
Objective 5: Reduce and, where possible, eliminate adverse impacts of habitat degradation and modification on sawfish and river shark species.
Relevant management action:</td></tr>
</table>

Receptor	Demonstration of Acceptability			
			• 5c. Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.	
		Approved conservation advice for *Pristis clavata* (Dwarf Sawfish) (TSSC 2009b)	Identifies habitat degradation due to increasing human development in northern Australia as a threat. No explicit relevant objectives or management actions.	
		Approved conservation advice for Green Sawfish (TSSC 2008a)	Identifies habitat degradation through coastal development as a potential threat. No explicit relevant objectives or management actions.	
		Approved Conservation Advice for *Pristis pristis* (Largetooth Sawfish) (DoE 2014a).	Identifies habitat degradation and modification as a main threat. No explicit relevant objectives. Relevant management action: • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	
		Conservation advice *Rhincodon typus* (Whale Shark) (TSSC 2015d)	Identifies habitat disruption from mineral exploration, production and transportation as a threat. No explicit relevant objectives or management actions.	
		Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (DoE 2014b)	Identifies ecosystem effects as a result of habitat modification as a threat. No explicit relevant objectives or management actions.	
	Summary of impact assessment			**Risk level**
	The impacts on *fish* from Accidental Release - MDO/MGO include:			Low

Receptor	Demonstration of Acceptability	
	• 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 highly mobile and as such are not likely to suffer extended exposure (e.g. >96 hours) at concentrations that would lead to chronic effects. • A foraging BIA has been identified within the area at risk of potential exposure from a release of MDO/MGO. Whale Sharks do not spend all their time in surface waters—they routinely move between surface and to depths of >30 m, and as such would not be continually exposed to dispersed or entrained oil within the surface layers, or the surface slick itself.	
	Statement of acceptability	
	Based on an assessment against the defined acceptable levels, the impacts on *fish* from Accidental Release - MDO/MGO is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO25:** Undertake the Amulet Development in a manner that will prevent an accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.	
Marine reptiles	**Acceptable level of impact**	
	With respect to Accidental Release - MDO/MGO, the Amulet Development will not result in significant impacts to *marine reptiles* identified as potentially affected, defined as a possibility that it will (Section 6.6): • have a substantial adverse effect on a population of fish, or the spatial distribution of the population. • modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. • seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	
	Acceptability assessment	
	Principles of ESD	Refer to details in *water quality* assessment (above)

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td rowspan="6"></td><td>Internal context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td rowspan="4">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - MDO/MGO from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to marine reptiles from Accidental Release - MDO/MGO, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>Recovery plan for Marine Turtles in Australia (CoA 2017)</td><td>Identifies chemical and terrestrial discharge as a threat.
Action Area A4 (minimise chemical and terrestrial discharge) relevant management actions:
• Ensure spill risk strategies and response programs adequately include management for marine turtles and their habitats, particularly in reference to ‘slow to recover habitats’, e.g. nesting habitat, seagrass meadows or coral reefs
• Quantify the impacts of decreased water quality on stock viability
• Quantify the accumulation and effects of anthropogenic toxins in marine turtles, their foraging habitats and subsequent stock viability.</td><td rowspan="2">Environmental risk assessment for Accidental Release - MDO/MGO on marine reptiles has been completed in this OPP (Section 7.2.7.3.2).
EPs and associated documents (e.g. OPEPs, OSMPs will be developed as part of the subsequent approvals process.
Adoption of the following control measures:
CM38: NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place.</td></tr>
<tr><td>Approved conservation advice for Dermochelys coriacea (Leatherback Turtle) (TSSC 2009a)</td><td>Identifies degradation of foraging areas and changes to breeding sites as a main threat. No explicit relevant objectives or management actions.</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="7"></td><td></td><td>Approved Conservation Advice for Aipysurus apraefrontalis (Short-nosed Seasnake) (TSSC 2011b)</td><td>Identifies oil and gas exploration, including seismic surveys and exploration drilling as a threat. No explicit relevant objectives or management actions.</td><td></td></tr>
<tr><td colspan="3">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="3">The impacts on marine reptiles from Accidental Release - MDO/MGO include:
• Stochastic modelling indicated that surface oil >10 g/m^2 may extend up to a maximum of 17 km. Due to the high volatility of MDO/MGO, most of the oil is expected to evaporate within several days once on the water surface. This relatively small (spatially and temporally) area of exposure is expected to have minimal impact on marine reptiles at sea.
• Stochastic modelling indicated no shoreline accumulation of >100 g/m^2, therefore no risk to nesting habitat for marine turtle species.</td><td>Low</td></tr>
<tr><td colspan="4">Statement of acceptability</td></tr>
<tr><td colspan="4">Based on an assessment against the defined acceptable levels, the impacts on marine reptiles from Accidental Release - MDO/MGO is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO25: Undertake the Amulet Development in a manner that will prevent an accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.</td></tr>
<tr><td rowspan="2">Marine mammals</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td colspan="4">With respect to Accidental Release - MDO/MGO, the Amulet Development will not result in significant impacts to marine mammals as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
</table>

Receptor	Demonstration of Acceptability			
	• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.			
	Acceptability assessment			
	Principles of ESD	Refer to details in *water quality* assessment (above)		
	Internal context	Refer to details in *water quality* assessment (above)		
	External context	Refer to details in *water quality* assessment (above)		
	Other requirements	The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - MDO/MGO from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices. With respect to potential impacts to *marine mammals* from Accidental Release - MDO/MGO, this specifically includes:		
		Requirement	*Relevant Item/Objective/Action*	*Addressed/Managed by Amulet Development*
		Conservation advice *Balaenoptera borealis* Sei Whale (TSSC 2015a)	Identifies habitat degradation including pollution as a threat. No explicit relevant objectives or management actions.	Environmental risk assessment for Accidental Release - MDO/MGO on marine reptiles has been completed in this OPP (Section 7.2.7.3.2).
		Conservation Management Plan for the Blue Whale: A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 2015–2025 (CoA 2015a)	Identifies habitat modification as a threat. No explicit relevant objectives or management actions.	
		Conservation advice *Balaenoptera physalus* Fin Whale (TSSC 2015b)	Identifies pollution (persistent toxic pollutants) as a threat. No explicit relevant objectives or management actions.	
		Approved Conservation Advice for *Megaptera novaeangliae* (Humpback Whale) (TSSC 2015c)	Identifies habitat degradation including coastal development and port expansion as a threat. No explicit relevant objectives or management actions.	

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="6"></td><td></td><td>Conservation Management Plan for the Southern Right Whale (DSEWPaC 2011)</td><td>Identifies habitat modification as a threat. No explicit relevant objectives or management actions.</td><td></td></tr>
<tr><td colspan="3">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="3">The impacts on marine mammals from Accidental Release - MDO/MGO include:
• Due to the high volatility of MDO/MGO, once on the surface most of the oil is expected to evaporate within several days. Stochastic modelling indicated that if/when entrained or dissolved oil did occur it remained in the surface layers (<10 m depth).
• Migratory BIAs for the Pygmy Blue Whale and Humpback Whale occur within the area that may be exposed from an oil spill from the Amulet Development.
• As highly mobile species, in general it is unlikely that these animals will be consistently (e.g. >96 hours) exposed to concentrations of oils in the water column that would lead to chronic effects.</td><td>Low</td></tr>
<tr><td colspan="4">Statement of acceptability</td></tr>
<tr><td colspan="4">Based on an assessment against the defined acceptable levels, the impacts on marine mammals from Accidental Release - MDO/MGO is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO25: Undertake the Amulet Development in a manner that will prevent an accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td rowspan="2">Australian Marine Parks</td><td colspan="4">Acceptable level of impact</td></tr>
<tr><td colspan="4">With respect to Accidental Release - MDO/MGO, the Amulet Development will not result in significant impacts to AMPs identified as potentially affected, defined as a possibility that it will (Section 6.6):
• modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td rowspan="12"></td><td colspan="4">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="3">Refer to details in water quality assessment (above)</td></tr>
<tr><td rowspan="3">Other requirements</td><td colspan="3">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - MDO/MGO from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to AMPs from Accidental Release - MDO/MGO, this specifically includes:</td></tr>
<tr><td>Requirement</td><td>Relevant Item/Objective/Action</td><td>Addressed/Managed by Amulet Development</td></tr>
<tr><td>North-west Marine Parks Network Management Plan</td><td>Identifies marine pollution as a pressure. No explicit relevant objectives or management actions.</td><td>Environmental risk assessment for Accidental Release - MDO/MGO on AMPs has been completed in this OPP (Section 7.2.7.3.3).</td></tr>
<tr><td colspan="3">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="3">The impacts on AMPs from Accidental Release - MDO/MGO include:
• Stochastic modelling predicted a low probability of exposure (≤3%) of entrained oil to the Montebello Marine Park. Entrained oil was predicted to remain within surface layers; therefore, impacts to pelagic values (e.g. marine fauna) are restricted to those in surface waters only. No other oil component (floating, dissolved, shoreline) was predicted to occur.
• Stochastic modelling did not predict exposure for any other AMP.
• No floating/surface oil was predicted to intersect with any marine protected area, therefore no temporary reduction in aesthetic values is expected to occur.</td><td>Low</td></tr>
<tr><td colspan="4">Statement of acceptability</td></tr>
<tr><td colspan="4">Based on an assessment against the defined acceptable levels, the impacts on AMPs from Accidental Release - MDO/MGO is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="3">Demonstration of Acceptability</th></tr>
<tr><td></td><td colspan="3">• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO25: Undertake the Amulet Development in a manner that will prevent an accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.</td></tr>
<tr><td rowspan="10">Commercial fisheries</td><td colspan="3">Acceptable level of impact</td></tr>
<tr><td colspan="3">With respect to Accidental Release - MDO/MGO, the Amulet Development will not result in significant impacts to commercial fisheries identified as potentially affected, defined as a possibility that it will (Section 6.6):
• have a substantial adverse effect on the sustainability of commercial fishing
An activity will contravene the OPGGS Act Section 280(2), and therefore result in a significant impact, if it is deemed to:
• interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.</td></tr>
<tr><td colspan="3">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td colspan="2">Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td colspan="2">The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - MDO/MGO from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to commercial fisheries from Accidental Release - MDO/MGO, no specific other requirements have been identified as relevant.</td></tr>
<tr><td colspan="2">Summary of impact assessment</td><td>Risk level</td></tr>
<tr><td colspan="2">The impacts on commercial fisheries from Accidental Release - MDO/MGO include:
• Any exclusion zones around the spill location is expected to be relatively small and temporary given the nature and behaviour of the MDO/MGO after release, as such any interruption to fishery access is expected to be minor.
• Given the volatility and predicted weathering of the MDO/MGO, significant amounts of tainting or toxicity impacts to commercial fish species are not expected.</td><td>Low</td></tr>
</table>

<table>
<tr><th>Receptor</th><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td rowspan="2"></td><td colspan="2">Statement of acceptability</td></tr>
<tr><td colspan="2">Based on an assessment against the defined acceptable levels, the impacts on commercial fisheries from Accidental Release - MDO/MGO is considered acceptable, given that:
• the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above
• the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013)
• the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices.
• the predicted level of impact is at or below the defined acceptable levels.
To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied:
• EPO25: Undertake the Amulet Development in a manner that will prevent an accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.</td></tr>
<tr><td rowspan="8">Industry</td><td colspan="2">Acceptable level of impact</td></tr>
<tr><td colspan="2">With respect to Accidental Release - MDO/MGO, the Amulet Development will not result in significant impacts to industry identified as potentially affected, defined as a possibility that it will (Section 6.6):
• interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.</td></tr>
<tr><td colspan="2">Acceptability assessment</td></tr>
<tr><td>Principles of ESD</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>Internal context</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>External context</td><td>Refer to details in water quality assessment (above)</td></tr>
<tr><td>Other requirements</td><td>The impact assessment, consequence levels and proposed controls for the Amulet Development are consistent with national and international standards, laws, and policies, and significant impact guidelines for MNES. The Amulet Development will also be managed in a manner that is consistent with management objectives and/or actions related to Accidental Release - MDO/MGO from management plans for relevant WHAs, AMPs, or species recovery plans and conservation plans/advices.
With respect to potential impacts to industry from Accidental Release - MDO/MGO, no specific other requirements have been identified as relevant.</td></tr>
<tr><td>Summary of impact assessment</td><td>Risk level</td></tr>
</table>

Receptor	Demonstration of Acceptability	
	The impacts on *industry* from Accidental Release - MDO/MGO include: • Any exclusion zones around the spill location is expected to be relatively small and temporary given the nature and behaviour of the MDO/MGO after release, as such any interruption to other industry users in the area is expected to be minor.	Low
	Statement of acceptability	
	Based on an assessment against the defined acceptable levels, the impacts on *industry* from Accidental Release - MDO/MGO is considered acceptable, given that: • the activity is aligned with the relevant principles of ESD, internal context, external context and other requirements assessed above • the assessment of impacts and risks of the activities has not predicted significant impacts for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013) • the Amulet Development will be managed in a manner that is consistent with management objectives and management actions evaluated above for relevant WHAs, AMPs, recovery plans and conservation plans/advices. • the predicted level of impact is at or below the defined acceptable levels. To manage impacts to receptors to at or below the defined acceptable levels the following EPO have been applied: • **EPO25:** Undertake the Amulet Development in a manner that will prevent an accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.	

A summary of the impact analysis and evaluation, including control measures adopted and EPOs, is provided in Table 7-139.

Table 7-139 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 rowspan="9">EPO25: Undertake the Amulet Development in a manner that will prevent an accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.</td><td rowspan="9">CM03: Pre-start notifications will be provided to relevant stakeholders at appropriate timing, including presence of 500 m exclusion and 2 km cautionary zones.
CM04: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction.
CM28: 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.
CM36: 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).
CM37: Emergency response capability (including equipment) will be maintained in accordance with SOPEPS/SMPEPs; and accepted EPs and OPEPs.
CM38: NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place.
CM40: Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken.</td><td>Minor</td><td>Unlikely</td><td>Low</td></tr>
<tr><td>Plankton</td><td>Injury / mortality to fauna</td><td>Minor</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>Minor</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>Minor</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>Australian Marine Parks</td><td>Change in water quality
Injury / mortality to fauna
Change in fauna behaviour
Changes to the functions, interests or activities of other users</td><td>Minor</td><td>Very unlikely</td><td>Low</td></tr>
<tr><td>Industry</td><td>Changes to the functions, interests or activities of other users</td><td>Minor</td><td>Very unlikely</td><td>Low</td></tr>
<tr><td>Commercial Fisheries</td><td>Changes to the functions, interests or activities of other users</td><td>Minor</td><td>Very unlikely</td><td>Low</td></tr>
</table>

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 Amulet Development. Given the low likelihood of unplanned events (e.g. accidental releases) occurring during the Amulet 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 Amulet 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 planned aspect interactions (i.e. spatial extent for each aspect described in Section 7.1). The potential impact areas for the planned activities for the Amulet Development are defined in Section 5.1 (i.e. Project Area and Light Area).

The largest potential impact area for any planned aspect is for light emissions. The Light Area for the Amulet Development has been defined as a 12.6 km radius around the expected position of the MOPU at Amulet and the manifold at facilities at Amulet and Talisman (Sections 5.1, 7.1.3), and is the worst-case extent of predicted measurable change to ambient light based on planned activities from the Amulet Development for the life of the project.

All other potential impact areas from planned aspects are within the Project Area (5 km radius around the expected position of the MOPU at Amulet and the manifold at Talisman; Section 5.1). Therefore, a conservative spatial extent of 12.6 km has been used for purposes of cumulative impact assessment for light emissions, and 5 km for other planned aspects, for the Amulet Development.

Temporal boundaries consider both the past and future activities and environments. A number of wells have previously been drilled within the WA-8-L permit area, with the most recent activity in 2006 (Section 3.2). No other developments exist in the immediate permit areas adjacent to the Amulet 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 Amulet 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 Amulet 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 Amulet field is expected following the Amulet 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 Amulet 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 Amulet Development, including:

- State- and Commonwealth-managed fisheries
- marine and coastal industries:
  - Existing oil and gas developments – closest are the Woodside-operated Angel platform and Okha FPSO, at ~40 km and ~57 km away from the Amulet Development respectively. Santos' Mutineer Exeter Development (~45 km northeast) is currently in cessation and the FPSO has left the field.
  - Potential exploration drilling undertaken by KATO in WA-8-L, during production drilling for Amulet / Talisman wells.
  - Commercial shipping.

Typically, cumulative impact assessments will also consider the effect of impacts associated with future industries / projects.

There is potential there may also be exploration targets within the WA-8-L permit area, that are as yet undiscovered and therefore undefined. Whilst on location drilling the Amulet and Talisman wells, KATO may take the opportunity to drill an exploration well into a nearby oil prospect that is within reach of the MODU. Note that exploration drilling is not within scope of this OPP process; but would be covered by a separate EP.

If exploration drilling is undertaken, it would be done during the same drilling campaign, from the same MODU. It would typically take 1-2 weeks to drill a pilot hole into the nearby oil prospect.

KATO have considered potential cumulative impacts from exploration drilling as follows:

- additional mobilisation of a MODU is not required
- exploration drilling would be undertaken from the same MODU location (i.e. MODU would not need to be relocated); therefore no additional seabed disturbance

- support operations and drilling activities would generate planned discharges and emissions during this period (typically 1-2 weeks). However, exploration drilling would be undertaken in sequence with production drilling (i.e. the two activities would not overlap).

The only additional potential environment impact identified is a greater accumulated volume of Planned discharge – Drilling cuttings and fluids. However, the seabed entry points for all the wells at the MODU location (both production and exploration wells) will be very close together – i.e. within a ~10 m by 10 m footprint; and the cuttings piles from each one will overlap. Therefore, the accumulated additional volume from exploration drilling would not result in an increase in spatial extent of impact, as would be within the ~200 m radius of impact evaluated for the Amulet production wells in Section 7.1.6.

KATO is unaware of any other projects planned that will be located in close-enough proximity to the Amulet Development to lead to cumulative impacts. Once the Amulet Development is complete, the honeybee production system will be relocated to the next field, which may be the Corowa Development (though Corowa may be undertaken first). Corowa is >335 km south-east from Amulet, and is subject to a separate OPP (KATO 2020j).

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 Amulet 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 Amulet 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 predominantly restricted to the Project Area, comprising a 5 km buffer around the expected position of the MOPU and Talisman manifold, with the exception of the Light Area, which has been modelled as a 12.6 km buffer (Section 7.1.3).

The only existing industries / projects within both these buffers (i.e. 5 km and 12.6 km spatial boundary for cumulative assessment for aspects) are:

- commercial fisheries
- industries (shipping)

A variety of vessels will operate throughout the duration of the Amulet Development, which is expected to be approximately five years (shown in Table 3-17). This number will peak during drilling, commissioning and decommissioning at approximately ten support vessels. Throughout the operations phase (~1.5–4.5 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)
- Emissions – Atmospheric (Section 8.2.4.4)

Some aspects may result in impacts extending beyond the Project Area (5 km). The closest oil and gas development is located 40 km away, however commercial shipping and fishing vessels will likely pass close to the Amulet Development and may result in impacts becoming cumulative. Aspects that may result in cumulative impacts include:

- Emissions – Light (Section 8.2.4.3).

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 Amulet Development impacts	Existing industries / project within spatial boundary	Potential for Cumulative Impacts?
Physical Presence – Interaction with Other Users	Project Area (5 km)	• Fisheries • Industries (shipping)	Interaction possible, but no cumulative impacts expected (Section 8.2.4.1)
Physical Presence – Seabed Disturbance	Project Area (5 km)	• Fisheries • Industries (shipping)	No interaction
Emissions – Light	Light Area (12.6 km)	• Fisheries • Industries (shipping, petroleum)	**Yes (Section 8.2.4.3)**
Emissions – Atmospheric Emissions	Project Area (5 km)	• Fisheries • Industries (shipping)	**Yes (Section 8.2.4.4**)
Emissions – Underwater Noise	Project Area (5 km)	• Fisheries • Industries (shipping)	No interaction
Planned Discharge – Drilling cuttings and Fluids	Project Area (5 km)	• Fisheries • Industries (shipping)	No interaction
Planned Discharge – Cement	Project Area (5 km)	• Fisheries • Industries (shipping)	No interaction
Planned Discharge – Commissioning Fluids	Project Area (5 km)	• Fisheries • Industries (shipping)	No interaction
Planned Discharge – Produced Formation Water	Project Area (5 km)	• Fisheries • Industries (shipping)	No interaction
Planned Discharge – Cooling Water and Brine	Project Area (5 km)	• Fisheries • Industries (shipping)	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)	Interaction possible, but no cumulative impacts expected (Section 8.2.4.2)

Aspect	Spatial Boundary of Amulet Development impacts	Existing industries / project within spatial boundary	Potential for Cumulative Impacts?
Planned Discharge – Sewage, Greywater and Food waste	Project Area (5 km)	• Fisheries • Industries (shipping)	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 Amulet Development on other marine users, specifically a change in the functions, interests or activities of other marine users. These impacts are assessed as being **Minor (1)** and acceptable to all receptors, as the Amulet Development will generate a low volume of vessel traffic throughout the project lifecycle, and a 500 m exclusion zone and 2 km cautionary zone will be established to inform other marine users of the physical presence of the Amulet Development.

Impacts from physical presence are limited to the Project Area, and the transit route of support vessels from port to the Amulet Development. Vessel traffic associated with the Amulet Development is low and therefore will not add a significant volume of marine traffic to the region. The number of vessels used for the Amulet 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 ~40 km away, and it is not expected that vessels transiting to the Angel platform or Okha FPSO will cross paths, other than possibly close to port.

Given the low vessel traffic required for the Amulet 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 Amulet Development, which will peak during drilling, commissioning and decommissioning phases at up to ten support vessels. Throughout the operations phase (~1.5–4.5 years), only one to two support vessels are expected, unless non-routine well intervention is required on Talisman, and the subsea tieback option has been selected. In this case, an ISV or a MODU towed by 2-3 AHTs may be required for ~1 month (Section 3.4.6.4). 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 Amulet Development will be located within the Project Area (5 km radius), except when in transit, when they are outside the scope of this OPP. Discharges from vessels will quickly dissipate in the high-energy marine environment of the North West Shelf, 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 Amulet 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 Amulet Development—navigational and safe working light from vessels and facilities, and flaring during drilling and operations. Facility lighting from the MOPU/MODU will produce the largest 'light field'.

Amulet 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.

The maximum distances of the Potential Impact Area for light emissions from the Amulet Development are:

- Flaring: ~8.3 km during peak (1.2 MMscf/d) operational flaring (first 6–9 months)
- Facility lighting: ~12.6 km over the life of the project.

Therefore, over the life of the project the maximum distance of the potential impact area for artificial light emissions from the Amulet Development is from facility lighting at ~12.6 km.

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 ~40 km and ~57 km from the expected MOPU location:

- 40 km – Woodside's Angel Platform
- 57 km – Woodside's Okha FPSO.

Other Marine and Industrial Activities

No fixed shipping or commercial fisheries facilities occur in the offshore area within the vicinity of the Amulet Development. However, the Amulet Development is located between two shipping fairways for Dampier Port (~9 km west and ~23 km east of the expected position of the MOPU). Assuming that vessels require some levels of navigational light, any vessels passing within the vicinity of the Amulet Development will result in cumulative impacts. However, these impacts will be temporary, ceasing once the vessel has moved away from the Amulet 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 Amulet Development are Dampier (~132 km) and Karratha (~138 km). Some small amount of sky glow is expected from these towns, however given their distance from the Amulet Development negligible

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 (refer to Table 7-13 for definitions).

No assessment of light intensity from the Woodside Angel Platform or Okha FPSO was publicly available. However, based on reported heights of the facilities (Woodside 2008), a line of sight assessment was undertaken using the methodology in Xodus Group (2020a; Appendix B). This calculation estimated that the Visible Light Exposure Area for the Angel Platform is ~50.4 km, and for the Okha FPSO is ~32.3 km.

Figure 8-1 shows a comparison of the Visible Light Exposure Area for the Amulet Development and these adjacent facilities. As can be seen, there is some overlap between the Visible Light Exposure Areas for the Angel platform and the Okha FPSO facilities and the Amulet Development. No offshore islands or other important habitat occurs within this overlap area.

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 Amulet Development is 12.6 km for the project life. This same area has been used for the Angel platform and Okha FPSO, using the same assumptions. The Potential Impact Area for Amulet does not intersect with that of any of the adjacent facilities (Figure 8-1).

Therefore, while there is expected to be some overlap of visual light (i.e. there will be areas of water where both the Amulet 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 Amulet Development or adjacent facilities.

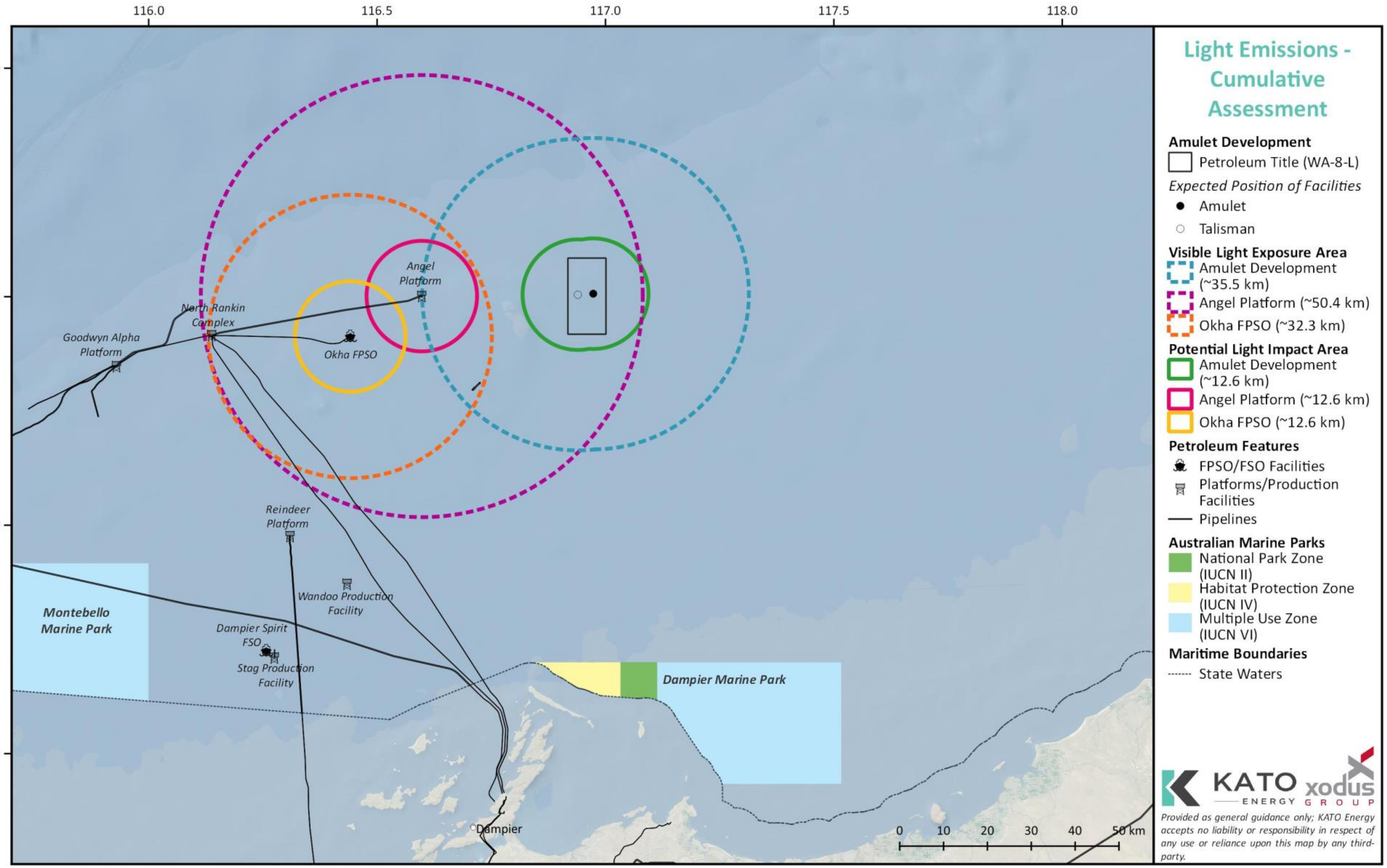


Figure 8-1 Visible Light Exposure Areas and Potential Impact Areas for the Amulet Development and Adjacent Oil and Gas Facilities

8.2.4.4 Emissions – Atmospheric

Atmospheric emissions can be classified into two categories:

- atmospheric pollutants (non-GHG emissions)
- 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 Woodside's Angel platform FPSO (~40 km away) and Okha FPSO (~58 km away). This is outside the spatial boundary, therefore no cumulative 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 500 m exclusion zone and 2 km cautionary zone, and any impacts will be localised and temporary due to the transitory nature of vessel movements. Therefore, no cumulative impacts from atmospheric pollutants from other vessels are expected.

Direct (Scope 1) GHG emissions (i.e. those generated directly as a result of Amulet Development activities) have been calculated as a total of 0.4 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 32% of GHG emissions during the operations phase. The maximum annual direct GHG emissions from the Amulet Development comprises 0.02% of Australia's annual GHG inventory (DoEE 2019), which is a very small contribution. The GHG emissions from Angel platform and Okha FPSO are not publicly available for each individual facility. These facilities provide hydrocarbons to the North West Shelf Joint Venture (NWSJV) Karratha Gas Plant in the Burrup Peninsula. Annual direct (Scope 1 and 2) emissions for the NWSJV are 7.7 MT CO_2-e (Woodside 2019a).

This will be expanded with Woodside's proposed Burrup Hub regional LNG concept, incorporating new fields (Scarborough, Browse, and other future fields) tying into the expanded Karratha Gas Plant and Pluto LNG. The project life of the Burrup Hub is expected to be ~50 years. In comparison, the Amulet Development is ~5 years.

As climate change is the result of net global GHG emissions, it is difficult to assign a spatial boundary for cumulative assessment, and assessing cumulative impacts only for existing industries in close proximity is not necessarily appropriate. Therefore, the cumulative impacts of Emissions – Atmospheric have been assessed on a broader scale.

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 Amulet Development?
- Could receptors be impacted by the same or multiple aspects as a result of the Amulet 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 Amulet Development. Assessment of the potential for cumulative impacts is provided in Table 8-2.

Where cumulative impacts are possible, either from the Amulet 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 and Operational 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 Amulet Development	Potential cumulative impacts from existing industries
Water quality		✓				✓	✓	✓	✓	✓	✓	✓	✓	X
Sediment quality						✓	✓	✓	✓	✓			✓	X
Air quality				✓									X	X
Climate				✓									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 Amulet 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 Amulet 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 Amulet 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 Amulet 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 Amulet 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 Climate

GHG emissions generated during the Amulet Development will contribute to the overall concentration of GHGs in the Earth's atmosphere. Anthropogenic climate change impacts cannot be directly attributed to any one development, as they are the result of net global GHG emissions, minus GHG sinks, that have accumulated in the atmosphere since the industrial revolution. Therefore, it is not possible to directly GHG emissions from the Amulet Development with climate change impacts to specific ecological receptors.

The calculated direct (Scope 1) emissions from the Amulet Development is 0.4 MT CO_2-e for the total field life of all phases of the project. The maximum annual direct (Scope 1) emissions from the Amulet Development represents 0.02% of Australia's annual GHG emissions (DoEE 2019c). This maximum occurs during the first year of production - after which emissions decline.

The maximum annual direct (Scope 1) emissions from the Amulet Development comprise 0.0001% of global annual CO_2-e emissions (UN Environment 2018), as reported for the year 2017. This is a very small contribution, due to the small absolute volumes of GHG emissions.

KATO undertook a benchmarking exercise of GHG intensity and annual GHG emissions of upstream oil and gas production for operators who are active within Australia. Source: Beach Energy Ltd 2019; Chevron 2018; ConocoPhillips 2018; Cooper Energy 2019a; Cooper Energy 2019b; Equinor 2019; ExxonMobil 2019; Murphy Oil 2017; Origin 2019; Santos 2019; Shell 2019; Total 2019; Woodside 2019.

Figure 7-12 shows that Amulet has a below-average GHG intensity (0.02 t CO_2-e) compared to other upstream oil and gas production for operators who are active within Australia – primarily due to the short-term nature of the project and the small total volume of associated gas, and therefore low GHG intensity.

Indirect (Scope 3) emissions for the Amulet Development occur outside Australia's jurisdiction – from the third-party use of oil once it has been sold, most likely in the Asia Pacific region. Amulet's total recoverable oil is equivalent to 0.03% – 0.04% of annual global oil production. The contribution of the Amulet Development to oil refinery products and the global oil market is a small proportion of supply. Oil plays a major role in the energy mix for a sustainable energy future has a place in energy transition, and provides the main source of energy for the transport sector for the foreseeable future (IEA 2019; BP 2019). The Asia Pacific Region (including Australia) is oil deficient in terms of supply and imports and it is predicted for this trend to continue. The Amulet Development will help address this local shortfall, and will reduce the need for long-distance transport to import oil from the rest of the world is reduced (i.e. results in a net reduction in Scope 3 emissions).

Total GHG emissions (Scope 1 and Scope 3) for the Amulet Development are 6.1 MT CO_2-e, of which 93% are indirect (Scope 3). For the whole project life, this is equivalent to 0.011% of global annual CO_2-e emissions (for the year 2017; UN Environment 2018). This is a very small contribution to a complex, global phenomena. The time frame of emissions is also relatively short, at ~5 years for whole project life.

Therefore, any changes to climate as a result of the GHG emissions from the whole project life of the Amulet Development are not considered to be substantial on a national or international scale.

The same difficulties (i.e. linking emissions directly to climate-related impacts on ecological receptors, as well as the lack of publicly available data for other developments, and determining the appropriate scale for assessment) apply to assessing cumulative impacts from other industries and developments.

It is not appropriate to attribute climate change or any particular climate-related impacts to GHG emissions from the Amulet Development, or any other individual development, due to:

- net global GHG concentrations cause climate change and climate-related impacts
- Scope 1 and Scope 3 emissions calculated for the Amulet Development are considered negligible in the context of existing and future predicted global GHG concentrations; due to the relatively small absolute volumes of GHG emissions, the small proportion of Australia's total emissions, and short duration of the development (~5 years).
- inability to precisely predict the amount of total future global GHG emissions
- inability to predict future national and international initiatives on climate change and the impact they will have on total future global GHG emissions, including Amulet emissions.

Due to the very small contribution of Amulet Development GHG emissions to national and international annual GHG emissions and the short duration of emissions (~ 5 years); and the difficulties with attributing climate change to individual developments, cumulative impacts have not been evaluated further.

8.3.1.4 Ambient Light

Impacts to ambient light are likely from all phases of the Amulet Development. Impacts to ambient light are likely to result from a combination of light generated by the Amulet Development and light generated by other marine activities, including commercial fisheries and industry (e.g. shipping).

As described in Section 8.2.4.3, the visible light overlap area for the Amulet Development and the Angel platform and the Okha FPSO does intersect. No offshore islands or other important habitat occurs within this overlap area.

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 Amulet Development is 12.6 km.

There was no published light intensity data available for the adjacent facilities and so a direct comparison of Potential Light Impact Areas is not possible. However, if we assume that the Angel Platform and Okha FSPO have similarly lit structures to the Amulet (and the Torosa drill rig the modelling was initially completed for), none of these areas would overlap, as all the facilities are >25.2 km (i.e. 2 x 12.6 km) apart.

Therefore, while there is expected to be some overlap of visual light (i.e. there will be areas of water where both the Amulet 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 Amulet Development or adjacent facilities. That is, there is no cumulative impact in measurable changes in ambient light from adjacent oil and gas developments predicted to occur.

8.3.1.4.1 Cumulative Impact Evaluation

Light emissions from the Amulet 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

There is overlap between the Visible Light Exposure Area from the Amulet Development and neighbouring facilities (Figure 8-1). However, the visibility of an artificial light does not necessarily imply a measurable change in ambient light (and therefore a potential impact).

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.

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 Amulet Development is 12.6 km.

There was no published light intensity data available for the adjacent facilities and so a direct comparison of Potential Light Impact Areas is not possible. However, if we assume that the Angel Platform and Okha FSPO have similarly lit structures to the Amulet (and the Tarosa drill rig the modelling was initially completed for), none of these areas would overlap, as all the facilities are >25.2 km (i.e. 2 x 12.6 km) apart.

Therefore, while there is expected to be some overlap of visual light (i.e. there will be areas of water where both the Amulet 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 Amulet Development or adjacent facilities.

While it is visible close to the source, in the offshore ocean environmental this does not reflect a significant change. A significant change in ambient light caused by cumulative effects is considered to be **Unlikely (C)** with the consequence of any impacts 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 Amulet Development. Assessment of the potential for cumulative impacts is provided in Table 8-4.

Where cumulative impacts are possible, either from the Amulet 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 - Atmospheric	Emissions – Underwater Noise	Planned Discharge – Drilling cuttings and Fluids	Planned Discharge – Cement	Planned Discharge – Produced Formation Water	Planned Discharge – Commissioning and Operational 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 Amulet Development	Potential cumulative impacts from existing industries
Plankton								✓		✓			✓	X
Benthic habitat and communities		✓				✓	✓						✓	X

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 – Produced Formation Water	Planned Discharge – Commissioning and Operational 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 Amulet Development	Potential cumulative impacts from existing industries
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	✓
<u>Injury/mortality to fauna</u> 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 Amulet Development, from seabed disturbance and planned discharges of drilling discharges (drilling fluids and cuttings, cement), and CW and brine.

All phases of the Amulet 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 Amulet 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 (5km), 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 Amulet 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 12.6 km from the Amulet Development. This Potential Impact Area does not intersect any island or mainland locations. The Potential Impact Area for light associated with the Amulet Development does intersect with a breeding BIA for the Wedge-tailed Shearwater.

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 was no published light intensity data available for the adjacent facilities and so a direct comparison of Potential Light Impact Areas is not possible. However, if we assume that the Angel Platform and Okha FSPO have similarly lit structures to the Amulet (and the Tarosa drill rig the modelling was initially completed for), none of these areas would overlap, as all the facilities are >25.2 km (i.e. 2 x 12.6 km) apart.

Therefore, while there is expected to be some overlap of visual light (i.e. there will be areas of water where both the Amulet 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 Amulet Development or adjacent facilities.

The National Light Pollution Guidelines (CoA 2020) 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 2020). As context for this cumulative assessment, the closest neighbouring facility to the Amulet Development is 40 km away (Angel platform), which is greater than the 20 km buffer.

There is no interaction in spatial boundary of impacts with the Amulet 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 Amulet Development, including light emissions, underwater noise 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 Amulet Development whilst noise emissions may result in a change in behaviour, depending on the phase of the project, therefore cumulative impacts are possible.

The Amulet Project Area is situated within a foraging BIA for the Whale Shark, although the preferred foraging areas around Ningaloo Reef, and deeper oceanic waters centred on the 200 m isobath, which is ~39 km to the north of the Project Area.

8.3.2.4.1 Cumulative Impact Assessment

Seabed disturbance, light and noise emissions resulting from the Amulet 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 ✓
<u>Injury / mortality to fauna</u> Seabed disturbance is predicted to result in injury / mortality to fauna, with any impacts localised to the immediate vicinity of the Amulet Development during installation and decommissioning activities. Light and

Fish ✓
noise emissions were not considered to cause injury / mortality to fish. As such, no injury / mortality cumulative impacts to fish are expected. Change in fauna behaviour Light and noise emissions may result in a change in fish behaviour. Light emissions may attract individuals towards the light source, however this expected to be very localised to the source itself. Impulsive noise emissions were determined as a low risk of resulting in behavioural impacts to finfish (Webster et al. 2018). However, continuous noise sources have been identified as a moderate risk of causing behavioural changes, a high risk of causing masking changes, within the near and intermediate vicinity of a sound source for all fish groups. Light emissions and underwater noise emissions will occur through all phases of the Amulet 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 is expected to be **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 Amulet Development, including both impulsive and continuous sources. Noise emissions are not at a level that is predicted to result in injury / mortality impacts (Table 7-36). Impulsive noises (e.g. VSP or SSS) may results in behavioural changes in marine reptiles; spherical modelling shows that these sound levels would be below the behavioural threshold for marine turtles within ~500 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 Amulet Development (the area corresponding to a measurable change in ambient light) is 12.6 km for 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 potential impact areas from noise emissions and light emissions on turtles, during some phases of the project. Individuals within 500 m of the facility during the survey and drilling phases may exhibit a change in fauna behaviour due to noise and/or light emissions. Outside this spatial boundary, and within other project phases, noise emissions will not be elevated above the behavioural threshold, and cumulative impacts will not occur.The Amulet Development is not within any BIAs for marine turtle species. Light is identified as a threat for marine turtles with specific reference to nesting adults and sea-finding behaviours of hatchlings. Given the location of the Amulet Development, and distance to any identified BIAs or island/mainland nesting areas, the potential for a change in fauna behaviour within 500 m of the facility is considered minimal. Once operations at Amulet 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 **Minor (1)** consequence due to the localised impact on threatened species.

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 Amulet Development. Assessment of the potential for cumulative impacts is provided in Table 8-4.

Where cumulative impacts are possible, either from the Amulet 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 – Atmospheric	Emissions – Underwater Noise	Planned Discharge – Drilling cuttings and Fluids	Planned Discharge – Cement	Planned Discharge – Produced Formation Water	Planned Discharge – Commissioning and Operational 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 Amulet 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 Amulet Development are assessed in Section 7. Commonwealth- and State-managed fisheries, and Industry, may be impacted by the Physical Presence of the Amulet Development (Section 7.1.1), specifically during installation when vessel activity will increase; however, these impacts have been assessed as **Minor (1)** 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 Amulet Development (Section 6.6).

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, fish and marine reptiles will be **Minor (1)** (limited/minor impact; localised and temporary on non-threatened species or their habitat).

The whole project life of the Amulet Development is relatively short, at only five years, with a conservative temporal boundary set at six years.

Analysis of light intensity showed that beyond 12.6 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 12.6 km has been used for purposes of cumulative impact assessment for the Amulet 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** for plankton, fish and 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 6.6 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 Amulet 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
		Marine reptiles	Change in fauna behaviour	Minor

9 Implementation Strategy

The Amulet 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 Amulet 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 OPPGS(E)R.

9.1 KATO Ownership Structure

WA-8-L is operated by KATO, an Australian company that was formed to combine ownership of the Amulet 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 Amulet.

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.

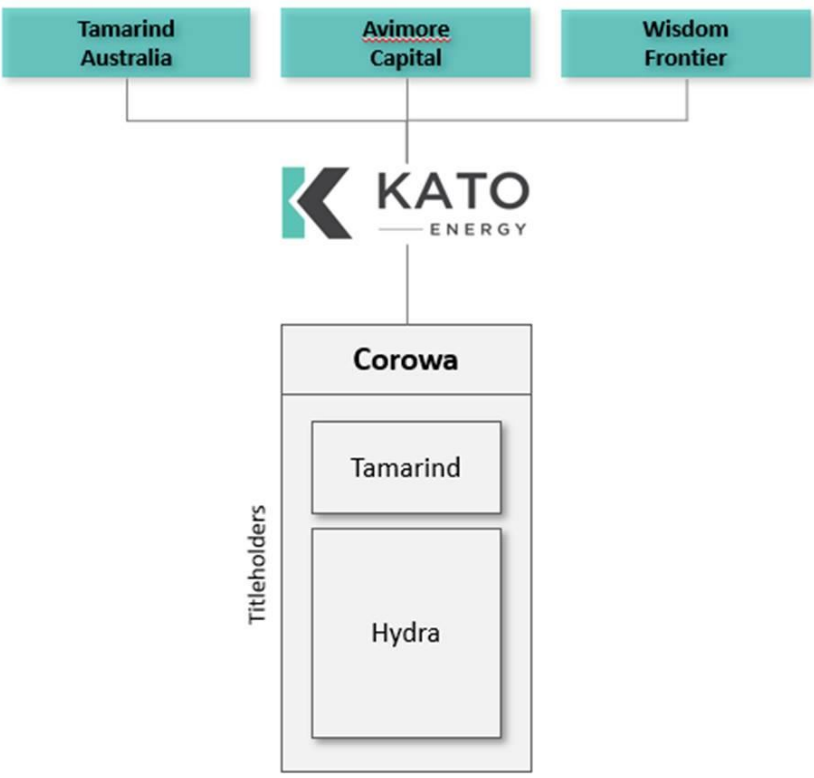


Figure 9-1 KATO Ownership Structure

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 (KAT-000-GN-PP-001) (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 (KAT-000-GN-PP-001) (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.

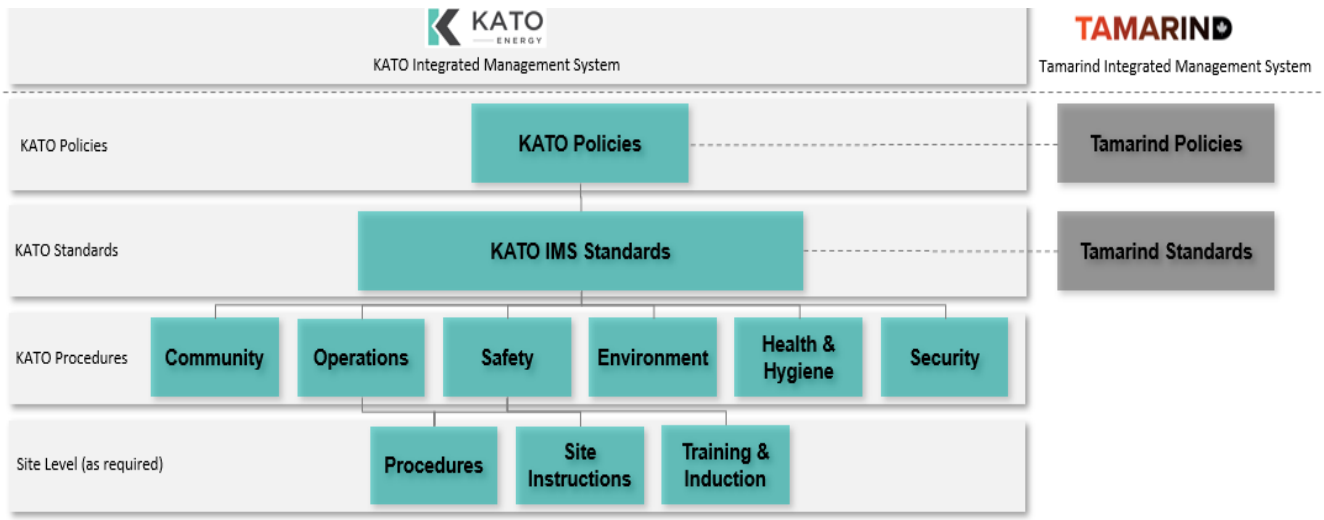


Figure 9-2 KATO Management System Overview

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.

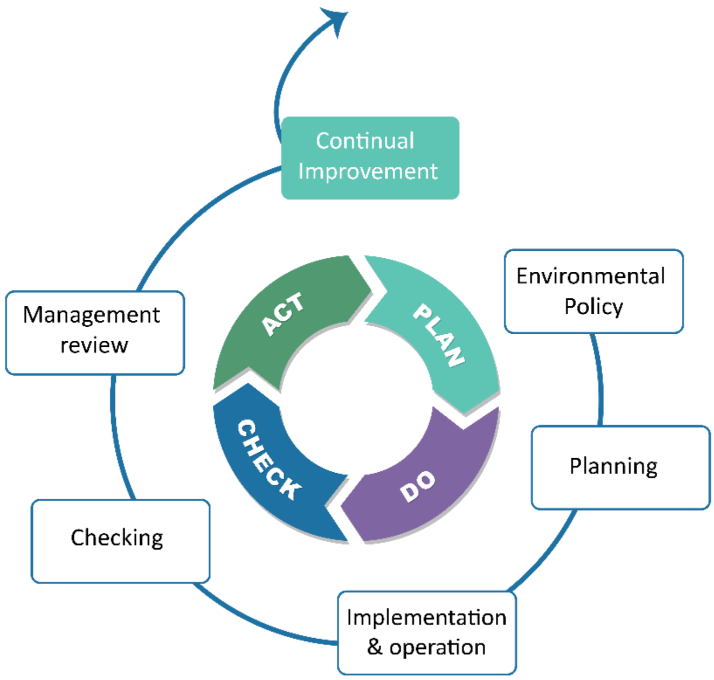


Figure 9-3 AS/NZS ISO 14001 Environmental Management Systems Model

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

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

KATO Director

Date

KATO HSE Policy KAT-000-HS-PP-001

Revision 0 2019

Figure 9-4 KATO HSE Policy

9.3 Training and Awareness

KATO's IMS requires that all employees, contractors and visitors working on or in connection the Amulet 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 Amulet 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 Amulet 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 (KAT-000-HS-PP-002) (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 Amulet Development are required to detail an Oil Pollution Emergency Plan (OPEP) as per Section 14(8) of the OPPGS(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 Amulet Development.

9.5 Management of Change

KATO's 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.

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 OPPGS (Environment) Regulations the Plan can be revised and changes recorded within it without resubmission to the Regulator.

9.6 Incident Investigation

KATO's Incident Management Procedure (KAT-000-GN-PP-003) (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 (KAT-000-GN-PP-001) 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 Amulet 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 OPPGS(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 OPPGES Environment Regulations require the reporting of incidents for future EPs. KATO's Incident Management Procedure (KAT-000-GN-PP-003) (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 OPPGS(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 Draft 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 6.6, 10 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 Amulet Development.

Table 9-3 Summary of Environmental Impacts and Risks Associated with the Amulet Project – Planned

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; Talisman subsea tieback; flowlines; CALM buoy and mooring arrangements; 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	**EPO1:** Undertake the Amulet Development in a manner that prevents a substantial adverse effect on the sustainability of commercial fishing. **EPO2:** Undertake the Amulet Development in a manner that does 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 500 m exclusion and 2 km cautionary zones. **CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction.	Minor
		Industry				Minor
Physical Presence – Seabed Disturbance	*Survey* geotechnical survey *Drilling* MODU positioning; top-hole drilling *Installation, Hook-up and commissioning* MOPU; Talisman subsea tieback;	**Ambient water quality**	Change in water quality	**EPO3:** Undertake the Amulet Development in a manner that does not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO4:** Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on	**CM05**: Mooring analysis will be undertaken, which will include an environmental sensitivity and seabed topography analysis. **CM06**: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below seabed and removed. **CM07**: If any objects are to be left in situ on the seabed, KATO will consult with DAWE to	Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
	flowlines; CALM buoy and mooring arrangements *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	marine ecosystem functioning or integrity results. **EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO8**: Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **EPO10**: Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species. **EPO11**: Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and communities, including life cycle and spatial distribution.	confirm any requirements, and apply for, a Sea Dumping Permit, if required. **CM08**: Locate Talisman subsea tieback infrastructure to avoid any abandoned production equipment discovered during the site survey.	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	**EPO4:** Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. **EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt the	**CM09**: Lighting will be sufficient for navigational, safety and emergency requirements (e.g. requirements contained in AMSA Marine Order Part 30 and Facility Safety Cases). **CM010:** An Artificial Light Management Plan will be developed in alignment with the	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	lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **EPO6:** Undertake the Amulet Development in a manner that will not result in the displacement of marine turtles from important foraging habitat or from habitat critical during nesting and internesting periods. **EPO7:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population. **EPO8:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **EPO9:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO10:** Undertake the Amulet Development in a manner that will not substantially modify, destroy or isolate an area of important habitat for a migratory species.	National Light Pollution Guidelines (CoA 2020).	Minor
		Fish				Minor
		Marine reptiles				Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
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	**EPO12:** Undertake the Amulet Development in a manner that will not result in a substantial change in air quality, which may adversely impact on biodiversity, ecological integrity, social amenity, or human health. **EPO13** Undertake the Amulet Development in a manner that will not significantly contribute to Australia's annual greenhouse gas emissions. **EPO14**: KATO will not export oil produced from the Amulet Development to countries that are not signatories to the Paris Agreement.	**CM11**: Compliance with AMSA Marine Order 97 (Marine pollution prevention — air pollution). **CM12**: 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*. **CM13**: Maximise the use of associated gas, for example, as fuel gas during operations.	Minor
		Climate	Climate change		**CM14**: Comply with the requirements of the Safeguard Mechanism, including purchase of Australian Carbon Units (ACCUs) if designated emissions baseline is exceeded, as determined by the Clean Energy Regulator. **CM15**: Operations designed to be optimised to enable the safe and economically efficient operation of the facility. **CM16:** Develop KATO Greenhouse Gas Management Plan and identify emissions mitigation hierarchy to reduce direct GHG emissions to ALARP during EP development, including consideration of: • Avoid – as per alternatives assessment (Section 4.3.1) • Reduce – identify opportunities for reduction of emissions during FEED (i.e. heat and power generation, energy efficiencies); and monitor new technologies for use of excess associated gas and evaluate	Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
					feasibility for use on the Amulet Development • Offsets – in alignment with Safeguard Mechanism • Monitor – Monitor Australia's and export countries' commitments under the Paris Agreement regarding NDCs, export of oil and Scope 3 emissions. • Mechanisms to ensure adaptive management of these measures for the duration of the Amulet Development via the EP mechanism. **CM17**: Reporting of GHG emissions as per the National Greenhouse and Energy Reporting (NGER) Scheme.	
Emissions – Underwater Noise	*Survey* geophysical survey (sonar) *Drilling* top-hole drilling; bottom-hole drilling; completions *Operations* well intervention *Decommissioning*	**Ambient noise**	Change in ambient noise	**EPO4:** Undertake the Amulet Development in a manner that will not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.	**CM04:** KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction.	Minor
		Fish	Change in fauna behaviour	**EPO5:** Undertake the Amulet Development in a manner that will not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	**CM18**: Vessels will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the project area. **CM19**: Vertical seismic profiling (VSP) operations will adhere to the EPBC Act Policy	Moderate

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
	Well P&A *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations; helicopter operations	**Marine mammals**	Injury / mortality to fauna	**EPO6:** Undertake the Amulet Development in a manner that will not result in the displacement of marine turtles from important foraging habitat or from habitat critical during nesting and internesting periods. **EPO8:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **EPO9:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO15:** Undertake the Amulet Development in a manner that will not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **EPO16:** Noise emissions are managed such that any Blue Whale continues to utilise the area without injury and is not displaced from a foraging BIA.	Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines. **CM20**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements.	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	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO4:** Undertake the Amulet Development in a manner that will not result in a change that may modify, destroy, fragment, isolate	**CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM22**: Solids removal and treatment equipment will be used to reduce and minimise the amount of residual fluid	Minor
		Ambient sediment quality	Change in sediment quality			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	**Benthic habitats and communities**	Change in habitat	or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. **EPO11:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and communities, including life cycle and spatial distribution. **EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	contained in drilled cuttings prior to discharge to the marine environment. **CM23**: Drilling and cementing procedures to standard industry practices will be developed that will describe specific well locations, design and fluid volumes. **CM24:** Whole SBM will not be discharged into the marine environment. **CM25:** Drilling of the conductor section will use seawater and/or WBM only.	Minor
			Injury / mortality to fauna			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	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO4:** Undertake the Amulet Development in a manner that will 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 results. **EPO11:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of benthic habitats and communities, including life cycle and spatial distribution. **EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may	**CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM23**: 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			Minor
			Injury / mortality to fauna			Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
				adversely impact on biodiversity, ecological integrity, social amenity or human health.		
Planned Discharge – Commissioning and Operational Fluids	*Installation, Hook-up and commissioning* Talisman subsea tieback; flowlines; FSO; MOPU *Operations* Hydrocarbon extraction *Decommissioning* disconnection of FSO and MOPU	**Ambient water quality**	Change in water quality	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM21**: 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	**EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Minor
Planned Discharge – Produced Formation Water	*Operations* hydrocarbon processing, storage and offloading	**Ambient water quality**	Change in water quality	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM26**: A management framework for produced formation water discharges will be developed.	Minor
		Ambient sediment quality	Change in sediment quality	**EPO17:** Undertake the Amulet Development in a manner that will not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Minor
		Plankton	Injury / mortality to fauna	**EPO18:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of plankton, including its life cycle and spatial distribution.		Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
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	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO18:** Undertake the Amulet Development in a manner that will not result in a change that may have an adverse effect on a population of plankton, including its life cycle and spatial distribution.	**CM20**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM21**: 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			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	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality, which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM20**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM27:** Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM28**: 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.	Minor

Aspect	*Phase* and Activity (source of aspect)	Receptor	Impact	EPO	Adopted Control Measures	Consequence
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	**EPO3:** Undertake the Amulet Development in a manner that will not result in a substantial change in water quality, which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM20**: Equipment will be maintained in accordance with the manufacturers' specifications, facility planned maintenance system and regulatory requirements. **CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM27**: Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM29:** Compliance with Marine Order 96 (Marine pollution prevention – Sewage) 2013. **CM30:** Compliance with Marine Order 95 (Marine pollution prevention – Garbage) 2013.	Minor

Table 9-4 Summary of Environmental Impacts and Risks Associated with the Amulet Project – Unplanned

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; Talisman subsea tieback; flowlines; CALM buoy and mooring arrangements; FSO *Decommissioning* inspection and cleaning *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations; vessel operations	**Benthic habitats and communities**	Change in ecosystem dynamics	**EPO19:** Undertake the Amulet Development in a manner that will prevent an IMS becoming established in the marine environment.	**CM31**: Requirements of the Australian Ballast Water Management Requirements Version 7 (DAWR 2017) to be met. **CM32**: Requirements of the National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry (DAFF 2009) to be met. **CM33**: 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. **CM34**: A Biofouling Management Plan will be developed as per the Anti-fouling and in-water Cleaning Guidelines (DoA 2015).	Serious	Unlikely	Medium
Unplanned Introduction of IMS		**Commercial Fisheries**	Changes to the functions, interests or activities of other users	**EPO19**	CM31–CM34	Moderate	Very unlikely	Low
Unplanned Introduction of IMS		**Industry**	Changes to the functions, interests or activities of other users	**EPO19**	CM31–CM34	Moderate	Very unlikely	Low
Physical Presence – Interaction with Marine Fauna	*Survey* geophysical survey; geotechnical survey *Support Activities (all phases)* MODU operations; MOPU operations;	**Fish**	Injury / mortality to fauna	**EPO20:** Undertake the Amulet Development in a manner that will prevent a vessel strike with protected marine fauna during project activities.	**CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction.	Minor	Unlikely	Low
Physical Presence – Interaction with Marine Fauna		**Marine mammals**	Injury / mortality to fauna	**EPO20**	CM04	Minor	Unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
	FSO operations; vessel operations; helicopter operations	**Marine Reptiles**			**CM18**: Vessels and aircraft will adhere to the EPBC Regulations 2000 – Part 8 Division 8.1 (Regulation 8.04) – Interacting with cetaceans within the Project Area. **CM35:** All marine mammal vessel strike incidents will be reported in the National Vessel Strike Database.	Minor	Unlikely	Low
Physical Presence – Unplanned Seabed Disturbance	*Installation, Hook-up and commissioning* MOPU; Talisman subsea tieback; flowlines; CALM buoy and mooring arrangements *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	**EPO21:** Undertake the Amulet Development in a manner that will prevent unplanned seabed disturbance.	**CM04:** KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM05**: Mooring analysis will be undertaken, which will include an environmental sensitivity and seabed topography analysis. **CM06**: The wells will be plugged and abandoned during decommissioning activities, with wellheads cut below the mudline and removed. **CM33**: 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	Minor	Unlikely	Low
		Benthic habitats and communities	Change in habitat Injury / mortality to fauna			Minor	Unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
					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	**EPO22:** Undertake the Amulet Development in a manner that will prevent an unplanned discharge of solid waste to the marine environment.	**CM27**: Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated. **CM30**: Compliance with Marine Order 95 (Marine Pollution Prevention – Garbage).	Minor	Very Unlikely	Low
		Seabirds and Shorebirds	Injury / mortality to fauna			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	**EPO23:** Undertake the Amulet Development in a manner that will prevent an unplanned discharge of chemicals or hydrocarbons to the marine environment.	**CM04:** KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM21**: Chemicals will be selected and applied with the lowest practicable environmental impacts, concentrations and risks to provide technical effectiveness. **CM27**: Implement waste management procedures including safe handling, treatment, transportation, and appropriate segregation and storage of all waste generated.	Minor	Very unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
					CM28: 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. **CM36**: 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). **CM37**: Emergency response capability (including equipment) will be maintained in accordance with SOPEPS/SMPEPs; and accepted EPs and OPEPs			
Accidental Release – Amulet 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	**Ambient water quality**	Change in water quality	**EPO24:** Undertake the Amulet Development in a manner that will prevent an accidental release of Amulet light crude oil to the marine environment due to a LOWC, or failure of a flowline or bulk tank.	**CM03**: Pre-start notifications will be provided to relevant stakeholders at appropriate timing. **CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM28**: Compliance with AMSA Marine Order Part 91 (Marine	Minor	Unlikely	Low
		Ambient sediment quality	Change in sediment quality			Minor	Unlikely	Low
		Plankton	Injury / mortality to fauna			Minor	Very unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
	repair; well intervention *Decommissioning* well P&A; removal of subsea infrastructure *Support Activities (all phases)* MODU operations; MOPU operations; FSO operations	**Benthic habitat and communities**	Change in habitat Injury / mortality to fauna Change in fauna behaviour		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. **CM36**: 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). **CM37:** Emergency response capability will be maintained in accordance with accepted EPs and OPEPs. **CM38:** NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place. **CM39:** NOPSEMA-accepted Well Operations Management Plan in place for all wells, in accordance with the OPGGS Act requirements. **CM40**: NOPSEMA-accepted Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken. **CM41**: If an infill drilling campaign is required, a simultaneous production and drilling (SIMOPS)	Moderate	Very unlikely	Low
		Coastal habitats and communities	Change in habitat Injury / mortality to fauna Change in fauna behaviour Change in aesthetic value			Moderate	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
		Australia Marine Parks	Change in water quality Change in sediment quality Change in habitat Injury / mortality to fauna			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 fauna behaviour Changes to the functions, interests or activities of other users Change in aesthetic value		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.	Moderate	Very unlikely	Low
		Heritage and cultural 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 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			Minor	Very unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
			Change in aesthetic value					
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	**EPO25:** Undertake the Amulet Development in a manner that will prevent an accidental release of MDO/MGO to the marine environment due to vessel collision or failure of a bulk tank.	**CM03**: Pre-start notifications will be provided to relevant stakeholders at appropriate timing. **CM04**: KATO Marine Operations Procedure (KATO 2020b) includes requirements for vessel entry to the immediate Project Area, notifications, separation distance, vessel speed, bunkering and transfer controls and marine fauna interaction. **CM28**: 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. **CM36**: 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). **CM37:** Emergency response capability will be maintained in accordance with accepted EPs and OPEPs.	Minor	Very unlikely	Low
		Plankton	Injury / mortality to fauna			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
		Australian Marine Parks	Change in water quality Change in habitat Injury / mortality to fauna Change in fauna behaviour			Moderate	Very unlikely	Low

Aspect	*Phase* and activity (source of aspect)	Receptor	Impact	EPOs	Adopted Control Measures	C	L	RL
			Changes to the functions, interests or activities of other users		**CM38:** NOPSEMA-accepted Environment Plans and Oil Pollution Emergency Plans will be in place. . **CM40**: NOPSEMA-accepted Safety cases for the MOPU and MODU will include procedures detailing how activities with support vessels will be undertaken.			
		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

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 (KAT-000-GN-RE-001) (KATO 2020f).

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

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 10-3 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 10-1 gives a summary of the key stakeholders, arranged by group.

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 10-3 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 10-1 Stakeholders Relevant to the Amulet Development

Stakeholder Group	Stakeholder	Pre-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, Water and the Environment (DAWE)	✓		✓

Stakeholder Group	Stakeholder	Pre-submission	Pre-public Comment	Pre-EP submission
	(formerly Department of Agriculture; and Department of Environment and Energy)			
	Director of National Parks (DAWE)	✓		✓
	Department of Industry, Innovation and Science (DoIIS)			✓
	Geoscience Australia	✓		✓
	NOPSEMA	✓		✓
	NOPTA	✓		✓
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)	✓		✓

Stakeholder Group	Stakeholder	Pre-submission	Pre-public Comment	Pre-EP submission
	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 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 – Amulet 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.

The honeybee system is relocatable, and KATO plan to have multiple titles/locations. As of mid-2019, two permit areas had been identified – the Amulet Development, and the Corowa Development (which is subject to a separate OPP, first submitted to NOPSEMA in August 2019; KATO 2020j). Therefore, KATO conducted combined stakeholder consultation on the two developments.

The Corowa Development OPP (KATO 2020j) was published by NOPSEMA for an 8-week public comment period, beginning on 27 February 2020. KATO will pre-emptively consider any responses received on the Corowa Development OPP for relevance to the Amulet Development OPP.

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.
Clean Energy Regulator (DoEE)	7 Aug 2019	Discussion on KATO's proposed gas strategy for the honeybee production system, and estimated greenhouse gas emissions (specifically for the Corowa Development. Feedback was: • ensuring KATO understood whether Corowa and KATO as a whole triggered the values for reporting under the NGERs act and whether KATO was considered a controlling corporation for reporting purposes. • suggested future engagement to clarify further how the facility baseline would be set.

Stakeholder	Date	Summary of Response
	22-25 May 2020	Emails exchanged with the CER – NGER and Safeguard Branch; and CER – Safeguard Baselines team, requesting clarification on how baseline will be calculated and Scope 3 emissions. Feedback was: • A calculated baseline may be applied for, to start on 1 July 2020. For a production variable, a site-specific emissions intensity can be used, or the default selected. • A calculated baseline is the sum of each of the forecast site-specific emissions intensity (or the default for a prescribed production variable) multiplied by the forecast quantity of that production variable. Each figure is using the baseline setting year for that baseline application, which will be the year of highest production of the primary production variable, depending on the date that the calculated baseline application is submitted. • Refer to the 'Using ACCUs to offset emissions' section of the Clean Energy Regulator's Managing excess emissions webpage. This includes a link to further guidance to purchase ACCUs from other businesses. Purchasing greenhouse gas offsets has no bearing on the figures that are reported under the NGER scheme. Some eligible carbon units can be used to acquit excess emissions under safeguard. However, this only becomes relevant if the safeguard baseline is exceeded. There are currently no obligations under the NGER scheme (or any scheme administered by the Clean Energy Regulator) to report and manage scope 3 emissions. There is no requirement to report scope 3 emissions now or in the future.
DoA – Marine & Aquatic Biosecurity Branch	1 July 2019	DoA requested clarification that introduction of NIS is also relevant for installations, not only support vessels.
DAWE (formerly DoA) – Conveyances and Ports	1 July 2019	Provided the Department of Agriculture's Offshore Installation – biosecurity guide for initial reference.
	31 Mar 2020	DAWE (formerly DoA) responded to the Corowa Development OPP public comment phase with the following comments relevant to the Amulet Development: • Provision of DAWE Questionnaire for Biosecurity Exemptions for Biosecurity Control Determination, to be submitted to DAWE at least one month prior to project commencement • Reminder to review DAWE's Offshore Installations webpage and associated biosecurity guide; and contact seaports@agriculture.gov.au for an assessment • Reminder to review Australian ballast water and biofouling requirements and pre-arrival reporting using MARS; and biosecurity reporting requirements for aircraft.
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).

Stakeholder	Date	Summary of Response
		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.
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; DAWE)	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/s. Directed KATO to DoT's Petroleum Industry Guidance Note.
	7 Apr 2020	DoT responded to the Corowa Development OPP public comment phase with the following comments relevant to the Amulet Development: • reminder that for future Oil Pollution Emergency Plans, DoT should be consulted as per the Department of Transport Offshore Petroleum Industry Guidance Note – Marine Oil Pollution: Response and Consultation Arrangements (September 2018) if there is a risk of a spill impacting State waters.
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 for the honeybee production system, and estimated greenhouse gas emissions (specifically for the Corowa Development) were held. Feedback was: • suggested KATO confirm appropriate emissions factors were used to calculate emisions • provision of contact person within Clean Energy Regulator for detailed discussion on calculations and reporting.
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.
	30 March 2020	KATO notified PPA the publicly available OPP was open for comment. Feedback was: • PPA conducted a review of the OPP and given the location, don't believe there will be any impact to PPA's operations at the Port of Ashburton.

Stakeholder	Date	Summary of Response
		Therefore, they have no comments on the OPP.
NOPTA	24 July 2019	No response.
	26 May 2020	Discussion on KATO's field development concept and status, associated gas strategy, and challenges.
NOPSEMA	May to June 2020	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.
Santos	30 Jan 2019 2 Aug 2019	Correspondence with Santos regarding the Talisman abandoned production equipment, as part of title transfer of WA-8-L. Santos shared the WA-8-L Production Equipment Abandonment EP (Santos 2018), and the close-out report with KATO, and outcomes of their relevant correspondence with DoEE and NOPSEMA.

10.3 Ongoing Consultation

As the Amulet Development has a short life span (~5 years), ongoing consultation will be undertaken during the development of the EP/s.

If stakeholders have made their preferred frequency, triggers and interests known, that preference will be implemented.

KATO will pre-emptively consider any responses received on the Corowa Development OPP for relevance to this OPP.

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
DAWE	Department of Agriculture, Water and the Environment
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

Acronyms	Description
DNP	Director of National Parks
DoA	Department of Agriculture
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
NGER	National Greenhouse and Energy Reporting
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
NT	Northern Territory
NWSP	North-west Shelf Province
NWSTF	North West Slope Trawl Fishery

Acronyms	Description
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
SCF	Western Australian Sea Cucumber Fishery
SEL	sound exposure level
SELcum	sound exposure level cumulative

Acronyms	Description
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
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	kilo-tonnes
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/d	millions of standard cubic feet per day
MMstb	million stock tank barrels
mol	mole
MT	Million tonnes
MV	megawatt
nm	nautical miles
pH	hydrogen ion concentration
ppm	parts per million
R_{max}	maximun value of a vector
scf/stb	standard cubic feet/standard barrels
sm^3	standard cubic metre
t	tonne
wt%	weight percentage
µPa	micropascal

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Appendix A: EPBC Act Protected Matters Reports

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.

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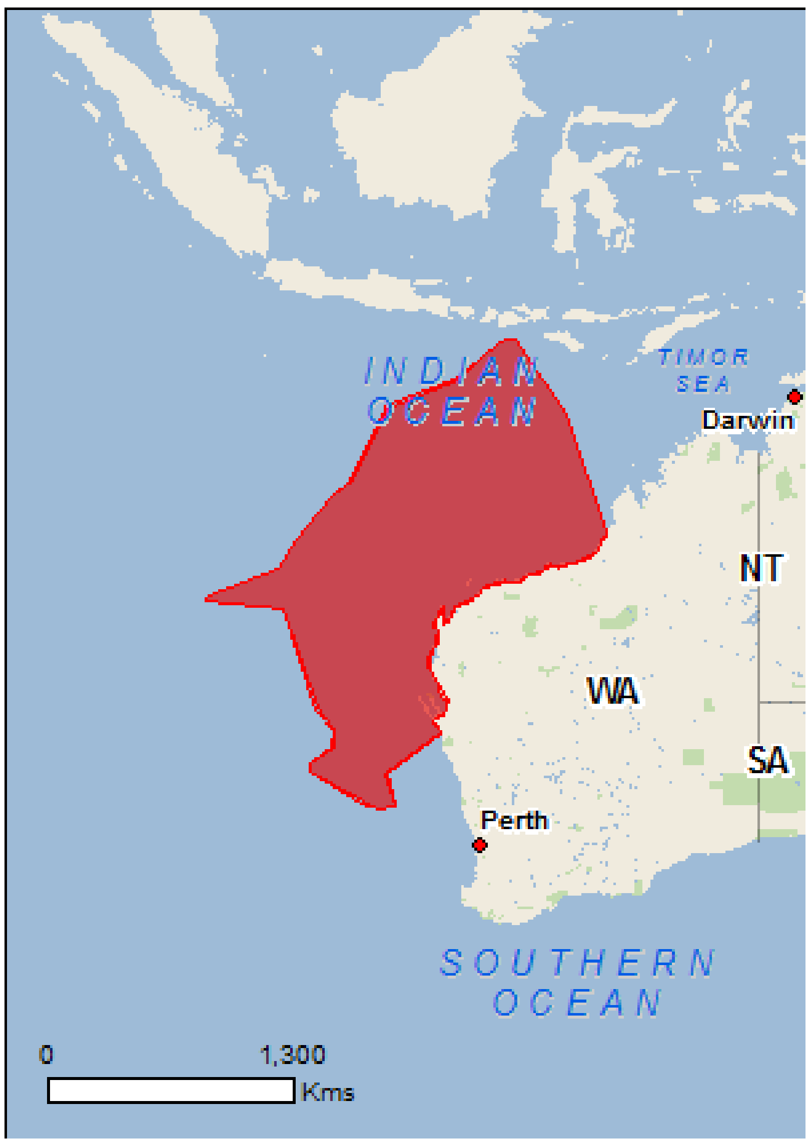

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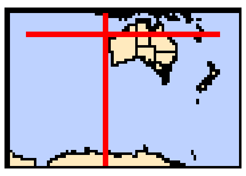

Summary

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:	6
Wetlands of International Importance:	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	80
Listed Migratory Species:	97

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:	11
Commonwealth Heritage Places:	4
Listed Marine Species:	168
Whales and Other Cetaceans:	39
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	21

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	71
Regional Forest Agreements:	None
Invasive Species:	26
Nationally Important Wetlands:	11
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
The West Kimberley	WA	Listed place
Indigenous		
Dampier Archipelago (including Burrup Peninsula)	WA	Listed place
Historic		
Dirk Hartog Landing Site 1616 - Cape Inscription Area	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

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
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anous tenuirostris melanops		
Australian Lesser Noddy [26000]	Vulnerable	Foraging, feeding or related behaviour likely 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	Species or species habitat likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat likely to 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
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
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
Polytelis alexandrae Princess Parrot, Alexandra's Parrot [758]	Vulnerable	Species or species habitat known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat 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 [82345]	Vulnerable	Species or species habitat may 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
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia lesueur Barrow and Boodie Islands subspecies Boodie, Burrowing Bettong (Barrow and Boodie Islands) [88021]	Vulnerable	Species or species habitat known to occur within area
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

Name	Status	Type of Presence
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
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
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
Osphranter robustus isabellinus Barrow Island Wallaroo, Barrow Island Euro [89262]	Vulnerable	Species or species habitat likely 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
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
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat may occur within area
Other		

Name	Status	Type of Presence
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		
Caladenia barbarella Small Dragon Orchid, Common Dragon Orchid [68686]	Endangered	Species or species habitat may occur within area
Caladenia hoffmanii Hoffman's Spider-orchid [56719]	Endangered	Species or species habitat likely to occur within area
Eucalyptus beardiana Beard's Mallee [18933]	Vulnerable	Species or species habitat known to occur within area
Pityrodia augustensis Mt Augustus Foxglove [4962]	Vulnerable	Species or species habitat likely 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 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	Species or species habitat 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
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

Name	Status	Type of Presence
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat 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

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 epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat likely 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 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
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 Shy Albatross [89224]	Vulnerable*	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	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*	Species or species habitat likely 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	Migration route known to occur within area

Name	Threatened	Type of Presence
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
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
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	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	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat likely 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	Breeding known to occur within area

Name	Threatened	Type of Presence
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		
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
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

Name	Threatened	Type of Presence
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]		Species or species habitat known to occur within area
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

Name	Threatened	Type of Presence
		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 - CARNARVON TRAINING DEPOT
Defence - EXMOUTH ADMIN & HF TRANSMITTING
Defence - EXMOUTH NAVAL HF RECEIVING STATION (H/F Receiving Station, Learmonth, WA)
Defence - EXMOUTH VLF TRANSMITTER STATION
Defence - KARRATHA TRAINING DEPOT
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

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Learmonth Air Weapons Range Facility	WA	Listed place
Mermaid Reef - Rowley Shoals	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	Foraging, feeding or related behaviour likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
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
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 epomophora Southern Royal Albatross [89221]	Vulnerable	Species or species habitat likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat likely to occur

Name	Threatened	Type of Presence
		within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Species or species habitat likely 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
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
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

Name	Threatened	Type of Presence
		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
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may 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
Phalaropus lobatus Red-necked Phalarope [838]		Species or species habitat 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 likely to occur within area
Puffinus assimilis Little Shearwater [59363]		Foraging, feeding or related behaviour 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 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 known to occur within area
Sterna albifrons Little Tern [813]		Breeding known to occur within area
Sterna anaethetus Bridled Tern [814]		Breeding known to occur

Name	Threatened	Type of Presence
		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
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 Shy Albatross [89224]	Vulnerable*	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Foraging, feeding or related behaviour likely 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

Name	Threatened	Type of Presence
		area
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
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
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
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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
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
Mammals		
Dugong dugon Dugong [28]		Breeding known to occur within area
Reptiles		

Name	Threatened	Type of Presence
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
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 czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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	Species or species habitat 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	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common 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 likely to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Globicephala melas Long-finned Pilot Whale [59282]		Species or species habitat may occur within

Name	Status	Type of Presence
		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
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 likely 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
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
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)
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)
Shark Bay	Multiple Use Zone (IUCN VI)

Extra Information

State and Territory Reserves	[Resource Information]
Name	State
Airlie Island	WA
Barrow Island	WA
Bedout Island	WA
Bernier And Dorre Islands	WA
Bessieres Island	WA
Boodie, Double Middle Islands	WA
Bundegi Coastal Park	WA
Burnside And Simpson Island	WA
Cape Range	WA
Chinamans Pool	WA
Dirk Hartog Island	WA
Faure Island	WA
Francois Peron	WA
Freycinet, Double Islands etc	WA
Giralia	WA
Gnandaroo Island	WA
Hamelin Station	WA
Jarrkunpungu	WA
Jinmarnkur	WA
Jinmarnkur Kulja	WA
Jurabi Coastal Park	WA
Karajarri	WA
Koks Island	WA
Kujungurru Warrarn	WA
Kujungurru Warrarn	WA
Little Rocky Island	WA
Locker Island	WA
Lowendal Islands	WA
Monkey Mia Reserve	WA
Montebello Islands	WA
Muiron Islands	WA
Murujuga	WA
Nanga Station	WA
North Sandy Island	WA
North Turtle Island	WA
Nyangumarta Warrarn	WA
One Tree Point	WA
Part Murchison house	WA
Round Island	WA
Serrurier Island	WA
Shell Beach	WA
Tamala Pastoral Lease (Part)	WA
Tent Island	WA
Unnamed WA26400	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 WA44665	WA
Unnamed WA44667	WA
Unnamed WA44672	WA
Unnamed WA44688	WA
Unnamed WA49144	WA
Unnamed WA52366	WA

Name	State
Unnamed WA53015	WA
Victor Island	WA
Weld Island	WA
Whalebone 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		
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
Streptopelia senegalensis		
Laughing Turtle-dove, Laughing Dove [781]		Species or species habitat likely to occur within area
Mammals		
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
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 habitat likely to occur

Name	Status	Type of Presence
		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 within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Cylindropuntia spp. Prickly Pears [85131]		Species or species habitat likely to 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
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
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
Bundera Sinkhole	WA
Cape Range Subterranean Waterways	WA
Eighty Mile Beach System	WA
Exmouth Gulf East	WA
Hamelin Pool	WA
Lake MacLeod	WA
Learmonth Air Weapons Range - Saline Coastal Flats	WA
Leslie (Port Hedland) Saltfields System	WA
McNeill Claypan System	WA
Mermaid Reef	EXT
Shark Bay East	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
Mermaid Reef and Commonwealth waters	North-west
Wallaby Saddle	North-west
Ancient coastline at 90-120m depth	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

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

-18.528 121.778,-18.611 121.789,-18.656 121.791,-18.702 121.748,-18.722 121.672,-18.801 121.652,-18.867 121.618,-19.043 121.531,-19.09 121.522,-19.381 121.316,-19.616 121.027,-19.875 120.345,-19.922 120.131,-19.937 119.98,-19.984 119.813,-20.084 119.581,-20.016 119.443,-19.957 119.196,-19.99 119.096,-20.02 119.075,-20.04 118.993,-20.122 118.972,-20.161 118.911,-20.27 118.825,-20.334 118.669,-20.302 118.643,-20.367 118.361,-20.332 118.346,-20.375 118.208,-20.343 118.189,-20.467 118.011,-20.482 117.949,-20.543 117.932,-20.669 117.781,-20.696 117.643,-20.714 117.555,-20.746 117.367,-20.699 117.211,-20.645 117.032,-20.711 116.934,-20.725 116.882,-20.695 116.811,-20.708 116.767,-20.775 116.691,-20.76 116.62,-20.72 116.628,-20.758 116.532,-20.826 116.466,-20.849 116.353,-20.882 116.305,-20.835 116.208,-20.982 116.176,-21.088 115.914,-21.236 115.837,-21.289 115.715,-21.436 115.521,-21.519 115.479,-21.505 115.44,-21.601 115.302,-21.584 115.241,-21.689 115.032,-21.68 114.982,-21.843 114.656,-21.977 114.62,-22.189 114.508,-22.496 114.376,-22.499 114.315,-22.443 114.315,-22.443 114.264,-22.515 114.212,-22.534 114.156,-22.486 114.118,-22.408 114.12,-22.345 114.181,-22.302 114.158,-22.333 114.112,-22.264 114.127,-22.177 114.077,-22.069 114.105,-21.943 114.136,-21.858 114.151,-21.817 114.185,-21.787 114.161,-21.808 114.133,-21.807 114.101,-21.878 114.003,-22.011 113.924,-22.143 113.868,-22.274 113.842,-22.389 113.771,-22.511 113.724,-22.552 113.67,-22.689 113.685,-22.745 113.756,-22.904 113.82,-22.984 113.832,-23.086 113.82,-23.125 113.771,-23.166 113.768,-23.292 113.798,-23.386 113.786,-23.516 113.767,-23.656 113.609,-23.769 113.562,-23.787 113.532,-23.834 113.523,-23.892 113.479,-24.033 113.457,-24.033 113.433,-24.089 113.432,-24.183 113.438,-24.231 113.401,-24.477 113.41,-24.762 113.635,-24.874 113.632,-24.916 113.689,-25.074 113.701,-25.206 113.853,-25.347 113.898,-25.653 114.056,-25.798 114.183,-25.841 114.295,-26.314 114.265,-26.462 114.114,-26.711 113.621,-26.951 113.808,-27.251 113.971,-28.936 111.383,-30.251 111.795,-30.391 111.094,-30.137 110.287,-28.848 107.849,-28.55 107.796,-27.866 108.928,-27.138 108.945,-26.235 108.147,-21.876 106.569,-21.526 102.929,-21.341 103.061,-20.21 106.306,-18.833 107.218,-16.895 108.875,-16.159 109.796,-12.853 111.418,-11.502 114.935,-10.345 116.127,-9.696 117.013,-9.696 117.548,-13.186 119.925,-18.528 121.778

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.

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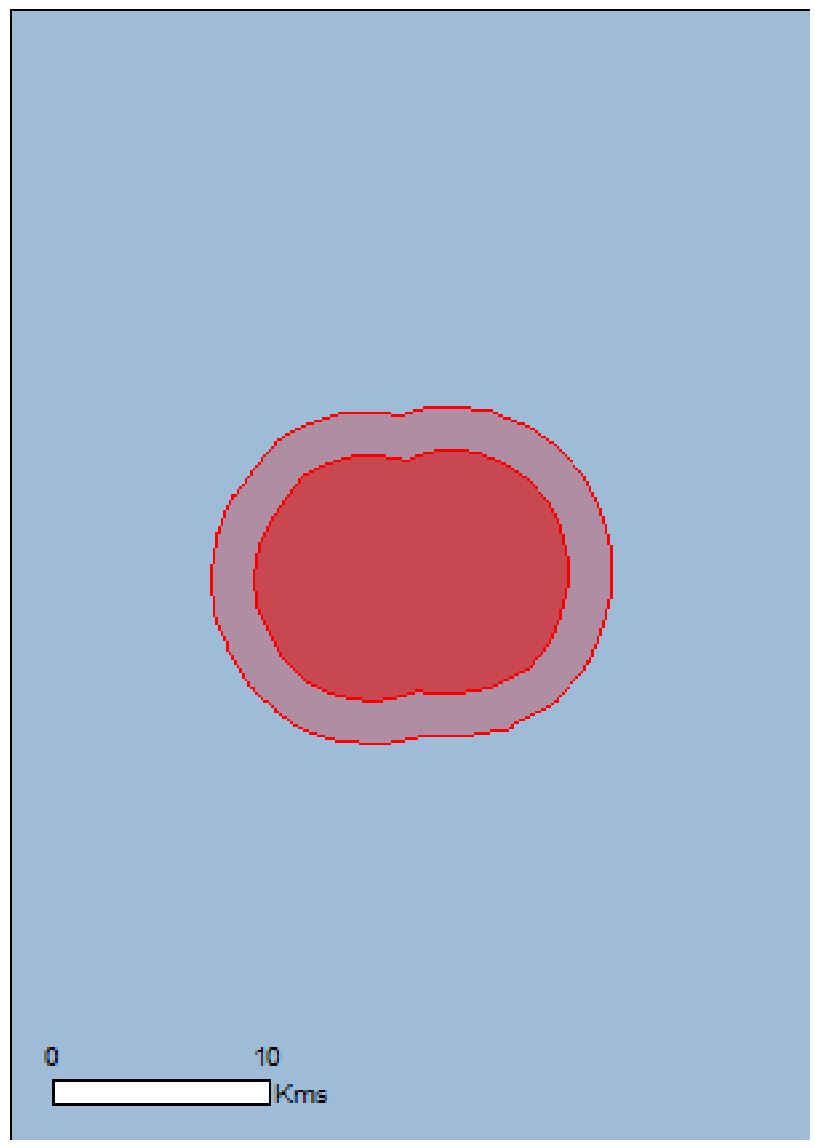
EPBC Act Protected Matters Report

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.

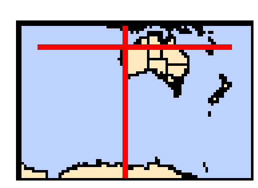
Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 26/03/20 13:06:15



Coordinates
Buffer: 2.0Km



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:	15
Listed Migratory Species:	30

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:	55
Whales and Other Cetaceans:	13
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)	None

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside 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
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	Species or species habitat may 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
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Reptiles		
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

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
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
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

Name	Threatened	Type of Presence
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat may 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 may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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 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
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		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		

Name	Threatened	Type of Presence
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 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
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 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

Name	Threatened	Type of Presence
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		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
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		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
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	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Disteira major Olive-headed Seasnake [1124]		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 likely to 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
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely 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 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
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

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.

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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.

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- 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

-19.464 116.904,-19.455 116.912,-19.45 116.922,-19.447 116.933,-19.447 116.941,-19.448 116.951,-19.449 116.954,-19.447 116.96,-19.445 116.968,-19.445 116.976,-19.446 116.985,-19.45 116.995,-19.457 117.006,-19.466 117.014,-19.476 117.019,-19.488 117.022,-19.498 117.022,-19.51 117.019,-19.521 117.014,-19.531 117.005,-19.539 116.99,-19.541 116.977,-19.541 116.964,-19.54 116.96,-19.542 116.953,-19.544 116.942,-19.543 116.931,-19.54 116.92,-19.535 116.912,-19.527 116.903,-19.516 116.896,-19.506 116.892,-19.495 116.891,-19.483 116.893,-19.473 116.897,-19.464 116.904

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.

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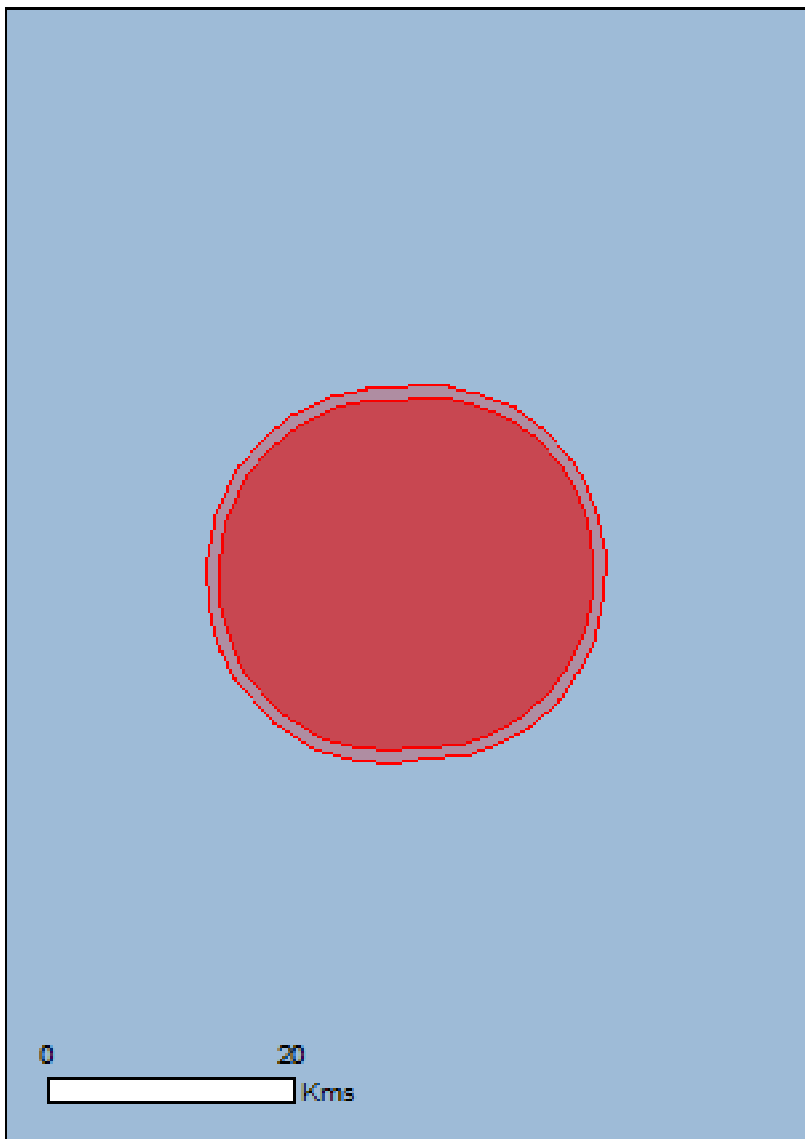
EPBC Act Protected Matters Report

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.

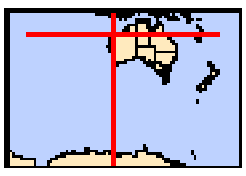
Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 26/03/20 13:53:30



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:	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:	17
Listed Migratory Species:	31

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:	56
Whales and Other Cetaceans:	23
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)	2

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
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	Species or species habitat may 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
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Breeding 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

Name	Status	Type of Presence
		habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis 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
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
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

Name	Threatened	Type of Presence
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 likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat may 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 may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
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 may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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 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 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
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		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		

Name	Threatened	Type of Presence
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 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
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 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

Name	Threatened	Type of Presence
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		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
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
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	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
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
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 likely to 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
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat 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 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
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

Name	Status	Type of Presence
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	Breeding 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
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
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
Glomar Shoals	North-west

Caveat

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Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-19.424 116.842,-19.408 116.857,-19.391 116.878,-19.379 116.908,-19.375 116.928,-19.375 116.949,-19.373 116.967,-19.373 116.986,-19.377 117.004,-19.382 117.019,-19.387 117.032,-19.401 117.052,-19.419 117.069,-19.438 117.081,-19.458 117.089,-19.484 117.094,-19.508 117.093,-19.535 117.087,-19.558 117.075,-19.576 117.062,-19.593 117.042,-19.603 117.023,-19.612 116.998,-19.614 116.97,-19.616 116.948,-19.615 116.922,-19.608 116.895,-19.591 116.865,-19.562 116.838,-19.544 116.829,-19.533 116.825,-19.514 116.82,-19.489 116.819,-19.46 116.824,-19.44 116.833,-19.424 116.842

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.

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Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

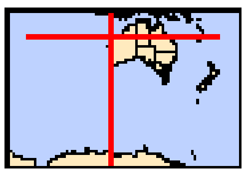
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

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: 26/03/20 22:37:53

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:	1
National Heritage Places:	1
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	48
Listed Migratory Species:	63

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:	2
Listed Marine Species:	116
Whales and Other Cetaceans:	31
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	8

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	14
Regional Forest Agreements:	None
Invasive Species:	11
Nationally Important Wetlands:	3
Key Ecological Features (Marine)	7

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
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

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may 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
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat may 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

Name	Status	Type of Presence
Malurus leucopterus edouardi White-winged Fairy-wren (Barrow Island), Barrow Island Black-and-white Fairy-wren [26194]	Vulnerable	Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta cauta Shy Albatross [82345]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta steadi White-capped Albatross [82344]	Vulnerable	Species or species habitat 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
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia lesueur Barrow and Boodie Islands subspecies Boodie, Burrowing Bettong (Barrow and Boodie Islands) [88021]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely 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
Megaptera novaeangliae Humpback Whale [38]	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
Other		
Kumonga exleyi Cape Range Remipede [86875]	Vulnerable	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 zastictus Hamelin Ctenotus [25570]	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	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	Species or species

Name	Status	Type of Presence
		habitat known to occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat 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 likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
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
Sterna dougallii Roseate Tern [817]		Breeding known to occur

Name	Threatened	Type of Presence
		within area
Sternula albifrons Little Tern [82849]		Congregation or aggregation known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta Shy Albatross [89224]	Vulnerable*	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Species or species habitat 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*	Species or species habitat likely 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	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat 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

Name	Threatened	Type of Presence
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	Breeding 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]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat 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 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		

Name	Threatened	Type of Presence
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		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 melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely 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 VLF TRANSMITTER STATION
Defence - LEARMONTH - AIR WEAPONS RANGE
Defence - LEARMONTH RADAR SITE - VLAMING HEAD EXMOUTH

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Learmonth Air Weapons Range Facility	WA	Listed place
Ningaloo Marine Area - Commonwealth Waters	WA	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		

Name	Threatened	Type of Presence
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	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 known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		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 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
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
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Larus novaehollandiae Silver Gull [810]		Breeding known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
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 may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may 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
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Species or species habitat likely 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 likely to occur within area
Sterna albifrons Little Tern [813]		Congregation or aggregation 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

Name	Threatened	Type of Presence
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 Shy Albatross [89224]	Vulnerable*	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Species or species habitat likely to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys galei Gale's Pipefish [66191]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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
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
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Breeding known to occur within area
Reptiles		

Name	Threatened	Type of Presence
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	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	Breeding known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		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

Name	Threatened	Type of Presence
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	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common 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 likely to occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within

Name	Status	Type of Presence
		area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
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 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
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)
Gascoyne	Habitat Protection Zone (IUCN IV)
Gascoyne	Multiple Use Zone (IUCN VI)
Montebello	Multiple Use Zone (IUCN VI)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)
Shark Bay	Multiple Use Zone (IUCN VI)

Extra Information

State and Territory Reserves	[Resource Information]
Name	State
Barrow Island	WA
Bessieres Island	WA
Boodie, Double Middle Islands	WA
Cape Range	WA
Jurabi Coastal Park	WA
Lowendal Islands	WA
Montebello Islands	WA
Muiron Islands	WA
Round Island	WA
Serrurier Island	WA
Unnamed WA40828	WA
Unnamed WA41080	WA
Unnamed WA44665	WA
Whalebone 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
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 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

Name	Status	Type of Presence
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 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
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species habitat likely to occur within area

Nationally Important Wetlands [Resource Information]

Name	State
Bundera Sinkhole	WA
Cape Range Subterranean Waterways	WA
Learmonth Air Weapons Range - Saline Coastal Flats	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
Mermaid Reef and Commonwealth waters	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

-16.921 114.838,-16.932 114.989,-17.288 115.211,-17.706 115.267,-17.376 115.527,-17.408 115.682,-17.193 115.768,-16.924 115.745,-16.846
115.78,-16.644 115.903,-16.688 115.966,-17.017 116.312,-16.927 116.372,-16.81 116.495,-17.033 116.451,-17.211 116.574,-17.328 116.746,-
17.316 116.942,-17.28 117.355,-17.544 117.685,-17.573 117.94,-17.508 118.341,-17.508 118.475,-17.56 118.901,-17.236 119.395,-17.321
119.389,-17.571 119.05,-17.772 119.186,-18.179 119.454,-18.396 119.402,-18.546 119.296,-18.724 119.043,-18.81 118.74,-19.11 118.362,-19.335
118.195,-19.479 117.983,-19.753 117.86,-19.931 117.694,-19.998 117.181,-20.018 116.897,-19.959 116.777,-19.983 116.697,-20.258 116.443,-
20.582 115.887,-20.483 115.745,-20.435 115.659,-20.464 115.615,-20.403 115.569,-20.644 115.536,-20.96 115.338,-21.055 115.193,-21.331
114.972,-21.483 114.786,-21.627 114.743,-21.751 114.547,-21.778 114.291,-22.198 114.384,-22.201 114.371,-21.786 114.267,-21.805 114.195,-
21.793 114.159,-21.852 114.029,-22.03 113.93,-22.341 113.812,-22.491 113.737,-22.578 113.654,-22.657 113.611,-22.783 113.491,-22.859
113.396,-23.237 113.295,-23.58 113.129,-24.148 112.747,-24.531 112.534,-25.016 112.423,-25.333 112.436,-25.679 112.557,-25.809 112.569,-
25.482 112.364,-24.949 112.328,-24.44 112.451,-23.635 112.81,-23.151 112.703,-22.637 112.364,-22.46 112.333,-22.16 111.926,-22.006
111.764,-21.865 111.799,-21.605 111.976,-21.584 112.04,-21.548 112.25,-21.447 112.38,-21.095 112.431,-20.957 112.478,-20.661 112.707,-
20.365 112.889,-20.231 112.89,-20.027 112.807,-19.931 112.822,-19.777 112.865,-19.753 112.908,-19.477 112.908,-19.265 112.653,-19.41
112.478,-19.584 112.265,-19.513 112.151,-19.193 112.576,-18.783 112.735,-18.609 112.829,-17.966 113.295,-17.785 113.83,-17.742 114.071,-
17.805 114.347,-17.764 114.728,-17.301 114.779,-17.042 114.761,-16.921 114.838

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-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.

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Appendix B: Amulet Development – Facility and Flare Light Assessment

Amulet Development

Facility and Flare Light Assessment

KATO Energy

Assignment Number: P100092-S00
Document Number: P-100092-S00-REPT-005

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Facility and Flare Light Assessment

P100092-S00

Client: KATO Energy
Document Type: Report
Document Number: P-100092-S00-REPT-005

A01	28/04/2020	Issued for Use	SH	MC	NK	BMC
R02	16/04/2020	Issued for Client Review	SH	MC	NK	BMC
R01	23/03/2020	Issued for Client Review	SH	NK	NK	BMC
Rev	**Date**	**Description**	**Issued By**	**Checked By**	**Approved By**	**Client Approval**

CONTENTS

1 INTRODUCTION

1.1 Project Overview

The Amulet Development will be centred on the Amulet and Talisman oil fields, located within petroleum permit WA-8-L in the Carnarvon Basin, approximately 132 km offshore from Dampier in Western Australia. The field is in Commonwealth waters in approximately 85 m water depth.

KATO Energy Pty Ltd (KATO) plan to develop the Amulet and Talisman oil fields 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 assessment undertaken to estimate the artificial light emissions from the Amulet Development.

1.3 Scope

The operations of vessels and facilities associated with the Amulet 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 report.

