Appendix A: Water Quality Study (AECOM 2016)

AECOM

Shell Crux Baseline Surveys
Shell Australia Pty Ltd
15-Sep-2016
Doc No. R1828/M&C4039

Commercial-in-Confidence

Crux Field Baseline Water Quality Assessment

Shell Crux Baseline Environmental Surveys

Crux Field Baseline Water Quality Assessment

Shell Crux Baseline Environmental Surveys

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15-Sep-2016

Job No.: 604955921

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Quality Information

Document	Crux Field Baseline Water Quality Assessment
Ref	604955921 \\auper1fp001.au.aecomnet.com\projects\604x\60495521\8. issued docs\8.1 reports\r1828 wq_report\rev 0\crux field baseline water quality_rev 0.docx
Date	15-Sep-2016
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Reviewed by	Ian Baxter

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	15-Jul-2016	For Client Review	Ian Baxter Technical Director - Marine Environment	
0	12-Sep-2016	For Use	Ian Baxter Technical Director - Marine Environment	

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Executive Summary

The Crux Field is located in Commonwealth waters in the Browse Basin (Timor Sea) approximately 110 km south-east of Cartier Island, 200 km off the Kimberley coast, 260 km from the Indonesian archipelago and East Timor and 600 km north-north-east of Broome, Western Australia. The field is on the Sahul Shelf in the Australian waters of the Territory of Ashmore and Cartier Islands Adjacent Area in permit AC/RL9. Water depths in the field range from 110 m to 170 m. The approximate field dimensions are 8 km long by 5 km wide (Shell 2014).

Shell Australia Proprietary Limited plans to pipe gas from the Crux Field, within the Browse Basin, to the Prelude Floating Liquefied Natural Gas Development, approximately 160 km south-west of the Crux Field.

The project is in the early Select Phase and as such a number of concepts are under consideration including:

- a Floating Production Storage and Offloading (FPSO) facility or a fixed platform in the Crux Field
- a pipeline from the Crux Field to the Prelude Field.

These proposed concepts, along with drilling, subsea and pipeline infrastructure will impact on the seabed environment throughout the project area during construction and ongoing operations.

This report outlines the outcomes from the water quality baseline survey undertaken in the Crux Field in April/May 2016. The survey included water sampling and analysis at 24 sites surrounding the proposed drill centres and FPSO locations, along the proposed pipeline route and at four reference sites.

The survey found water quality in the AC/RL9 area to be generally very good and can be classified as effectively unmodified which would be expected given the remote location of the Crux Field. This is reflected in the results presented whereby all but a very small number of toxicant concentrations were observed to be below the Guideline 99% species protection (where PQLs were sufficiently low). Findings of this study included:

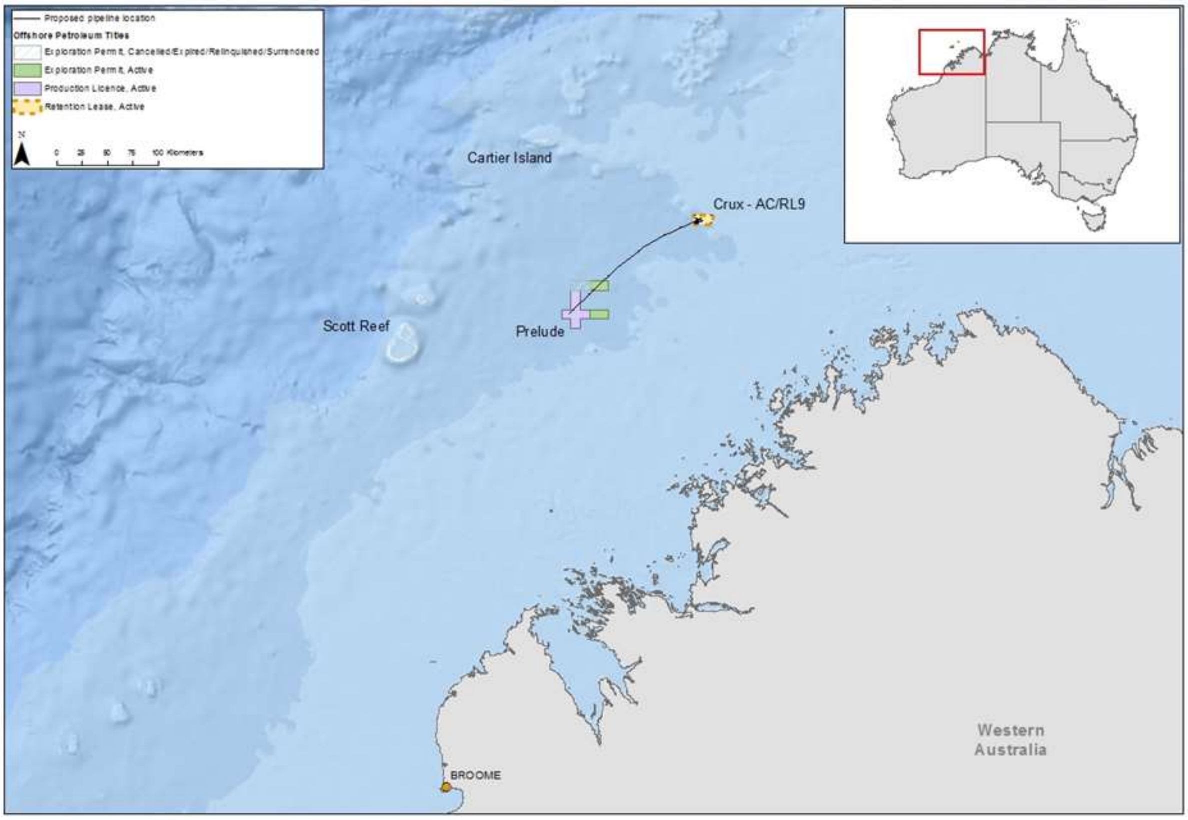
- Petroleum hydrocarbons below the detectable limit indicating no evidence of impact from petroleum development sites or natural seeps in the region.
- Metals concentrations were all within expected ranges with all but four results showing concentrations below the applicable Guideline 99% or 95% species protection levels and within levels expected for open ocean marine environments.
- Nutrient concentrations were very low across all sites. Combined with the analytical results for chlorophyll and phaeophytin, there is no evidence of any unexpected nutrient loads.
- Photosynthetic pigments in surface waters were very low. These concentrations may display seasonal variability, however the timing of this survey was such that it likely would have captured some of the higher concentrations that would be expected over the course of a year.
- Physical characteristics were within the expected ranges for this time of year when compared to the background data presented in previous desk top studies (Shell 2014, 2015).

The baseline data presented in this report may be used for future comparison to monitor environmental impact due to construction or routine operations and provides the initial data from which a set of site specific trigger levels may be developed as suggested by ANZECC & ARMCANZ guidelines.

1.0 Introduction

The Crux Field is located in Commonwealth waters in the Browse Basin (Timor Sea) approximately 110 km south-east of Cartier Island, 200 km off the Kimberley coast, 260 km from the Indonesian archipelago and East Timor and 600 km north-north-east of Broome, Western Australia (WA). The field is on the Sahul Shelf in the Australian waters of the Territory of Ashmore and Cartier Islands Adjacent Area in permit AC/RL9. Water depths in the field range from 110 m to 170 m. The approximate field dimensions are 8 km long by 5 km wide (Shell 2014).

Figure 1 Shell Crux Field retention lease AC/RL9 location



1.1 Objectives

This report presents the results of the baseline water quality survey completed between 30 April and 2 May 2016 at the AC/RL9 location and along the proposed pipeline route to the Prelude Field.

The objective of this survey was to collect data to describe the existing physical and chemical water quality characteristics at locations that may potentially be impacted by development of the field with a view to:

- characterise the pre-development water quality of the AC/RL9 site to inform the environmental permitting process
- provide a baseline dataset to which post impact (construction and operations) water quality measurements can be compared.

1.2 Survey overview

The survey was completed over three days in April/May 2016 on board the *MV Warrego* on completion of a metocean instrumentation deployment at the Crux Field and along the proposed pipeline route.

The survey comprised the collection of samples for physical and chemical analysis of water parameters, and the measurement of physicochemical profiles, at a total of 24 sites:

- 17 sites surrounding the proposed drill centres and Floating Production Storage and Offloading (FPSO) locations
- three sites along the pipeline route between AC/RL9 and the Prelude Field
- four reference sites (one at each corner of the AC/RL9 lease).