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 Amulet 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 Amulet 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:

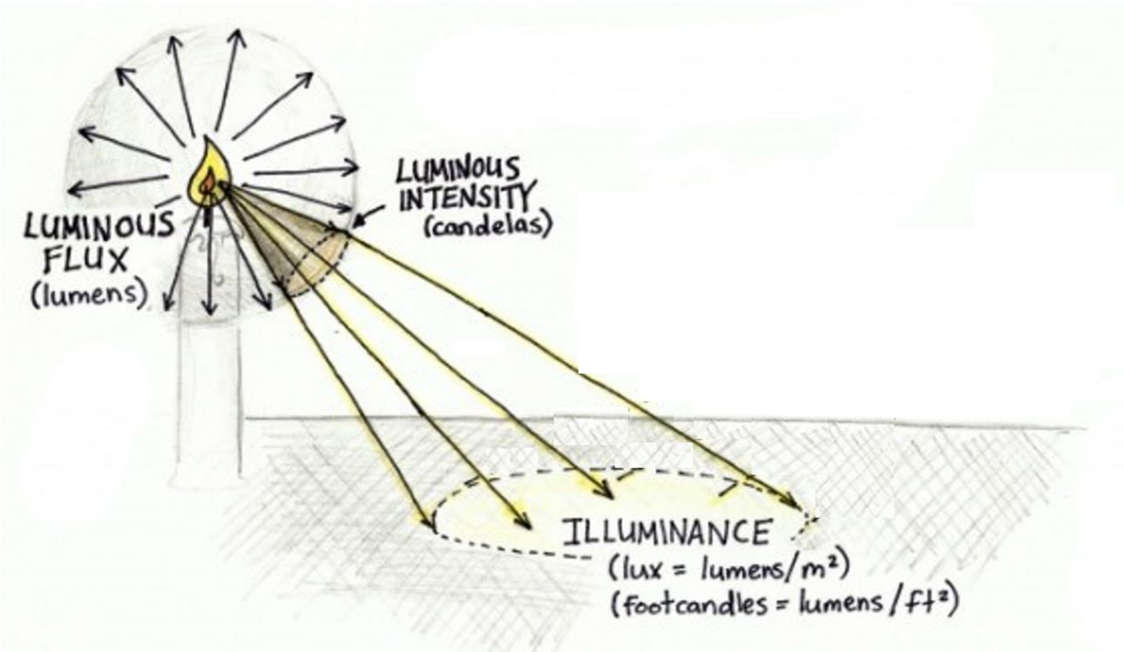
> luminous flux is a measure of the amount of light from a source emitted in total regardless of direction (unit of measurement: lumens)

> 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 Amulet 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 Amulet 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 Amulet Development were assessed separately, using published modelled and measured data as analogues.

As the MOPU, MODU, and support vessels may all undertake activities at both the Amulet and Talisman locations (~3.5 km apart), both locations have been used as the source location for the light intensity modelling.

3.1 Facility Lighting

It is expected that the MOPU and MODU for the Amulet 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 Amulet Development and are shown in Figure 3-4.

3.2 Flare Lighting

The proposed Amulet 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 ~1.2 MMscfd during the initial 6–9 months (P50–P10 estimates of reservoir outcomes respectively) of operation, and then decline as the reservoir depletes to end of field life (Figure 3-1). While the flaring profiles for the P10 and P50 reservoir outcomes are similar, including the same initial peak flaring rate, the P10 profile has been used to identify the flaring durations, as the most conservative measure.

To inform the environmental impact assessment for Amulet Development environmental approvals, light intensity from the peak flare flow rate were modelled.

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 2 m above the MOPU flare tower tip in calm conditions. During operations, the reservoir is predicted to deplete such that only a pilot flame, of up to approximately 50 cm height above the MOPU flare tower, would be present.

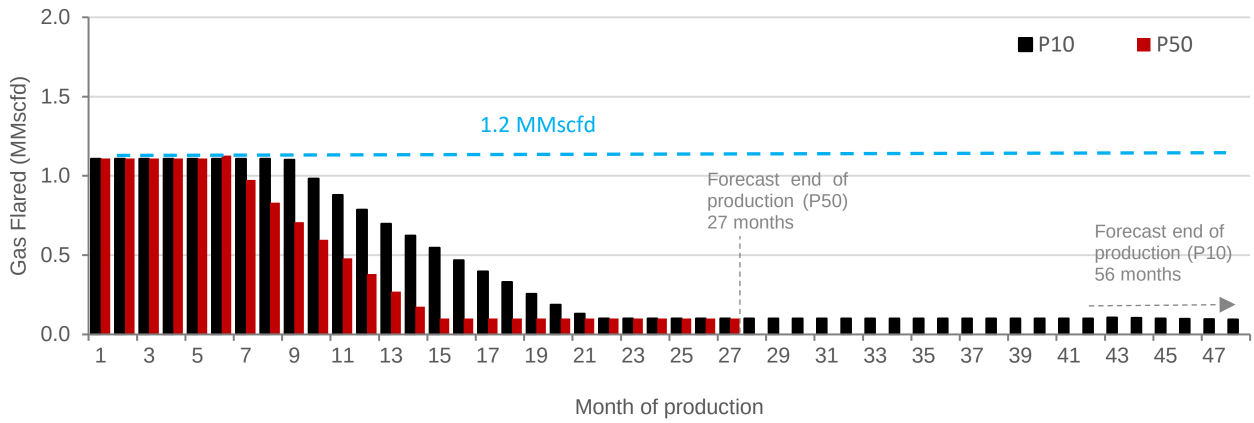


Figure 3-1 Amulet expected gas flaring profiles (P10 and P50) and the modelled flaring rate

3.2.1 Method

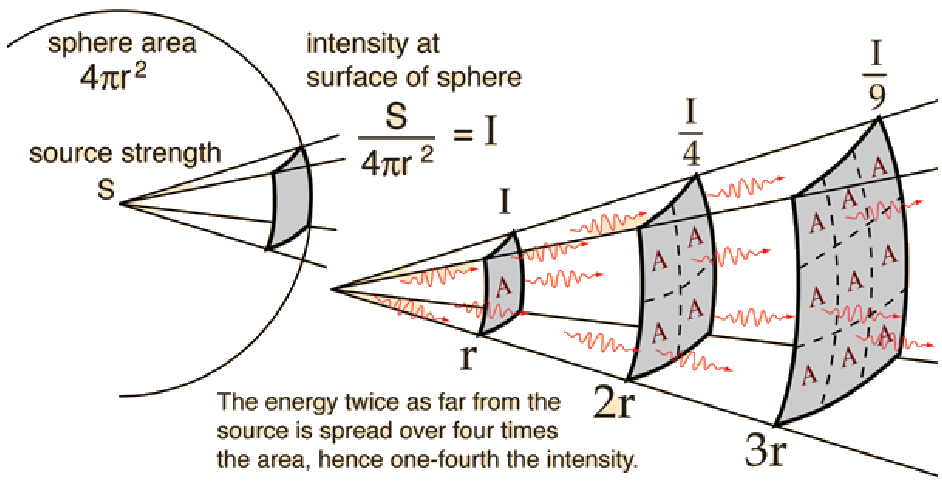
3.2.1.1 Inverse Law

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 Amulet 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 light intensity modelling undertaken for the Amulet Development is the same as that developed for the Corowa Development (Xodus Group 2019). The analogue previously identified as most suitable for the basis of flare light intensity modelling was the Obigbo Oil Production Facility. The Obigbo facility has a continuous flare of similar service and has a flare rate of similar magnitude to the peak rate expected for the Corowa Development (Table 3-1). 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.

Table 3-1 Details of analogue natural gas flares

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
Corowa Development	Proposed oil field development by KATO with continuous gas flare	~17 MMscfd (peak)	Modelled intensity	Modelled illuminance (lux)	Xodus Group 2019

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 Amulet 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 MMscfd has been removed from the gas produciton profile to calculate flaring for Amulet.

Illuminance was calculated every 100 m 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 and shown graphically for the Amulet Development in Figure 3-3.

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								
Amulet Development Peak flaring (1.2 MMscfd)	~72,200	0.29	0.07	0.003	0.001	0.000	0.000	0.000

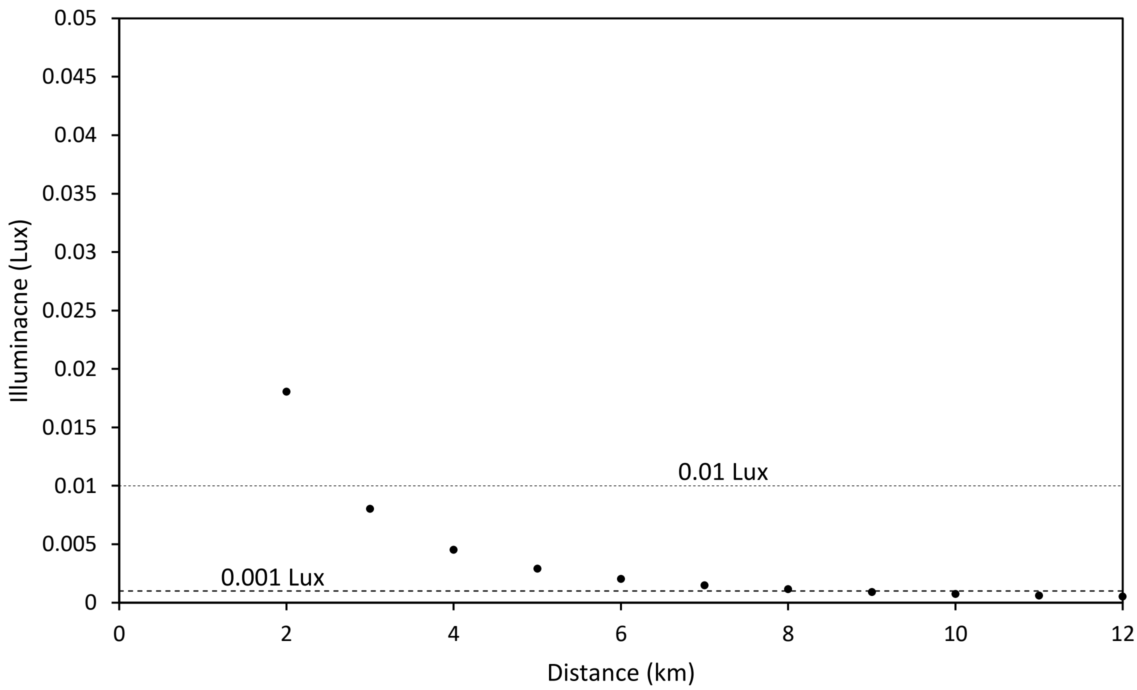


Figure 3-3 Flare Illuminance peak flaring (1.2 MMsfd)

For the Amulet Development, the model predicted the following for peak flaring rate of 1.2 MMscfd during operations (Figure 3-5):

> Light intensity levels greater than 0.1 Lux up to 0.9 km from the MOPU, comparable to ambient light levels during full moon to twilight

- Between 0.9 km and 2.7 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 2.7 km and 8.3 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 8.3 km there was no measurable change to the ambient light intensity levels.

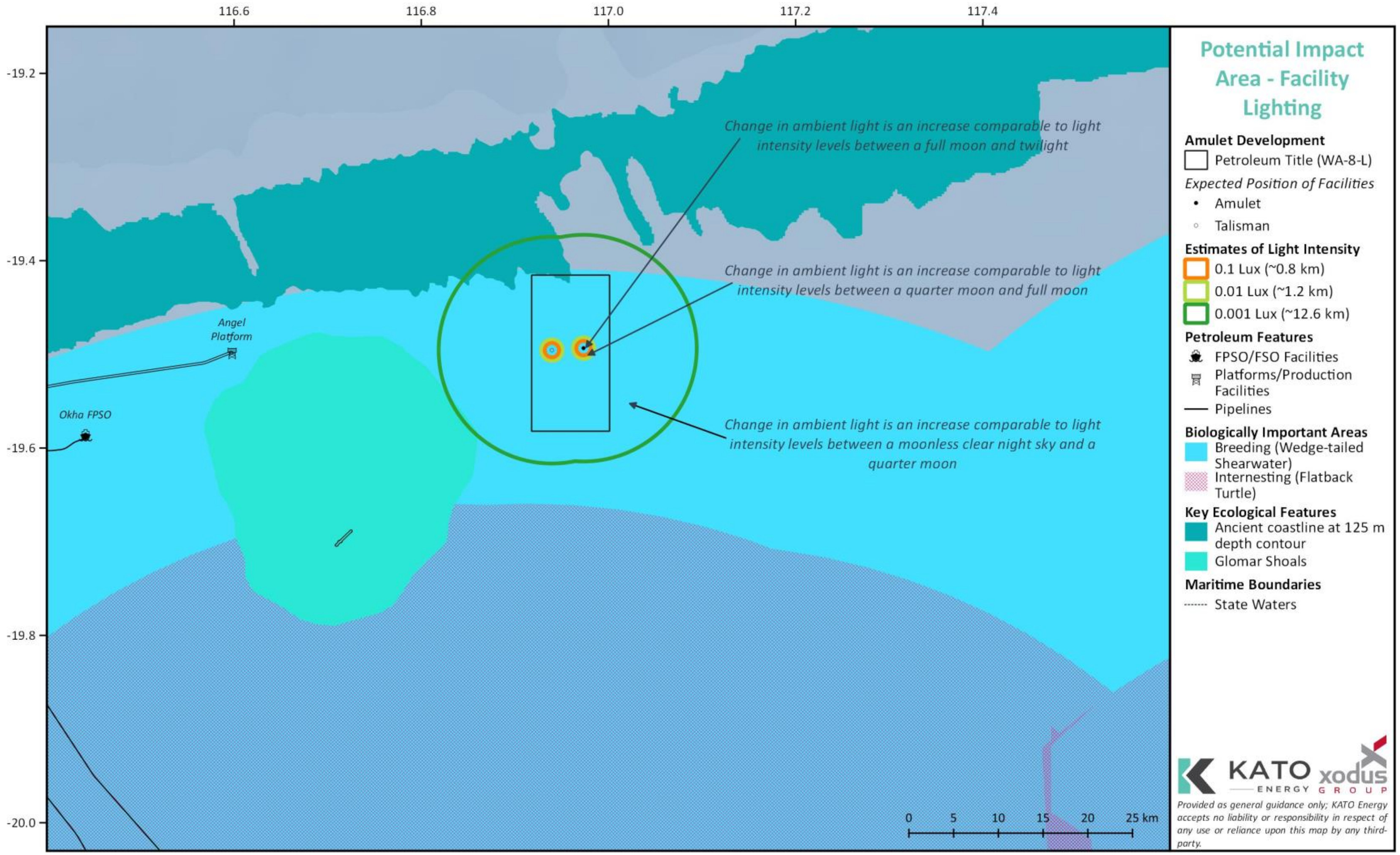


Figure 3-4 Expected light intensity levels from the Facility Lighting of the MOPU and MODU

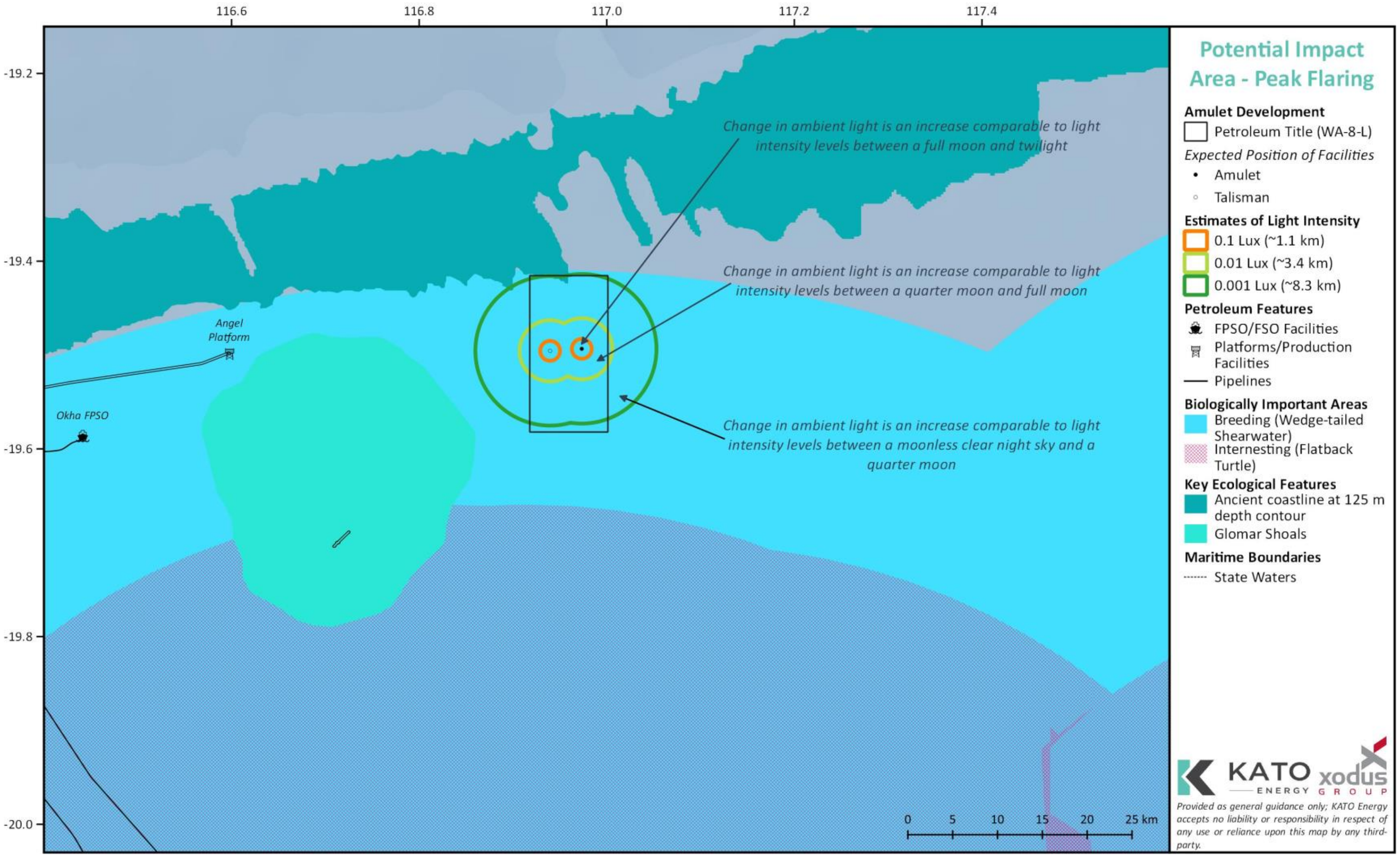


Figure 3-5 Expected light intensity levels from Flaring on the MOPU (during peak flaring at 1.2 MMscfd)

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
- d_l = total line of sight.

The analysis was completed using assumed heights of the MOPU and MODU for the Amulet Development, with final designs being confirmed during FEED (Table 4-1). Note that as the Amulet flare height reduces over time during production as the field is depleted, therefore this maximum height of the flame tip will decrease towards approximately 80.5 m, the height of the flare tower tip where a small pilot flame will be burning continuously (~50cm).

As the MOPU, MODU, and support vessels may all undertake activities at both the Amulet and Talisman locations (~3.5 km apart), both locations have been used as the source location for the line of sight distance.

Table 4-1 Amulet Development Facility Infrastructure Heights

Facility	Infrastructure	Height of Facility / Lighting / Flare
MOPU/MODU	Main deck lights	32 m
MOPU	Process module lights	50 m
MOPU/MODU	Lighting on the flare tower/drill rig	80 m
MODU	Derrick (navigation lights)	99 m
MOPU	2 m high flame from the flare tower	82 m
MOPU	0.5 m high flame from the flare tower	80.5 m

4.2 Results

The Amulet Development line of sight assessment showed that the maximum distances light may be visible extends up to approximately 32.3 km for a 2 m high flame from the flare (Table 4-2 and Figure 4-1). Note that as the flare height reduces over time as the field is depleted, this maximum distance of 32.3 km will drop towards 32.0 km, that is associated with the height of the pilot flare.

The line of sight assessment indicates that the Amulet Development will not be visible from any offshore islands or the mainland. It will likely be visible as a small object or light on the horizon from of some of the nearby oil and gas facilities (see Section 5).

Table 4-2 Amulet Facility Visual Impact Line of Sight Distances

Facility	Infrastructure	Visible radius – line of sight analysis
MOPU/MODU	Main deck lights	20.2 km
MOPU	Process module lights	25.2 km
MOPU/MODU	Lighting on the flare tower/drill rig	31.9 km
MODU	Derrick (navigation lights)	35.5 km
MOPU	2 m high flame from the flare tower	32.3 km
MOPU	0.5 m high flame from the flare tower	32.0 km

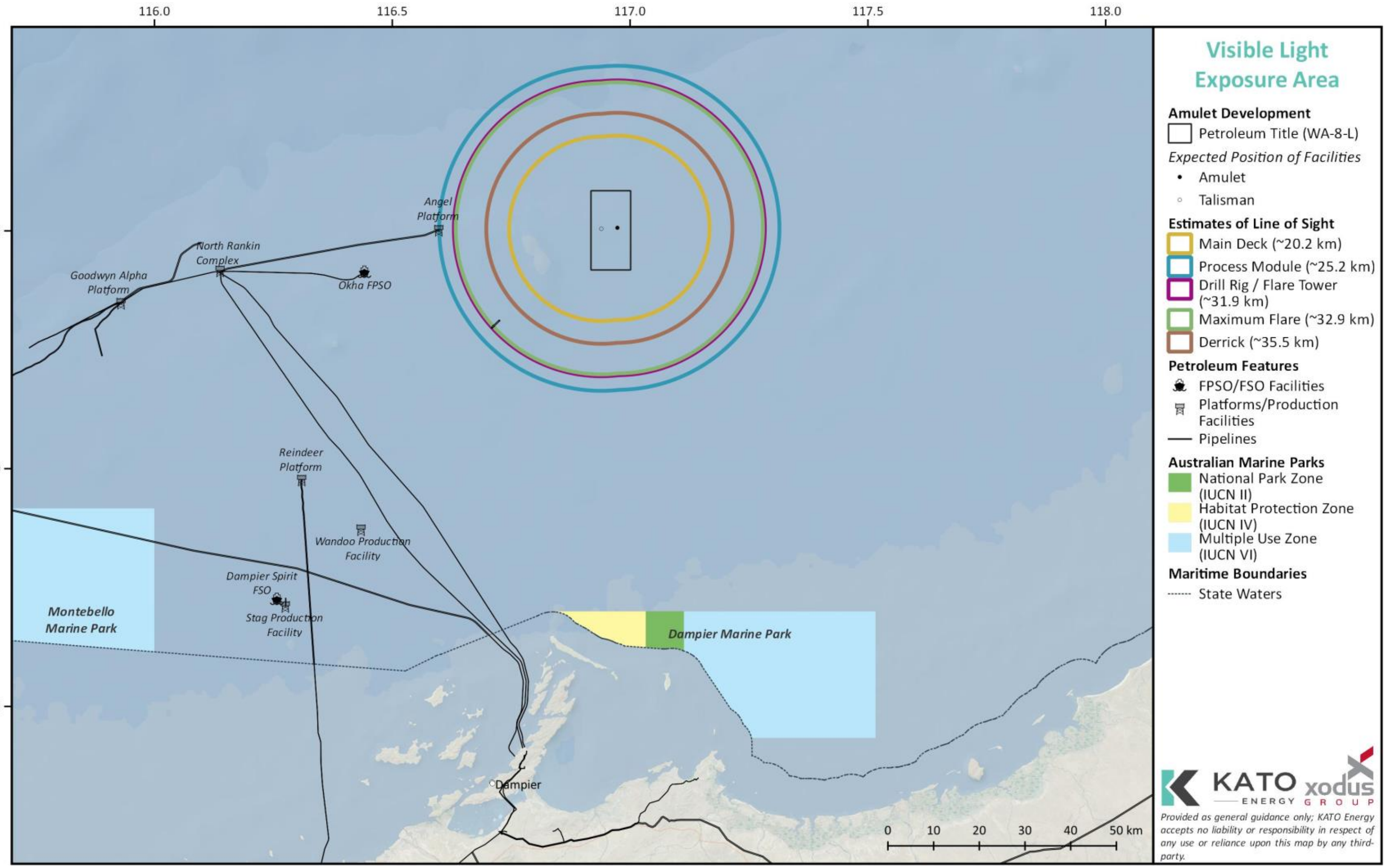


Figure 4-1 Visible Light Exposure Area for the Amulet Development

5 CUMULATIVE IMPACT ASSESSMENT

The offshore Woodside-operated Angel Platform and Okha FPSO are located in the same region as the Amulet Development (~40 km and 57 km away respectively), and therefore there is the potential for cumulative impacts.

5.1 Line of Sight Assessment

Line of sight analyses were not publicly available for the two adjacent facilities. Therefore, line of sight calculations were completed for the two facilities based on details in Table 5-1.

Table 5-1 Height of Neighbouring Facility Infrastructure

Facility	Height of Facility / Lighting
Angel Platform flare tower (no flaring assumed)	~200 m
Okha FPSO flare tower (no flaring assumed)	~82 m

(Source: Woodside 2008)

Table 5-2 summarises the line of sight assessment for the oil and gas facilities neighbouring the Amulet Development. The line of sight assessment showed that the maximum distances light may be visible extends up to approximately 50.4 km and 32.3 km for Angel Platform and Okha FPSO respectively.

Figure 5-1 shows the line of sight assessment for the Amulet Development and the neighbouring facilities. Overlap in the Visible Light Exposure Areas for each of the three facilities is predicted to occur.

Table 5-2 Visual Impact Line of Sight Distances for neighbouring facilities

Facility	Visible radius – line of sight analysis
Angel Platform	~50.4 km
Okha FPSO	~32.3 km

5.2 Light Intensity Assessment

Light intensity assessments were not publicly available for the two adjacent facilities. However, for the purposes of comparison, it has been assumed that the Angel Platform and the Okha FSPO have similarly lit structures to the Woodside-operated Torosa Platform, and as such the ERM (2010) light intensity modelling could be applied as an analogue.

Based on this assumption, if each of the facilities (i.e. Amulet Development, Angel Platform and Okha FSPO) has a maximum distance of 12.6 km that measurable changes in light can be detected, none of these areas (i.e. Potential Impact Areas) would overlap as the facilities are greater than 25.2 km (i.e. 2 x 12.6 km) apart from each other (Figure 5-1).

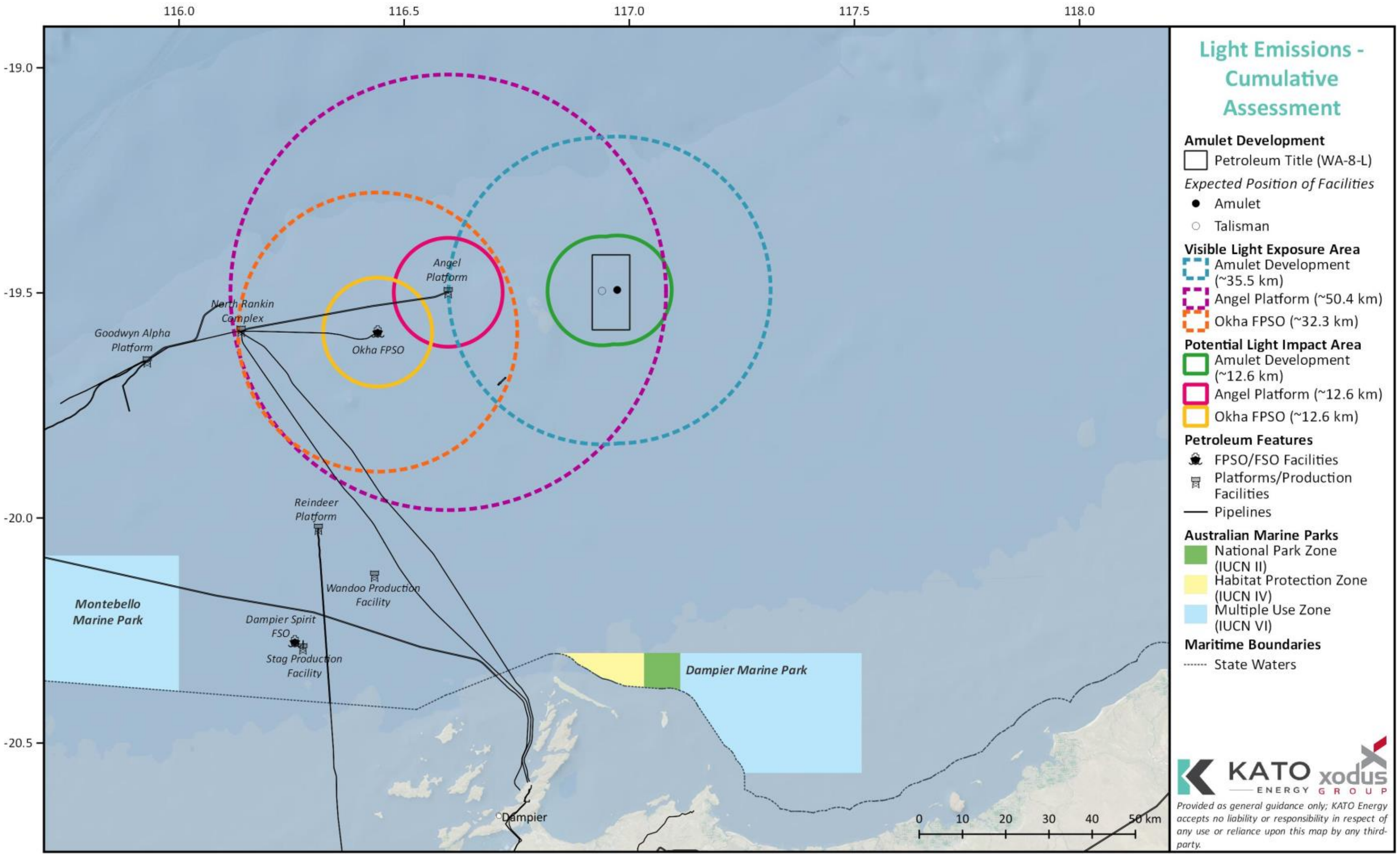


Figure 5-1 Line of Sight and Light Intensity Assessment with Neighbouring Facilities

6 ABBREVIATIONS

Acronym	Description
cm	centimetre (unit of measurement for distance)
FEED	Front end engineering design
FID	Final investment decision
FPSO	Floating production storage and offtake facility
FSO	Floating storage and offloading
KATO	KATO Energy Pty Ltd
km	kilometre (unit of measurement for distance)
m	metre (unit of measurement for distance)
m^2	metres squared (unit of measurement for area)
MMscfd	Million standard cubic feet per day (unit of measurement for gas)
MODU	Mobile offshore drilling unit
MOPU	Mobile offshore production unit

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Appendix C: Amulet Development – Greenhouse Gas Assessment

Amulet Development

Greenhouse Gas Assessment

KATO Energy

Assignment Number: P100092-S00
Document Number: P-100092-S00-REPT-004

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Greenhouse Gas Assessment

P100092-S00

Client: KATO Energy
Document Type: Report
Document Number: P-100092-S00-REPT-004

A02	30 Jun 2020	Issued for use in Amulet Development OPP Revision 1	SH	NK	NK	BMC
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Rev	**Date**	**Description**	**Issued By**	**Checked By**	**Approved By**	**Client Approval**

CONTENTS

1 INTRODUCTION

1.1 Project Overview

The Amulet Development will be centred on the Amulet and Talisman oil fields, located within petroleum permit WA-8-L in the Carnarvon Basin, approximately 132 km offshore from Dampier in Western Australia. The field is in Commonwealth waters in approximately 85 m water depth.

KATO Energy Pty Ltd (KATO) plan to develop the Amulet and Talisman fields 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 Agriculture, Water and the Environment (DAWE) 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 Amulet Development. This Commonwealth guidance has been used as the basis for the calculation of GHG emissions from the Amulet 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 Amulet 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 Amulet 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 Amulet 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 Amulet, 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 Amulet Development, oil will most likely be exported to international markets.

2.1 Significant GHG Emissions Sources

The significant GHG emission sources from the Amulet 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

> 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 Amulet.

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 waste water
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

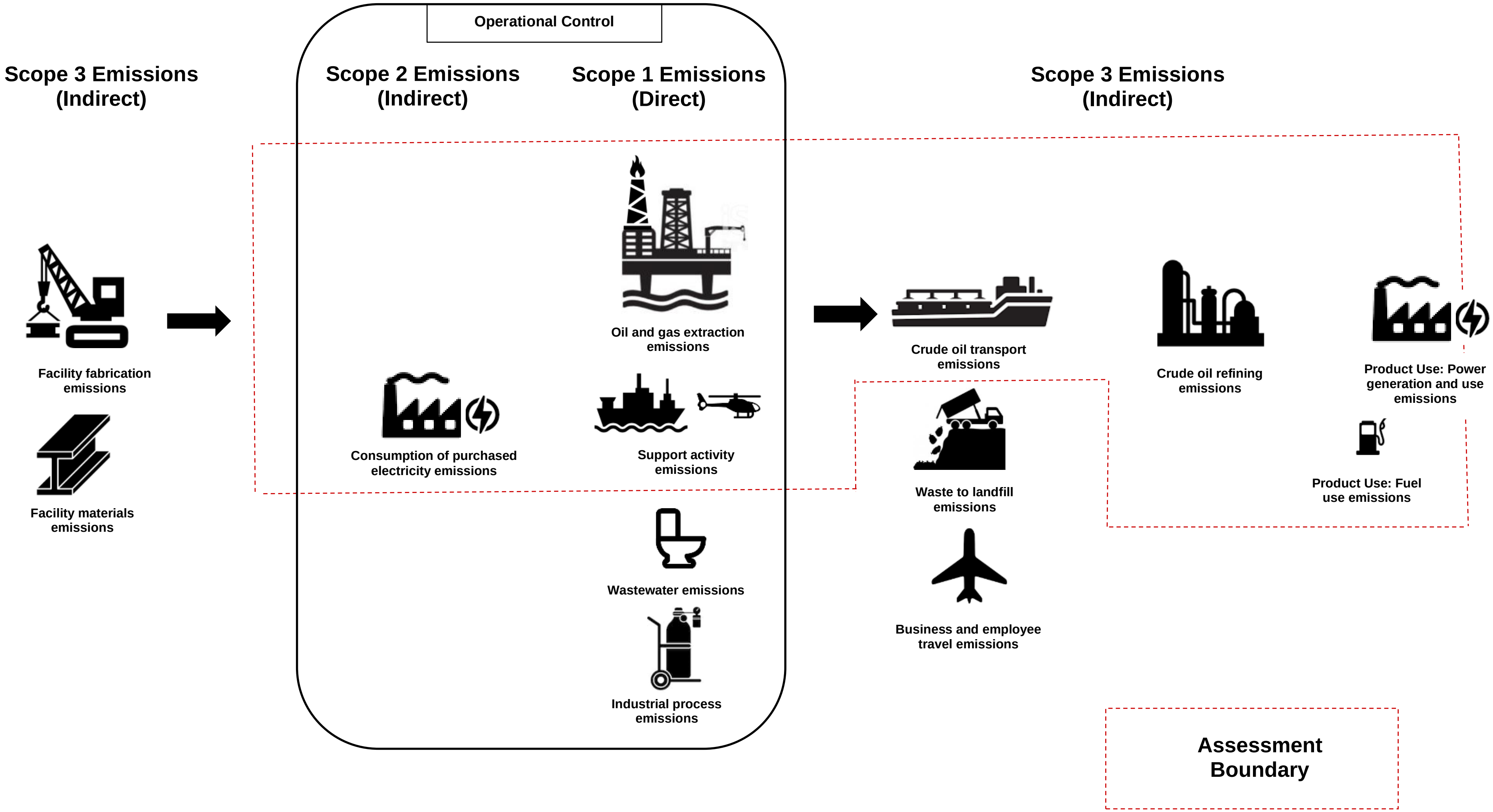

Figure 2-1: Amulet Greenhouse Gas Emissions Assessment Boundary

3 METHODS

3.1 Emissions factors and calculation methodology

The Amulet Development 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 Amulet facility and are appropriate for the purpose of environmental impact assessment for the Amulet Development 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:

- Eij 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.
- Qi 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.
- ECi is the energy content factor of fuel type (i) estimated (Table 3-1).
- EFijoxec is the emission factor for each gas type (j) released during the year (which includes the effect of an oxidation factor) measured in kilograms CO2-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:

- Eij is the emissions of gas type (j) measured in CO2-e tonnes from a fuel type (i) flared in crude oil production during the year.
- Qi is the quantity of fuel type (i) measured in tonnes flared in crude oil production during the year.
- EFij is the emission factor for gas type (j) measured in tonnes of CO2-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 the Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry, (API, 2009) Section 6.1.1.

$$E_{ij} = Q_i \text{ x } E_{ij} \text{ x } GHP_{CH4}$$

Where:

- Eij is the fugitive emissions of methane (j) from fuel type (i) being crude oil produced from the offshore facility during the year measured in CO2-e tonnes.
- Qi is the quantity of crude oil (i) produced from the offshore facility measured in m3.
- EFij is the emission factor for methane (j) being 3.84 x 10-5 TCH4/ bbl crude oil produced.
- Note: The emissions factor 9.38 x 10-5 TCH4/bbl is taken from Table 6-2 Offshore oil production the reference methane composition and was corrected to 3.84 x 10-5 TCH4/bbl corrected for composition for Amulet gas composition (32.25mol% methane).
- GHPCH4 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:

- Eij is the fugitive emissions of methane (j) from fuel type (i) being crude oil stored in tanks during the year measured in CO2-e tonnes.
- Qi is the quantity of crude oil (i) stored in tanks during the year measured in tonnes.
- EFij is the emission factor for methane (j) being 1.5 x 10-4 tonnes CO2-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.*

$$E_{ij} = \Sigma_i \, Q_i \text{ x } E_{ij}$$

Where:

- Eij is the fugitive emissions of methane (j) from fuel type (i) being crude oil

- refined during the year measured in CO_2-e tonnes.
- ΣI is the sum of emissions of methane (j) released during refining and transportation.
- Qi is the quantity of crude oil (i) refined or transported during the year measured in tonnes.
- EFij is the emission factor for methane (j) being 8.5 x 10-4 tonnes CO_2-e per tonne of crude oil refined or 8.7 x 10-4 tonnes CO_2-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.*

$$E_{ij} = (Q_i \times EC_i \times EF_{ijoxec}) / 1000$$

Where:

- Eij 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 CO_2-e tonnes.
- Qi is the quantity of product (i) combusted measured in cubic metres or gigajoules.
- ECi is the energy content factor of the product type (i) estimated (Table 3-1).
- EFijoxec 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-e per gigajoule of fuel type (Table 3-1).

Table 3-1 Emissions Factors for gaseous and liquid fuels

Activity	Purpose	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
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

Activity	Purpose	Emission Factor: EF CO_2 $tCO_{2\text{-}e}/t$ flared gas	EF CH_4 $tCO_{2\text{-}e}/t$ flared gas	EF N_2O $tCO_{2\text{-}e}/t$ flared gas	EF $CO_{2\text{-}e}$ $tCO_{2\text{-}e}/t$ flared gas
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 (assume from SE Asia 1,500 nm)	20 days, two towing AHTS burning 40 m^3/day per vessel	Fuel Oil
	MODU Transit (assume from SE Asia 1,500 nm)	SE Asia (1,500nm) up to 20 days each mobilisation, two towing AHTS burning 40 m^3/day per vessel	Fuel Oil
	MOPU Installation (after tow)	Three AHTs burning 25 m^3/day per vessel for 4 days	Fuel Oil
		MOPU Power Generation 6MW (jacking) for 12 hours	Diesel
	MODU Installation (after tow)	Assume three positioning AHTS burning 25 m^3/day for 4 days per drilling campaign	Fuel Oil
		MODU Power Generation 6MW (jacking) for 12 hours per campaign.	Diesel
	CALM & Mooring Installation	ISV MOB/DEMOB 5 days at 40T/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 Boats burning average 15 MT/day each	Fuel Oil
		One supply boat burning average 15 MT/day for additional drilling campaign	Fuel Oil
		Eight S76 Helicopter round trips per week (to/from Dampier)	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 & P&A (assume one of each)	Assume duration 21 days each event • commissioning • workover • preparation for removal & well P&A	NA
		30 dedicated POB for additional operations + 20 allowance for Ops	NA

Phase	Activity	Detail	Fuel Type
		Assume MOPU power consumption 2 MW for duration (all diesel)	Diesel
		One supply vessel burning 12 MT/day each	Fuel Oil
		Four S76 Helicopter round trips per week	Kerosene for aviation
	Well Cleanup	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	Diesel
		MOPU Process fugitive emissions	NA
		One supply vessel burning average 12 MT/day each	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 10MT/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 tonne/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 Amulet Development total 0.3 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 (0.30 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 32% of GHG emissions during the operations phase (0.10 MT CO_2-e).

Table 4-1 Amulet 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	100,475	96	819	101,390
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	1,143	0	10	1,153
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	75,061	21,446	804	104,264
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	Diesel oil	100,003	130	286	100,432
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	Diesel oil	42,513	61	122	42,695
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		14,744		14,744
Approximate Total Direct Emissions							**400,500 (0.4 MT CO_2-e)**

Assumptions:

- *Assumed four and a half years of production for P10 outcome.*
- *Flaring emissions assumed to be P10 reservoir outcome.*
- *Flaring reduced by 0.5mmscfd month 1-21 due to fuel gas use. 0.1mmscfd flare purge maintined for rest of field life.*
- *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)*

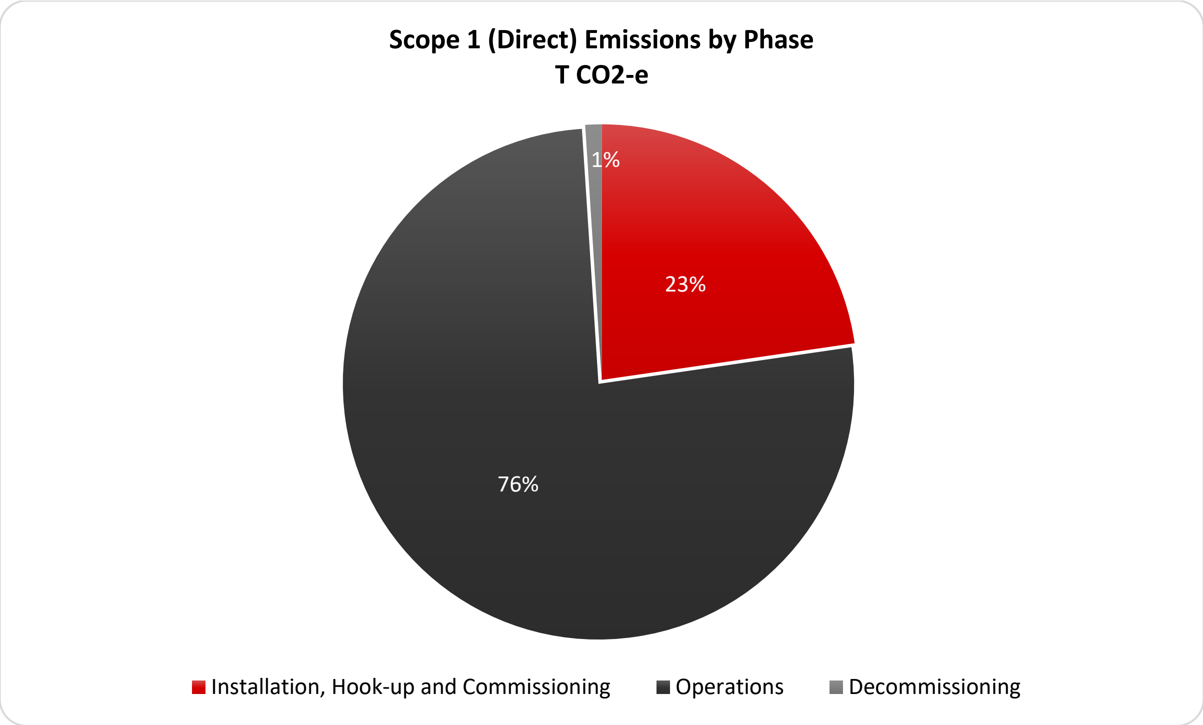

Figure 4-1 Amulet Development GHG emissions by Phase

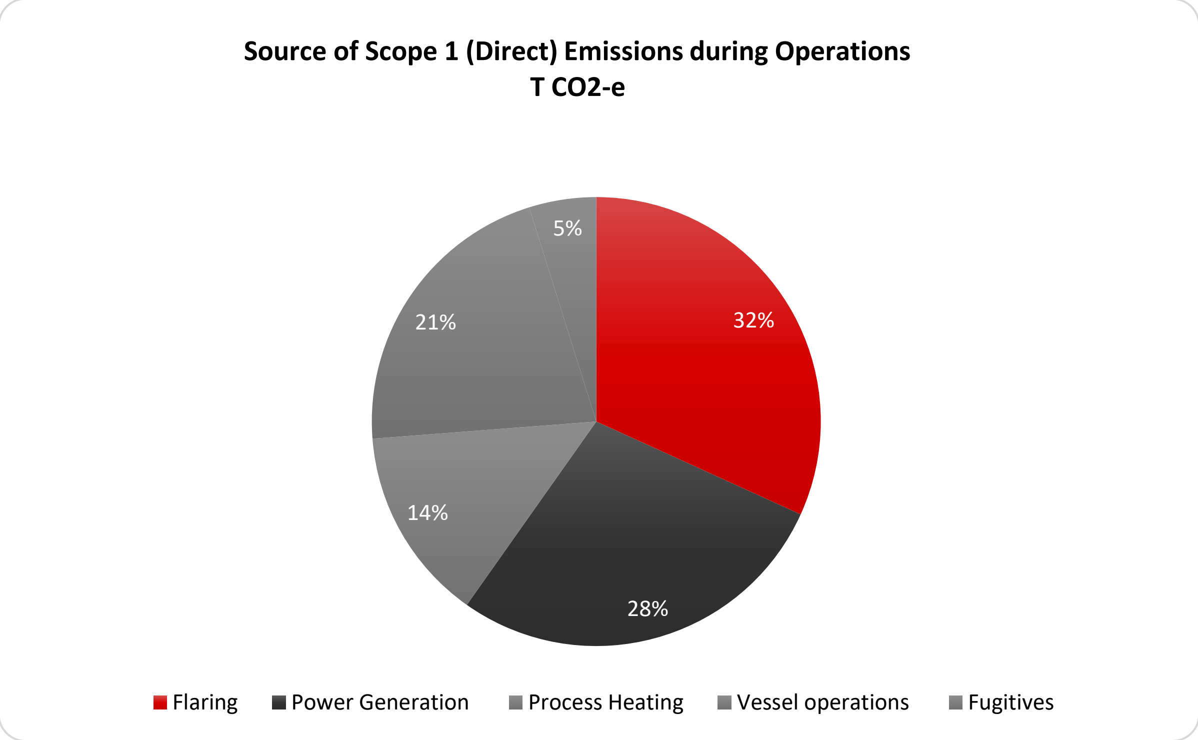

Figure 4-2 Amulet Development Operations Phase - GHG emissions by activity

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 Amulet Development direct (Scope 1) emissions against the total GHG inventory for WA and Australia.

Table 4-2 Comparison of Amulet Scope 1 Emissions to WA and Australian GHG emissions

Source of Emissions - Operations	% of WA's Annual GHG Emissions^	% of Australia's Annual GHG Emissions^
Maximum annual emissions of the Amulet Development*	0.13%	0.02%
Maximum emissions of total field life of Amulet Development#	0.46%	0.07%
Assumptions: • ** Using first year of high estimate (P10 profile)* • *# <3.5 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 Amulet 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 approximately 5.7 MT CO_2e.

Table 4-3 Amulet 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	1,554
Oil Refining	NGER (Measurement) Determination 2008: Crude oil refining	Oil Throughput	Crude oil refining	1,518
Oil Storage	NGER (Measurement) Determination 2008: Crude oil refining	Oil Throughput	Fixed roof tank	267
Consumer Use	NGER (Measurement) Determination 2008: Appendix 4 Scope 3 emission factors	Oil Throughput	Crude oil including crude oil condensates	5,656,998
			TOTAL Indirect (Scope 3) Emissions	**5,660,339 (5.7 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 GAS STRATEGY ALTERNATIVES - NET EMISSIONS

The Amulet reservoir will produce associated gas with the oil. This gas must be used, exported or disposed of to allow for production of the oil. Design / activity alternatives were identified for the Corowa Development's gas strategy in the OPP.

All options were considered as standalone and as a possible combination with other options. For ease of understanding and comprehension of the assessment, each option is presented here individually.

Table 5-1 shows the net GHG emissions for each option, calculated using the most conservative P10 basis over the full 48-month production profile.

Option 1 – Fuel gas can be combined with all other options and aggregates the GHG reduction – i.e. if used in combination, Option 1 – Fuel gas would provide an additional 0.1 MT $C0_2$-e reduction for each option.

Table 5-1 Net GHG Emissions – Gas Strategy Options

Gas Strategy Option		Net GHG Emissions	Assumptions
1	Fuel gas	This option would offset the use of liquid fuels such as diesel and reduce emissions from the facility to a maximum of ~0.1 MT $CO_2$2-e (P10).	Refer Section 3.2.1
2	Export via pipeline to existing gas treatment facility	If feasible, would reduce emissions by a maximum of ~0.9 MT CO_2-e (P10).	Assumed sizing for 100% of gas stream to be exported or injected, maintaining 0.1mmscfd flare purge.
3	Reinject gas to reservoir	If technically feasible, reinjection of associated gas would reduce emission by a maximum of ~0.06 MT CO_2-e (P10).	Assumed sizing for 100% of gas stream to be exported or injected, maintaining 0.1mmscfd flare purge.
4	Flare	0.1 MT CO_2-e (after use as fuel gas).	Refer Section 3.2.1
5	Gas to wire	If feasible may offset a maximum of ~0.06 MT CO_2-e (P10) of emissions from power generation facilities utilising other fuel sources.	This option would not reduce emissions from the MOPU facility.
6	New technologies (Compressed Natural Gas – CNG	If feasible, CNG could reduce emissions by a maximum of ~0.06 MT CO_2-e over the life of the project (P10).	CNG capacity assumed to be 6 MMscf/d for 16 months. Reduction in flaring of up to 6 MMscf/d.
	/ Mini Liquified natural gas (LNG)	If feasible, Mini-LNG (with feed of ~1 MMscf/d) could reduce emissions by a maximum of ~0.04 MT CO_2-e over the life of the project (P10).	LNG capacity: 6mmscfd feed gas = 0.042mtpa LNG, assumed turndown capacity would be 50% of this. 33% of feed gas assumed to be fuel use for LNG production. Could run for 16months @ P10.
7	Carbon Capture and Storage (CCS)	If technically feasible, CCS could remove emissions from heat and power fired equipment would reduce emission by a maximum of ~0.1 MT CO_2-e (P10).	

6 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.

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Appendix D: Amulet Development – Produced Formation Water and Cooling Water Discharge Modelling

Amulet Development

Produced Formation Water and Cooling Water Discharge Modelling

KATO Energy

Assignment Number: P100092-S00
Document Number: P-100092-S00-REPT-003

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Produced Formation Water and Cooling Water Discharge Modelling

P100092-S00

Client: KATO Energy
Document Type: Report
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CONTENTS

1 INTRODUCTION

1.1 Project Overview

The Amulet Development will be centred on the Amulet and Talisman oil fields, located within petroleum permit WA-8-L in the Carnarvon Basin, approximately 132 km offshore from Dampier in Western Australia. The field is in Commonwealth waters in approximately 85 m water depth.

KATO Energy Pty Ltd (KATO) plan to develop the Amulet and Talisman fields 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 Amulet Development.

1.3 Scope

During operations for the Amulet 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 some depth below sea level, from a pipe within one of the support legs of the MOPU.

The processing facilities and the machinery onboard the MODU, MOPU, FSO and vessels throughout all phases of the Amulet 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 MOPU will be at or some depth below sea level, from a pipe within one of the support legs. The discharge point from the FSO and vessels is also likely to be below sea level, however, will be vessel specific.

An assessment of near-field and far-field mixing behaviour of each of the PFW and CW discharge streams from the MOPU was undertaken to support an environmental risk assessment.

1.4 Abbreviations

The following abbreviations (Table 1-1) and units (Table 1-2) are used in this report.

Table 1-1 Abbreviations

Abbreviation	Description
CW	Cooling water
DGV	Default guideline value
EHS	Environmental, health and safety
FEED	Front end engineering design
FF	Far-field
FSO	Floating storage and offloading
HYCOM	Hybrid Coordinate Ocean Model

Abbreviation	Description
KATO	KATO Energy Pty Ltd
MODU	Mobile offshore drilling unit
MOPU	Mobile offshore production unit
NF	Near-field
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

Table 1-2 Units

Unit	Description
°C	degrees Celsius
µg/L	micrograms per litre
km	kilometre
m	metre
m/s	metres per second
mg/L	milligrams per litre
m^3/hr	cubic metres per hour
m^3/s	cubic metres per second
ppb	parts per billion

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 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 Environmental thresholds

2.2.1 Produced formation water

For the PFW discharge, the critical parameters that have the potential to impact the marine environment are the residual hydrocarbons and any temperature differential. The following 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, 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 residual chlorine (from treatment to prevent biofouling of pipework) and any temperature differential. The following 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 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.

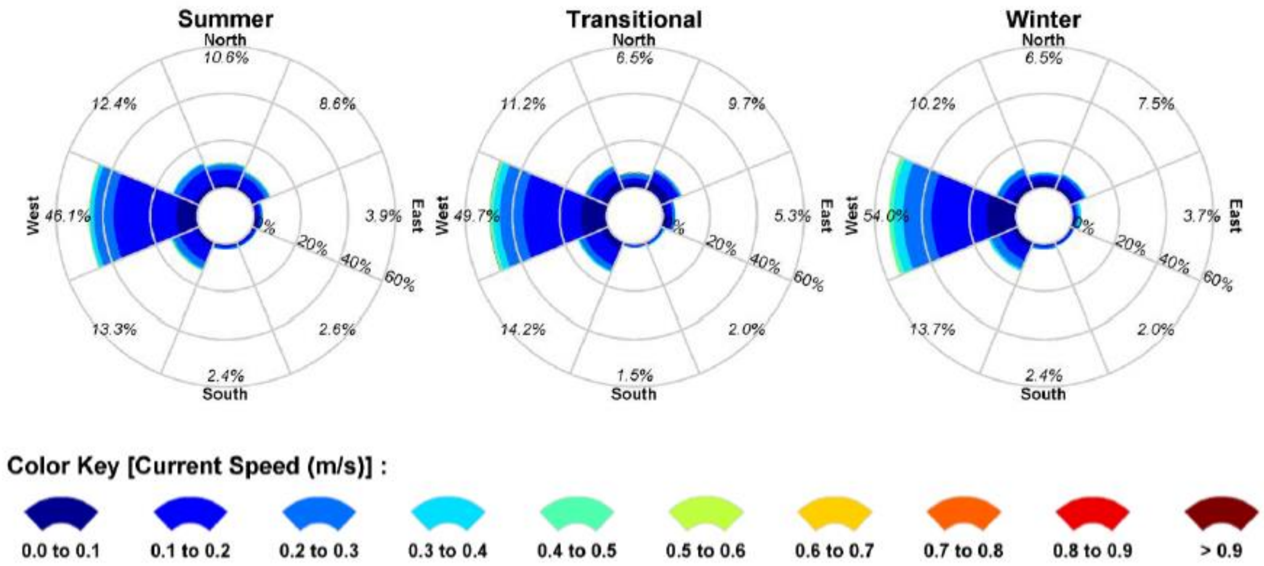
Table 2-1 Ambient temperature and salinity conditions

Depth (m)	Temperature (°C)	Salinity
0	25.3	34.9
30	25.2	34.9
40	25.1	34.9
50	25.0	34.9
60	24.5	35.0
75	24.0	35.0
80	24.0	35.0

2.3.2 Currents

Hybrid Coordinate Ocean Model (HYCOM) is a global circulation model. A ten year (2009–2018) hindcast dataset was extracted to provide current estimates for a point closest to the Amulet Development (Figure 2-1; RPS 2019).

Three current speeds across a typical expected range were used in the model simulations (0.05 m/s, 0.2 m/s and 0.5 m/s); with a consistent current direction (west) applied to all simulations.



Source: RPS 2019

^ The convention for defining current direction is the direction the current is flowing towards.

Figure 2-1 Expected seasonal current distribution in vicinity of Amulet Development

3 PRODUCED FORMATION WATER DISCHARGE

3.1 Scenario

The worst-case credible scenario for PFW discharge from the Amulet Development is when production is concurrent from both the Amulet and Talisman fields; this corresponds to a maximum discharge volume of 185 m^3/hr at 65 °C (Table 3-1). Model simulations were run for this worst-case discharge using variations in discharge depth (from near-surface to near-seabed alternatives) and ambient current conditions to evaluate the differences in plume mixing behaviour and spatial extent to reach environmental thresholds (Table 3-1). Final configuration of the PFW discharge (including volume, temperature and discharge depth) from the MOPU will occur during front end engineering design (FEED).

Note: There is only a single discharge of PFW for the Amulet Development as all fluids from the subsea wells at Talisman will be transferred to the MOPU at Amulet for processing and discharge.

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	30 m	0 m
Water depth	85 m		
Discharge characteristics			
Flow type	Continuous		
Flow rate	185 m^3/hr (0.051 m^3/s)		
Temperature	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 velocity	0.05 m/s	0.2 m/s	0.5 m/s
Current direction *	West		

^ Far-field dilution simulations used the same ambient characteristics and a default conservative value of a diffusion coefficient of 0.0003 $m^{2/3}/s^2$ and the 4/3 Power Law for open waters (Frick et al. 2003).

** The convention for defining current direction is the direction the current is flowing towards.*

3.2 Results

Table 3-2, Table 3-3 and Table 3-4 summarise the results of the PFW modelling simulations and mixing behaviours to reach the hydrocarbon and temperature thresholds.

Figure 3-1 shows a comparison of the different plume dynamics in the near-field resulting from discharging at different depths in the water column. The PFW discharges at depth (30 m and 75 m) for the selected scenario both show trapping of the near-field mixing as the plume dilutes to a similar density as the receiving ocean water at a depth below the ocean surface.

Screen grabs from model outputs are also shown in Appendix A.

Table 3-2 Mixing behaviour of PFW discharge under weak (0.05 m/s) ambient current conditions

Discharge Depth (below sea level)	0 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~34	~455	~350
Approximate horizontal extent of near-field mixing	~3 m	~23 m	~23 m
Approximate vertical extent of near-field mixing	Surface	Surface	Trap Level, ~62 m
Hydrocarbon threshold			
Approximate horizontal distance required to reach hydrocarbon threshold	~295 m	~22 m	~75 m
Approximate width of plume at this horizontal distance	~67 m	~22 m	~30 m
Type of mixing required to dilute PFW to meet the hydrocarbon threshold	NF + FF	NF	NF + FF
Temperature threshold			
Plume temperature at the edge of near-field mixing	~26.4 °C	~25.3 °C	~24.4 °C
Approximate horizontal distance that plume temperature first reaches ≤3°C variation from ambient conditions	<1 m	<1 m	<1 m
≤3°C variation from ambient conditions met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes
Type of mixing required to dilute PFW to meet the temperature threshold	NF	NF	NF

NF = Near field; FF = Far field

Table 3-3 Mixing behaviour of PFW discharge under average (0.2 m/s) ambient current conditions

Discharge Depth (below sea level)	0 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~69	~223	~962
Approximate horizontal extent of near-field mixing	~12 m	~36 m	~107 m
Approximate vertical extent of near-field mixing	Surface	Trap Level, ~31 m	Trap Level, ~71 m
Hydrocarbon threshold			
Approximate horizontal distance required to reach hydrocarbon threshold	~735 m	~340 m	~38 m
Approximate width of plume at this horizontal distance	~39 m	~22 m	~12 m
Type of mixing required to dilute PFW to meet the hydrocarbon threshold	NF + FF	NF + FF	NF
Temperature threshold			
Plume temperature at the edge of near-field mixing	~25.9 °C	~25.0 °C	~24.1 °C
Approximate horizontal distance that plume temperature first reaches ≤3°C variation from ambient conditions	<1 m	<1 m	<1 m
≤3°C variation from ambient conditions met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes
Type of mixing required to dilute PFW to meet the temperature threshold	NF	NF	NF

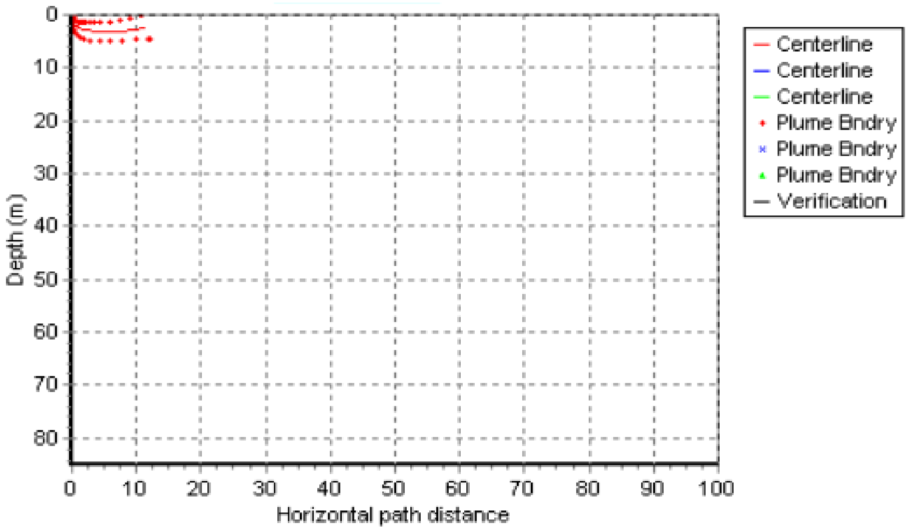
NF = Near field; FF = Far field

Table 3-4 Mixing behaviour of PFW discharge under strong (0.5 m/s) ambient current conditions

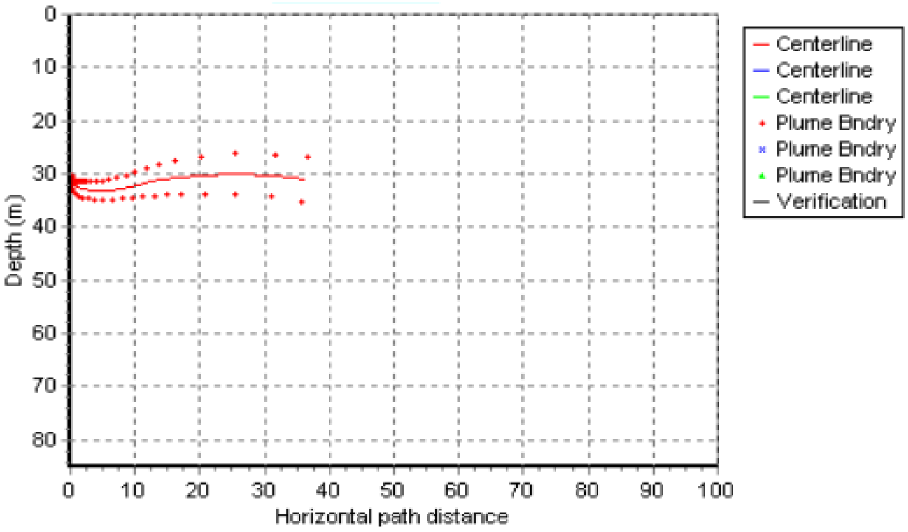
Discharge Depth (below sea level)	0 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~85	~310	~1,253
Approximate horizontal extent of near-field mixing	~26 m	~96 m	~261 m
Approximate vertical extent of near-field mixing	Surface	Trap Level, ~30 m	Trap Level, ~72 m
Hydrocarbon threshold			
Approximate horizontal distance required to reach hydrocarbon threshold	~1,215 m	~440 m	~75 m
Approximate width of plume at this horizontal distance	~22 m	~11 m	~7 m
Type of mixing required to dilute PFW to meet the hydrocarbon threshold	NF + FF	NF + FF	NF
Temperature threshold			
Plume temperature at the edge of near-field mixing	~25.8 °C	~25.1 °C	~24.1 °C
Approximate horizontal distance that plume temperature first reaches ≤3°C variation from ambient conditions	<1 m	<1 m	<1 m
≤3°C variation from ambient conditions met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes
Type of mixing required to dilute PFW to meet the temperature threshold	NF	NF	NF

NF = Near field; FF = Far field

Discharge Depth = 0 m



Discharge Depth = 30 m



Discharge Depth = 75 m

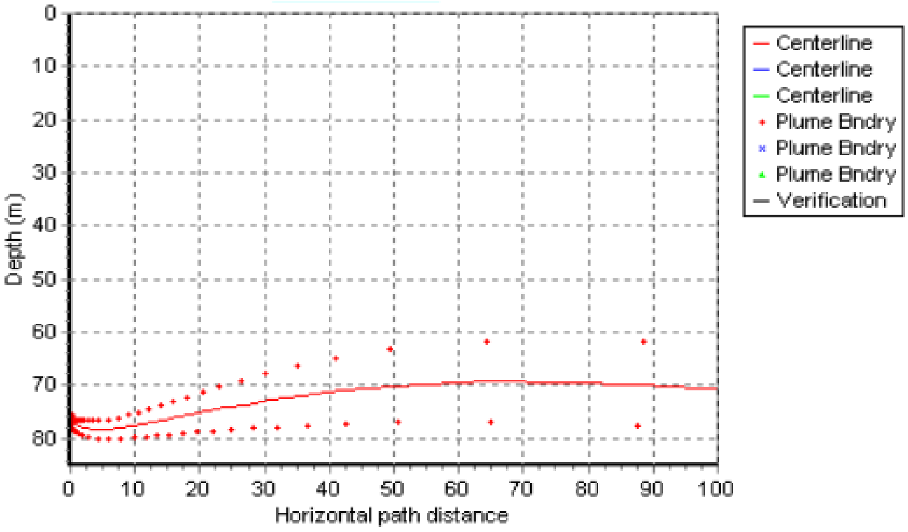


Figure 3-1 Predicted near-field PFW plume behaviour under average (0.2 m/s) ambient currents for different discharge depths (0 m, 30 m and 75 m below water surface)

3.3 Summary

The discharge modelling showed the following mixing behaviours for PFW from the MOPU:

- The PFW discharge is initially buoyant compared to ambient seawater, but for discharges at depths (e.g. ≥30 m) the discharged PFW plume is not always 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 spatial extent of the near-field mixing zone (i.e. the initial dilution phase) varies between ~3 m to ~261 m depending on the combination of discharge and ambient conditions.
- The PFW discharge plume is never predicted to interact with the seabed, even from the deepest modelled discharge (i.e. 75 m depth or 10 m above seabed).
- The spatial extent of mixing required to meet the hydrocarbon threshold varies between ~22 m and ~1,215 m. The hydrocarbon threshold is met under either near-field or far-field mixing depending on the combination of discharge and ambient conditions.
- The spatial extent of mixing required to meet the temperature threshold is <1 m. The temperature threshold is met under near-field mixing for all combinations of discharge and ambient conditions.

Therefore, the maximum horizontal mixing zone predicted to be needed for the PFW discharge from the MOPU for the Amulet Development is 1,215 m.

4 COOLING WATER DISCHARGE

4.1 Scenario

The worst-case credible scenario for CW discharge from the Amulet Development is from the MOPU at Amulet; this corresponds to a maximum discharge volume of 170 m^3/hr at 65 °C (Table 4-1). Model simulations were run for this worst-case discharge using variations in discharge depth (from near-surface to near-seabed alternatives) and ambient current conditions to evaluate the differences in plume mixing behaviour and spatial extent to reach environmental thresholds (Table 4-1). Final configuration of the CW discharge (including volume, temperature and discharge depth) from the MOPU will occur during FEED.

Note: There will be CW discharge from other vessels and facilities, but these are expected to be a smaller volume and/or discontinuous flows. Therefore, only the discharge from the MOPU has been modelled as this represents the largest continuous point source of CW discharge.

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	30 m	2 m
Water depth	85 m		
Discharge characteristics			
Flow type	Continuous		
Flow rate	170 m^3/hr (0.047 m^3/s)		
Temperature	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
Current direction *	West		

^ Far-field dilution simulations used the same ambient characteristics and a default conservative value of a diffusion coefficient of 0.0003 $m^{2/3}/s^2$ and the 4/3 Power Law for open waters (Frick et al. 2003).

** The convention for defining current direction is the direction the current is flowing towards.*

4.2 Results

Table 4-2, Table 4-3 and Table 4-4 summarise the results of the CW modelling simulations and the mixing behaviours to reach the chlorine and temperature thresholds.

Figure 4-1 shows a comparison of the different plume dynamics in the near-field resulting from discharging at different depths in the water column. The CW discharge at 75 m depth for the selected simulation shows trapping of the plume within the near-field as an equilibrium density between the plume and the receiving ocean water is met at a depth below the ocean surface.

Screen grabs from model outputs are also shown in Appendix B.

Table 4-2 Mixing behaviour of CW discharge under weak (0.05 m/s) ambient current conditions

Discharge Depth (below sea level)	2 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~11	~289	~277
Approximate horizontal extent of near-field mixing	~1 m	~11 m	~18 m
Approximate vertical extent of near-field mixing	Surface	Surface	Trap Level, ~57 m
Chlorine threshold			
Approximate horizontal distance required to reach chlorine threshold	~555 m	~150 m	~180 m
Approximate width of plume at this horizontal distance	~149 m	~43 m	~53 m
Type of mixing required to dilute CW to meet the chlorine threshold	NF + FF	NF	NF + FF
Temperature threshold			
Plume temperature at the edge of near-field mixing	~28.8 °C	~25.4 °C	~24.7 °C
Approximate horizontal distance that plume temperature first reaches ≤3°C variation from ambient conditions	~15 m	<2 m	<2 m
≤3°C variation from ambient conditions met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes
Type of mixing required to dilute CW to meet the temperature threshold	NF + FF	NF	NF

NF = Near field; FF = Far field

Table 4-3 Mixing behaviour of CW discharge under average (0.2 m/s) ambient current conditions

Discharge Depth (below sea level)	2 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~34	~2,064	~906
Approximate horizontal extent of near-field mixing	~5 m	~110 m	~99 m
Approximate vertical extent of near-field mixing	Surface	Surface	Trap Level, ~68 m
Chlorine threshold			
Approximate horizontal distance required to reach chlorine threshold	~1,440 m	~44 m	~58 m
Approximate width of plume at this horizontal distance	~85 m	~14 m	~14 m
Type of mixing required to dilute CW to meet the chlorine threshold	NF + FF	NF	NF
Temperature threshold			
Plume temperature at the edge of near-field mixing	~26.4 °C	~25.3 °C	~24.2 °C
Approximate horizontal distance that plume temperature first reaches ≤3°C variation from ambient conditions	<3 m	<3 m	<3 m
≤3°C variation from ambient conditions met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes
Type of mixing required to dilute CW to meet the temperature threshold	NF	NF	NF

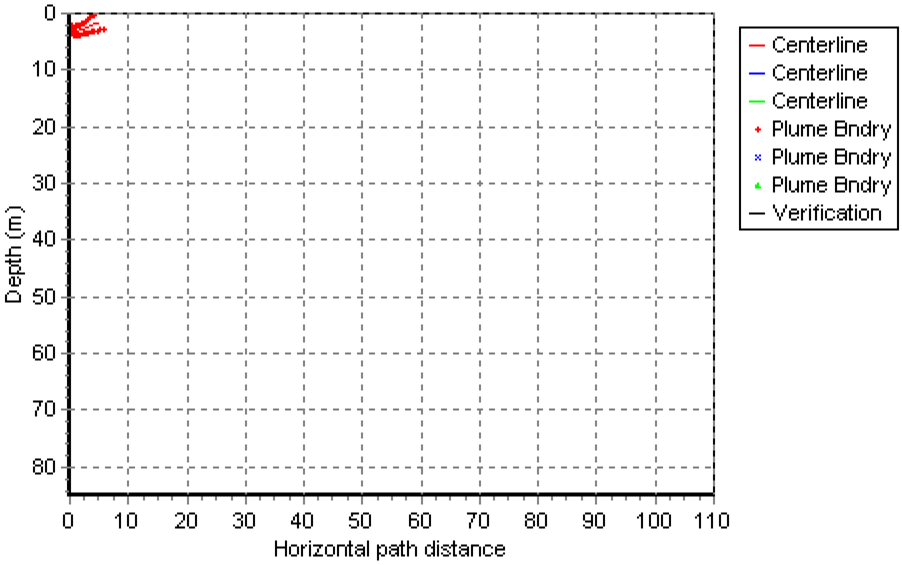
NF = Near field; FF = Far field

Table 4-4 Mixing behaviour of CW discharge under strong (0.5 m/s) ambient current conditions

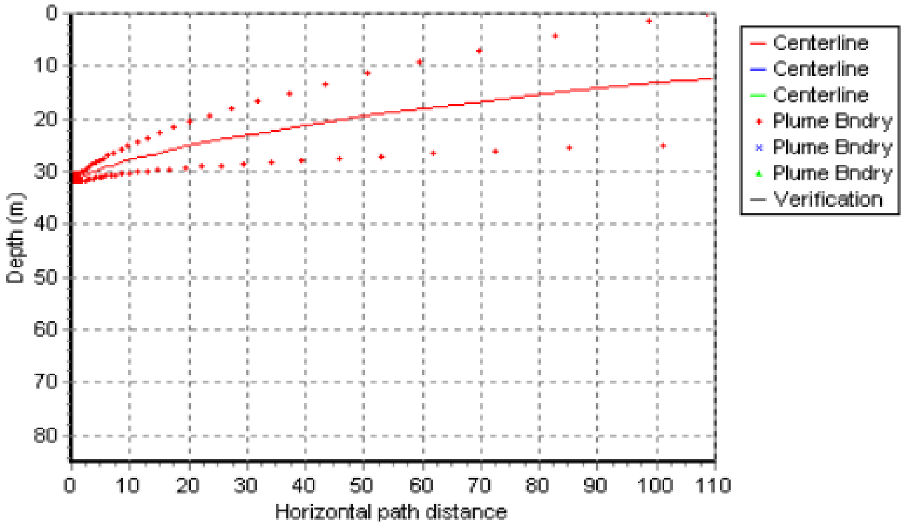
Discharge Depth (below sea level)	2 m	30 m	75 m
Near-field mixing zone			
Predicted average dilution under near-field mixing	~70	~5,446	~1,230
Approximate horizontal extent of near-field mixing	~17 m	~760 m	~247 m
Approximate vertical extent of near-field mixing	Surface	Trap Level, ~17 m	Trap Level, ~70 m
Chlorine threshold			
Approximate horizontal distance required to reach chlorine threshold	~1,960 m	~86 m	~96 m
Approximate width of plume at this horizontal distance	~38 m	~9 m	~9 m
Type of mixing required to dilute CW to meet the chlorine threshold	NF + FF	NF	NF
Temperature threshold			
Plume temperature at the edge of near-field mixing	~25.8 °C	~25.2 °C	~24.2 °C
Approximate horizontal distance that plume temperature first reaches ≤3°C variation from ambient conditions	<5 m	<8 m	<5 m
≤3°C variation from ambient conditions met at the edge of the near-field mixing zone and/or within 100 m from point of discharge	Yes	Yes	Yes
Type of mixing required to dilute CW to meet the temperature threshold	NF	NF	NF

NF = Near field; FF = Far field

Discharge Depth = 2 m



Discharge Depth = 30 m



Discharge Depth = 75 m

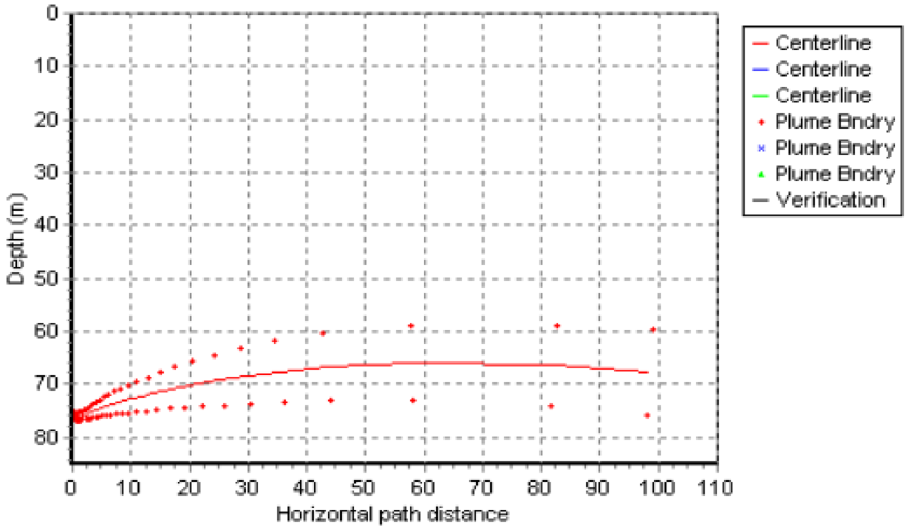


Figure 4-1 Predicted near-field CW plume behaviour under average (0.2 m/s) ambient currents for different discharge depths (2 m, 30 m and 75 m below water surface)

4.3 Summary

The discharge modelling showed the following mixing behaviours for CW from the MOPU:

> The CW discharge is initially buoyant compared to ambient seawater, but for discharges at depths (e.g. ≥30 m) the discharged CW plume is not always 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 spatial extent of the near-field mixing zone (i.e. the initial dilution phase) varies between ~1 m to ~760 m depending on the combination of discharge and ambient conditions.

> The CW discharge plume is never predicted to interact with the seabed, even from the deepest modelled discharge (i.e. 75 m depth or 10 m above seabed).

> The spatial extent of mixing required to meet the chlorine threshold varies between ~44 m and ~1,960 m. The chlorine threshold is met under either near-field or far-field mixing depending on the combination of discharge and ambient conditions.

> The spatial extent of mixing required to meet the temperature threshold varies between <2 m and ~15 m. The temperature threshold is predominantly met under near-field mixing.

> One simulation required some far-field mixing to occur to meet the temperature threshold (see 2 m depth discharge simulation in Table 4-2), however the threshold was still met well within the default 100 m distance defined in the EHS Guidelines (IFC 2015). This default part of the guideline is considered appropriate for this simulation 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 mixing zone predicted to be needed for the CW discharge from the MOPU for the Amulet Development is 1,960 m.

5 REFERENCES

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APPENDIX A VPLUMES RESULTS FOR PRODUCED FORMATION WATER MODELLING

Appendix A.1 Discharge under weak (0.05 m/s) ambient currents

Port Depth = 0 m

```
/ UM3. 3/21/2020 12:20:37 AM
Case 1; ambient file c:\plumes\VP plume 5.001.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     180.0      34.9      25.3       0.0       0.0      0.05     180.0    0.0003      23.2
.....
       80.0      0.05     180.0      35.0      24.0       0.0       0.0      0.05     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    85.0   -90.0   180.0     1.0   100.0  5000.0     0.0   0.051    37.0    65.0    29.0

Simulation:
Froude number:       18.56; effluent density (sigma-T)      6.656; effleunt velocity     2.886(m/s);
        Depth  Amb-cur    P-dia      Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn   y-posn
Step      (m)    (m/s)      (m)       (C)    (ppm)    (ppm)       ()       ()      (m)      (m)
   0      0.0     0.05     0.15      65.0     29.0     29.0      1.0      1.0      0.0      0.0;
   8   0.0627     0.05    0.174     59.18    24.75    24.75    1.168      1.0-0.000105      0.0; matched energy radia
.....
 138    4.217     0.05    2.777      28.2    2.122    2.122    13.46    6.324   -0.599      0.0; begin overlap;
 140    4.261     0.05    2.859     28.15    2.089    2.089    13.67    6.363    -0.62      0.0;
.....
 390    1.492     0.05    3.704     26.63    0.976    0.976    29.26    14.23   -2.963      0.0;
 398    0.595     0.05    3.989     26.43    0.833    0.833    34.28    16.68   -3.295      0.0; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of      3.99 m
    conc   dilutn    width distnce     time
   (ppm)              (m)     (m)    (hrs) (kg/kg)    (s-1)     (m/s)(m0.67/s2)
 0.83187    34.31    4.185     5.0  0.00947    0.0      0.0      0.05 3.00E-4
 0.82546    34.58    4.778    10.0   0.0373    0.0      0.0      0.05 3.00E-4
.....
 7.10E-2    408.2    65.67   290.0    1.593    0.0      0.0      0.05 3.00E-4
 6.94E-2    417.2    67.13   295.0    1.621    0.0      0.0      0.05 3.00E-4
 6.79E-2    426.4     68.6   300.0    1.648    0.0      0.0      0.05 3.00E-4
 6.65E-2    435.6    70.07   305.0    1.676    0.0      0.0      0.05 3.00E-4
 6.51E-2    444.8    71.56   310.0    1.704    0.0      0.0      0.05 3.00E-4
 6.38E-2    454.1    73.06   315.0    1.732    0.0      0.0      0.05 3.00E-4
 6.25E-2    463.5    74.57   320.0    1.759    0.0      0.0      0.05 3.00E-4
 6.12E-2    473.0    76.09   325.0    1.787    0.0      0.0      0.05 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 3/20/2020 1:03:30 AM
Case 1; ambient file c:\plumes\VP plume 3.001.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     180.0      34.9      25.3       0.0       0.0      0.05     180.0    0.0003      23.2
.....
       80.0      0.05     180.0      35.0      24.0       0.0       0.0      0.05     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    55.0   -90.0   180.0     1.0   100.0  5000.0    30.0   0.051    37.0    65.0    29.0

Simulation:
Froude number:       18.55; effluent density (sigma-T)      6.656; effleunt velocity     2.886(m/s);
        Depth  Amb-cur    P-dia      Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn   y-posn
Step      (m)    (m/s)      (m)       (C)    (ppm)    (ppm)       ()       ()      (m)      (m)
   0     30.0     0.05     0.15      65.0     29.0     29.0      1.0      1.0      0.0      0.0;
   5    30.04     0.05    0.164     61.25    26.27    26.27    1.102      1.0-4.117E-5      0.0;
.....
 125    33.73     0.05    2.185     28.09    2.494    2.494    11.45    5.642   -0.429      0.0;
 130     33.9     0.05    2.424     27.86    2.352    2.352    12.14    5.874   -0.489      0.0;
.....
 505    15.76     0.05    15.73     25.29    0.116    0.116    246.2     89.0   -14.12      0.0;
 510    14.87     0.05    16.73     25.29    0.105    0.105    271.8    96.11   -15.25      0.0;
 515    13.96     0.05    17.79     25.28   0.0951   0.0951    300.1    103.7   -16.49      0.0;
 520    13.04     0.05    18.91     25.28   0.0861   0.0861    331.3    111.7   -17.83      0.0;
 525    12.11     0.05     20.1     25.28    0.078    0.078    365.8    120.2    -19.3      0.0;
 530    11.16     0.05    21.35     25.28   0.0706   0.0706    403.9    129.2   -20.91      0.0;
 534    10.41     0.05    22.41     25.28   0.0653   0.0653    437.2    136.8   -22.32      0.0; trap level;
 535    10.22     0.05    22.68     25.28    0.064    0.064    445.9    138.8   -22.69      0.0;
 536    10.03     0.05    22.96     25.28   0.0627   0.0627    454.9    140.7   -23.07      0.0; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of     22.96 m
    conc   dilutn    width distnce     time
   (ppm)              (m)     (m)    (hrs) (kg/kg)    (s-1)     (m/s)(m0.67/s2)
 6.27E-2    455.2    24.39    30.0   0.0385    0.0      0.0      0.05 3.00E-4
 6.26E-2    456.1    26.51    40.0   0.0941    0.0      0.0      0.05 3.00E-4
 6.14E-2    464.5    28.68    50.0     0.15    0.0      0.0      0.05 3.00E-4
 5.93E-2    481.3    30.91    60.0    0.205    0.0      0.0      0.05 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 3/20/2020 12:05:57 AM
Case 1; ambient file c:\plumes\VP plume 3.001.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      180.0       34.9       25.3        0.0        0.0      0.05     180.0    0.0003      23.2
.....
      80.0      0.05      180.0       35.0       24.0        0.0        0.0      0.05     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    10.0   -90.0   180.0     1.0   100.0  5000.0    75.0   0.051    37.0    65.0    29.0

Simulation:
Froude number:      18.31; effleunt density (sigma-T)     6.656; effleunt velocity      2.886(m/s);
        Depth  Amb-cur    P-dia      Temp  Polutnt  4/3Eddy   Dilutn  CL-diln    x-posn    y-posn
Step      (m)    (m/s)      (m)       (C)    (ppm)    (ppm)       ()       ()       (m)       (m)
   0     75.0     0.05     0.15      65.0     29.0     29.0      1.0      1.0       0.0       0.0;
  10    75.08     0.05    0.181     57.63    23.79    23.79    1.214      1.0-0.000167        0.0;
.....
 130    78.98     0.05    2.415     27.26    2.306    2.306    12.38     6.01    -0.504       0.0;
 138    79.21     0.05    2.778     27.01    2.127    2.127    13.42    6.299    -0.597       0.0; begin overlap;
.....
 640    60.91     0.05    18.01     24.45   0.0917   0.0917    310.9    109.1    -21.26       0.0;
 646    62.22     0.05    19.25     24.45   0.0815   0.0815    350.1    120.2    -23.06       0.0; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       19.25 m
    conc   dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs) (kg/kg)   (s-1)    (m/s)(m0.67/s2)
 8.14E-2    350.4    20.61    30.0  0.0386     0.0     0.0    0.05 3.00E-4
 8.11E-2    351.9    22.61    40.0  0.0941     0.0     0.0    0.05 3.00E-4
 7.90E-2    361.3    24.68    50.0    0.15     0.0     0.0    0.05 3.00E-4
 7.55E-2    378.0     26.8    60.0   0.205     0.0     0.0    0.05 3.00E-4
 7.15E-2    399.6    28.99    70.0   0.261     0.0     0.0    0.05 3.00E-4
 6.74E-2    424.4    31.23    80.0   0.316     0.0     0.0    0.05 3.00E-4
 6.34E-2    451.4    33.52    90.0   0.372     0.0     0.0    0.05 3.00E-4
 5.97E-2    480.0    35.87   100.0   0.427     0.0     0.0    0.05 3.00E-4
 5.62E-2    509.9    38.27   110.0   0.483     0.0     0.0    0.05 3.00E-4
 5.30E-2    541.0    40.72   120.0   0.539     0.0     0.0    0.05 3.00E-4
 5.01E-2    573.0    43.22   130.0   0.594     0.0     0.0    0.05 3.00E-4
```

Appendix A.2 Discharge under average (0.2 m/s) ambient currents

Port Depth = 0 m

```
/ UM3. 3/21/2020 12:23:24 AM
Case 1; ambient file c:\plumes\VP plume 5.001.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      180.0       34.9       25.3        0.0        0.0       0.2     180.0    0.0003      23.2
.....
      80.0       0.2      180.0       35.0       24.0        0.0        0.0       0.2     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    85.0   -90.0   180.0     1.0   100.0  5000.0     0.0   0.051    37.0    65.0    29.0

Simulation:
Froude number:      18.56; effleunt density (sigma-T)     6.656; effleunt velocity      2.886(m/s);
        Depth  Amb-cur    P-dia      Temp  Polutnt  4/3Eddy   Dilutn  CL-diln    x-posn    y-posn
Step      (m)    (m/s)      (m)       (C)    (ppm)    (ppm)       ()       ()       (m)       (m)
   0      0.0      0.2     0.15      65.0     29.0     29.0      1.0      1.0       0.0       0.0;
   8   0.0627      0.2    0.174     59.18    24.75    24.75    1.168      1.0 -0.00042        0.0; matched energy radia
.....
 130     2.11      0.2    1.677     28.58      2.4      2.4     11.9    4.633    -0.658       0.0;
 140     2.25      0.2    1.889     28.12    2.064    2.064    13.84    5.024    -0.801       0.0;
 150    2.385      0.2    2.109     27.73    1.778    1.778    16.06    5.427    -0.969       0.0;
.....
 250    2.327      0.2    4.616     25.88     0.43     0.43    66.41    17.76    -11.22       0.0;
 252    2.248      0.2    4.705     25.86    0.413    0.413    69.09    18.51    -11.55       0.0; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of        4.70 m
    conc   dilutn    width distnce     time
   (ppm)               (m)     (m)    (hrs) (kg/kg)   (s-1)    (m/s)(m0.67/s2)
 0.41231    69.21    4.809    15.0 0.00479     0.0     0.0     0.2 3.00E-4
.....
 7.21E-2    401.0    37.73   715.0   0.977     0.0     0.0     0.2 3.00E-4
 7.15E-2    404.2    38.03   720.0   0.984     0.0     0.0     0.2 3.00E-4
 7.10E-2    407.4    38.33   725.0   0.991     0.0     0.0     0.2 3.00E-4
 7.04E-2    410.7    38.64   730.0   0.998     0.0     0.0     0.2 3.00E-4
 6.99E-2    413.8    38.94   735.0   1.005     0.0     0.0     0.2 3.00E-4
 6.94E-2    417.0    39.25   740.0   1.012     0.0     0.0     0.2 3.00E-4
 6.88E-2    420.3    39.55   745.0   1.019     0.0     0.0     0.2 3.00E-4
 6.83E-2    423.5    39.86   750.0   1.026     0.0     0.0     0.2 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 3/20/2020 12:58:12 AM
Case 1; ambient file c:\plumes\VP plume 3.001.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     180.0      34.9      25.3       0.0       0.0       0.2     180.0    0.0003      23.2
.....
      80.0       0.2     180.0      35.0      24.0       0.0       0.0       0.2     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    55.0   -90.0   180.0     1.0   100.0  5000.0    30.0   0.051    37.0    65.0    29.0

Simulation:
Froude number:     18.55; effleunt density (sigma-T)    6.656; effleunt velocity    2.886(m/s);
        Depth  Amb-cur    P-dia     Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn   y-posn
Step      (m)    (m/s)      (m)      (C)    (ppm)    (ppm)       ()       ()      (m)      (m)
  0      30.0      0.2     0.15     65.0     29.0     29.0      1.0      1.0      0.0      0.0;
  5     30.04      0.2    0.164    61.25    26.27    26.27    1.102      1.0-0.000165     0.0;
.....
 130     32.1      0.2    1.675    28.14    2.409    2.409    11.85     4.61   -0.654      0.0;
 135    32.17      0.2    1.779    27.88    2.236    2.236    12.77    4.799   -0.722      0.0;
.....
 320    30.36      0.2     7.87    24.98     0.15     0.15    190.6    49.26   -31.38      0.0;
 325    30.72      0.2    8.259    24.99    0.136    0.136    210.4    54.57   -34.53      0.0;
 328    30.91      0.2    8.508    24.99    0.128    0.128    223.3    57.86    -36.3      0.0; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of        8.51 m
    conc  dilutn    width distnce     time
   (ppm)             (m)     (m)    (hrs) (kg/kg)   (s-1)   (m/s)(m0.67/s2)
 0.12748   223.8   8.644    40.0  0.00514     0.0     0.0     0.2 3.00E-4
 0.12765   223.5   9.016    50.0    0.019     0.0     0.0     0.2 3.00E-4
.....
 7.06E-2   407.0   21.33   330.0    0.408     0.0     0.0     0.2 3.00E-4
 6.90E-2   416.4   21.83   340.0    0.422     0.0     0.0     0.2 3.00E-4
 6.75E-2   425.9   22.34   350.0    0.436     0.0     0.0     0.2 3.00E-4
 6.60E-2   435.4   22.85   360.0     0.45     0.0     0.0     0.2 3.00E-4
 6.46E-2   445.1   23.36   370.0    0.463     0.0     0.0     0.2 3.00E-4
 6.33E-2   454.8   23.88   380.0    0.477     0.0     0.0     0.2 3.00E-4
 6.19E-2   464.6    24.4   390.0    0.491     0.0     0.0     0.2 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 3/20/2020 12:27:39 AM
Case 1; ambient file c:\plumes\VP plume 3.001.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     180.0      34.9      25.3       0.0       0.0       0.2     180.0    0.0003      23.2
.....
      80.0       0.2     180.0      35.0      24.0       0.0       0.0       0.2     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle    Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    10.0   -90.0   180.0     1.0   100.0  5000.0    75.0   0.051    37.0    65.0    29.0

Simulation:
Froude number:     18.31; effleunt density (sigma-T)    6.656; effleunt velocity    2.886(m/s);
        Depth  Amb-cur    P-dia     Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn   y-posn
Step      (m)    (m/s)      (m)      (C)    (ppm)    (ppm)       ()       ()      (m)      (m)
  0      75.0      0.2     0.15     65.0     29.0     29.0      1.0      1.0      0.0      0.0;
  5     75.04      0.2    0.164    61.13    26.27    26.27    1.102      1.0-0.000165     0.0;
.....
 135    77.18      0.2    1.782    27.15    2.227    2.227    12.82     4.82   -0.726      0.0;
 140    77.25      0.2    1.888    26.92    2.066    2.066    13.81    5.014     -0.8      0.0;
.....
 335    72.38      0.2    10.68    24.14   0.0801   0.0801    355.9    94.09   -33.38      0.0;
 340    71.96      0.2    11.23    24.13   0.0726   0.0726    392.9    103.5   -35.85      0.0;
 345    71.52      0.2    11.81    24.13   0.0657   0.0657    433.8    113.9   -38.64      0.0;
 348    71.25      0.2    12.17    24.13    0.062    0.062    460.3    120.6   -40.49      0.0; trap level;
 350    71.07      0.2    12.42    24.13   0.0595   0.0595    478.9    125.2   -41.81      0.0;
 355     70.6      0.2    13.07    24.13   0.0539   0.0539    528.8    137.7   -45.51      0.0;
 360    70.11      0.2    13.74    24.13   0.0488   0.0488    583.8    151.4   -49.99      0.0;
 365    69.63      0.2    14.46    24.13   0.0442   0.0442    644.6    166.4   -55.75      0.0;
 370    69.19      0.2     15.2    24.14   0.0401   0.0401    711.7    183.0   -64.53      0.0;
 374     69.1      0.2    15.55    24.14   0.0383   0.0383    743.8    191.0   -73.52      0.0; local maximum rise o
 375    69.14      0.2    15.58    24.14   0.0382   0.0382    746.7    191.8   -75.75      0.0;
 380    69.69      0.2    16.01    24.14   0.0361   0.0361    789.6    203.6   -87.94      0.0;
 385    70.44      0.2    16.81    24.15   0.0327   0.0327    871.7    225.3   -98.01      0.0;
 387    70.72      0.2    17.14    24.15   0.0314   0.0314    907.0    234.4   -101.5      0.0; acute zone;
 390    71.12      0.2    17.66    24.15   0.0296   0.0296    962.5    248.7   -106.7      0.0; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       17.66 m
```

Appendix A.3 Discharge under strong (0.5 m/s) ambient currents

Port Depth = 0 m

```
/ UM3. 3/21/2020 12:16:57 AM
Case 1; ambient file c:\plumes\VP plume 5.001.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     180.0      34.9      25.3       0.0       0.0       0.5     180.0    0.0003      23.2
.....
      80.0      0.5     180.0      35.0      24.0       0.0       0.0       0.5     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    85.0   -90.0   180.0     1.0   100.0  5000.0     0.0   0.051    37.0    65.0    29.0

Simulation:
Froude number:       18.56; effleunt density (sigma-T)     6.656; effleunt velocity      2.886(m/s);
        Depth  Amb-cur     P-dia     Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn    y-posn
Step      (m)    (m/s)       (m)      (C)    (ppm)    (ppm)       ()       ()      (m)       (m)
   0      0.0      0.5      0.15     65.0     29.0     29.0      1.0      1.0      0.0       0.0;
  10    0.068      0.5     0.181    57.87    23.79    23.79    1.214      1.0  -0.0014       0.0; matched energy radia
.....
 140    1.101      0.5     1.296    28.29    2.184    2.184    13.07    3.671   -0.775       0.0;
 150      1.2      0.5     1.444    27.75    1.792    1.792    15.94    4.292   -1.036       0.0;
.....
 230    1.763      0.5     3.178     25.8    0.371    0.371    76.88    19.57   -23.61       0.0;
 235    1.633      0.5     3.337    25.75    0.336    0.336    84.88    21.65   -25.84       0.0; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of      3.34 m
    conc   dilutn    width distnce    time
   (ppm)               (m)     (m)   (hrs) (kg/kg)   (s-1)   (m/s)(m0.67/s2)
 0.33539    85.08    3.382    30.0 0.00231     0.0     0.0     0.5 3.00E-4
 0.33569     85.0    3.436    35.0 0.00509     0.0     0.0     0.5 3.00E-4
.....|
 7.15E-2    404.5    21.97  1195.0    0.65     0.0     0.0     0.5 3.00E-4
 7.11E-2    406.3    22.07  1200.0   0.652     0.0     0.0     0.5 3.00E-4
 7.08E-2    408.2    22.18  1205.0   0.655     0.0     0.0     0.5 3.00E-4
 7.05E-2    410.1    22.28  1210.0   0.658     0.0     0.0     0.5 3.00E-4
 7.02E-2    411.9    22.38  1215.0   0.661     0.0     0.0     0.5 3.00E-4
 6.98E-2    413.8    22.48  1220.0   0.663     0.0     0.0     0.5 3.00E-4
 6.95E-2    415.7    22.58  1225.0   0.666     0.0     0.0     0.5 3.00E-4
 6.92E-2    417.5    22.68  1230.0   0.669     0.0     0.0     0.5 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 3/20/2020 12:42:16 AM
Case 1; ambient file c:\plumes\VP plume 3.001.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     180.0      34.9      25.3       0.0       0.0       0.5     180.0    0.0003      23.2
.....
      80.0      0.5     180.0      35.0      24.0       0.0       0.0       0.5     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    55.0   -90.0   180.0     1.0   100.0  5000.0    30.0   0.051    37.0    65.0    29.0

Simulation:
Froude number:       18.55; effleunt density (sigma-T)     6.656; effleunt velocity      2.886(m/s);
        Depth  Amb-cur     P-dia     Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn    y-posn
Step      (m)    (m/s)       (m)      (C)    (ppm)    (ppm)       ()       ()      (m)       (m)
   0     30.0      0.5      0.15     65.0     29.0     29.0      1.0      1.0      0.0       0.0;
   5    30.03      0.5     0.164    61.25    26.27    26.27    1.102      1.0-0.000356       0.0;
.....
 135    31.05      0.5     1.226    28.31    2.413    2.413    11.83    3.411   -0.672       0.0;
 140     31.1      0.5     1.296    27.99    2.186    2.186    13.06    3.667   -0.774       0.0;
.....
 290    29.85      0.5     5.704    25.08    0.114    0.114    249.5    63.91   -70.55       0.0; local maximum rise or
 295     30.2      0.5     5.991     25.1    0.104    0.104    275.5    70.65   -86.76       0.0;
 300    30.45      0.5     6.294     25.1   0.0938   0.0938    304.2    78.03   -94.93       0.0;
 301     30.5      0.5     6.357     25.1    0.092    0.092    310.3    79.59   -96.54       0.0; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      6.36 m
    conc   dilutn    width distnce    time
   (ppm)               (m)     (m)   (hrs) (kg/kg)   (s-1)   (m/s)(m0.67/s2)
 9.17E-2    311.2    6.403   100.0 0.00192     0.0     0.0     0.5 3.00E-4
 9.18E-2    310.7    6.537   110.0 0.00748     0.0     0.0     0.5 3.00E-4
.....|
 7.03E-2    407.1    11.29   430.0   0.185     0.0     0.0     0.5 3.00E-4
 6.95E-2    412.4    11.45   440.0   0.191     0.0     0.0     0.5 3.00E-4
 6.86E-2    417.7    11.61   450.0   0.196     0.0     0.0     0.5 3.00E-4
 6.77E-2    423.1    11.78   460.0   0.202     0.0     0.0     0.5 3.00E-4
 6.69E-2    428.6    11.94   470.0   0.207     0.0     0.0     0.5 3.00E-4
 6.60E-2    434.1    12.11   480.0   0.213     0.0     0.0     0.5 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 3/20/2020 12:35:31 AM
Case 1; ambient file c:\plumes\VP plume 3.001.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      180.0       34.9       25.3        0.0        0.0        0.5      180.0    0.0003       23.2
.....
      80.0        0.5      180.0       35.0       24.0        0.0        0.0        0.5      180.0    0.0003      23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppm)
    0.15    10.0   -90.0   180.0     1.0   100.0  5000.0    75.0   0.051    37.0    65.0    29.0

Simulation:|
Froude number:      18.31; effleunt density (sigma-T)     6.656; effleunt velocity     2.886(m/s);
       Depth  Amb-cur     P-dia     Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn   y-posn
Step     (m)    (m/s)       (m)      (C)    (ppm)    (ppm)       ()       ()      (m)      (m)
   0    75.0      0.5      0.15     65.0     29.0     29.0      1.0      1.0      0.0     0.0;
   5   75.03      0.5     0.164    61.13    26.27    26.27    1.102      1.0-0.000355     0.0;
.....
 135   76.05      0.5     1.226    27.41    2.412    2.412    11.83    3.411   -0.672     0.0;
 140    76.1      0.5     1.296    27.09    2.185    2.185    13.06    3.667   -0.774     0.0;
 145   76.15      0.5     1.368     26.8    1.979    1.979    14.42    3.958   -0.894     0.0;
.....
 310   73.74      0.5     6.977    24.12   0.0762   0.0762    374.5    96.37   -69.88     0.0;
 315   73.46      0.5     7.331    24.11    0.069    0.069    413.5    106.4   -74.76     0.0;
 320   73.17      0.5     7.703     24.1   0.0625   0.0625    456.5    117.5   -80.13     0.0;
 325   72.87      0.5     8.093     24.1   0.0566   0.0566    504.0    129.7   -86.08     0.0;
 330   72.55      0.5     8.504     24.1   0.0513   0.0513    556.5    143.1   -92.76     0.0;
 335   72.22      0.5     8.936     24.1   0.0464   0.0464    614.4    158.0   -100.3     0.0; trap level, acute zo
 340   71.88      0.5     9.389     24.1    0.042    0.042    678.3    174.4   -109.1     0.0;
 345   71.52      0.5     9.866     24.1   0.0381   0.0381    748.9    192.5   -119.5     0.0;
 350   71.16      0.5     10.37     24.1   0.0345   0.0345    826.9    212.5   -132.6     0.0;
 355   70.81      0.5     10.89     24.1   0.0312   0.0312    912.9    234.6   -150.7     0.0;
 360   70.72      0.5     11.45    24.11   0.0283   0.0283   1008.0    258.9   -192.2     0.0; local maximum rise o
 365   71.44      0.5     12.03    24.11   0.0256   0.0256   1112.9    286.0   -234.3     0.0;
 370   71.95      0.5     12.64    24.11   0.0232   0.0232   1228.7    315.9   -256.6     0.0;
 371   72.04      0.5     12.76    24.11   0.0228   0.0228   1253.3    322.2   -261.1     0.0; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      12.76 m
```

APPENDIX B VPLUMES RESULTS FOR COOLING WATER MODELLING

Appendix B.1 Discharge under weak (0.05 m/s) ambient currents

Port Depth = 2 m

```
/ UM3. 4/5/2020 4:42:17 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     180.0      34.9      25.3       0.0       0.0      0.05     180.0    0.0003      23.2
.....
      75.0      0.05     180.0      35.0      24.0       0.0       0.0      0.05     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppb)
   0.254    83.0   -90.0   180.0     1.0   100.0  5000.0     2.0   0.047    35.0    65.0  2000.0

Simulation:
Froude number:     4.385; effluent density (sigma-T)     5.142; effluent velocity     0.928(m/s);
           Depth  Amb-cur    P-dia      Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn   y-posn
Step         (m)    (m/s)      (m)       (C)    (ppb)    (ppb)       ()       ()      (m)      (m)
   0         2.0     0.05    0.254      65.0   2000.0   2000.0      1.0      1.0      0.0      0.0;
  10       2.136     0.05     0.31     57.87   1640.7   1640.7    1.214      1.0-0.000905      0.0;
.....
 380       0.208     0.05    1.742      28.9    181.6    181.6    10.83     5.48   -0.926      0.0;
 381       0.141     0.05    1.762     28.83    178.1    178.1    11.04    5.588    -0.94      0.0; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       1.76 m
    conc   dilutn    width distnce     time
   (ppb)              (m)     (m)     (hrs) (kg/kg)    (s-1)     (m/s)(m0.67/s2)
 176.254    11.16    2.127     5.0  0.0226     0.0      0.0     0.05 3.00E-4
 158.445    12.44    2.606    10.0  0.0503     0.0      0.0     0.05 3.00E-4
 136.732    14.44    3.117    15.0  0.0781     0.0      0.0     0.05 3.00E-4
 118.039    16.76    3.657    20.0   0.106     0.0      0.0     0.05 3.00E-4
.....
  3.0448    656.7    144.8   545.0   3.023     0.0      0.0     0.05 3.00E-4
 3.00549    665.3    146.7   550.0    3.05     0.0      0.0     0.05 3.00E-4
 2.96702    673.9    148.6   555.0   3.078     0.0      0.0     0.05 3.00E-4
 2.92936    682.6    150.5   560.0   3.106     0.0      0.0     0.05 3.00E-4
 2.89249    691.3    152.4   565.0   3.134     0.0      0.0     0.05 3.00E-4
 2.85638    700.0    154.3   570.0   3.161     0.0      0.0     0.05 3.00E-4
 2.82102    708.8    156.3   575.0   3.189     0.0      0.0     0.05 3.00E-4
 2.78639    717.6    158.2   580.0   3.217     0.0      0.0     0.05 3.00E-4
 2.75246    726.4    160.2   585.0   3.245     0.0      0.0     0.05 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 3/20/2020 9:18:31 PM
Case 1; ambient file c:\plumes\VP plume 5.001.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     180.0      34.9      25.3       0.0       0.0      0.05     180.0    0.0003      23.2
....
      80.0      0.05     180.0      35.0      24.0       0.0       0.0      0.05     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppb)
   0.254    55.0   -90.0   180.0     1.0   100.0  5000.0    30.0   0.047    35.0    65.0  2000.0

Simulation:
Froude number:     4.381; effluent density (sigma-T)     5.142; effluent velocity     0.928(m/s);
           Depth  Amb-cur    P-dia      Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn   y-posn
Step         (m)    (m/s)      (m)       (C)    (ppb)    (ppb)       ()       ()      (m)      (m)
   0        30.0     0.05    0.254      65.0   2000.0   2000.0      1.0      1.0      0.0      0.0;
.....
 380       28.21     0.05    1.742     28.82    181.8    181.8    10.82    5.476   -0.925      0.0;
 390       27.52     0.05    1.953     28.17    149.1    149.1    13.19    6.659   -1.081      0.0;
 400       26.75     0.05    2.195     27.64    122.3    122.3    16.07    8.095   -1.261      0.0;
.....
 540       4.722     0.05    12.35      25.4    7.647    7.647    256.9    116.7   -10.26      0.0; matched energy radia
 546       3.138     0.05    13.34     25.39     6.79     6.79    289.3    130.1   -11.19      0.0; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of      13.34 m
    conc   dilutn    width distnce     time
   (ppb)              (m)     (m)     (hrs) (kg/kg)    (s-1)     (m/s)(m0.67/s2)
 6.78583    289.5    14.87    20.0  0.0489     0.0      0.0     0.05 3.00E-4
.....
 3.10903    638.1    40.57   140.0   0.716     0.0      0.0     0.05 3.00E-4
 2.93136    677.1    43.07   150.0   0.771     0.0      0.0     0.05 3.00E-4
 2.76959    716.9    45.62   160.0   0.827     0.0      0.0     0.05 3.00E-4
 2.62188    757.6    48.21   170.0   0.882     0.0      0.0     0.05 3.00E-4
 2.48682    799.0    50.86   180.0   0.938     0.0      0.0     0.05 3.00E-4
 2.36305    841.2    53.55   190.0   0.993     0.0      0.0     0.05 3.00E-4
 2.24909    884.1    56.28   200.0   1.049     0.0      0.0     0.05 3.00E-4
 2.14392    927.7    59.07   210.0   1.104     0.0      0.0     0.05 3.00E-4
 2.04661    972.0    61.89   220.0    1.16     0.0      0.0     0.05 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 3/20/2020 9:21:39 PM
Case 1; ambient file c:\plumes\VP plume 5.001.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     180.0      34.9      25.3       0.0       0.0      0.05     180.0    0.0003     23.2
.....
      80.0      0.05     180.0      35.0      24.0       0.0       0.0      0.05     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppb)
   0.254    10.0   -90.0   180.0     1.0   100.0  5000.0    75.0   0.047    35.0    65.0  2000.0

Simulation:
Froude number:      4.329; effluent density (sigma-T)     5.142; effluent velocity     0.928(m/s);
        Depth  Amb-cur     P-dia      Temp  Polutnt  4/3Eddy   Dilutn  CL-diln    x-posn    y-posn
Step      (m)    (m/s)       (m)       (C)    (ppb)    (ppb)       ()       ()       (m)       (m)
   0     75.0     0.05     0.254      65.0   2000.0   2000.0      1.0      1.0       0.0       0.0;
  10    75.14     0.05      0.31     57.63   1640.7   1640.7    1.214      1.0-0.000905      0.0;
.....
 390    72.52     0.05     1.939     27.11    150.5    150.5    13.06    6.597    -1.064       0.0;
 400    71.76     0.05     2.182     26.57    123.5    123.5    15.92    8.018    -1.243       0.0;
.....
 684    55.21     0.05     14.43     24.68    8.603    8.603    228.3    84.54    -15.19       0.0; end overlap;
 690    56.37     0.05      14.8     24.68    7.833    7.833    250.8    95.38    -16.43       0.0;
 695     57.4     0.05     15.71     24.68    7.095    7.095    276.9    102.8    -17.56       0.0; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of       15.71 m
    conc  dilutn    width distnce     time
   (ppb)              (m)     (m)    (hrs)  (kg/kg)    (s-1)    (m/s)(m0.67/s2)
 7.08439   277.3    16.15    20.0  0.0136      0.0      0.0     0.05 3.00E-4
.....
 3.26999   606.6    47.47   160.0   0.791      0.0      0.0     0.05 3.00E-4
 3.10099   639.9     50.1   170.0   0.847      0.0      0.0     0.05 3.00E-4
  2.9457   673.9    52.77   180.0   0.902      0.0      0.0     0.05 3.00E-4
 2.80268   708.6     55.5   190.0   0.958      0.0      0.0     0.05 3.00E-4
 2.67063   743.8    58.27   200.0   1.014      0.0      0.0     0.05 3.00E-4
 2.54891   779.6    61.08   210.0   1.069      0.0      0.0     0.05 3.00E-4
 2.43604   816.0    63.94   220.0   1.125      0.0      0.0     0.05 3.00E-4
 2.33117   852.9    66.84   230.0    1.18      0.0      0.0     0.05 3.00E-4
```

Appendix B.2 Discharge under average (0.2 m/s) ambient currents

Port Depth = 2 m

```
/ UM3. 4/5/2020 4:46:09 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       0.2     180.0      34.9      25.3       0.0       0.0       0.2     180.0    0.0003     23.2
.....
      75.0       0.2     180.0      35.0      24.0       0.0       0.0       0.2     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppb)
   0.254    83.0   -90.0   180.0     1.0   100.0  5000.0     2.0   0.047    35.0    65.0  2000.0

Simulation:
Froude number:      4.385; effluent density (sigma-T)     5.142; effluent velocity     0.928(m/s);
        Depth  Amb-cur     P-dia      Temp  Polutnt  4/3Eddy   Dilutn  CL-diln    x-posn    y-posn
Step      (m)    (m/s)       (m)       (C)    (ppb)    (ppb)       ()       ()       (m)       (m)
   0      2.0      0.2     0.254      65.0   2000.0   2000.0      1.0      1.0       0.0       0.0;
  10    2.104      0.2     0.309     57.87   1640.7   1640.7    1.214      1.0   -0.0027       0.0;
.....
 220    2.661      0.2     1.806     28.88    180.7    180.7    10.89    3.062    -2.362       0.0;
 230    2.484      0.2     1.971     28.23    148.2    148.2    13.27    3.812    -2.741       0.0;
 240    2.294      0.2     2.162     27.71    121.6    121.6    16.17    4.683    -3.147       0.0;
 250    2.089      0.2     2.379     27.27    99.76    99.76    19.71    5.714    -3.596       0.0;
 260    1.866      0.2     2.623     26.92    81.83    81.83    24.02    6.944    -4.101       0.0;
 270    1.623      0.2     2.894     26.63    67.13    67.13    29.28    8.422    -4.676       0.0;
 277     1.44      0.2     3.102     26.45    58.44    58.44    33.63    9.632    -5.128       0.0; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of        3.10 m
    conc  dilutn    width distnce     time
   (ppb)              (m)     (m)    (hrs)  (kg/kg)    (s-1)    (m/s)(m0.67/s2)
 58.3813   33.67    3.231    10.0 0.00677      0.0      0.0      0.2 3.00E-4
 58.3811   33.67    3.501    20.0  0.0207      0.0      0.0      0.2 3.00E-4
.....
 3.05034   655.1    83.51  1420.0   1.965      0.0      0.0      0.2 3.00E-4
 3.02185   661.3     84.3  1430.0   1.979      0.0      0.0      0.2 3.00E-4
  2.9938   667.5    85.09  1440.0   1.993      0.0      0.0      0.2 3.00E-4
 2.96619   673.7    85.88  1450.0   2.007      0.0      0.0      0.2 3.00E-4
   2.939   679.9    86.68  1460.0   2.021      0.0      0.0      0.2 3.00E-4
 2.91222   686.2    87.48  1470.0   2.035      0.0      0.0      0.2 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 3/20/2020 9:27:58 PM
Case 1; ambient file c:\plumes\VP plume 5.001.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     180.0      34.9      25.3       0.0       0.0       0.2     180.0    0.0003      23.2
.....
      80.0       0.2     180.0      35.0      24.0       0.0       0.0       0.2     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppb)
   0.254    55.0   -90.0   180.0     1.0   100.0  5000.0    30.0   0.047    35.0    65.0  2000.0

Simulation:
Froude number:      4.381; effleunt density (sigma-T)     5.142; effleunt velocity     0.928(m/s);
        Depth  Amb-cur     P-dia     Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn   y-posn
Step      (m)    (m/s)       (m)      (C)    (ppb)    (ppb)       ()       ()      (m)      (m)
   0     30.0      0.2     0.254     65.0   2000.0   2000.0      1.0      1.0      0.0      0.0;
  10     30.1      0.2     0.309    57.85   1640.7   1640.7    1.214      1.0  -0.0027      0.0;
.....
 220    30.66      0.2     1.805    28.79    181.0    181.0    10.87    3.058   -2.358      0.0;
 230    30.48      0.2      1.97    28.15    148.5    148.5    13.24    3.806   -2.737      0.0;
 240    30.29      0.2     2.161    27.62    121.8    121.8    16.14    4.676   -3.142      0.0;
.....
 400     23.3      0.2     10.62    25.31    5.124    5.124    383.4    102.3   -28.46      0.0;
 410    22.41      0.2     11.73     25.3    4.204    4.204    467.4    124.2   -32.98      0.0;
 420    21.44      0.2     12.96    25.29    3.448    3.448    569.8    150.9   -38.27      0.0;
 430    20.37      0.2     14.33    25.28    2.829    2.829    694.5    183.3   -44.48      0.0;
 440    19.19      0.2     15.83    25.27    2.321    2.321    846.6    222.7   -51.81      0.0;
 450    17.89      0.2     17.49    25.26    1.904    1.904   1032.0    270.5   -60.53      0.0;
 460    16.47      0.2     19.33    25.26    1.562    1.562   1258.0    328.7   -71.02      0.0;
 470    14.91      0.2     21.36    25.26    1.281    1.281   1533.5    399.3   -83.83      0.0;
 480    13.21      0.2      23.6    25.26    1.051    1.051   1869.4    485.1   -99.94      0.0;
 481    13.03      0.2     23.83    25.26     1.03     1.03   1906.7    494.6   -101.8      0.0; acute zone;
 482    12.85      0.2     24.07    25.26     1.01     1.01   1944.9    504.4   -103.7      0.0; trap level;
 485     12.3      0.2     24.81    25.26    0.952    0.952   2063.9    534.7   -109.8      0.0; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of      24.81 m
    conc  dilutn   width distnce    time
   (ppb)             (m)     (m)   (hrs) (kg/kg)   (s-1)   (m/s)(m0.67/s2)
```

Port Depth = 75 m

```
/ UM3. 3/20/2020 9:32:44 PM
Case 1; ambient file c:\plumes\VP plume 5.001.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     180.0      34.9      25.3       0.0       0.0       0.2     180.0    0.0003      23.2
.....
      80.0       0.2     180.0      35.0      24.0       0.0       0.0       0.2     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppb)
   0.254    10.0   -90.0   180.0     1.0   100.0  5000.0    75.0   0.047    35.0    65.0  2000.0

Simulation:
Froude number:      4.329; effleunt density (sigma-T)     5.142; effleunt velocity     0.928(m/s);
        Depth  Amb-cur     P-dia     Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn   y-posn
Step      (m)    (m/s)       (m)      (C)    (ppb)    (ppb)       ()       ()      (m)      (m)
   0     75.0      0.2     0.254     65.0   2000.0   2000.0      1.0      1.0      0.0      0.0;
  10     75.1      0.2     0.309    57.63   1640.7   1640.7    1.214      1.0  -0.0027      0.0;
.....
 220    75.66      0.2     1.783     27.8    185.5    185.5     10.6    2.985   -2.305      0.0;
 230    75.49      0.2     1.945    27.12    152.2    152.2    12.92    3.719   -2.676      0.0;
 240     75.3      0.2     2.133    26.56    124.8    124.8    15.75     4.57   -3.073      0.0;
.....
 370    70.59      0.2     7.782    24.27    9.512    9.512    206.5    55.42   -18.37      0.0;
 380    69.94      0.2     8.606    24.25    7.803    7.803    251.7    67.11   -21.41      0.0;
 390    69.24      0.2     9.517    24.24    6.401    6.401    306.8    81.25   -25.08      0.0;
 400    68.47      0.2     10.52    24.23    5.251    5.251    374.0    98.34   -29.61      0.0;
 407    67.89      0.2     11.29    24.23    4.571    4.571    429.6    112.4    -33.5      0.0; trap level;
 410    67.63      0.2     11.64    24.23    4.308    4.308    455.9    119.0   -35.42      0.0;
 420    66.74      0.2     12.88    24.24    3.534    3.534    555.7    143.9   -43.47      0.0;
 430    65.88      0.2     14.24    24.24    2.899    2.899    677.5    174.1    -58.0      0.0;
 434    65.82      0.2     14.56    24.25    2.776    2.776    707.4    181.7   -67.36      0.0; local maximum rise o
 440    66.46      0.2     15.06    24.25     2.59     2.59    758.4    195.6   -82.24      0.0;
 449    67.65      0.2     16.45    24.25    2.167    2.167    906.4    234.1   -98.54      0.0; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      16.45 m
    conc  dilutn   width distnce    time
   (ppb)             (m)     (m)   (hrs) (kg/kg)   (s-1)   (m/s)(m0.67/s2)
 2.15866   909.9   16.52   100.0 0.00203     0.0     0.0     0.2 3.00E-4
```

Appendix B.3 Discharge under strong (0.5 m/s) ambient currents

Port Depth = 2 m

```
/ UM3. 4/5/2020 4:51:33 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       0.5      180.0       34.9       25.3        0.0        0.0       0.5     180.0    0.0003      23.2
.....
       75.0       0.5      180.0       35.0       24.0        0.0        0.0       0.5     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppb)
   0.254    83.0   -90.0   180.0     1.0   100.0  5000.0     2.0   0.047    35.0     65.0  2000.0

Simulation:
Froude number:      4.385; effleunt density (sigma-T)     5.142; effleunt velocity     0.928(m/s);
        Depth  Amb-cur     P-dia      Temp  Polutnt   4/3Eddy   Dilutn  CL-diln    x-posn    y-posn
Step      (m)    (m/s)       (m)       (C)    (ppb)     (ppb)       ()       ()       (m)       (m)
   0      2.0      0.5     0.254      65.0   2000.0    2000.0      1.0      1.0       0.0       0.0;
  10    2.048      0.5     0.299     58.78   1686.7    1686.7    1.181      1.0  -0.00261       0.0;
.....
 170    2.706      0.5     1.276     28.41    157.1     157.1    12.52    2.939    -3.008       0.0;
 171    2.705      0.5     1.284     28.37    154.9     154.9     12.7    2.986    -3.226       0.0; local maximum rise o1
 180    2.625      0.5     1.382     27.91    131.8     131.8    14.91     3.58    -5.051       0.0;
.....
 250     1.59      0.5     2.687     25.95    32.96     32.96    59.61    15.22    -15.24       0.0;
 258    1.418      0.5     2.905     25.85    28.13     28.13    69.84    17.87     -17.0       0.0; surface;
4/3 Power Law.  Farfield dispersion based on wastefield width of       2.91 m
    conc  dilutn    width distnce      time
   (ppb)              (m)     (m)     (hrs)  (kg/kg)    (s-1)     (m/s)(m0.67/s2)
 28.0619   70.03    2.936    20.0   0.00167      0.0      0.0       0.5 3.00E-4
 28.1075   69.91     3.04    30.0   0.00722      0.0      0.0       0.5 3.00E-4
.....
 3.03561   657.6    37.82  1940.0     1.068      0.0      0.0       0.5 3.00E-4
 3.01636   661.8    38.06  1950.0     1.074      0.0      0.0       0.5 3.00E-4
 2.99731   666.0     38.3  1960.0     1.079      0.0      0.0       0.5 3.00E-4
 2.97845   670.2    38.54  1970.0     1.085      0.0      0.0       0.5 3.00E-4
  2.9598   674.5    38.79  1980.0     1.091      0.0      0.0       0.5 3.00E-4
 2.94134   678.7    39.03  1990.0     1.096      0.0      0.0       0.5 3.00E-4
 2.92307   683.0    39.28  2000.0     1.102      0.0      0.0       0.5 3.00E-4
```

Port Depth = 30 m

```
/ UM3. 3/20/2020 7:42:34 PM
Case 1; ambient file c:\plumes\VP plume 5.001.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      180.0       34.9       25.3        0.0        0.0       0.5     180.0    0.0003      23.2
.....
       80.0       0.5      180.0       35.0       24.0        0.0        0.0       0.5     180.0    0.0003     23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)      (C)   (ppb)
   0.254    55.0   -90.0   180.0     1.0   100.0  5000.0    30.0   0.047    35.0     65.0  2000.0

Simulation:
Froude number:      4.381; effleunt density (sigma-T)     5.142; effleunt velocity     0.928(m/s);
        Depth  Amb-cur     P-dia      Temp  Polutnt   4/3Eddy   Dilutn  CL-diln    x-posn    y-posn
Step      (m)    (m/s)       (m)       (C)    (ppb)     (ppb)       ()       ()       (m)       (m)
   0     30.0      0.5     0.254      65.0   2000.0    2000.0      1.0      1.0       0.0       0.0;
   5    30.03      0.5     0.276     61.59   1828.6    1828.6    1.092      1.0-0.000766       0.0;
.....
 195    30.46      0.5     1.586     27.14    97.97     97.97    20.07    4.943      -6.9       0.0;
 200     30.4      0.5     1.662     26.96    88.73     88.73    22.15    5.491    -7.492       0.0;
 205    30.34      0.5     1.742     26.79    80.37     80.37    24.46    6.094    -8.098       0.0;
.....
 365    25.13      0.5      8.34     25.28    3.381     3.381    581.1    149.7     -77.4       0.0;
 370     24.8      0.5     8.763     25.27    3.062     3.062    641.6    165.2    -83.33       0.0;
 375    24.46      0.5     9.207     25.27    2.774     2.774    708.3    182.4    -89.74       0.0;
 380    24.09      0.5     9.674     25.26    2.512     2.512    782.1    201.4    -96.69       0.0;
 383    23.86      0.5     9.966     25.26    2.367     2.367    829.9    213.7    -101.1       0.0; acute zone;
.....
 467    14.83      0.5      22.9     25.24    0.449     0.449   4379.8   1126.0    -555.8       0.0; local maximum rise o1
 470    15.81      0.5     23.59     25.24    0.423     0.423   4647.9   1195.1    -646.0       0.0;
 475    16.86      0.5     24.78     25.24    0.383     0.383   5131.6   1319.6    -719.2       0.0;
 478    17.45      0.5     25.53     25.24    0.361     0.361   5445.7   1400.4    -759.9       0.0; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      25.53 m
    conc  dilutn    width distnce      time
   (ppb)              (m)     (m)     (hrs)  (kg/kg)    (s-1)     (m/s)(m0.67/s2)
 0.35911  5471.4    25.53   760.0    8.20E-5     0.0      0.0       0.5 3.00E-4
 0.35974  5461.7    25.75   770.0   0.00564      0.0      0.0       0.5 3.00E-4
```

Port Depth = 75 m

```
/ UM3. 3/20/2020 7:38:46 PM
Case 1; ambient file c:\plumes\VP plume 5.001.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      180.0       34.9       25.3        0.0        0.0        0.5      180.0     0.0003       23.2
.....
      80.0        0.5      180.0       35.0       24.0        0.0        0.0        0.5      180.0     0.0003      23.67

Diffuser table:
   P-dia  P-elev V-angle H-angle   Ports AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg)   (deg)      ()     (m)     (m)     (m)  (m3/s)   (psu)     (C)   (ppb)
   0.254    10.0   -90.0   180.0     1.0   100.0  5000.0    75.0   0.047    35.0    65.0  2000.0

Simulation:
Froude number:      4.329; effleunt density (sigma-T)     5.142; effleunt velocity     0.928(m/s);
        Depth  Amb-cur     P-dia     Temp  Polutnt  4/3Eddy   Dilutn  CL-diln   x-posn   y-posn
Step      (m)    (m/s)       (m)      (C)    (ppb)    (ppb)       ()       ()      (m)      (m)
   0     75.0      0.5     0.254     65.0   2000.0   2000.0      1.0      1.0      0.0      0.0;
   5    75.03      0.5     0.276    61.49   1828.7   1828.7    1.091      1.0-0.000765      0.0;
.....
 171     75.7      0.5     1.282    27.19    155.4    155.4    12.65    2.974   -3.261      0.0; local maximum rise o
 175    75.67      0.5      1.32    26.99    145.9    145.9    13.48    3.195   -4.195      0.0;
.....
 366     70.1      0.5     8.416    24.16    3.321    3.321    591.3    152.1   -85.25      0.0; trap level;
 370    69.85      0.5     8.756    24.16    3.068    3.068    640.0    164.6   -91.94      0.0;
 375    69.51      0.5     9.201    24.16    2.779    2.779    706.7    181.6   -101.7      0.0; acute zone;
 380    69.17      0.5     9.668    24.16    2.517    2.517    780.2    200.5   -113.7      0.0;
 385    68.84      0.5     10.16    24.17     2.28     2.28    861.4    221.3   -129.8      0.0;
 390    68.58      0.5     10.67    24.17    2.065    2.065    951.1    244.3   -158.3      0.0;
 391    68.62      0.5     10.78    24.17    2.024    2.024    970.1    249.2   -170.6      0.0; local maximum rise o
 395    69.23      0.5     11.21    24.17     1.87     1.87   1050.1    269.9   -211.5      0.0;
 400    69.72      0.5     11.78    24.17    1.694    1.694   1159.4    298.0   -234.3      0.0;
 403    69.99      0.5     12.14    24.17    1.596    1.596   1230.3    316.2   -247.4      0.0; trap level;
4/3 Power Law.  Farfield dispersion based on wastefield width of      12.14 m
   conc  dilutn   width distnce    time
  (ppb)             (m)     (m)   (hrs) (kg/kg)   (s-1)   (m/s)(m0.67/s2)
 1.59003  1235.2   12.18   250.0 0.00144     0.0     0.0     0.5 3.00E-4
 1.59308  1232.8   12.35   260.0 0.00699     0.0     0.0     0.5 3.00E-4
 1.59411  1232.0   12.51   270.0  0.0126     0.0     0.0     0.5 3.00E-4
```

Appendix E: Amulet Development – Quantatative Oil Spill Modelling

KATO OIL QUANTITATIVE SPILL RISK ASSESSMENT - REPORT

Amulet Field – Subsurface Crude and Surface Marine Gas Oil Spills

MAW0843J.000
Kato Oil QSRA – Amulet
Report
Rev 0
29 November 2019

rpsgroup.com

Document status					
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Approval for issue		
Scott Langtry		29 November 2019

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Contents

Tables

Figures

EXECUTIVE SUMMARY

RPS was commissioned by Kato Energy (Kato) to conduct a quantitative oil spill risk assessment for hydrocarbon spill scenarios associated with the Amulet field in permit area WA-8-L, located approximately 140 km offshore from Karratha 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 would result from accidental, uncontrolled, releases; and (ii) to quantify risks to sensitive receptors (emergent features, submerged features and shorelines) posed by the releases 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 Amulet 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 subsurface release of 69,801 m^3 of Amulet Crude within the Amulet field (116° 58' 52.64" E, 19° 29' 30.19" S), representing a 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 Amulet field (116° 58' 52.64" E, 19° 29' 30.19" 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 Amulet 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 79% of the mass will be expected to evaporate in around 24 hours and another 16% 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 Amulet Crude within the Amulet 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 the worst-case spill simulation was calculated as 18 m^3, for a spill commencing in summer (run 11). During this deterministic case, the highest accumulation was predicted for the Ningaloo World Heritage Area shoreline receptor.

- The maximum extent of hydrocarbon exposure from the spill location for this case is predicted as 495 km for the entrained oil at concentrations equal to or greater than the moderate (100 ppb) threshold.

Stochastic Modelling Assessment

- Floating oil concentrations exceeding the low threshold (1 g/m^2) could travel up to 393 km from the release location, with distances reducing at the moderate (10 g/m^2; 58 km) and high (25 g/m^2; 19 km) thresholds.

- Floating oil contact at the low threshold (1 g/m^2) is not predicted to occur at any of the assessed shoreline receptors, in any season.

- The worst-case oil accumulation on a shoreline is predicted for the Ningaloo Coast World Heritage Area receptor in summer, with an accumulated concentration and volume of 173 g/m^2 and 18 m^3, respectively.

- The worst-case maximum length of shoreline with concentrations exceeding the low threshold (10 g/m^2) was calculated as 28 km at the Ningaloo Coast WH and Ningaloo MP (State) receptors in summer

- Entrained oil concentrations exceeding the low threshold (10 ppb) could travel up to 1,483 km from the release location, with distances reducing at the moderate (100 ppb; 832 km) and high (1,000 ppb; 212 km) thresholds.

- The probability of contact by entrained oil concentrations at the moderate threshold (100 ppb) is predicted to be greatest at Seabirds, Sharks and Whales Biologically Important Areas and Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery at 100% across all seasons. Entrained oil at the moderate threshold is predicted to arrive at these receptors within 1 hours after the release commences.

- The worst-case instantaneous entrained oil concentration at any receptor is predicted at the Seabirds, Sharks and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 5,246 ppb.

- Entrained oil concentrations in the vicinity of the release site above the moderate (100 ppb) and high (1,000 ppb) thresholds are not expected to exceed depths of around 25 m and 35 m BMSL, respectively, in any season. Therefore, limiting benthic contact below this depth.

- Time-integrated entrained oil exposure at or above the 960 ppb.hr threshold could travel up to 992 km from the release location, with the distance reducing to 483 km and 40 km as contact thresholds increase to 9,600 ppb.hr and 96,000 ppb.hr, respectively.

- The probability of contact by time-integrated exposure of entrained oil concentrations at the 96,00 ppb.hr threshold is predicted to be greatest at Biologically Important Areas for Seabirds, Sharks and Whales and the Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery with a probability of 100% across all seasons.

- The worst-case entrained oil maximum integrated exposure is predicted at Seabirds, Sharks and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 135,616 ppb.hr.

- Dissolved aromatic hydrocarbon concentrations exceeding the low threshold (10 ppb) could travel up to 626 km from the release location, with distances reducing at the moderate (50 ppb; 584 km) and high (400 ppb; 51 km) thresholds.

- The probability of contact by dissolved aromatic hydrocarbon concentrations at the moderate threshold (50 ppb) is predicted to be greatest at Biologically Important Areas for Seabirds, Sharks and Whales and the Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors with probabilities of 100% across all seasons.

- The worst-case dissolved aromatic hydrocarbon concentrations at any receptor is predicted as 576 ppb at the Ancient Coastline at 125 m Depth Contour Key Ecological Feature, Seabirds, Sharks and Whales Biologically Important Areas and Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries.

- Dissolved aromatic hydrocarbon concentrations in the vicinity of the release site above the high threshold (400 ppb) are not expected to exceed depths of around 80 m BMSL in any season. Therefore, limiting benthic contact below this depth.

- Time integrated dissolved aromatic hydrocarbon exposure at or above 960 ppb.hr are predicted to occur up to 723 km from the release site, with the distance reducing to 605 km as the contact threshold increases to 4,800 ppb.hr.

- The probability of contact by dissolved aromatic hydrocarbon exposure at the 4,800 ppb.hr threshold was predicted to be greatest at the Seabirds, Sharks and Whales Biologically Important Areas and Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors with a probability of 10% in the surface layer (0-10 m) in winter.

- The worst-case maximum dissolved aromatic hydrocarbon exposure concentration at any receptor is predicted at Biologically Important Areas for Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 9,417 ppb.hr.

- 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 1.5 m^3 for a spill commencing in summer (replicate 32). During this deterministic case, the maximum oil loading along an individual shoreline receptor was predicted at Lowendal Islands.

- The maximum extent of hydrocarbon exposure from the spill location for this deterministic case is predicted as 70 km for the shoreline oil at or above the moderate (100 g/m^2) threshold.

Stochastic Modelling Assessment

- Floating oil concentrations exceeding the low threshold (1 g/m^2) could travel up to 217 km from the release, with the distance reducing at the moderate (10 g/m^2; 17 km) and high (25 g/m^2; 14 km) thresholds.

- Floating oil contact at the low threshold (1 g/m^2) is not predicted to occur at any of the assessed shoreline receptors, in any season.

- The worst-case oil accumulation on a given shoreline is forecast in the summer season at the Southern Pilbara Islands receptor with a predicted accumulated concentration and volume of 42 g/m^2 and 1 m^3, respectively.

- The worst-case maximum length of shoreline with concentrations exceeding the low threshold (10 g/m^2) was calculated as 2 km at the Southern Pilbara – Islands receptor in summer.

- Entrained oil concentrations exceeding the low threshold (10 ppb) could travel up to 725 km from the release location, with the distance reducing at the moderate (100 ppb; 376 km) and high (1,000 ppb; 76 km) thresholds.

- The probability of contact by entrained oil concentrations at the moderate threshold (100 ppb) is predicted to be greatest at the Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery at 34-63% across all seasons. Entrained oil concentrations at the moderate 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 at Biologically Important Areas for Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 2,112 ppb in winter.

- Entrained oil concentrations in the vicinity of the release site above the moderate (100 ppb) and high (1,000 ppb) thresholds are expected to exceed depths of around 25 m and 35 m BMSL, respectively, in any season. Therefore, limiting benthic contact below this depth.

- Time-integrated entrained oil exposure at or above the 960 ppb.hr threshold could travel up to 571 km from the release location, with the distance reducing to 198 km as the contact threshold increases to 9,600 ppb.hr.

- The probability of contact by time-integrated exposure of entrained oil concentrations at the 9,600 ppb.hr threshold is predicted to be greatest at the Seabirds, Sharks and Whales Biologically Important Areas and for the Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors with a probability of 100% in the surface layer (0-10 m) in transitional months.
- The worst-case entrained oil maximum integrated exposure is predicted at Biologically Important Areas for Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 60,636 ppb.hr.
- Dissolved aromatic hydrocarbon concentrations exceeding the low threshold (10 ppb) could travel up to 352 km from the release location, with distances reducing at the moderate (50 ppb; 234 km) threshold.
- The probability of contact by dissolved aromatic hydrocarbon concentrations at the moderate threshold (50 ppb) is predicted to be greatest at the Seabirds, Sharks, and Whales Biologically Important Areas and Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries at 19-32% across all seasons.
- The worst-case dissolved aromatic hydrocarbon concentrations at any receptor is predicted at Biologically Important Areas for Seabirds, Sharks and Whales and Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries receptors as 275 ppb in summer.
- Dissolved aromatic hydrocarbon concentrations in the vicinity of the release site above the moderate threshold (50 ppb) are not expected to exceed depths of around 30 m BMSL in any season. Therefore, limiting benthic contact below this depth.
- Time integrated dissolved aromatic hydrocarbon exposure at or above 960 ppb.hr are predicted to occur up to 10 km from the release site.
- Dissolved aromatic hydrocarbon exposure above the 960 ppb.hr threshold was not predicted at any receptor with probabilities greater than 2%, across all seasons in the surface layer.
- The worst-case maximum dissolved aromatic hydrocarbon exposure concentration at any receptor is predicted at the Seabirds, Sharks and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 1,795 ppb.hr.
- 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 hydrocarbon spill scenarios associated with the Amulet field in permit area WA-8L, located approximately 140 km offshore from Karratha 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 would result from accidental, uncontrolled, releases; and (ii) to quantify risks to sensitive receptors (emergent features, submerged features and shorelines) posed by the releases on the basis of the probability of exposure above defined exposure concentrations.

Kato identified two hypothetical hydrocarbon spill scenarios that could potentially occur at the Amulet location. 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 to 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 subsurface release of 69,801 m^3 of Amulet Crude within the Amulet field (116° 58' 52.64" E, 19° 29' 30.19" S), representing a 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 Amulet field (116° 58' 52.64" E, 19° 29' 30.19" S), representing a rupture of a support vessel tank.

The physical and chemical properties of Amulet Crude and marine gas oil were applied.

Table 1.1 Summary of the hydrocarbon spill scenario 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 blow out	Amulet Crude	69,801	967-797 m^3/day	116° 58' 52.64" E 19° 29' 30.19" S	86 m	80 days	108 days
Surface release after a rupture of the support vessel tank	Marine gas oil	500	83.33 m^3/hour	116° 58' 52.64" E 19° 29' 30.19" S	0 m	6 hours	30 days

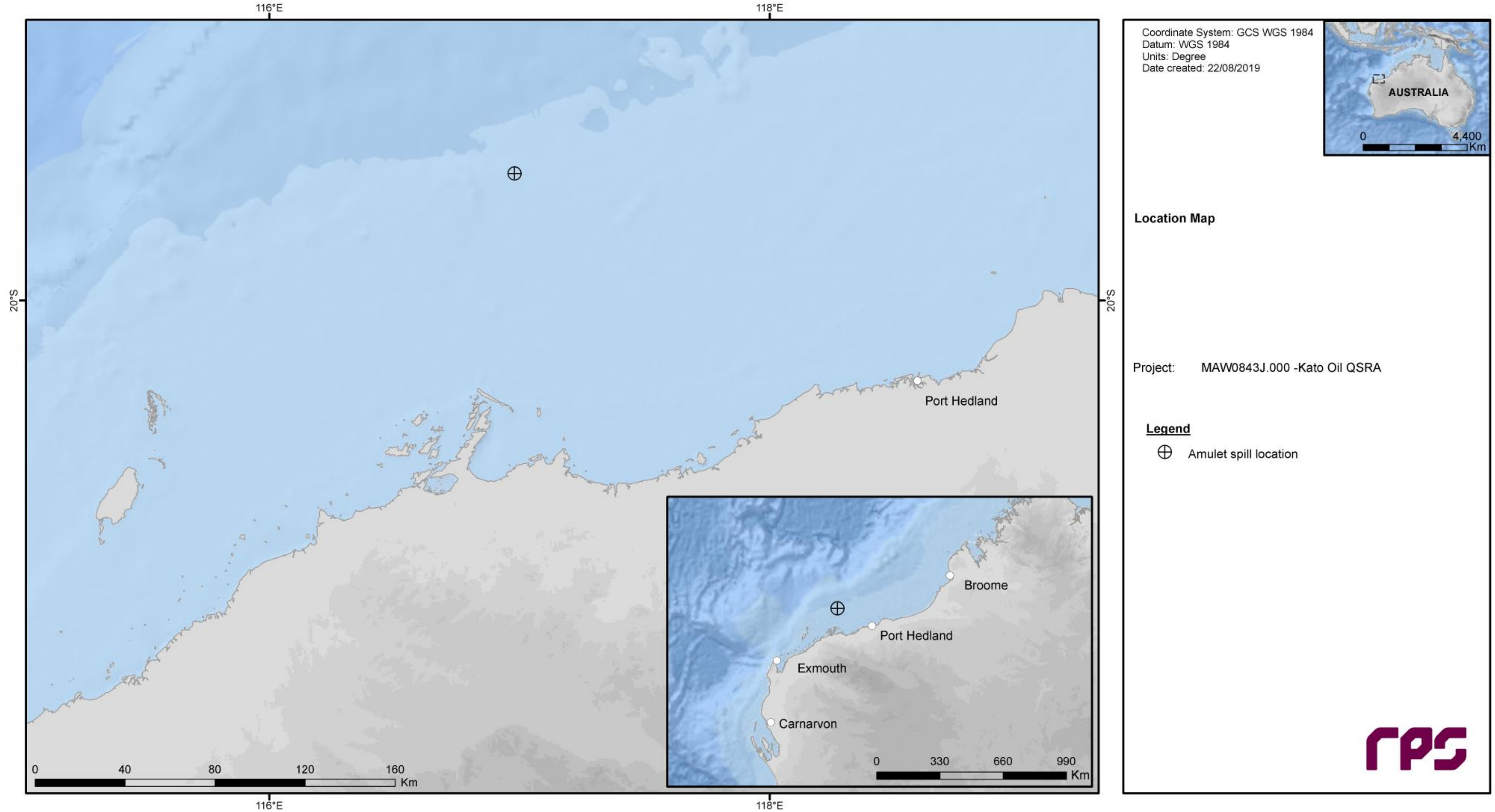

Figure 1.1 Location of the modelled hydrocarbon spill scenarios release site within the Amulet field.

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.

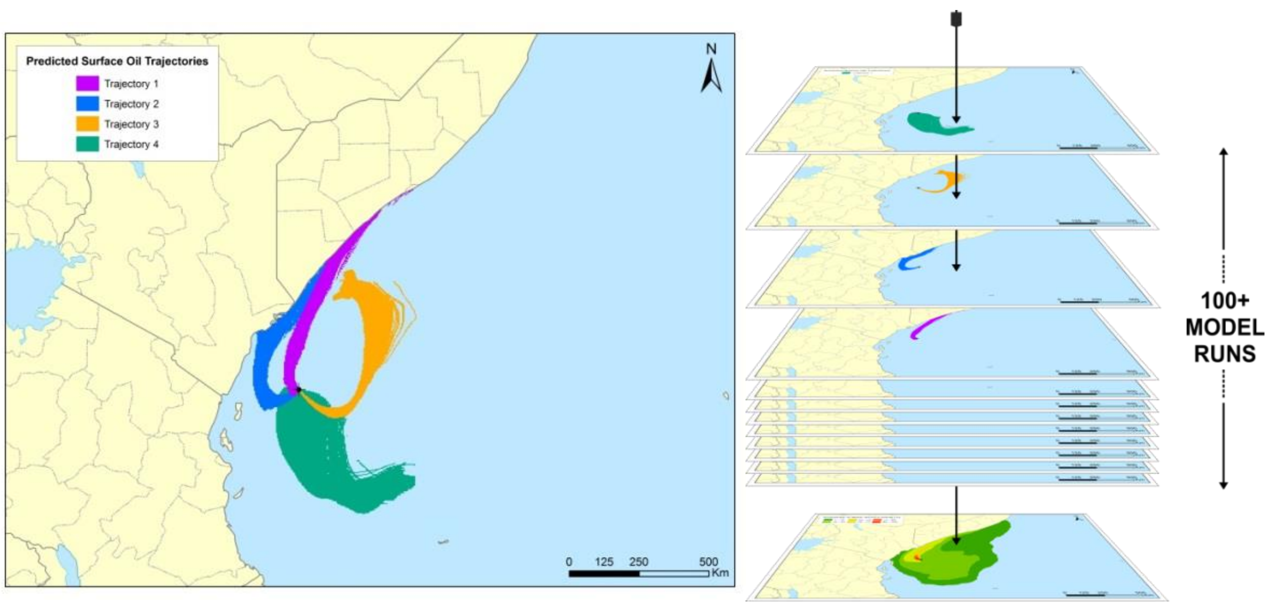

Figure 1.2 Examples of four individual spill trajectories (four replicate simulations) predicted by SIMAP for a spill scenario. The frequency of contact with given locations is used to calculate the probability of impacts during a spill. Essentially, all model runs are overlain (shown as the stacked 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.

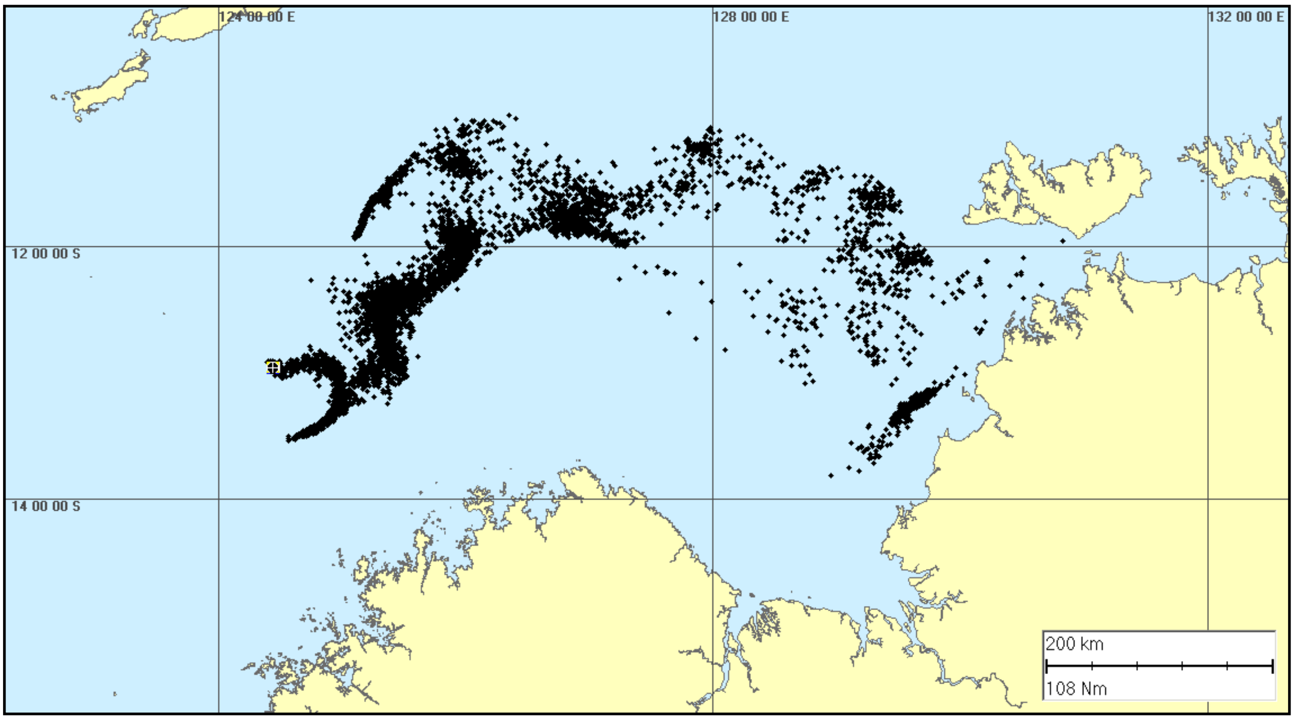

Figure 1.3 Example of an individual spill trajectory predicted by SIMAP for a spill scenario.

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 sensitive 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 an evolution of the 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 transport 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.

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.

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 a large number of 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.

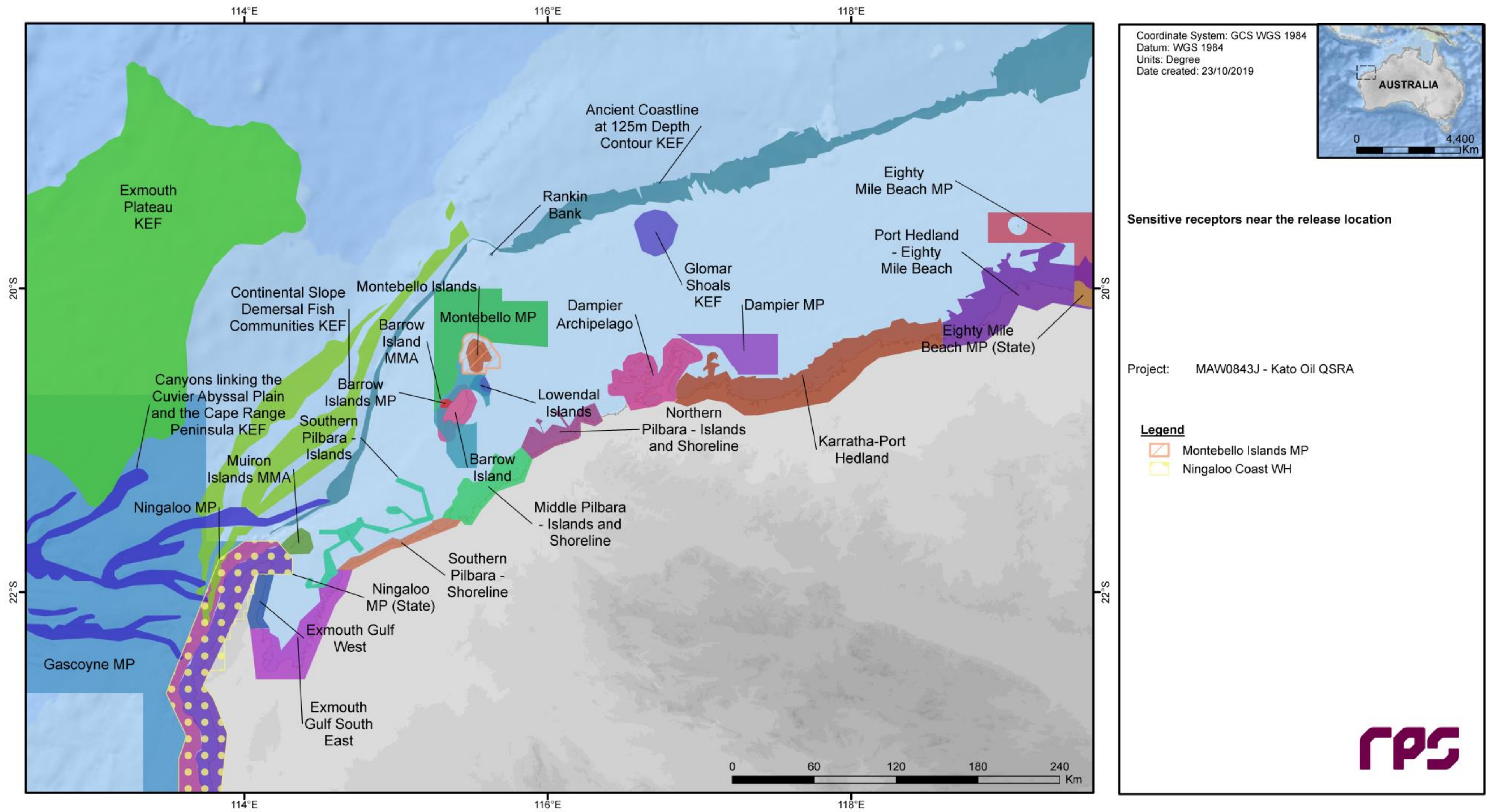

Figure 2.1 Locations of sensitive receptors near the release location.

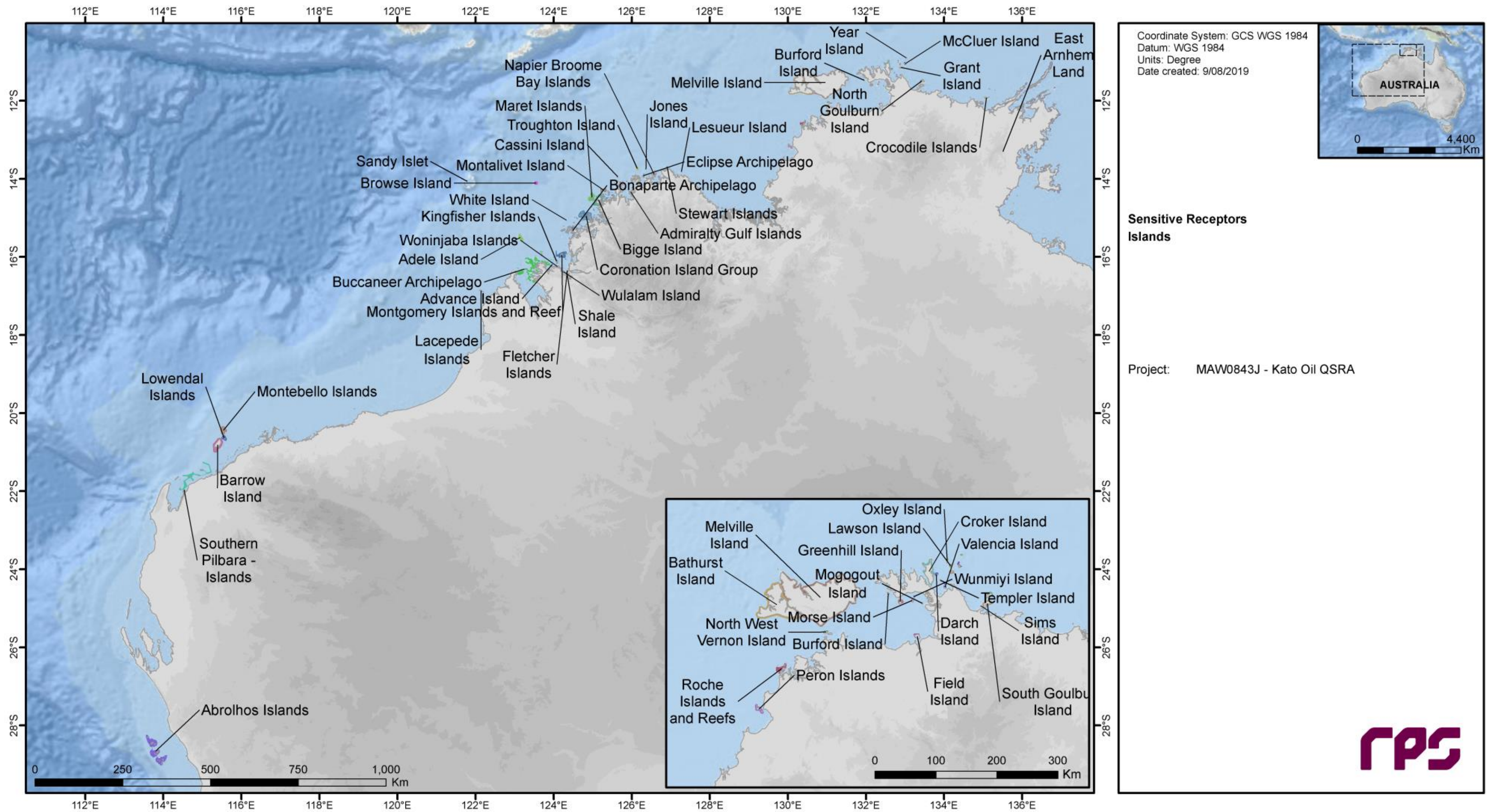

Figure 2.2 Locations of Island sensitive receptors within the study region.

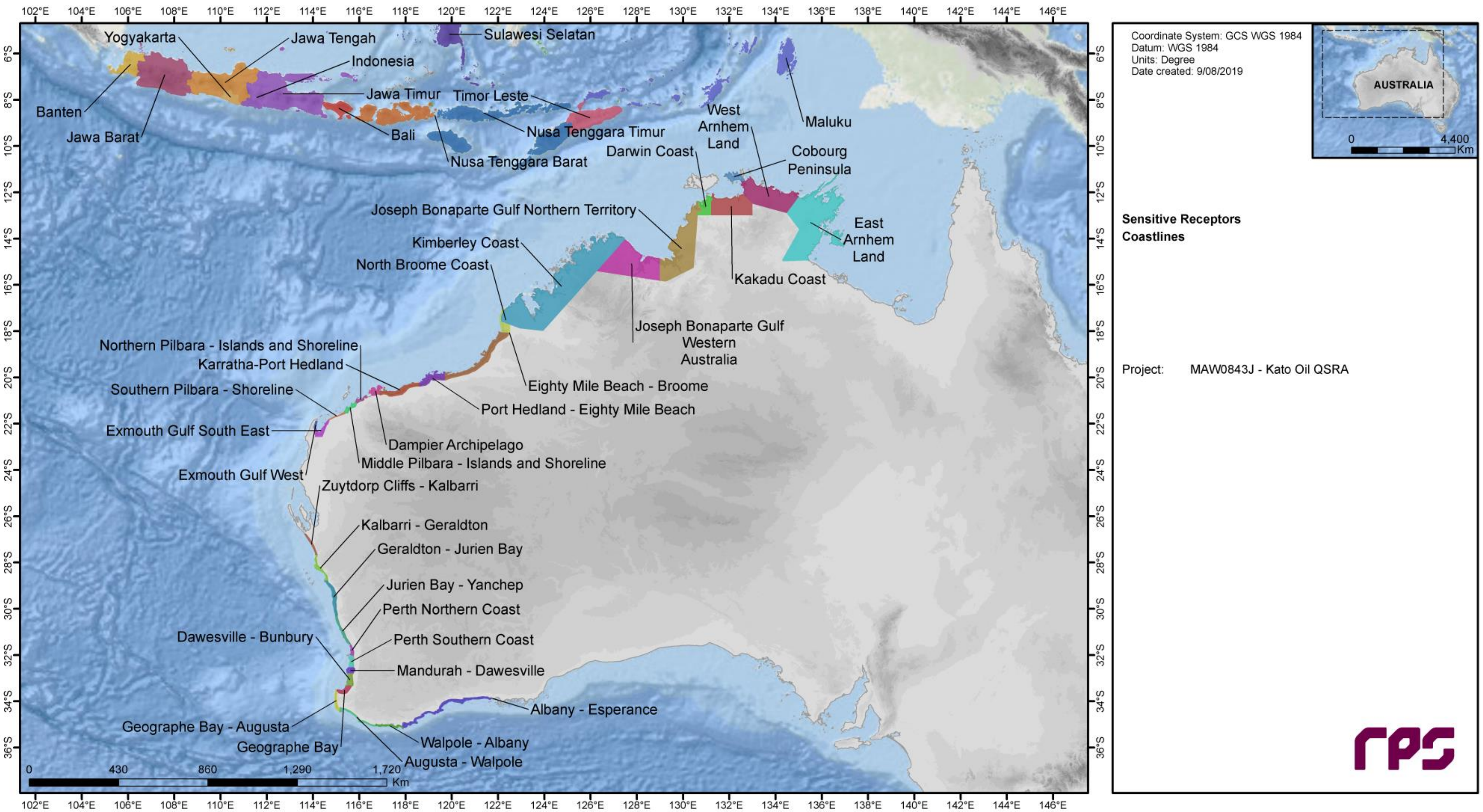

Figure 2.3 Locations of Coastline sensitive receptors within the study region.

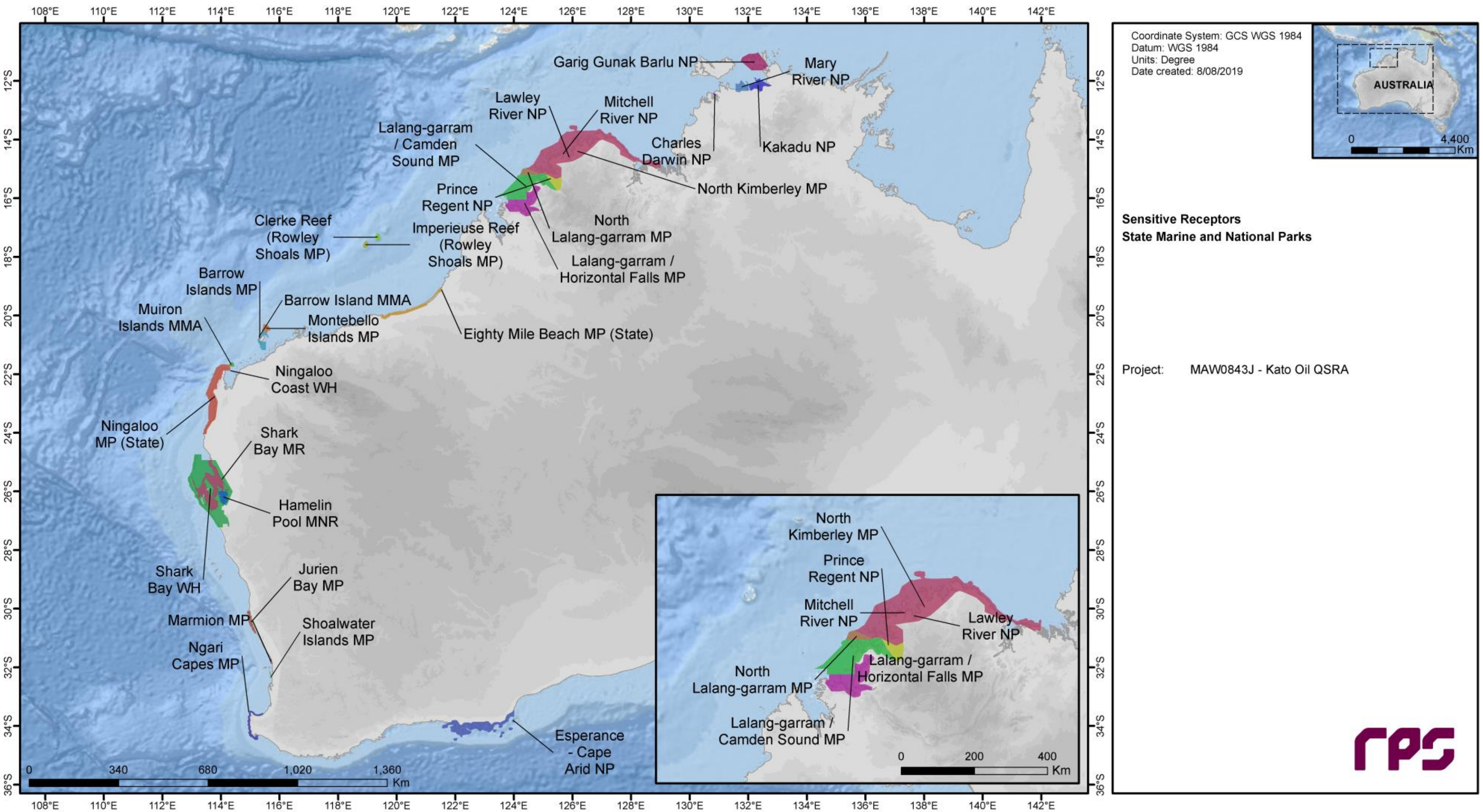

Figure 2.4 Locations of State Marine and National Park sensitive receptors within the study region.

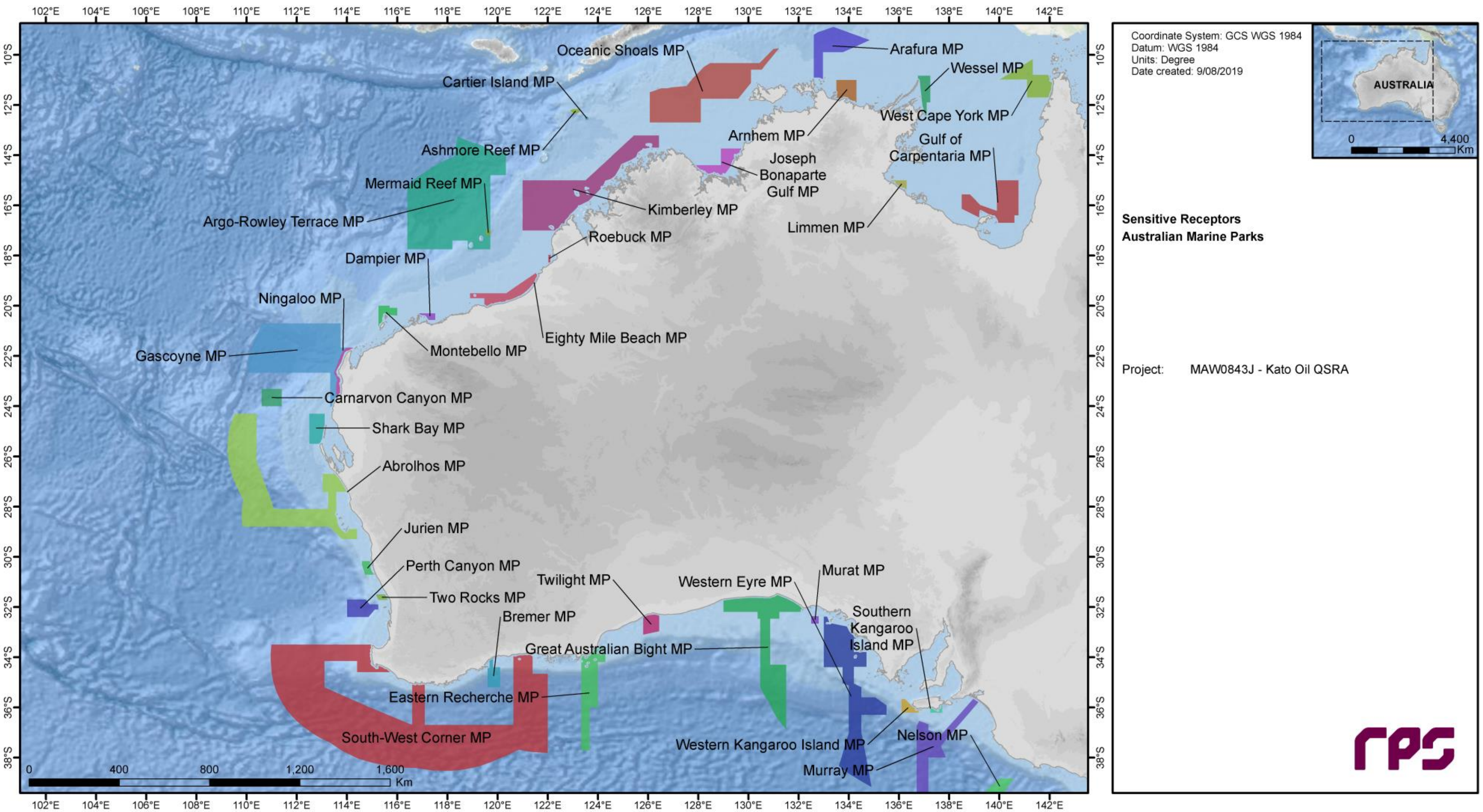

Figure 2.5 Locations of Australian Marine Park sensitive receptors within the study region.

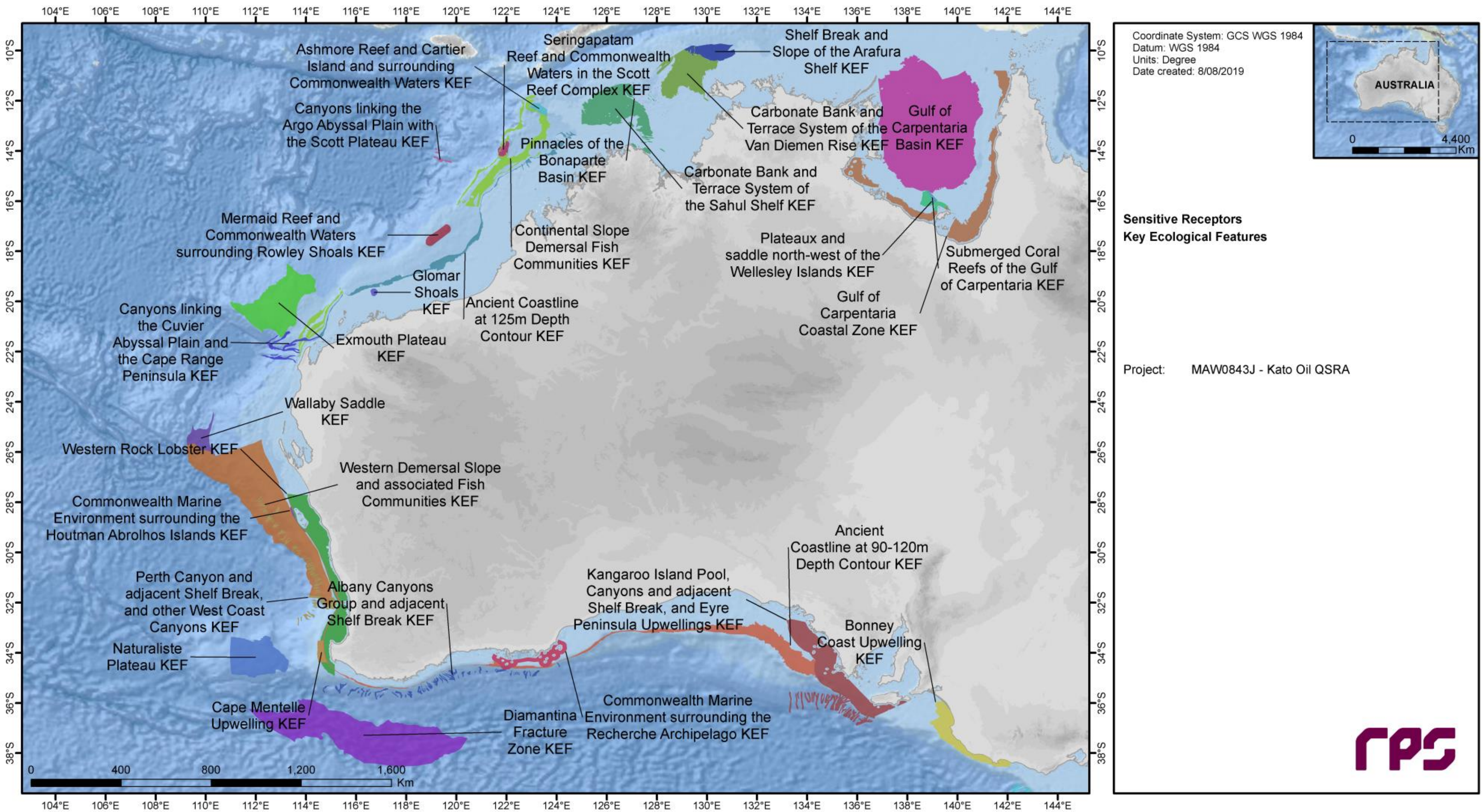

Figure 2.6 Locations of Key Ecological Features (KEF) sensitive receptors within the study region.

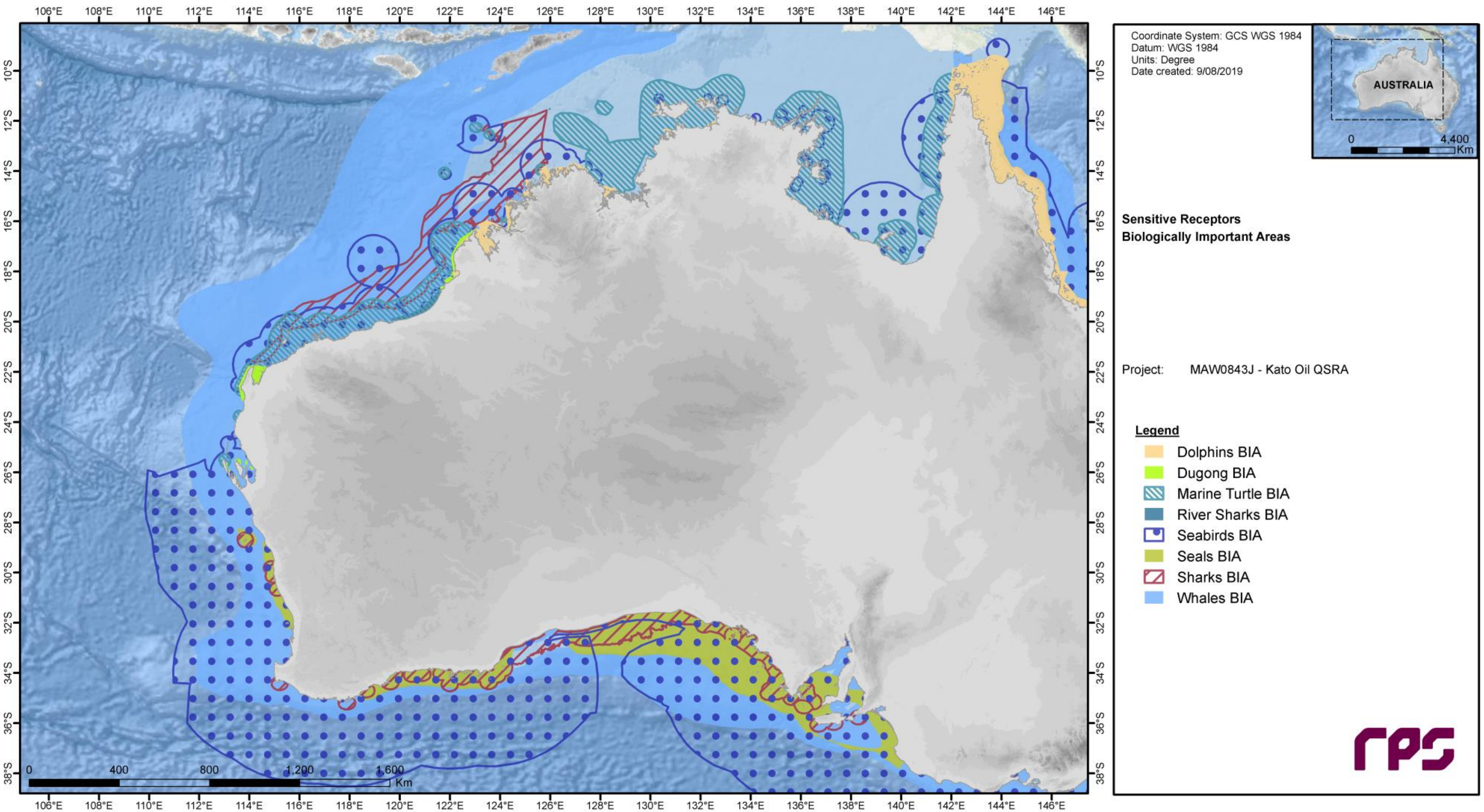

Figure 2.7 Locations of Biologically Important Areas (BIA) sensitive receptors within the study region.

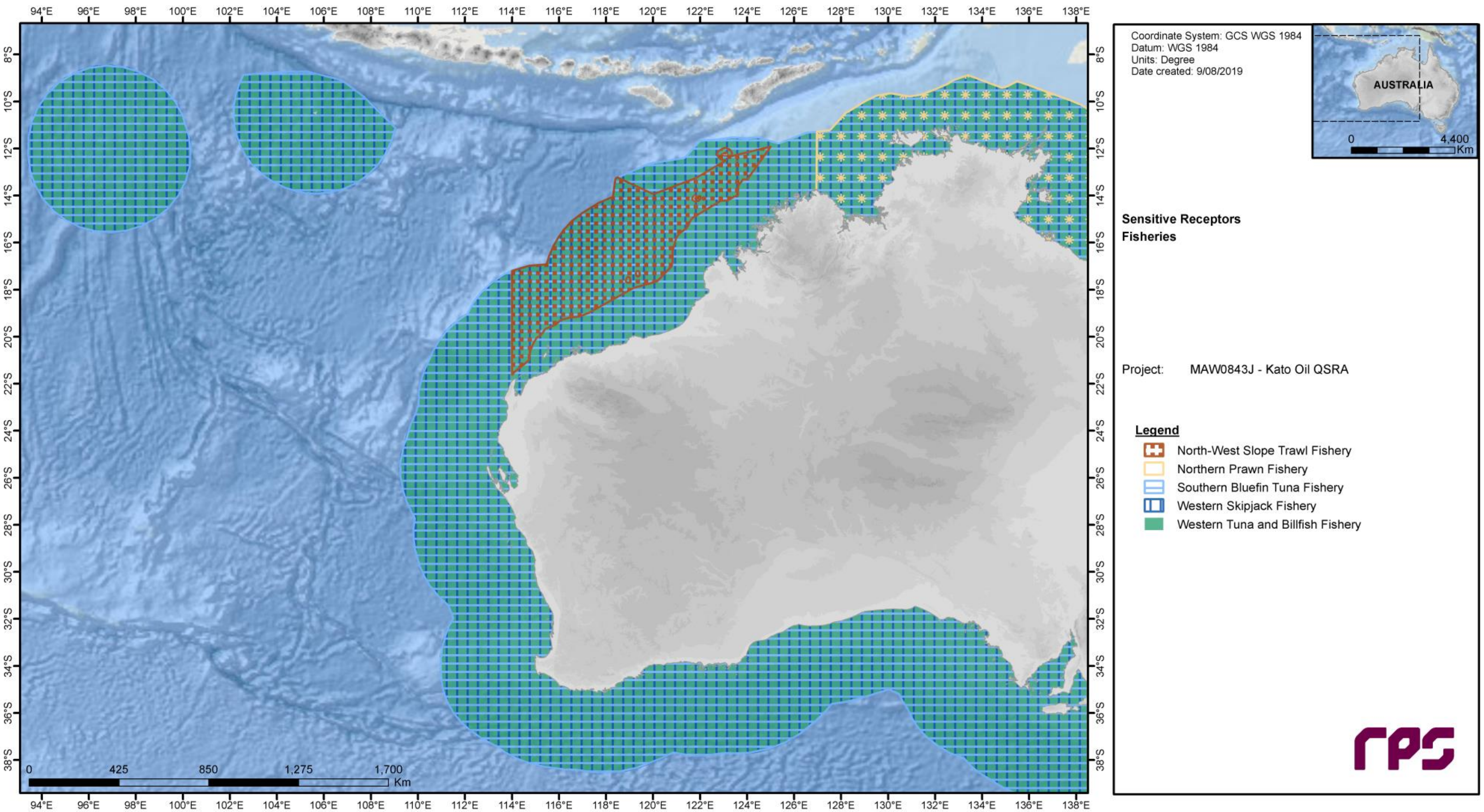

Figure 2.8 Locations of fishery sensitive receptors within the study region.

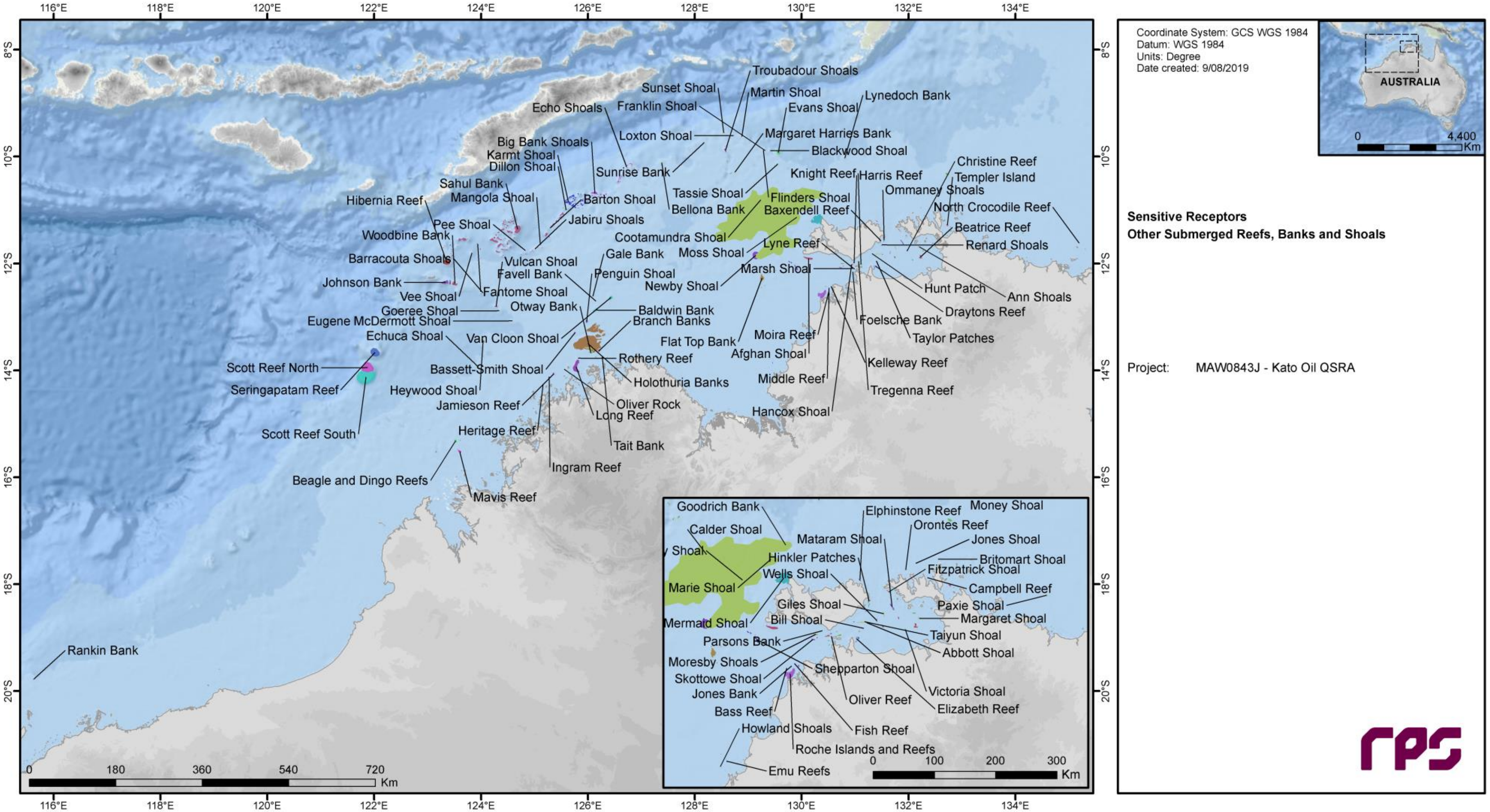

Figure 2.9 Locations of submerged Reef, Shoal and Bank sensitive receptors within the study region.

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.

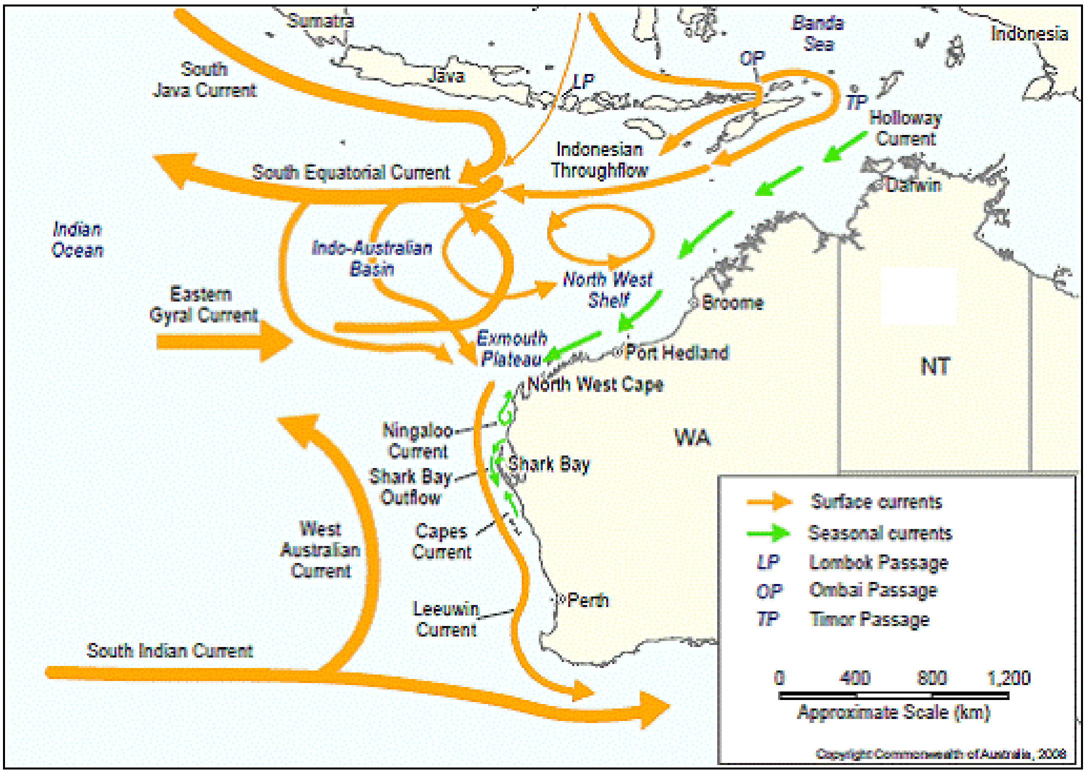

Figure 2.10 A map of the major currents off the Western Australian coast (DEWHA, 2008).

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 the Amulet field. Note that the convention for defining current direction is the direction the current is flowing *towards*. The data indicates average current speeds are approximately 0.17 m/s across the summer, winter and transitional seasons. Westerly currents are dominant in all seasons.

The extracted current data near the spill location 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.

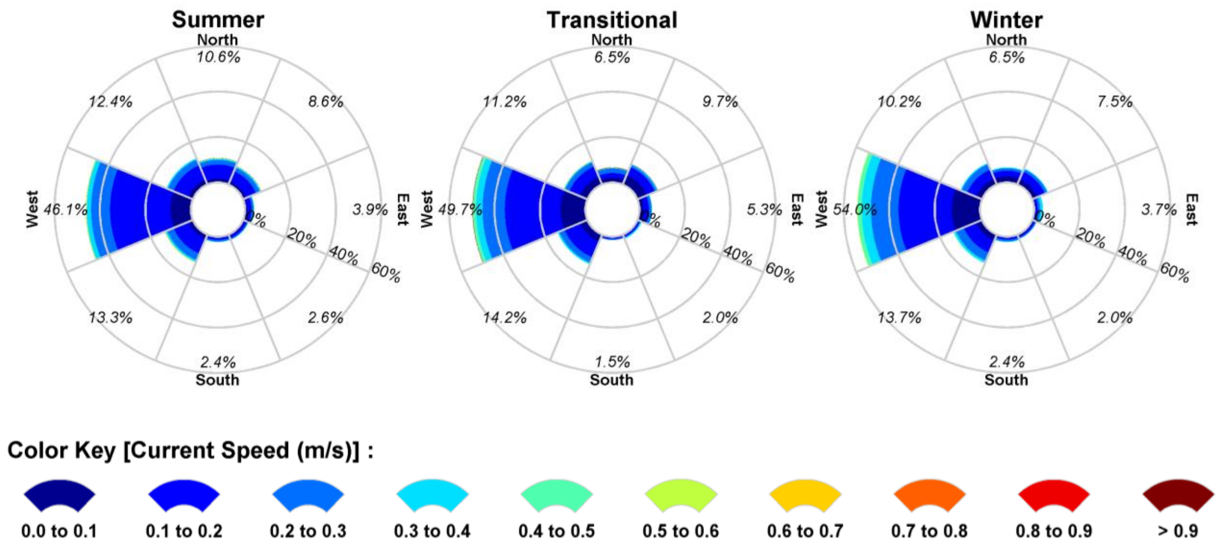

Figure 2.11 Seasonal current distribution (2009-2018, inclusive) derived from the HYCOM database at the point nearest to the Amulet field. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the 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.

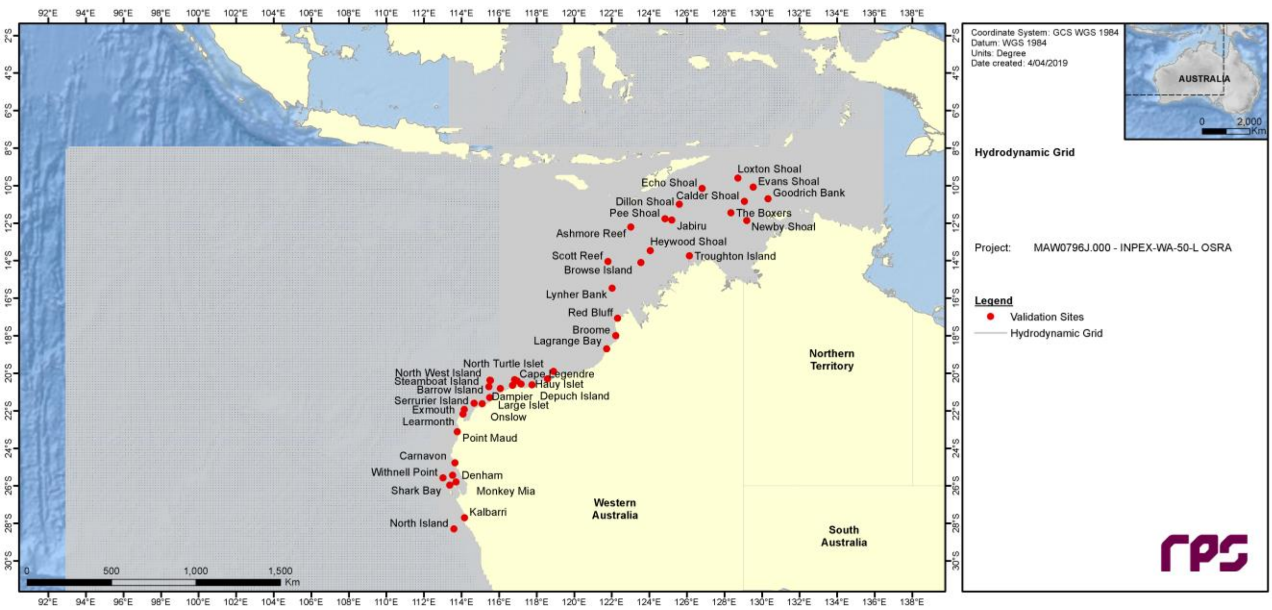

Figure 2.12 Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing the full domain in context with the continental land mass and the locations available for tidal comparisons (red labelled dots). Higher-resolution areas are indicated by the denser mesh zones.

2.3.1.3.4 Tidal Elevation Validation

For 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. Of more than 80 tidal stations within the HYDROMAP model domain, 18 sites near the release location were used for comparison.

Time series comparisons were completed for a six-month period from January to June 2010. Water level time series for these locations are shown in Figure 2.13, Figure 2.14 and Figure 2.15 for a one-month period (March 2010). 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.

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 location. A scatter plot of the observed and modelled amplitude (top) and phase (bottom) of the five dominant tidal constituents (S_2, M_2, N_2, K_1 and O_1) is presented in Figure 2.16. 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.

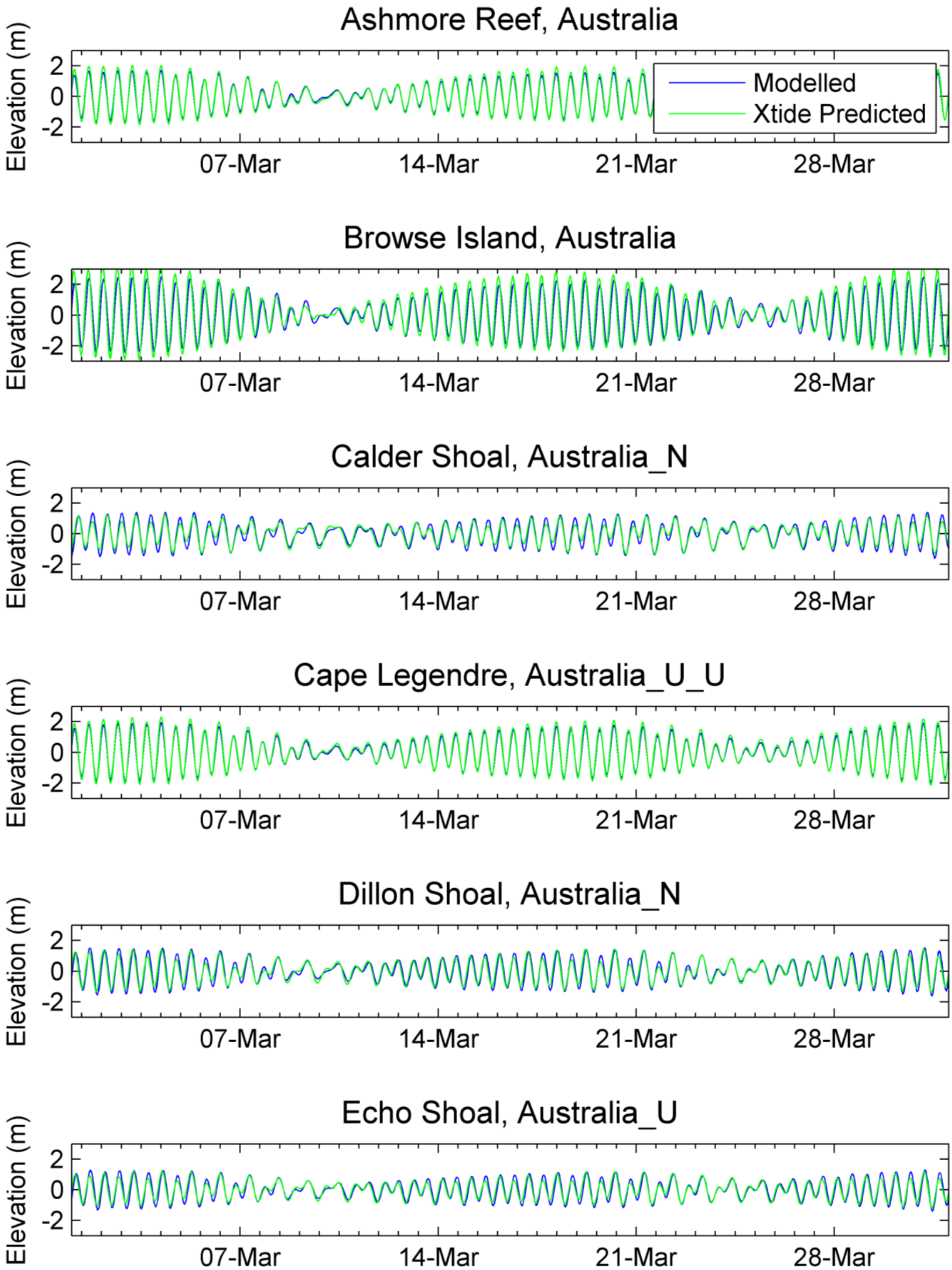

Figure 2.13 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

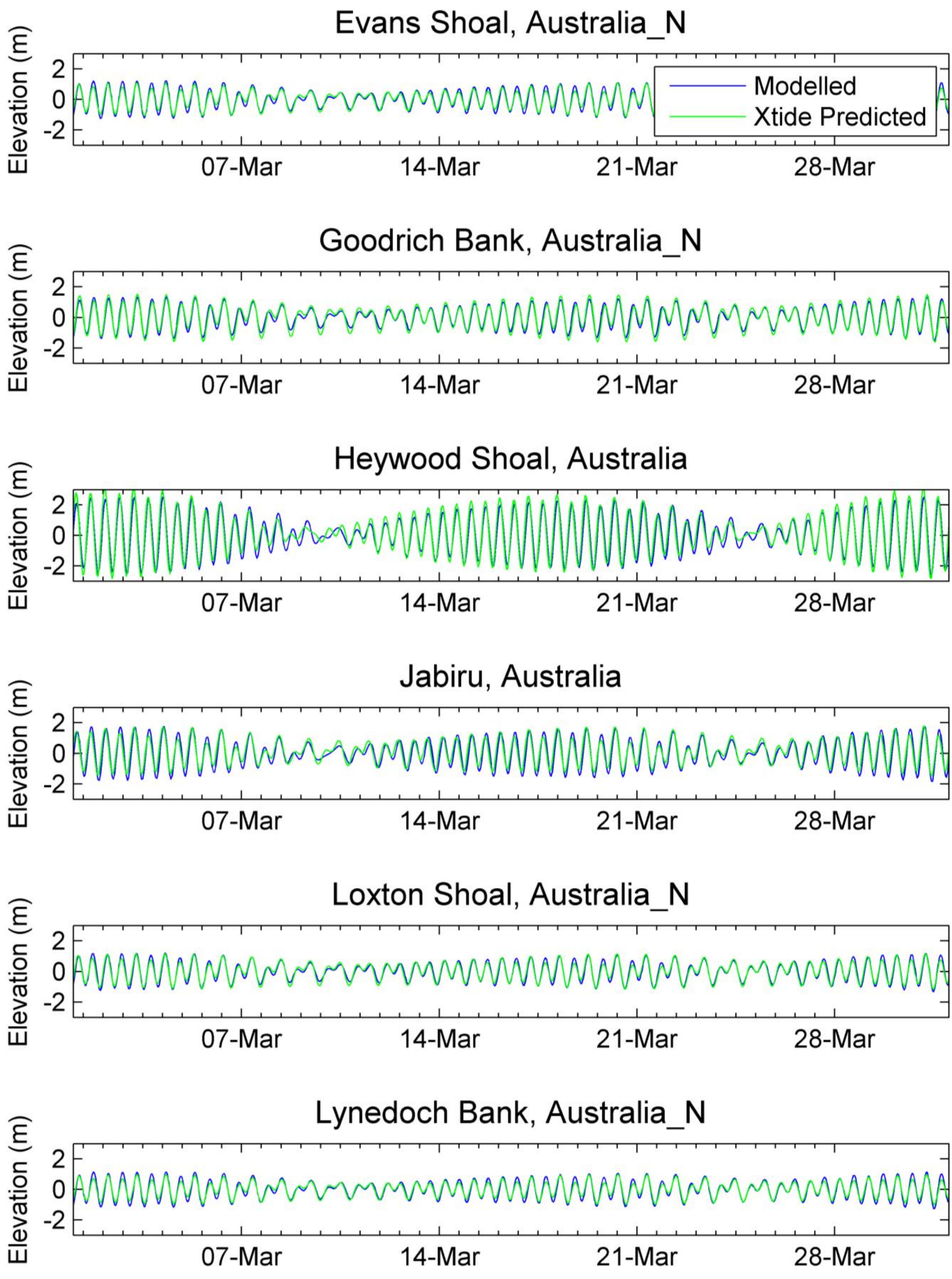

Figure 2.14 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

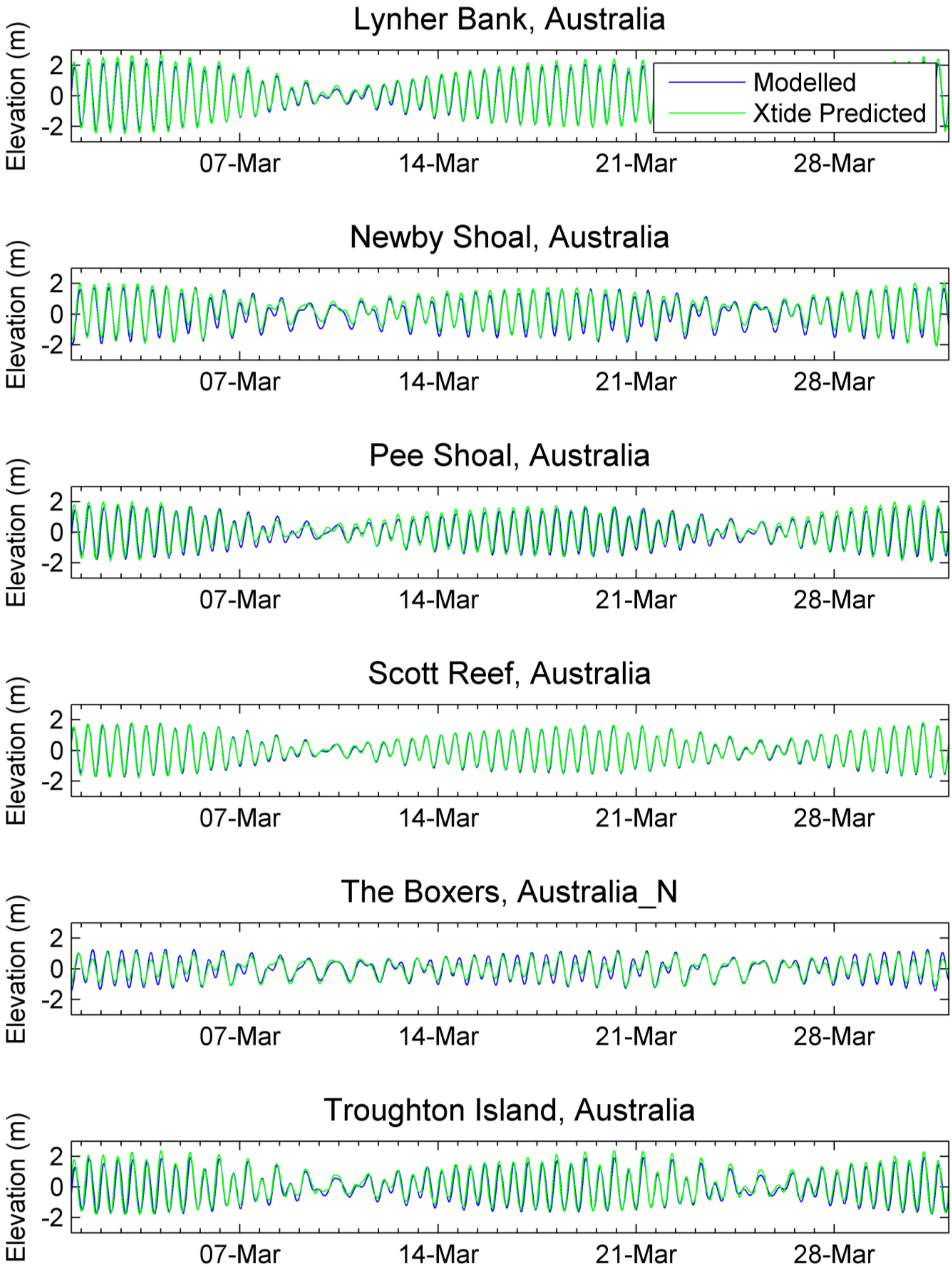

Figure 2.15 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

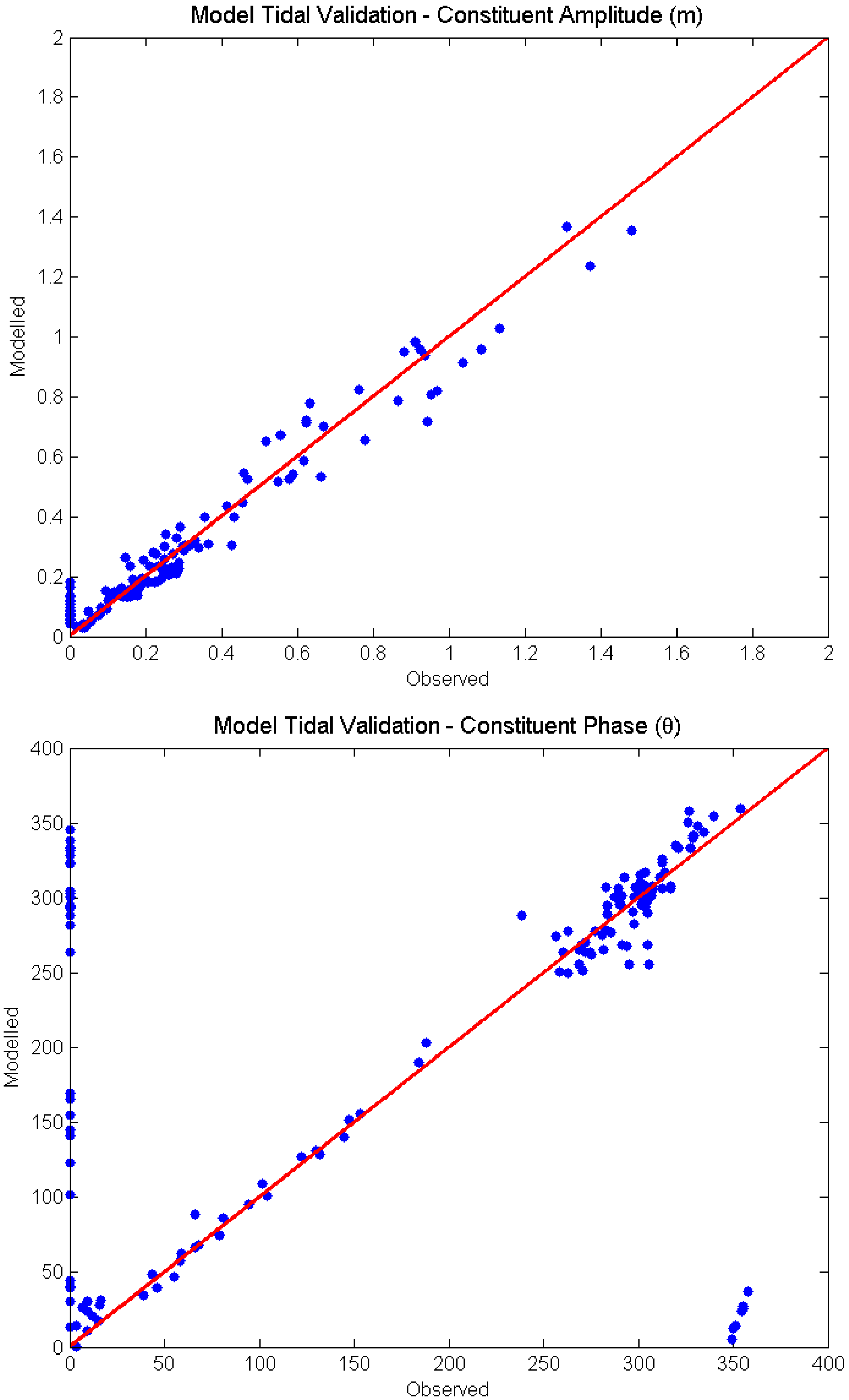

Figure 2.16 Comparisons between predicted tidal constituent amplitudes (top) and phases (bottom) from HYDROMAP and XTide at all stations in the tidal model domain. The red line indicates a 1:1 correlation between the respective data sets.