A detailed description of the survey is provided in Section 3.2.1 with sample site locations shown in Figure 3.

2.0 Background

2.1 Crux Field development

Shell Australia Proprietary Limited (Shell) plans to pipe gas from the Crux Field, within the Browse Basin, to the Prelude Floating Liquefied Natural Gas (FLNG) Development, approximately 160 km south-west of the Crux Field.

The project is in the early Select Phase and as such a number of concepts are under consideration including:

- an FPSO facility or a fixed platform in the Crux Field
- a pipeline from the Crux Field to the Prelude Field.

These proposed concepts, along with drilling, subsea and pipeline infrastructure will impact on the seabed environment throughout the project area during construction and ongoing operations.

2.2 Local environment

This study covers the Crux Field which is located on the North West Shelf, some 200 km off the Kimberly coast and the proposed pipeline route between the Crux and Prelude Fields. A description of the environment of the field is provided below.

2.2.1 Bathymetry, seabed features and associated habitats

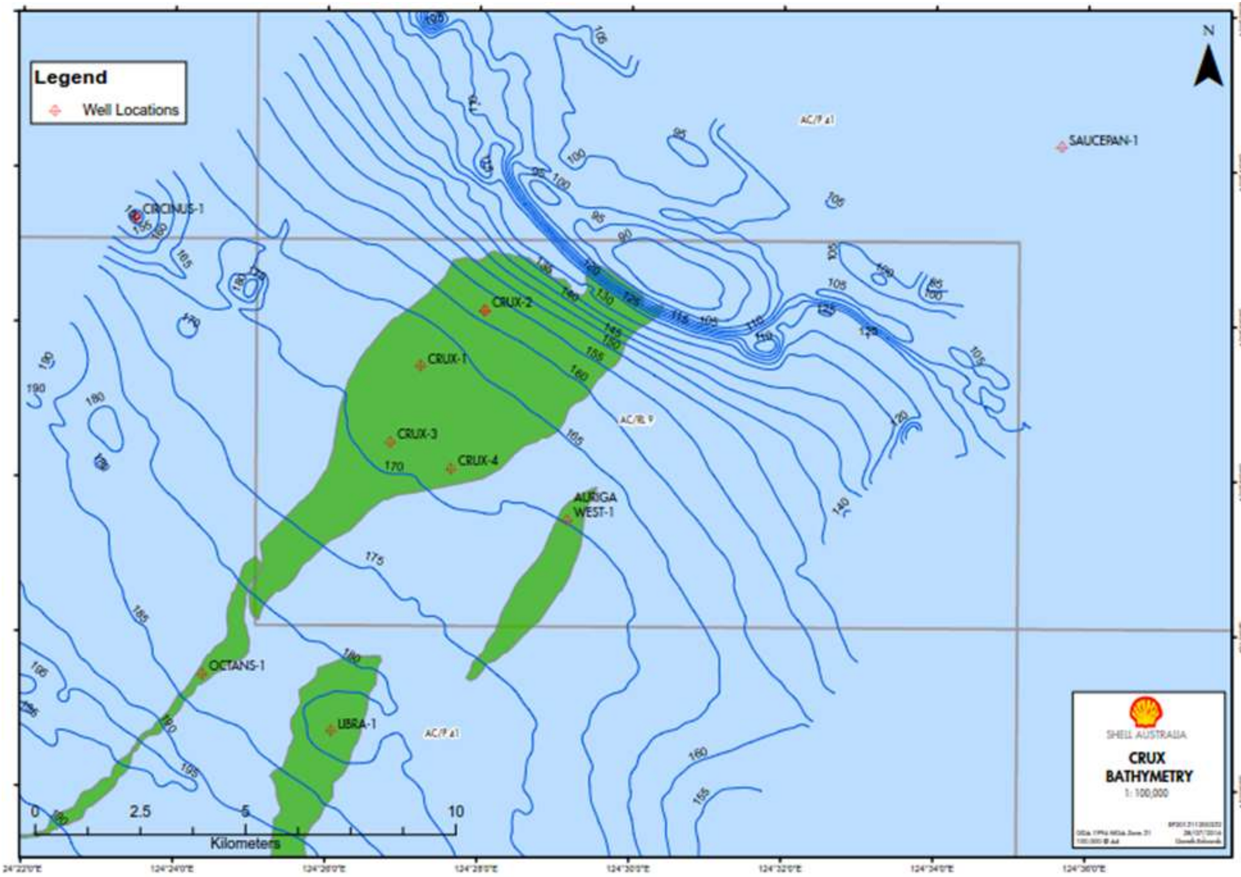
The seabed of the Crux Field is relatively uniform with depths varying from approximately 90 to 160 m observed during the survey. The shallower depths are found in the north-west section of the AC/RL9 lease. The seabed is typically composed of soft sediment