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 Amulet 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 north-west and south-east axis across all seasons, with maximum speeds of around 0.8 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 site, particularly towards the coast, would be subject to considerable variation in the tidal current regime.

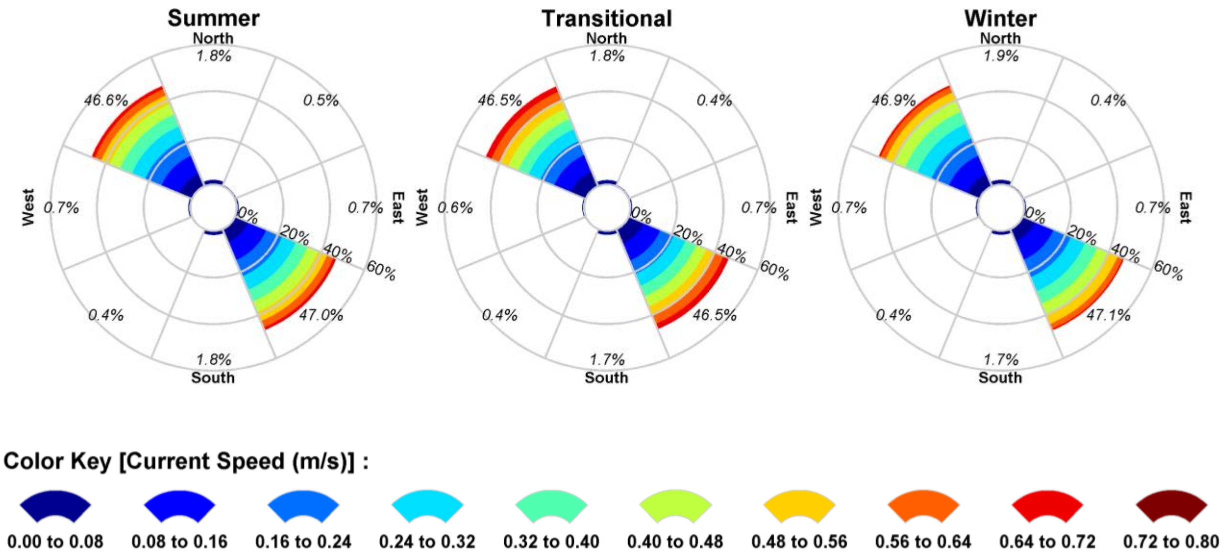

Figure 2.17 Seasonal current distribution (2009-2018, inclusive) derived from the HYDROMAP database point near the Amulet field. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage 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 Amulet 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 winter months (6.5 m/s), from a predominantly easterly direction. Lowest average wind speeds are likely to occur during the transitional months (5.6 m/s) from a predominately south-westerly direction.

The extracted wind data near the spill location 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.

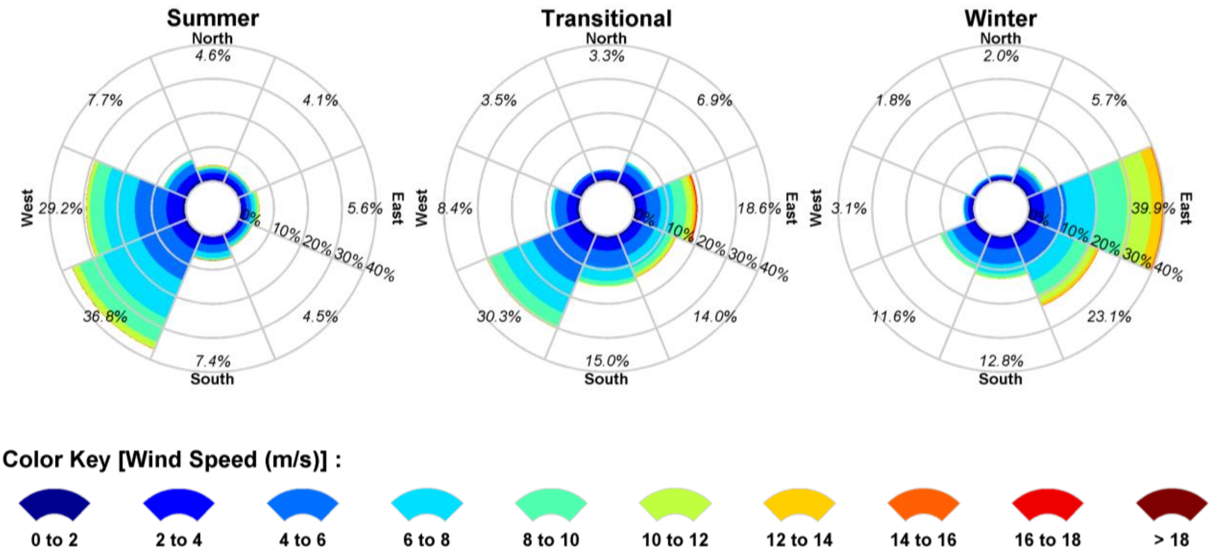

Figure 2.18 Wind distribution for simulation periods (2009-2018, inclusive) derived from the CFSR database point nearest to the Amulet field. The colour key shows the wind magnitude, the compass direction provides the direction from which the wind is blowing, and the size of the wedge gives the percentage 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 near the release location were retrieved from a data point (19° 30' 0.00" S, 116° 30' 0.00" E) in the WOA13 database nearby to the Amulet 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 the Amulet scenarios, a total of 50 (subsea well blowout) and 100 (short-term surface release) replicate simulations were run per season (i.e. an annualised total of 150; subsea well blowout and 300; short-term surface release).

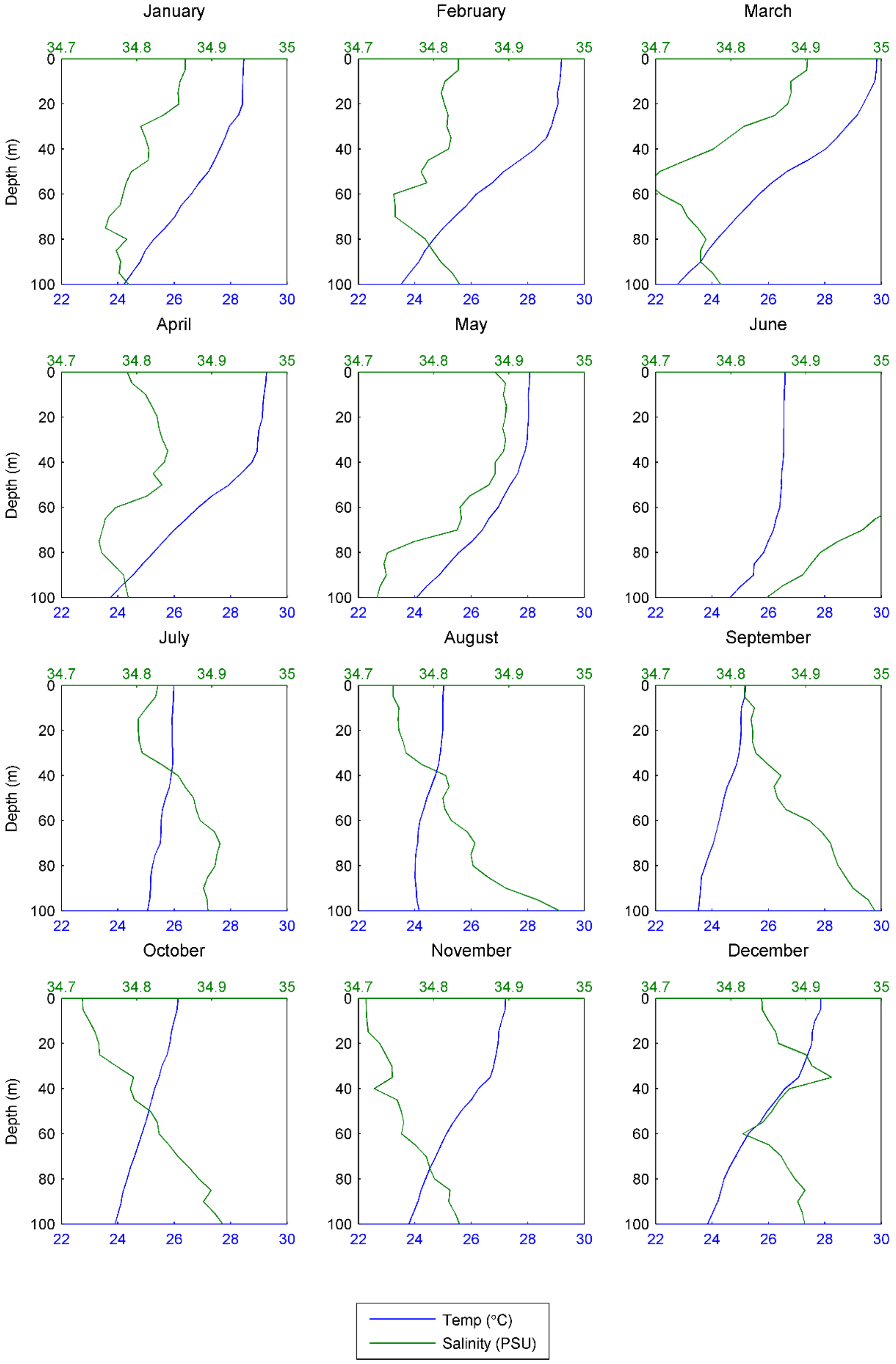

Figure 2.19 The temperature (blue line) and salinity (green line) profile derived from the WOA09 database at the point closest to the Amulet field, representative of the period 2009-2018, inclusive (NOAA 2009). Depth of 0 m is the sea surface.

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.

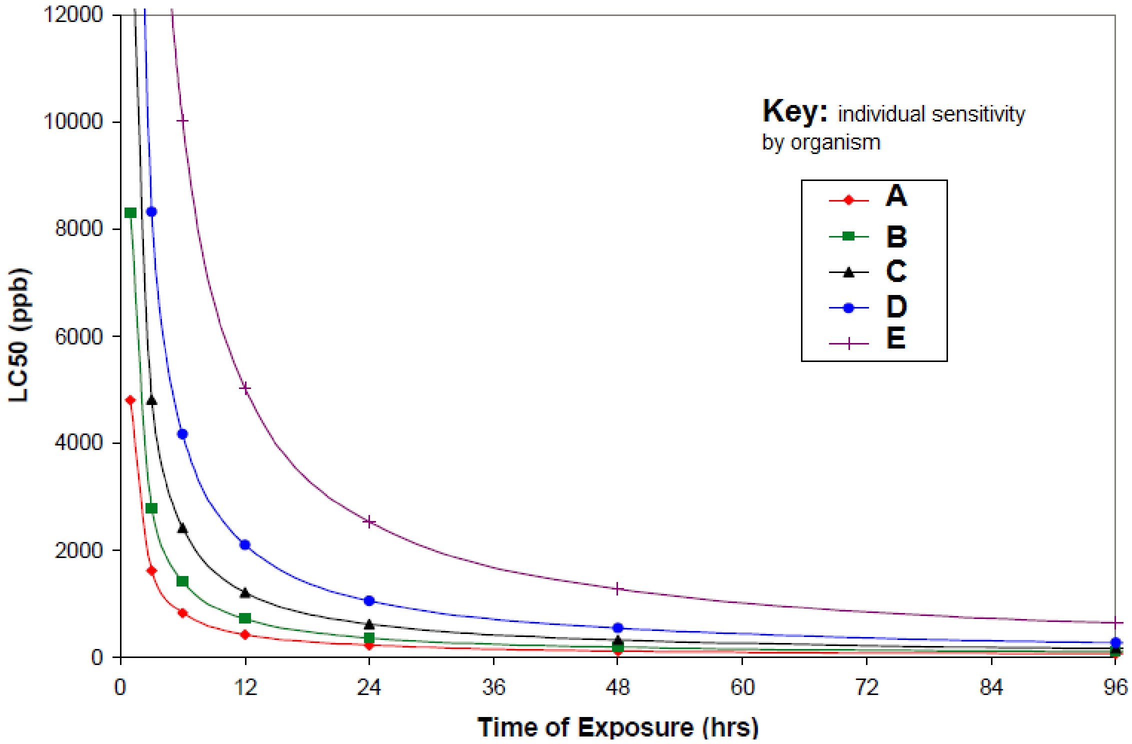

Figure 2.20 Illustrative representation of the general relationship between effect concentration, exposure time and species sensitivity (from high sensitivity A to low sensitivity E) to dissolved aromatic hydrocarbons. Data are conceptual values only.

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 Amulet 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 releases.

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
Amulet Crude	0.803 [at 15 °C]	2.355 [at 15 °C]	% of total	57.0	22.0	16.0	5.0	11.0
			% aromatics	7.0	3.0	1.0	-	-
Marine gas oil	0.830 [at 15 °C]	2.50 [at 40 °C]	% of total	16.4	49	31.9	2.7	4.6
			% aromatics	1.9	1.1	1.6	-	-

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 the surface will be subject to atmospheric weathering and will be transported by prevailing currents and winds. Oil that entrains or dissolves in the water column will be transported by prevailing currents 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. As a result, discharge conditions (which affect droplet size distribution and rise times) will have a strong influence on exposure risks for surrounding resources.

2.3.7.2 Amulet Crude

Amulet Crude (API 43.7) has a dynamic viscosity of 2.355 cP (at 15 °C) and a low pour point (9 °C) relative to seawater temperatures around the Amulet 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.

The mixture is composed of hydrocarbons that have a wide range of boiling points and volatiles 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 57% of the oil mass should evaporate within the first 12 hours (BP < 180 °C); a further 22% should evaporate within the first 24 hours (180 °C < BP < 265 °C); and a further 16% should evaporate over several days (265 °C < BP < 380 °C). The oil contains a relatively low proportion (5% 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 11% by mass of the whole oil. Around 7% 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 the surface will tend to evaporate rapidly.

2.3.7.3 Marine Gas Oil

Marine gas oil (API 34.9) 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 (2.50 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 mixture is composed of hydrocarbons that have a wide range of boiling points and volatiles 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 Amulet 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 Amulet Crude for 80 days at the rate specified for the subsea well blowout (decreasing from 967 m^3/day to 797 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 Amulet Crude

The results for the constant-wind case (Figure 2.21) indicate that a significant proportion of Amulet Crude will tend to persist on the sea surface (5.5% after 7 days) during calm wind conditions, with negligible levels of entrainment and around 81.6% of the spilled volume expected to evaporate within the first 24 hours. The results for the variable-wind case (Figure 2.22) indicate that the wind conditions will have a large impact on the proportion of Amulet Crude 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 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:0.4% after 24 hours compared with <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 75.6% of the spilled volume expected to evaporate after 7 days as compared to 91.6% 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 6.8% after 7 days. In comparison to a rate of ~0.2% and an accumulated total of 1.1% in the constant-wind case. The slow degradation of this weathered oil 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 Amulet Crude 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 17% of the volume 12 hours after the spill commencement to around 4% by the end of the simulation. Losses are predominately due to evaporation (79%) and degradation (16%) after 94 days. A low volume of oil is expected to surface over time (<6% after day 2), due to the high evaporation rates. Evaporation and decay losses represent approximately 79% (55,143 m^3) and 16% (11,168 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 (~8% after 7 days) during calm wind conditions, with negligible levels of entrainment and around 68% 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 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:1.6% after 24 hours compared with <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 56.4% of the spilled volume expected to evaporate after 7 days as compared to 90.6% for the lower-wind case.

Biological and photochemical degradation is predicted to be greater in the variable-wind case with a rate of ~1.6% per day and an accumulated total of 11% after 7 days. In comparison to a rate of ~0.1% and an accumulated total of 0.8% in the constant-wind case. The slow degradation of this weathered oil 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.

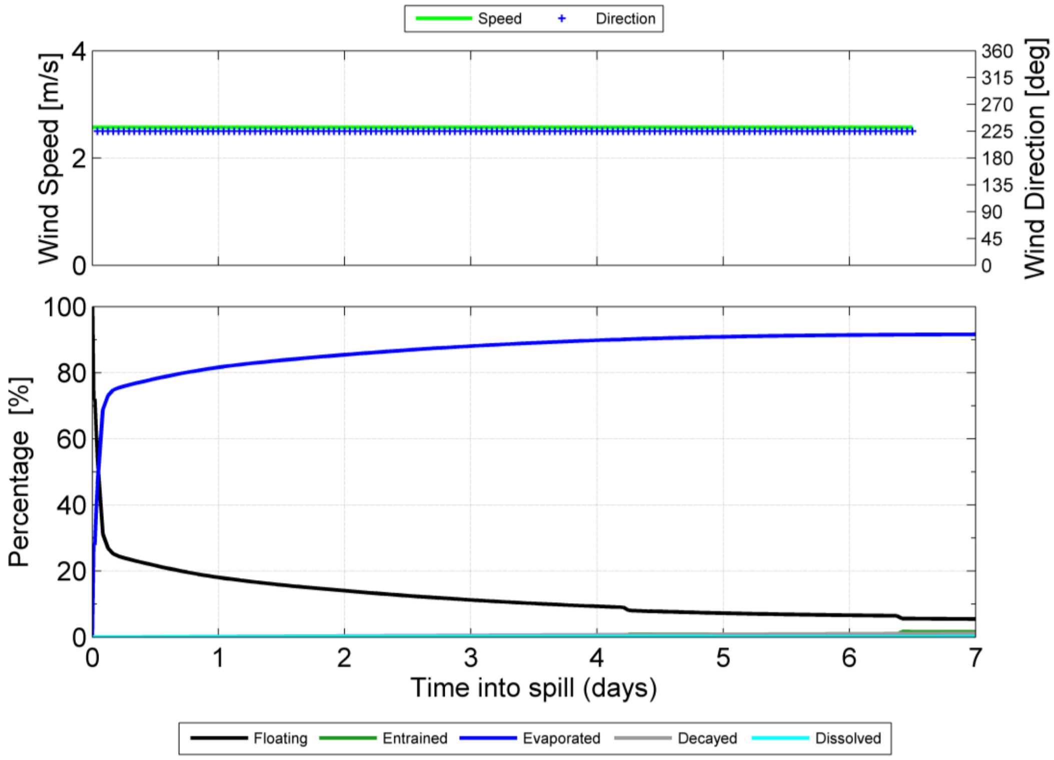

Figure 2.21 Mass balance plot representing, as a proportion, the weathering of Amulet Crude spilled onto the water surface as a one-off release (50 m^3) and subject to a constant 5 kn (2.6 m/s) wind at 27 °C water temperature and 25 °C air temperature.

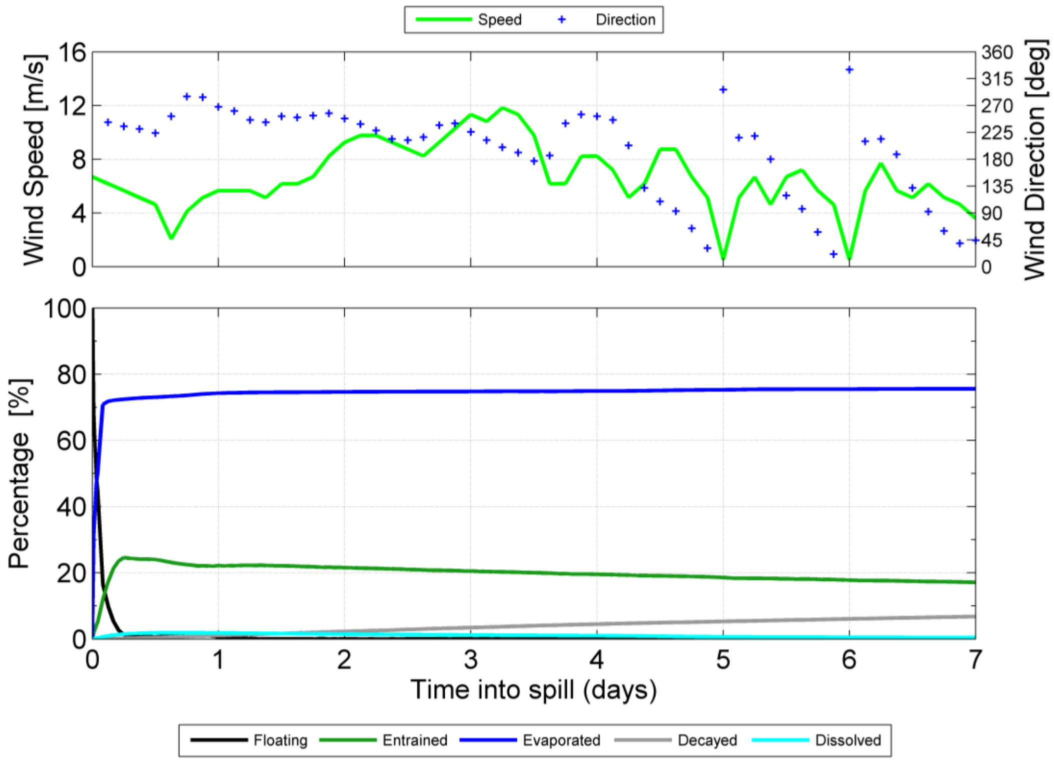

Figure 2.22 Mass balance plot representing, as a proportion, the weathering of Amulet Crude spilled onto the water surface as a one-off release (50 m^3) and subject to variable wind at 27 °C water temperature and 25 °C air temperature.

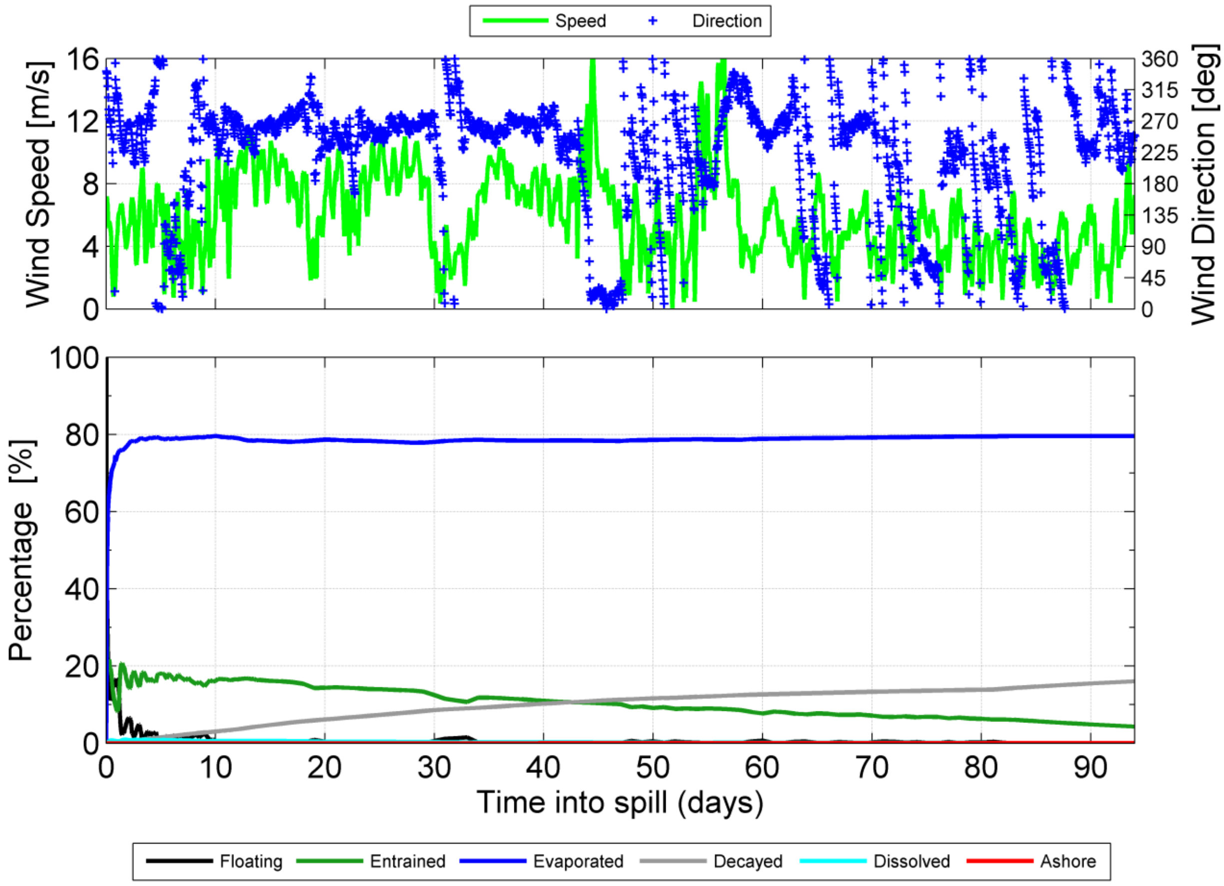

Figure 2.23 Mass balance plot representing, as a proportion, the weathering of a continuous subsea release of 69,801 m³ of Amulet Crude and subject to time varying environmental conditions.

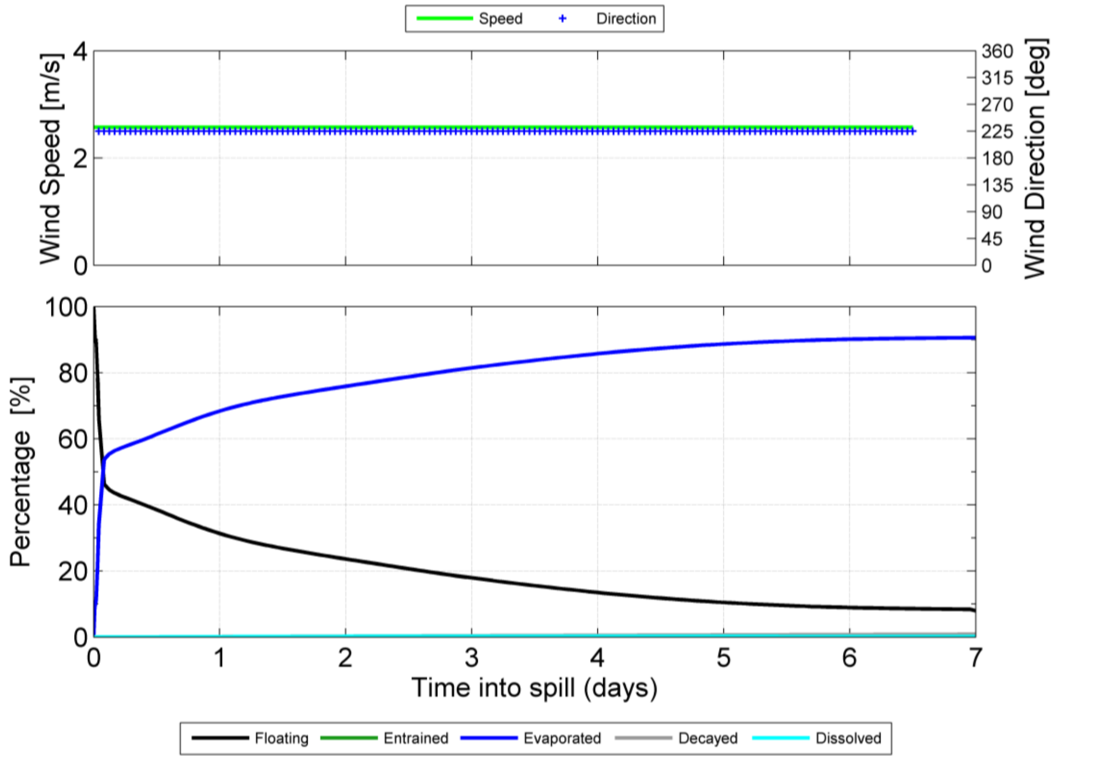

Figure 2.24 Mass balance plot representing, as a proportion, the weathering of marine gas oil spilled onto the water surface as a one-off release (50 m^3) and subject to a constant 5 kn (2.6 m/s) wind at 27 °C water temperature and 25 °C air temperature.

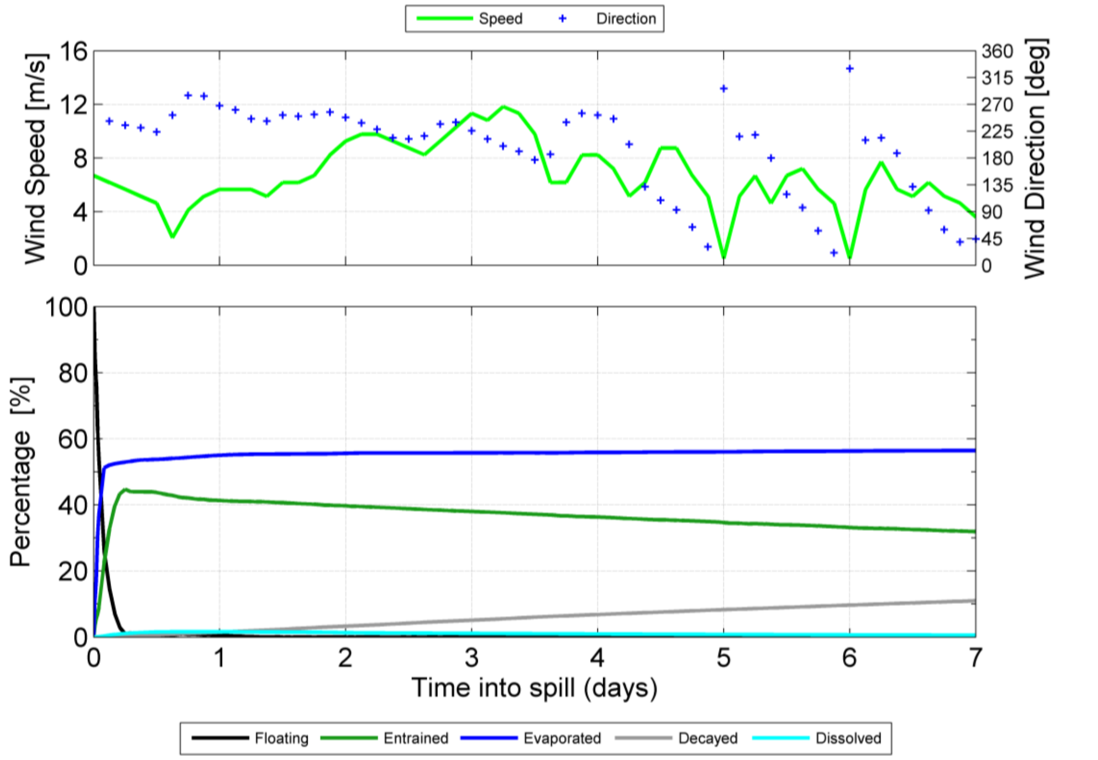

Figure 2.25 Mass balance plot representing, as a proportion, the weathering of marine gas oil spilled onto the water surface as a one-off release (50 m^3) and subject to variable wind at 27 °C water temperature and 25 °C air temperature.

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 subsurface discharge in Scenario 1.

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 subsea well blowout are presented in the following section.

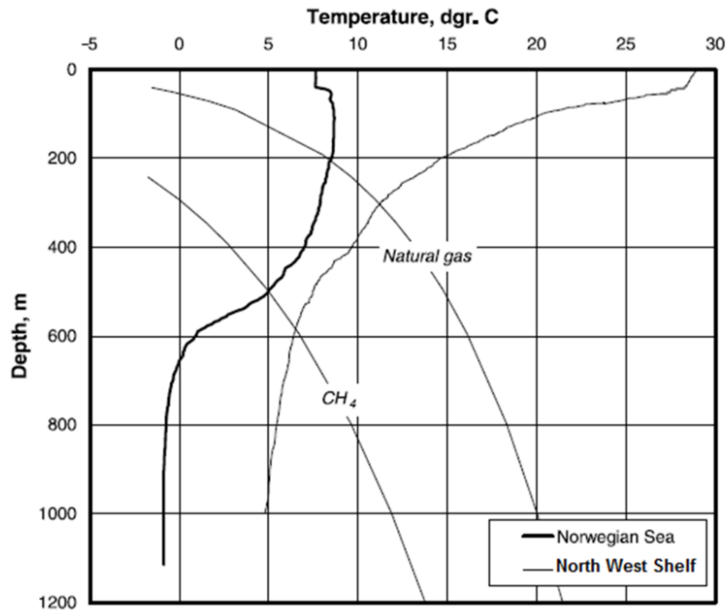

Figure 2.26 Theoretical equilibrium lines for hydrate formation based on the temperature and pressure at the release point. The line for "natural gas" assumes 80% methane, 10% ethane and 10% propane. Typical indicative sea temperature profiles with depth are indicated (Johansen, 2003).

2.3.9.2 Long-term (80-day) subsea well blowout of Amulet Crude within the Amulet 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 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 1.6 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 11 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.

OILMAP	Parameter	Value
Inputs	Release depth (m BMSL)	80
	Oil density (g/cm^3) (at 15 °C)	0.803
	Oil viscosity (cP) (at 15 °C)	2.355
	Oil temperature (°C)	69.8
	Reservoir pressure (psi)	500
	Hole diameter (m) [in]	0.76 [30]
	Gas:oil ratio (m^3/m^3) [scf/bbl]	12.74 [71.6]
	Week 1 oil flow rate (m^3/d) [bbl/d]	967 [6,084]
	Week 11 oil flow rate (m^3/d) [bbl/d]	797 [5,014]
Outputs	Plume diameter (m)	11
	Plume height (m ASB)	86 (surface)
	Plume initial rise velocity (m/s)	1.6
	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 Amulet Crude within the Amulet 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 Amulet Crude, assuming a variable (decreasing) rate of discharge due to depressurisation, and totalling 69,801 m^3 from a depth of 86 m at a location (116° 58' 52.64" E, 19° 29' 30.19" S) within the Amulet 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 shorelines during the worst-case spill simulation was calculated as 18 m^3, for a spill commencing in summer (replicate 11; Table 3.1). During this deterministic case, the highest accumulation was predicted for the Ningaloo World Heritage Area (WH) shoreline receptor.

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	11	18 m^3	Ningaloo WH

* Volume results refer to model predictions for all shorelines in the region, not for any specific receptor.

Figure 3.1 to Figure 3.5 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, respectively, at 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 495 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 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, respectively. The plots summarise the highest concentrations ever calculated for locations along contour lines relative to the bathymetry.

Figure 3.11 shows a time-series of the predicted concentrations of surface, in-water (entrained and dissolved) and shoreline oil during this deterministic case at intervals of 1 day, 3 days, 2 weeks and 11 weeks following the commencement of the spill.

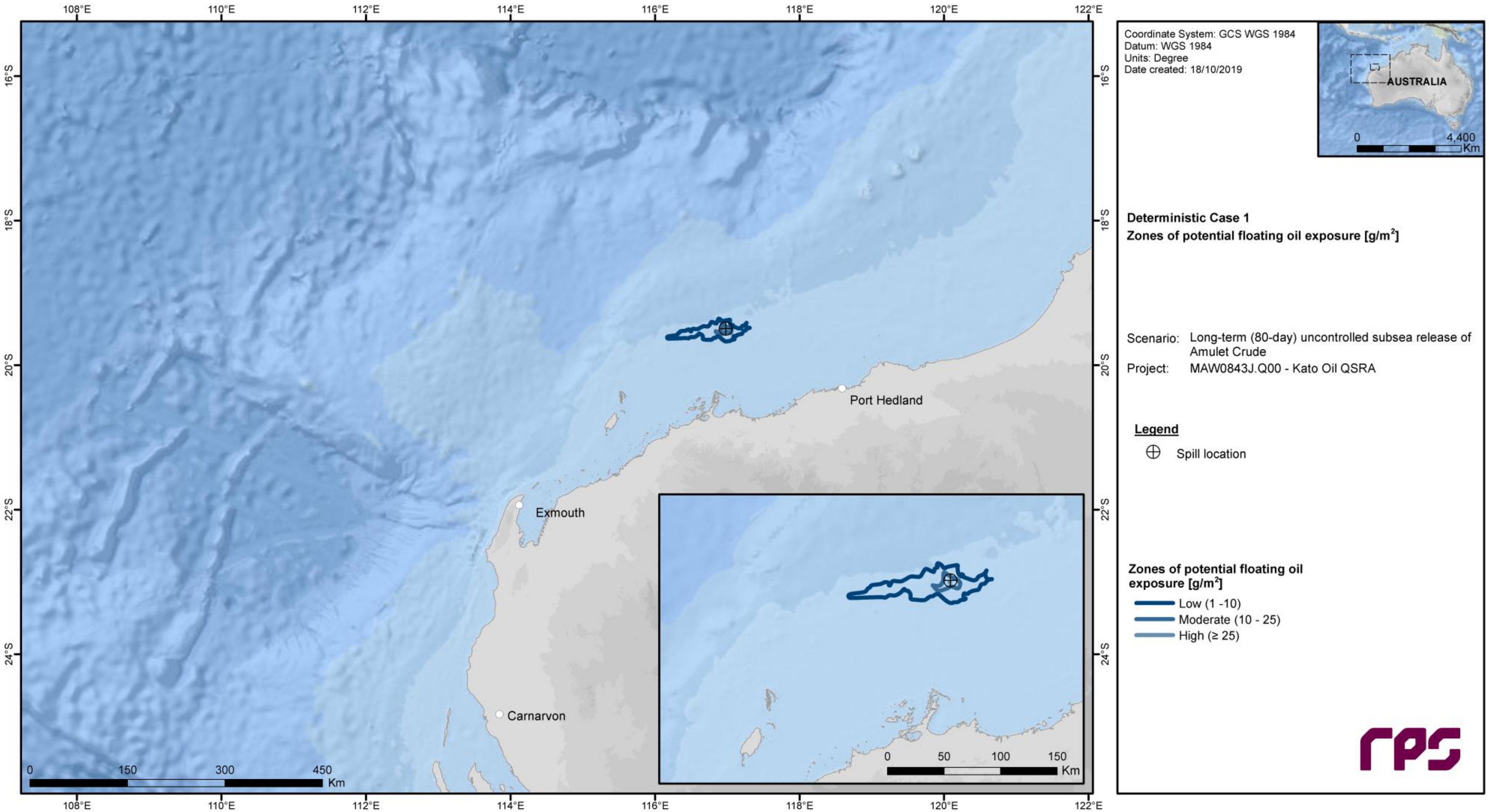

Figure 3.1 Predicted zones of potential floating oil exposure resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 11).

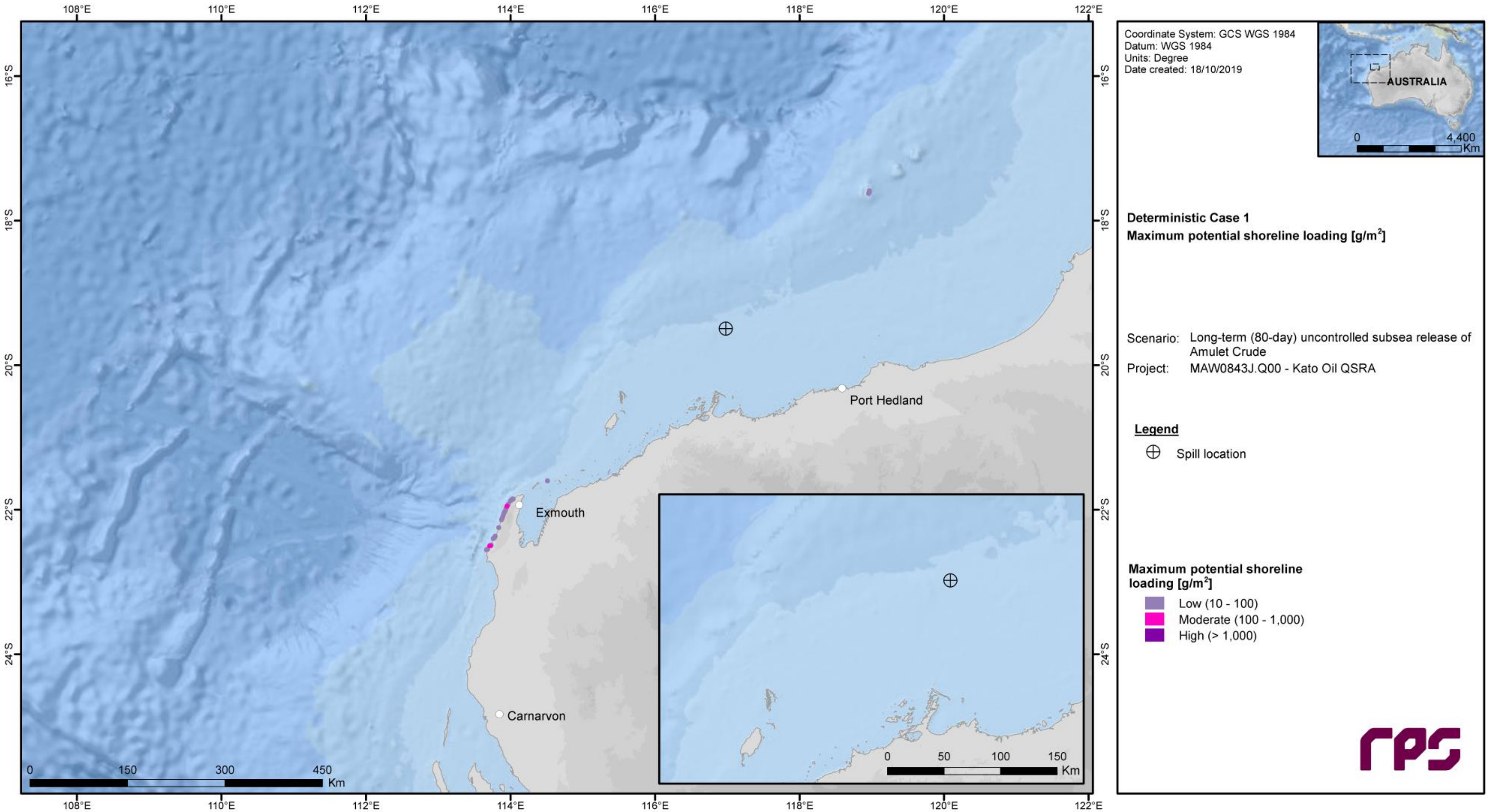

Figure 3.2 Predicted maximum potential shoreline loading resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 11).

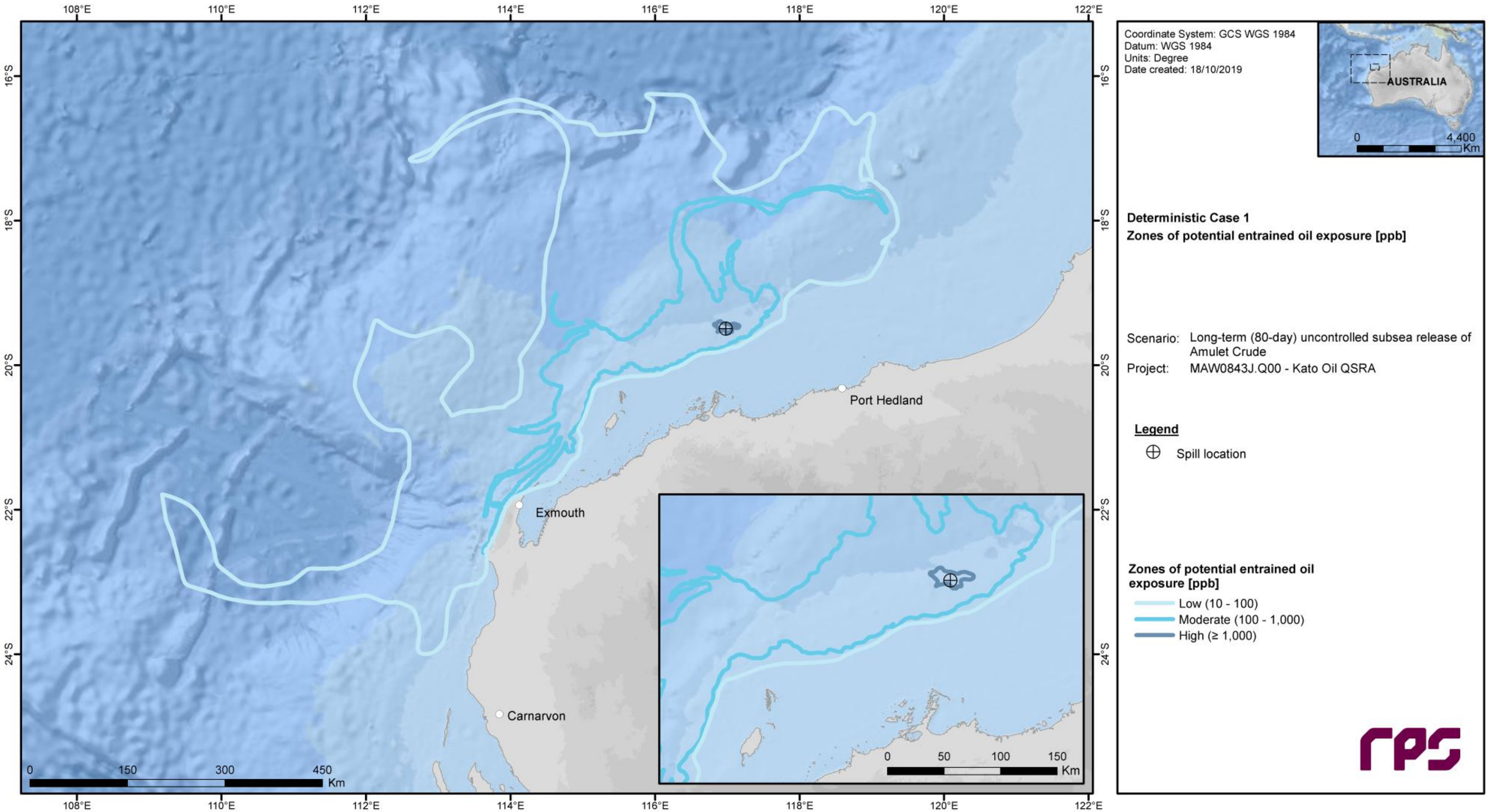

Figure 3.3 Predicted zones of potential instantaneous entrained oil exposure resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 11).

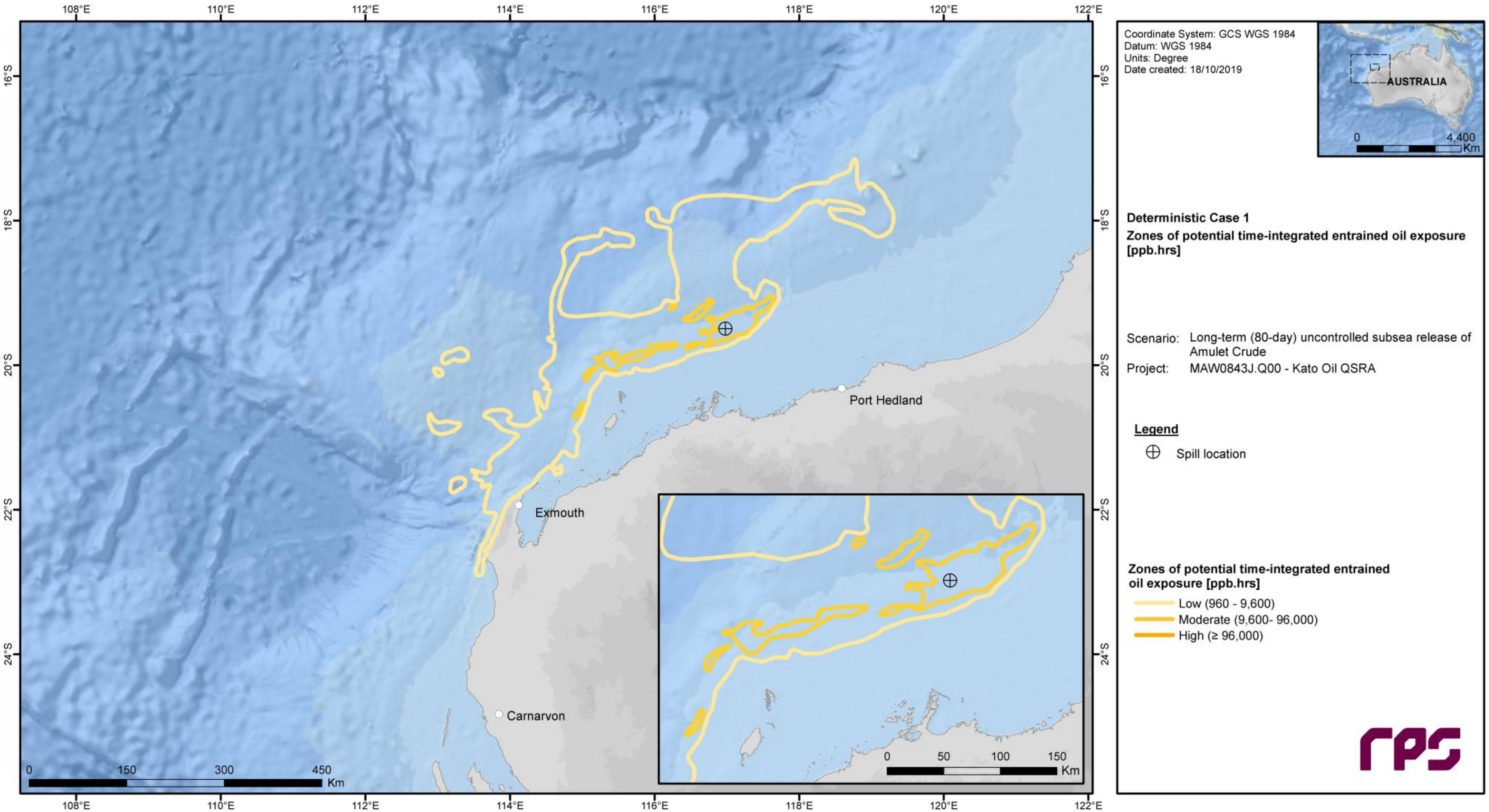

Figure 3.4 Predicted zones of potential time-integrated entrained oil exposure resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 11).

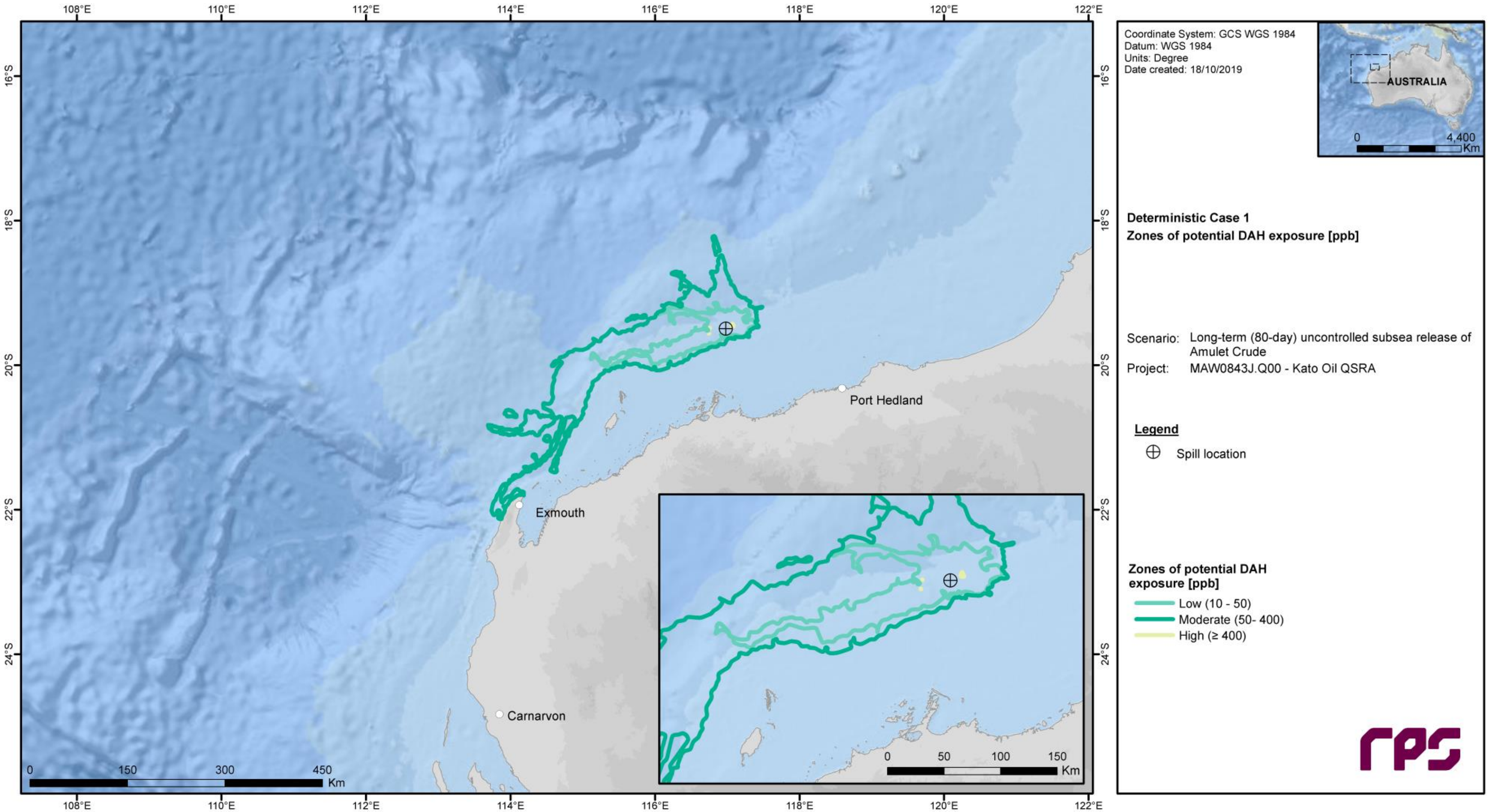

Figure 3.5 Predicted zones of potential instantaneous dissolved aromatic hydrocarbon exposure resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 11).

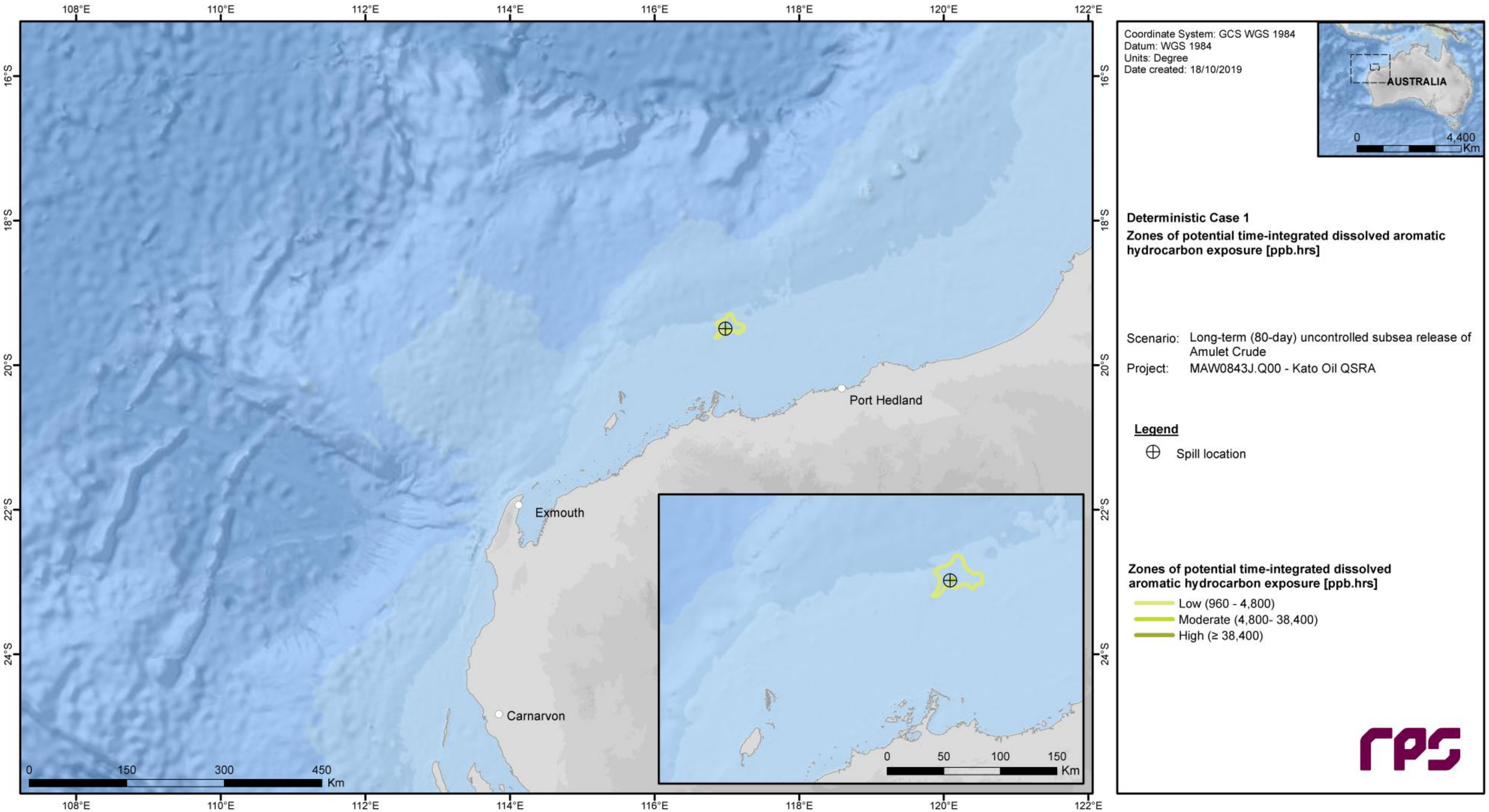

Figure 3.6 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 11).

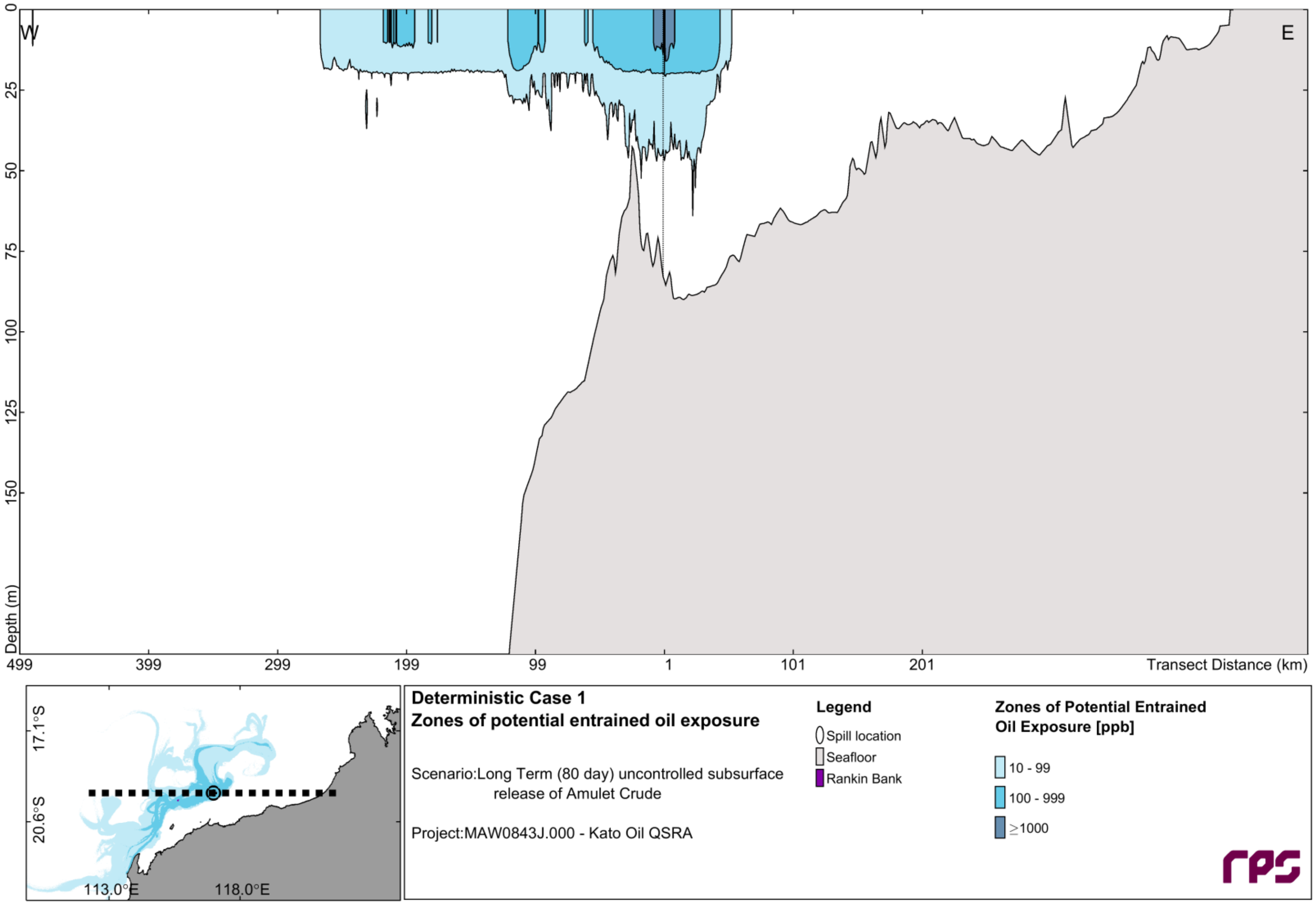

Figure 3.7 East-West cross-section transect of predicted maximum entrained oil concentrations from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 11). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

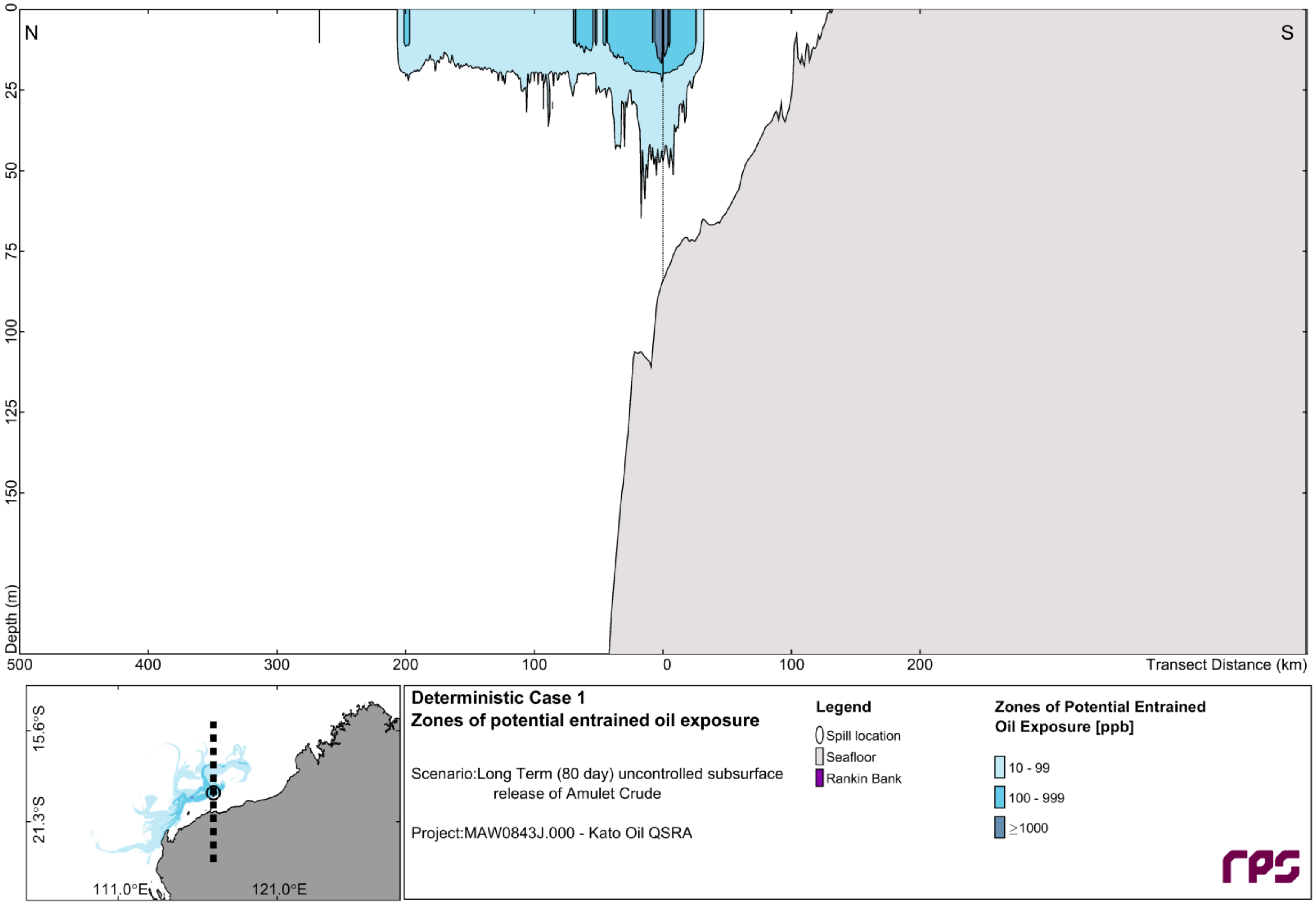

Figure 3.8 North-South cross-section transect of predicted maximum entrained oil concentrations from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 11). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

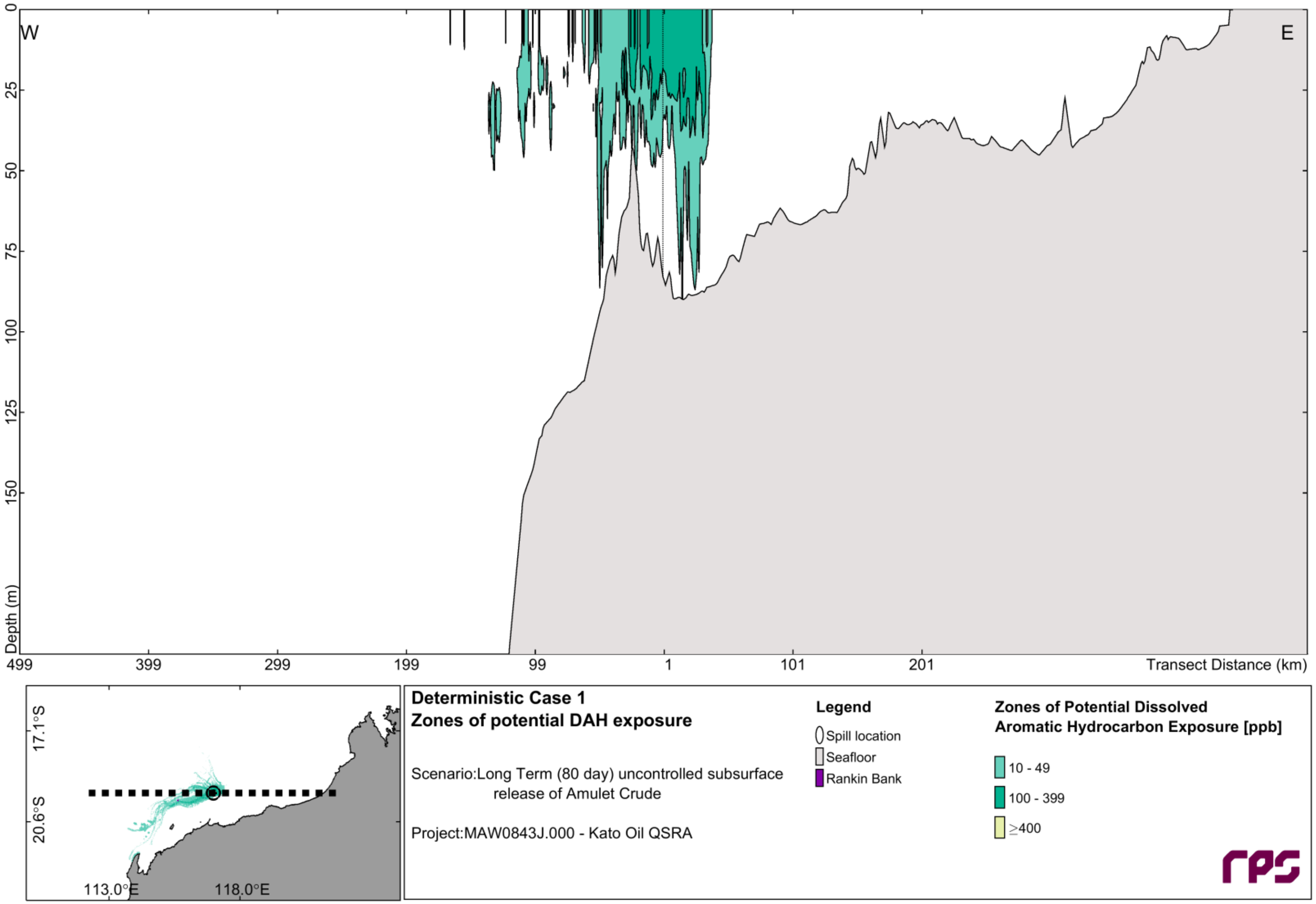

Figure 3.9 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 11). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

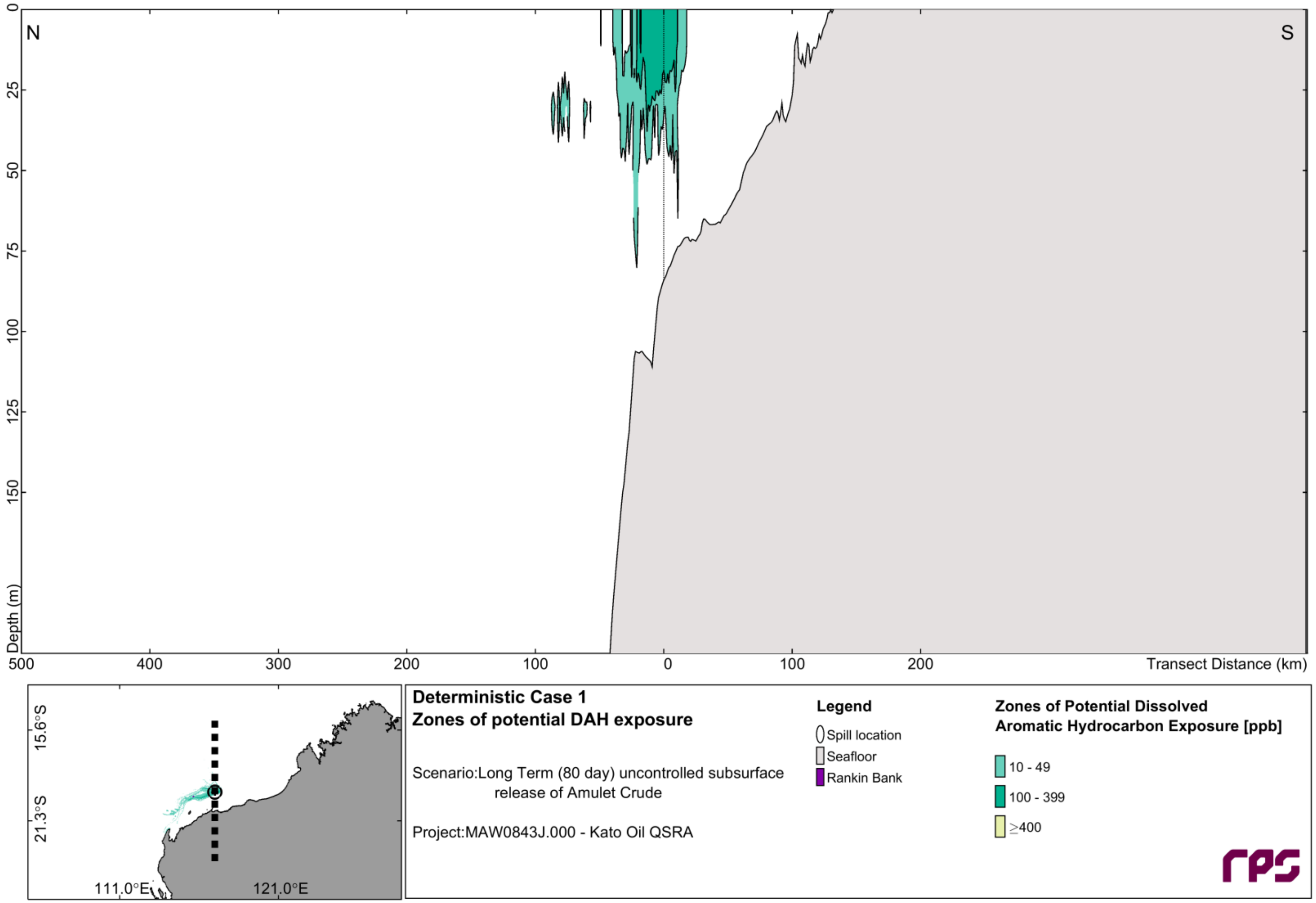

Figure 3.10 North-South cross-section transect of predicted dissolved aromatic hydrocarbon concentrations from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 11). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

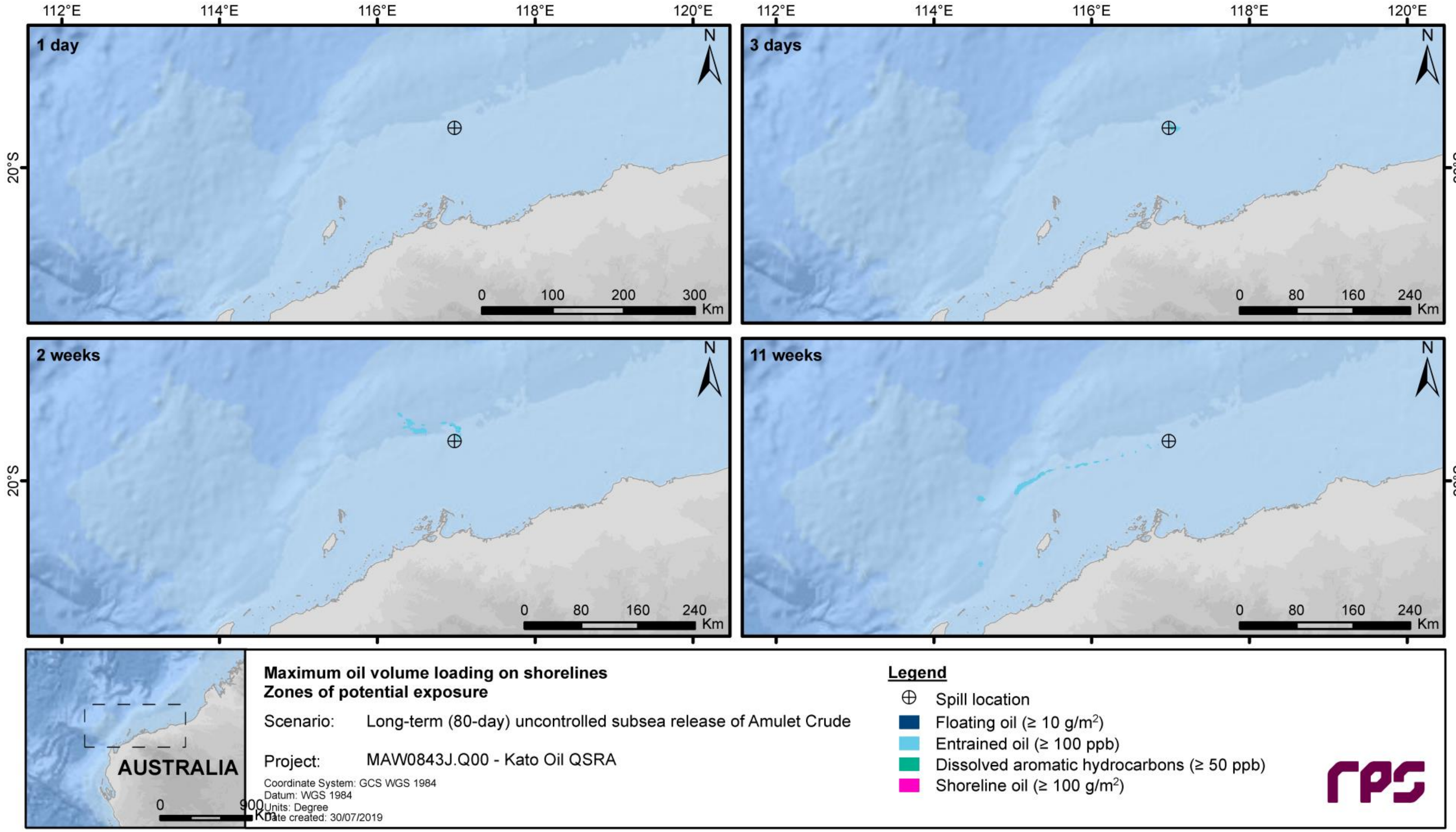

Figure 3.11 Time varying areal extent of predicted zones of potential exposure for floating oil (≥ 1 g/m^2) entrained oil (≥ 100 ppb), dissolved aromatic hydrocarbons (≥ 100 ppb) and shoreline oil (≥ 100 g/m^2) resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 11).

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 393 km from the release location, with distances reducing at the moderate (10 g/m^2; 58 km) and high (25 g/m^2; 19 km) thresholds (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	393	58	19

Floating oil contact at the low threshold (1 g/m^2) is not predicted to occur at any of the assessed shoreline receptors, in any season. Floating oil concentrations at the moderate threshold (10 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 Biologically Important Areas (BIAs) for Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries at 100% across all seasons.

The worst-case oil accumulation on a shoreline is predicted for the Ningaloo Coast WH receptor in summer, with an accumulated concentration and volume of 173 g/m^2 and 18 m^3, respectively (Table 3.5).

The worst-case maximum length of shoreline with concentrations exceeding the low threshold (10 g/m^2) was calculated as 28 km at the Ningaloo Coast WH and Ningaloo MP (State) receptors 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 1,483 km from the release location, with distances reducing at the moderate (100 ppb; 832 km) and high (1,000 ppb; 212 km) thresholds (Table 3.3).

The seasonal zones of potential entrained oil exposure at the assessed contact thresholds are depicted in Figure 3.14 (summer), Figure 3.24 (winter) and Figure 3.34 (transitional months).

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	1,483	832	212

The probability of contact by entrained oil concentrations at the moderate threshold (100 ppb) is predicted to be greatest at the Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery at 100% across all seasons (Table 3.6, Table 3.11 and Table 3.17). Entrained oil at the moderate threshold is predicted to arrive at these receptors within 1 hour after the release commences, across all seasons.

The worst-case instantaneous entrained oil concentration at any receptor is predicted at the Seabirds, Sharks and Whales BIAs and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 5,246 ppb (winter; Table 3.11).

The cross-sectional transects (summer; Figure 3.15/Figure 3.16, winter, Figure 3.25/Figure 3.26; and transitional months; Figure 3.35/Figure 3.36) of maximum entrained oil concentrations in the vicinity of the release site above the moderate (100 ppb) and high (1,000 ppb) thresholds are not expected to exceed depths of around 25 m and 35 m BMSL, respectively, in any season.

3.2.3.1.3 Entrained Oil - Exposure

Time-integrated entrained oil exposure at or above 960 ppb.hr could travel up to 992 km from the release location in transitional months, with distances reducing to 483 km and 40 km as contact thresholds increase to 9,600 ppb.hr and 96,000 ppb.hr, respectively.

Entrained oil exposure above the 9,600 ppb.hr threshold was predicted to be greatest at the Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery 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 exposure concentration is predicted at the Seabirds, Sharks and Whales BIAs and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 135,616 ppb.hr in summer (Table 3.7).

3.2.3.1.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Dissolved aromatic hydrocarbon concentrations at the low threshold (10 ppb) could travel up to 626 km from the release location, with distances reducing at the moderate(50 ppb; 584 km) and high (400 ppb; 51 km) thresholds (Table 3.4).

The seasonal zones of potential 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 months).

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	626	584	51

The probability of contact by dissolved aromatic hydrocarbon concentrations at the moderate threshold (50 ppb) is predicted to be greatest at the Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors at 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 in winter at the Ancient Coastline at 125 m Depth Contour Key Ecological Feature (KEF), BIAs for Seabirds, Sharks and

Whales and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 576 ppb (Table 3.13).

The cross-sectional transects (summer; Figure 3.19/Figure 3.20, winter; Figure 3.29/Figure 3.30 and transitional months; Figure 3.39/Figure 3.40) of maximum dissolved aromatic hydrocarbon concentrations in the vicinity of the release site above the high threshold (400 ppb) are not expected to exceed depths of around 80 m BMSL in any season.

3.2.3.1.5 Dissolved Aromatic Hydrocarbons - Exposure

Time-integrated dissolved aromatic hydrocarbon exposure at or above 960 ppb.hr are predicted to occur up to 723 km from the release site in winter, with the distance reducing to 605 km (winter) and 434 km (winter) as contact thresholds increase to 4,800 ppb.hr and 38,400 ppb.hr, respectively.

Dissolved aromatic hydrocarbon exposure above the 4,800 ppb.hr threshold was predicted to be greatest at BIAs for Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries receptors with probabilities of 10% (winter), 8% (summer) and 6% (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 Seabirds, Sharks and Whales BIAs and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 9,417 ppb.hr 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 Amulet Crude within the Amulet 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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Barrow Island	<2	<2	<2	NC	NC	NC	4	<2	<2	497	NC	NC	0.7	22	<1	<1	<1	1	NC	NC	NC	NC
	Browse Island	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	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	523	NC	NC	0.2	12	<1	<1	<1	1	NC	NC	NC	NC
	Montebello Islands	<2	<2	<2	NC	NC	NC	2	<2	<2	467	NC	NC	1.1	48	<1	3	<1	7	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	<2	<2	<2	NC	NC	NC	10	<2	<2	621	NC	NC	3.6	70	<1	2	<1	6	NC	NC	NC	NC
Coastlines	Buccaneer Archipelago	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Exmouth Gulf West	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	<0.1	4.8	<1	<1	NC	NC	NC	NC	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	<0.1	2.3	<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	<0.1	5	<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	Barrow Island MMA	<2	<2	<2	NC	NC	NC	4	<2	<2	523	NC	NC	0.7	15	<1	<1	<1	1	NC	NC	NC	NC
	Barrow Islands MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	6	<2	<2	1,171	NC	NC	1.2	32	<1	<1	<1	3	NC	NC	NC	NC

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
	Eighty Mile Beach - Broome	<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	6	<2	<2	960	NC	NC	1.8	22	<1	<1	<1	4	NC	NC	NC	NC
	Lalang-garram / Camden Sound 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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Montebello Islands MP	<2	<2	<2	NC	NC	NC	2	<2	<2	467	NC	NC	1.1	48	<1	3	<1	7	NC	NC	NC	NC
	Muiron Islands MMA	<2	<2	<2	NC	NC	NC	6	<2	<2	595	NC	NC	0.8	19	<1	<1	<1	2	NC	NC	NC	NC
	Ningaloo Coast WH	<2	<2	<2	NC	NC	NC	16	4	<2	582	598	NC	11	173	2	18	4	28	<1	3	NC	NC
	Ningaloo MP (State)	<2	<2	<2	NC	NC	NC	16	4	<2	582	598	NC	11	173	2	18	4	28	<1	3	NC	NC
	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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Australian Marine Parks	Abrolhos MP*	<2	<2	<2	NC	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
	Ashmore Reef MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Carnarvon Canyon MP*	<2	<2	<2	NC	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*	2	<2	<2	1,182	NC	NC	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	466	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ningaloo MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Oceanic Shoals MP*	<2	<2	<2	NC	NC	NC	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
	Roebuck 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*	<2	<2	<2	NC	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	34	<2	4	11	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*	<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/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
	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*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carbonate Bank and Terrace System of the Sahul Shelf KEF*	<2	<2	<2	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*	<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**	8	<2	<2	224	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Exmouth Plateau KEF*	2	<2	<2	1,182	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Glomar Shoals KEF*	96	8	<2	47	190	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*	<2	<2	<2	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*	<2	<2	<2	NC	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*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marine Turtle BIA*†	30	2	<2	20	1,195	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	River Sharks BIA*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seabirds BIA*†	100	100	56	1	1	2	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

	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
	Sharks BIA*	100	100	56	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Whales BIA*	100	100	56	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	North-West Slope Trawl Fishery*	8	<2	<2	224	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Southern Bluefin Tuna Fishery*	100	100	56	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Skipjack Fishery*	100	100	56	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Tuna and Billfish Fishery*	100	100	56	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other Submerged Reefs, Banks and Shoals	Barracouta Shoals*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Barton Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Bassett-Smith Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Big Bank Shoals*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dillon Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Echo Shoals*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Echuca Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	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
	Fantome Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Goeree Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Heywood Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Hibernia Reef*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jabiru Shoals*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Johnson Bank*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Karmt Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mangola Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Pee 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
	Sahul 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
	Vee Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Vulcan Shoal*	<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.

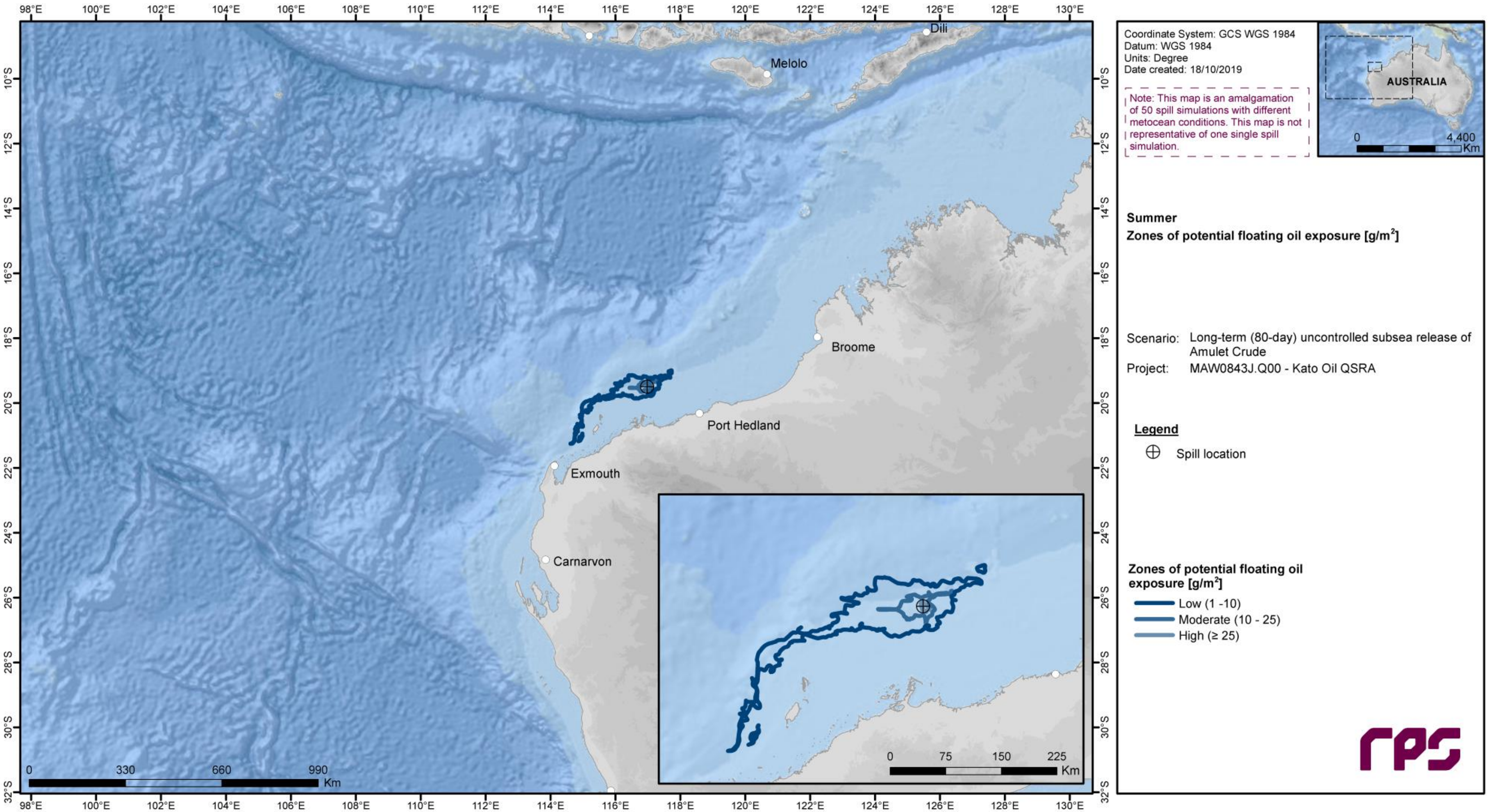

Figure 3.12 Predicted zones of potential floating oil exposure resulting from a long-term (80 days) subsea release of Amulet Crude within the Amulet field, starting in summer.

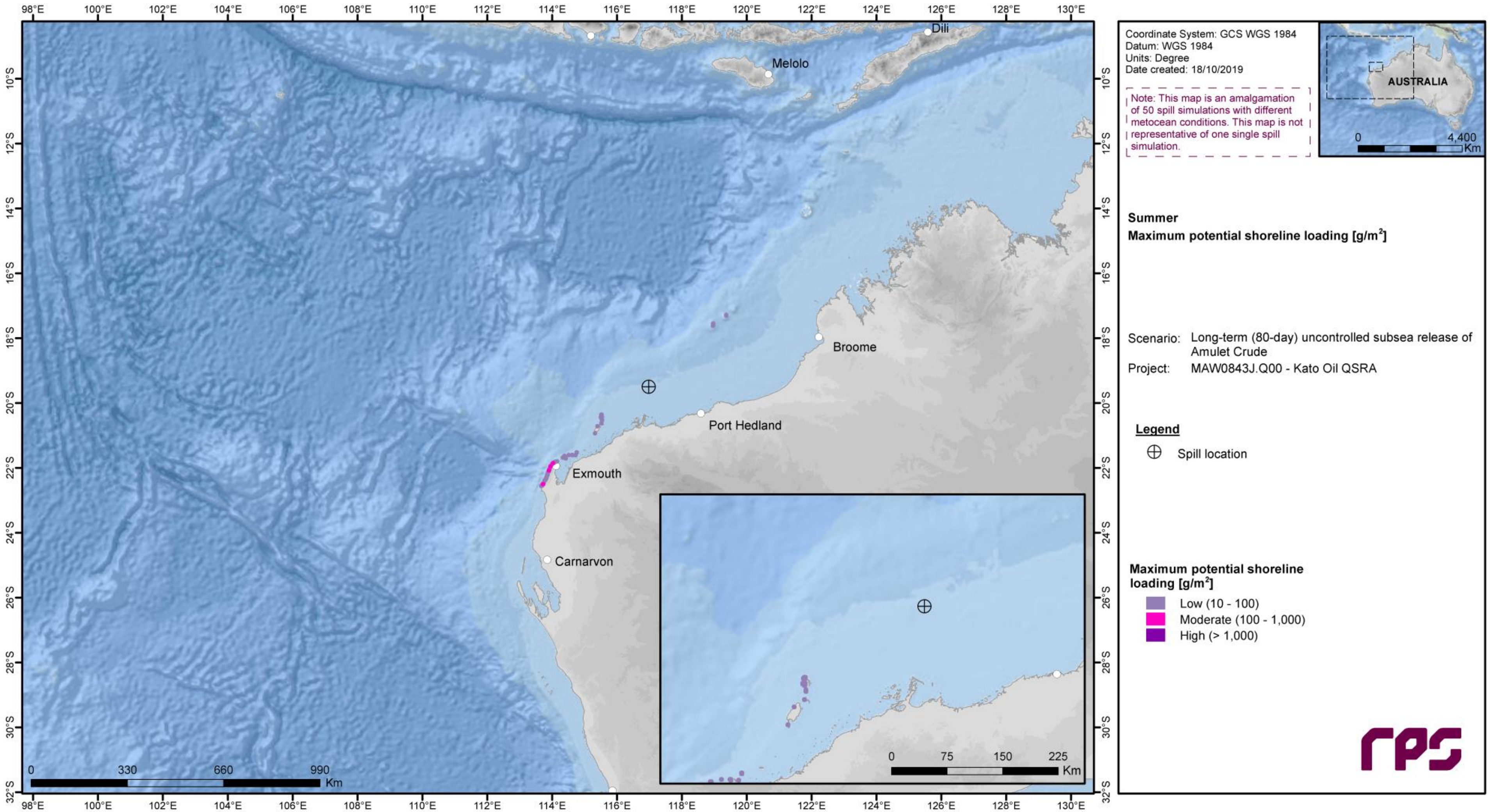

Figure 3.13 Predicted maximum potential shoreline loading resulting from a long-term (80 days) subsea release of Amulet Crude within the Amulet field, starting in summer.

3.2.3.2.2 Entrained Oil - Instantaneous

Table 3.6 Expected entrained oil outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in summer months.

Receptors		Probability (%) of entrained hydrocarbon concentration contact at ≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	Minimum time (hours) to receptor waters at ≥ 10 ppb	≥ 100 ppb	≥ 1,000 ppb	Maximum entrained hydrocarbon concentration (ppb) averaged over all replicate simulations	at any depth, in the worst replicate
Islands	Abrolhos Islands	<2	<2	<2	NC	NC	NC	<1	5
	Barrow Island	28	<2	<2	471	NC	NC	8	71
	Browse Island	<2	<2	<2	NC	NC	NC	<1	<1
	Lacepede Islands	<2	<2	<2	NC	NC	NC	<1	<1
	Lowendal Islands	10	<2	<2	500	NC	NC	3	44
	Montebello Islands	22	2	<2	441	469	NC	11	155
	Sandy Islet	<2	<2	<2	NC	NC	NC	<1	3
	Southern Pilbara - Islands	20	4	<2	578	595	NC	17	259
Coastlines	Buccaneer Archipelago	<2	<2	<2	NC	NC	NC	<1	<1
	Dampier Archipelago	<2	<2	<2	NC	NC	NC	<1	3
	Exmouth Gulf South East	<2	<2	<2	NC	NC	NC	<1	3
	Exmouth Gulf West	6	<2	<2	667	NC	NC	2	37
	Geraldton - Jurien Bay	<2	<2	<2	NC	NC	NC	<1	2
	Jurien Bay - Yanchep	<2	<2	<2	NC	NC	NC	<1	2
	Kalbarri - Geraldton	<2	<2	<2	NC	NC	NC	NC	NC
	Karratha-Port Hedland	<2	<2	<2	NC	NC	NC	<1	<1
	Kimberley Coast	<2	<2	<2	NC	NC	NC	<1	<1
	Middle Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<1	5
	North Broome Coast	<2	<2	<2	NC	NC	NC	<1	2
	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<1	4
	Perth Northern Coast	<2	<2	<2	NC	NC	NC	<1	2
	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC	NC	<1	<1
	Southern Pilbara - Shoreline	<2	<2	<2	NC	NC	NC	<1	3
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC	NC	<1	<1
State National and Marine Parks	Barrow Island MMA	28	<2	<2	448	NC	NC	9	71
	Barrow Islands MP	26	<2	<2	484	NC	NC	7	50
	Clerke Reef (Rowley Shoals MP)	6	<2	<2	1,078	NC	NC	2	17
	Eighty Mile Beach - Broome	<2	<2	<2	NC	NC	NC	<1	<1
	Imperieuse Reef (Rowley Shoals MP)	32	2	<2	595	940	NC	10	177
	Lalang-garram / Camden Sound MP	<2	<2	<2	NC	NC	NC	NC	NC
	Marmion MP	<2	<2	<2	NC	NC	NC	<1	<1
	Montebello Islands MP	38	8	<2	406	441	NC	20	213
	Muiron Islands MMA	34	4	<2	551	571	NC	18	229
	Ningaloo Coast WH	74	16	<2	362	580	NC	43	352
	Ningaloo MP (State)	52	16	<2	550	580	NC	38	352
	Shark Bay MR	<2	<2	<2	NC	NC	NC	<1	2
	Shark Bay WH	<2	<2	<2	NC	NC	NC	<1	4
Australian Marine Parks	Abrolhos MP	6	<2	<2	1,501	NC	NC	3	33
	Argo-Rowley Terrace MP	48	10	<2	319	466	NC	22	165
	Ashmore Reef MP	<2	<2	<2	NC	NC	NC	<1	<1
	Carnarvon Canyon MP	16	<2	<2	736	NC	NC	5	36
	Cartier Island MP	<2	<2	<2	NC	NC	NC	<1	3
	Dampier MP	<2	<2	<2	NC	NC	NC	<1	5
	Eighty Mile Beach MP	<2	<2	<2	NC	NC	NC	<1	4
	Gascoyne MP	86	20	<2	365	520	NC	55	628
	Jurien Bay MP	<2	<2	<2	NC	NC	NC	<1	2
	Jurien MP	<2	<2	<2	NC	NC	NC	<1	3
	Kimberley MP	<2	<2	<2	NC	NC	NC	<1	3
	Mermaid Reef MP	2	<2	<2	1,333	NC	NC	2	11
	Montebello MP	98	58	2	165	172	1,087	158	1,004
	Ningaloo MP	74	16	<2	362	583	NC	43	304

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
	Oceanic Shoals MP	<2	<2	<2	NC	NC	NC	<1	2
	Perth Canyon MP	<2	<2	<2	NC	NC	NC	<1	4
	Roebuck MP	<2	<2	<2	NC	NC	NC	NC	NC
	Shark Bay MP	24	<2	<2	717	NC	NC	6	58
	Two Rocks MP	<2	<2	<2	NC	NC	NC	<1	2
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	100	100	54	4	4	12	984	1,992
	Ancient Coastline at 90-120m Depth Contour KEF	<2	<2	<2	NC	NC	NC	<1	5
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	<2	<2	<2	NC	NC	NC	<1	3
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	2	<2	<2	2,240	NC	NC	<1	13
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	86	20	<2	316	333	NC	53	353
	Carbonate Bank and Terrace System of the Sahul Shelf KEF	<2	<2	<2	NC	NC	NC	<1	3
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	<2	<2	<2	NC	NC	NC	<1	8
	Continental Slope Demersal Fish Communities KEF	100	72	<2	164	193	NC	170	854
	Exmouth Plateau KEF	60	6	<2	431	598	NC	27	628
	Glomar Shoals KEF §	96	<2	<2	31	33	134	675	54
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	32	2	<2	573	924	NC	10	177
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	<2	<2	<2	NC	NC	NC	<1	10
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	<2	<2	<2	NC	NC	NC	<1	5
	Wallaby Saddle KEF	6	<2	<2	1,513	NC	NC	2	33
	Western Demersal Slope and associated Fish Communities KEF	16	<2	<2	899	NC	NC	4	42
	Western Rock Lobster KEF	<2	<2	<2	NC	NC	NC	<1	5
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC	NC	<1	<1
	Dugong BIA	52	16	<2	380	580	NC	38	352
	Marine Turtle BIA	100	76	10	29	41	126	341	1,796
	River Sharks BIA	<2	<2	<2	NC	NC	NC	<1	<1
	Seabirds BIA	100	100	100	1	1	4	2,735	4,980
	Seals BIA	<2	<2	<2	NC	NC	NC	<1	5
	Sharks BIA	100	100	100	1	1	4	2,735	4,980
	Whales BIA	100	100	100	1	1	4	2,735	4,980
Fisheries	North-West Slope Trawl Fishery	100	86	2	72	113	1,878	261	1,326
	Southern Bluefin Tuna Fishery	100	100	100	1	1	4	2,735	4,980
	Western Skipjack Fishery	100	100	100	1	1	4	2,735	4,980
	Western Tuna and Billfish Fishery	100	100	100	1	1	4	2,735	4,980
Other Submerged Reefs, Banks and Shoals	Barracouta Shoals §	<2	<2	<2	NC	NC	NC	<1	<1
	Barton Shoal	<2	<2	<2	NC	NC	NC	<1	<1
	Bassett-Smith Shoal	<2	<2	<2	NC	NC	NC	<1	<1
	Big Bank Shoals	<2	<2	<2	NC	NC	NC	<1	2
	Dillon Shoal	<2	<2	<2	NC	NC	NC	<1	<1
	Echo Shoals §	<2	<2	<2	NC	NC	NC	<1	<1
	Echuca Shoal §	<2	<2	<2	NC	NC	NC	<1	NC
	Eugene McDermott Shoal §	<2	<2	<2	NC	NC	NC	<1	<1
	Fantome Shoal §	<2	<2	<2	NC	NC	NC	<1	<1
	Goeree Shoal §	<2	<2	<2	NC	NC	NC	<1	NC
	Heywood Shoal	<2	<2	<2	NC	NC	NC	<1	<1
	Hibernia Reef	<2	<2	<2	NC	NC	NC	<1	<1
	Jabiru Shoals	<2	<2	<2	NC	NC	NC	<1	<1
	Johnson Bank	<2	<2	<2	NC	NC	NC	<1	2

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
Karmt Shoal	<2	<2	<2	NC	NC	NC	<1	<1
Mangola Shoal	<2	<2	<2	NC	NC	NC	<1	<1
Pee Shoal	<2	<2	<2	NC	NC	NC	<1	<1
Rankin Bank §	74	<2	<2	174	260	1,140	218	60
Sahul Bank §	<2	<2	<2	NC	NC	NC	<1	<1
Scott Reef North	<2	<2	<2	NC	NC	NC	<1	3
Scott Reef South	<2	<2	<2	NC	NC	NC	<1	3
Seringapatam Reef	<2	<2	<2	NC	NC	NC	<1	3
Vee Shoal	<2	<2	<2	NC	NC	NC	<1	<1
Vulcan Shoal §	<2	<2	<2	NC	NC	NC	<1	<1
Woodbine Bank	<2	<2	<2	NC	NC	NC	<1	3

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

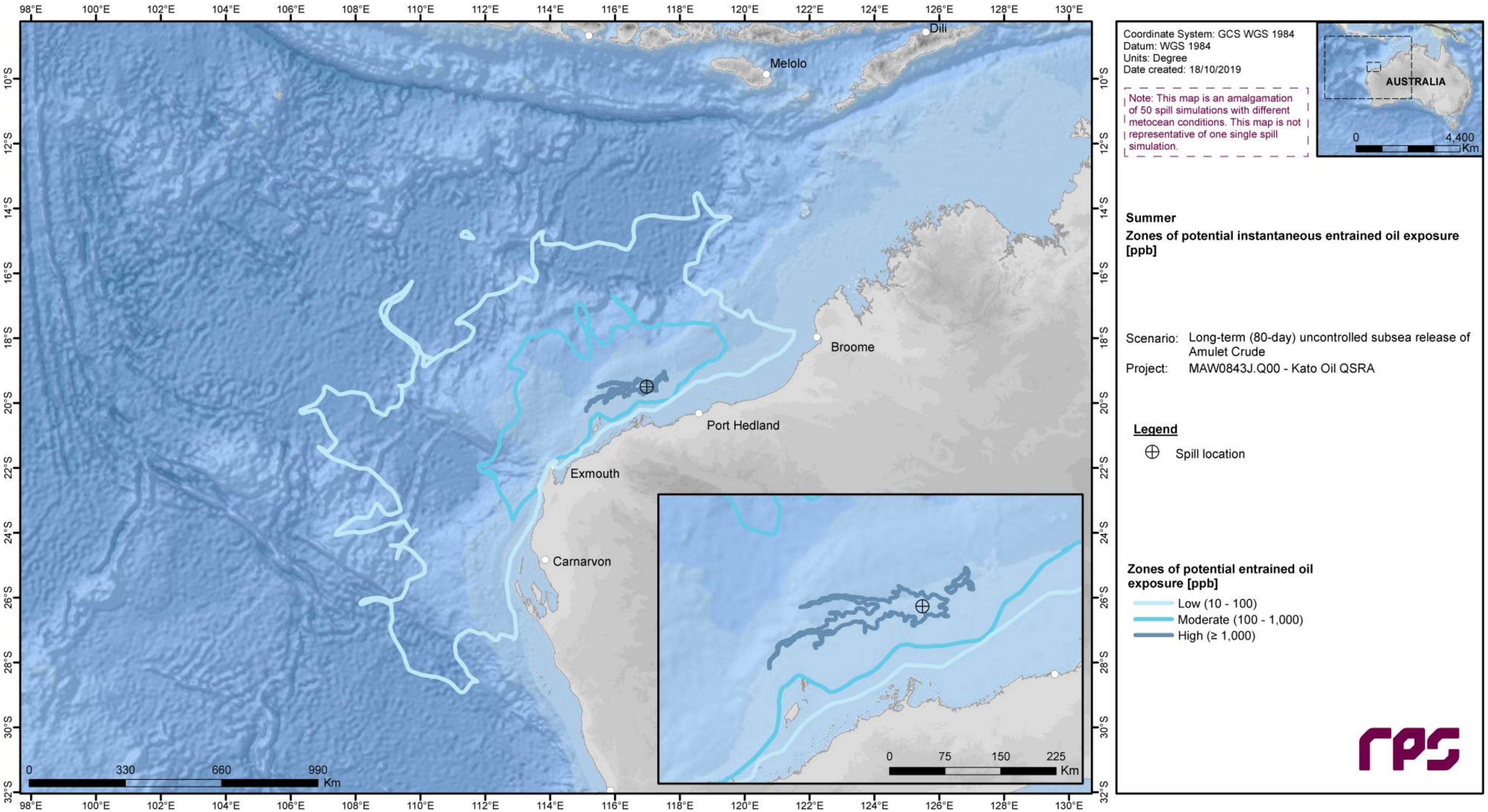

Figure 3.14 Predicted zones of potential instantaneous entrained oil exposure resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in summer months.

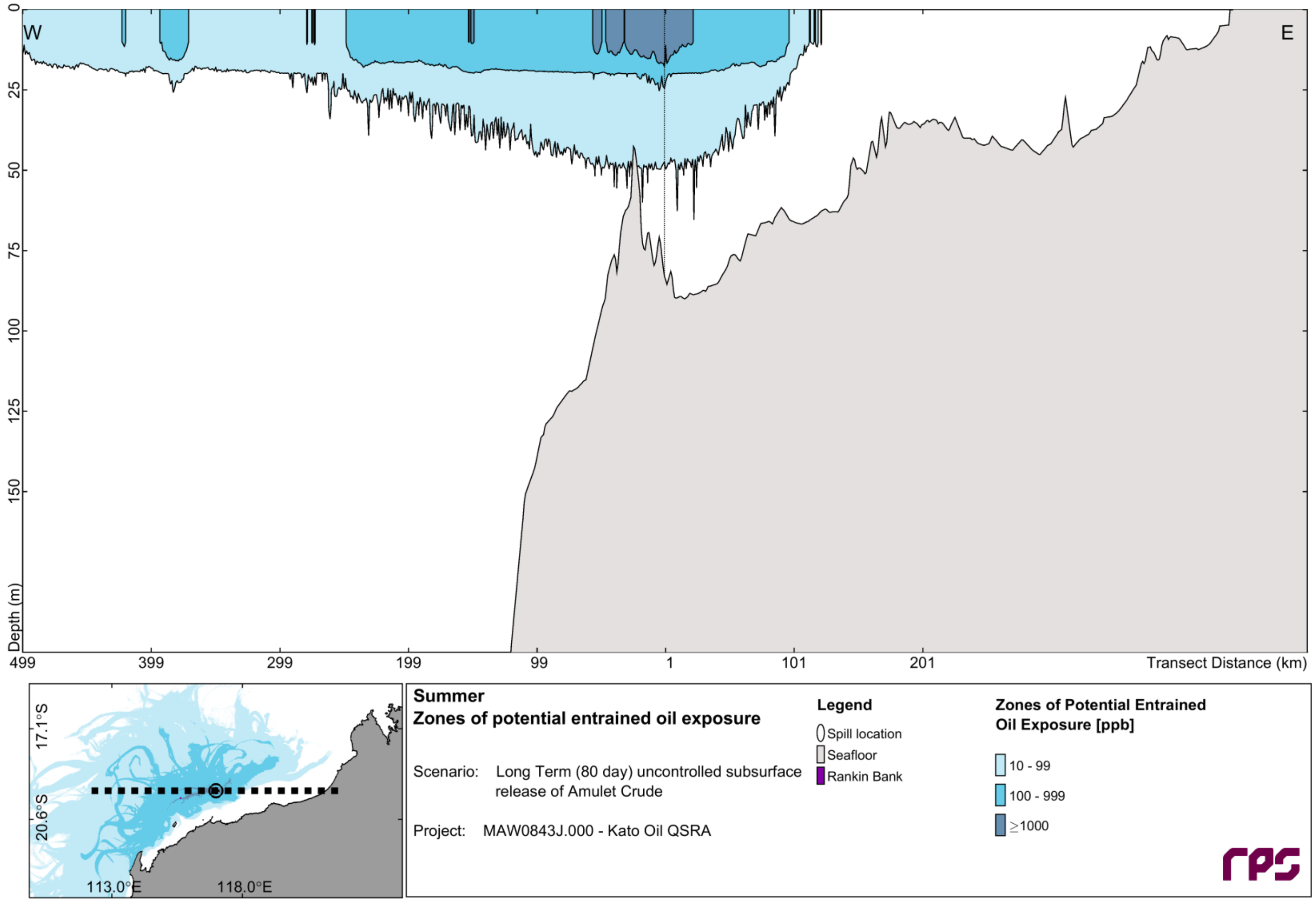

Figure 3.15 East-West cross-section transect of predicted maximum entrained oil concentration from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the summer season. The results were calculated from 50 spill trajectories.

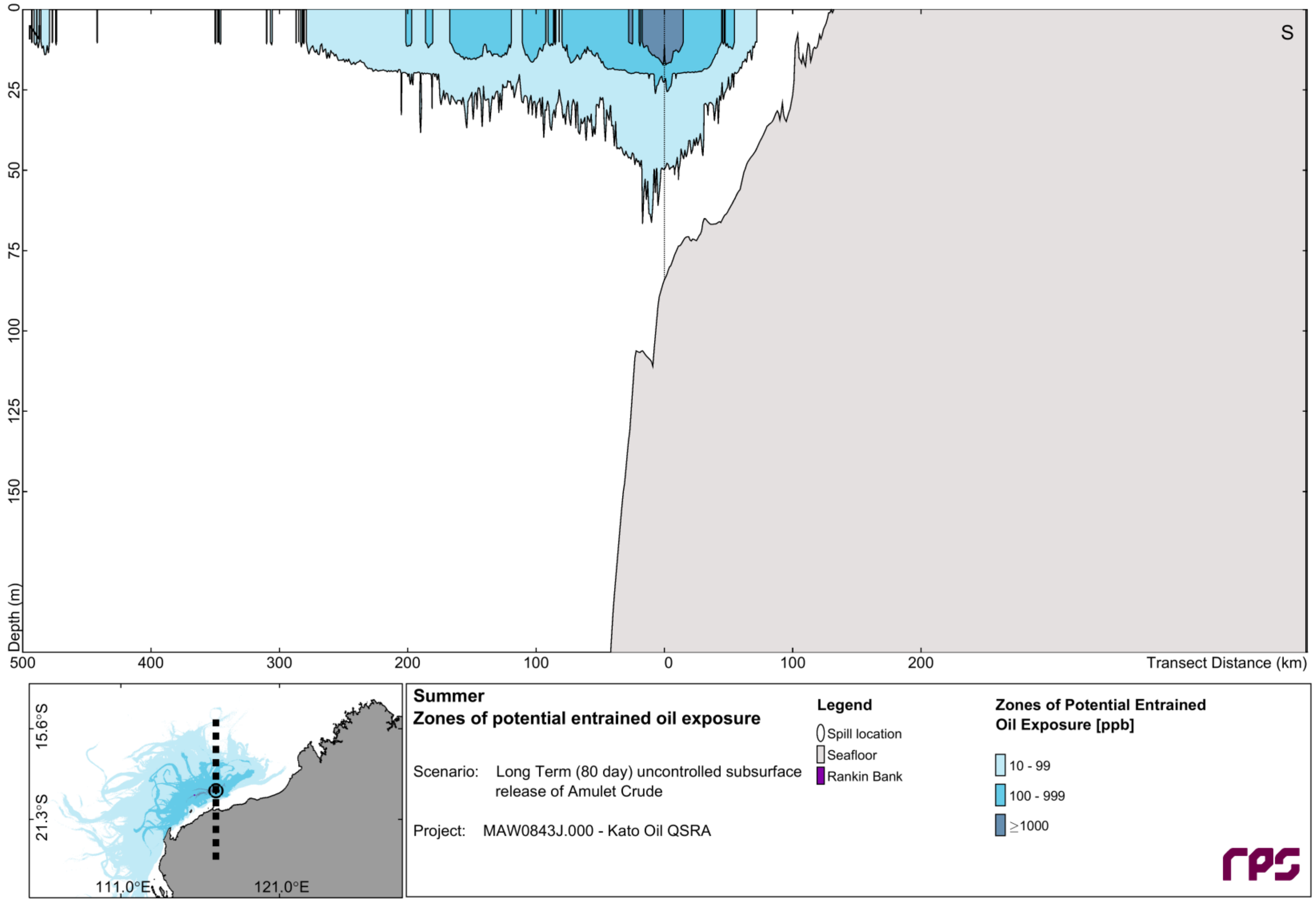

Figure 3.16 North-South cross-section transect of predicted maximum entrained oil concentration from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the summer season. The results were calculated from 50 spill trajectories.

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 Amulet Crude within the Amulet field, starting in summer months.

	Receptor	Threshold (ppb.hr)	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 (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	107	16	8	3	NC	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	2,989	221	36	13	BS	BS
	Browse Island	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
	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	2	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	1,340	22	4	BS	BS	BS
	Montebello Islands	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	4,277	174	23	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	28	2	NC	NC	NC	NC
	Southern Pilbara - Islands	Probability (%) >960	12	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	8,330	448	44	BS	BS	BS
Coastlines	Buccaneer Archipelago	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	3	NC	NC	NC	NC	BS
	Dampier Archipelago	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS

Receptor	Threshold (ppb.hr)	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	20	15	1	NC	BS	BS
Exmouth Gulf South East	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	27	BS	BS	BS	BS	BS
Exmouth Gulf West	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	1,057	64	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	18	3	1	NC	BS	BS
Jurien Bay - Yanchep	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	24	4	1	NC	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	NC	NC	NC	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	4	1	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	12	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	53	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
	Probability (%) >96,000	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	26	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	33	3	BS	BS	BS	BS

Receptor		Threshold (ppb.hr)	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 (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	18	2	NC	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	1	NC	BS	BS	BS	BS
	Southern Pilbara - Shoreline	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	36	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	NC	2	1	NC	NC	BS
State National and Marine Parks	Barrow Island MMA	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	3,084	226	128	30	BS	BS
	Barrow Islands 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	1,610	130	22	8	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	590	32	10	2	NC	NC
	Eighty Mile Beach - Broome	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
	Imperieuse Reef (Rowley Shoals MP)	Probability (%) >960	12	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	9,527	527	53	4	NC	NC
	Lalang-garram / Camden Sound MP	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
	Marmion MP	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	3	NC	NC	BS	BS	BS
	Montebello Islands MP	Probability (%) >960	16	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	6,639	311	110	28	BS	BS
	Muiron Islands MMA	Probability (%) >960	10	NC	NC	NC	NC	BS
		Probability (%) >9,600	4	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	10,418	771	65	18	5	BS
	Ningaloo Coast WH	Probability (%) >960	28	NC	NC	NC	NC	NC
		Probability (%) >9,600	10	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,256	733	238	61	9	1
	Ningaloo MP (State)	Probability (%) >960	20	NC	NC	NC	NC	NC
		Probability (%) >9,600	10	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,256	733	238	61	8	1
	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	7	4	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	48	8	9	5	1	BS
Australian Marine Parks	Abrolhos 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	763	63	19	6	2	1
	Argo-Rowley Terrace MP	Probability (%) >960	24	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	9,989	578	112	41	10	3
	Ashmore 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	7	2	NC	NC	NC	NC
	Carnarvon 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	1,461	70	20	5	1	NC

Receptor	Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
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	25	4	1	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	12	3	2	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	13	1	NC	NC	BS	BS
Gascoyne MP	Probability (%) >960	46	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	24,565	1,301	198	39	12	6
Jurien Bay 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	28	4	2	NC	BS	BS
Jurien 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	22	5	5	NC	NC	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
	Maximum Integrated Exposure	24	4	3	1	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	239	21	5	3	NC	NC
Montebello MP	Probability (%) >960	80	4	NC	NC	NC	NC
	Probability (%) >9,600	18	NC	NC	NC	NC	NC
	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	24,977	1,867	416	139	14	NC
Ningaloo MP	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	6,083	427	119	33	9	1
Oceanic Shoals MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >9,600	NC	NC	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	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	30	2	NC	NC	NC	NC
	Perth Canyon 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	87	11	5	2	1	NC
	Roebuck MP	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
	Shark Bay 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	1,325	109	29	9	7	4
	Two Rocks MP	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	10	6	6	1	NC	BS
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	100	54	NC	NC	NC	NC
		Probability (%) >9,600	94	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	65,194	3,503	671	167	41	11
	Ancient Coastline at 90-120m Depth Contour 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	65	10	5	5	NC	NC
	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	25	4	1	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	285	18	7	2	NC	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	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	11,292	674	124	60	9	6
	Carbonate Bank and Terrace System of the Sahul Shelf 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	50	4	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands 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	149	21	9	5	1	NC
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	92	4	NC	NC	NC	NC
		Probability (%) >9,600	16	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	20,994	1,420	318	87	15	3
	Exmouth Plateau KEF	Probability (%) >960	24	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	24,565	1,301	198	43	8	2
	Glomar Shoals KEF	Probability (%) >960	100	30	NC	NC	NC	BS
		Probability (%) >9,600	78	NC	NC	NC	NC	BS
		Probability (%) >96,000	2	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	103,689	5,110	773	177	29	BS
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	Probability (%) >960	12	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	9,989	578	62	8	NC	NC
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons 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	117	21	8	3	1	NC
	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	55	10	2	NC	NC	NC
	Wallaby Saddle 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	451	32	8	4	NC	NC
	Western Demersal Slope and associated Fish Communities 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	926	81	18	8	2	NC
	Western Rock Lobster 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	76	13	6	5	1	NC
Biological	Dolphins BIA	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	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	6	NC	NC	NC	NC	NC
	Dugong BIA	Probability (%) >960	20	NC	NC	NC	NC	NC
		Probability (%) >9,600	10	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	16,256	733	238	61	8	1
	Marine Turtle BIA	Probability (%) >960	98	12	NC	NC	NC	NC
		Probability (%) >9,600	24	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	65,951	3,200	634	195	34	7
	River Sharks BIA	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	2	NC	NC	NC	NC	BS
	Seabirds BIA	Probability (%) >960	100	58	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	135,616	5,404	1,130	234	50	6
	Seals 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	107	16	8	4	1	NC
	Sharks BIA	Probability (%) >960	100	58	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	135,616	5,404	1,130	234	50	11
	Whales BIA	Probability (%) >960	100	58	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	135,616	5,404	1,130	234	50	11
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	100	12	NC	NC	NC	NC
		Probability (%) >9,600	32	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	23,829	1,545	477	104	19	4
	Southern Bluefin Tuna Fishery	Probability (%) >960	100	58	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	135,616	5,404	1,130	234	50	11
	Western Skipjack Fishery	Probability (%) >960	100	58	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	135,616	5,404	1,130	234	50	11

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Western Tuna and Billfish Fishery	Probability (%) >960	100	58	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	135,616	5,404	1,130	234	50	11
Other Submerged Reefs, Shoals and Banks	Barracouta Shoals	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	27	1	NC	NC	BS	BS
	Barton Shoal	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	1	NC	NC	NC	NC	BS
	Bassett-Smith 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
	Big Bank Shoals	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	33	2	NC	NC	NC	NC
	Dillon Shoal	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
	Echo Shoals	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	NC	NC	NC	NC	NC
	Echuca Shoal	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
	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	3	NC	NC	NC	BS	BS
	Fantome 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
	Goeree Shoal	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >9,600	NC	NC	NC	NC	BS	BS

Receptor	Threshold (ppb.hr)	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	6	NC	NC	NC	BS	BS
Heywood Shoal	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	7	1	NC	NC	NC	BS
Hibernia 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	6	1	NC	NC	NC	NC
Jabiru Shoals	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	6	NC	NC	NC	NC	BS
Johnson 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	19	4	NC	NC	NC	BS
Karmt Shoal	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	14	1	NC	NC	NC	NC
Mangola Shoal	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	NC	NC	NC	NC	BS
Pee 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	3	NC	NC	NC	BS	BS
Rankin Bank	Probability (%) >960	74	NC	NC	BS	BS	BS
	Probability (%) >9,600	10	NC	NC	BS	BS	BS
	Probability (%) >96,000	NC	NC	NC	BS	BS	BS
	Maximum Integrated Exposure	15,502	837	213	BS	BS	BS
Sahul Bank	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
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	35	10	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	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	42	4	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	34	6	2	NC	NC	NC
	Vee Shoal	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	2	NC	NC	NC	NC	BS
	Vulcan 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	10	NC	NC	NC	BS	BS
	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	23	3	NC	NC	NC	BS

NC: No contact to receptor predicted for specified threshold.
BS: Below seabed.

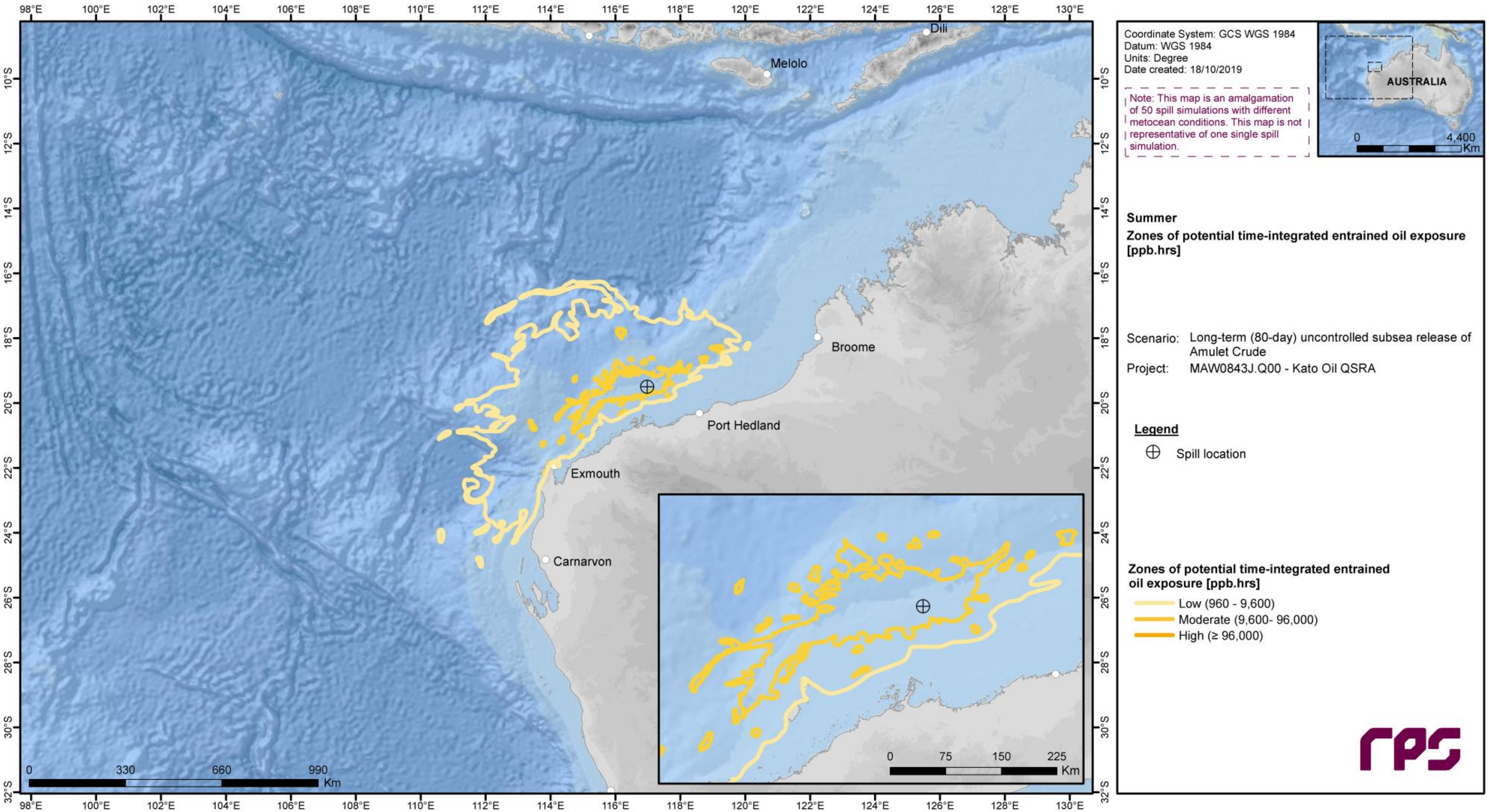

Figure 3.17 Predicted zones of potential time-integrated entrained oil exposure resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in summer months.

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 Amulet Crude within the Amulet 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	Abrolhos Islands	<2	<2	<2	NC	NC
	Barrow Island	<2	<2	<2	<1	<1
	Browse Island	<2	<2	<2	NC	NC
	Lacepede Islands	<2	<2	<2	NC	NC
	Lowendal Islands	2	<2	<2	<1	16
	Montebello Islands	14	4	<2	5	120
	Sandy Islet	<2	<2	<2	NC	NC
	Southern Pilbara - Islands	<2	<2	<2	<1	3
Coastlines	Buccaneer Archipelago	<2	<2	<2	NC	NC
	Dampier Archipelago	<2	<2	<2	<1	<1
	Exmouth Gulf South East	<2	<2	<2	NC	NC
	Exmouth Gulf West	<2	<2	<2	NC	NC
	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	NC	NC
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC
State National and Marine Parks	Barrow Island MMA	2	<2	<2	<1	12
	Barrow Islands MP	<2	<2	<2	<1	<1
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC
	Eighty Mile Beach - Broome	<2	<2	<2	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC
	Lalang-garram / Camden Sound MP	<2	<2	<2	NC	NC

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
	Marmion MP	<2	<2	<2	NC	NC
	Montebello Islands MP	16	4	<2	6	120
	Muiron Islands MMA	2	<2	<2	<1	39
	Ningaloo Coast WH	16	4	<2	6	146
	Ningaloo MP (State)	6	2	<2	3	95
	Shark Bay MR	<2	<2	<2	NC	NC
	Shark Bay WH	<2	<2	<2	NC	NC
Australian Marine Parks	Abrolhos MP	<2	<2	<2	NC	NC
	Argo-Rowley Terrace MP	8	<2	<2	2	48
	Ashmore Reef MP	<2	<2	<2	NC	NC
	Carnarvon Canyon MP	<2	<2	<2	<1	<1
	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	16	4	<2	6	129
	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	60	8	<2	16	181
	Ningaloo MP	16	4	<2	6	146
	Oceanic Shoals MP	<2	<2	<2	NC	NC
	Perth Canyon MP	<2	<2	<2	NC	NC
	Roebuck MP	<2	<2	<2	NC	NC
	Shark Bay MP	<2	<2	<2	<1	<1
	Two Rocks MP	<2	<2	<2	NC	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	100	100	2	131	502
	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	16	6	<2	7	150
	Carbonate Bank and Terrace System of the Sahul Shelf KEF	<2	<2	<2	NC	NC

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	<2	<2	<2	NC	NC
	Continental Slope Demersal Fish Communities KEF	66	8	<2	17	178
	Exmouth Plateau KEF	6	2	<2	2	64
	Glomar Shoals KEF §	100	26	<2	94	248
	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	NC	NC
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	<2	<2	<2	NC	NC
	Wallaby Saddle KEF	<2	<2	<2	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	<2	<2	<2	NC	NC
	Western Rock Lobster KEF	<2	<2	<2	NC	NC
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC
	Dugong BIA	6	2	<2	3	95
	Marine Turtle BIA	90	26	<2	33	264
	River Sharks BIA	<2	<2	<2	NC	NC
	Seabirds BIA	100	100	2	176	505
	Seals BIA	<2	<2	<2	NC	NC
	Sharks BIA	100	100	2	176	520
	Whales BIA	100	100	2	176	520
Fisheries	North-West Slope Trawl Fishery	82	14	<2	20	290
	Southern Bluefin Tuna Fishery	100	100	2	176	520
	Western Skipjack Fishery	100	100	2	176	520
	Western Tuna and Billfish Fishery	100	100	2	176	520
Other Submerged Reefs, Banks and Shoals	Barracouta Shoals §	<2	<2	<2	NC	NC
	Barton Shoal	<2	<2	<2	NC	NC
	Bassett-Smith Shoal	<2	<2	<2	NC	NC
	Big Bank Shoals	<2	<2	<2	NC	NC
	Dillon Shoal	<2	<2	<2	NC	NC
	Echo Shoals §	<2	<2	<2	NC	NC
	Echuca Shoal §	<2	<2	<2	NC	NC
	Eugene McDermott Shoal §	<2	<2	<2	NC	NC
	Fantome Shoal §	<2	<2	<2	NC	NC

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
Goeree Shoal §	<2	<2	<2	NC	NC
Heywood Shoal	<2	<2	<2	NC	NC
Hibernia Reef	<2	<2	<2	NC	NC
Jabiru Shoals	<2	<2	<2	NC	NC
Johnson Bank	<2	<2	<2	NC	NC
Karmt Shoal	<2	<2	<2	NC	NC
Mangola Shoal	<2	<2	<2	NC	NC
Pee Shoal	<2	<2	<2	NC	NC
Rankin Bank §	52	2	<2	21	83
Sahul Bank §	<2	<2	<2	NC	NC
Scott Reef North	<2	<2	<2	NC	NC
Scott Reef South	<2	<2	<2	NC	NC
Seringapatam Reef	<2	<2	<2	NC	NC
Vee Shoal	<2	<2	<2	NC	NC
Vulcan Shoal §	<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.

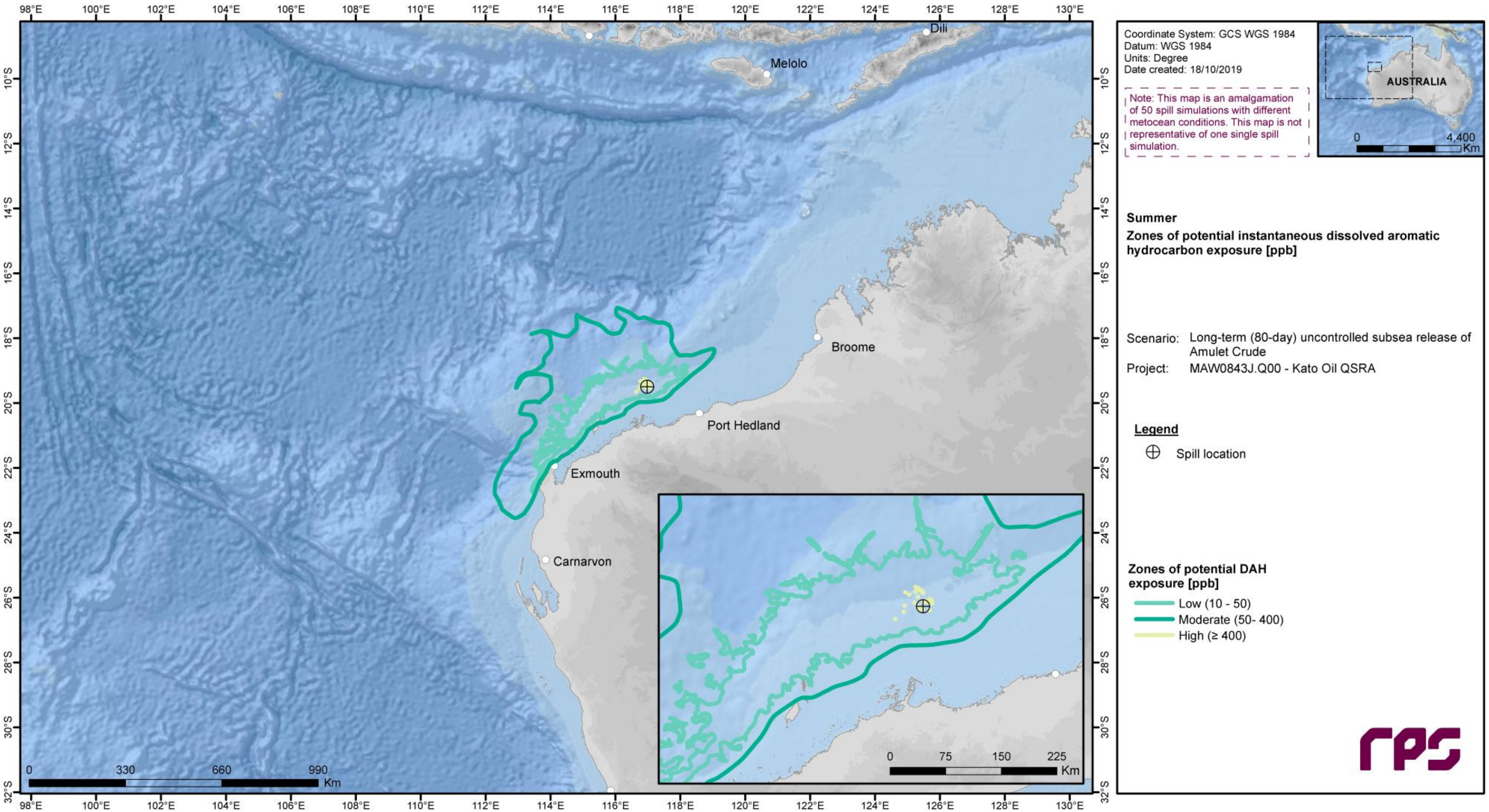

Figure 3.18 Predicted zones of potential instantaneous dissolved aromatic hydrocarbon exposure resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet Field, starting in summer months.

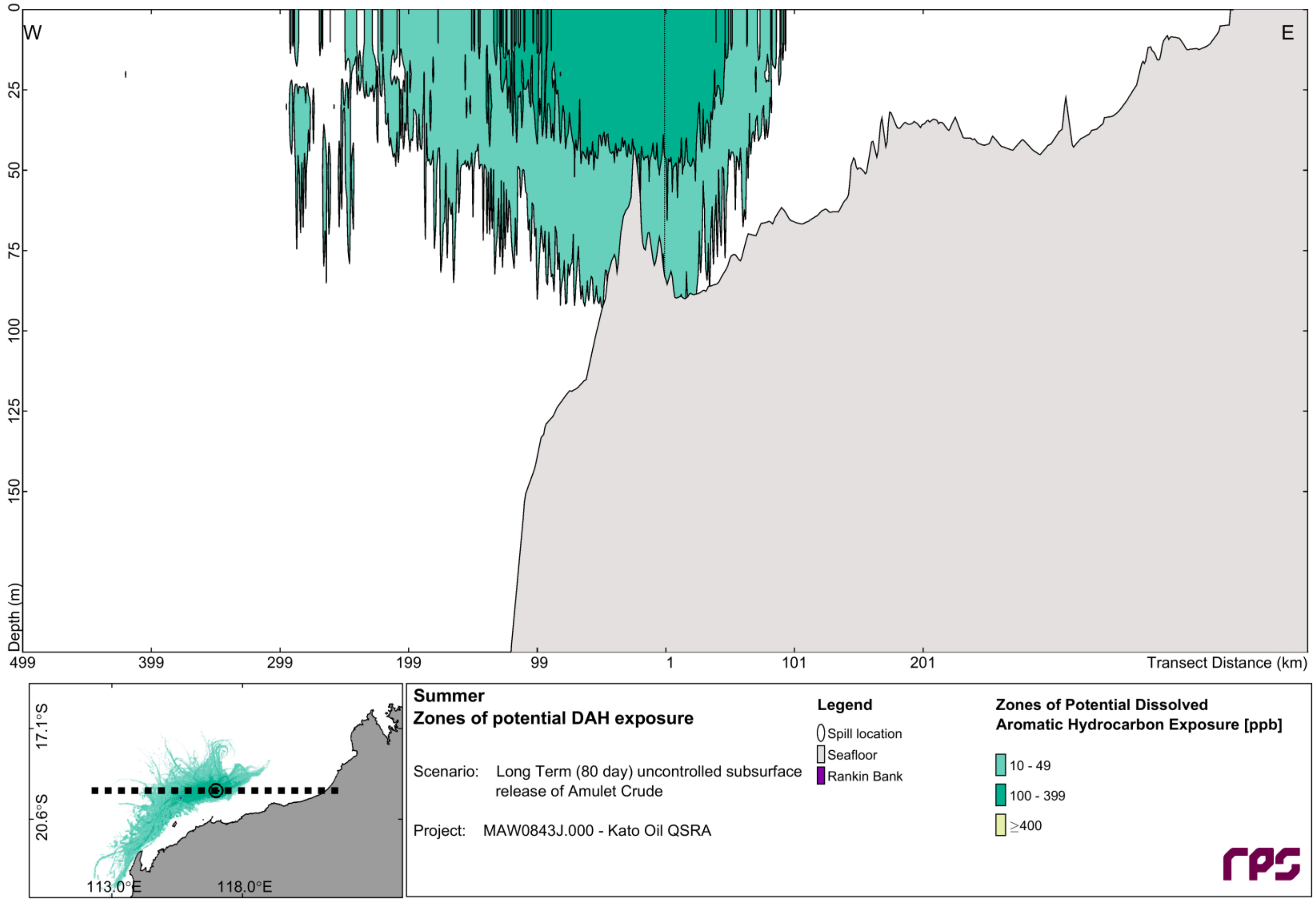

Figure 3.19 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the summer season. The results were calculated from 50 spill trajectories.

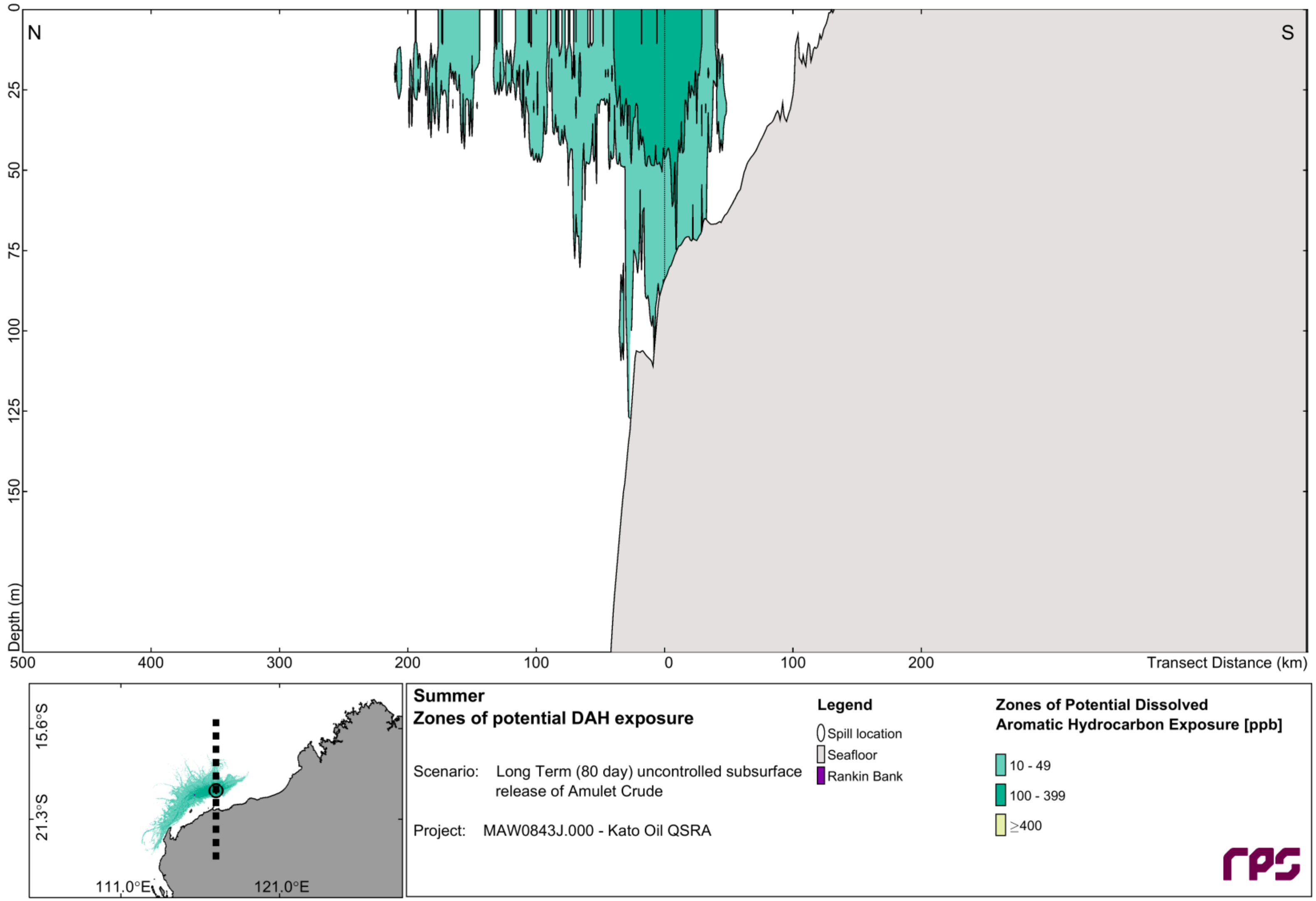

Figure 3.20 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the summer season. The results were calculated from 50 spill trajectories.

3.2.3.2.5 Dissolved Aromatic Hydrocarbon - Exposure

Table 3.9 Expected dissolved aromatic hydrocarbons exposure outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in summer months.

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m 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
	Browse Island	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
	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	50	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	954	303	52	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	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	7	11	2	BS	BS	BS

	Receptor	Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
Coastlines								
	Buccaneer Archipelago	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
	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
		Probability (%) >38,400	NC	BS	BS	BS	BS	BS
		Maximum Integrated Exposure	NC	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	NC	NC	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

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
		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
	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	NC	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 National and Marine 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	28	4	8	NC	BS	BS
	Barrow Islands MP	Probability (%) >960	NC	NC	NC	NC	BS	BS

Receptor	Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	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
Eighty Mile Beach - Broome	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
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
Lalang-garram / Camden Sound 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
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	954	303	263	9	BS	BS
Muiron Islands MMA	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	66	132	60	6	3	BS
Ningaloo Coast WH	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	403	259	218	166	12	NC

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	Ningaloo MP (State)	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	259	71	70	107	4	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	NC	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	NC	NC	NC	NC	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	64	120	107	88	19	NC
	Ashmore 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
	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	NC	NC	NC	NC	NC	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

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
		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	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	468	304	289	186	34	2
	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
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	727	786	680	674	102	NC
	Ningaloo 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	403	259	218	166	12	NC
	Oceanic Shoals MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	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
	Roebuck MP	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 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
	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	56	12	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	3,118	2,309	1,298	424	128	4
	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	NC	NC	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	184	201	313	186	22	2
	Carbonate Bank and Terrace System of the Sahul Shelf 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
	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	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	599	640	404	234	24	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	97	103	170	156	9	1
	Glomar Shoals KEF	Probability (%) >960	6	2	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	1,906	1,301	836	378	85	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

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	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	NC	NC	NC	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	NC	NC	NC	NC	NC	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	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	259	216	151	160	9	NC
	Marine Turtle BIA	Probability (%) >960	4	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	1,604	1,210	935	922	176	3
	River Sharks BIA	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
	Seabirds BIA	Probability (%) >960	98	12	2	NC	NC	NC
		Probability (%) >4,800	8	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	9,417	4,739	1,549	922	283	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

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Sharks BIA	Probability (%) >960	98	16	2	NC	NC	NC
		Probability (%) >4,800	8	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	9,417	4,739	1,549	922	283	7
	Whales BIA	Probability (%) >960	98	16	2	NC	NC	NC
		Probability (%) >4,800	8	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	9,417	4,739	1,549	922	283	12
Fisheries	North-West Slope Trawl Fishery	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	867	709	521	234	62	12
	Southern Bluefin Tuna Fishery	Probability (%) >960	98	16	2	NC	NC	NC
		Probability (%) >4,800	8	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	9,417	4,739	1,549	922	283	12
	Western Skipjack Fishery	Probability (%) >960	98	16	2	NC	NC	NC
		Probability (%) >4,800	8	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	9,417	4,739	1,549	922	283	12
	Western Tuna and Billfish Fishery	Probability (%) >960	98	16	2	NC	NC	NC
		Probability (%) >4,800	8	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	9,417	4,739	1,549	922	283	12
Other Submerged Reefs, Shoals and Banks	Barracouta Shoals	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
	Barton Shoal	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
	Bassett-Smith Shoal	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS

Receptor	Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	Probability (%) >38,400	NC	NC	NC	NC	BS	BS
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Big Bank Shoals	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
Dillon Shoal	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
Echo Shoals	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
Echuca Shoal	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
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
Fantome 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
Goeree 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
Heywood Shoal	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
Hibernia Reef	Probability (%) >960	NC	NC	NC	NC	NC	NC

Receptor	Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	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
Jabiru Shoals	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
Johnson 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
Karmt Shoal	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
Mangola Shoal	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
Pee 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	185	198	287	BS	BS	BS
Sahul Bank	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 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

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	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
	Vee Shoal	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
	Vulcan 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
	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.

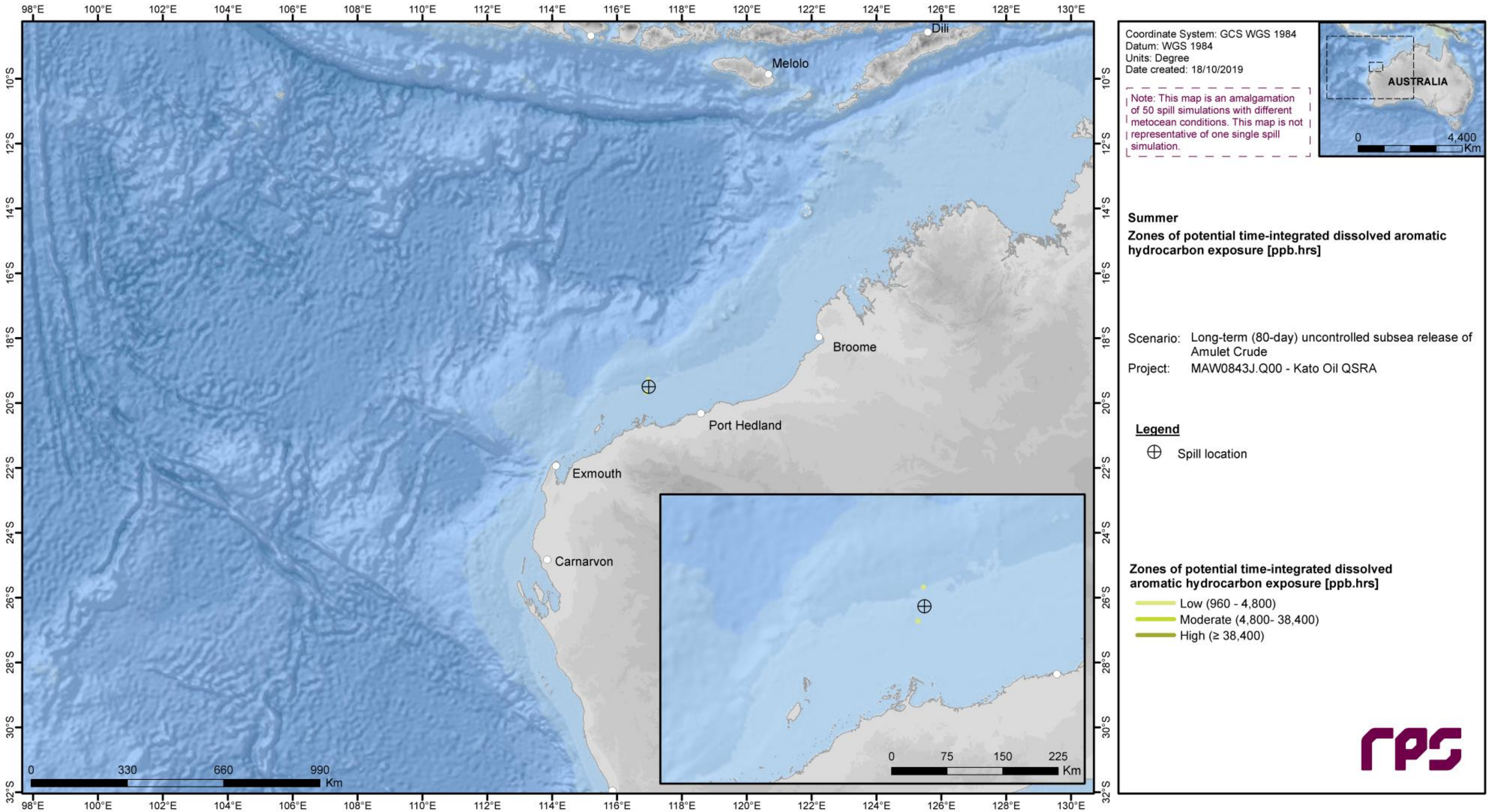

Figure 3.21 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet Field, starting in summer months.

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 Amulet Crude within the Amulet 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 /m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 /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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Barrow Island	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	<0.1	4.6	<1	<1	NC	NC	NC	NC	NC	NC
	Browse Island	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Lacepede Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	<0.1	1.9	<1	<1	NC	NC	NC	NC	NC	NC
	Lowendal Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Montebello Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.1	3.8	<1	<1	NC	NC	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	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	<0.1	3.8	<1	<1	NC	NC	NC	NC	NC	NC
Coastlines	Buccaneer Archipelago	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Exmouth Gulf West	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Geraldton - Jurien Bay	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	<0.1	1.1	<1	<1	NC	NC	NC	NC	NC	NC
	Jurien Bay - Yanchep	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	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	NC	NC	NC	NC	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	<0.1	1.1	<1	<1	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	NC	NC	NC	<2	<2	<2	NC	NC	NC	<0.1	4.6	<1	<1	NC	NC	NC	NC	NC	NC
	Barrow Islands MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.1	6.8	<1	<1	NC	NC	NC	NC	NC	NC
	Eighty Mile Beach - Broome	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC

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 /m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 /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
	Imperieuse Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	2	<2	<2	1,981	NC	NC	0.8	20	<1	<1	<1	1	NC	NC	NC	NC
	Lalang-garram / Camden Sound 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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Montebello Islands MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.1	3.8	<1	<1	NC	NC	NC	NC	NC	NC
	Muiron Islands MMA	<2	<2	<2	NC	NC	NC	2	<2	<2	590	NC	NC	0.3	16	<1	<1	<1	1	NC	NC	NC	NC
	Ningaloo Coast WH	<2	<2	<2	NC	NC	NC	4	<2	<2	631	NC	NC	1.1	23	<1	<1	<1	1	NC	NC	NC	NC
	Ningaloo MP (State)	<2	<2	<2	NC	NC	NC	4	<2	<2	631	NC	NC	1.1	23	<1	<1	<1	1	NC	NC	NC	NC
	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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Australian Marine Parks	Abrolhos MP*	<2	<2	<2	NC	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
	Ashmore Reef MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Carnarvon Canyon MP*	<2	<2	<2	NC	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*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Montebello MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ningaloo MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Oceanic Shoals MP*	<2	<2	<2	NC	NC	NC	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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Roebuck 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*	<2	<2	<2	NC	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	44	<2	5	55	NC	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	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

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 /m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 /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 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*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Carbonate Bank and Terrace System of the Sahul Shelf KEF*	<2	<2	<2	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*	<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**	2	<2	<2	122	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Exmouth Plateau KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Glomar Shoals KEF*	84	<2	<2	23	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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Wallaby Saddle KEF*	<2	<2	<2	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*	<2	<2	<2	NC	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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Dugong BIA*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marine Turtle BIA*†	14	<2	<2	47	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	River Sharks BIA*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seabirds BIA*†	100	100	62	1	1	2	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	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	62	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Whales BIA*	100	100	62	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	North-West Slope Trawl Fishery*	14	<2	<2	182	NC	NC	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Southern Bluefin Tuna Fishery*	100	100	62	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Skipjack Fishery*	100	100	62	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Tuna and Billfish Fishery*	100	100	62	1	1	2	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 /m²	≥ 25 g/m²	≥ 1 g/m²	≥ 10 /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
Other Submerged Reefs, Banks and Shoals	Barracouta Shoals*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Barton Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Bassett-Smith Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Big Bank Shoals*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dillon Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Echo Shoals*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Echuca Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	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
	Fantome Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Goeree Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Heywood Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Hibernia Reef*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jabiru Shoals*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Johnson Bank*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Karmt Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mangola Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Pee Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Rankin Bank*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sahul 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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Seringapatam Reef*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Vee Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Vulcan Shoal*	<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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC

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.

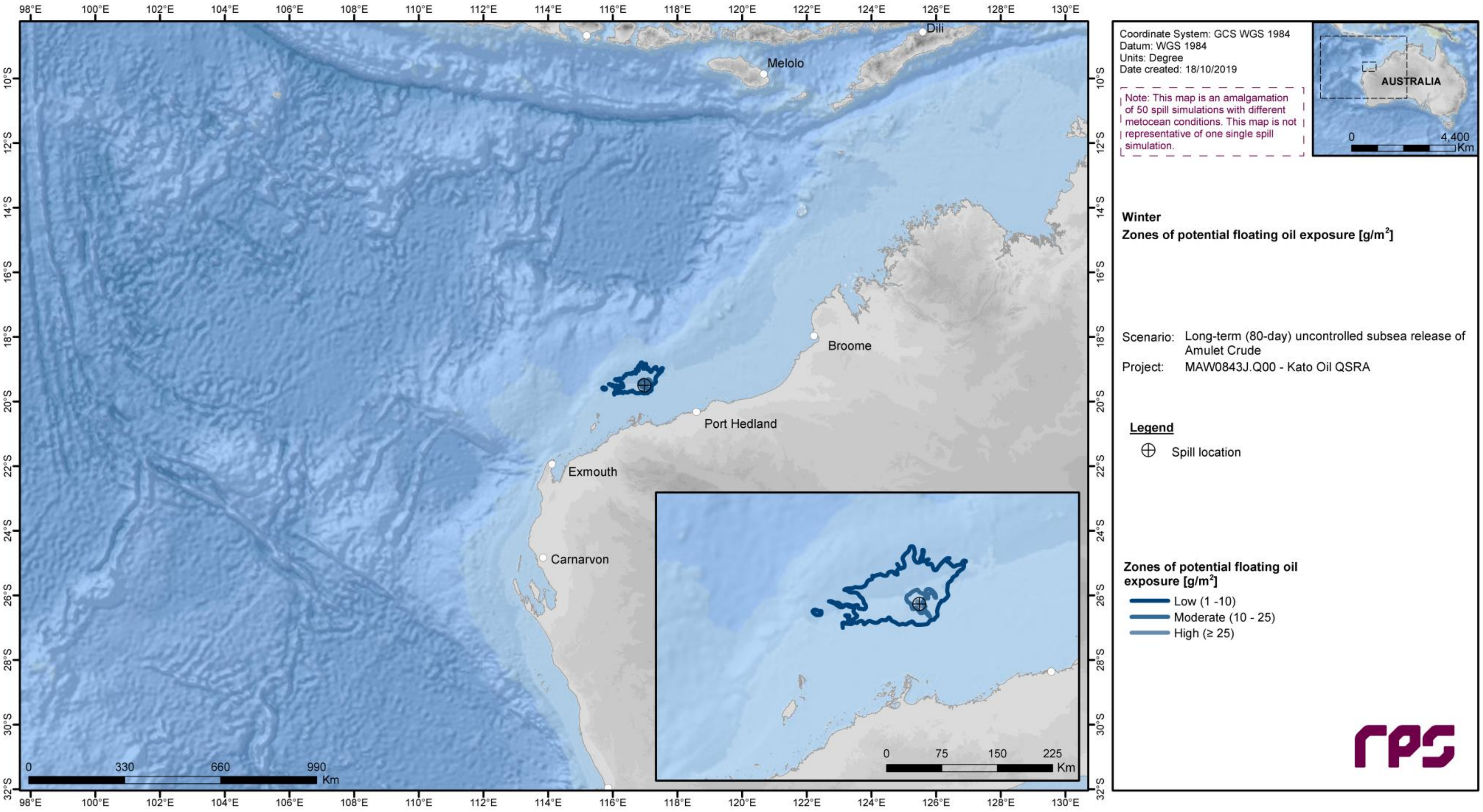

Figure 3.22 Predicted zones of potential floating oil exposure resulting from a long-term (80 days) subsea release of Amulet Crude within the Amulet field, starting in winter.

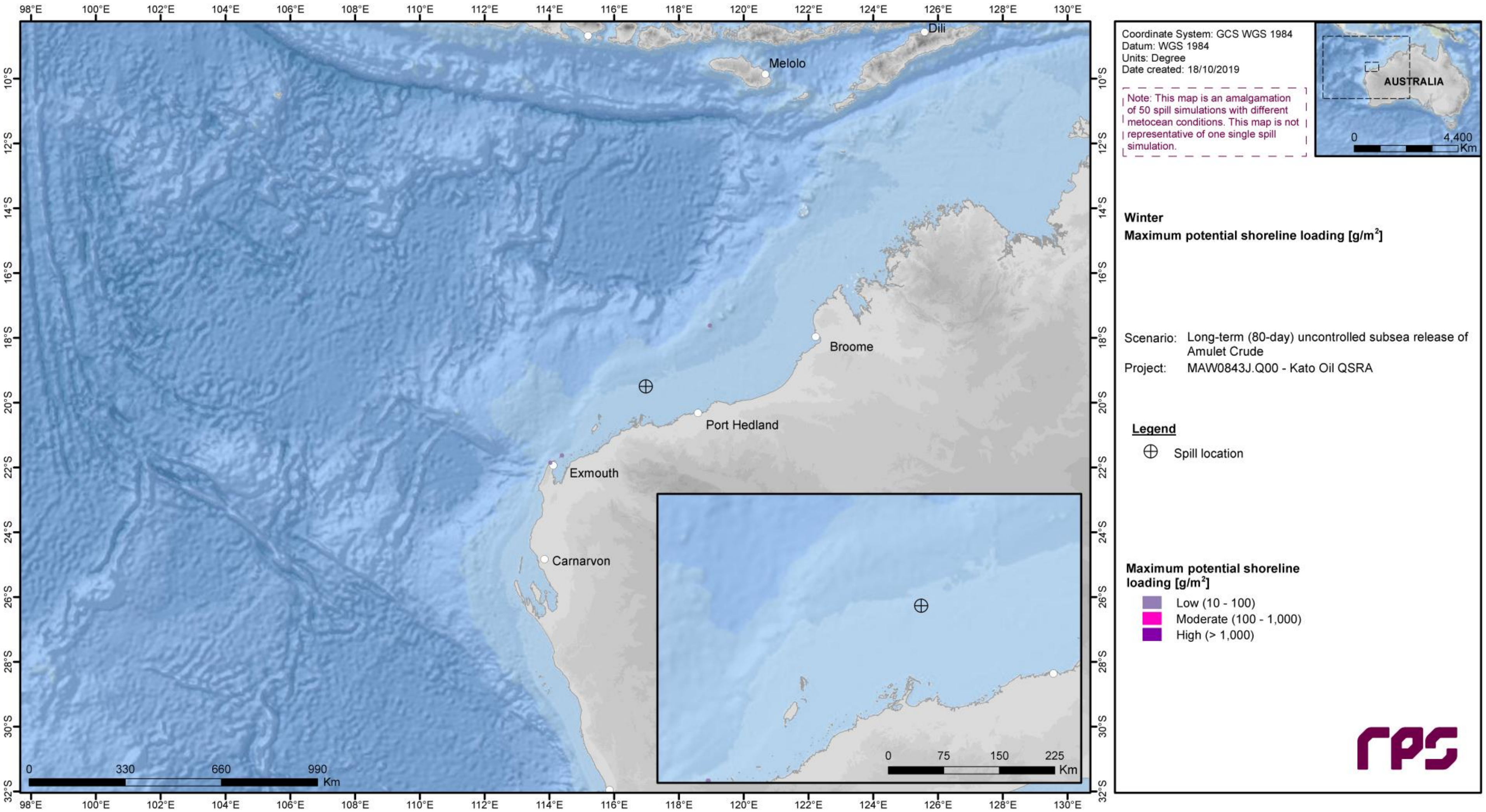

Figure 3.23 Predicted maximum potential shoreline loading resulting from a long-term (80 days) subsea release of Amulet Crude within the Amulet field, starting in winter.

3.2.3.3.2 Entrained Oil - Instantaneous

Table 3.11 Expected entrained oil outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in winter months.

Receptors		Probability (%) of entrained hydrocarbon concentration contact at			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	<2	<2	<2	NC	NC	NC	<1	3
	Barrow Island	10	<2	<2	1,197	NC	NC	3	28
	Browse Island	<2	<2	<2	NC	NC	NC	NC	NC
	Lacepede Islands	<2	<2	<2	NC	NC	NC	<1	3
	Lowendal Islands	<2	<2	<2	NC	NC	NC	<1	9
	Montebello Islands	16	<2	<2	390	NC	NC	6	50
	Sandy Islet	<2	<2	<2	NC	NC	NC	<1	4
	Southern Pilbara - Islands	4	<2	<2	859	NC	NC	3	13
Coastlines	Buccaneer Archipelago	<2	<2	<2	NC	NC	NC	<1	<1
	Dampier Archipelago	<2	<2	<2	NC	NC	NC	NC	NC
	Exmouth Gulf South East	<2	<2	<2	NC	NC	NC	<1	2
	Exmouth Gulf West	2	<2	<2	878	NC	NC	<1	11
	Geraldton - Jurien Bay	<2	<2	<2	NC	NC	NC	<1	3
	Jurien Bay - Yanchep	<2	<2	<2	NC	NC	NC	<1	2
	Kalbarri - Geraldton	<2	<2	<2	NC	NC	NC	<1	2
	Karratha-Port Hedland	<2	<2	<2	NC	NC	NC	NC	NC
	Kimberley Coast	<2	<2	<2	NC	NC	NC	<1	2
	Middle Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	<1	3
	North Broome Coast	<2	<2	<2	NC	NC	NC	<1	3
	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	NC	NC
	Perth Northern Coast	<2	<2	<2	NC	NC	NC	<1	5
	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC	NC	NC	NC
	Southern Pilbara - Shoreline	<2	<2	<2	NC	NC	NC	<1	3
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC	NC	<1	<1
State National and Marine Parks	Barrow Island MMA	14	<2	<2	587	NC	NC	6	65
	Barrow Islands MP	10	<2	<2	1,238	NC	NC	4	44
	Clerke Reef (Rowley Shoals MP)	6	<2	<2	751	NC	NC	2	21
	Eighty Mile Beach - Broome	<2	<2	<2	NC	NC	NC	<1	<1
	Imperieuse Reef (Rowley Shoals MP)	6	<2	<2	679	NC	NC	2	21
	Lalang-garram / Camden Sound MP	<2	<2	<2	NC	NC	NC	<1	<1
	Marmion MP	<2	<2	<2	NC	NC	NC	<1	3
	Montebello Islands MP	26	<2	<2	377	NC	NC	11	99
	Muiron Islands MMA	14	<2	<2	471	NC	NC	5	35
	Ningaloo Coast WH	24	6	<2	441	801	NC	12	166
	Ningaloo MP (State)	14	6	<2	441	814	NC	11	148
	Shark Bay MR	<2	<2	<2	NC	NC	NC	<1	<1
	Shark Bay WH	<2	<2	<2	NC	NC	NC	<1	3
Australian Marine Parks	Abrolhos MP	6	<2	<2	1,021	NC	NC	2	22
	Argo-Rowley Terrace MP	52	8	<2	388	748	NC	19	151
	Ashmore Reef MP	<2	<2	<2	NC	NC	NC	NC	NC
	Carnarvon Canyon MP	10	<2	<2	596	NC	NC	3	32
	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	68	16	<2	293	334	NC	37	168
	Jurien Bay MP	<2	<2	<2	NC	NC	NC	<1	<1
	Jurien MP	<2	<2	<2	NC	NC	NC	<1	2
	Kimberley MP	<2	<2	<2	NC	NC	NC	<1	7
	Mermaid Reef MP	<2	<2	<2	NC	NC	NC	<1	7
	Montebello MP	98	52	<2	164	191	NC	111	485
	Ningaloo MP	24	6	<2	504	801	NC	12	166
	Oceanic Shoals MP	<2	<2	<2	NC	NC	NC	NC	NC

Receptors		Probability (%) of entrained hydrocarbon concentration contact at			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
	Perth Canyon MP	<2	<2	<2	NC	NC	NC	<1	10
	Roebuck MP	<2	<2	<2	NC	NC	NC	<1	<1
	Shark Bay MP	<2	<2	<2	NC	NC	NC	<1	9
	Two Rocks MP	<2	<2	<2	NC	NC	NC	<1	4
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	100	100	54	5	5	36	1,030	1,665
	Ancient Coastline at 90-120m Depth Contour KEF	<2	<2	<2	NC	NC	NC	<1	6
	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	NC	NC	NC	<1	10
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	42	6	<2	281	386	NC	17	152
	Carbonate Bank and Terrace System of the Sahul Shelf KEF	<2	<2	<2	NC	NC	NC	NC	NC
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	<2	<2	<2	NC	NC	NC	<1	4
	Continental Slope Demersal Fish Communities KEF	100	86	<2	93	103	NC	204	655
	Exmouth Plateau KEF	82	16	<2	307	322	NC	42	211
	Glomar Shoals KEF §	100	<2	<2	11	12	218	701	54
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	10	<2	<2	543	NC	NC	2	25
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	<2	<2	<2	NC	NC	NC	<1	10
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	<2	<2	<2	NC	NC	NC	<1	4
	Wallaby Saddle KEF	4	<2	<2	1,026	NC	NC	2	16
	Western Demersal Slope and associated Fish Communities KEF	2	<2	<2	896	NC	NC	<1	15
	Western Rock Lobster KEF	<2	<2	<2	NC	NC	NC	<1	6
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC	NC	<1	2
	Dugong BIA	16	6	<2	441	810	NC	12	166
	Marine Turtle BIA	100	92	2	36	45	610	255	1,058
	River Sharks BIA	<2	<2	<2	NC	NC	NC	<1	<1
	Seabirds BIA	100	100	100	1	1	6	2,726	5,246
	Seals BIA	<2	<2	<2	NC	NC	NC	<1	6
	Sharks BIA	100	100	100	1	1	6	2,726	5,246
	Whales BIA	100	100	100	1	1	6	2,726	5,246
Fisheries	North-West Slope Trawl Fishery	100	86	<2	71	103	NC	217	916
	Southern Bluefin Tuna Fishery	100	100	100	1	1	6	2,726	5,246
	Western Skipjack Fishery	100	100	100	1	1	6	2,726	5,246
	Western Tuna and Billfish Fishery	100	100	100	1	1	6	2,726	5,246
Other Submerged Reefs, Banks and Shoals	Barracouta Shoals §	<2	<2	<2	NC	NC	NC	NC	NC
	Barton Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Bassett-Smith Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Big Bank Shoals	<2	<2	<2	NC	NC	NC	NC	NC
	Dillon Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Echo Shoals §	<2	<2	<2	NC	NC	NC	NC	NC
	Echuca Shoal §	<2	<2	<2	NC	NC	NC	NC	NC
	Eugene McDermott Shoal §	<2	<2	<2	NC	NC	NC	NC	NC
	Fantome Shoal §	<2	<2	<2	NC	NC	NC	NC	NC
	Goeree Shoal §	<2	<2	<2	NC	NC	NC	NC	NC
	Heywood Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Hibernia Reef	<2	<2	<2	NC	NC	NC	NC	NC
	Jabiru Shoals	<2	<2	<2	NC	NC	NC	NC	NC
	Johnson Bank	<2	<2	<2	NC	NC	NC	NC	NC
	Karmt Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Mangola Shoal	<2	<2	<2	NC	NC	NC	NC	NC

Receptors	Probability (%) of entrained hydrocarbon concentration contact at			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
Pee Shoal	<2	<2	<2	NC	NC	NC	NC	NC
Rankin Bank §	86	<2	<2	113	163	NC	188	53
Sahul Bank §	<2	<2	<2	NC	NC	NC	NC	NC
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
Vee Shoal	<2	<2	<2	NC	NC	NC	NC	NC
Vulcan Shoal §	<2	<2	<2	NC	NC	NC	NC	NC
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.

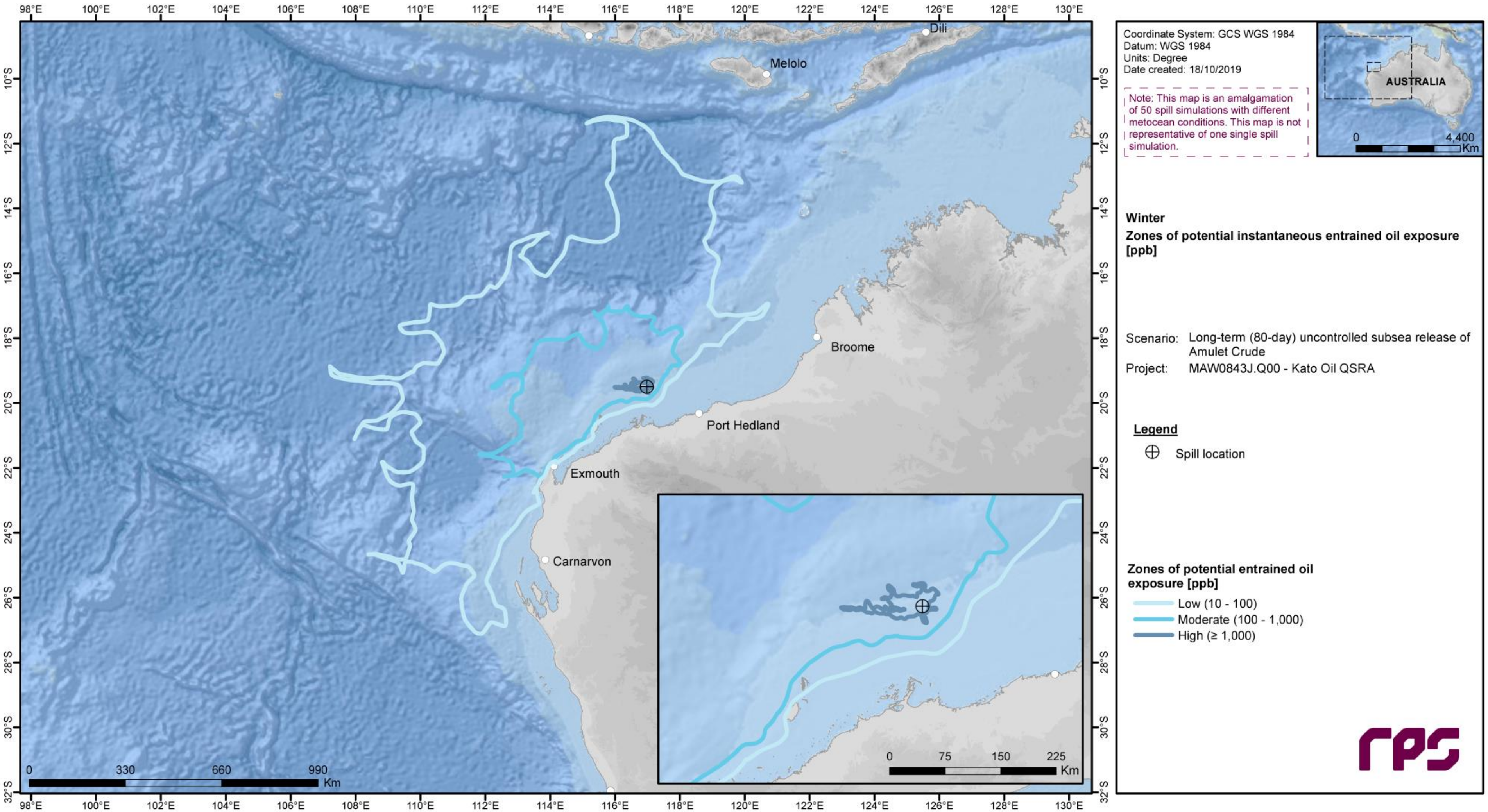

Figure 3.24 Predicted zones of potential entrained oil exposure resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in winter months.

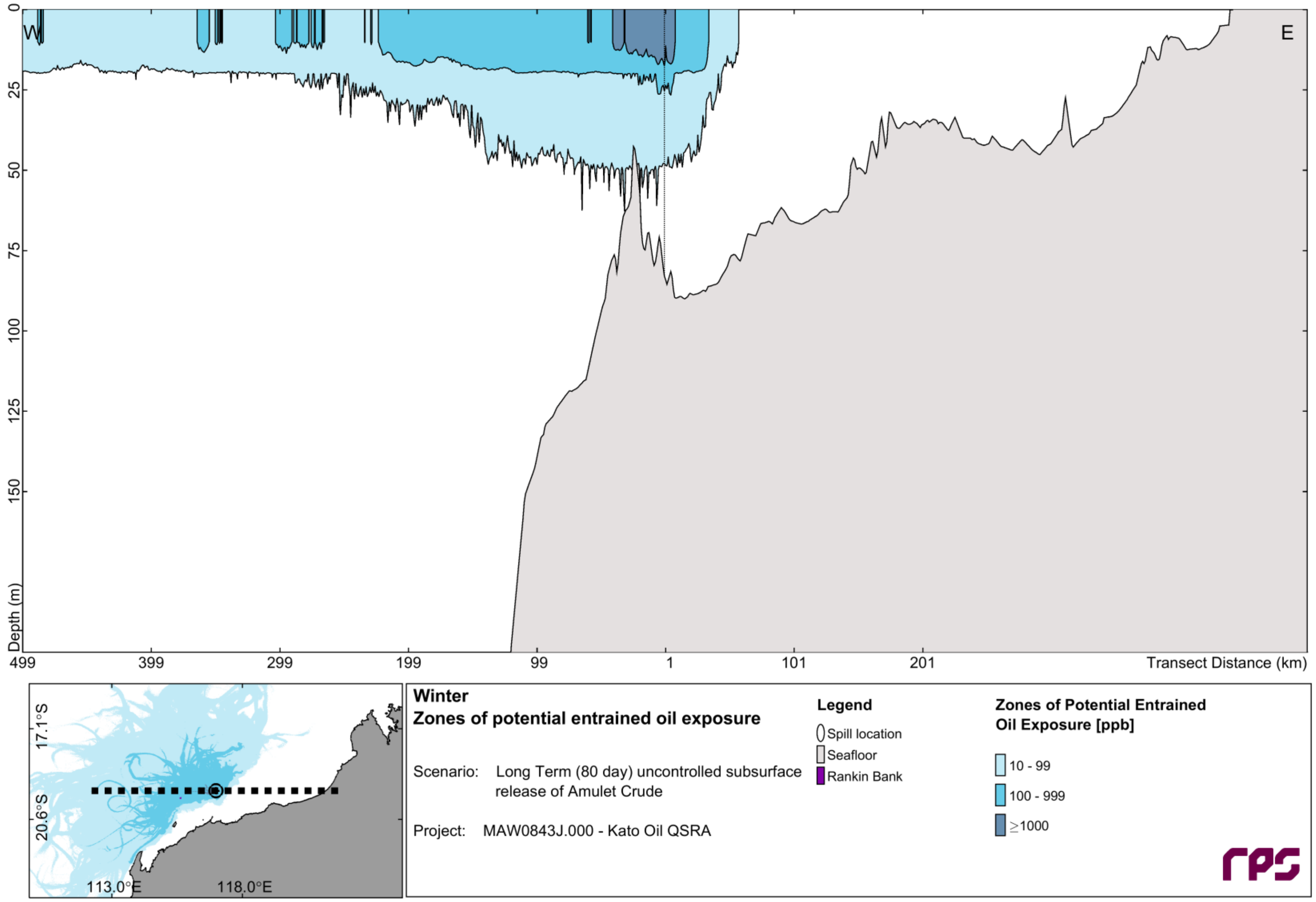

Figure 3.25 East-West cross-section transect of predicted maximum entrained oil concentration from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the winter season. The results were calculated from 50 spill trajectories.

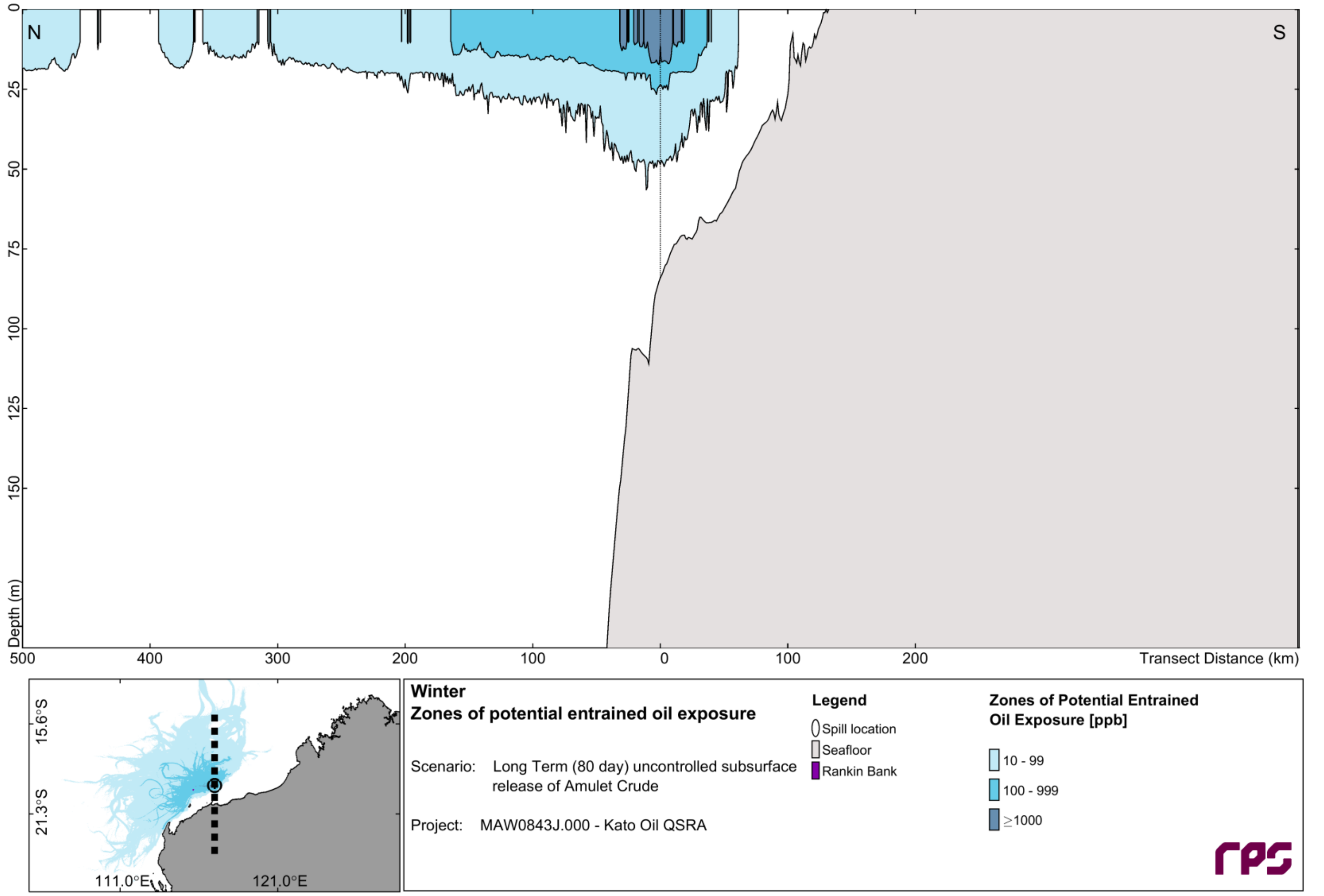

Figure 3.26 North-South cross-section transect of predicted maximum entrained oil concentration from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the winter season. The results were calculated from 50 spill trajectories.

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 Amulet Crude within the Amulet field, starting in winter months.

Receptor		Threshold (ppb.hr)	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 (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	37	7	4	NC	NC	BS
	Barrow Island	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	588	45	17	7	BS	BS
	Browse Island	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
	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	28	BS	BS	BS	BS	BS
	Lowendal Islands	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	145	5	NC	BS	BS	BS
	Montebello Islands	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	473	35	27	5	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	37	7	2	1	NC	NC
	Southern Pilbara - Islands	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	347	48	27	BS	BS	BS
Coastlines	Buccaneer Archipelago	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	5	NC	NC	NC	NC	BS
		Probability (%) >960	NC	NC	NC	NC	BS	BS

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Dampier Archipelago	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
	Exmouth Gulf South East	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	6	BS	BS	BS	BS	BS
	Exmouth Gulf West	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	295	34	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	71	14	3	NC	BS	BS
	Jurien Bay - Yanchep	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	31	3	1	NC	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	13	4	NC	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	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	24	1	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	13	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	47	4	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

	Receptor	Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
	Perth Northern Coast	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	121	12	3	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	NC	NC	BS	BS	BS	BS
	Southern Pilbara - Shoreline	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	18	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	1	1	NC	NC	NC	BS
State National and Marine Parks	Barrow Island MMA	Probability (%) >960	4	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	1,046	86	36	12	BS	BS
	Barrow Islands 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	693	66	12	6	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	490	55	20	9	NC	NC
	Eighty Mile Beach - Broome	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	2	NC	BS	BS	BS	BS
	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	887	125	19	14	4	NC
	Lalang-garram / Camden Sound MP	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	1	1	NC	NC	NC	BS
	Marmion MP	Probability (%) >960	NC	NC	NC	BS	BS	BS

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	55	5	NC	BS	BS	BS
	Montebello Islands 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	969	108	49	9	BS	BS
	Muiron Islands MMA	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	1,131	155	45	31	5	BS
	Ningaloo Coast WH	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	5,399	457	116	26	7	3
	Ningaloo MP (State)	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	4,913	382	101	26	7	3
	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	2	1	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	15	3	2	5	NC	BS
Australian Marine Parks	Abrolhos 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	574	28	18	4	1	NC
	Argo-Rowley Terrace MP	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	9,160	595	115	34	6	3
	Ashmore 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	NC	NC	NC	NC	NC	NC
	Carnarvon Canyon 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

Receptor	Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Maximum Integrated Exposure	802	55	24	10	1	NC
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	44	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	5,402	404	133	67	16	7
Jurien Bay 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	4	1	1	NC	BS	BS
Jurien 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	6	2	NC	NC	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
	Maximum Integrated Exposure	98	17	8	4	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	75	11	7	NC	NC	NC
Montebello MP	Probability (%) >960	82	6	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	7,750	1,200	310	131	36	1
Ningaloo MP	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	5,399	457	116	25	6	3
	Probability (%) >960	NC	NC	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Oceanic Shoals MP	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
	Perth Canyon 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	403	48	15	3	NC	NC
	Roebuck MP	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	1	NC	BS	BS	BS	BS
	Shark Bay 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	147	24	17	7	3	1
	Two Rocks MP	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	138	14	4	NC	NC	BS
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	100	52	2	NC	NC	NC
		Probability (%) >9,600	92	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	77,621	5,327	1,137	230	58	16
	Ancient Coastline at 90-120m Depth Contour 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	143	13	5	1	NC	NC
	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	171	26	7	2	NC	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	18	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	3,397	394	126	57	12	1
	Carbonate Bank and Terrace System of the Sahul Shelf 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

Receptor	Threshold (ppb.hr)	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
Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands 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	37	8	4	1	NC	NC
Continental Slope Demersal Fish Communities KEF	Probability (%) >960	96	12	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	17,325	1,761	722	111	18	3
Exmouth Plateau KEF	Probability (%) >960	44	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	8,907	523	123	44	18	7
Glomar Shoals KEF	Probability (%) >960	100	42	2	NC	NC	BS
	Probability (%) >9,600	86	NC	NC	NC	NC	BS
	Probability (%) >96,000	NC	NC	NC	NC	NC	BS
	Maximum Integrated Exposure	43,839	4,334	1,359	377	55	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	887	125	34	14	4	NC
Perth Canyon and adjacent Shelf Break, and other West Coast Canyons 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	359	31	6	1	NC	NC
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	52	7	4	2	NC	NC
Wallaby Saddle 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	191	22	9	4	1	NC
Western Demersal Slope and associated Fish Communities 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	403	48	15	6	1	NC
Western Rock Lobster 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	15	5	2	1	NC

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
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	15	2	NC	NC	NC	NC
	Dugong BIA	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	5,350	447	116	26	7	3
	Marine Turtle BIA	Probability (%) >960	96	16	NC	NC	NC	NC
		Probability (%) >9,600	28	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	31,106	1,989	488	167	58	22
	River Sharks BIA	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	NC	NC	NC	NC	BS
	Seabirds BIA	Probability (%) >960	100	54	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	120,284	4,962	1,359	377	62	14
	Seals 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	160	18	5	1	NC	NC
	Sharks BIA	Probability (%) >960	100	54	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	120,284	5,327	1,359	377	62	22
	Whales BIA	Probability (%) >960	100	54	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	120,284	5,327	1,359	377	62	22
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	100	22	NC	NC	NC	NC
		Probability (%) >9,600	24	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	34,977	3,198	791	201	20	7
	Southern Bluefin Tuna Fishery	Probability (%) >960	100	54	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	120,284	5,327	1,359	377	62	22
	Western Skipjack Fishery	Probability (%) >960	100	54	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	120,284	5,327	1,359	377	62	22
	Western Tuna and Billfish Fishery	Probability (%) >960	100	54	2	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	4	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	120,284	5,327	1,359	377	62	22
Other Submerged Reefs, Shoals and Banks	Barracouta Shoals	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
	Barton Shoal	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
	Bassett-Smith 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
	Big Bank Shoals	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
	Dillon Shoal	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
	Echo Shoals	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
	Echuca Shoal	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
	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
	Fantome 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

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Goeree 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
	Heywood Shoal	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
	Hibernia 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	NC	NC	NC	NC	NC	NC
	Jabiru Shoals	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
	Johnson 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
	Karmt Shoal	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
	Mangola Shoal	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
	Pee 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	88	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	8,608	663	319	BS	BS	BS
	Sahul Bank	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
	Scott Reef North	Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	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	39	7	3	1	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	52	7	4	2	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	38	4	3	NC	NC	NC
	Vee Shoal	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
	Vulcan 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
	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.

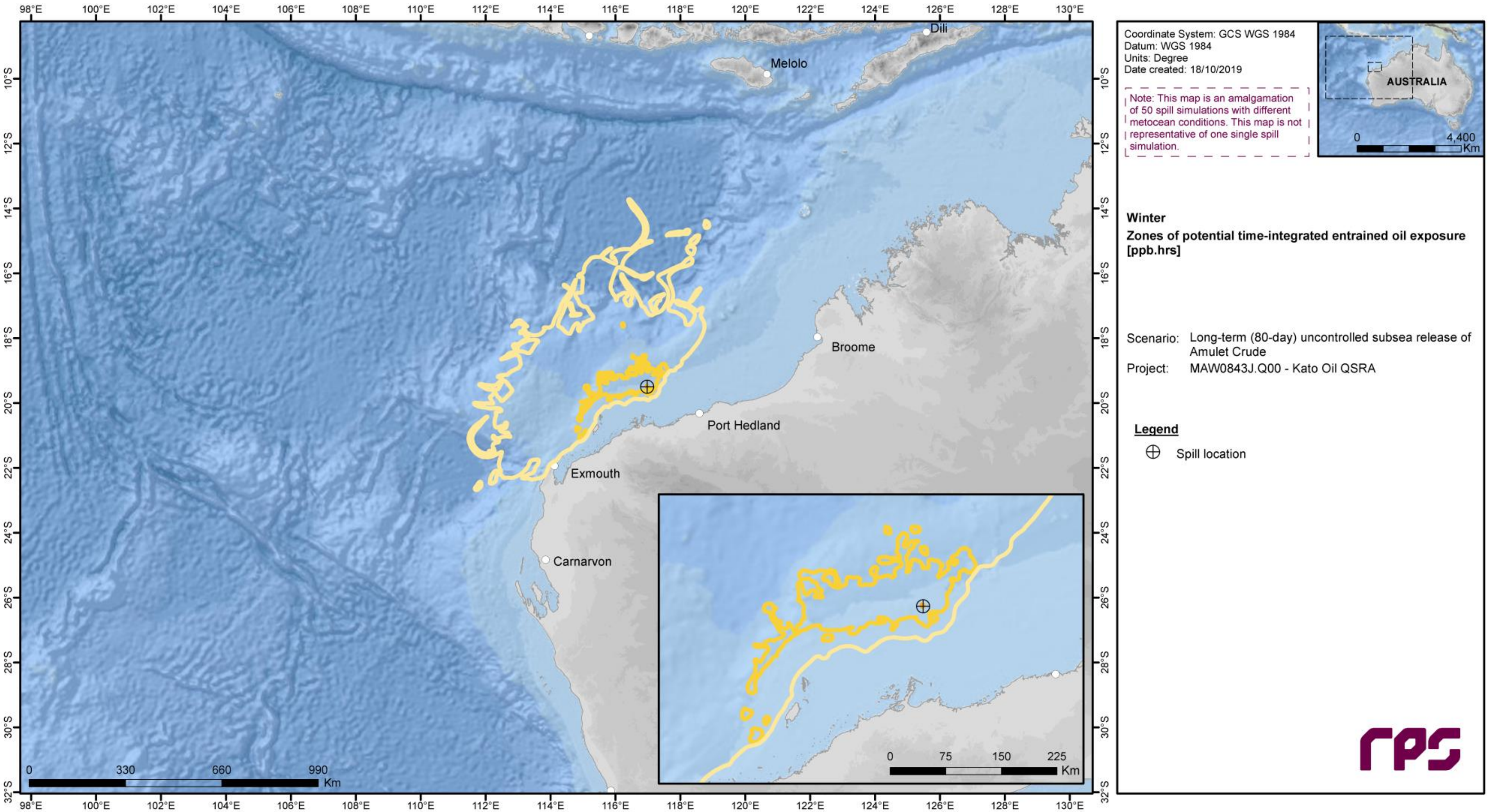

Figure 3.27 Predicted zones of potential time-integrated entrained oil exposure resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in winter months.

3.2.3.3.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Table 3.13 Expected dissolved aromatic hydrocarbons outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet 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	Abrolhos Islands	<2	<2	<2	NC	NC
	Barrow Island	<2	<2	<2	<1	<1
	Browse Island	<2	<2	<2	NC	NC
	Lacepede Islands	<2	<2	<2	NC	NC
	Lowendal Islands	<2	<2	<2	NC	NC
	Montebello Islands	4	<2	<2	<1	26
	Sandy Islet	<2	<2	<2	NC	NC
	Southern Pilbara - Islands	<2	<2	<2	<1	2
Coastlines	Buccaneer Archipelago	<2	<2	<2	NC	NC
	Dampier Archipelago	<2	<2	<2	NC	NC
	Exmouth Gulf South East	<2	<2	<2	NC	NC
	Exmouth Gulf West	<2	<2	<2	NC	NC
	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	NC	NC
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC
State National and Marine Parks	Barrow Island MMA	<2	<2	<2	<1	7
	Barrow Islands MP	<2	<2	<2	<1	<1
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	<1	<1
	Eighty Mile Beach - Broome	<2	<2	<2	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<2	<2	<2	<1	2
	Lalang-garram / Camden Sound MP	<2	<2	<2	NC	NC

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
	Marmion MP	<2	<2	<2	NC	NC
	Montebello Islands MP	4	<2	<2	<1	34
	Muiron Islands MMA	<2	<2	<2	<1	7
	Ningaloo Coast WH	2	<2	<2	<1	23
	Ningaloo MP (State)	2	<2	<2	<1	12
	Shark Bay MR	<2	<2	<2	NC	NC
	Shark Bay WH	<2	<2	<2	NC	NC
Australian Marine Parks	Abrolhos MP	<2	<2	<2	NC	NC
	Argo-Rowley Terrace MP	4	<2	<2	2	35
	Ashmore Reef MP	<2	<2	<2	NC	NC
	Carnarvon Canyon MP	<2	<2	<2	<1	<1
	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	6	2	<2	2	67
	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	60	4	<2	16	164
	Ningaloo MP	2	<2	<2	<1	23
	Oceanic Shoals MP	<2	<2	<2	NC	NC
	Perth Canyon MP	<2	<2	<2	NC	NC
	Roebuck MP	<2	<2	<2	NC	NC
	Shark Bay MP	<2	<2	<2	<1	3
	Two Rocks MP	<2	<2	<2	NC	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	100	100	2	122	576
	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	6	2	<2	3	70
	Carbonate Bank and Terrace System of the Sahul Shelf KEF	<2	<2	<2	NC	NC

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
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	<2	<2	<2	NC	NC
	Continental Slope Demersal Fish Communities KEF	72	8	<2	19	152
	Exmouth Plateau KEF	8	2	<2	4	153
	Glomar Shoals KEF §	100	30	<2	119	344
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	<2	<2	<2	<1	3
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	<2	<2	<2	NC	NC
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	<2	<2	<2	NC	NC
	Wallaby Saddle KEF	<2	<2	<2	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	<2	<2	<2	NC	NC
	Western Rock Lobster KEF	<2	<2	<2	NC	NC
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC
	Dugong BIA	2	<2	<2	<1	15
	Marine Turtle BIA	96	22	<2	34	276
	River Sharks BIA	<2	<2	<2	NC	NC
	Seabirds BIA	100	100	2	167	549
	Seals BIA	<2	<2	<2	NC	NC
	Sharks BIA	100	100	2	167	576
	Whales BIA	100	100	2	167	576
Fisheries	North-West Slope Trawl Fishery	76	16	<2	23	245
	Southern Bluefin Tuna Fishery	100	100	2	167	576
	Western Skipjack Fishery	100	100	2	167	576
	Western Tuna and Billfish Fishery	100	100	2	167	576
Other Submerged Reefs, Banks and Shoals	Barracouta Shoals §	<2	<2	<2	NC	NC
	Barton Shoal	<2	<2	<2	NC	NC
	Bassett-Smith Shoal	<2	<2	<2	NC	NC
	Big Bank Shoals	<2	<2	<2	NC	NC
	Dillon Shoal	<2	<2	<2	NC	NC
	Echo Shoals §	<2	<2	<2	NC	NC
	Echuca Shoal §	<2	<2	<2	NC	NC
	Eugene McDermott Shoal §	<2	<2	<2	NC	NC
	Fantome Shoal §	<2	<2	<2	NC	NC

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
Goeree Shoal §	<2	<2	<2	NC	NC
Heywood Shoal	<2	<2	<2	NC	NC
Hibernia Reef	<2	<2	<2	NC	NC
Jabiru Shoals	<2	<2	<2	NC	NC
Johnson Bank	<2	<2	<2	NC	NC
Karmt Shoal	<2	<2	<2	NC	NC
Mangola Shoal	<2	<2	<2	NC	NC
Pee Shoal	<2	<2	<2	NC	NC
Rankin Bank §	58	4	<2	20	76
Sahul Bank §	<2	<2	<2	NC	NC
Scott Reef North	<2	<2	<2	NC	NC
Scott Reef South	<2	<2	<2	NC	NC
Seringapatam Reef	<2	<2	<2	NC	NC
Vee Shoal	<2	<2	<2	NC	NC
Vulcan Shoal §	<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.

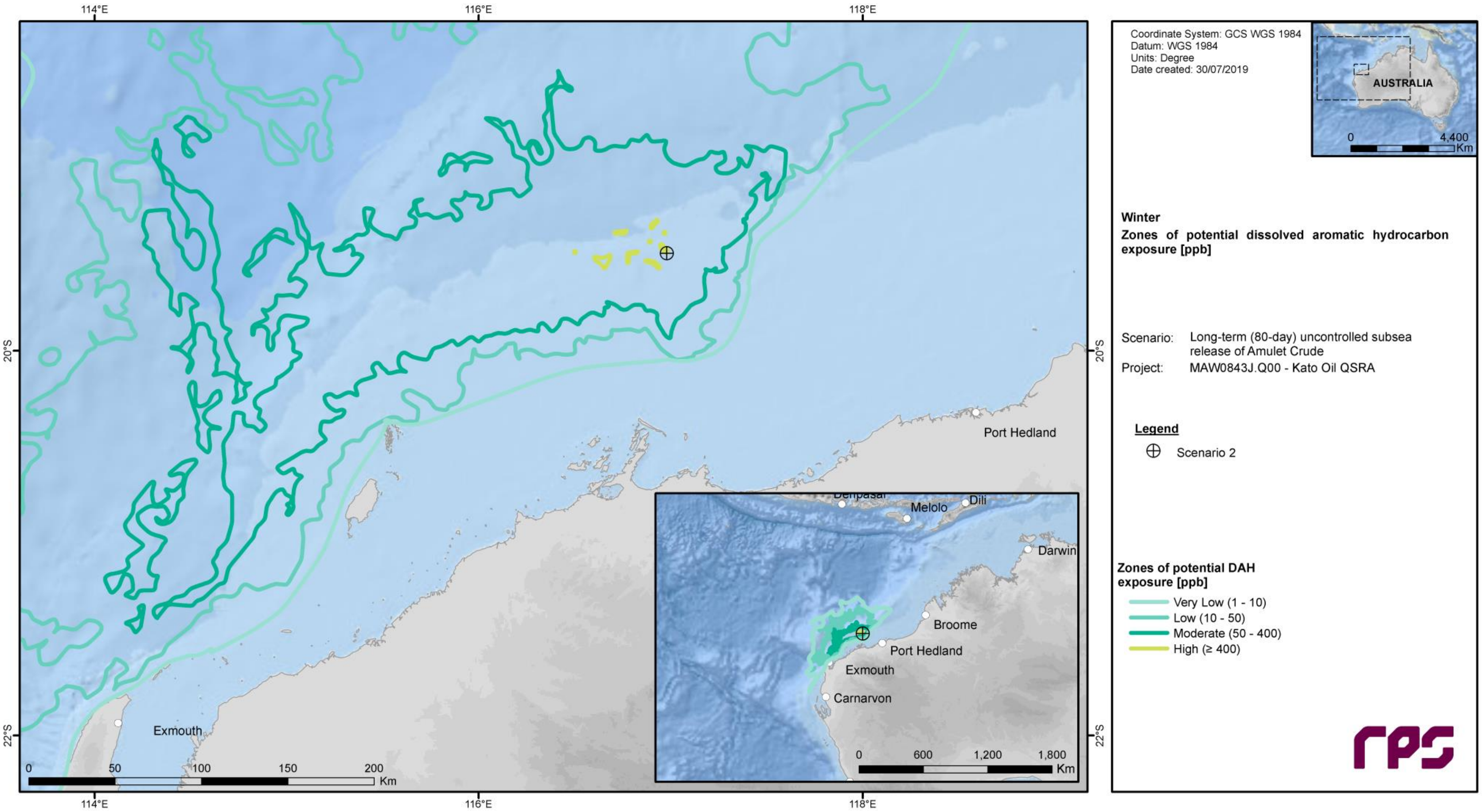

Figure 3.28 Predicted zones of potential instantaneous dissolved aromatic hydrocarbon (DAH) exposure for a long-term (80 day) subsea release of Amulet Crude within the Amulet Field, starting in winter months.