The AC/RL9 permit area bathymetry and seabed features have been described in Shell (2014), and are summarised below. Further bathymetry data will be required for the pipeline route and will be gained from hydrographic, geotechnical and habitat surveys.

- The project area is located on the Sahul Shelf; a broad shallow platform off the north-west coast of Australia.
- The seabed comprises fine clays, muds and sands. No reefs or areas of rocky substrate are known to occur within the nearby Prelude project area (Shell, 2009). Further investigation is required along the pipeline route and across the AC/RL9 permit area; however, the seafloor in those areas is believed to be fairly uniform comprising predominantly of soft sediment.
- Bathymetry of the AC/RL9 permit area is characterised by a shallow area towards the north-east corner of the lease area where depths of 90 to 100 m are typical. The depth falls to approximately 160 m in a south-westerly direction over approximately 2.5 km. The depth continues on a slight gradient until it reaches approximately 180 m depth in the south-west corner of the lease area (Figure 2).
- Single beam echo sounder bathymetry data captured during this survey reflects the above observations of bathymetry across the AC/RL permit area and shows a typically constant increase in depth along the proposed pipeline route.
- The major bathymetric feature along the pipeline route is a trench feature where the seabed drops from depths of approximately 210 m to a depth of approximately 270 m before returning to the regular depths around 250 m in the Prelude region. This feature is located closer to the Prelude field some 115 km south-west of the AC/RL lease.
- A number of shoals in the wider region present the most sensitive seabed habitats in the greater Browse Basin (Shell, 2014). The closest of these to the AC/RL9 lease area include:
  - Barracouta Shoals (approximately 90 km to the north-west)
  - Vulcan Shoals (approximately 18 km to the east)
  - Heywood Shoals approximately 13 km to the south-west)

The seabed of the Crux Field and proposed pipeline route will be described in more detail by a geophysical survey to be completed at a later date.

Figure 2 Bathymetry of the AC/RL9 lease area



2.2.2 Climate

The climate of the Browse Basin/Timor Sea region is monsoonal, and comprises two distinct seasons, winter (dry) from April to September and summer (wet) from October to March, with very rapid transition seasons, generally in April and September/October between the two main seasons (Shell, 2015a).

The location of the Crux Field is means that it is subjected to tropical cyclone activity with the highest chance of such storms occurring between November and April. Data suggest the peak cyclone frequency falls in January and March with the most intense cyclone activities observed in December and March – April (Shell, 2015a).

2.2.3 Tides and currents

Local tides and currents will impact the dispersion of any discharges to the marine environment and therefore the impact that these discharges may have. The Crux Field Development Metocean Reference Document (Shell, 2015a) details the key oceanographic systems at play in the region and suggests that currents at the Crux location are expected to be largely characterised by the tides.

Tides at the Crux site are predominantly semi-diurnal with successive tides generally being unequal and flowing along an approximate north-west – south-east axis (Shell, 2015a).

2.2.4 Physical water parameters

Existing data describing the physical water characteristics in the region have been summarised in various desktop study reports by Shell (2014, 2015a) with additional data expected to be collected in metocean surveys currently in progress. Existing information suggests:

- Sea surface temperatures generally range between 27 °C and 30 °C annually, in waters deeper than ~150 m the temperature is approximately 19 °C (Shell, 2014). Short term and long term variability could be expected at the Crux site (Shell, 2015a).
- Average monthly salinity profile data from the World Ocean Atlas for the Crux Filed location was presented in Shell (2015a). Salinity ranged from 34.5 – 35.1 PSU. Salinity profiles from CSIRO Marine and

Atmospheric Research in the region were also referenced showing salinity ranging from 33.3 – 34.8 PSU. It was also noted that short and long term variability would be expected to be observed.

2.3 Marine environmental effects

The Crux Field development will potentially comprise a number of installations and vessel operations that may impact marine water quality both during construction and once operational. Primarily, these impacts may result from routine discharges which may include:

- in situ overboard disposal of expended water-based mud (WBM) and associated drill cuttings from the Mobile Offshore Drilling Unit (MODU)
- macerated sewage and putrescible food scraps
- treated grey water from accommodation facilities and support vessels
- untreated deck drainage (deck wash and stormwater).
- treated oily water from FPSO and marine vessels
- treated drainage water discharges from platforms
- ballast water
- treated produced formation water (PFW) discharges from platforms / FPSO
- cooling water containing biofouling and corrosion control chemicals
- firewater and firefighting foam discharges (during system testing).

Seabed disturbance during installation may also impact water quality for short periods of time.

3.0 Crux Field Marine Water Quality Baseline Methodology

3.1 Objectives

The objective of the water quality baseline environmental survey was to gather data to inform the environmental planning and approvals process for the development of the Crux Field.

As well as providing data to understand the existing environment at the site of the proposed development, it can be used for future comparison to measure impacts of development activities in the field.

3.2 Water quality assessment

Water quality assessment consisted of water column vertical profiling, water sampling for nutrient and chemical analysis and phytoplankton sampling. A total of 24 sites were sampled across the Crux Field and along the proposed pipeline route to the Prelude location.

3.2.1 Sampling site locations

The sampling locations were selected to provide a spread of measurements around the sites of proposed infrastructure which includes wells, an FPSO/platform and a pipeline to the Prelude development some 160 km to the south-west. Sample sites were located as follows.

3.2.1.1 Sampling surrounding drill centres

Sample sites were located surrounding the three identified potential drill centres at:

- a central point (DC0) located approximately 1 km from the three drill centres on the western side
- two points along a transect north-west of DC1 and NE of DC2 at distances of 1000 and 2000 m
- two samples at distances of 1000 m and 2000 m along a transect extending south-west from DC0.

3.2.1.2 Sampling surrounding FPSO locations

The two potential FPSO locations were sampled at a number of sites:

- a point centrally located between the two potential FPSO positions (FPSO_0)
- two points located at a distance of 1000 m and 2000 m to the north-east of FPSO_0
- two points located at a distance of 1000 m and 2000 m to the south-west of FPSO_0
- two points located at a distance of 1000 m and 2000 m to the south-east of FPSO_0.

Sample sites are shown in Figure 3.