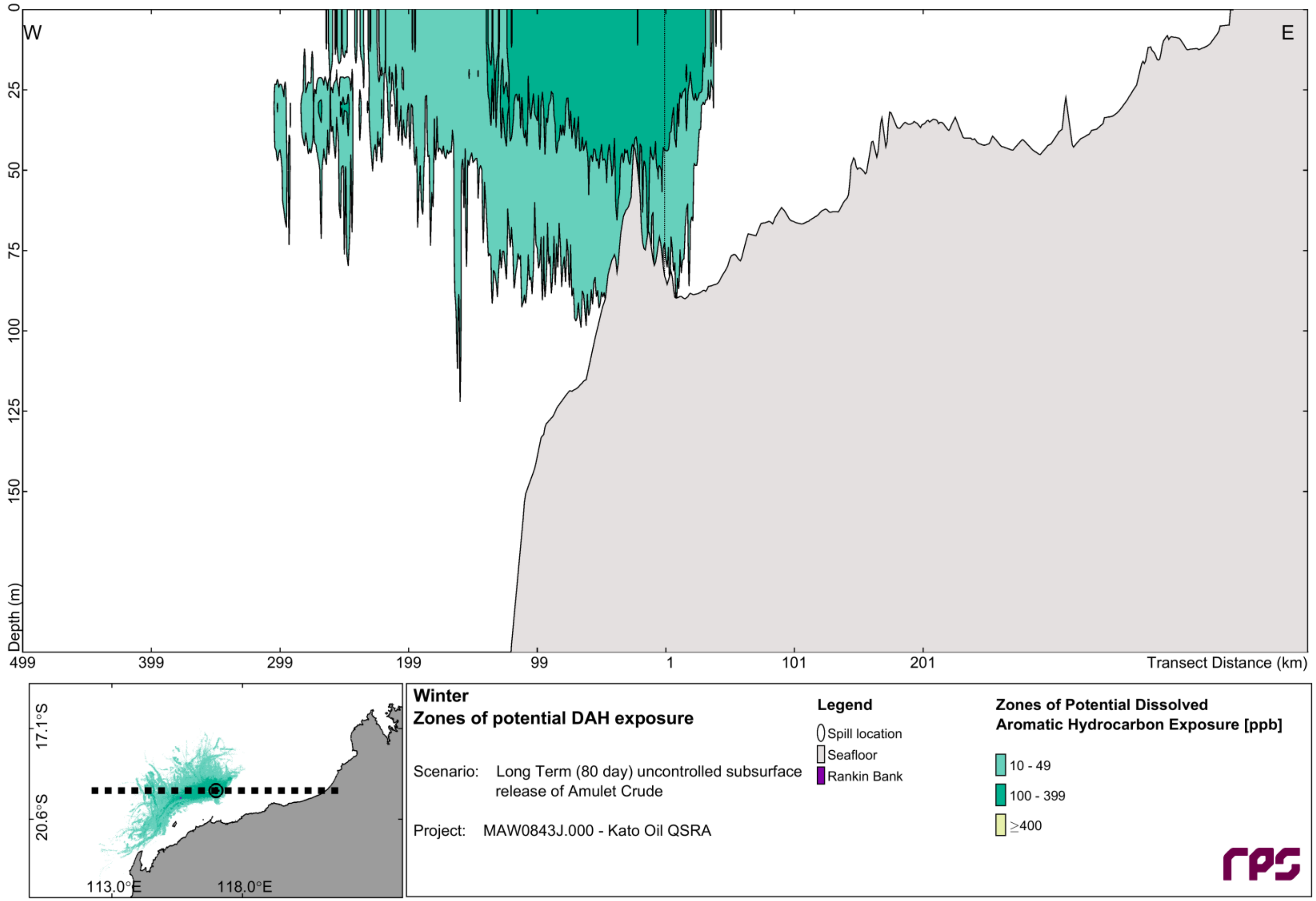

Figure 3.29 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the winter season. The results were calculated from 50 spill trajectories.

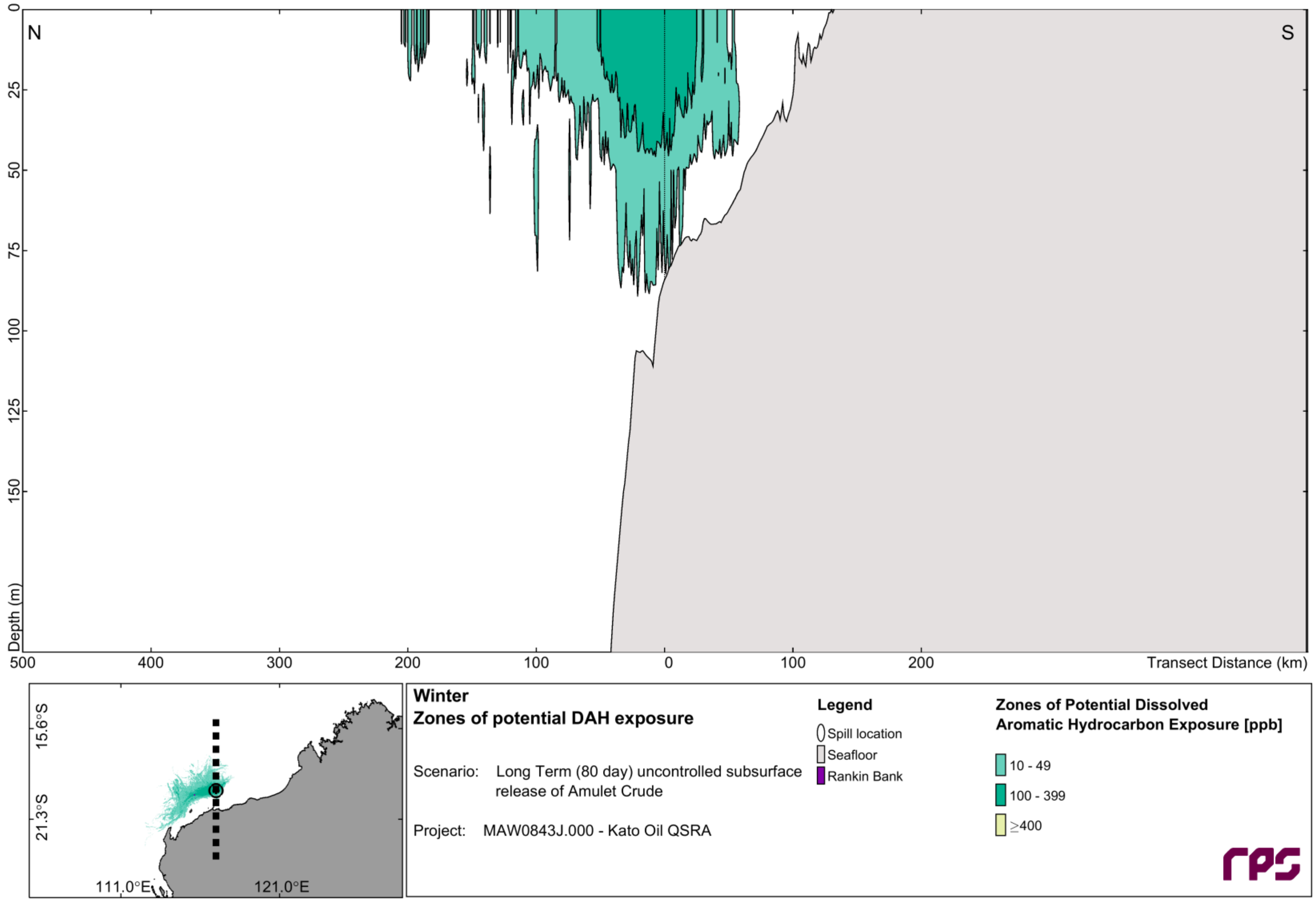

Figure 3.30 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the transitional period. The results were calculated from 50 spill trajectories.

3.2.3.3.5 Dissolved Aromatic Hydrocarbon - Exposure

Table 3.14 Expected dissolved aromatic hydrocarbons exposure outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in winter months.

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m 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	1	3	2	NC	BS	BS
	Browse Island	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
	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	21	11	2	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	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	3	3	BS	BS	BS
	Buccaneer Archipelago	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
	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

Receptor	Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m 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	NC	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	NC	NC	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
Perth Northern Coast	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >4,800	NC	NC	NC	NC	BS	BS

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
		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	NC	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 National and Marine 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	13	3	8	2	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	1	1	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	1	NC	NC
	Eighty Mile Beach - Broome	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
	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	4	1	NC	NC
	Lalang-garram / Camden Sound 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
	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
		Probability (%) >960	NC	NC	NC	NC	BS	BS

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	Montebello Islands MP	Probability (%) >4,800	NC	NC	NC	NC	BS	BS
		Probability (%) >38,400	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	61	32	42	4	BS	BS
	Muiron Islands MMA	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	20	10	5	2	NC	BS
	Ningaloo Coast WH	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	12	50	44	12	7	NC
	Ningaloo MP (State)	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	36	13	11	1	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	NC	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	NC	NC	NC	NC	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	153	93	57	33	6	NC
	Ashmore 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
	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	NC	NC	NC	1	NC	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

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	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	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	211	189	122	130	14	NC
	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
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	565	446	843	608	42	1
	Ningaloo 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	12	50	44	12	7	NC
	Oceanic 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
	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

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Roebuck MP	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 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	3	NC	NC	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	56	8	4	2	NC	NC
		Probability (%) >4,800	2	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	4,896	2,431	1,829	995	117	1
	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
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula 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	101	87	147	106	14	NC
	Carbonate Bank and Terrace System of the Sahul Shelf 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
	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
		Probability (%) >960	NC	NC	NC	NC	NC	NC
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC

	Receptor	Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	Continental Slope Demersal Fish Communities KEF	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	730	404	712	243	86	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	78	336	188	115	7	NC
	Glomar Shoals KEF	Probability (%) >960	46	8	2	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	2,684	2,119	1,204	621	54	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	2	4	2	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	NC	NC	NC	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	NC	NC	NC	NC	NC	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	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	13	39	11	2	NC
	Marine Turtle BIA	Probability (%) >960	NC	NC	2	NC	NC	NC

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	758	625	1,341	608	121	3
	River Sharks BIA	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
	Seabirds BIA	Probability (%) >960	100	14	4	NC	NC	NC
		Probability (%) >4,800	10	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,823	3,153	1,912	945	183	3
	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	14	4	2	NC	NC
		Probability (%) >4,800	10	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,823	3,153	1,912	995	183	3
	Whales BIA	Probability (%) >960	100	14	4	2	NC	NC
		Probability (%) >4,800	10	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,823	3,153	1,912	995	183	3
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	4	NC	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	1,640	816	1,124	357	86	2
	Southern Bluefin Tuna Fishery	Probability (%) >960	100	14	4	2	NC	NC
		Probability (%) >4,800	10	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,823	3,153	1,912	995	183	3
	Western Skipjack Fishery	Probability (%) >960	100	14	4	2	NC	NC
		Probability (%) >4,800	10	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,823	3,153	1,912	995	183	3
	Western Tuna and Billfish Fishery	Probability (%) >960	100	14	4	2	NC	NC
		Probability (%) >4,800	10	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	7,823	3,153	1,912	995	183	3
Other Submerged Reefs, Shoals	Barracouta Shoals	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

Receptor	Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
Barton Shoal	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
Bassett-Smith 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
Big Bank Shoals	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
Dillon Shoal	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
Echo Shoals	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
Echuca Shoal	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
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
Fantome 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
Goeree 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
Heywood Shoal	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
Hibernia 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

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Jabiru Shoals	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
	Johnson 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
	Karmt Shoal	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
	Mangola Shoal	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
	Pee 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	197	339	309	BS	BS	BS
	Sahul Bank	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 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
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Vee Shoal	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	BS
	Vulcan 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
	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 sea.

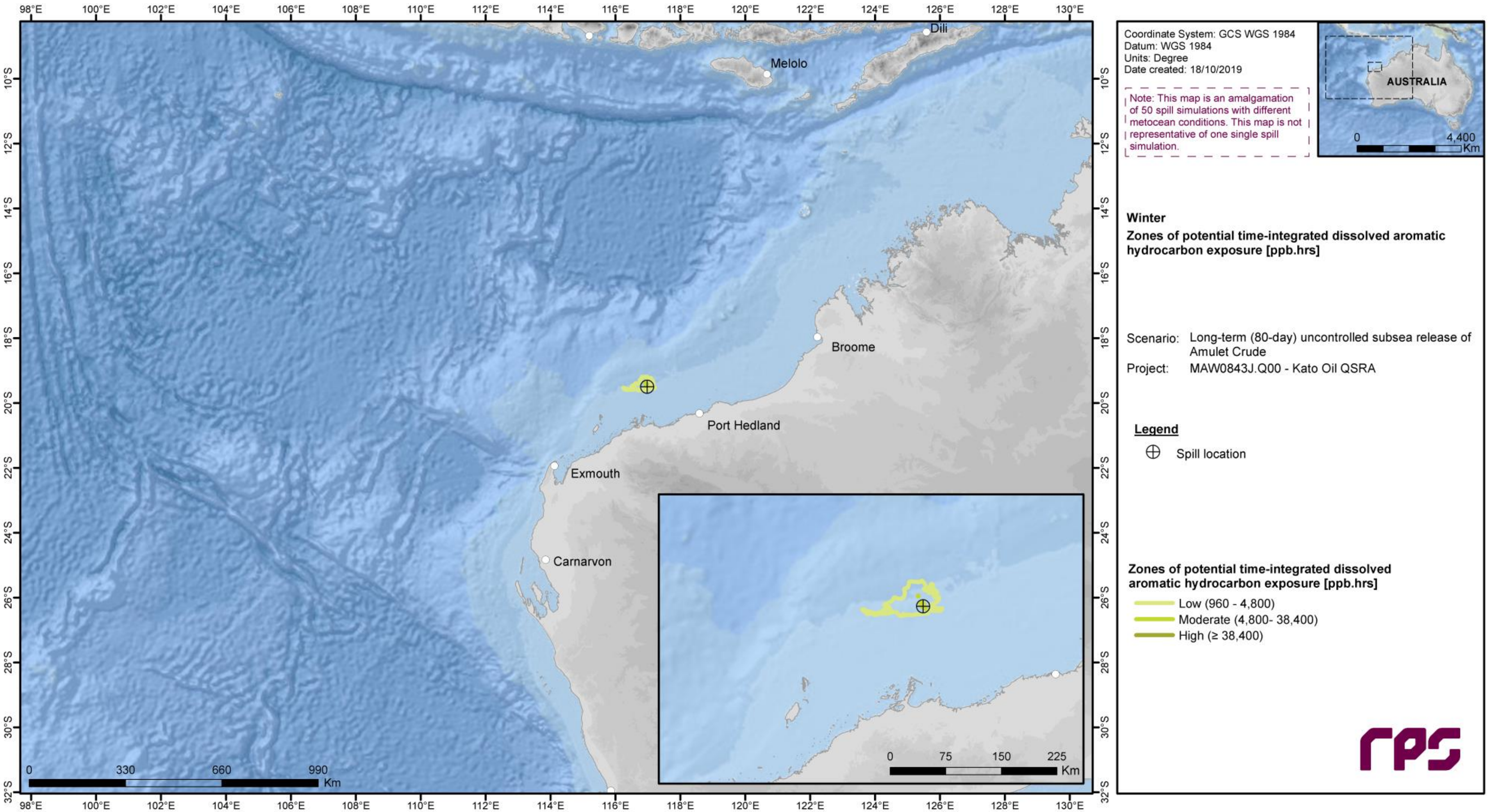

Figure 3.31 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon (DAH) exposure for a long-term (80 day) subsea release of Amulet Crude within the Amulet Field, starting in winter months.

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 Amulet Crude within the Amulet 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/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
Islands	Abrolhos Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	<0.1	3.7	<1	<1	NC	NC	NC	NC	NC	NC
	Barrow Island	<2	<2	<2	NC	NC	NC	2	<2	<2	1,612	NC	NC	0.3	11	<1	<1	<1	1	NC	NC	NC	NC
	Browse Island	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Montebello Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.1	6.9	<1	<1	NC	NC	NC	NC	NC	NC
	Sandy Islet	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	<0.1	3.2	<1	<1	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Coastlines	Buccaneer Archipelago	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Exmouth Gulf West	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	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	<0.1	1.8	<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	NC	NC	NC	NC	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	NC	NC	NC	2	<2	<2	1,612	NC	NC	0.3	11	<1	<1	<1	1	NC	NC	NC	NC
	Barrow Islands MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	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
	Eighty Mile Beach - Broome	<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	<0.1	4.7	<1	<1	NC	NC	NC	NC	NC	NC

	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
	Lalang-garram / Camden Sound 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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Montebello Islands MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.1	6.9	<1	<1	NC	NC	NC	NC	NC	NC
	Muiron Islands MMA	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	0.3	7.1	<1	<1	NC	NC	NC	NC	NC	NC
	Ningaloo Coast WH	<2	<2	<2	NC	NC	NC	2	<2	<2	889	NC	NC	0.4	14	<1	<1	<1	1	NC	NC	NC	NC
	Ningaloo MP (State)	<2	<2	<2	NC	NC	NC	2	<2	<2	889	NC	NC	0.4	14	<1	<1	<1	1	NC	NC	NC	NC
	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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Australian Marine Parks	Abrolhos MP*	<2	<2	<2	NC	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
	Ashmore Reef MP	<2	<2	<2	NC	NC	NC	<2	<2	<2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Carnarvon Canyon MP*	<2	<2	<2	NC	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*	<2	<2	<2	NC	NC	NC	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	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ningaloo MP*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Oceanic Shoals MP*	<2	<2	<2	NC	NC	NC	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
	Roebuck 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*	<2	<2	<2	NC	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	34	<2	6	7	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*	<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

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
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carbonate Bank and Terrace System of the Sahul Shelf KEF*	<2	<2	<2	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*	<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**	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Exmouth Plateau KEF*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Glomar Shoals KEF*	96	10	2	19	85	257	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*	<2	<2	<2	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*	<2	<2	<2	NC	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*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marine Turtle BIA*†	14	2	<2	127	1,720	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	River Sharks BIA*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seabirds BIA*†	100	100	66	1	1	2	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	66	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Whales BIA*	100	100	66	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	North-West Slope Trawl Fishery*	6	<2	<2	94	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Southern Bluefin Tuna Fishery*	100	100	66	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Skipjack Fishery*	100	100	66	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Tuna and Billfish Fishery*	100	100	66	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ot he	Barracouta Shoals*	<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
Barton Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bassett-Smith Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Big Bank Shoals*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dillon Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Echo Shoals*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Echuca Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
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
Fantome Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Goeree Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heywood Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hibernia Reef*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Jabiru Shoals*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Johnson Bank*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Karmt Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mangola Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pee 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
Sahul 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
Vee Shoal*	<2	<2	<2	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vulcan Shoal*	<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.

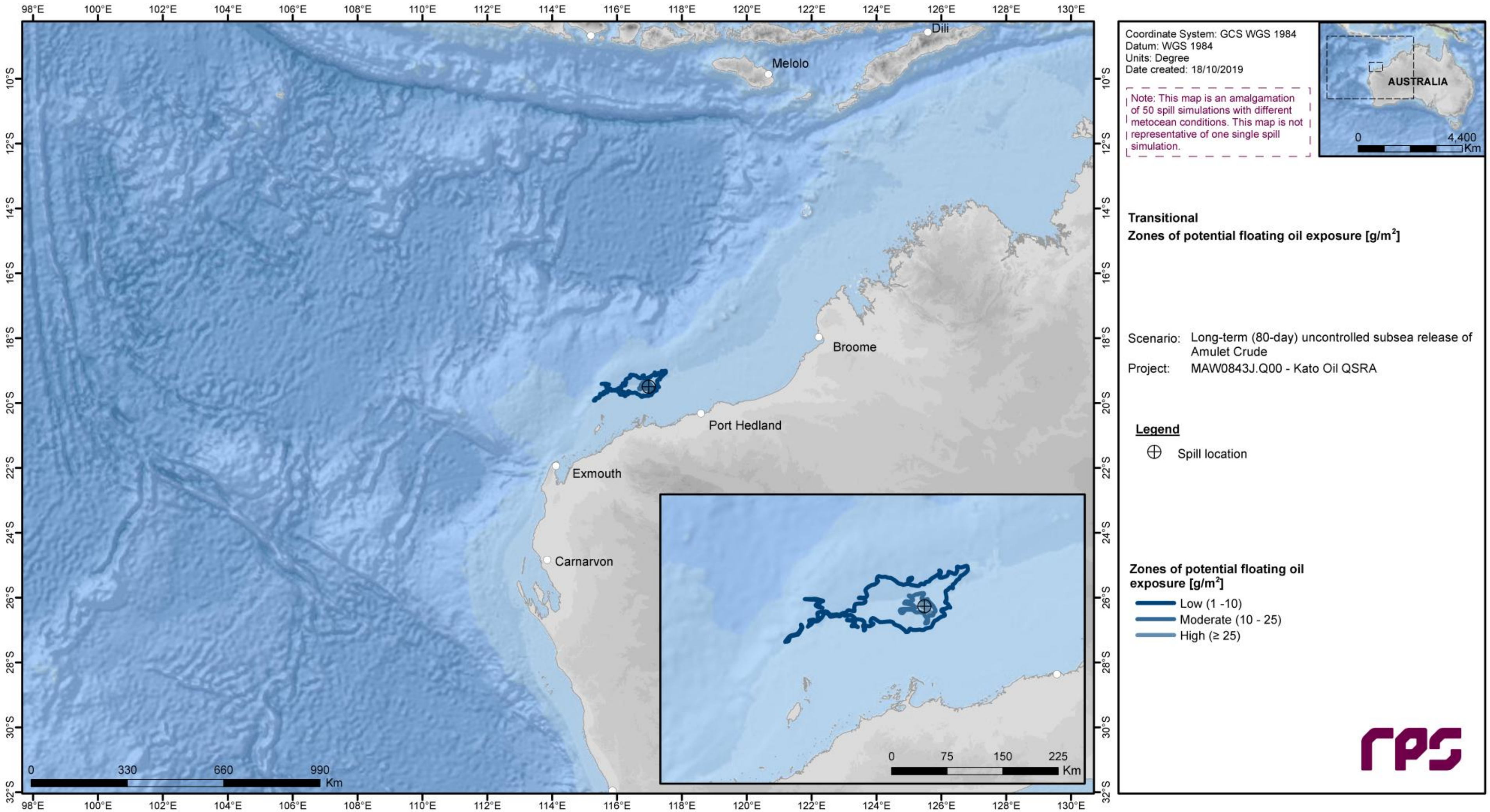

Figure 3.32 Predicted zones of potential floating oil exposure resulting from a long-term (80 days) subsea release of Amulet Crude within the Amulet field, starting in transitional months.

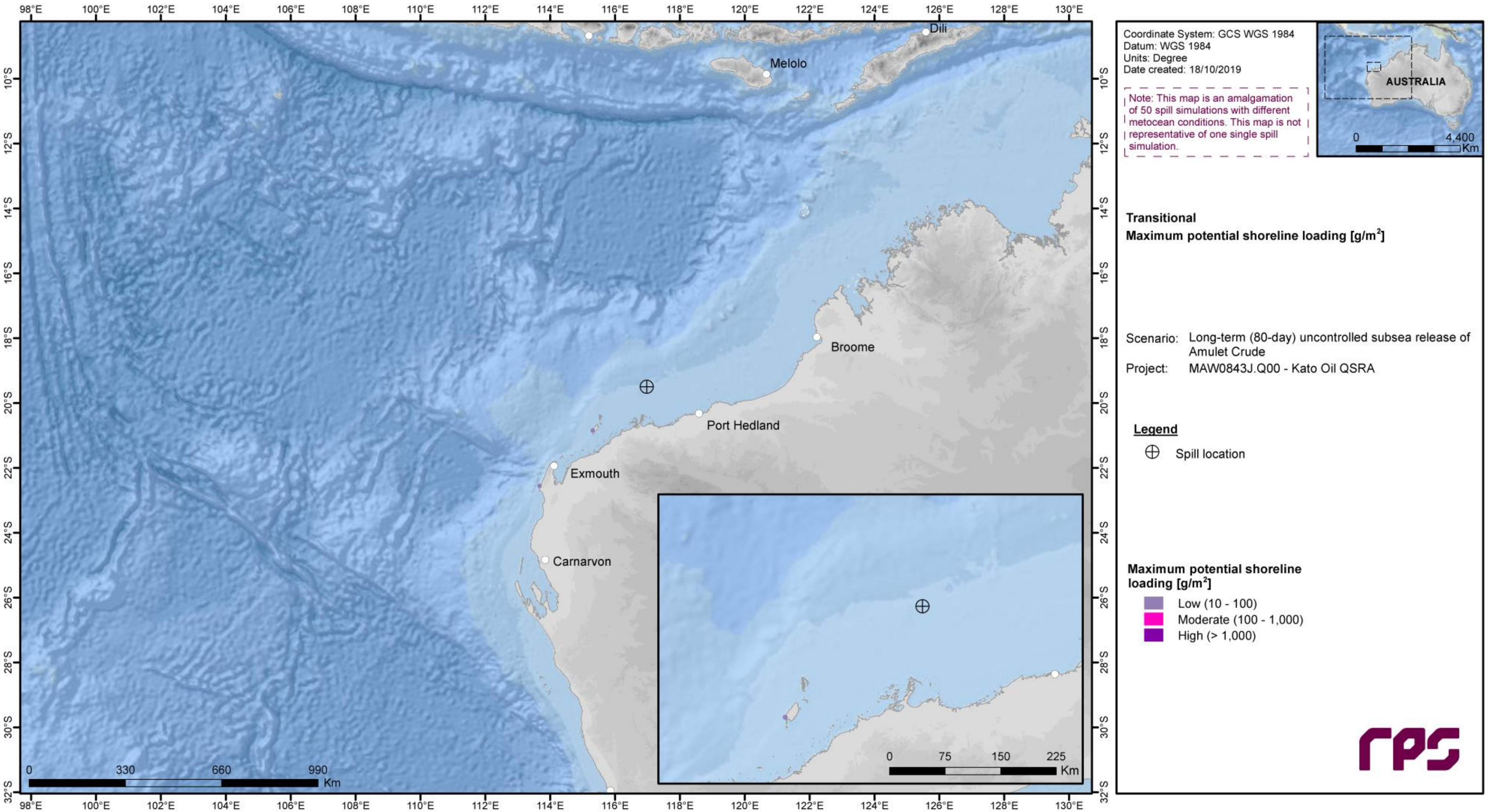

Figure 3.33 Predicted maximum potential shoreline loading resulting from a long-term (80 days) subsea release of Amulet Crude within the Amulet field, starting in transitional months.

3.2.3.4.2 Entrained Oil - Instantaneous

Table 3.16 Expected entrained oil outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in transitional 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	<2	<2	<2	NC	NC	NC	<1	5
	Barrow Island	8	<2	<2	904	NC	NC	3	15
	Browse Island	<2	<2	<2	NC	NC	NC	<1	<1
	Lacepede Islands	<2	<2	<2	NC	NC	NC	NC	NC
	Lowendal Islands	<2	<2	<2	NC	NC	NC	<1	5
	Montebello Islands	6	<2	<2	654	NC	NC	4	24
	Sandy Islet	<2	<2	<2	NC	NC	NC	<1	4
	Southern Pilbara - Islands	<2	<2	<2	NC	NC	NC	2	10
Coastlines	Buccaneer Archipelago	<2	<2	<2	NC	NC	NC	NC	NC
	Dampier Archipelago	<2	<2	<2	NC	NC	NC	NC	NC
	Exmouth Gulf South East	<2	<2	<2	NC	NC	NC	<1	<1
	Exmouth Gulf West	2	<2	<2	1,166	NC	NC	<1	11
	Geraldton - Jurien Bay	<2	<2	<2	NC	NC	NC	<1	2
	Jurien Bay - Yanchep	<2	<2	<2	NC	NC	NC	<1	3
	Kalbarri - Geraldton	<2	<2	<2	NC	NC	NC	<1	<1
	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	<1
	North Broome Coast	<2	<2	<2	NC	NC	NC	NC	NC
	Northern Pilbara - Islands and Shoreline	<2	<2	<2	NC	NC	NC	NC	NC
	Perth Northern Coast	<2	<2	<2	NC	NC	NC	<1	5
	Port Hedland - Eighty Mile Beach	<2	<2	<2	NC	NC	NC	NC	NC
	Southern Pilbara - Shoreline	<2	<2	<2	NC	NC	NC	<1	2
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC	NC	<1	<1
State National and Marine Parks	Barrow Island MMA	14	<2	<2	596	NC	NC	3	22
	Barrow Islands MP	2	<2	<2	2,007	NC	NC	2	13
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	<1	3
	Eighty Mile Beach - Broome	<2	<2	<2	NC	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC	NC	<1	6
	Lalang-garram / Camden Sound MP	<2	<2	<2	NC	NC	NC	NC	NC
	Marmion MP	<2	<2	<2	NC	NC	NC	<1	3
	Montebello Islands MP	22	4	<2	407	500	NC	10	128
	Muiron Islands MMA	14	<2	<2	884	NC	NC	4	33
	Ningaloo Coast WH	42	16	<2	345	751	NC	40	270
	Ningaloo MP (State)	34	4	<2	551	1,986	NC	15	133
	Shark Bay MR	<2	<2	<2	NC	NC	NC	<1	2
	Shark Bay WH	<2	<2	<2	NC	NC	NC	<1	5
Australian Marine Parks	Abrolhos MP	16	<2	<2	1,152	NC	NC	4	37
	Argo-Rowley Terrace MP	38	8	<2	308	460	NC	15	136
	Ashmore Reef MP	<2	<2	<2	NC	NC	NC	NC	NC
	Carnarvon Canyon MP	16	<2	<2	459	NC	NC	4	29
	Cartier Island MP	<2	<2	<2	NC	NC	NC	<1	<1
	Dampier MP	<2	<2	<2	NC	NC	NC	NC	NC
	Eighty Mile Beach MP	<2	<2	<2	NC	NC	NC	NC	NC
	Gascoyne MP	66	22	<2	208	484	NC	52	381
	Jurien Bay MP	<2	<2	<2	NC	NC	NC	<1	3
	Jurien MP	<2	<2	<2	NC	NC	NC	<1	4
	Kimberley MP	<2	<2	<2	NC	NC	NC	<1	4
	Mermaid Reef MP	<2	<2	<2	NC	NC	NC	<1	3
	Montebello MP	78	54	<2	176	255	NC	108	692
	Ningaloo MP	42	16	<2	345	751	NC	40	270
	Oceanic Shoals MP	<2	<2	<2	NC	NC	NC	NC	NC

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
	Perth Canyon MP	2	<2	<2	1,898	NC	NC	<1	17
	Roebuck MP	<2	<2	<2	NC	NC	NC	NC	NC
	Shark Bay MP	24	14	<2	795	1,148	NC	17	138
	Two Rocks MP	<2	<2	<2	NC	NC	NC	<1	3
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	100	100	48	4	6	12	919	1,523
	Ancient Coastline at 90-120m Depth Contour KEF	<2	<2	<2	NC	NC	NC	<1	6
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters KEF	<2	<2	<2	NC	NC	NC	<1	<1
	Canyons linking the Argo Abyssal Plain with the Scott Plateau KEF	2	<2	<2	1,745	NC	NC	2	11
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	60	22	<2	251	485	NC	46	338
	Carbonate Bank and Terrace System of the Sahul Shelf KEF	<2	<2	<2	NC	NC	NC	NC	NC
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands KEF	2	<2	<2	1,539	NC	NC	<1	11
	Continental Slope Demersal Fish Communities KEF	100	72	<2	55	56	NC	204	694
	Exmouth Plateau KEF	94	18	<2	248	475	NC	49	301
	Glomar Shoals KEF §	100	<2	<2	11	12	134	664	50
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	8	<2	<2	1,136	NC	NC	2	13
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons KEF	14	<2	<2	1,262	NC	NC	4	42
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	<2	<2	<2	NC	NC	NC	<1	5
	Wallaby Saddle KEF	2	<2	<2	1,433	NC	NC	2	13
	Western Demersal Slope and associated Fish Communities KEF	26	<2	<2	764	NC	NC	6	47
	Western Rock Lobster KEF	<2	<2	<2	NC	NC	NC	<1	8
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC	NC	NC	NC
	Dugong BIA	34	6	<2	548	985	NC	21	142
	Marine Turtle BIA	100	74	4	46	47	270	250	1,375
	River Sharks BIA	<2	<2	<2	NC	NC	NC	NC	NC
	Seabirds BIA	100	100	100	1	1	3	2,514	4,154
	Seals BIA	<2	<2	<2	NC	NC	NC	<1	6
	Sharks BIA	100	100	100	1	1	3	2,514	4,154
	Whales BIA	100	100	100	1	1	3	2,514	4,154
Fisheries	North-West Slope Trawl Fishery	100	94	<2	54	58	NC	247	925
	Southern Bluefin Tuna Fishery	100	100	100	1	1	3	2,514	4,154
	Western Skipjack Fishery	100	100	100	1	1	3	2,514	4,154
	Western Tuna and Billfish Fishery	100	100	100	1	1	3	2,514	4,154
Other Submerged Reefs, Banks and Shoals	Barracouta Shoals §	<2	<2	<2	NC	NC	NC	NC	NC
	Barton Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Bassett-Smith Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Big Bank Shoals	<2	<2	<2	NC	NC	NC	NC	NC
	Dillon Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Echo Shoals §	<2	<2	<2	NC	NC	NC	NC	NC
	Echuca Shoal §	<2	<2	<2	NC	NC	NC	<1	NC
	Eugene McDermott Shoal §	<2	<2	<2	NC	NC	NC	NC	NC
	Fantome Shoal §	<2	<2	<2	NC	NC	NC	NC	NC
	Goeree Shoal §	<2	<2	<2	NC	NC	NC	NC	NC
	Heywood Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Hibernia Reef	<2	<2	<2	NC	NC	NC	<1	<1
	Jabiru Shoals	<2	<2	<2	NC	NC	NC	NC	NC
	Johnson Bank	<2	<2	<2	NC	NC	NC	<1	<1
	Karmt Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Mangola Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Pee Shoal	<2	<2	<2	NC	NC	NC	NC	NC
	Rankin Bank §	72	<2	<2	137	183	NC	172	51
	Sahul Bank §	<2	<2	<2	NC	NC	NC	<1	<1
	Scott Reef North	<2	<2	<2	NC	NC	NC	<1	4

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
Scott Reef South	<2	<2	<2	NC	NC	NC	<1	5
Seringapatam Reef	<2	<2	<2	NC	NC	NC	<1	3
Vee Shoal	<2	<2	<2	NC	NC	NC	<1	<1
Vulcan Shoal §	<2	<2	<2	NC	NC	NC	NC	NC
Woodbine Bank	<2	<2	<2	NC	NC	NC	<1	<1

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

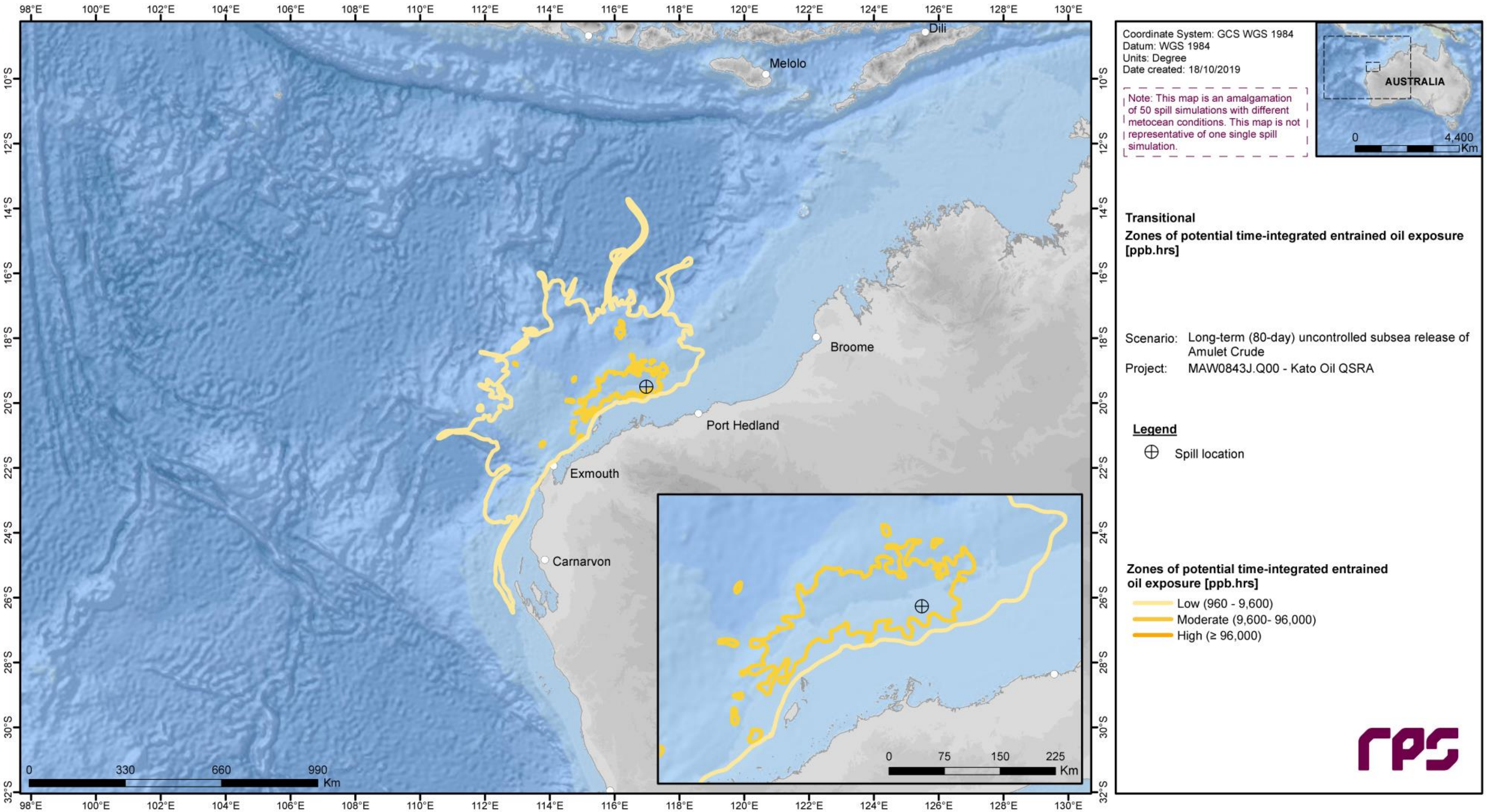

Figure 3.34 Predicted zones of potential entrained oil exposure for a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in transitional months.

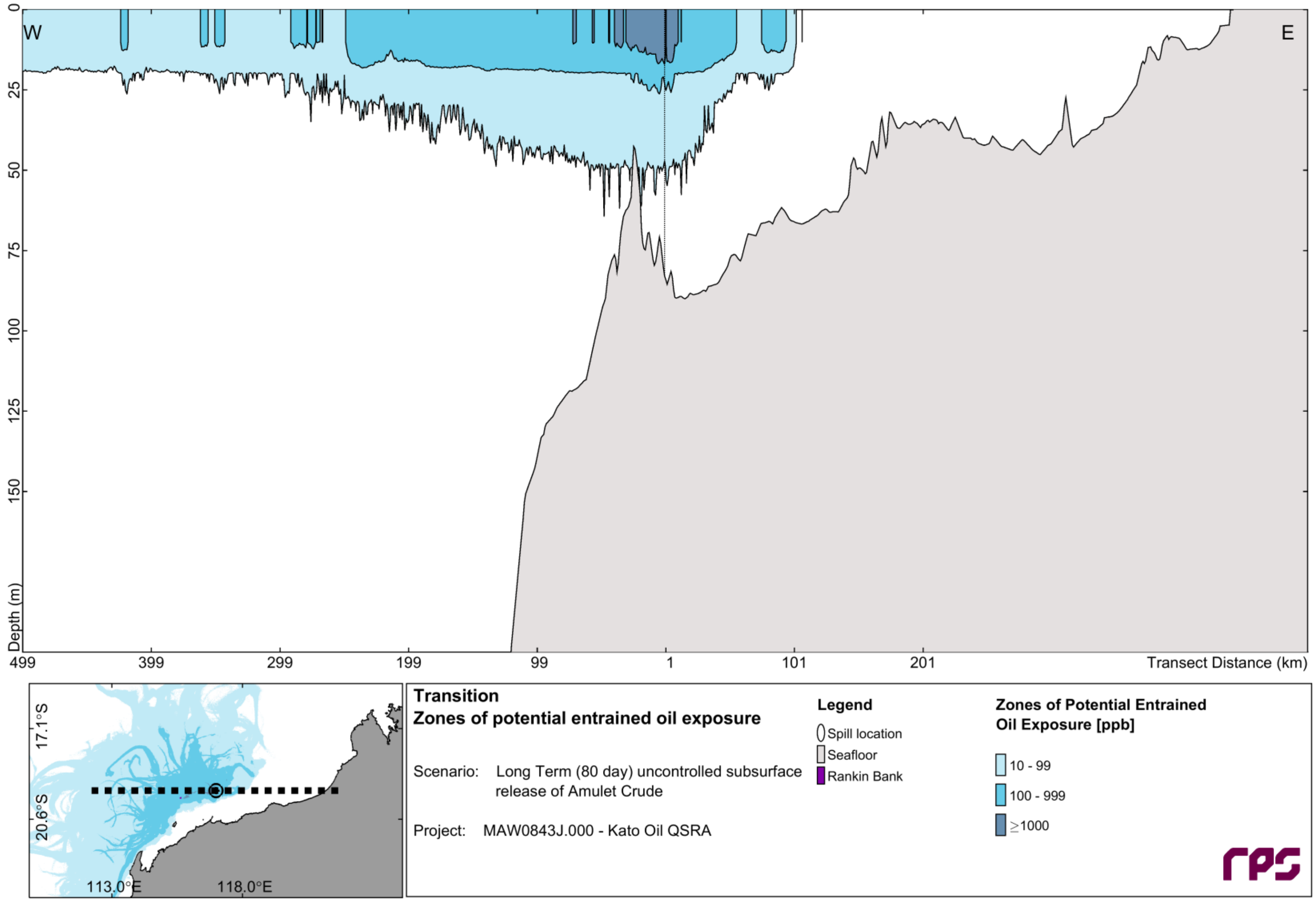

Figure 3.35 East-West cross-section transect of predicted maximum entrained oil concentration from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the transitional period. The results were calculated from 50 spill trajectories.

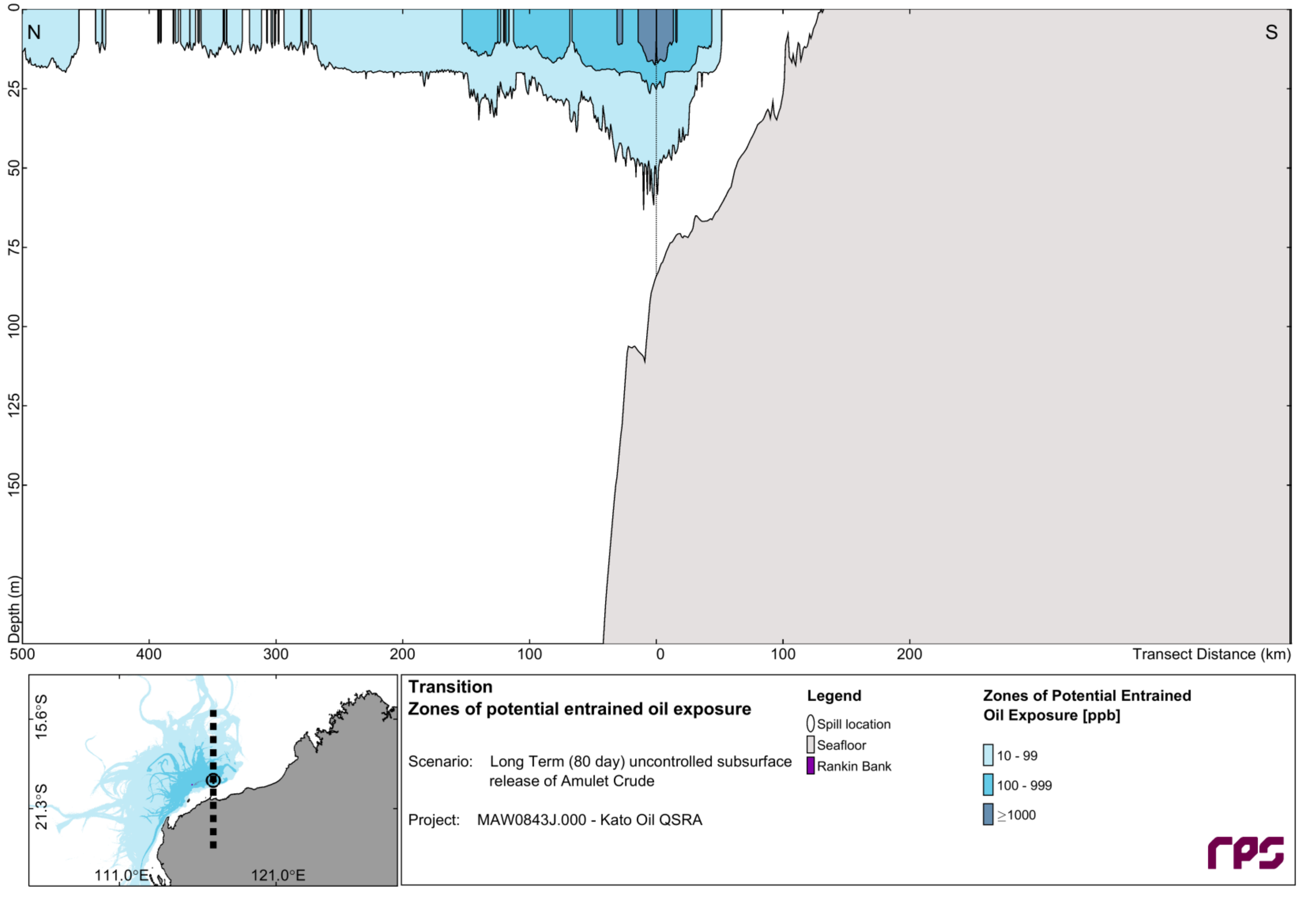

Figure 3.36 North-South cross-section transect of predicted maximum entrained oil concentration from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the transitional period. The results were calculated from 50 spill trajectories.

3.2.3.4.3 Entrained Oil - Exposure

Table 3.17 Expected entrained oil exposure outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in transitional months

Receptor		Threshold (ppb.hr)	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 (%) >9,600	NC	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	146	23	8	5	1	BS
	Barrow Island	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	662	64	30	9	BS	BS
	Browse Island	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
	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	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	56	4	1	BS	BS	BS
	Montebello Islands	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	441	40	12	1	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	57	7	4	1	NC	NC
	Southern Pilbara - Islands	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	277	55	30	BS	BS	BS
	Buccaneer Archipelago	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
	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

Receptor	Threshold (ppb.hr)	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 (%) >9,600	NC	BS	BS	BS	BS	BS
	Probability (%) >96,000	NC	BS	BS	BS	BS	BS
	Maximum Integrated Exposure	1	BS	BS	BS	BS	BS
Exmouth Gulf West	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	290	17	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	31	4	2	NC	BS	BS
Jurien Bay - Yanchep	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	56	7	3	NC	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	3	1	NC	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	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	1	NC	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	NC	NC	BS	BS	BS	BS
Perth Northern Coast	Probability (%) >960	NC	NC	NC	NC	BS	BS
	Probability (%) >9,600	NC	NC	NC	NC	BS	BS

Receptor		Threshold (ppb.hr)	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	176	22	6	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	NC	NC	BS	BS	BS	BS
	Southern Pilbara - Shoreline	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	18	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	1	NC	NC	NC	NC	BS
State National and Marine Parks	Barrow Island MMA	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	662	66	30	11	BS	BS
	Barrow Islands 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	477	59	27	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	22	2	NC	NC	NC	NC
	Eighty Mile Beach - Broome	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
	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	152	5	2	1	NC	NC
	Lalang-garram / Camden Sound MP	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
	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	24	4	1	BS	BS	BS
		Probability (%) >960	6	NC	NC	NC	BS	BS

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Montebello Islands MP	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	2,983	181	25	5	BS	BS
	Muiron Islands MMA	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	1,017	121	37	20	3	BS
	Ningaloo Coast WH	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	4,841	399	113	42	9	1
	Ningaloo MP (State)	Probability (%) >960	12	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	4,328	382	113	42	9	1
	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	6	3	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	34	11	9	7	1	BS
Australian Marine Parks	Abrolhos 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	622	60	15	5	2	NC
	Argo-Rowley Terrace MP	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	6,575	489	92	43	7	3
	Ashmore 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	NC	NC	NC	NC	NC	NC
	Carnarvon Canyon 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	600	64	23	10	1	NC
	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

Receptor		Threshold (ppb.hr)	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	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	34	NC	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	15,092	664	112	37	10	3
	Jurien Bay 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	56	7	3	1	BS	BS
	Jurien 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	39	7	6	3	NC	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
		Maximum Integrated Exposure	17	3	3	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	14	3	1	NC	NC	NC
	Montebello MP	Probability (%) >960	60	NC	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	15,686	768	288	117	23	NC
	Ningaloo MP	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	4,841	399	107	31	8	1
	Oceanic 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	NC	NC	NC	NC	NC	NC
	Perth Canyon 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

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Maximum Integrated Exposure	932	77	19	5	1	NC
	Roebuck MP	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
	Shark Bay MP	Probability (%) >960	12	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	2,100	168	50	20	5	1
	Two Rocks MP	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	20	4	3	1	NC	BS
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	100	40	NC	NC	NC	NC
		Probability (%) >9,600	88	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	57,238	3,856	892	246	38	12
	Ancient Coastline at 90-120m Depth Contour 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	108	21	7	3	1	NC
	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	117	13	5	2	NC	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	34	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	6,189	427	116	55	13	3
	Carbonate Bank and Terrace System of the Sahul Shelf 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
	Commonwealth Marine Environment surrounding the Houtman Abrolhos Islands 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	145	29	9	4	2	NC
		Probability (%) >960	88	10	NC	NC	NC	NC
		Probability (%) >9,600	22	NC	NC	NC	NC	NC

	Receptor	Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Continental Slope Demersal Fish Communities KEF	Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	18,016	1,430	353	106	17	6
	Exmouth Plateau KEF	Probability (%) >960	36	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	8,073	568	113	36	10	2
	Glomar Shoals KEF	Probability (%) >960	100	34	NC	NC	NC	BS
		Probability (%) >9,600	82	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	27,962	2,088	491	192	34	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	447	20	3	1	NC	NC
	Perth Canyon and adjacent Shelf Break, and other West Coast Canyons 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	775	65	17	5	1	NC
	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	57	13	5	1	NC	NC
	Wallaby Saddle 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	279	26	7	2	NC	NC
	Western Demersal Slope and associated Fish Communities 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	1,011	82	21	10	3	1
	Western Rock Lobster 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	108	28	9	4	2	NC
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	22	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	4,755	386	113	42	9	1
	Marine Turtle BIA	Probability (%) >960	96	10	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >9,600	24	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	43,044	2,236	451	180	40	12
	River Sharks BIA	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
	Seabirds BIA	Probability (%) >960	100	54	NC	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	86,682	4,201	795	242	55	12
	Seals 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	176	27	9	7	2	NC
	Sharks BIA	Probability (%) >960	100	54	NC	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	86,682	4,201	892	246	55	12
	Whales BIA	Probability (%) >960	100	54	NC	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	86,682	4,201	892	246	55	12
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	100	10	NC	NC	NC	NC
		Probability (%) >9,600	24	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	29,936	2,922	767	140	25	6
	Southern Bluefin Tuna Fishery	Probability (%) >960	100	54	NC	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	86,682	4,201	892	246	55	12
	Western Skipjack Fishery	Probability (%) >960	100	54	NC	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	86,682	4,201	892	246	55	12
	Western Tuna and Billfish Fishery	Probability (%) >960	100	54	NC	NC	NC	NC
		Probability (%) >9,600	100	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	86,682	4,201	892	246	55	12
Other Submerged Reefs, Shoals	Barracouta Shoals	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

Receptor		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Barton Shoal	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
	Bassett-Smith 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
	Big Bank Shoals	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
	Dillon Shoal	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
	Echo Shoals	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
	Echuca Shoal	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
	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
	Fantome 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
	Goeree 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
	Heywood Shoal	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
	Hibernia 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

Receptor		Threshold (ppb.hr)	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
	Jabiru Shoals	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
	Johnson 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
	Karmt Shoal	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
	Mangola Shoal	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
	Pee 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	70	NC	NC	BS	BS	BS
		Probability (%) >9,600	2	NC	NC	BS	BS	BS
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	10,849	630	256	BS	BS	BS
	Sahul Bank	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
	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	46	13	2	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	57	8	5	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	40	4	1	NC	NC	NC
	Vee Shoal	Probability (%) >960	NC	NC	NC	NC	NC	BS
		Probability (%) >9,600	NC	NC	NC	NC	NC	BS

Receptor		Threshold (ppb.hr)	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	NC	NC	NC	NC	NC	BS
	Vulcan 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
	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.

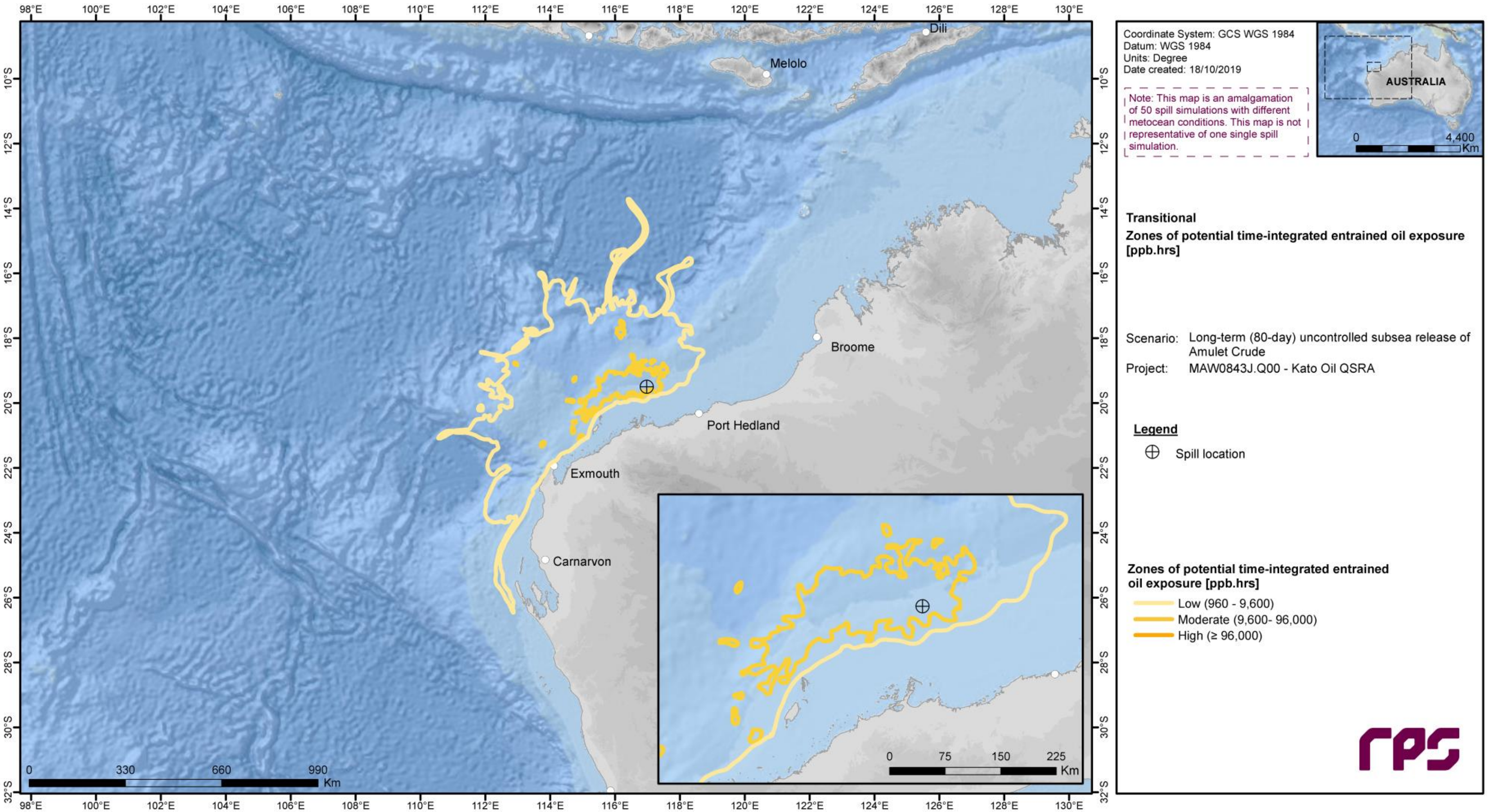

Figure 3.37 Predicted zones of potential time-integrated entrained oil exposure for a long-term (80-day) subsurface release of Amulet Crude within the Amulet Field, starting during transitional months.

3.2.3.4.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Table 3.18 Expected dissolved aromatic hydrocarbons outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet 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	Abrolhos Islands	<2	<2	<2	NC	NC
	Barrow Island	<2	<2	<2	<1	<1
	Browse Island	<2	<2	<2	NC	NC
	Lacepede Islands	<2	<2	<2	NC	NC
	Lowendal Islands	<2	<2	<2	NC	NC
	Montebello Islands	6	<2	<2	2	41
	Sandy Islet	<2	<2	<2	NC	NC
	Southern Pilbara - Islands	<2	<2	<2	<1	3
Coastlines	Buccaneer Archipelago	<2	<2	<2	NC	NC
	Dampier Archipelago	<2	<2	<2	NC	NC
	Exmouth Gulf South East	<2	<2	<2	NC	NC
	Exmouth Gulf West	<2	<2	<2	<1	<1
	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	NC	NC
	Zuytdorp Cliffs - Kalbarri	<2	<2	<2	NC	NC
State National and Marine Parks	Barrow Island MMA	2	<2	<2	<1	16
	Barrow Islands MP	<2	<2	<2	<1	3
	Clerke Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC
	Eighty Mile Beach - Broome	<2	<2	<2	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<2	<2	<2	NC	NC
	Lalang-garram / Camden Sound MP	<2	<2	<2	NC	NC

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
	Marmion MP	<2	<2	<2	NC	NC
	Montebello Islands MP	8	2	<2	3	90
	Muiron Islands MMA	<2	<2	<2	<1	9
	Ningaloo Coast WH	14	4	<2	4	94
	Ningaloo MP (State)	8	<2	<2	3	50
	Shark Bay MR	<2	<2	<2	NC	NC
	Shark Bay WH	<2	<2	<2	NC	NC
Australian Marine Parks	Abrolhos MP	<2	<2	<2	NC	NC
	Argo-Rowley Terrace MP	4	<2	<2	<1	20
	Ashmore Reef MP	<2	<2	<2	NC	NC
	Carnarvon Canyon MP	<2	<2	<2	NC	NC
	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	10	4	<2	4	75
	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	60	6	<2	13	165
	Ningaloo MP	14	4	<2	4	94
	Oceanic Shoals MP	<2	<2	<2	NC	NC
	Perth Canyon MP	<2	<2	<2	NC	NC
	Roebuck MP	<2	<2	<2	NC	NC
	Shark Bay MP	<2	<2	<2	<1	<1
	Two Rocks MP	<2	<2	<2	NC	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	100	98	2	110	467
	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	10	2	<2	4	71
	Carbonate Bank and Terrace System of the Sahul Shelf KEF	<2	<2	<2	NC	NC

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	<2	<2	<2	NC	NC
	Continental Slope Demersal Fish Communities KEF	88	10	<2	23	178
	Exmouth Plateau KEF	10	2	<2	3	67
	Glomar Shoals KEF §	100	26	<2	96	192
	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	NC	NC
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF	<2	<2	<2	NC	NC
	Wallaby Saddle KEF	<2	<2	<2	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	<2	<2	<2	<1	<1
	Western Rock Lobster KEF	<2	<2	<2	NC	NC
Biologically Important Areas	Dolphins BIA	<2	<2	<2	NC	NC
	Dugong BIA	10	4	<2	4	70
	Marine Turtle BIA	88	18	<2	29	239
	River Sharks BIA	<2	<2	<2	NC	NC
	Seabirds BIA	100	100	2	159	435
	Seals BIA	<2	<2	<2	NC	NC
	Sharks BIA	100	100	2	159	467
	Whales BIA	100	100	2	159	467
Fisheries	North-West Slope Trawl Fishery	90	16	<2	25	218
	Southern Bluefin Tuna Fishery	100	100	2	159	467
	Western Skipjack Fishery	100	100	2	159	467
	Western Tuna and Billfish Fishery	100	100	2	159	467
Other Submerged Reefs, Banks and Shoals	Barracouta Shoals §	<2	<2	<2	NC	NC
	Barton Shoal	<2	<2	<2	NC	NC
	Bassett-Smith Shoal	<2	<2	<2	NC	NC
	Big Bank Shoals	<2	<2	<2	NC	NC
	Dillon Shoal	<2	<2	<2	NC	NC
	Echo Shoals §	<2	<2	<2	NC	NC
	Echuca Shoal §	<2	<2	<2	NC	NC
	Eugene McDermott Shoal §	<2	<2	<2	NC	NC
	Fantome Shoal §	<2	<2	<2	NC	NC
	Goeree Shoal §	<2	<2	<2	NC	NC
	Heywood Shoal	<2	<2	<2	NC	NC

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
Hibernia Reef	<2	<2	<2	NC	NC
Jabiru Shoals	<2	<2	<2	NC	NC
Johnson Bank	<2	<2	<2	NC	NC
Karmt Shoal	<2	<2	<2	NC	NC
Mangola Shoal	<2	<2	<2	NC	NC
Pee Shoal	<2	<2	<2	NC	NC
Rankin Bank §	54	4	<2	22	154
Sahul Bank §	<2	<2	<2	NC	NC
Scott Reef North	<2	<2	<2	NC	NC
Scott Reef South	<2	<2	<2	NC	NC
Seringapatam Reef	<2	<2	<2	NC	NC
Vee Shoal	<2	<2	<2	NC	NC
Vulcan Shoal §	<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.

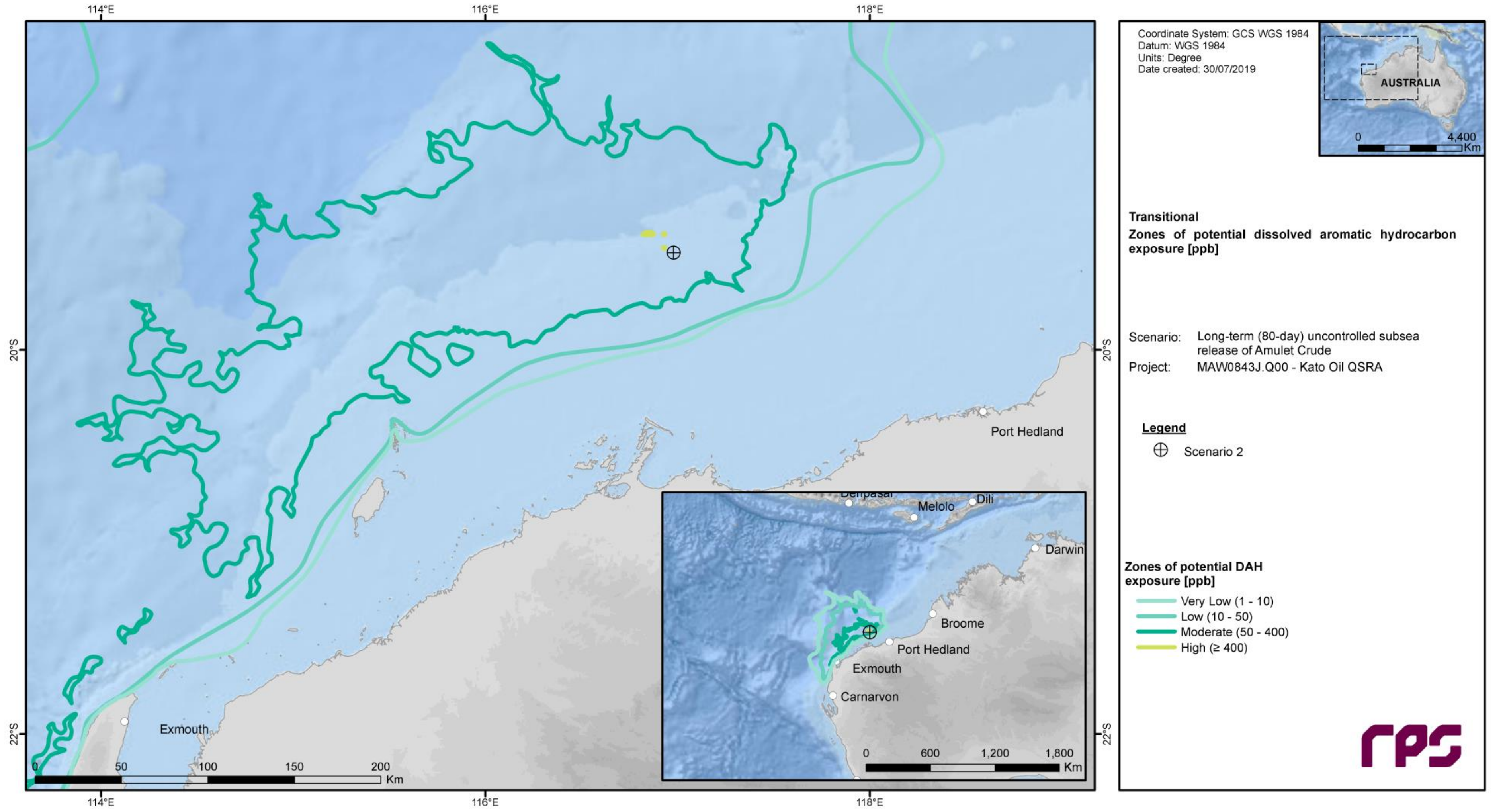

Figure 3.38 Predicted zones of potential dissolved aromatic hydrocarbon exposure for a long-term (80 day) subsea release of Amulet Crude within the Amulet Field, starting in transitional months.

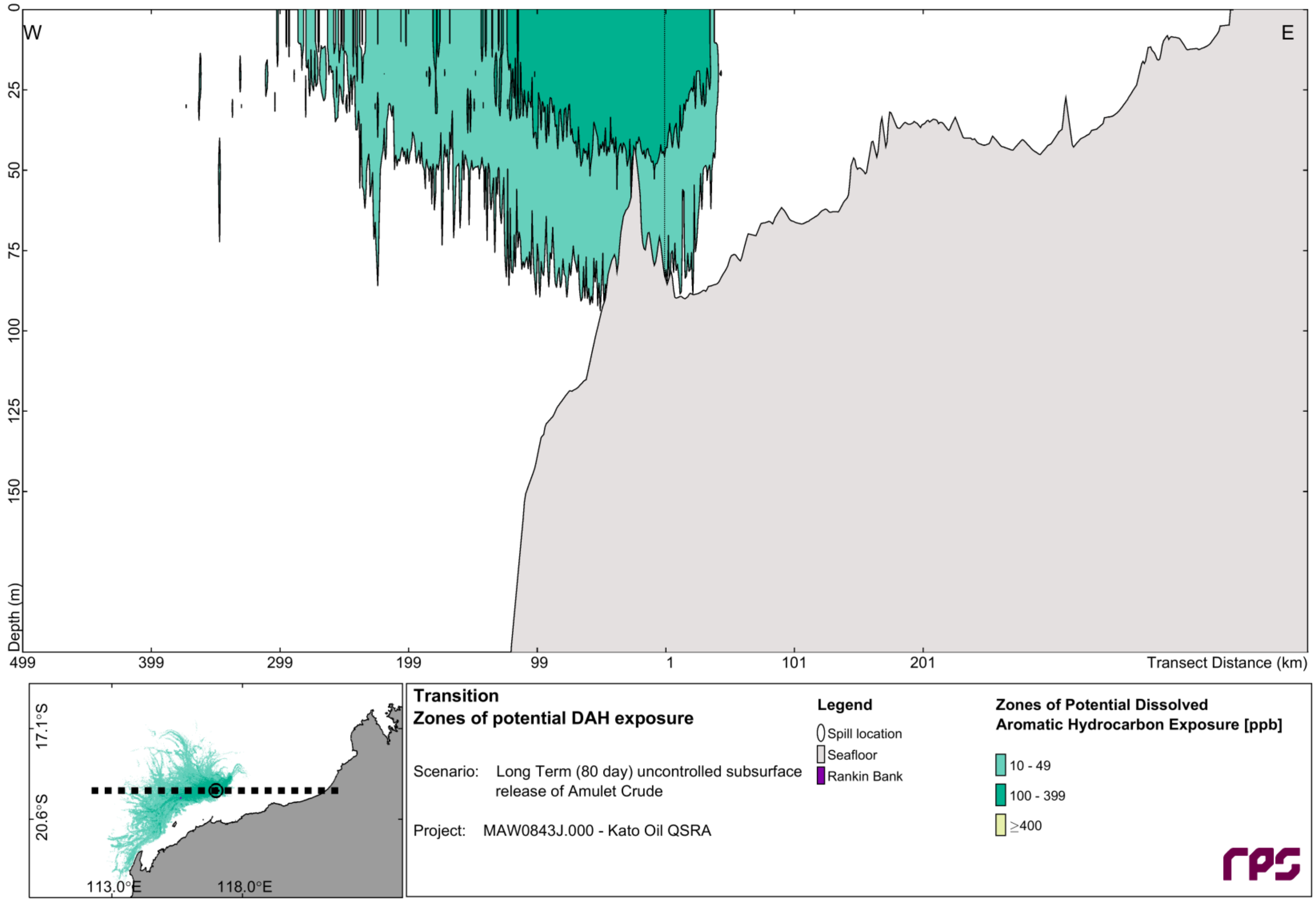

Figure 3.39 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the transitional period. The results were calculated from 50 spill trajectories.

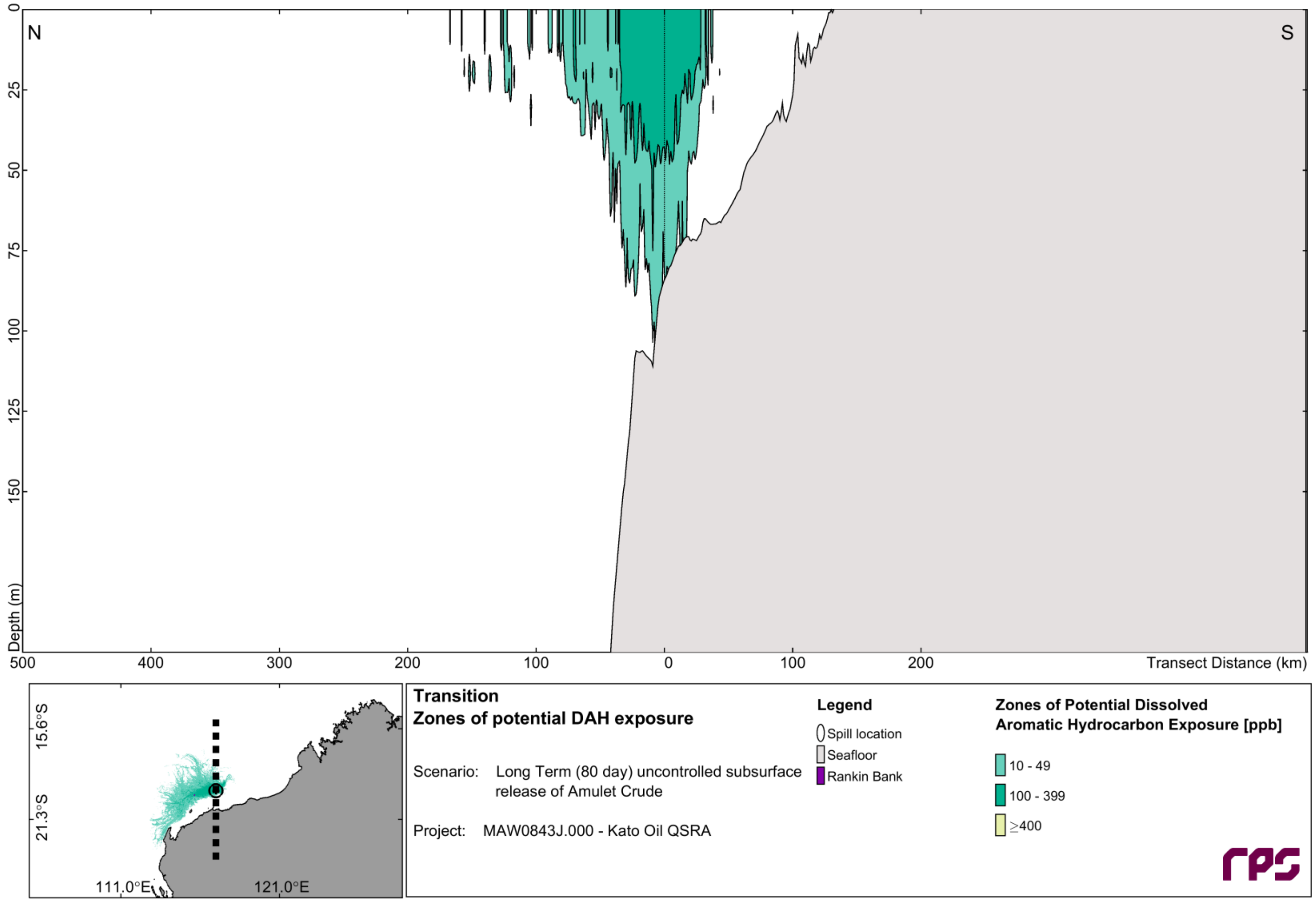

Figure 3.40 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a long-term (80-day) subsea release of Amulet Crude within the Amulet field, commencing in the transitional period. The results were calculated from 50 spill trajectories.

3.2.3.4.5 Dissolved Aromatic Hydrocarbon - Exposure

Table 3.19 Expected dissolved aromatic hydrocarbons exposure outcomes at sensitive receptors resulting from a long-term (80 day) subsea release of Amulet Crude within the Amulet field, starting in winter months.

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m 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
	Browse Island	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
	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	161	43	200	24	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	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	3	BS	BS	BS
	Buccaneer Archipelago	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
	Dampier Archipelago	Probability (%) >960	NC	NC	NC	NC	BS	BS
		Probability (%) >4,800	NC	NC	NC	NC	BS	BS

Receptor	Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	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
	Probability (%) >38,400	NC	BS	BS	BS	BS	BS
	Maximum Integrated Exposure	NC	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	NC	NC	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
	Probability (%) >960	NC	NC	NC	NC	BS	BS

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	Perth Northern Coast	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	NC	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 National and Marine 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	35	4	30	2	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	5	1	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
	Eighty Mile Beach - Broome	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
	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
	Lalang-garram / Camden Sound 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
	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

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m 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	161	81	401	69	BS	BS
	Muiron Islands MMA	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	20	23	7	2	NC	BS
	Ningaloo Coast WH	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	119	252	201	39	7	NC
	Ningaloo MP (State)	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	107	196	119	24	2	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	NC	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	NC	NC	NC	NC	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	112	58	63	12	2	NC
	Ashmore 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
	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	NC	NC	NC	NC	NC	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

Receptor	Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	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	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	149	216	391	170	24	NC
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	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	237	540	1,012	552	90	NC
Ningaloo 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	119	252	201	39	7	NC
Oceanic 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
Perth Canyon MP	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
	Roebuck MP	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 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
	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	54	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	3,263	1,704	1,320	528	147	10
	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
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula 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	141	148	193	105	15	3
	Carbonate Bank and Terrace System of the Sahul Shelf 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
	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
		Probability (%) >960	NC	NC	NC	NC	NC	NC

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	Continental Slope Demersal Fish Communities KEF	Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	568	533	724	410	93	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	167	194	146	118	21	3
	Glomar Shoals KEF	Probability (%) >960	30	4	2	NC	NC	BS
		Probability (%) >4,800	NC	NC	NC	NC	NC	BS
		Probability (%) >38,400	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	2,136	1,736	1,048	679	47	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	NC	NC	NC	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	NC	NC	NC	NC	NC	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	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	107	196	165	29	6	NC

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	Marine Turtle BIA	Probability (%) >960	2	2	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	1,047	1,014	1,285	594	106	14
	River Sharks BIA	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
	Seabirds BIA	Probability (%) >960	100	12	4	NC	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	6,293	2,875	2,246	679	288	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	14	4	NC	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	6,293	2,875	2,246	679	288	14
	Whales BIA	Probability (%) >960	100	14	4	NC	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	6,293	2,875	2,246	679	288	14
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	2	NC	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	1,038	676	1,006	410	93	3
	Southern Bluefin Tuna Fishery	Probability (%) >960	100	14	4	NC	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	6,293	2,875	2,246	679	288	14
	Western Skipjack Fishery	Probability (%) >960	100	14	4	NC	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	6,293	2,875	2,246	679	288	14
	Western Tuna and Billfish Fishery	Probability (%) >960	100	14	4	NC	NC	NC
		Probability (%) >4,800	6	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	6,293	2,875	2,246	679	288	14
Other Submerged Reefs	Barracouta Shoals	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

Receptor	Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Barton Shoal	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
Bassett-Smith 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
Big Bank Shoals	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
Dillon Shoal	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
Echo Shoals	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
Echuca Shoal	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
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
Fantome 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
Goeree 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
Heywood Shoal	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
Hibernia Reef	Probability (%) >960	NC	NC	NC	NC	NC	NC
	Probability (%) >4,800	NC	NC	NC	NC	NC	NC

Receptor	Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Jabiru Shoals	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
Johnson 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
Karmt Shoal	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
Mangola Shoal	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
Pee 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	160	235	336	BS	BS	BS
Sahul Bank	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 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
	Probability (%) >38,400	NC	NC	NC	NC	NC	NC
	Maximum Integrated Exposure	NC	NC	NC	NC	NC	NC
Vee Shoal	Probability (%) >960	NC	NC	NC	NC	NC	BS

Receptor		Threshold (ppb.hr)	0-10 m BMSL	10-20 m BMSL	20-30 m BMSL	30-50 m BMSL	50-100 m BMSL	100-150m BMSL
		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
	Vulcan 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
	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.

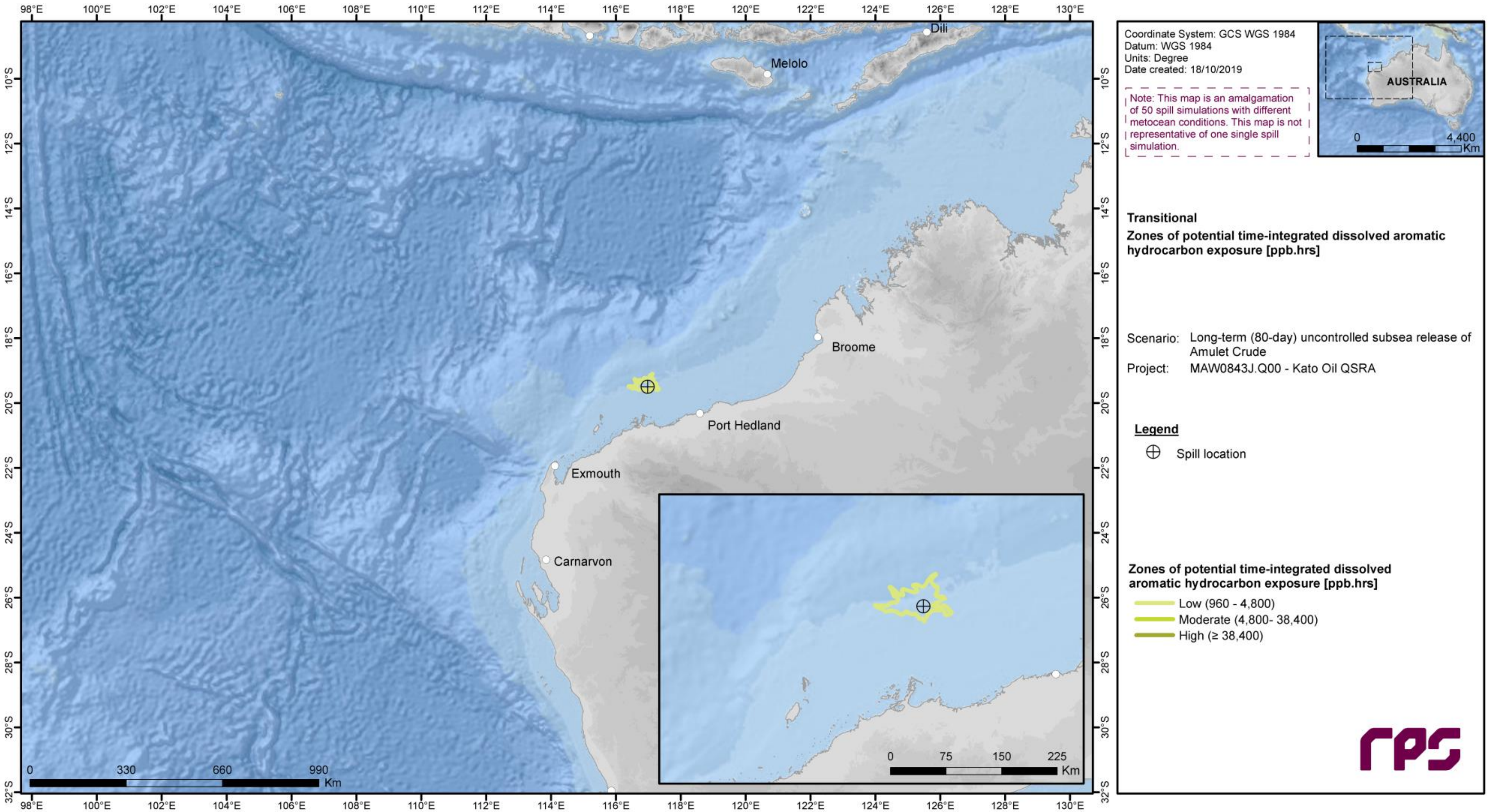

Figure 3.41 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure for a long-term (80-day) subsurface release of Amulet Crude within the Amulet Field, starting during transitional months.

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 oil for surrounding regions is there was a short term (6-hour) surface release of 500 m^3 of marine gas oil after a rupture of a support vessel tank at a location (116° 58' 52.64" E, 19° 58' 52.61" S) within the Amulet 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 shorelines during the worst-case spill simulation was calculated as 1.5 m^3, for a spill commencing in summer (replicate 32; Table 3.20). During this deterministic case, the highest accumulation was predicted for Lowendal Islands 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	32	1.5 m^3	Lowendal Islands

* Volume results refer to model predictions for all shorelines in the region, not for any specific receptor.

The maximum extent of hydrocarbon exposure in this deterministic case is predicted as 70 km for entrained oil at or above the moderate threshold (100 ppb).Figure 3.41 to Figure 3.46 to 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.

Calculations for the horizontal and vertical distribution of entrained oil and dissolved aromatic hydrocarbon concentrations during this case have been illustrated as cross-section plots in Figure 3.47 to Figure 3.50.

Figure 3.51 shows a time-series of the predicted concentrations of surface, in-water (entrained and dissolved) and shoreline oil during this deterministic case at intervals of 1 day, 3 days, 1 week and 2 weeks following the commencement of the spill.

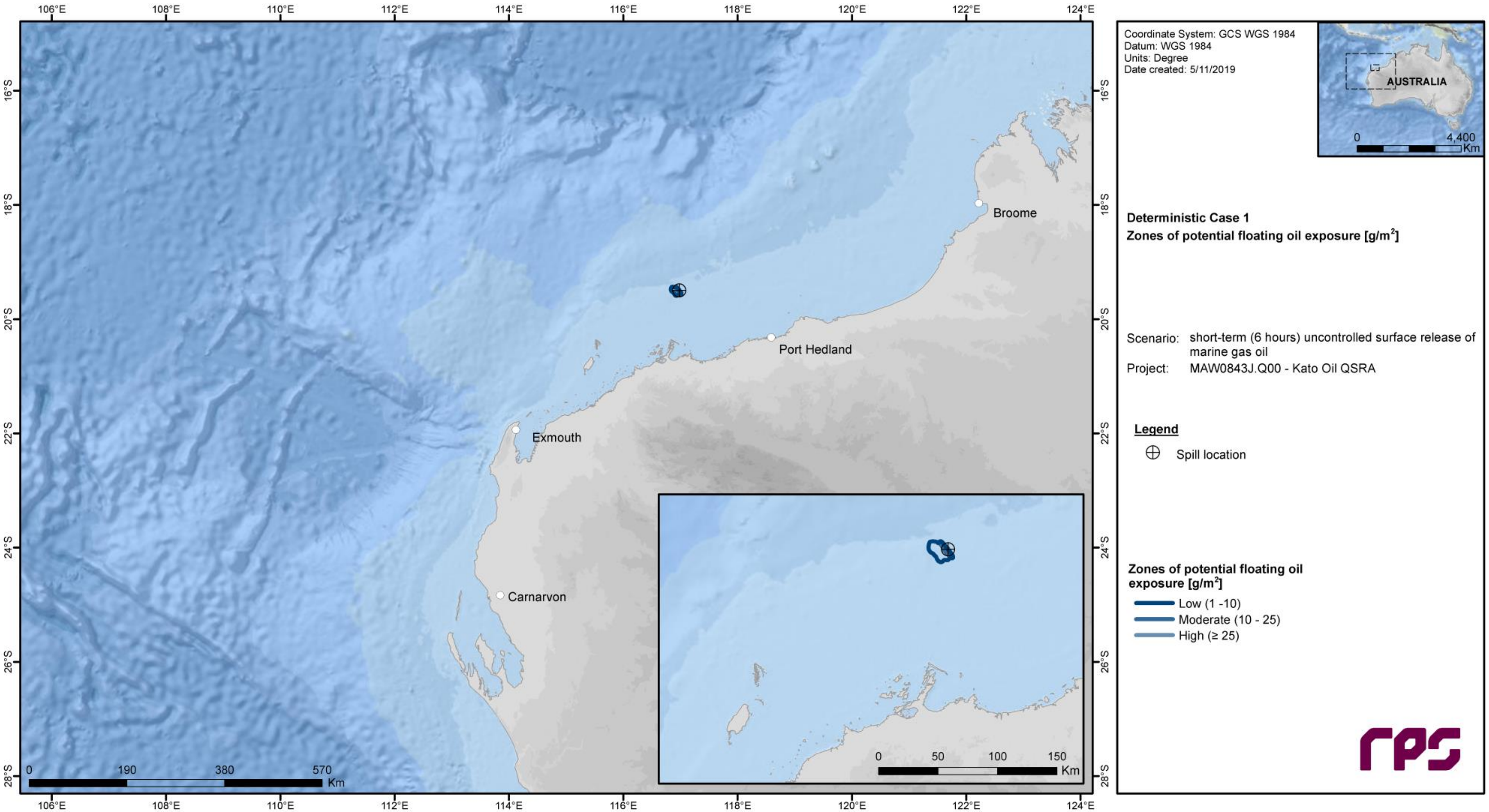

Figure 3.42 Predicted zones of potential floating oil exposure resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, for the deterministic case with the <u>largest oil volume loading on shorelines</u> (summer, run 32).

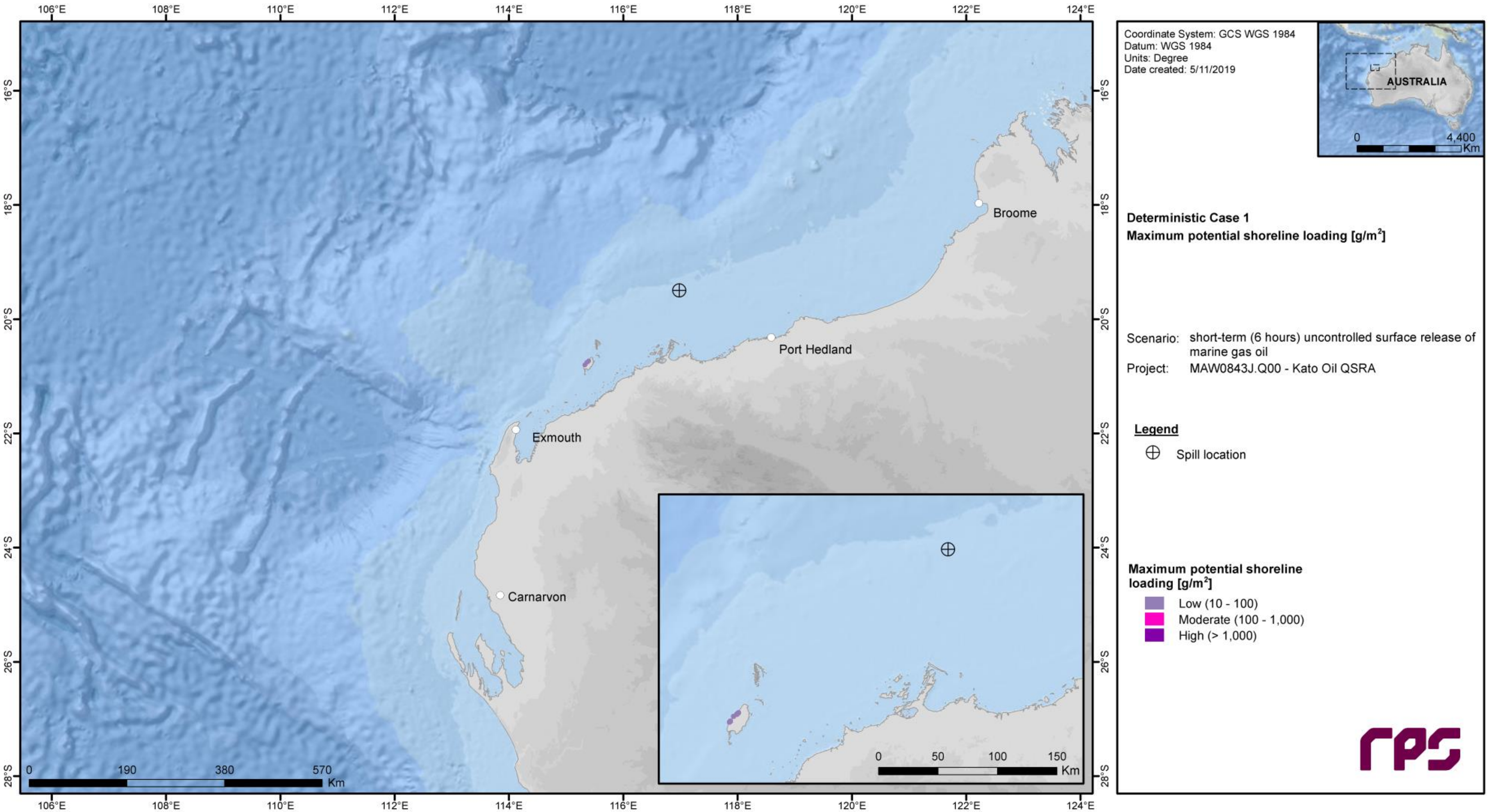

Figure 3.43 Predicted maximum potential shoreline loading resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 32).

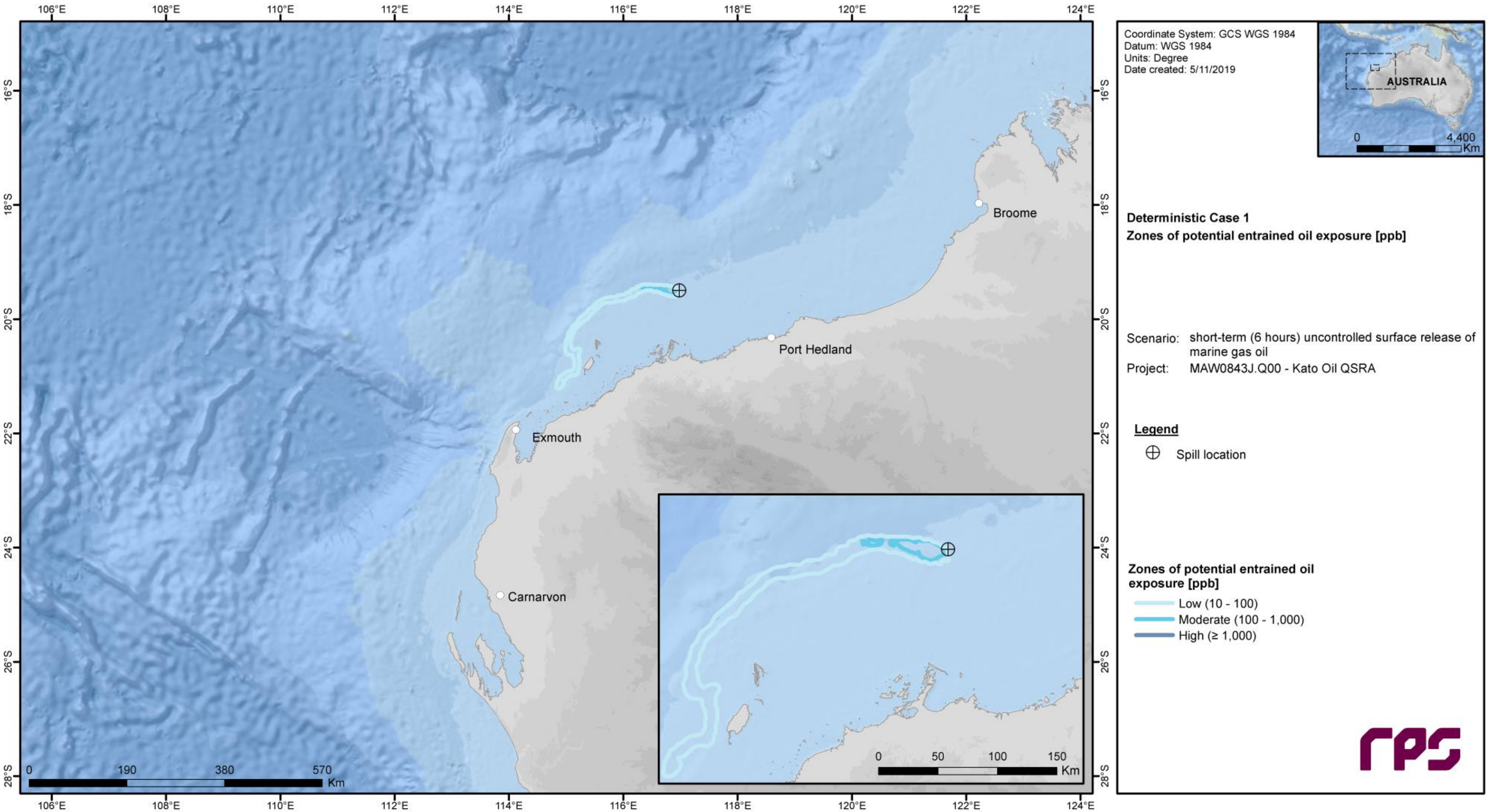

Figure 3.44 Predicted zones of potential instantaneous entrained oil exposure resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 32).

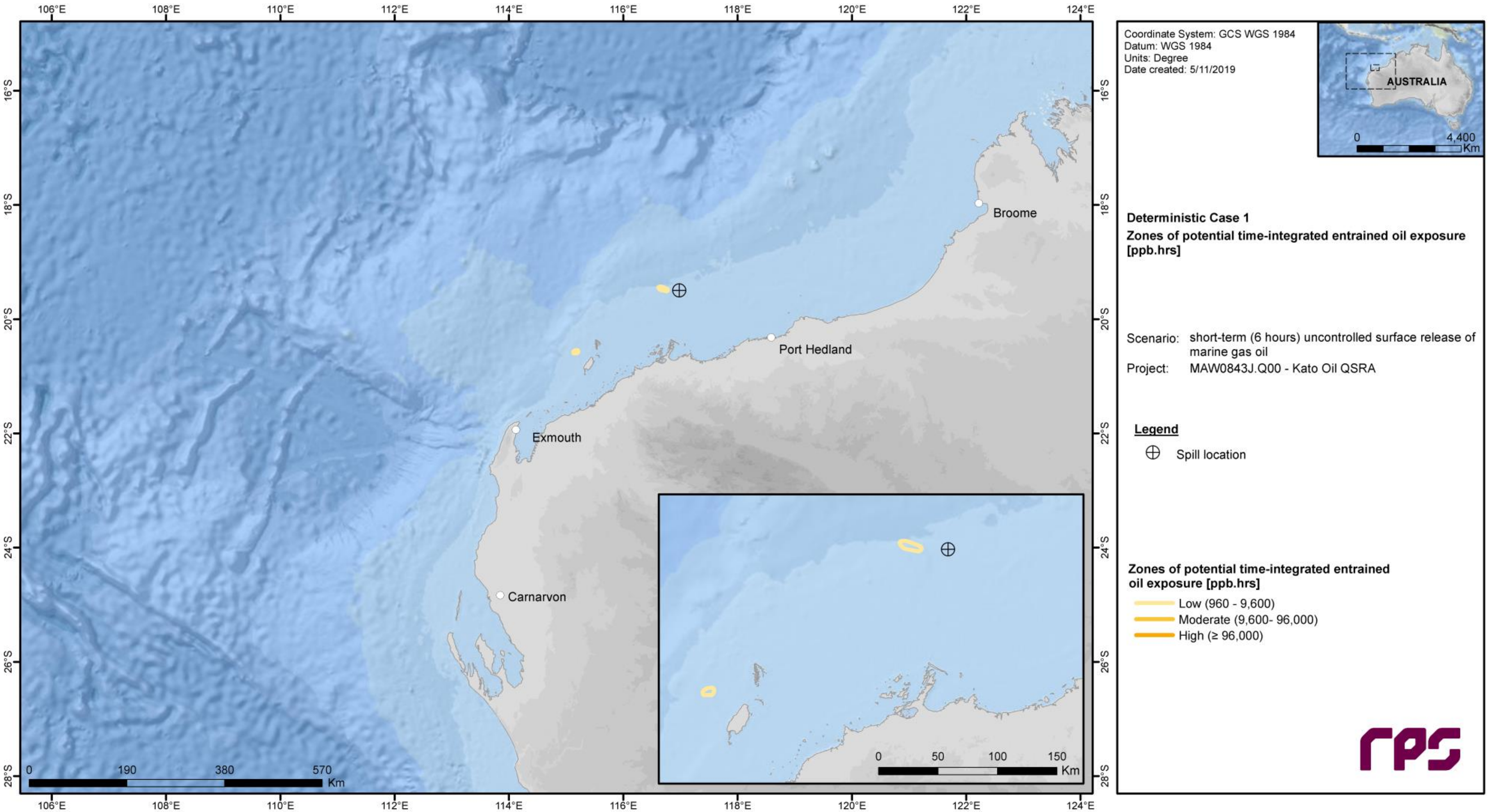

Figure 3.45 Predicted zones of potential instantaneous entrained oil exposure resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 32).