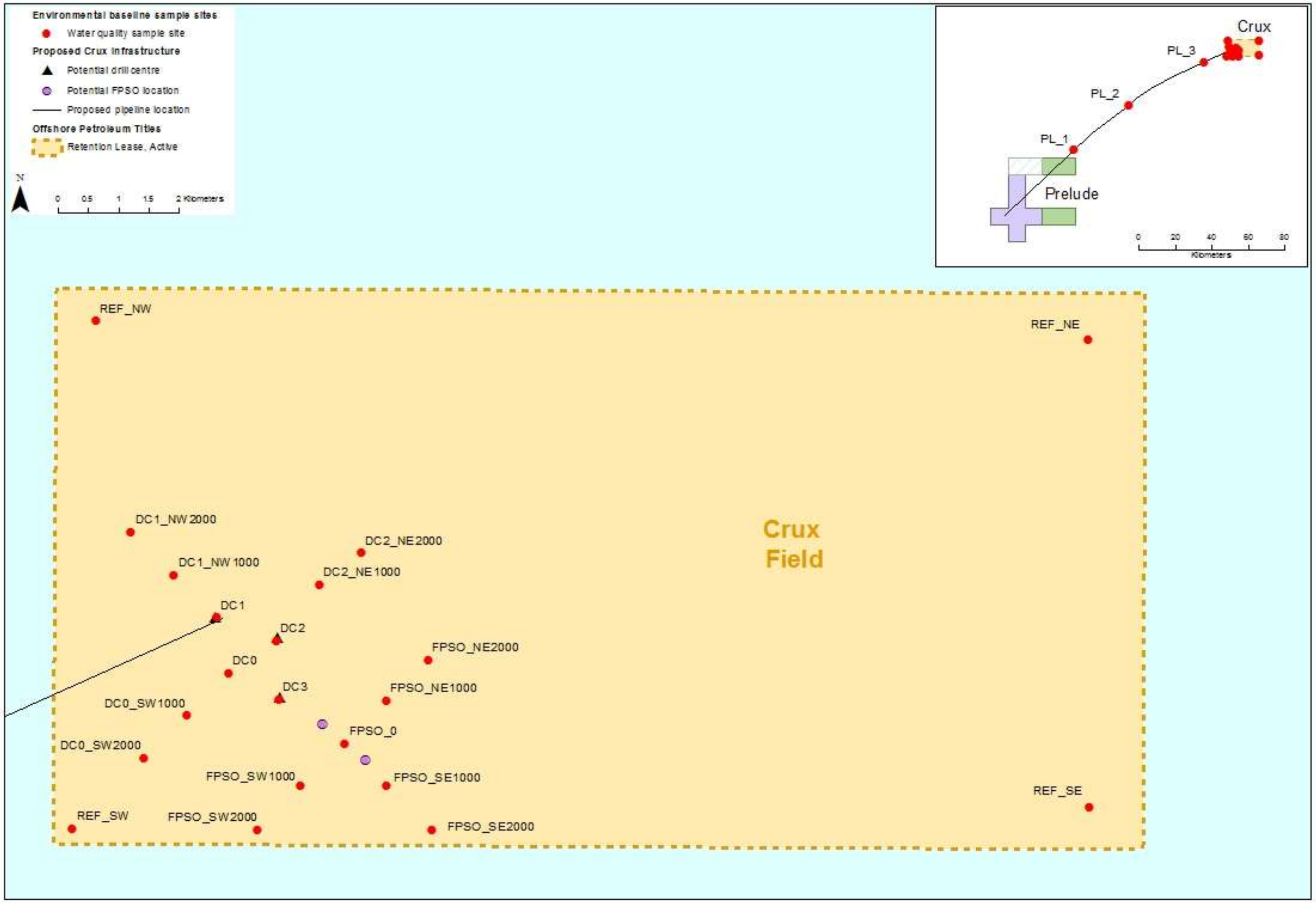
3.2.2 Vertical profiling

A Seabird SBE 19 plus V2 multi-parameter sonde was used to collect water quality data through vertical profiles of the water column at 24 sites (three along the pipeline route and 21 sites within the Crux Field). The sonde was set on internal logging mode and lowered to just above the seabed using the deck winch on the survey vessel, with each parameter measured every half second.

The sonde measured a suite of water quality parameters including depth (m), salinity (PSU), temperature (°C), turbidity (NTU) pH and dissolved oxygen (DO) (%).

The sonde was calibrated by RPS Metocean prior to the field survey, with the calibration certificate included in Appendix A. Water column profile data were used in calculating summary statistics for each site. Mean values were derived for each 10 m depth interval from the surface to the seabed between approximately 95 and 210 m water depth.

Figure 3 Water quality baseline sample sites



3.3 Sample collection

3.3.1 Sampling procedures

Water samples were collected using a Niskin sampler to collect a water sample just below the water surface (0.5 – 1 m depth).

The survey vessel was positioned such that sampling occurred on the upstream side of the vessel considering prevailing currents and wind direction to avoid any potential contamination from the vessel wash. All vessel discharge points were closed for the duration of sampling.

The Niskin bottle was deployed over the side of the vessel using the deck crane and lowered to a depth of approximately one metre below the water surface where it was triggered to collect a water sample.

The sampler was brought back on board the vessel and samples decanted directly into the sample containers using the pouring mechanism on the sampler.

A decontamination procedure for the water sampler was implemented after sampling each site. A solution of Decon 90 detergent and fresh water was mixed in a plastic bucket. Once a sample had been collected, the sampling equipment was thoroughly rinsed with the Decon 90 solution before a double freshwater rinse.