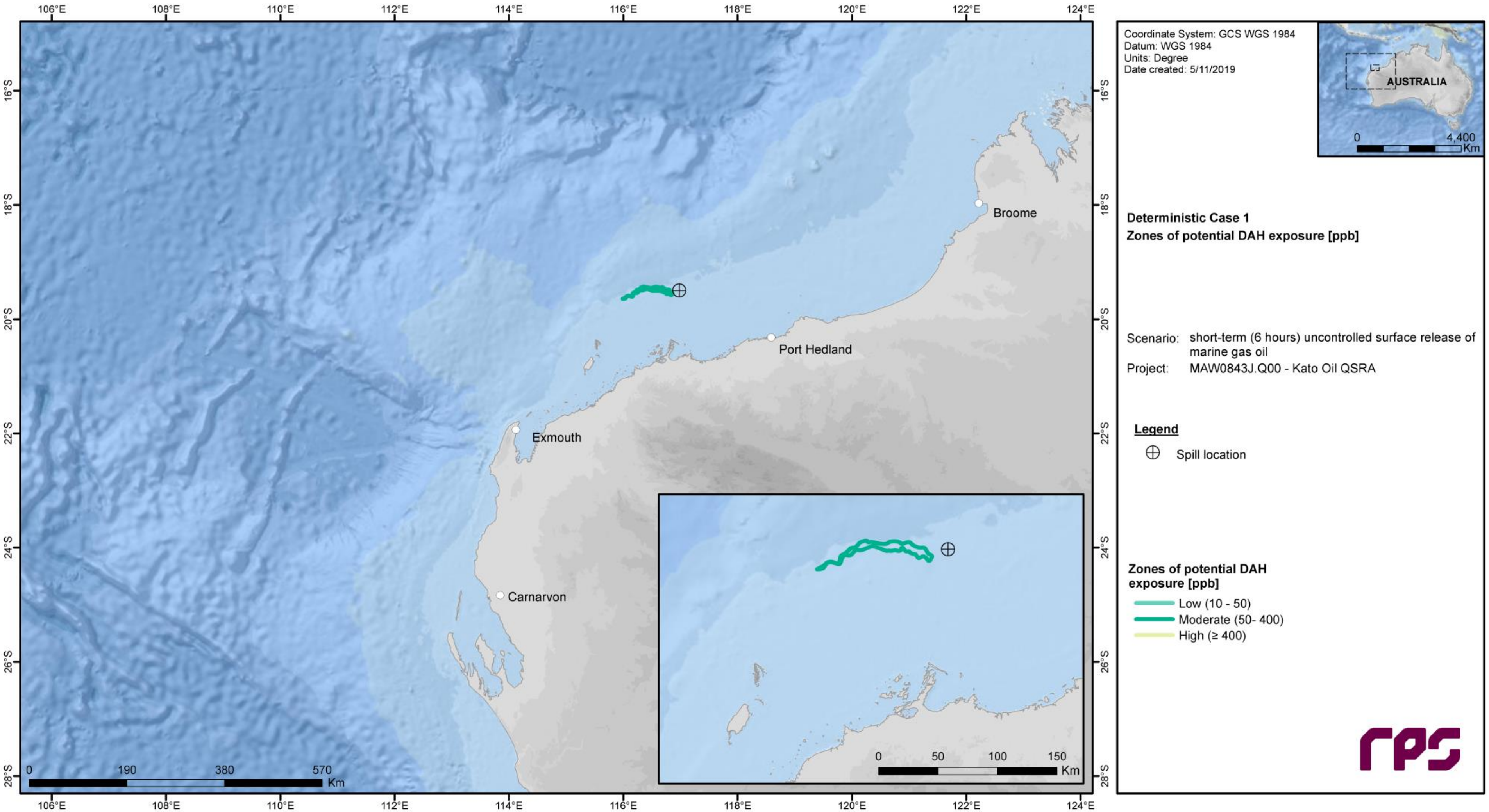

Figure 3.46 Predicted zones of potential instantaneous dissolved aromatic hydrocarbon exposure resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, for the deterministic case with the <u>largest oil volume loading on shorelines </u>(summer, run 32).

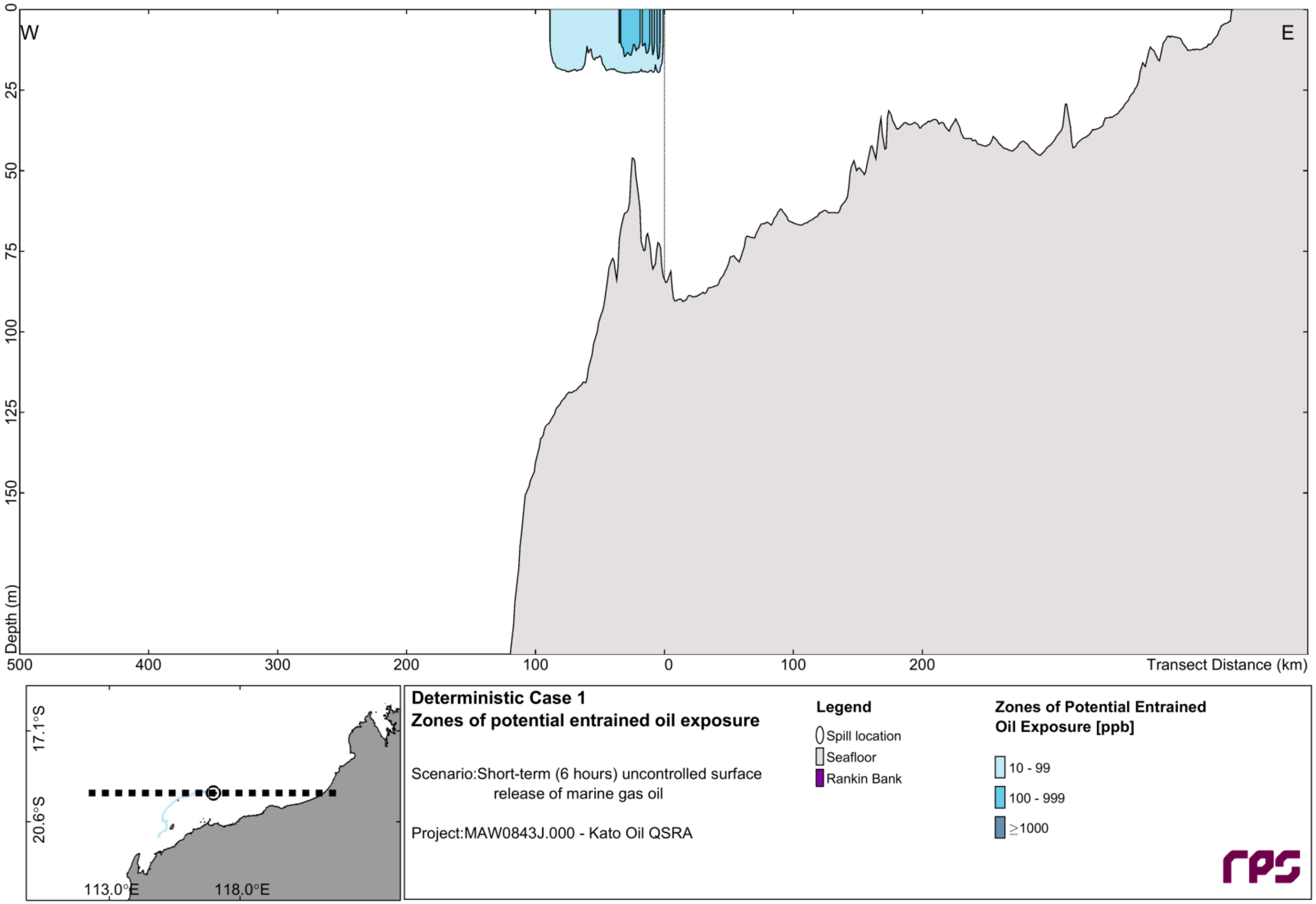

Figure 3.47 East-West cross-section transect of predicted maximum entrained oil concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 32). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

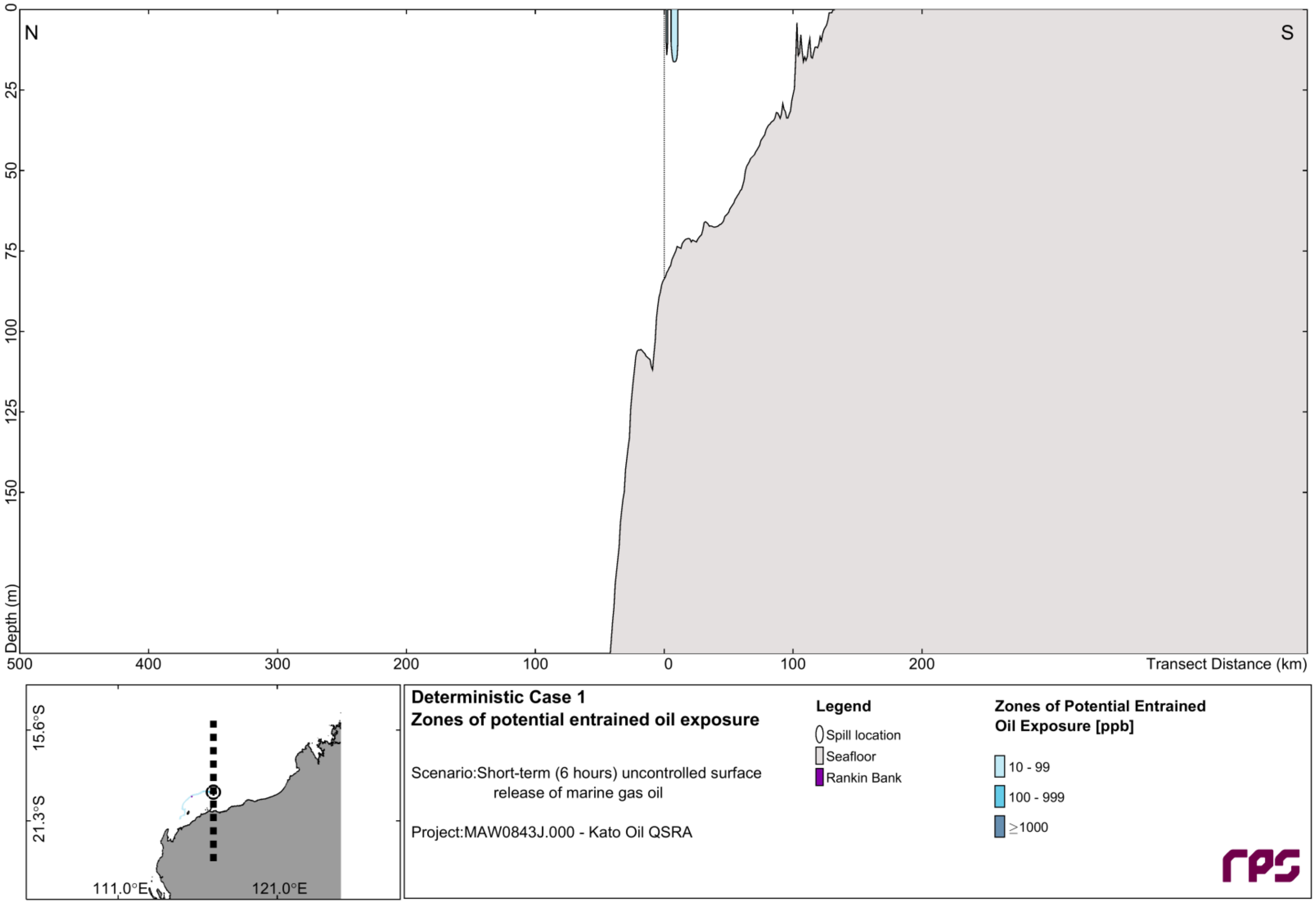

Figure 3.48 North-South cross-section transect of predicted maximum entrained oil concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 32). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

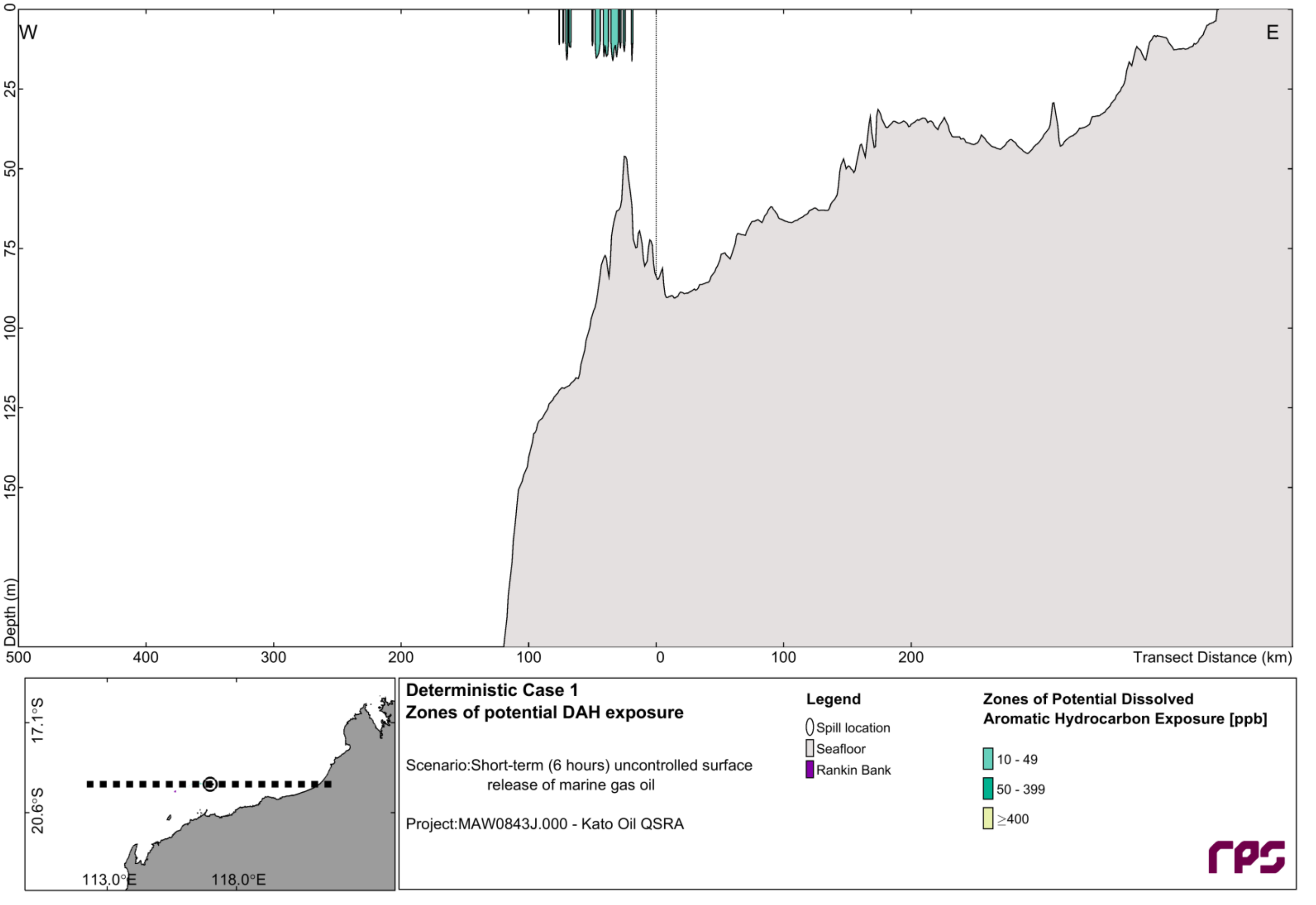

Figure 3.49 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 32). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

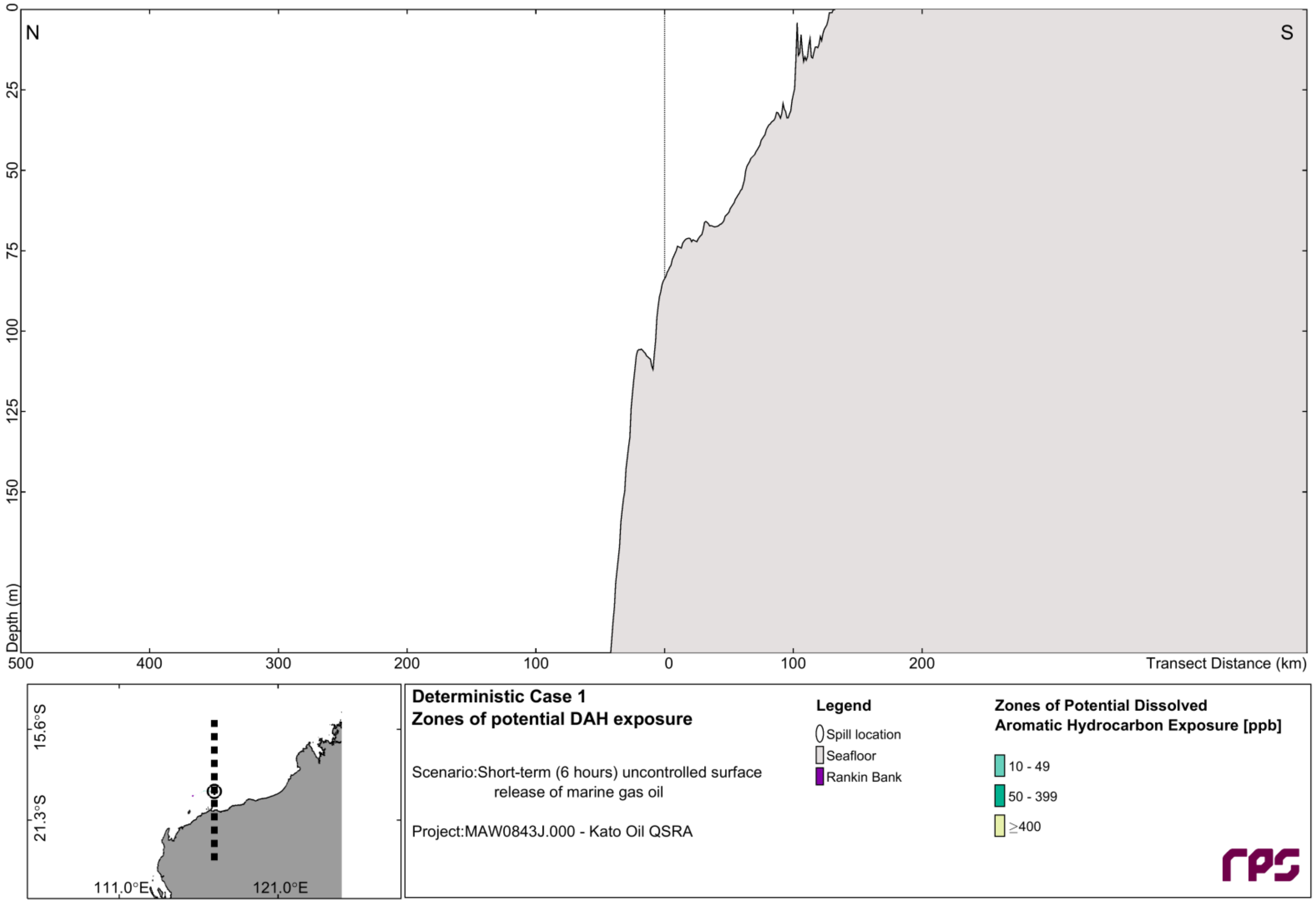

Figure 3.50 North-South cross-section transect of predicted dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 32). The figure shows the maximum concentration calculated for each location over the duration of the simulation.

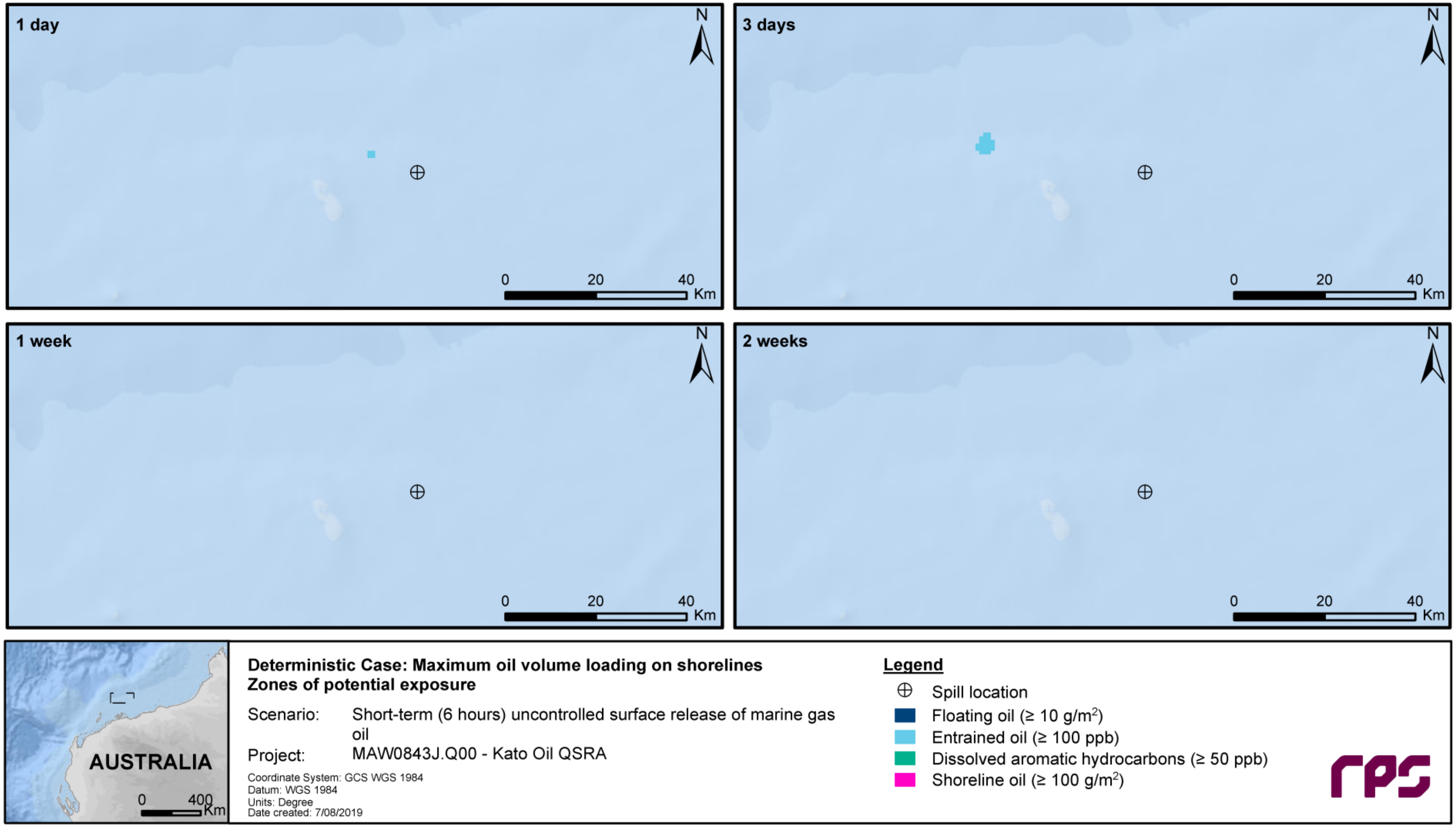

Figure 3.51 Time varying areal extent of predicted Zones of Potential Exposure for floating oil (≥ 1 g/m^2) entrained oil (≥ 100 ppb), dissolved aromatic hydrocarbons (≥ 100 ppb) and shoreline oil (≥ 100 g/m^2) resulting from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, for the deterministic case with the largest oil volume loading on shorelines (summer, run 32).

3.3.3 Stochastic Assessment Results

3.3.3.1 Discussion of Results

3.3.3.1.1 Floating and Shoreline Oil

Floating concentrations at the low threshold (1 g/m^2) could travel up to 217 km from the release, with the distance reducing at the moderate (10 g/m^2; 17 km) and high (25 g/m^2; 14 km) thresholds (Table 3.21).

The seasonal zones of potential exposure at the assessed contact thresholds are depicted in Figure 3.52 (summer), Figure 3.62 (winter) and Figure 3.72 (transitional) for floating oil and Figure 3.53 (summer), Figure 3.63 (winter) and Figure 3.73 (transitional) for shoreline oil.

Table 3.21 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	217	17	14

Floating oil contact at the low threshold (1 g/m^2) is not predicted to occur at any of the assessed shoreline receptors, in any season (Table 3.24, Table 3.29, Table 3.34).

Floating oil concentrations at the high threshold (25 g/m^2) might pass over several submerged receptors (Table 3.24, Table 3.29, Table 3.34). The highest probabilities were forecast for the Seabirds, Sharks and Whales BIAs and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries at 85-96% across all seasons.

The worst-case oil accumulation on a shoreline is predicted for the Southern Pilbara - Islands receptor in summer, with an accumulated concentration and volume of 42 g/m^2 and less than 1 m^3, respectively (Table 3.24, Table 3.29, Table 3.34).

The worst-case maximum length of shoreline with concentrations exceeding the low threshold (10 g/m^2) was calculated as 2 km at the Southern Pilbara – Islands receptor in summer (Table 3.24).

3.3.3.1.2 Entrained Oil - Instantaneous

Entrained oil concentrations at the low threshold (10 ppb) could travel up to 725 km from the release location, with the distance reducing at the moderate (100 ppb; 376 km) and high (1,000 ppb; 76 km) thresholds (Table 3.22).

Table 3.22 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	725	376	76

The seasonal zones of potential entrained oil exposure at the assessed contact thresholds are depicted in Figure 3.54 (summer), Figure 3.64 (winter) and Figure 3.74 (transitional months).

The probability of contact by entrained oil concentrations at the moderate threshold (100 ppb) is predicted to be greatest at the Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery at 34-63% across all seasons (Table 3.25, Table 3.30, Table 3.35). Entrained oil at the moderate threshold is predicted to arrive at these receptors within 1 hour after the release commences across all seasons.

The worst-case instantaneous entrained oil concentration at any receptor is predicted at the Seabirds, Sharks and Whales BIAs and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 2,112 ppb (winter; Table 3.30).

The cross-sectional transects (summer; Figure 3.55/Figure 3.56, winter; Figure 3.65/Figure 3.66 and transitional months; Figure 3.75/Figure 3.76) of maximum entrained oil concentrations in the vicinity of the release site above the moderate (100 ppb) and high (1,000 ppb) thresholds are expected to exceed depths of around 25 m and 35 m BMSL, respectively, in any season.

3.3.3.1.3 Entrained Oil - Exposure

Time-integrated entrained oil exposure at or above the 960 ppb.hr threshold could travel up to 571 km from the release location in winter, with distance reducing to 198 km at 9,600 ppb.hr in transitional months.

Entrained oil exposure above the 9,600 ppb.hr threshold was predicted to be greatest at the Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors with 100% probability in the surface layer (0-10 m) across all seasons (Table 3.26, Table 3.31 and Table 3.36).

The worst-case maximum entrained oil exposure concentration is predicted at the Seabirds, Sharks and Whales BIAs and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 60,636 ppb.hr in transitional months (Table 3.36).

3.3.3.1.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Dissolved aromatic hydrocarbon concentrations at the low threshold (10 ppb) could travel up to 352 km from the release location, with distances reducing at the moderate (50 ppb; 234 km) threshold (Table 3.23).

The seasonal zones of potential dissolved aromatic hydrocarbon exposure at all assessed contact thresholds are depicted in Figure 3.58 (summer), Figure 3.68 (winter) and Figure 3.78 (transitional months).

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	352	234	-

The probability of contact by dissolved aromatic hydrocarbon concentrations at the moderate threshold (50 ppb) is predicted to be greatest at the Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors at 19-32% 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 the Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors at 275 ppb in summer (Table 3.27).

The cross-sectional transects (summer; Figure 3.79/Figure 3.80, winter; Figure 3.69/Figure 3.70and transitional months; Figure 3.79/Figure 3.80**Error! Reference source not found.**) of maximum dissolved aromatic hydrocarbon concentrations in the vicinity of the release site above the moderate threshold (50 ppb) are not expected to exceed depths of around 30 m BMSL in any season.

3.3.3.1.5 Dissolved Aromatic Hydrocarbons - Exposure

Time-integrated dissolved aromatic hydrocarbon exposure at or above 960 ppb.hr are predicted to occur up to 10 km from the release site in summer.

Dissolved aromatic hydrocarbon exposure above the 960 ppb.hr threshold was not predicted at any receptor with probabilities greater than 2%, across all seasons 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 Seabirds, Sharks and Whales BIAs and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 1,795 ppb.hr 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 for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during summer.

	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
Islands	Barrow Island	<1	<1	<1	NC	NC	NC	1	<1	<1	537	NC	NC	0.3	32	<1	2	<1	5	NC	NC	NC	NC
	Lowendal Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	3.2	<1	<1	NC	NC	NC	NC	NC	NC
	Montebello Islands	<1	<1	<1	NC	NC	NC	1	<1	<1	286	NC	NC	0.1	12	<1	<1	<1	1	NC	NC	NC	NC
	Southern Pilbara - Islands	<1	<1	<1	NC	NC	NC	1	<1	<1	452	NC	NC	0.4	42	<1	<1	<1	2	NC	NC	NC	NC
Coastlines	Dampier Archipelago	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	2.4	<1	<1	NC	NC	NC	NC	NC	NC
	Eighty Mile Beach - Broome	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	2.2	<1	<1	NC	NC	NC	NC	NC	NC
	Exmouth Gulf South East	<1	<1	<1	NC	NC	NC	1	<1	<1	500	NC	NC	0.1	12	<1	<1	<1	1	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
	Karratha-Port Hedland	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Kimberley Coast	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.2	<1	<1	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	1.7	<1	<1	NC	NC	NC	NC	NC	NC
	North Broome Coast	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.5	<1	<1	NC	NC	NC	NC	NC	NC
	Northern Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.7	<1	<1	NC	NC	NC	NC	NC	NC
	Port Hedland - Eighty Mile Beach	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.3	<1	<1	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	2.3	<1	<1	NC	NC	NC	NC	NC	NC
State Marine and National Parks	Barrow Island MMA	<1	<1	<1	NC	NC	NC	1	<1	<1	537	NC	NC	0.2	22	<1	<1	<1	1	NC	NC	NC	NC
	Barrow Islands MP	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Clerke Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.4	<1	<1	NC	NC	NC	NC	NC	NC
	Eighty Mile Beach MP (State)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	2.2	<1	<1	NC	NC	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	3.6	<1	<1	NC	NC	NC	NC	NC	NC
	Montebello Islands MP	<1	<1	<1	NC	NC	NC	1	<1	<1	286	NC	NC	0.1	12	<1	<1	<1	1	NC	NC	NC	NC
	Muiron Islands MMA	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.3	<1	<1	NC	NC	NC	NC	NC	NC
	Ningaloo Coast WH	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.9	<1	<1	NC	NC	NC	NC	NC	NC
	Ningaloo MP (State)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.9	<1	<1	NC	NC	NC	NC	NC	NC
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
	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
	Dampier MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Eighty Mile Beach MP*	<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 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
	Gascoyne MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Reef MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	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*	<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
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF*	8	2	1	4	6	7	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*	<1	<1	<1	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*	<1	<1	<1	NC	NC	NC	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
	Glomar Shoals KEF*	2	<1	<1	12	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*†	<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
Biologically Important Areas	Dolphins BIA*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dugong BIA*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marine Turtle BIA*†	2	<1	<1	20	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	River Sharks BIA*	<1	<1	<1	NC	NC	NC	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
	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*	<1	<1	<1	NC	NC	NC	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 Subme	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.

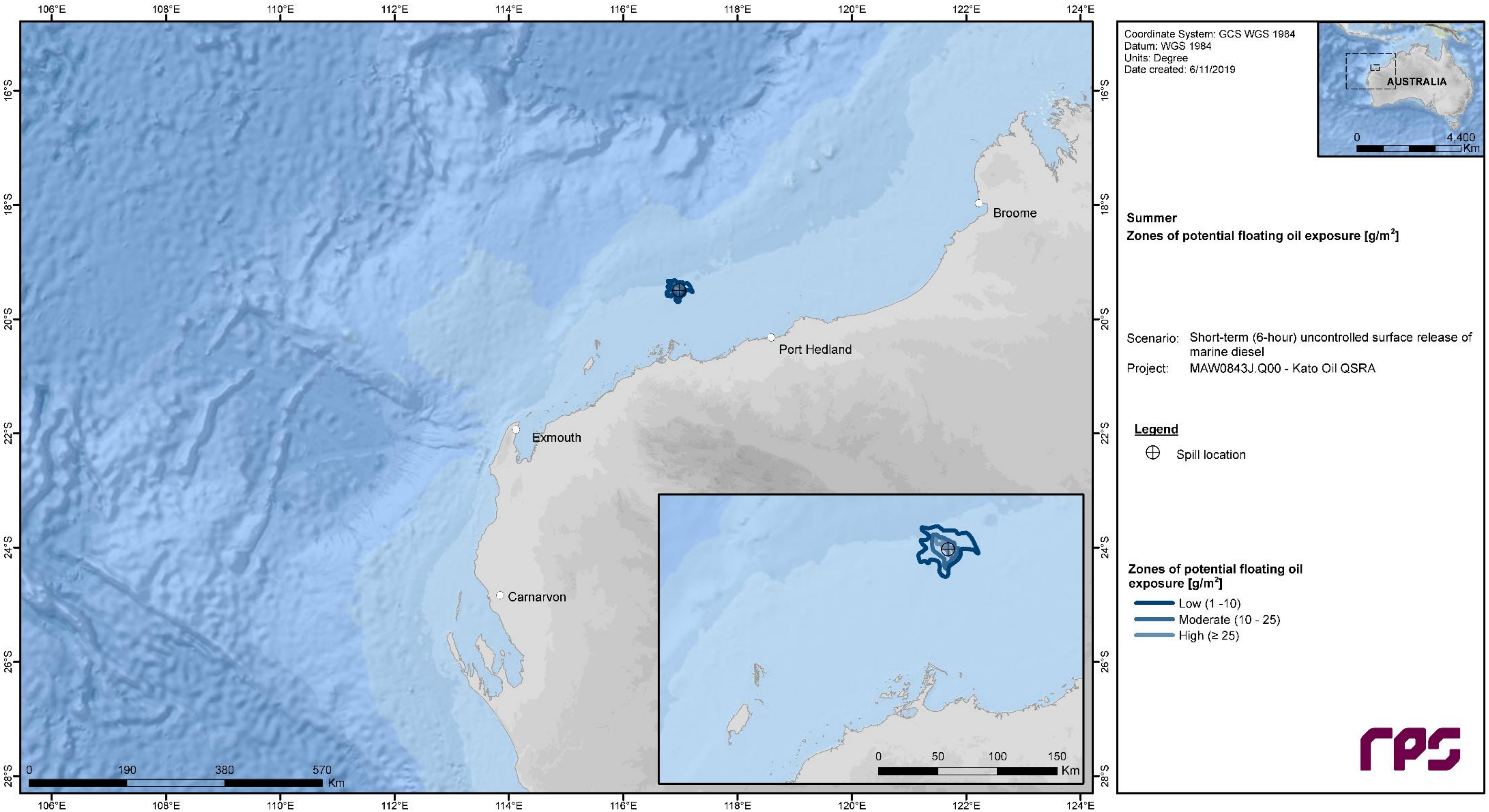

Figure 3.52 Predicted zones of potential floating oil exposure resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting in summer.

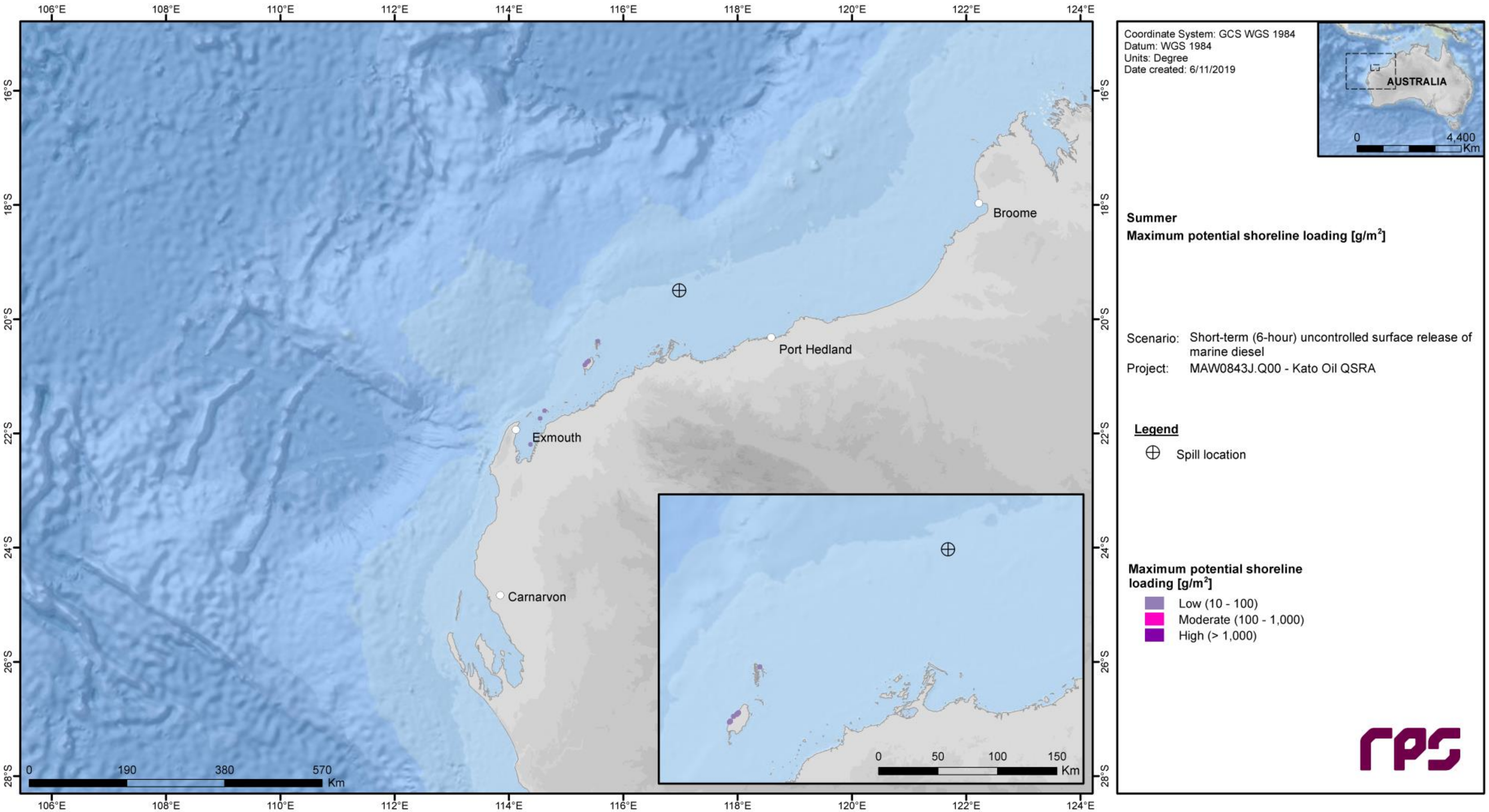

Figure 3.53 Predicted maximum potential shoreline loading resulting a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting in summer.

3.3.3.2.2 Entrained Oil - Instantaneous

Table 3.25 Expected entrained oil outcomes at sensitive receptors for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during summer.

Receptor		Probability (%) of entrained hydrocarbon concentration contact at			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	Barrow Island	<1	<1	<1	NC	NC	NC	<1	2
	Lowendal Islands	<1	<1	<1	NC	NC	NC	<1	<1
	Montebello Islands	1	<1	<1	489	NC	NC	<1	23
	Southern Pilbara - Islands	<1	<1	<1	NC	NC	NC	<1	8
Coastlines	Dampier Archipelago	<1	<1	<1	NC	NC	NC	<1	<1
	Eighty Mile Beach - Broome	<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	<1	2
	Karratha-Port Hedland	<1	<1	<1	NC	NC	NC	NC	NC
	Kimberley Coast	<1	<1	<1	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	<1	<1
	North Broome Coast	<1	<1	<1	NC	NC	NC	NC	NC
	Northern Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
	Port Hedland - Eighty Mile Beach	<1	<1	<1	NC	NC	NC	NC	NC
	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
State Marine and National Parks	Barrow Island MMA	<1	<1	<1	NC	NC	NC	<1	9
	Barrow Islands MP	<1	<1	<1	NC	NC	NC	<1	2
	Clerke Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	NC	NC
	Eighty Mile Beach MP (State)	<1	<1	<1	NC	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	<1	8
	Montebello Islands MP	1	<1	<1	475	NC	NC	<1	29
	Muiron Islands MMA	<1	<1	<1	NC	NC	NC	<1	10
	Ningaloo Coast WH	3	<1	<1	371	NC	NC	<1	35
	Ningaloo MP (State)	2	<1	<1	570	NC	NC	<1	21
Australian Marine Parks	Argo-Rowley Terrace MP	2	<1	<1	291	NC	NC	<1	44
	Carnarvon Canyon MP	<1	<1	<1	NC	NC	NC	<1	6
	Dampier MP	<1	<1	<1	NC	NC	NC	NC	NC
	Eighty Mile Beach MP	<1	<1	<1	NC	NC	NC	NC	NC
	Gascoyne MP	2	<1	<1	317	NC	NC	<1	82
	Mermaid Reef MP	<1	<1	<1	NC	NC	NC	NC	NC
	Montebello MP	8	1	<1	166	172	NC	4	109
	Ningaloo MP	3	<1	<1	371	NC	NC	<1	35
	Shark Bay MP	<1	<1	<1	NC	NC	NC	<1	<1
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	64	33	11	4	4	8	260	3,553
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	3	<1	<1	318	NC	NC	2	75
	Continental Slope Demersal Fish Communities KEF	16	1	<1	163	224	NC	5	178
	Exmouth Plateau KEF	2	<1	<1	347	NC	NC	<1	66
	Glomar Shoals KEF	42	20	1	11	12	13	72	1,487
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	1	<1	<1	623	NC	NC	<1	11
	Western Demersal Slope and associated Fish Communities KEF	<1	<1	<1	NC	NC	NC	NC	NC
Biologically Important Areas	Dolphins BIA	<1	<1	<1	NC	NC	NC	NC	NC
	Dugong BIA	2	<1	<1	579	NC	NC	<1	21
	Marine Turtle BIA	14	3	<1	29	30	NC	12	914
	River Sharks BIA	<1	<1	<1	NC	NC	NC	NC	NC
	Seabirds BIA	96	80	42	1	1	1	1,384	12,033
	Sharks BIA	96	80	42	1	1	1	1,384	12,033
	Whales BIA	96	80	42	1	1	1	1,384	12,033
Fi sh eri	North-West Slope Trawl Fishery	27	9	<1	66	69	NC	23	737

Receptor		Probability (%) of entrained hydrocarbon concentration contact at			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
	Southern Bluefin Tuna Fishery	96	80	42	1	1	1	1,384	12,033
	Western Skipjack Fishery	96	80	42	1	1	1	1,384	12,033
	Western Tuna and Billfish Fishery	96	80	42	1	1	1	1,384	12,033
Other	Rankin Bank	9	1	<1	167	210	NC	4	201

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

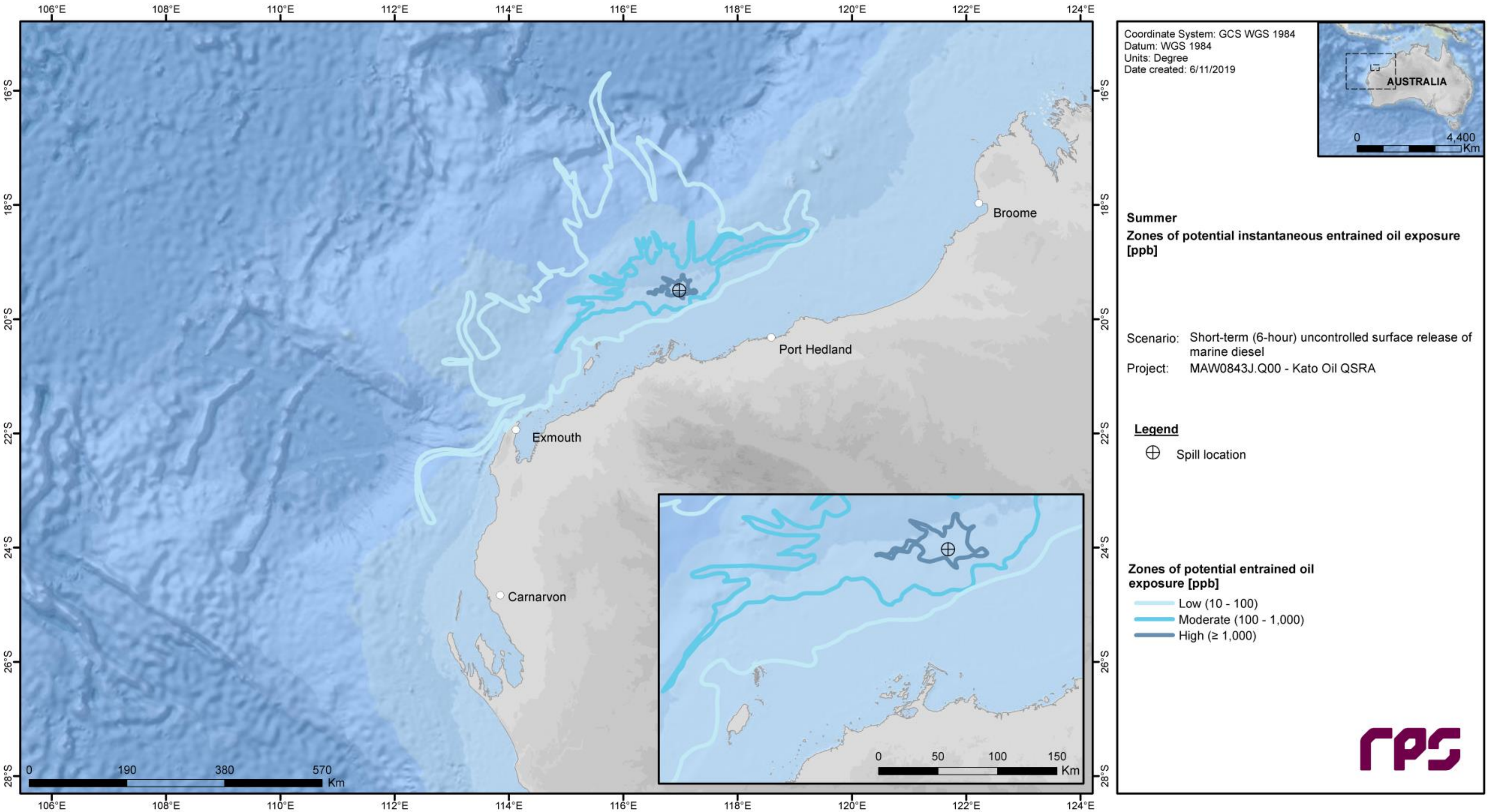

Figure 3.54 Predicted zones of potential instantaneous entrained oil exposure a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting in summer months..

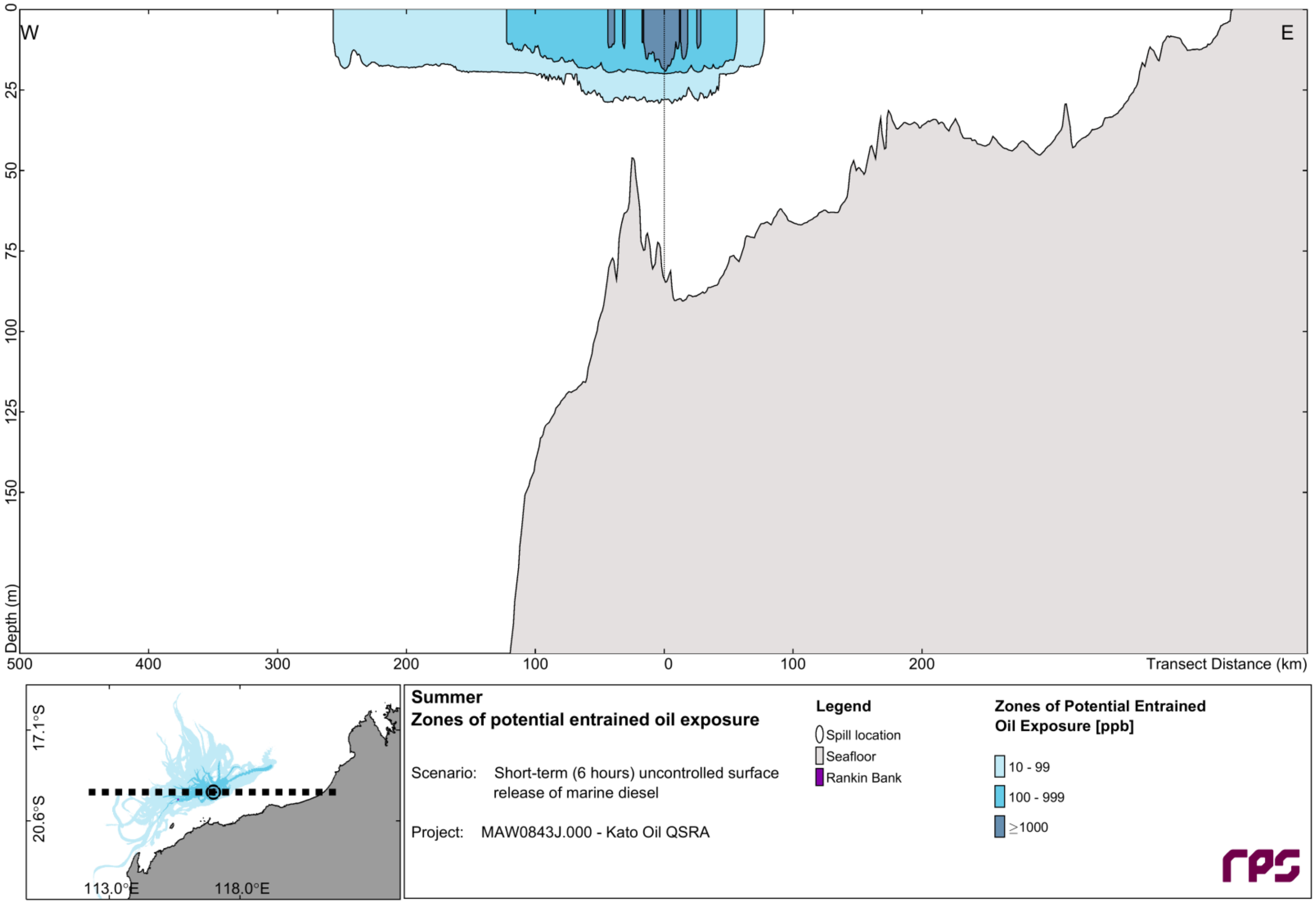

Figure 3.55 East-West cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the summer season. The results were calculated from 100 spill trajectories.

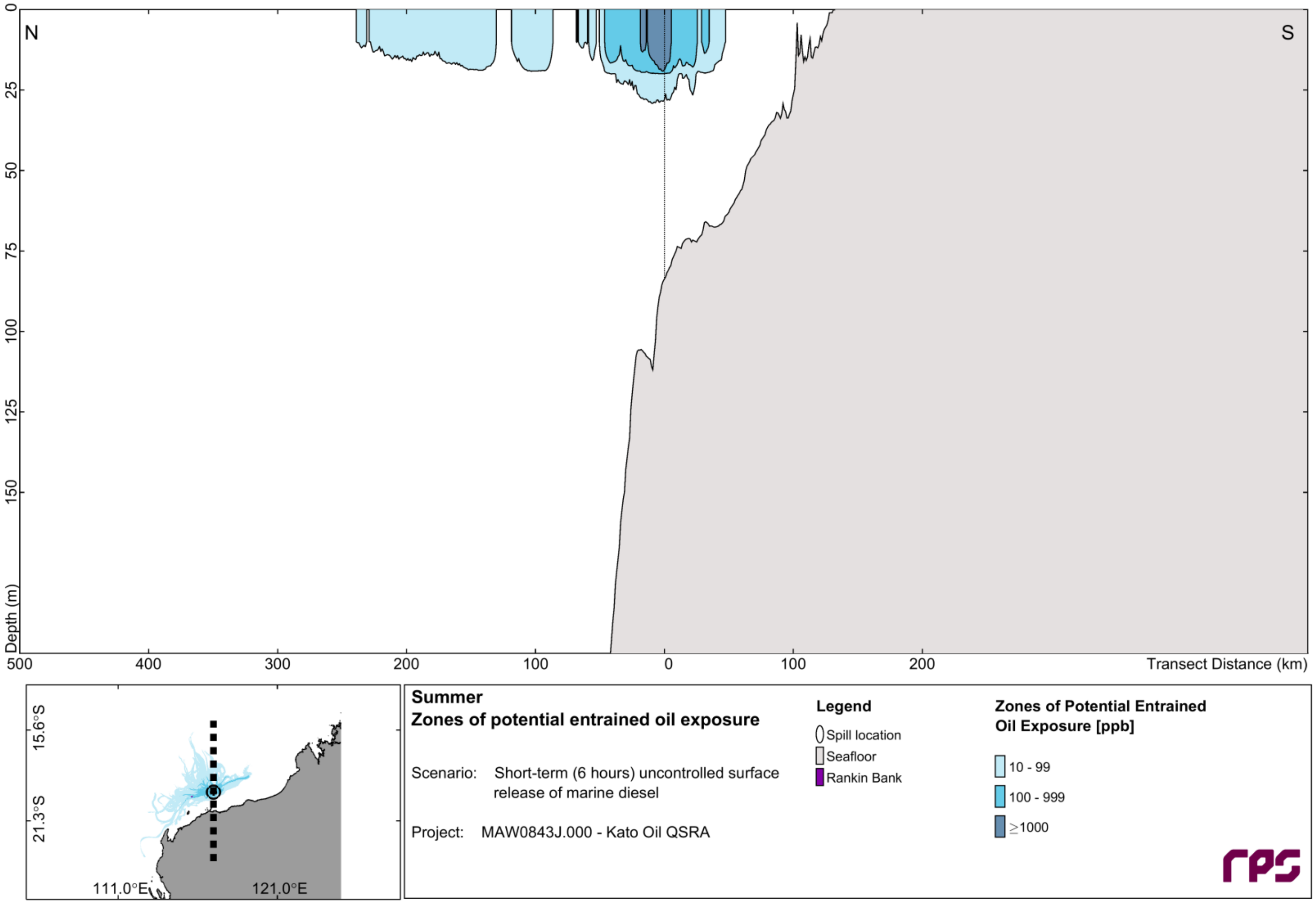

Figure 3.56 North-South cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the summer season. The results were calculated from 100 spill trajectories.

3.3.3.2.3 Entrained Oil - Exposure

Table 3.26 Expected entrained oil exposure outcomes at sensitive receptors for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during summer.

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	Barrow Island	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	30	3	1	NC	BS	BS
	Lowendal Islands	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	4	NC	NC	BS	BS	BS
	Montebello Islands	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	632	32	2	NC	BS	BS
	Southern Pilbara - Islands	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	343	15	4	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	NC	NC	NC	NC	BS	BS
	Eighty Mile Beach - Broome	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
	Exmouth Gulf South East	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
	Exmouth Gulf West	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	5	NC	BS	BS	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

Receptors		Threshold (ppb.hr)	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	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	NC	NC	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	NC	NC	BS	BS	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	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
State Marine and National Parks	Barrow Island MMA	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	158	8	1	NC	BS	BS
	Barrow Islands 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	29	4	2	NC	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	NC	NC	NC	NC	NC	NC
	Eighty Mile Beach MP (State)	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
	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	234	27	6	1	NC	NC

Receptors		Threshold (ppb.hr)	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 (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	868	54	9	NC	BS	BS
	Muiron Islands MMA	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	370	36	5	NC	NC	BS
	Ningaloo Coast WH	Probability (%) >960	1	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	1,025	45	17	6	NC	NC
	Ningaloo MP (State)	Probability (%) >960	1	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	1,025	40	17	6	NC	NC
Australian Marine Parks	Argo-Rowley Terrace 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	942	81	18	3	NC	NC
	Carnarvon Canyon 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	34	3	1	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	1	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	2,226	169	19	2	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	NC	NC	NC	NC	NC	NC
	Montebello MP	Probability (%) >960	2	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC

Receptors		Threshold (ppb.hr)	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	1,312	108	31	7	NC	NC
	Ningaloo 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	588	45	8	3	NC	NC
	Shark Bay 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	3	1	NC	NC	NC	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	32	1	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	17,828	1,112	134	20	2	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula 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	1,194	67	9	2	NC	NC
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	1	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	1,688	90	22	4	NC	NC
	Exmouth Plateau KEF	Probability (%) >960	1	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	2,226	169	19	3	NC	NC
	Glomar Shoals KEF	Probability (%) >960	20	NC	NC	NC	NC	BS
		Probability (%) >9,600	1	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	14,437	749	116	21	2	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	387	35	11	1	NC	NC
	Western Demersal Slope and associated Fish Communities 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
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

	Receptors	Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Dugong BIA	Probability (%) >960	1	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	1,025	40	17	6	NC	NC
	Marine Turtle BIA	Probability (%) >960	4	NC	NC	NC	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	17,646	754	110	18	2	NC
	River Sharks BIA	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
	Seabirds BIA	Probability (%) >960	66	1	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	55,981	1,349	195	31	2	NC
	Sharks BIA	Probability (%) >960	66	2	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	55,981	1,802	195	31	2	NC
	Whales BIA	Probability (%) >960	66	2	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	55,981	1,802	195	31	2	NC
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	12	NC	NC	NC	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	10,439	376	63	14	1	NC
	Southern Bluefin Tuna Fishery	Probability (%) >960	66	2	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	55,981	1,802	195	31	2	NC
	Western Skipjack Fishery	Probability (%) >960	66	2	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	55,981	1,802	195	31	2	NC
	Western Tuna and Billfish Fishery	Probability (%) >960	66	2	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	55,981	1,802	195	31	2	NC
Other Submerged	Rankin Bank	Probability (%) >960	1	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	2,697	170	55	BS	BS	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

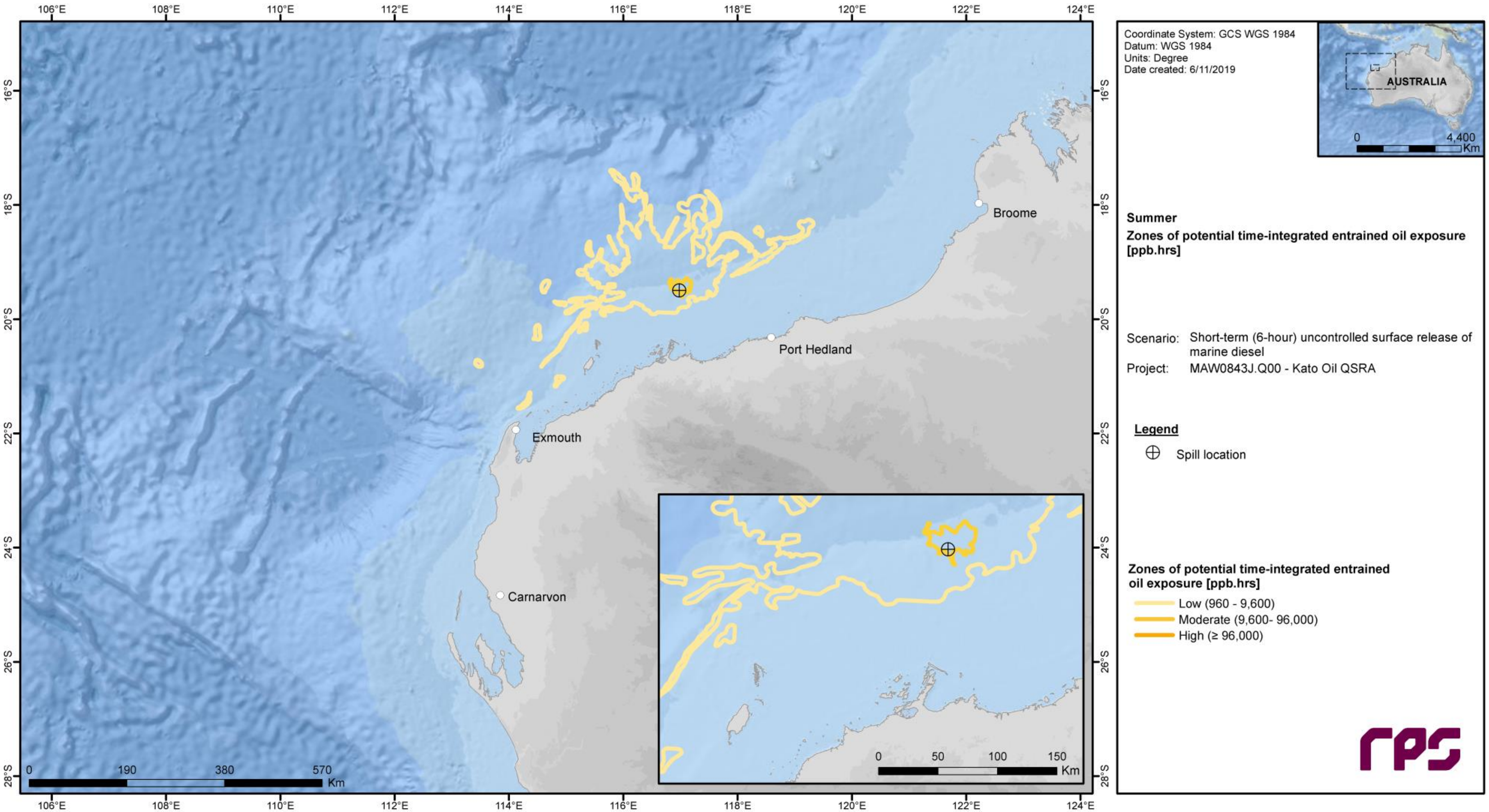

Figure 3.57 Predicted zones of potential time-integrated entrained oil exposure a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting in summer months.

3.3.3.2.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Table 3.27 Expected dissolved aromatic hydrocarbons outcomes at sensitive receptors resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during summer.

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	5
	Lowendal Islands	<1	<1	<1	NC	NC
	Montebello Islands	<1	<1	<1	<1	<1
	Southern Pilbara - Islands	<1	<1	<1	<1	<1
Coastlines	Dampier Archipelago	<1	<1	<1	<1	<1
	Eighty Mile Beach - Broome	<1	<1	<1	NC	NC
	Exmouth Gulf South East	<1	<1	<1	NC	NC
	Exmouth Gulf West	<1	<1	<1	NC	NC
	Karratha-Port Hedland	<1	<1	<1	NC	NC
	Kimberley Coast	<1	<1	<1	NC	NC
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC
	North Broome Coast	<1	<1	<1	NC	NC
	Northern Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC
	Port Hedland - Eighty Mile Beach	<1	<1	<1	NC	NC
	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC
State Marine and National Parks	Barrow Island MMA	<1	<1	<1	<1	5
	Barrow Islands MP	<1	<1	<1	<1	<1
	Clerke Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC
	Eighty Mile Beach MP (State)	<1	<1	<1	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC
	Montebello Islands MP	<1	<1	<1	<1	3
	Muiron Islands MMA	<1	<1	<1	<1	<1
	Ningaloo Coast WH	<1	<1	<1	<1	4
	Ningaloo MP (State)	<1	<1	<1	<1	<1
Australian Marine Parks	Argo-Rowley Terrace MP	<1	<1	<1	<1	10
	Carnarvon Canyon MP	<1	<1	<1	NC	NC
	Dampier MP	<1	<1	<1	<1	<1
	Eighty Mile Beach MP	<1	<1	<1	NC	NC
	Gascoyne MP	<1	<1	<1	<1	7
	Mermaid Reef MP	<1	<1	<1	NC	NC
	Montebello MP	2	<1	<1	<1	17

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
	Ningaloo MP	<1	<1	<1	<1	4
	Shark Bay MP	<1	<1	<1	NC	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	32	8	<1	13	240
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	<1	<1	<1	<1	8
	Continental Slope Demersal Fish Communities KEF	2	<1	<1	<1	31
	Exmouth Plateau KEF	<1	<1	<1	<1	6
	Glomar Shoals KEF	17	4	<1	6	147
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	<1	<1	<1	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	<1	<1	<1	NC	NC
Biologically Important Areas	Dolphins BIA	<1	<1	<1	NC	NC
	Dugong BIA	<1	<1	<1	<1	<1
	Marine Turtle BIA	4	1	<1	2	71
	River Sharks BIA	<1	<1	<1	NC	NC
	Seabirds BIA	60	25	<1	31	300
	Sharks BIA	60	25	<1	31	300
	Whales BIA	60	25	<1	31	300
Fisheries	North-West Slope Trawl Fishery	4	2	<1	2	99
	Southern Bluefin Tuna Fishery	60	25	<1	31	300
	Western Skipjack Fishery	60	25	<1	31	300
	Western Tuna and Billfish Fishery	60	25	<1	31	300
Ot he	Rankin Bank	<1	<1	<1	<1	8

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

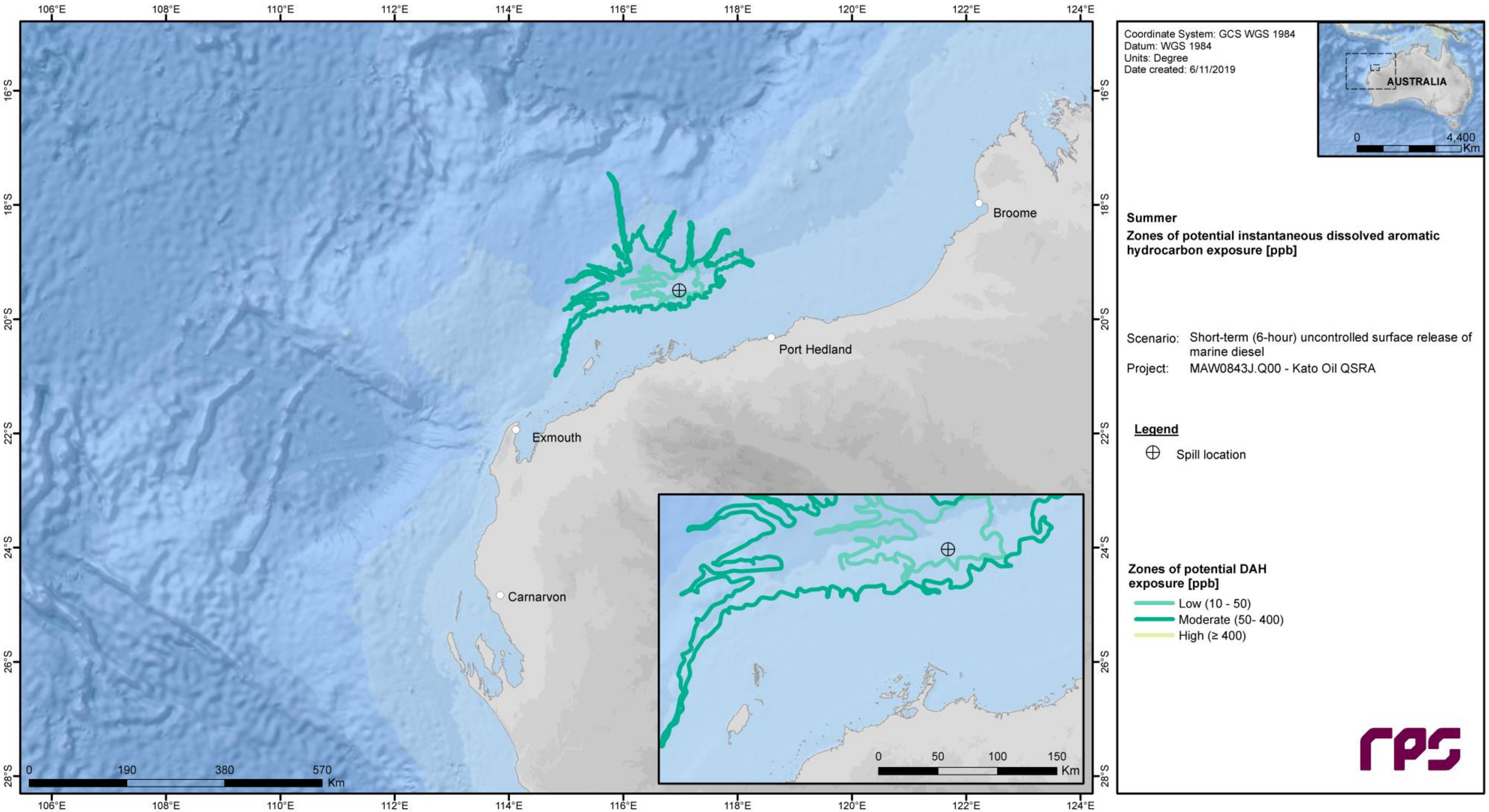

Figure 3.58 Predicted zones of potential instantaneous dissolved aromatic hydrocarbon exposure for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during summer.

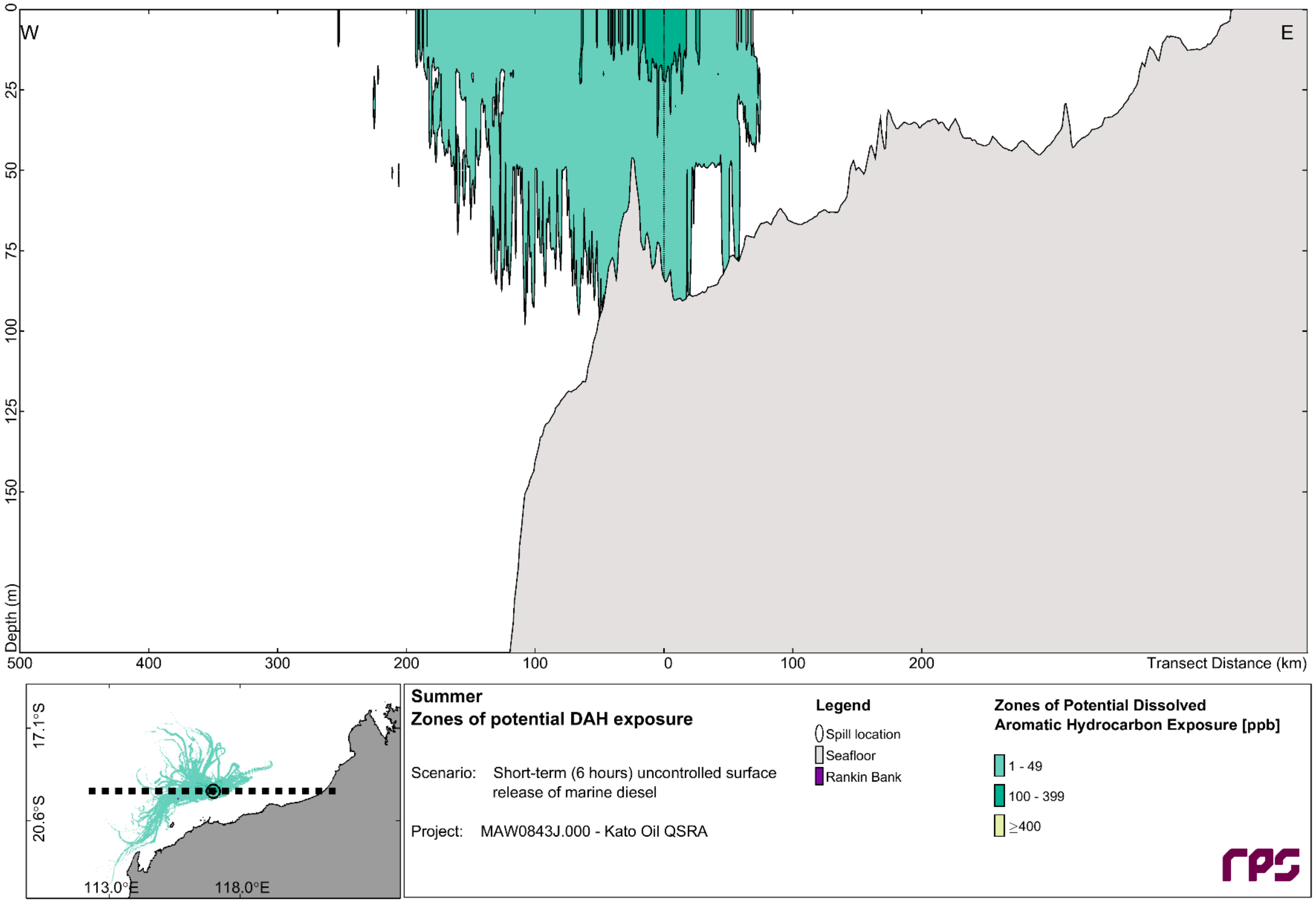

Figure 3.59 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the summer season. The results were calculated from 100 spill trajectories.

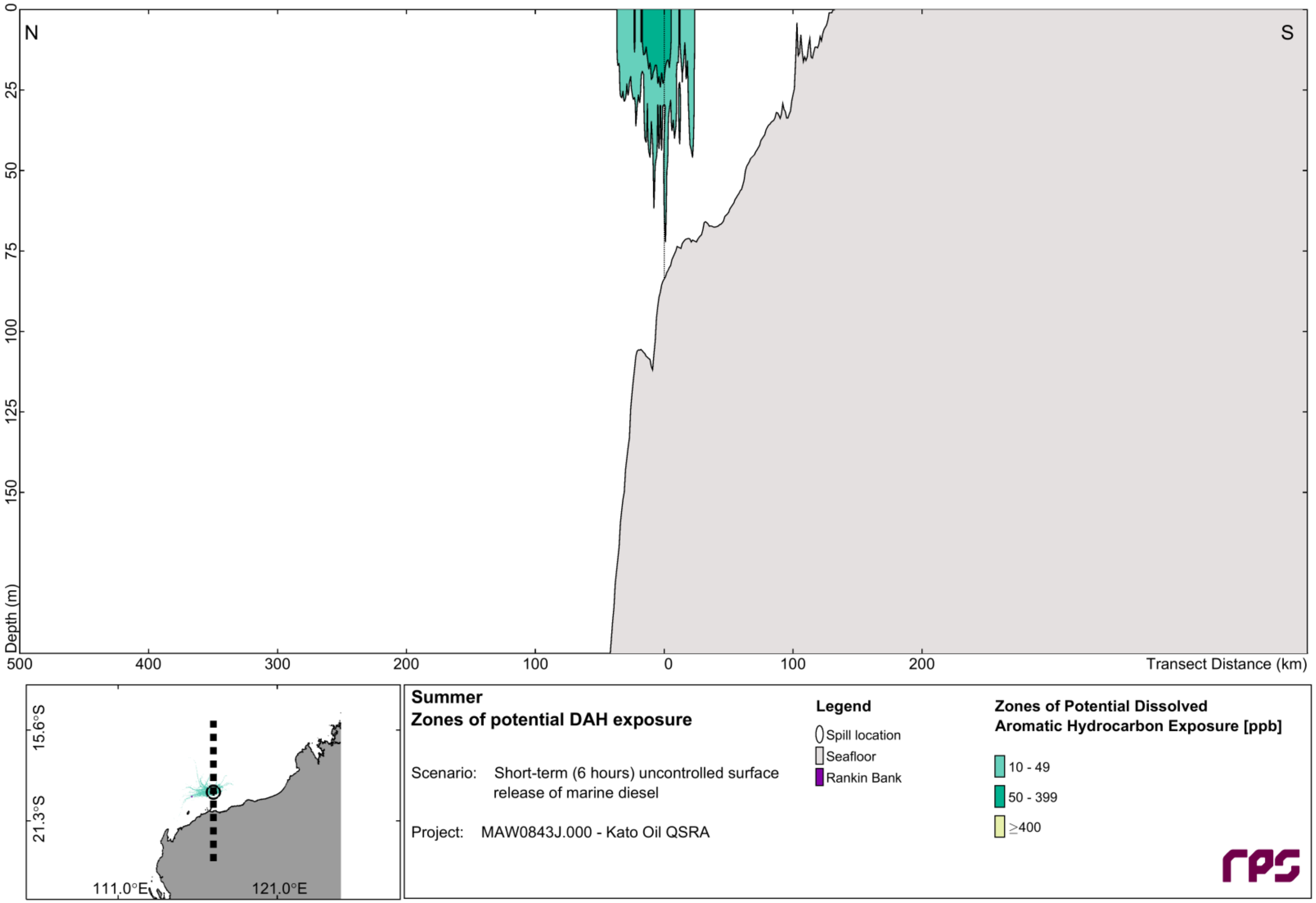

Figure 3.60 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the summer season. The results were calculated from 100 spill trajectories.

3.3.3.2.5 Dissolved Aromatic Hydrocarbon - Exposure

Table 3.28 Expected dissolved aromatic hydrocarbon exposure outcomes at sensitive receptors for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during summer.

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	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	3	13	3	NC	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
	Southern Pilbara - 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
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
	Eighty Mile Beach - Broome	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
	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	NC	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	NC	NC	BS	BS	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

	Receptors	Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		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
	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	NC	BS	BS	BS	BS	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	5	13	3	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	1	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
	Eighty Mile Beach MP (State)	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
	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

Receptors		Threshold (ppb.hr)	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 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	4	2	NC	BS	BS
	Muiron Islands MMA	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
	Ningaloo Coast WH	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	5	6	3	NC	NC
	Ningaloo MP (State)	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	1	NC	NC	NC
Australian Marine Parks	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	12	14	26	14	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	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	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	13	10	11	5	3	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

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >4,800	NC	NC	NC	NC	NC	NC
		Probability (%) >38,400	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	23	10	31	12	NC	NC
	Ningaloo 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	5	6	3	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	NC	NC	NC	NC	NC	NC
Key Ecological Features	Ancient Coastline at 125m 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	680	523	238	99	23	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula 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	11	11	7	3	NC	NC
	Continental Slope Demersal 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	59	28	55	24	4	NC
	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	11	13	6	2	NC	NC
	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	381	288	127	92	5	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
	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	NC	NC	NC	NC	NC	NC
Biologically Important	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

	Receptors	Threshold (ppb.hr)	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
	Dugong 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	1	1	1	NC	NC
	Marine Turtle 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	544	417	212	56	16	NC
	River Sharks BIA	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
	Seabirds BIA	Probability (%) >960	1	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	1,330	943	422	106	25	NC
	Sharks BIA	Probability (%) >960	2	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	1,330	943	422	191	27	NC
	Whales BIA	Probability (%) >960	2	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	1,330	943	422	191	27	NC
Fisheries	North-West Slope Trawl Fishery	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	314	246	84	55	12	NC
	Southern Bluefin Tuna Fishery	Probability (%) >960	2	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	1,330	943	422	191	27	NC
	Western Skipjack Fishery	Probability (%) >960	2	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	1,330	943	422	191	27	NC
	Western Tuna and Billfish Fishery	Probability (%) >960	2	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	1,330	943	422	191	27	NC
Othe	Rankin Bank	Probability (%) >960	NC	NC	NC	BS	BS	BS

Receptors		Threshold (ppb.hr)	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	2	12	48	BS	BS	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

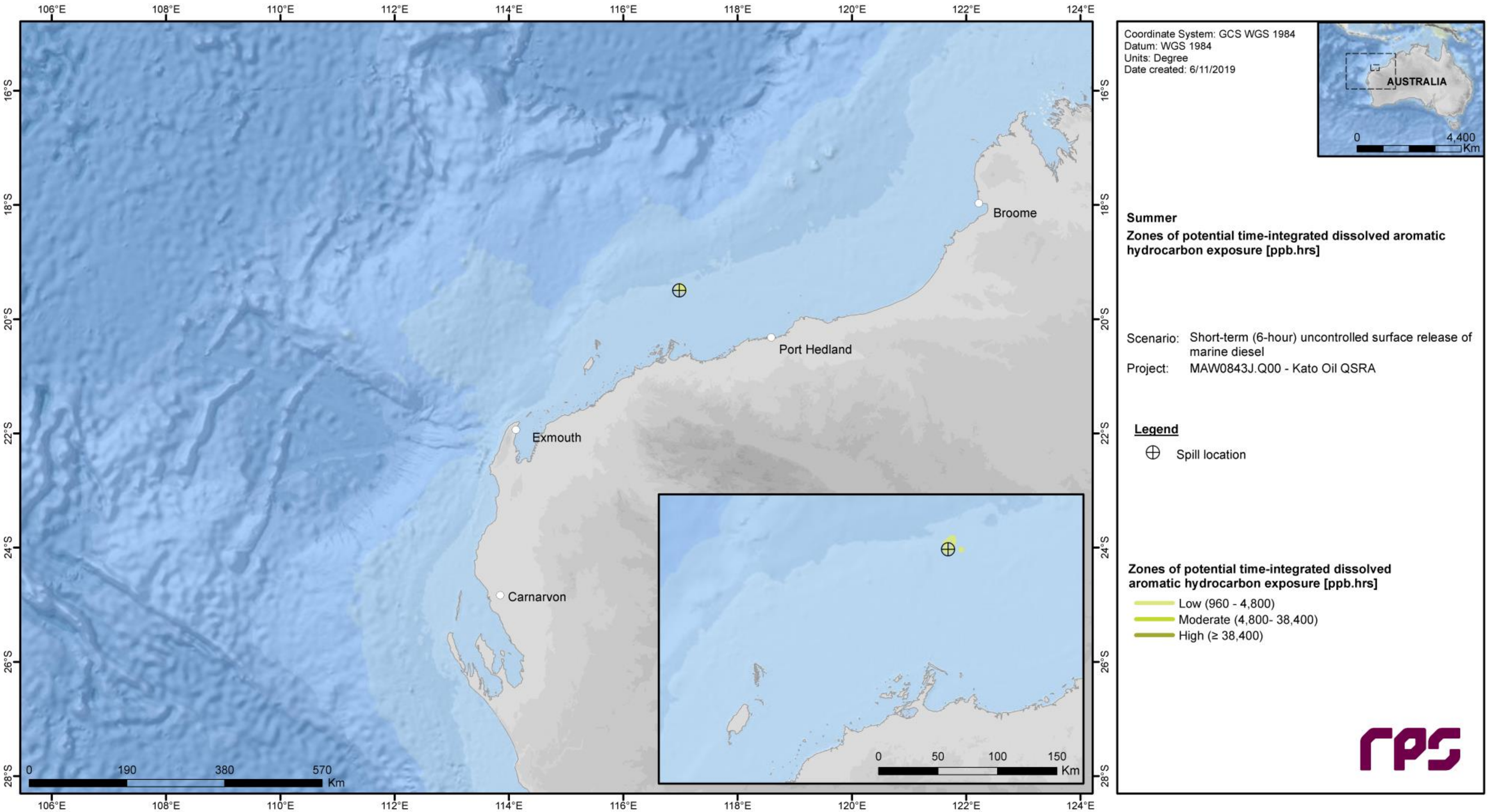

Figure 3.61 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during summer.

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 for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during winter.

	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
Islands	Barrow Island	<1	<1	<1	NC	NC	NC	1	<1	<1	329	NC	NC	0.1	11	<1	<1	NC	NC	NC	NC	NC	NC
	Lowendal Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC	NC	NC	NC	NC
	Montebello Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	2.8	<1	<1	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC	NC	NC	NC	NC
Coastlines	Dampier Archipelago	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Eighty Mile Beach - Broome	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	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
	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
	Karratha-Port Hedland	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Kimberley Coast	<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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	North Broome Coast	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Northern 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
	Port Hedland - Eighty Mile Beach	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	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
State Marine and National Parks	Barrow Island MMA	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	7.6	<1	<1	NC	NC	NC	NC	NC	NC
	Barrow Islands MP	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Clerke Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Eighty Mile Beach MP (State)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Montebello Islands MP	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	2.8	<1	<1	NC	NC	NC	NC	NC	NC
	Muiron Islands MMA	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.3	<1	<1	NC	NC	NC	NC	NC	NC
	Ningaloo Coast WH	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	1.9	<1	<1	NC	NC	NC	NC	NC	NC
	Ningaloo MP (State)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	1.9	<1	<1	NC	NC	NC	NC	NC	NC
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
	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
	Dampier MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Eighty Mile Beach MP*	<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 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
	Gascoyne MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Reef MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	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*	<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
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF*	9	1	<1	4	5	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*	<1	<1	<1	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*	<1	<1	<1	NC	NC	NC	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
	Glomar Shoals KEF*	4	<1	<1	22	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*†	<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
Biologically Important Areas	Dolphins BIA*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dugong BIA*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marine Turtle BIA*†	1	<1	<1	57	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	River Sharks BIA*	<1	<1	<1	NC	NC	NC	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
	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*	1	<1	<1	273	NC	NC	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
Ot he	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.

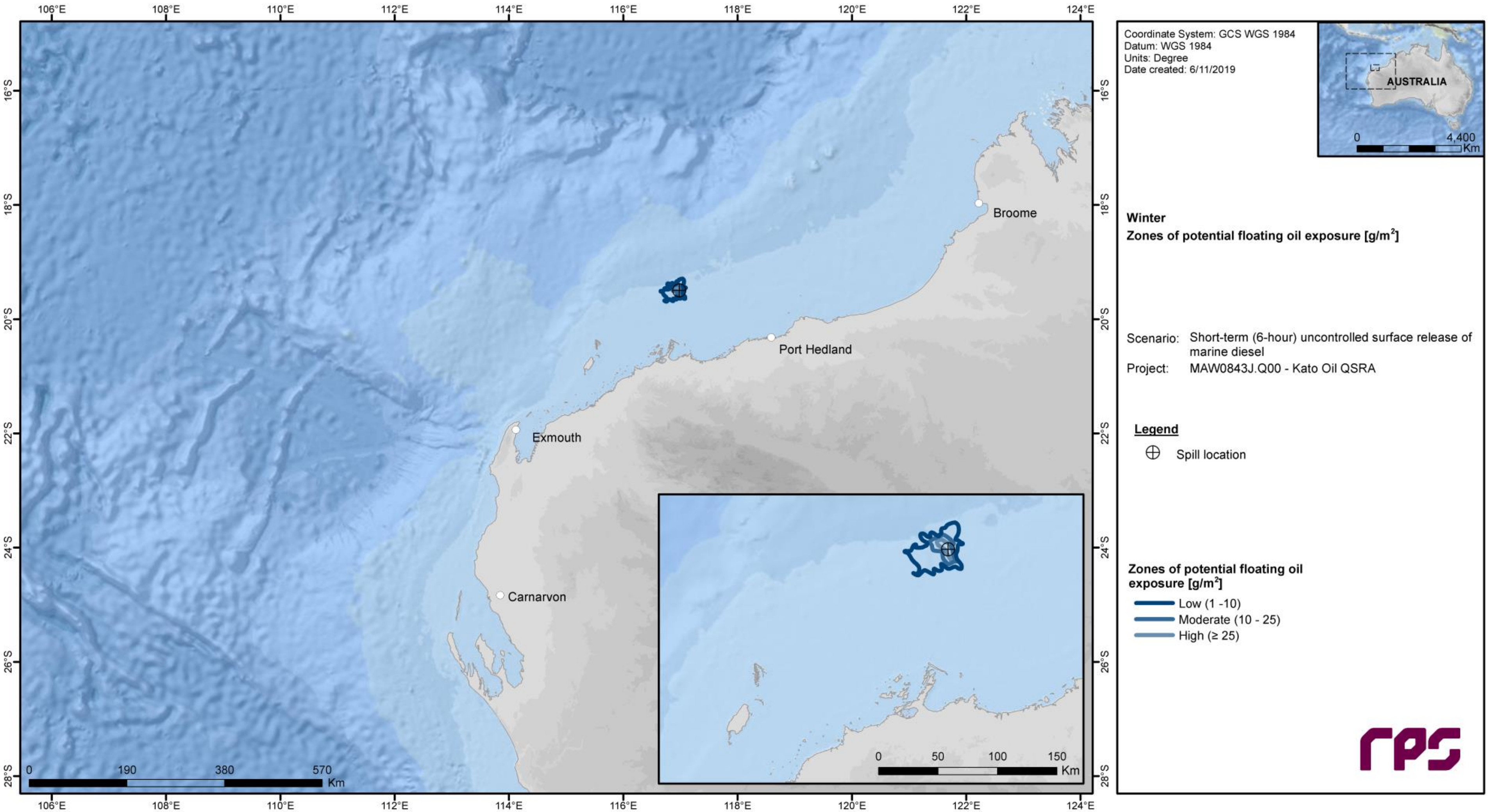

Figure 3.62 Predicted zones of potential floating oil exposure resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting in winter.

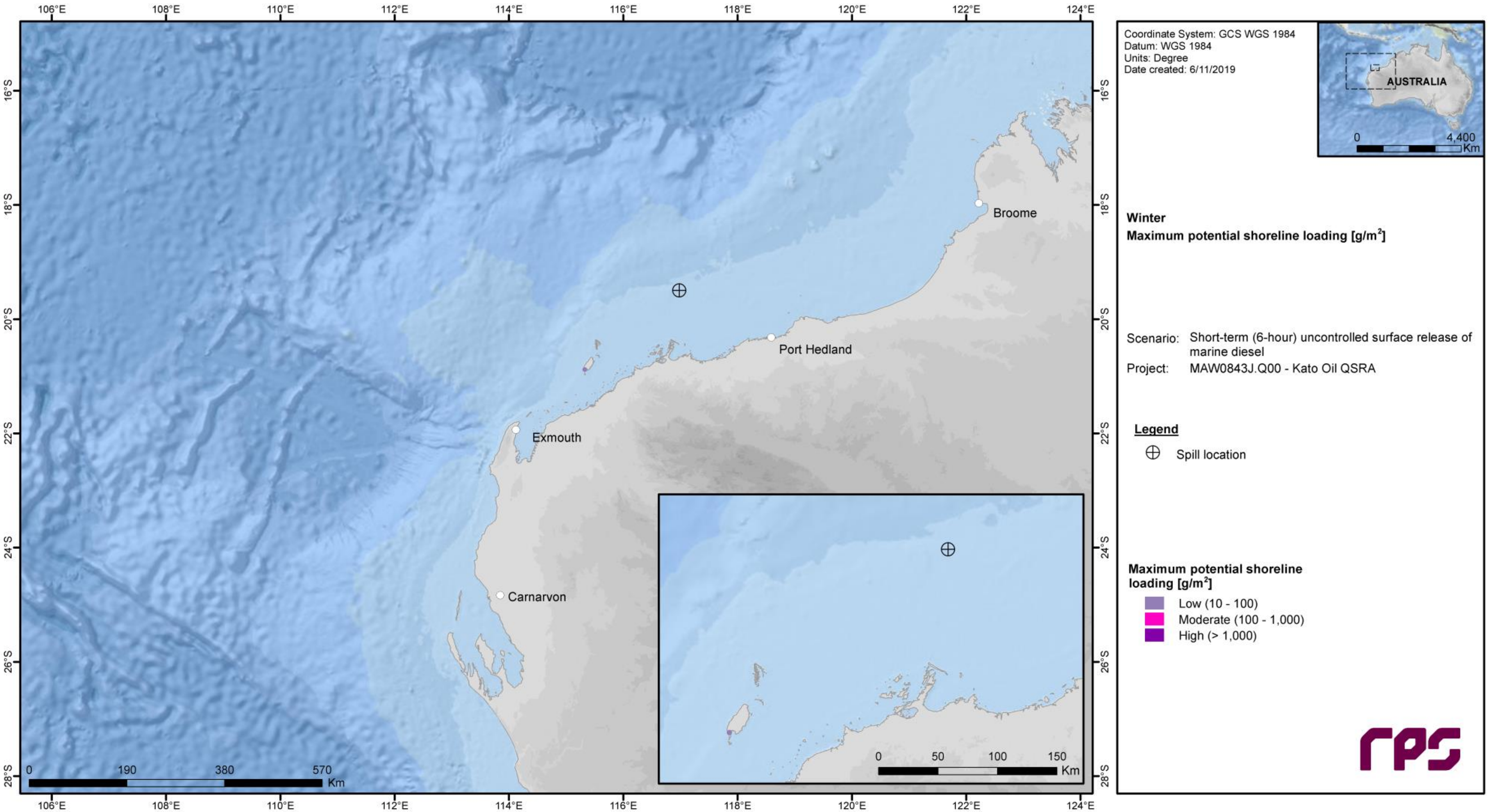

Figure 3.63 Predicted maximum potential shoreline loading resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting in winter.

3.3.3.3.2 Entrained Oil – Instantaneous

Table 3.30 Expected entrained oil outcomes at sensitive receptors for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during winter.

Receptors		Probability (%) of entrained hydrocarbon concentration contact at			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	Barrow Island	<1	<1	<1	NC	NC	NC	<1	6
	Lowendal Islands	<1	<1	<1	NC	NC	NC	<1	<1
	Montebello Islands	<1	<1	<1	NC	NC	NC	<1	9
	Southern Pilbara - Islands	<1	<1	<1	NC	NC	NC	<1	2
Coastlines	Dampier Archipelago	<1	<1	<1	NC	NC	NC	NC	NC
	Eighty Mile Beach - Broome	<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	<1	3
	Karratha-Port Hedland	<1	<1	<1	NC	NC	NC	NC	NC
	Kimberley Coast	<1	<1	<1	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
	North Broome Coast	<1	<1	<1	NC	NC	NC	NC	NC
	Northern Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
	Port Hedland - Eighty Mile Beach	<1	<1	<1	NC	NC	NC	NC	NC
	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
State Marine and National Parks	Barrow Island MMA	1	<1	<1	538	NC	NC	<1	14
	Barrow Islands MP	1	<1	<1	540	NC	NC	<1	15
	Clerke Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	NC	NC
	Eighty Mile Beach MP (State)	<1	<1	<1	NC	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	<1	<1
	Montebello Islands MP	1	<1	<1	585	NC	NC	<1	15
	Muiron Islands MMA	1	<1	<1	471	NC	NC	<1	11
	Ningaloo Coast WH	1	<1	<1	505	NC	NC	<1	20
	Ningaloo MP (State)	1	<1	<1	513	NC	NC	<1	18
Australian Marine Parks	Argo-Rowley Terrace MP	1	<1	<1	511	NC	NC	<1	17
	Carnarvon Canyon MP	<1	<1	<1	NC	NC	NC	<1	<1
	Dampier MP	<1	<1	<1	NC	NC	NC	NC	NC
	Eighty Mile Beach MP	<1	<1	<1	NC	NC	NC	NC	NC
	Gascoyne MP	4	<1	<1	282	NC	NC	2	78
	Mermaid Reef MP	<1	<1	<1	NC	NC	NC	NC	NC
	Montebello MP	17	3	<1	148	169	NC	7	167
	Ningaloo MP	1	<1	<1	505	NC	NC	<1	20
	Shark Bay MP	<1	<1	<1	NC	NC	NC	<1	2
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	51	29	5	4	5	5	188	2,125
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	4	<1	<1	274	NC	NC	2	44
	Continental Slope Demersal Fish Communities KEF	36	8	<1	86	90	NC	19	312
	Exmouth Plateau KEF	7	1	<1	289	320	NC	3	105
	Glomar Shoals KEF	77	65	14	11	12	12	376	1,924
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	<1	<1	<1	NC	NC	NC	<1	<1
	Western Demersal Slope and associated Fish Communities KEF	<1	<1	<1	NC	NC	NC	<1	<1
Biologically Important Areas	Dolphins BIA	<1	<1	<1	NC	NC	NC	NC	NC
	Dugong BIA	1	<1	<1	516	NC	NC	<1	18
	Marine Turtle BIA	41	12	<1	35	36	NC	27	821
	River Sharks BIA	<1	<1	<1	NC	NC	NC	NC	NC
	Seabirds BIA	96	89	63	1	1	1	2,112	8,987
	Sharks BIA	96	89	63	1	1	1	2,112	8,987
	Whales BIA	96	89	63	1	1	1	2,112	8,987
Fi sh eri	North-West Slope Trawl Fishery	35	9	<1	72	84	NC	23	345

Receptors		Probability (%) of entrained hydrocarbon concentration contact at			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
	Southern Bluefin Tuna Fishery	96	89	63	1	1	1	2,112	8,987
	Western Skipjack Fishery	96	89	63	1	1	1	2,112	8,987
	Western Tuna and Billfish Fishery	96	89	63	1	1	1	2,112	8,987
Other	Rankin Bank	28	4	<1	111	162	NC	14	220

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

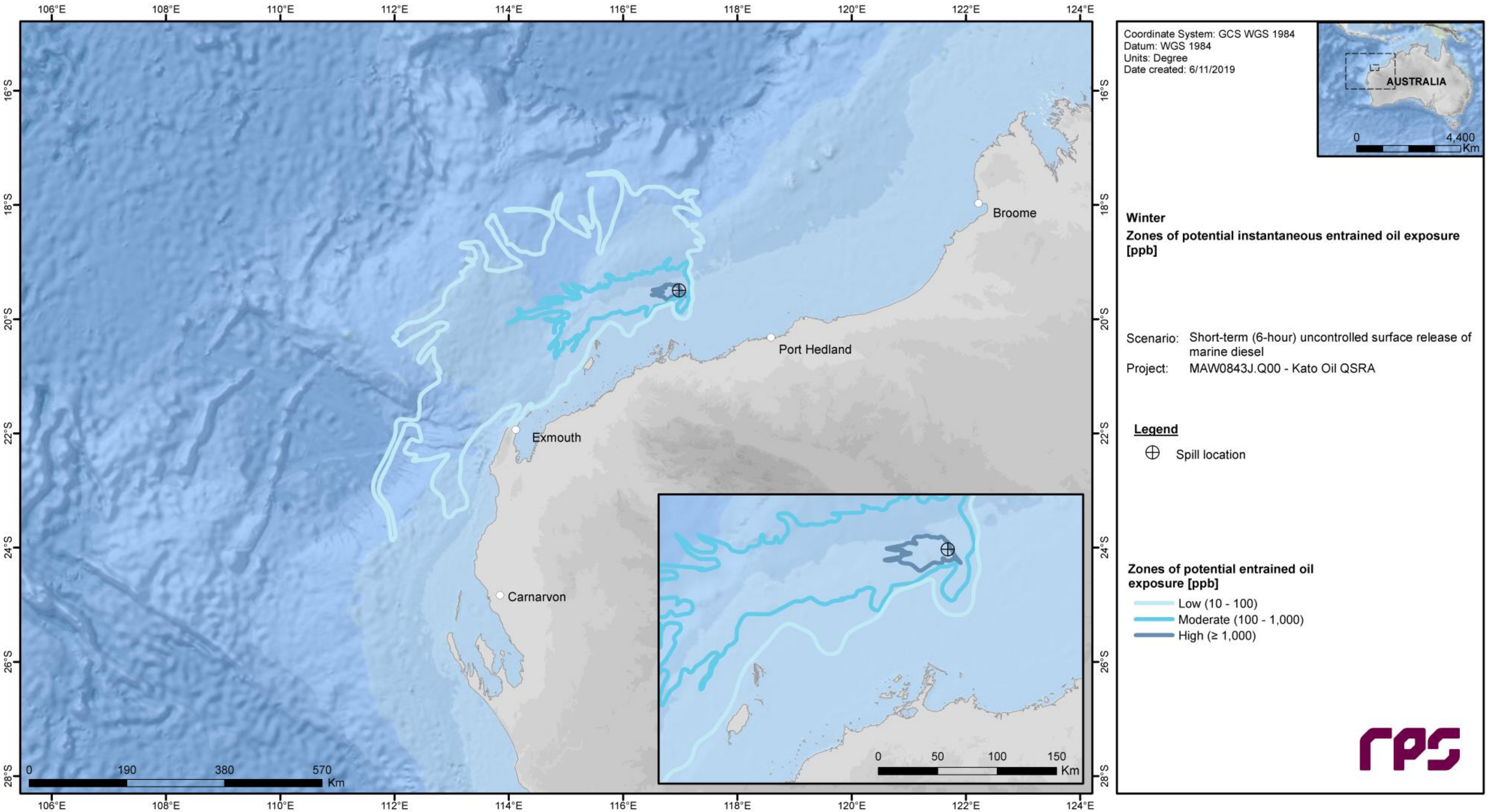

Figure 3.64 Predicted zones of potential entrained oil exposure a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting in winter months.

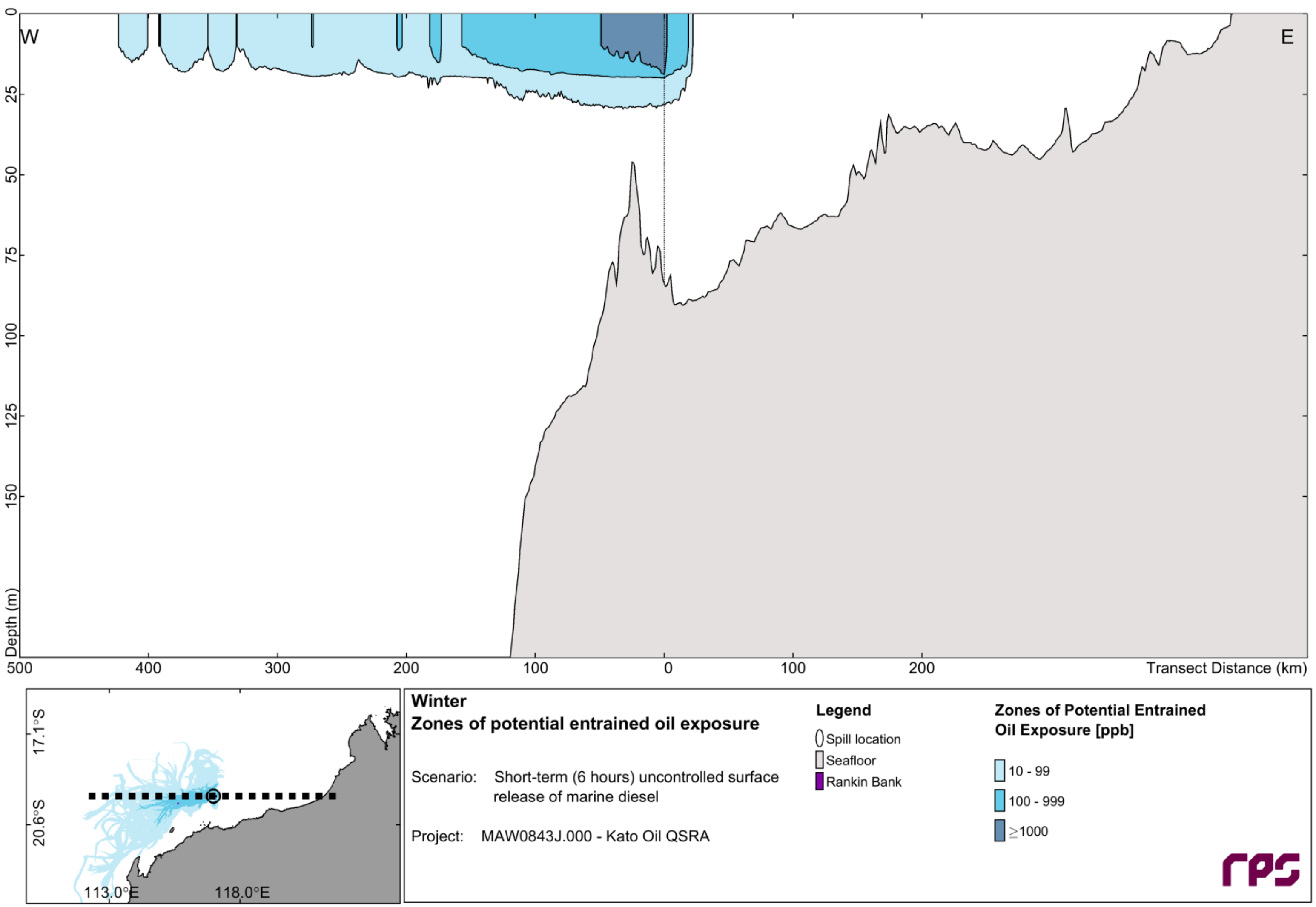

Figure 3.65 East-West cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the winter season. The results were calculated from 100 spill trajectories.

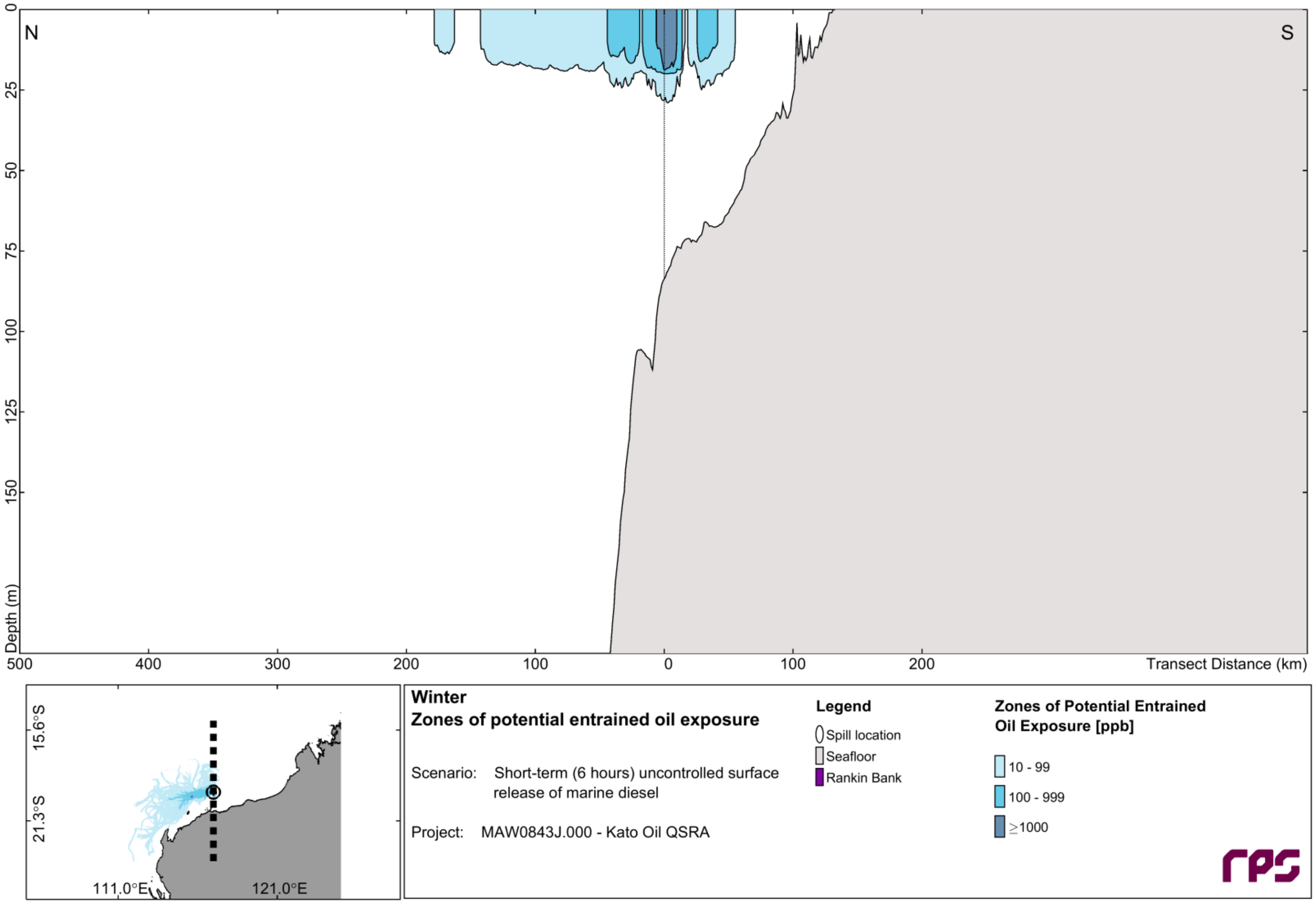

Figure 3.66 North-South cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the winter season. The results were calculated from 100 spill trajectories.

3.3.3.3.3 Entrained Oil - Exposure

Table 3.31 Expected entrained oil exposure outcomes at sensitive receptors for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during winter.

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	Barrow Island	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	71	8	1	NC	BS	BS
	Lowendal Islands	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	NC	NC	NC	BS	BS	BS
	Montebello Islands	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	47	8	3	NC	BS	BS
	Southern Pilbara - Islands	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	44	6	5	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	NC	NC	NC	NC	BS	BS
	Eighty Mile Beach - Broome	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
	Exmouth Gulf South East	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
	Exmouth Gulf West	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	87	3	BS	BS	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

Receptors		Threshold (ppb.hr)	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	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	NC	NC	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	NC	NC	BS	BS	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	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
State Marine and National Parks	Barrow Island MMA	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	173	23	4	NC	BS	BS
	Barrow Islands 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	198	26	4	NC	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	NC	NC	NC	NC	NC	NC
	Eighty Mile Beach MP (State)	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
	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	NC	NC	NC	NC	NC	NC

Receptors		Threshold (ppb.hr)	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 (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	174	24	8	NC	BS	BS
	Muiron Islands MMA	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	200	26	5	3	NC	BS
	Ningaloo Coast WH	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	694	56	10	3	NC	NC
	Ningaloo MP (State)	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	598	52	10	3	NC	NC
Australian Marine Parks	Argo-Rowley Terrace 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	389	47	8	2	NC	NC
	Carnarvon Canyon 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	3	1	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	1	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	1,011	69	16	5	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	NC	NC	NC	NC	NC	NC
	Montebello MP	Probability (%) >960	4	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC

Receptors		Threshold (ppb.hr)	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	2,792	164	54	27	2	NC
	Ningaloo 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	694	56	9	2	NC	NC
	Shark Bay 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	8	1	NC	NC	NC	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	27	1	NC	NC	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	35,166	2,331	401	79	2	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	Probability (%) >960	1	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	1,759	163	25	4	NC	NC
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	11	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	7,711	636	81	13	1	NC
	Exmouth Plateau KEF	Probability (%) >960	1	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	1,182	112	17	3	NC	NC
	Glomar Shoals KEF	Probability (%) >960	55	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	15,335	801	98	17	1	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	NC	NC	NC	NC	NC	NC
	Western Demersal Slope and associated Fish Communities 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
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

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Dugong 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	595	51	10	3	NC	NC
	Marine Turtle BIA	Probability (%) >960	12	NC	NC	NC	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	10,372	750	148	37	2	NC
	River Sharks BIA	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
	Seabirds BIA	Probability (%) >960	82	1	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	44,581	2,368	401	79	4	NC
	Sharks BIA	Probability (%) >960	82	1	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	44,581	2,368	401	79	4	NC
	Whales BIA	Probability (%) >960	82	1	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	44,581	2,368	401	79	4	NC
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	11	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	8,646	636	120	24	2	NC
	Southern Bluefin Tuna Fishery	Probability (%) >960	82	1	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	44,581	2,368	401	79	4	NC
	Western Skipjack Fishery	Probability (%) >960	82	1	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	44,581	2,368	401	79	4	NC
	Western Tuna and Billfish Fishery	Probability (%) >960	82	1	NC	NC	NC	NC
		Probability (%) >9,600	19	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	44,581	2,368	401	79	4	NC
Other Subm	Rankin Bank	Probability (%) >960	8	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	3,812	216	40	BS	BS	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

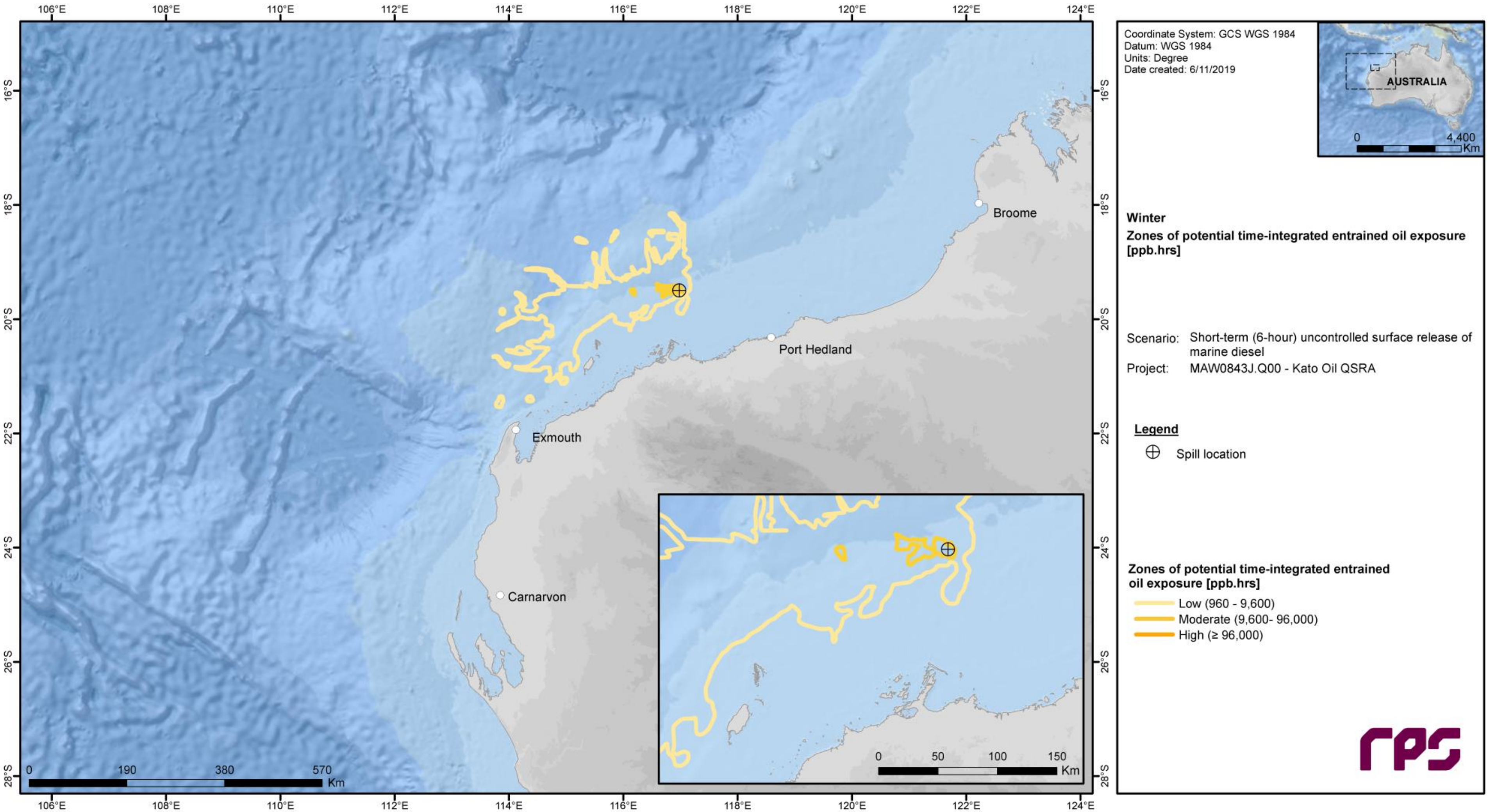

Figure 3.67 Predicted zones of potential time-integrated entrained oil exposure for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during winter.

3.3.3.3.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Table 3.32 Expected dissolved aromatic hydrocarbons outcomes at sensitive receptors resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during winter.

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	<1
	Southern Pilbara - Islands	<1	<1	<1	<1	<1
Coastlines	Dampier Archipelago	<1	<1	<1	NC	NC
	Eighty Mile Beach - Broome	<1	<1	<1	NC	NC
	Exmouth Gulf South East	<1	<1	<1	NC	NC
	Exmouth Gulf West	<1	<1	<1	NC	NC
	Karratha-Port Hedland	<1	<1	<1	NC	NC
	Kimberley Coast	<1	<1	<1	NC	NC
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC
	North Broome Coast	<1	<1	<1	NC	NC
	Northern Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC
	Port Hedland - Eighty Mile Beach	<1	<1	<1	NC	NC
	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC
State Marine and National Parks	Barrow Island MMA	<1	<1	<1	<1	<1
	Barrow Islands MP	<1	<1	<1	<1	<1
	Clerke Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC
	Eighty Mile Beach MP (State)	<1	<1	<1	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC
	Montebello Islands MP	<1	<1	<1	<1	<1
	Muiron Islands MMA	<1	<1	<1	<1	<1
	Ningaloo Coast WH	<1	<1	<1	<1	4
	Ningaloo MP (State)	<1	<1	<1	<1	4
Australian Marine Parks	Argo-Rowley Terrace MP	<1	<1	<1	<1	3
	Carnarvon Canyon MP	<1	<1	<1	NC	NC
	Dampier MP	<1	<1	<1	NC	NC
	Eighty Mile Beach MP	<1	<1	<1	NC	NC
	Gascoyne MP	<1	<1	<1	<1	10
	Mermaid Reef MP	<1	<1	<1	NC	NC
	Montebello MP	2	<1	<1	<1	46

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
	Ningaloo MP	<1	<1	<1	<1	3
	Shark Bay MP	<1	<1	<1	NC	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	28	7	<1	8	169
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	<1	<1	<1	<1	10
	Continental Slope Demersal Fish Communities KEF	5	1	<1	2	51
	Exmouth Plateau KEF	1	<1	<1	<1	13
	Glomar Shoals KEF	60	15	<1	21	218
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	<1	<1	<1	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	<1	<1	<1	NC	NC
Biologically Important Areas	Dolphins BIA	<1	<1	<1	NC	NC
	Dugong BIA	<1	<1	<1	<1	4
	Marine Turtle BIA	10	1	<1	3	168
	River Sharks BIA	<1	<1	<1	NC	NC
	Seabirds BIA	82	32	<1	40	265
	Sharks BIA	82	32	<1	40	265
	Whales BIA	82	32	<1	40	265
Fisheries	North-West Slope Trawl Fishery	5	1	<1	2	53
	Southern Bluefin Tuna Fishery	82	32	<1	40	265
	Western Skipjack Fishery	82	32	<1	40	265
	Western Tuna and Billfish Fishery	82	32	<1	40	265
Other	Rankin Bank	4	<1	<1	<1	18

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

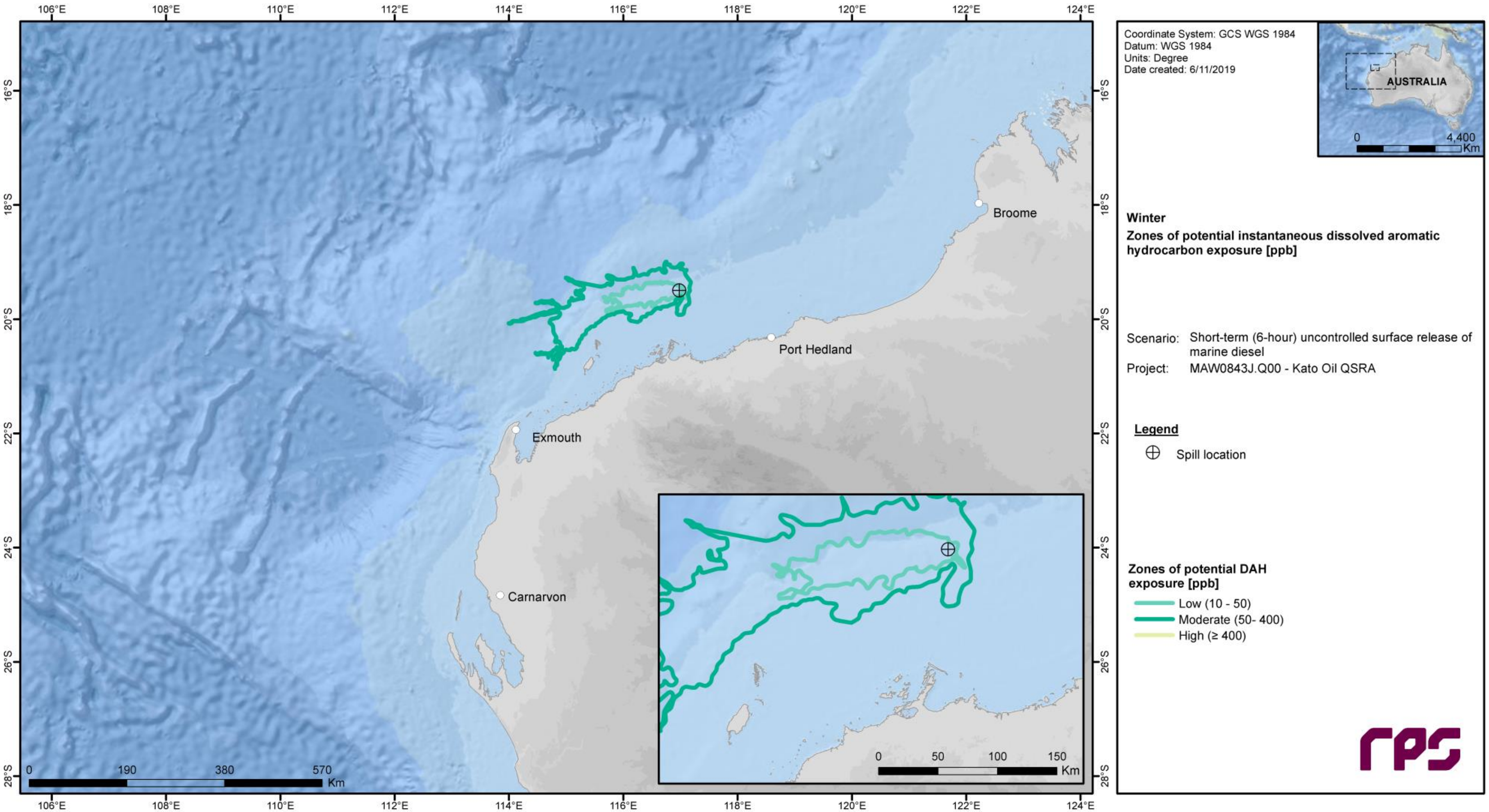

Figure 3.68 Predicted zones of potential dissolved aromatic hydrocarbon (DAH) exposure for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during winter.

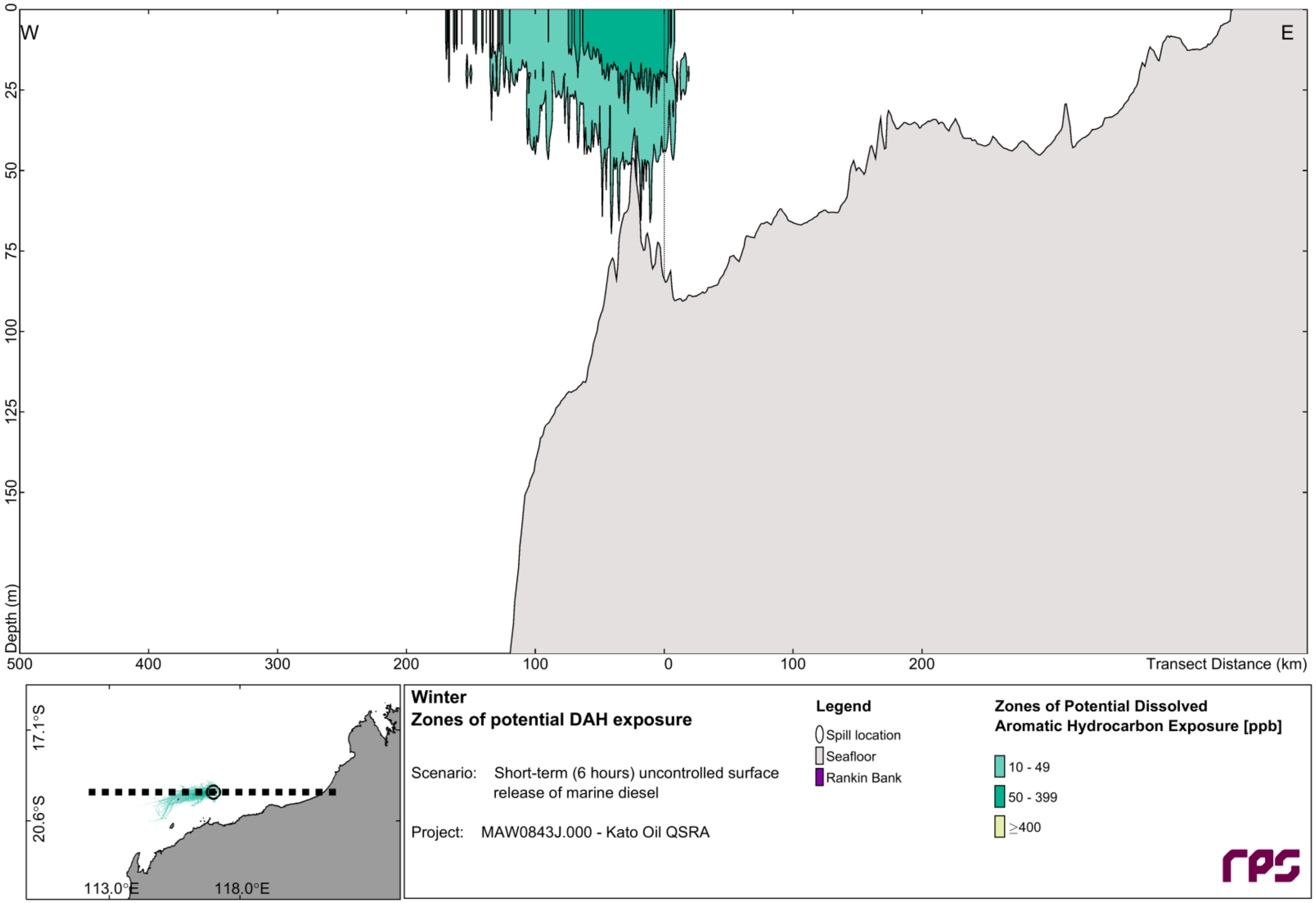

Figure 3.69 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the winter season. The results were calculated from 100 spill trajectories.

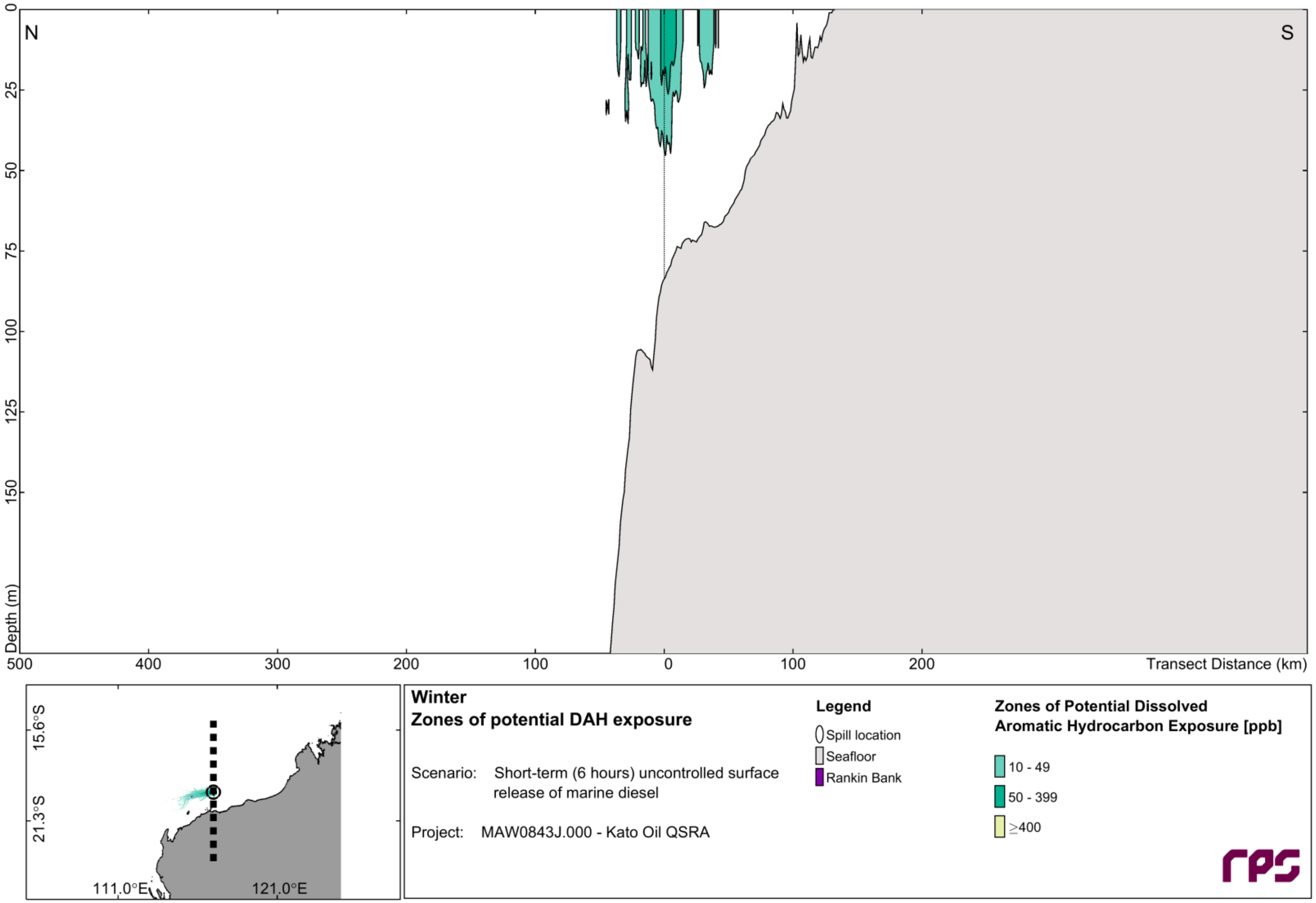

Figure 3.70 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the winter season. The results were calculated from 100 spill trajectories.

3.3.3.3.5 Dissolved Aromatic Hydrocarbon - Exposure

Table 3.33 Expected dissolved aromatic hydrocarbon exposure outcomes at sensitive receptors for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during winter.

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	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
	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
	Southern Pilbara - 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	1	1	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
	Eighty Mile Beach - Broome	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
	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	NC	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	NC	NC	BS	BS	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

	Receptors	Threshold (ppb.hr)	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
	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
	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	NC	BS	BS	BS	BS	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
	Eighty Mile Beach MP (State)	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
	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

	Receptors	Threshold (ppb.hr)	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	NC	NC	NC	NC	BS	BS
	Muiron Islands MMA	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	2	NC	2	NC	1	BS
	Ningaloo Coast WH	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	12	2	NC	2	NC	NC
	Ningaloo MP (State)	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	12	1	NC	1	NC	NC
Australian Marine Parks	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	3	4	3	2	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	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	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	14	15	10	11	2	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

Receptors		Threshold (ppb.hr)	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	64	71	31	29	8	NC
	Ningaloo 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	7	2	NC	2	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	NC	NC	NC	NC	NC	NC
Key Ecological Features	Ancient Coastline at 125m 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	635	581	213	88	19	2
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula 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	9	7	2	1	NC
	Continental Slope Demersal 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	122	108	141	26	5	NC
	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	13	16	19	7	NC	NC
	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	631	333	191	61	17	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
	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	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

	Receptors	Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Dugong 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	12	2	NC	1	NC	NC
	Marine Turtle 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	539	410	321	117	20	1
	River Sharks BIA	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
	Seabirds BIA	Probability (%) >960	1	1	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	1,389	1,112	377	174	35	NC
	Sharks BIA	Probability (%) >960	1	1	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	1,389	1,112	377	174	35	2
	Whales BIA	Probability (%) >960	1	1	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	1,389	1,112	377	174	35	2
Fisheries	North-West Slope Trawl Fishery	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	277	169	141	30	6	NC
	Southern Bluefin Tuna Fishery	Probability (%) >960	1	1	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	1,389	1,112	377	174	35	2
	Western Skipjack Fishery	Probability (%) >960	1	1	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	1,389	1,112	377	174	35	2
	Western Tuna and Billfish Fishery	Probability (%) >960	1	1	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	1,389	1,112	377	174	35	2
Other Submerged	Rankin Bank	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	19	71	39	BS	BS	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

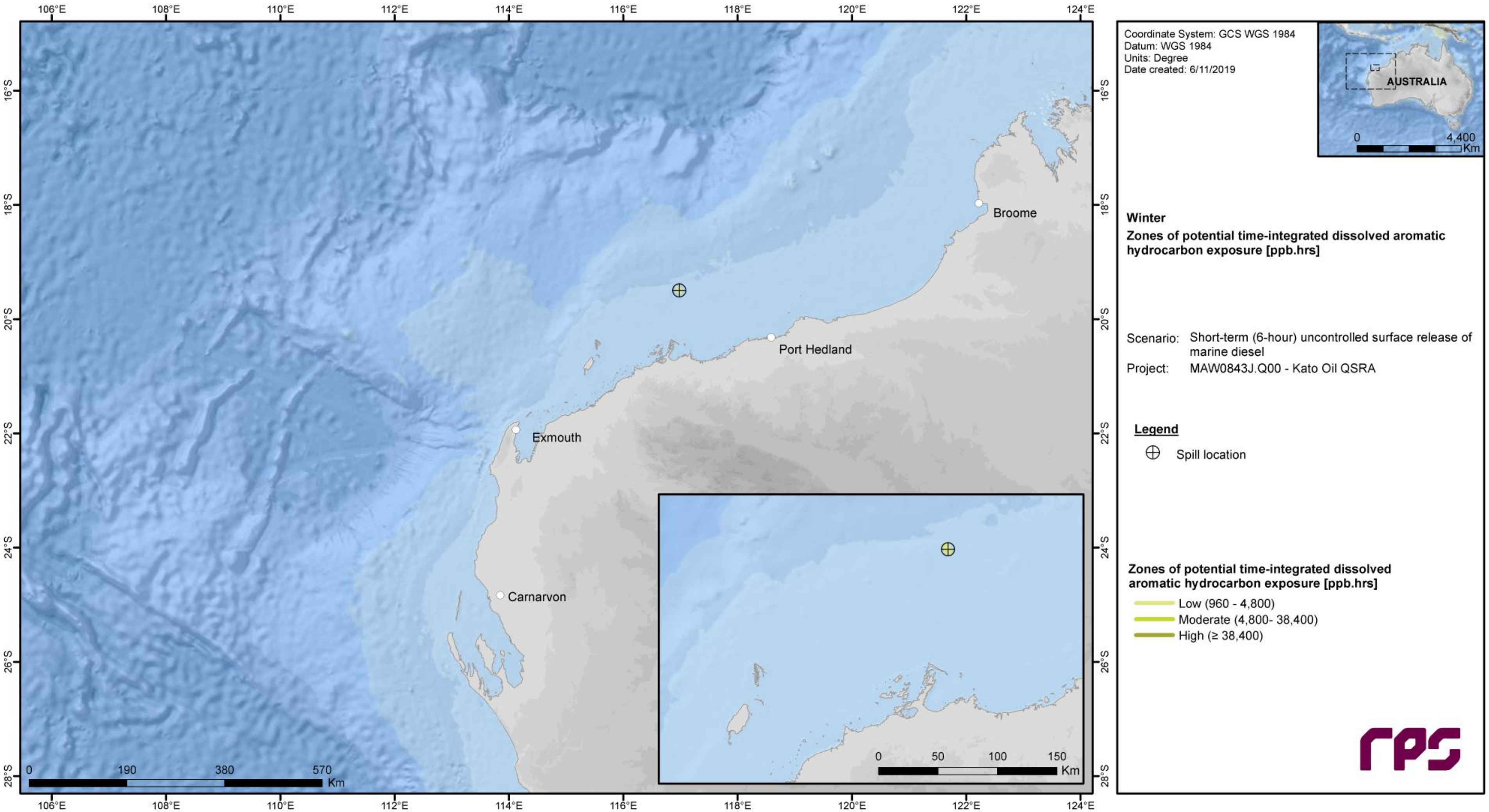

Figure 3.71 Predicted zones of potential time-averaged dissolved aromatic hydrocarbon exposure for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during winter.

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 for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during 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	Barrow Island	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	3.1	<1	<1	NC	NC	NC	NC	NC	NC
	Lowendal Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Montebello Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	1.5	<1	<1	NC	NC	NC	NC	NC	NC
	Southern Pilbara - Islands	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.5	<1	<1	NC	NC	NC	NC	NC	NC
Coastlines	Dampier Archipelago	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Eighty Mile Beach - Broome	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	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
	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
	Karratha-Port Hedland	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Kimberley Coast	<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	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	North Broome Coast	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Northern 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
	Port Hedland - Eighty Mile Beach	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	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
State Marine and National Parks	Barrow Island MMA	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.8	<1	<1	NC	NC	NC	NC	NC	NC
	Barrow Islands MP	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Clerke Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	4.4	<1	<1	NC	NC	NC	NC	NC	NC
	Eighty Mile Beach MP (State)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.7	<1	<1	NC	NC	NC	NC	NC	NC
	Montebello Islands MP	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	1.5	<1	<1	NC	NC	NC	NC	NC	NC
	Muiron Islands MMA	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Ningaloo Coast WH	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC	NC	NC	NC	NC
	Ningaloo MP (State)	<1	<1	<1	NC	NC	NC	<1	<1	<1	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC	NC	NC	NC	NC
Australian	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
	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
	Dampier MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Eighty Mile Beach MP*	<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 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
	Gascoyne MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Reef MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	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*	<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
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF*	10	4	1	6	6	7	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*	<1	<1	<1	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*	<1	<1	<1	NC	NC	NC	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
	Glomar Shoals KEF*	2	<1	<1	13	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*†	<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
Biologically Important Areas	Dolphins BIA*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dugong BIA*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marine Turtle BIA*†	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	River Sharks BIA*	<1	<1	<1	NC	NC	NC	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
	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*	<1	<1	<1	NC	NC	NC	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
Ot	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.

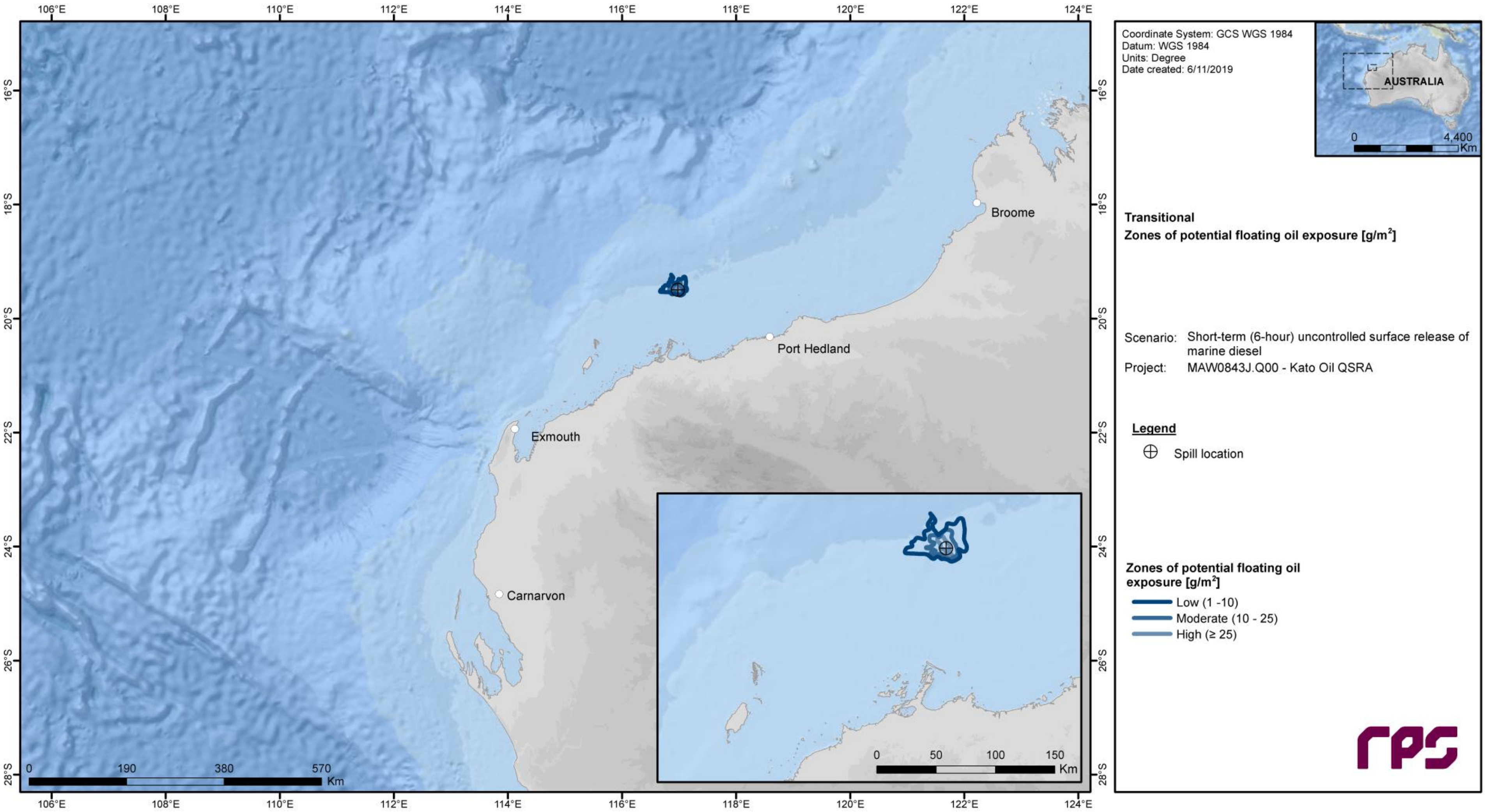

Figure 3.72 Predicted zones of potential floating oil exposure resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting in transitional months.

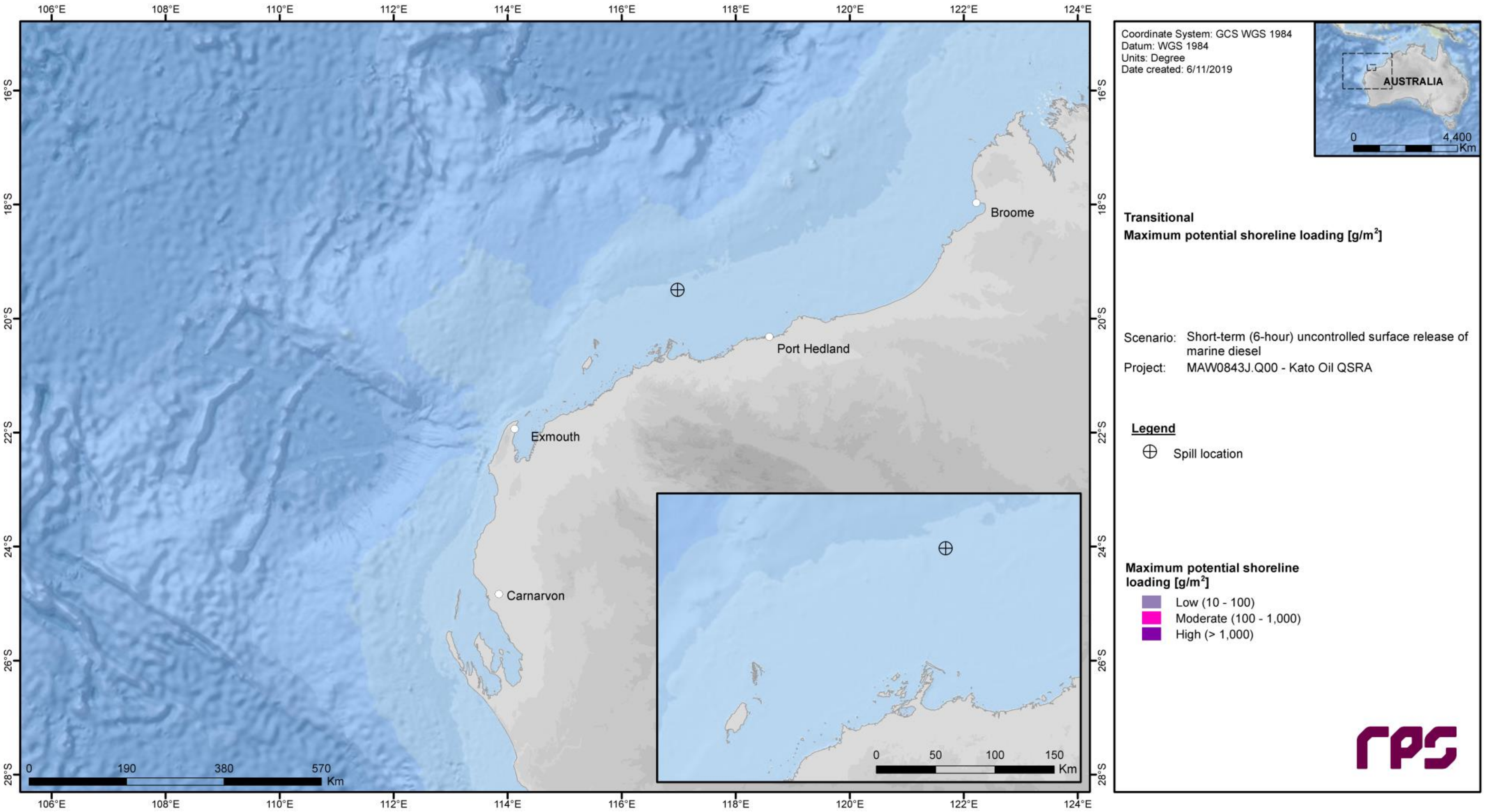

Figure 3.73 Predicted maximum potential shoreline loading resulting a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting in transitional months.

3.3.3.4.2 Entrained Oil - Instantaneous

Table 3.35 Expected entrained oil outcomes at sensitive receptors for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during summer.

Receptors		Probability (%) of entrained hydrocarbon concentration contact at			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	Barrow Island	<1	<1	<1	NC	NC	NC	<1	<1
	Lowendal Islands	<1	<1	<1	NC	NC	NC	NC	NC
	Montebello Islands	<1	<1	<1	NC	NC	NC	<1	<1
	Southern Pilbara - Islands	<1	<1	<1	NC	NC	NC	<1	2
Coastlines	Dampier Archipelago	<1	<1	<1	NC	NC	NC	NC	NC
	Eighty Mile Beach - Broome	<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	<1	<1
	Karratha-Port Hedland	<1	<1	<1	NC	NC	NC	NC	NC
	Kimberley Coast	<1	<1	<1	NC	NC	NC	NC	NC
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
	North Broome Coast	<1	<1	<1	NC	NC	NC	NC	NC
	Northern Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
	Port Hedland - Eighty Mile Beach	<1	<1	<1	NC	NC	NC	NC	NC
	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC	NC	NC	NC
State Marine and National Parks	Barrow Island MMA	<1	<1	<1	NC	NC	NC	<1	<1
	Barrow Islands MP	<1	<1	<1	NC	NC	NC	<1	<1
	Clerke Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	NC	NC
	Eighty Mile Beach MP (State)	<1	<1	<1	NC	NC	NC	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC	NC	NC	NC
	Montebello Islands MP	<1	<1	<1	NC	NC	NC	<1	5
	Muiron Islands MMA	<1	<1	<1	NC	NC	NC	<1	2
	Ningaloo Coast WH	1	<1	<1	335	NC	NC	<1	16
	Ningaloo MP (State)	<1	<1	<1	NC	NC	NC	<1	6
Australian Marine Parks	Argo-Rowley Terrace MP	3	<1	<1	310	NC	NC	<1	45
	Carnarvon Canyon MP	<1	<1	<1	NC	NC	NC	<1	3
	Dampier MP	<1	<1	<1	NC	NC	NC	NC	NC
	Eighty Mile Beach MP	<1	<1	<1	NC	NC	NC	NC	NC
	Gascoyne MP	5	<1	<1	188	NC	NC	2	95
	Mermaid Reef MP	<1	<1	<1	NC	NC	NC	NC	NC
	Montebello MP	13	1	<1	184	209	NC	6	212
	Ningaloo MP	1	<1	<1	335	NC	NC	<1	16
	Shark Bay MP	<1	<1	<1	NC	NC	NC	<1	<1
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	58	40	9	4	4	5	270	4,064
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	5	1	<1	217	300	NC	2	132
	Continental Slope Demersal Fish Communities KEF	27	8	<1	48	48	NC	20	601
	Exmouth Plateau KEF	5	<1	<1	260	NC	NC	2	57
	Glomar Shoals KEF	68	48	4	6	6	7	210	1,613
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	<1	<1	<1	NC	NC	NC	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	<1	<1	<1	NC	NC	NC	<1	<1
Biologically Important Areas	Dolphins BIA	<1	<1	<1	NC	NC	NC	NC	NC
	Dugong BIA	<1	<1	<1	NC	NC	NC	<1	6
	Marine Turtle BIA	38	13	<1	45	46	NC	33	524
	River Sharks BIA	<1	<1	<1	NC	NC	NC	NC	NC
	Seabirds BIA	90	79	34	1	1	1	1,082	13,028
	Sharks BIA	90	79	34	1	1	1	1,082	13,028
	Whales BIA	90	79	34	1	1	1	1,082	13,028
Fisheri	North-West Slope Trawl Fishery	27	8	<1	40	42	NC	20	601

Receptors		Probability (%) of entrained hydrocarbon concentration contact at			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
	Southern Bluefin Tuna Fishery	90	79	34	1	1	1	1,082	13,028
	Western Skipjack Fishery	90	79	34	1	1	1	1,082	13,028
	Western Tuna and Billfish Fishery	90	79	34	1	1	1	1,082	13,028
Other	Rankin Bank	16	3	<1	137	147	NC	11	248

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

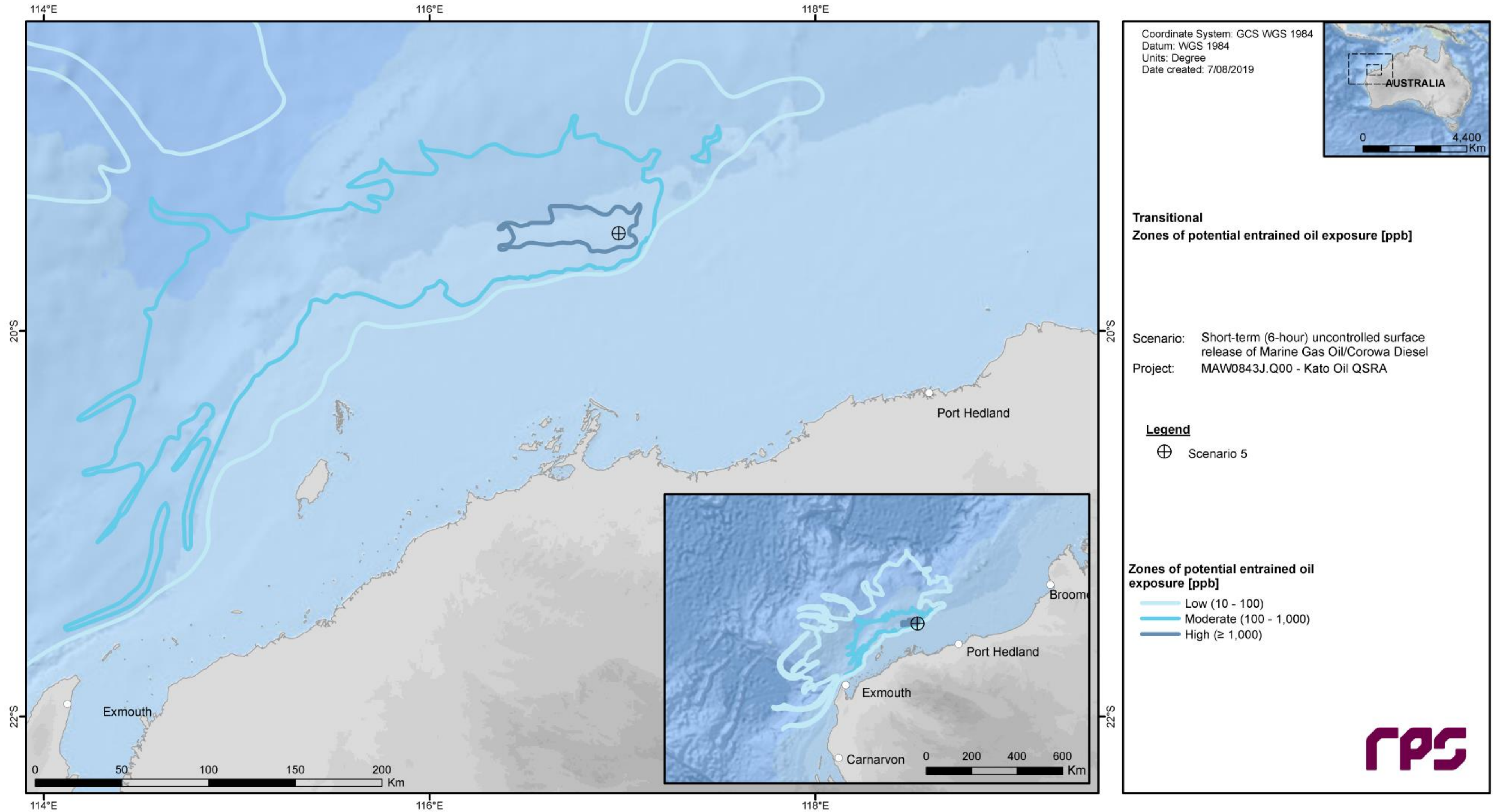

Figure 3.74 Predicted zones of potential entrained oil exposure for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during transitional months.

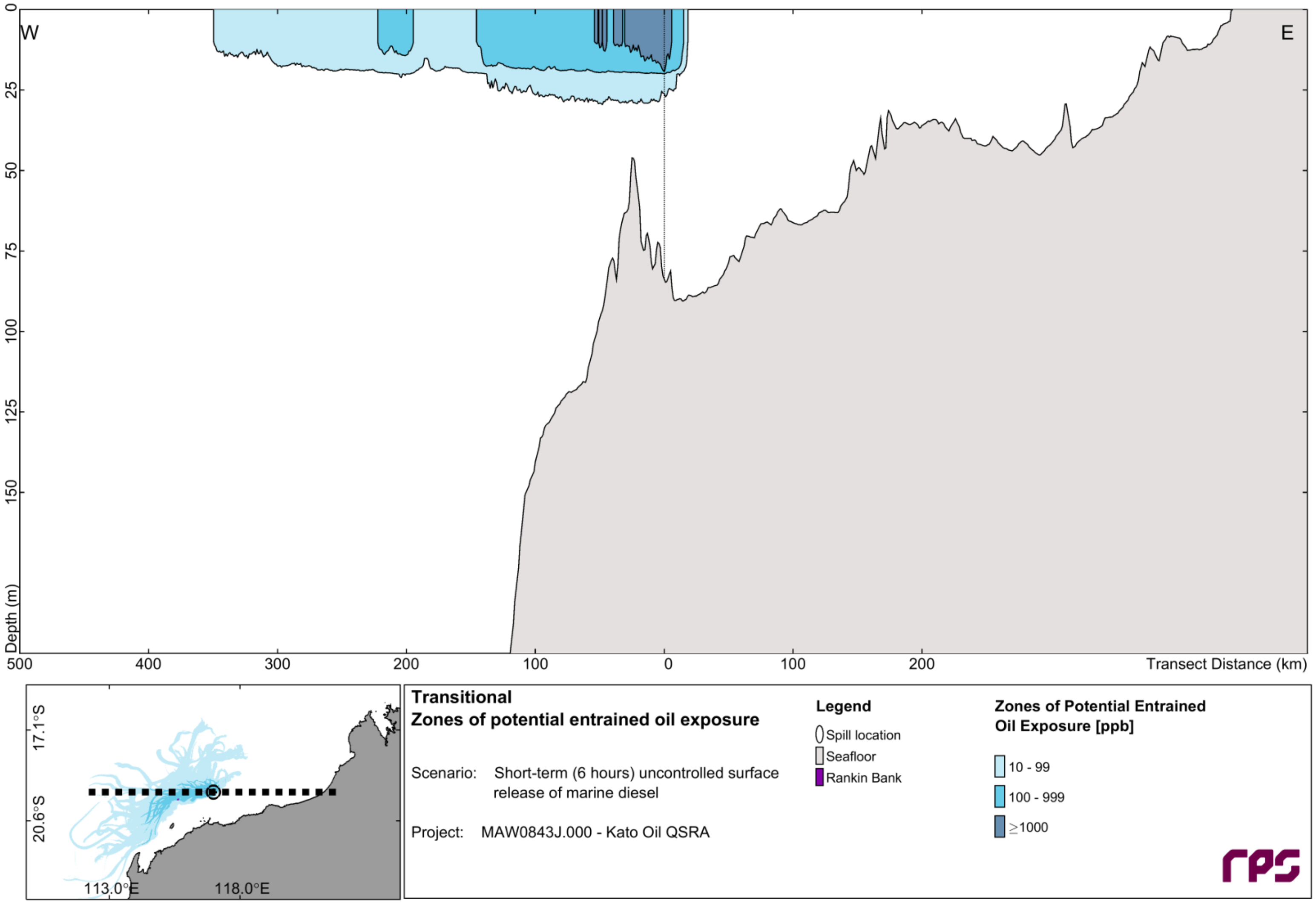

Figure 3.75 East-West cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the transitional period. The results were calculated from 100 spill trajectories.

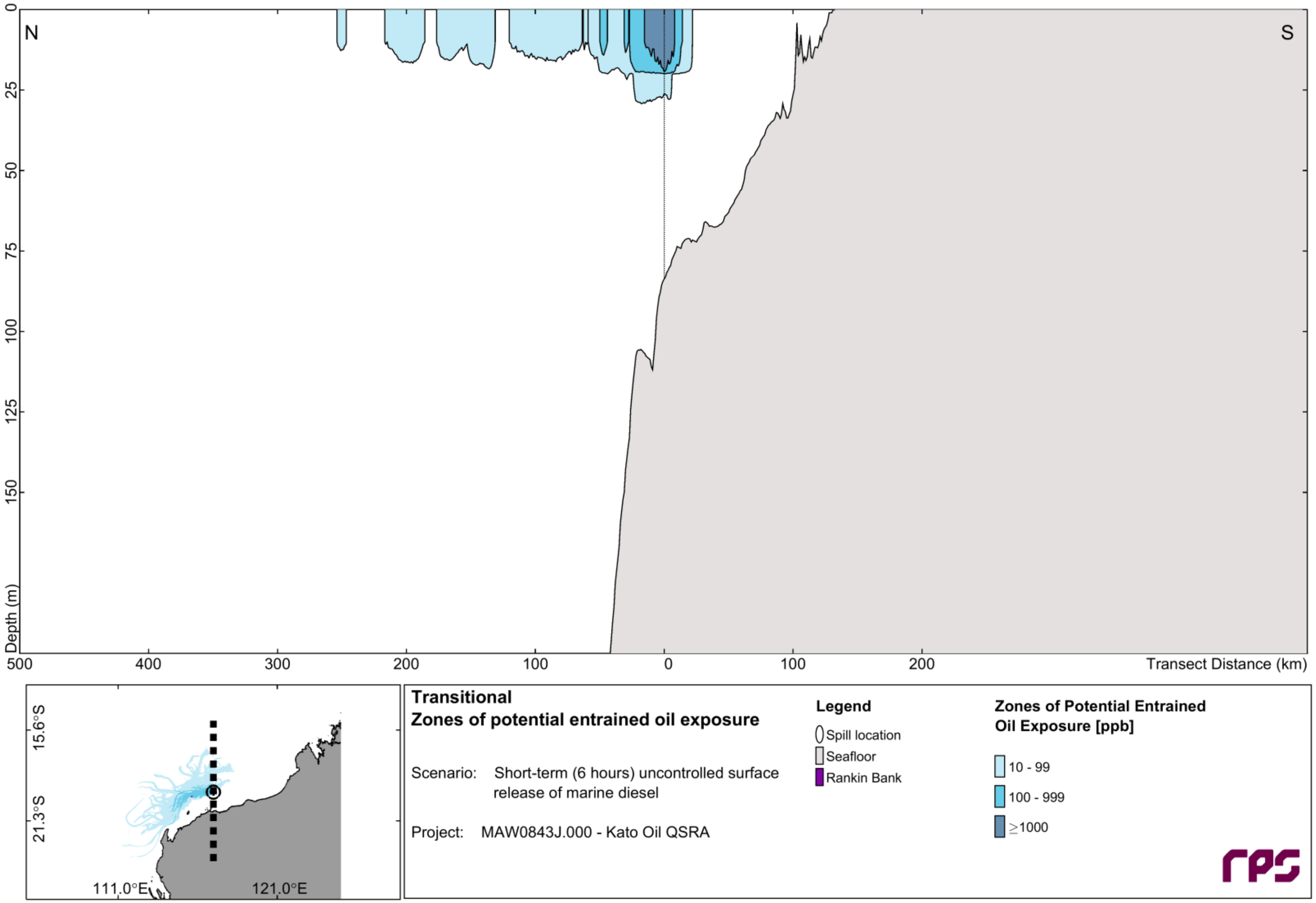

Figure 3.76 North-South cross-section transect of predicted maximum entrained oil concentration from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the transitional period. The results were calculated from 100 spill trajectories.

3.3.3.4.3 Entrained Oil - Exposure Outcomes

Table 3.36 Expected entrained oil exposure outcomes at sensitive receptors for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during transitional months.

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	Barrow Island	Probability (%) >960	NC	NC	NC	NC	BS	BS
Islands	Barrow Island	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
Islands	Barrow Island	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
Islands	Barrow Island	Maximum Integrated Exposure	14	2	NC	NC	BS	BS
Islands	Lowendal Islands	Probability (%) >960	NC	NC	NC	BS	BS	BS
Islands	Lowendal Islands	Probability (%) >9,600	NC	NC	NC	BS	BS	BS
Islands	Lowendal Islands	Probability (%) >96,000	NC	NC	NC	BS	BS	BS
Islands	Lowendal Islands	Maximum Integrated Exposure	NC	NC	NC	BS	BS	BS
Islands	Montebello Islands	Probability (%) >960	NC	NC	NC	NC	BS	BS
Islands	Montebello Islands	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
Islands	Montebello Islands	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
Islands	Montebello Islands	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Islands	Southern Pilbara - Islands	Probability (%) >960	NC	NC	NC	BS	BS	BS
Islands	Southern Pilbara - Islands	Probability (%) >9,600	NC	NC	NC	BS	BS	BS
Islands	Southern Pilbara - Islands	Probability (%) >96,000	NC	NC	NC	BS	BS	BS
Islands	Southern Pilbara - Islands	Maximum Integrated Exposure	37	4	1	BS	BS	BS
Coastlines	Dampier Archipelago	Probability (%) >960	NC	NC	NC	NC	BS	BS
Coastlines	Dampier Archipelago	Probability (%) >9,600	NC	NC	NC	NC	BS	BS
Coastlines	Dampier Archipelago	Probability (%) >96,000	NC	NC	NC	NC	BS	BS
Coastlines	Dampier Archipelago	Maximum Integrated Exposure	NC	NC	NC	NC	BS	BS
Coastlines	Eighty Mile Beach - Broome	Probability (%) >960	NC	NC	BS	BS	BS	BS
Coastlines	Eighty Mile Beach - Broome	Probability (%) >9,600	NC	NC	BS	BS	BS	BS
Coastlines	Eighty Mile Beach - Broome	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
Coastlines	Eighty Mile Beach - Broome	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
Coastlines	Exmouth Gulf South East	Probability (%) >960	NC	BS	BS	BS	BS	BS
Coastlines	Exmouth Gulf South East	Probability (%) >9,600	NC	BS	BS	BS	BS	BS
Coastlines	Exmouth Gulf South East	Probability (%) >96,000	NC	BS	BS	BS	BS	BS
Coastlines	Exmouth Gulf South East	Maximum Integrated Exposure	NC	BS	BS	BS	BS	BS
Coastlines	Exmouth Gulf West	Probability (%) >960	NC	NC	BS	BS	BS	BS
Coastlines	Exmouth Gulf West	Probability (%) >9,600	NC	NC	BS	BS	BS	BS
Coastlines	Exmouth Gulf West	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
Coastlines	Exmouth Gulf West	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
Coastlines	Karratha-Port Hedland	Probability (%) >960	NC	NC	BS	BS	BS	BS
Coastlines	Karratha-Port Hedland	Probability (%) >9,600	NC	NC	BS	BS	BS	BS
Coastlines	Karratha-Port Hedland	Probability (%) >96,000	NC	NC	BS	BS	BS	BS
Coastlines	Karratha-Port Hedland	Maximum Integrated Exposure	NC	NC	BS	BS	BS	BS
Coastlines	Kimberley Coast	Probability (%) >960	NC	NC	NC	NC	NC	BS
Coastlines	Kimberley Coast	Probability (%) >9,600	NC	NC	NC	NC	NC	BS

	Receptors	Threshold (ppb.hr)	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	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	NC	NC	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	NC	NC	BS	BS	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	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
State Marine and National Parks	Barrow Island MMA	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	19	4	NC	NC	BS	BS
	Barrow Islands 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	6	NC	NC	NC	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	NC	NC	NC	NC	NC	NC
	Eighty Mile Beach MP (State)	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
	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	NC	NC	NC	NC	NC	NC

	Receptors	Threshold (ppb.hr)	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 (%) >9,600	NC	NC	NC	NC	BS	BS
		Probability (%) >96,000	NC	NC	NC	NC	BS	BS
		Maximum Integrated Exposure	43	2	NC	NC	BS	BS
	Muiron Islands MMA	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	12	11	10	10	NC	BS
	Ningaloo Coast WH	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	325	32	10	2	NC	NC
	Ningaloo MP (State)	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	168	20	10	1	NC	NC
Australian Marine Parks	Argo-Rowley Terrace MP	Probability (%) >960	1	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	1,604	117	20	2	NC	NC
	Carnarvon Canyon 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	32	6	2	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	1	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	1,471	121	15	3	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	NC	NC	NC	NC	NC	NC
	Montebello MP	Probability (%) >960	2	NC	NC	NC	NC	NC
		Probability (%) >9,600	NC	NC	NC	NC	NC	NC

Receptors		Threshold (ppb.hr)	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	1,611	118	32	8	1	NC
	Ningaloo 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	325	32	7	2	NC	NC
	Shark Bay 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
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	31	1	NC	NC	NC	NC
		Probability (%) >9,600	3	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	20,411	1,243	207	24	2	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula 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	902	69	11	4	NC	NC
	Continental Slope Demersal Fish Communities KEF	Probability (%) >960	8	NC	NC	NC	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	10,346	533	54	10	1	NC
	Exmouth Plateau KEF	Probability (%) >960	1	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	1,268	100	17	4	NC	NC
	Glomar Shoals KEF	Probability (%) >960	34	NC	NC	NC	NC	BS
		Probability (%) >9,600	1	NC	NC	NC	NC	BS
		Probability (%) >96,000	NC	NC	NC	NC	NC	BS
		Maximum Integrated Exposure	10,549	573	99	32	1	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	NC	NC	NC	NC	NC	NC
	Western Demersal Slope and associated Fish Communities 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	2	NC	NC	NC	NC	NC
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

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Dugong 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	203	25	10	2	NC	NC
	Marine Turtle BIA	Probability (%) >960	12	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	6,996	529	78	14	1	NC
	River Sharks BIA	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
	Seabirds BIA	Probability (%) >960	59	1	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	60,636	1,236	154	33	2	NC
	Sharks BIA	Probability (%) >960	59	1	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	60,636	1,250	207	33	2	NC
	Whales BIA	Probability (%) >960	59	1	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	60,636	1,250	207	33	2	NC
Fisheries	North-West Slope Trawl Fishery	Probability (%) >960	8	NC	NC	NC	NC	NC
		Probability (%) >9,600	1	NC	NC	NC	NC	NC
		Probability (%) >96,000	NC	NC	NC	NC	NC	NC
		Maximum Integrated Exposure	10,346	518	60	12	1	NC
	Southern Bluefin Tuna Fishery	Probability (%) >960	59	1	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	60,636	1,250	207	33	2	NC
	Western Skipjack Fishery	Probability (%) >960	59	1	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	60,636	1,250	207	33	2	NC
	Western Tuna and Billfish Fishery	Probability (%) >960	59	1	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	60,636	1,250	207	33	2	NC
Other Submerged	Rankin Bank	Probability (%) >960	3	NC	NC	BS	BS	BS
		Probability (%) >9,600	NC	NC	NC	BS	BS	BS

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >96,000	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	2,167	117	37	BS	BS	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

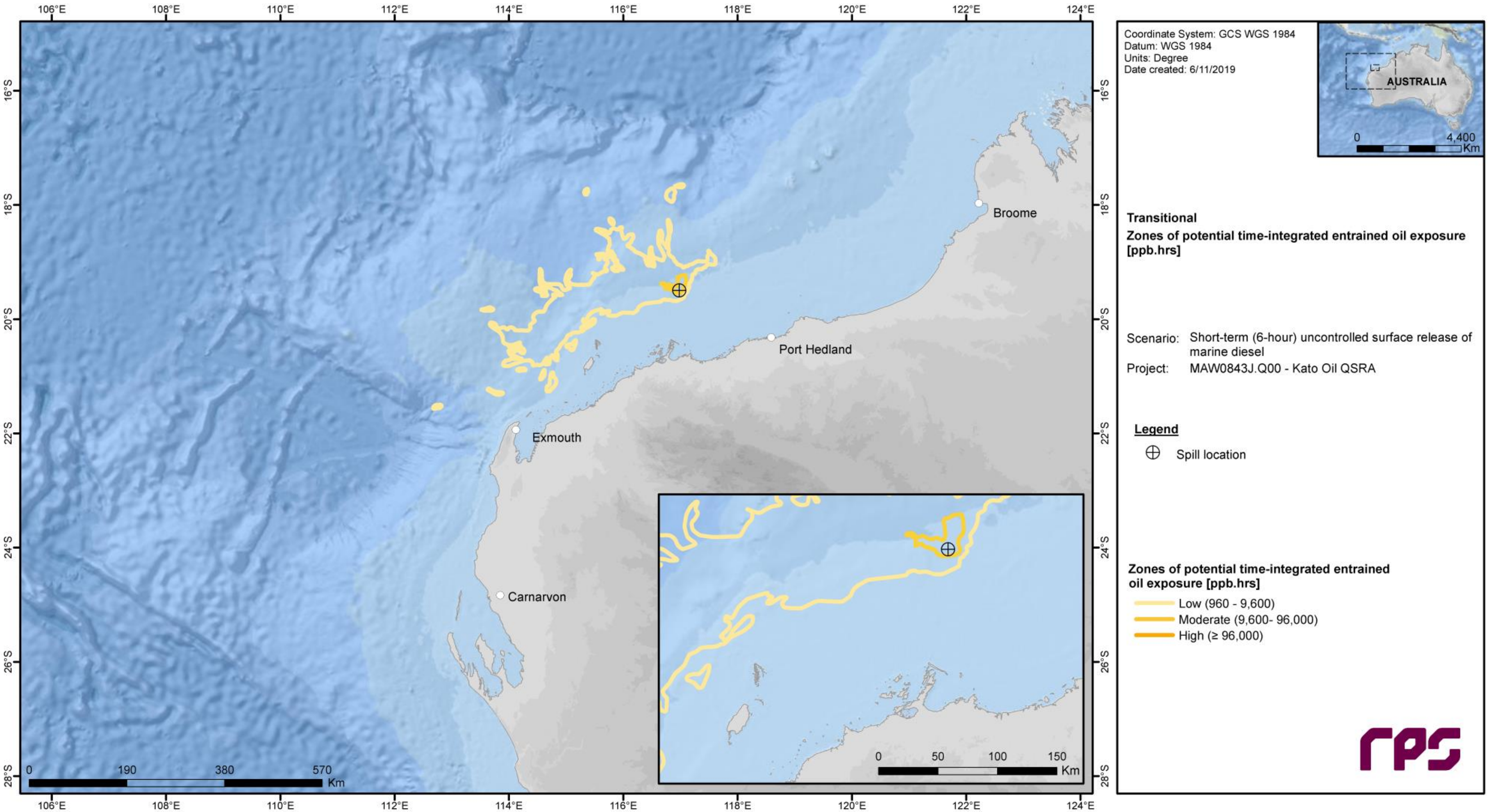

Figure 3.77 Predicted zones of potential time-averaged entrained oil exposure for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during transitional months.

3.3.3.4.4 Dissolved Aromatic Hydrocarbons - Instantaneous

Table 3.37 Expected dissolved aromatic hydrocarbons outcomes at sensitive receptors resulting from a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during 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	<1	<1
	Southern Pilbara - Islands	<1	<1	<1	<1	<1
Coastlines	Dampier Archipelago	<1	<1	<1	NC	NC
	Eighty Mile Beach - Broome	<1	<1	<1	NC	NC
	Exmouth Gulf South East	<1	<1	<1	NC	NC
	Exmouth Gulf West	<1	<1	<1	NC	NC
	Karratha-Port Hedland	<1	<1	<1	NC	NC
	Kimberley Coast	<1	<1	<1	NC	NC
	Middle Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC
	North Broome Coast	<1	<1	<1	NC	NC
	Northern Pilbara - Islands and Shoreline	<1	<1	<1	NC	NC
	Port Hedland - Eighty Mile Beach	<1	<1	<1	NC	NC
	Southern Pilbara - Shoreline	<1	<1	<1	NC	NC
State Marine and National Parks	Barrow Island MMA	<1	<1	<1	<1	<1
	Barrow Islands MP	<1	<1	<1	<1	<1
	Clerke Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC
	Eighty Mile Beach MP (State)	<1	<1	<1	NC	NC
	Imperieuse Reef (Rowley Shoals MP)	<1	<1	<1	NC	NC
	Montebello Islands MP	<1	<1	<1	<1	<1
	Muiron Islands MMA	<1	<1	<1	<1	<1
	Ningaloo Coast WH	<1	<1	<1	<1	2
	Ningaloo MP (State)	<1	<1	<1	<1	<1
Australian Marine Parks	Argo-Rowley Terrace MP	<1	<1	<1	<1	7
	Carnarvon Canyon MP	<1	<1	<1	NC	NC
	Dampier MP	<1	<1	<1	NC	NC
	Eighty Mile Beach MP	<1	<1	<1	NC	NC
	Gascoyne MP	<1	<1	<1	<1	6
	Mermaid Reef MP	<1	<1	<1	NC	NC
	Montebello MP	2	<1	<1	<1	33

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
	Ningaloo MP	<1	<1	<1	<1	2
	Shark Bay MP	<1	<1	<1	<1	<1
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	32	8	<1	11	266
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF	<1	<1	<1	<1	7
	Continental Slope Demersal Fish Communities KEF	7	1	<1	2	68
	Exmouth Plateau KEF	1	<1	<1	<1	13
	Glomar Shoals KEF	44	7	<1	12	210
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals KEF	<1	<1	<1	NC	NC
	Western Demersal Slope and associated Fish Communities KEF	<1	<1	<1	NC	NC
Biologically Important Areas	Dolphins BIA	<1	<1	<1	NC	NC
	Dugong BIA	<1	<1	<1	<1	2
	Marine Turtle BIA	8	1	<1	3	89
	River Sharks BIA	<1	<1	<1	NC	NC
	Seabirds BIA	57	19	<1	26	296
	Sharks BIA	57	19	<1	26	296
	Whales BIA	57	19	<1	26	296
Fisheries	North-West Slope Trawl Fishery	7	1	<1	2	85
	Southern Bluefin Tuna Fishery	57	19	<1	26	296
	Western Skipjack Fishery	57	19	<1	26	296
	Western Tuna and Billfish Fishery	57	19	<1	26	296
Ot he	Rankin Bank	4	<1	<1	2	40

NC: No contact to receptor predicted for specified threshold.

§ Probabilities and maximum concentrations calculated at depth of submerged feature.

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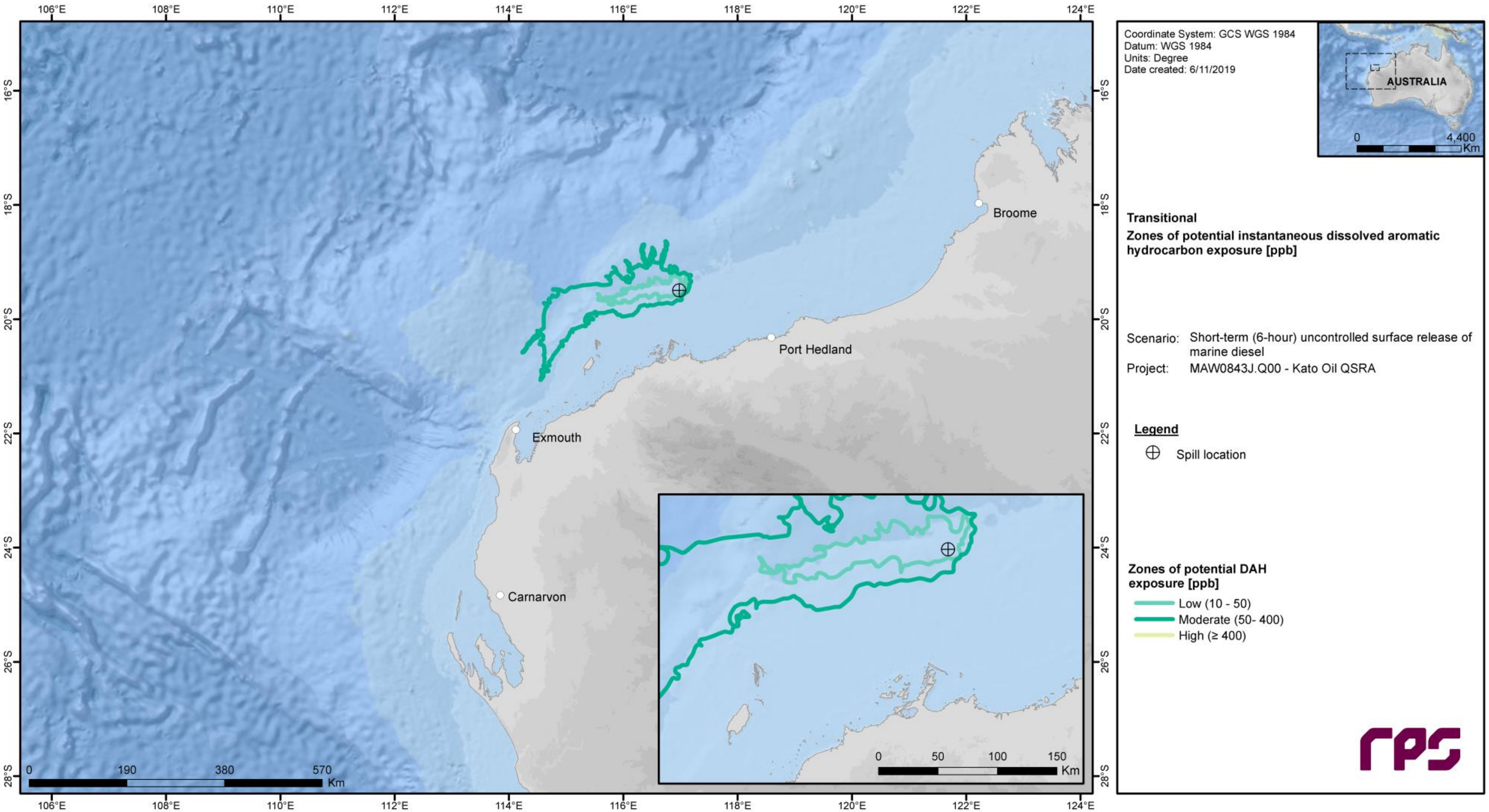

Figure 3.78 Predicted zones of potential dissolved aromatic hydrocarbon (DAH) exposure for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting in transitional months.

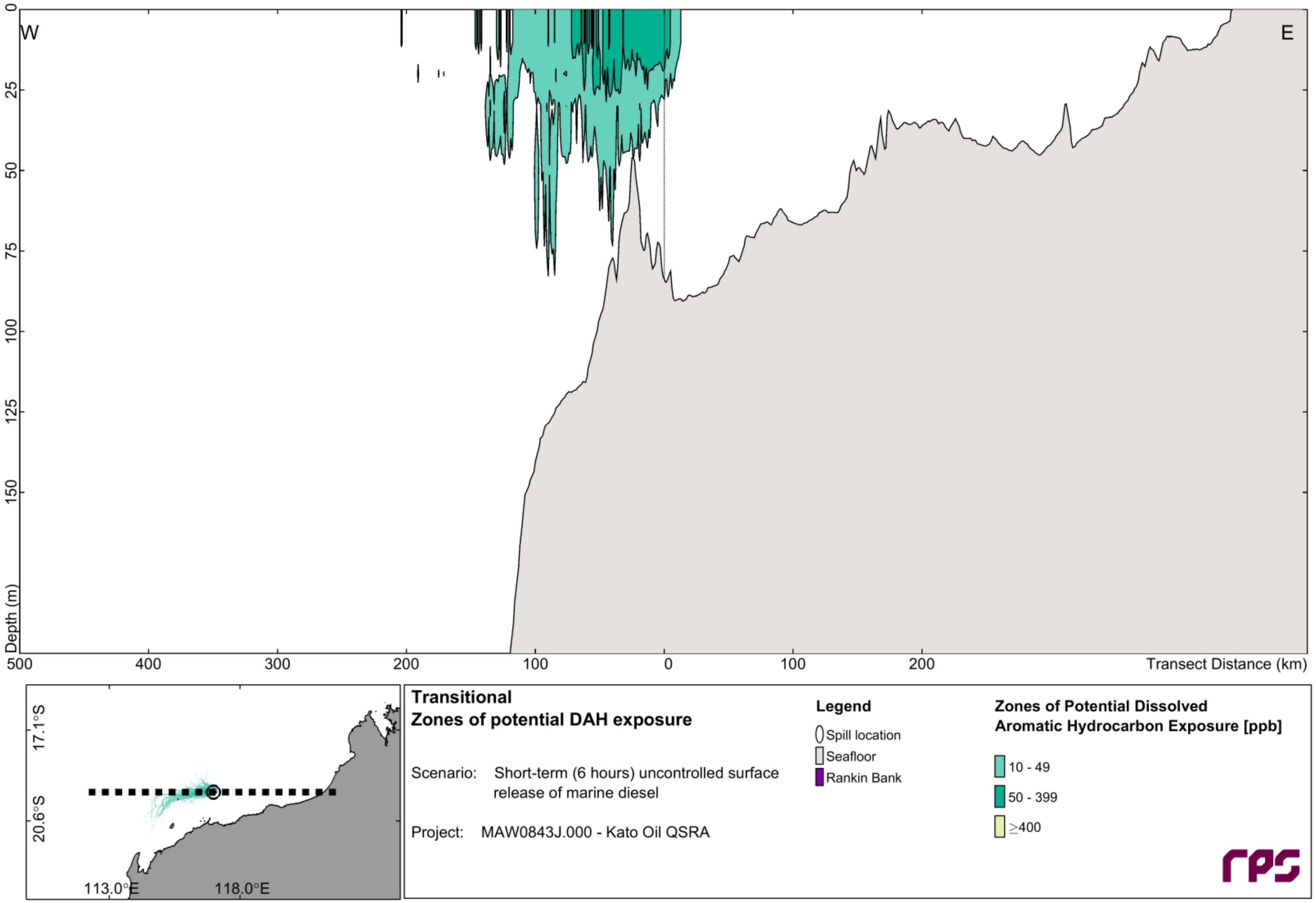

Figure 3.79 East-West cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the transitional period. The results were calculated from 100 spill trajectories.

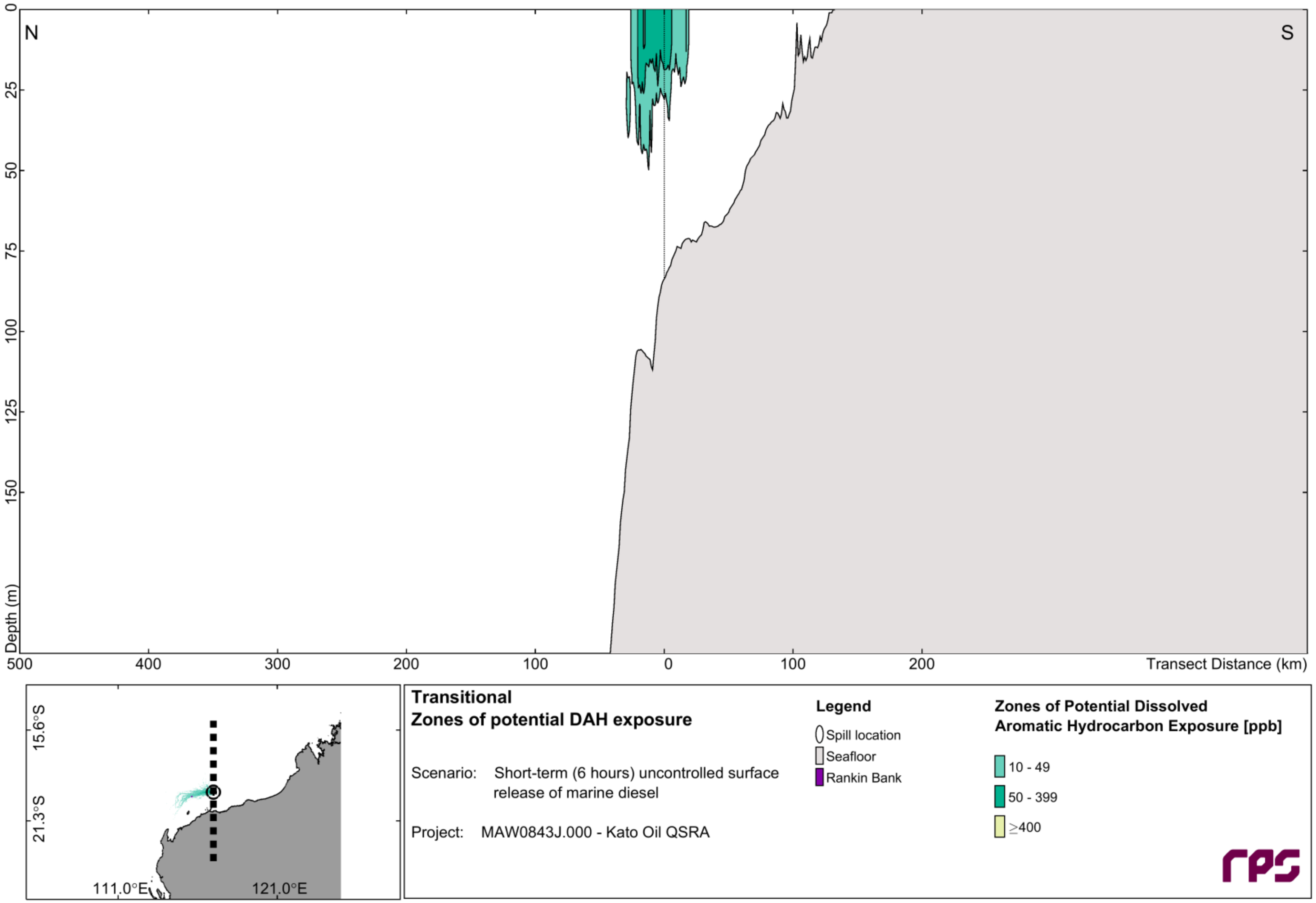

Figure 3.80 North-South cross-section transect of predicted maximum dissolved aromatic hydrocarbon concentrations from a short term (6-hour) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, commencing in the transitional period. The results were calculated from 100 spill trajectories.

3.3.3.4.5 Dissolved Aromatic Hydrocarbon - Exposure

Table 3.38 Expected dissolved aromatic hydrocarbon exposure outcomes at sensitive receptors for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during transitional months.

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
Islands	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
	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
	Southern Pilbara - 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
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
	Eighty Mile Beach - Broome	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
	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	NC	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	NC	NC	BS	BS	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

	Receptors	Threshold (ppb.hr)	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
	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
	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	NC	BS	BS	BS	BS	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
	Eighty Mile Beach MP (State)	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
	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

Receptors		Threshold (ppb.hr)	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	NC	NC	NC	NC	BS	BS
	Muiron Islands MMA	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
	Ningaloo Coast WH	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	2	1	NC	1	1	NC
	Ningaloo MP (State)	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
Australian Marine Parks	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	21	19	13	2	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	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	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	12	7	6	2	1	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

Receptors		Threshold (ppb.hr)	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	65	25	36	36	3	NC
	Ningaloo 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	2	1	NC	1	1	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	NC	NC	NC	NC	NC	NC
Key Ecological Features	Ancient Coastline at 125m Depth Contour KEF	Probability (%) >960	NC	1	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	779	1,219	329	97	23	NC
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula 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	13	13	6	3	1	NC
	Continental Slope Demersal 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	98	136	123	37	8	NC
	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	16	14	20	10	1	NC
	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	340	329	150	75	5	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
	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	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

	Receptors	Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
	Dugong 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	1	NC	NC
	Marine Turtle 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	205	131	110	52	47	NC
	River Sharks BIA	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
	Seabirds BIA	Probability (%) >960	2	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	1,795	528	304	132	47	NC
	Sharks BIA	Probability (%) >960	2	1	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	1,795	1,219	403	132	47	NC
	Whales BIA	Probability (%) >960	2	1	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	1,795	1,219	403	132	47	NC
Fisheries	North-West Slope Trawl Fishery	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	150	189	213	59	6	NC
	Southern Bluefin Tuna Fishery	Probability (%) >960	2	1	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	1,795	1,219	403	132	47	NC
	Western Skipjack Fishery	Probability (%) >960	2	1	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	1,795	1,219	403	132	47	NC
	Western Tuna and Billfish Fishery	Probability (%) >960	2	1	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	1,795	1,219	403	132	47	NC
Other Submerged	Rankin Bank	Probability (%) >960	NC	NC	NC	BS	BS	BS
		Probability (%) >4,800	NC	NC	NC	BS	BS	BS

Receptors		Threshold (ppb.hr)	0-10m BMSL	10-20m BMSL	20-30m BMSL	30-50m BMSL	50-100m BMSL	100-150m BMSL
		Probability (%) >38,400	NC	NC	NC	BS	BS	BS
		Maximum Integrated Exposure	16	103	94	BS	BS	BS

NC: No contact to receptor predicted for specified threshold.

BS: Below seabed.

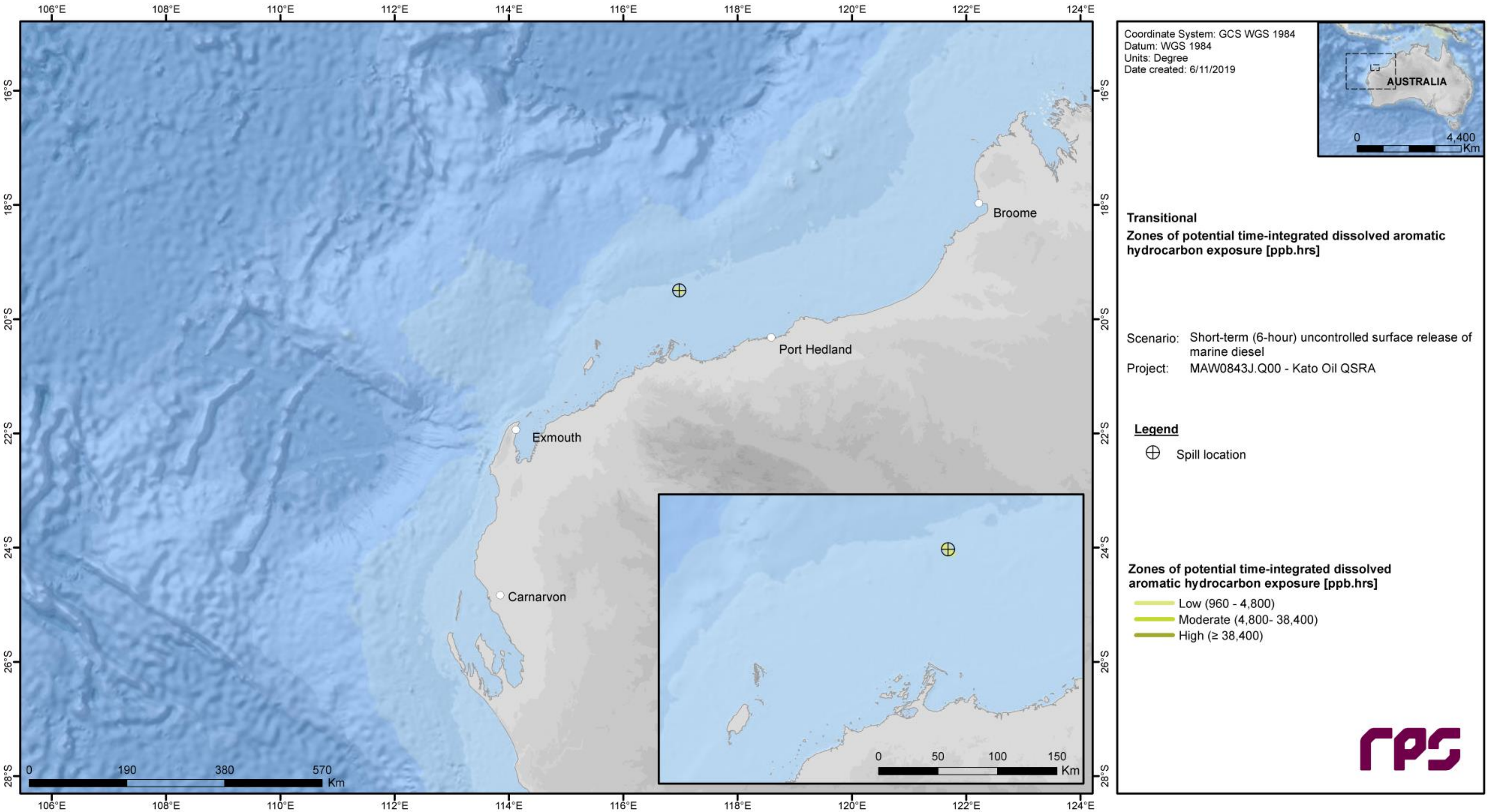

Figure 3.81 Predicted zones of potential time-integrated dissolved aromatic hydrocarbon exposure for a short-term (6 hours) surface release of marine gas oil from a rupture of a supply vessel tank within the Amulet field, starting during transitional months.

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 Amulet 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 79% of the mass will be expected to evaporate in around 24 hours and another 16% 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 Amulet Crude within the Amulet 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 the worst-case spill simulation was calculated as 18 m^3, for a spill commencing in summer (run 11). During this deterministic case, the highest accumulation was predicted for the Ningaloo World Heritage Area shoreline receptor.

- The maximum extent of hydrocarbon exposure from the spill location for this case is predicted as 495 km for the entrained oil at concentrations equal to or greater than the moderate (100 ppb) threshold.

Stochastic Modelling Assessment

- Floating oil concentrations exceeding the low threshold (1 g/m^2) could travel up to 393 km from the release location, with distances reducing at the moderate (10 g/m^2; 58 km) and high (25 g/m^2; 19 km) thresholds.
- Floating oil contact at the low threshold (1 g/m^2) is not predicted to occur at any of the assessed shoreline receptors, in any season.
- The worst-case oil accumulation on a shoreline is predicted for the Ningaloo Coast World Heritage Area receptor in summer, with an accumulated concentration and volume of 173 g/m^2 and 18 m^3, respectively.
- The worst-case maximum length of shoreline with concentrations exceeding the low threshold (10 g/m^2) was calculated as 28 km at the Ningaloo Coast WH and Ningaloo MP (State) receptors in summer
- Entrained oil concentrations exceeding the low threshold (10 ppb) could travel up to 1,483 km from the release location, with distances reducing at the moderate (100 ppb; 832 km) and high (1,000 ppb; 212 km) thresholds.
- The probability of contact by entrained oil concentrations at the moderate threshold (100 ppb) is predicted to be greatest at Seabirds, Sharks and Whales Biologically Important Areas and Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery at 100% across all seasons. Entrained oil at the moderate threshold is predicted to arrive at these receptors within 1 hours after the release commences.
- The worst-case instantaneous entrained oil concentration at any receptor is predicted at the Seabirds, Sharks and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 5,246 ppb.
- Entrained oil concentrations in the vicinity of the release site above the moderate (100 ppb) and high (1,000 ppb) thresholds are not expected to exceed depths of around 25 m and 35 m BMSL, respectively, in any season. Therefore, limiting benthic contact below this depth.
- Time-integrated entrained oil exposure at or above the 960 ppb.hr threshold could travel up to 992 km from the release location, with the distance reducing to 483 km and 40 km as contact thresholds increase to 9,600 ppb.hr and 96,000 ppb.hr, respectively.
- The probability of contact by time-integrated exposure of entrained oil concentrations at the 96,00 ppb.hr threshold is predicted to be greatest at Biologically Important Areas for Seabirds, Sharks and Whales and the Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery with a probability of 100% across all seasons.
- The worst-case entrained oil maximum integrated exposure is predicted at Seabirds, Sharks and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 135,616 ppb.hr.
- Dissolved aromatic hydrocarbon concentrations exceeding the low threshold (10 ppb) could travel up to 626 km from the release location, with distances reducing at the moderate (50 ppb; 584 km) and high (400 ppb; 51 km) thresholds.
- The probability of contact by dissolved aromatic hydrocarbon concentrations at the moderate threshold (50 ppb) is predicted to be greatest at Biologically Important Areas for Seabirds, Sharks and Whales and the Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors with probabilities of 100% across all seasons.

- The worst-case dissolved aromatic hydrocarbon concentrations at any receptor is predicted as 576 ppb at the Ancient Coastline at 125 m Depth Contour Key Ecological Feature, Seabirds, Sharks and Whales Biologically Important Areas and Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries.

- Dissolved aromatic hydrocarbon concentrations in the vicinity of the release site above the high threshold (400 ppb) are not expected to exceed depths of around 80 m BMSL in any season. Therefore, limiting benthic contact below this depth.

- Time integrated dissolved aromatic hydrocarbon exposure at or above 960 ppb.hr are predicted to occur up to 723 km from the release site, with the distance reducing to 605 km as the contact threshold increases to 4,800 ppb.hr.

- The probability of contact by dissolved aromatic hydrocarbon exposure at the 4,800 ppb.hr threshold was predicted to be greatest at the Seabirds, Sharks and Whales Biologically Important Areas and Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors with a probability of 10% in the surface layer (0-10 m) in winter.

- The worst-case maximum dissolved aromatic hydrocarbon exposure concentration at any receptor is predicted at Biologically Important Areas for Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 9,417 ppb.hr.

- 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 1.5 m^3 for a spill commencing in summer (replicate 32). During this deterministic case, the maximum oil loading along an individual shoreline receptor was predicted at Lowendal Islands.

- The maximum extent of hydrocarbon exposure from the spill location for this deterministic case is predicted as 70 km for the shoreline oil at or above the moderate (100 g/m^2) threshold.

Stochastic Modelling Assessment

- Floating oil concentrations exceeding the low threshold (1 g/m^2) could travel up to 217 km from the release, with the distance reducing at the moderate (10 g/m^2; 17 km) and high (25 g/m^2; 14 km) thresholds.

- Floating oil contact at the low threshold (1 g/m^2) is not predicted to occur at any of the assessed shoreline receptors, in any season.

- The worst-case oil accumulation on a given shoreline is forecast in the summer season at the Southern Pilbara Islands receptor with a predicted accumulated concentration and volume of 42 g/m^2 and 1 m^3, respectively.

- The worst-case maximum length of shoreline with concentrations exceeding the low threshold (10 g/m^2) was calculated as 2 km at the Southern Pilbara – Islands receptor in summer.

- Entrained oil concentrations exceeding the low threshold (10 ppb) could travel up to 725 km from the release location, with the distance reducing at the moderate (100 ppb; 376 km) and high (1,000 ppb; 76 km) thresholds.
- The probability of contact by entrained oil concentrations at the moderate threshold (100 ppb) is predicted to be greatest at the Seabirds BIA, Sharks BIA, Whales BIA, Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery at 34-63% across all seasons. Entrained oil concentrations at the moderate 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 at Biologically Important Areas for Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 2,112 ppb in winter.
- Entrained oil concentrations in the vicinity of the release site above the moderate (100 ppb) and high (1,000 ppb) thresholds are expected to exceed depths of around 25 m and 35 m BMSL, respectively, in any season. Therefore, limiting benthic contact below this depth.
- Time-integrated entrained oil exposure at or above the 960 ppb.hr threshold could travel up to 571 km from the release location, with the distance reducing to 198 km as the contact threshold increases to 9,600 ppb.hr.
- The probability of contact by time-integrated exposure of entrained oil concentrations at the 9,600 ppb.hr threshold is predicted to be greatest at the Seabirds, Sharks and Whales Biologically Important Areas and for the Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors with a probability of 100% in the surface layer (0-10 m) in transitional months.
- The worst-case entrained oil maximum integrated exposure is predicted at Biologically Important Areas for Seabirds, Sharks and Whales and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 60,636 ppb.hr.
- Dissolved aromatic hydrocarbon concentrations exceeding the low threshold (10 ppb) could travel up to 352 km from the release location, with distances reducing at the moderate (50 ppb; 234 km) threshold.
- The probability of contact by dissolved aromatic hydrocarbon concentrations at the moderate threshold (50 ppb) is predicted to be greatest at the Seabirds, Sharks, and Whales Biologically Important Areas and Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries at 19-32% across all seasons.
- The worst-case dissolved aromatic hydrocarbon concentrations at any receptor is predicted at Biologically Important Areas for Seabirds, Sharks and Whales and Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries receptors as 275 ppb in summer.
- Dissolved aromatic hydrocarbon concentrations in the vicinity of the release site above the moderate threshold (50 ppb) are not expected to exceed depths of around 30 m BMSL in any season. Therefore, limiting benthic contact below this depth.
- Time integrated dissolved aromatic hydrocarbon exposure at or above 960 ppb.hr are predicted to occur up to 10 km from the release site.
- Dissolved aromatic hydrocarbon exposure above the 960 ppb.hr threshold was not predicted at any receptor with probabilities greater than 2%, across all seasons in the surface layer.
- The worst-case maximum dissolved aromatic hydrocarbon exposure concentration at any receptor is predicted at the Seabirds, Sharks and Whales Biologically Important Areas and the Southern Bluefin Tuna, Western Skipjack and Western Tuna and Billfish Fisheries as 1,795 ppb.hr.

- 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.

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