3.3.2 Nutrients and contaminants

Collection of water samples for nutrient and contaminant analysis was undertaken at each of the 24 sampling sites.

Surface water samples were collected and analysed to quantify the background concentrations of nutrients and potential hydrocarbon pollutants in the waters at the time of the survey. The samples were analysed for Total Phosphorous (TP), Total Nitrogen (TN), Total Kjeldahl Nitrogen (TKN), Total Recoverable Hydrocarbons (TRH) (C10-C36), Benzene, Toluene, Ethylbenzene, Xylenes (BTEX) and photosynthetic pigments (chlorophyll and phaeophytin).

TP and TN samples were collected in pre-cleaned 1 L polyethylene bottles. All nutrient samples were frozen for storage prior to analysis. Samples for analysis of TRH concentrations were collected in pre-cleaned 500 mL glass bottles and refrigerated in the dark until analysis. BTEX samples were collected in pairs of 40 mL glass vials.

All sample bottles were pre-washed and all samples were collected and stored in accordance with Australian/New Zealand Standard AS/NZS 5567.1 1998 (Standards Australia 1998). The samples were delivered to Analytical Reference Laboratory (ARL) for analysis within seven days of collection.

3.3.3 Phytoplankton

Chlorophyll concentrations in extracts of seawater filtrate were measured as an index of phytoplankton biomass. Five litres of fresh seawater was filtered through a glass fibre filter paper (GF/C) and the filter paper frozen for subsequent extraction and analysis of total chlorophyll, chlorophylls 'a', 'b' and 'c', and phaeophytin. The ratio of the three forms of chlorophyll (‘a’, ‘b’ and ‘c’) can be used as an indicator of the composition of the phytoplankton assemblages. Changes in the ratio of the pigments suggest changes in assemblage structure.

Photosynthetic pigments were extracted and measured by the Marine and Freshwater Research Laboratory (MAFRL) at Murdoch University according to the Standard Methods for Examination of Water and Wastewater.

3.3.4 Quality Assurance and Quality Control (QA/QC) samples

In addition to the primary water samples, a number of QA/QC samples were collected in accordance with Australian/New Zealand Standard AS/NZS 5567.1 1998 (Standards Australia 1998). These comprised:

- duplicate samples at three sites
- triplicate samples at two sites
- one field blank
- two rinsate blanks
- one trip blank.

Duplicate samples were collected from the same water sample as primary samples while triplicate samples were collected by deploying the Niskin sampler three separate times at the same site, one after the other. One of the three triplicate samples at each site was sent to a secondary laboratory for analysis.

Duplicate and triplicate samples were labelled so as to be identifiable to the sampler as replicates, but so that they were unrecognisable to the analysing laboratory as replicates.

3.4 Analysis of water samples

Sample analysis was undertaken by National Association of Testing Authorities (NATA) accredited laboratories for the analysis being undertaken. ARL analysed the primary contaminant and nutrient samples while ALS analysed the inter-laboratory duplicates. The Marine and Freshwater Resources Laboratory (MAFRL) conducted sample analysis for chlorophyll and phaeophytin.

Where possible, analysis was undertaken to a Practical Quantitation Limit (PQL) sufficiently low so as to allow assessment of results against the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment & Conservation Council and Agriculture & Resource Management Council of Australia and New Zealand [ANZECC & ARMCANZ] 2000; hereafter 'the Guidelines'. The PQLs applied are listed in Table 1.

The following analyses were undertaken:

- TRH ($C_{6\text{-}9}$, $C_{10\text{-}14}$, $C_{15\text{-}28}$, $C_{29\text{-}36}$, $C_{>36}$)
- BTEX
- total metals (aluminium, arsenic, barium, cadmium, cobalt, chromium, copper, iron, lead, mercury, nickel and zinc)
- nutrients (Total Nitrogen [TN], Total Kjeldahl Nitrogen [TKN] and Total Phosphorus [TP])
- photosynthetic pigments (chlorophyll and phaeophytin).

Table 1 Laboratory analysis and proposed PQL to be applied.

Analyte	Trigger Level^ (mg/L)	PQL (mg/L)
Hydrocarbons		
TRH	-	0.01
BTEX	0.5 (Benzene)	0.001 – 0.003
Total Metals:		
As	-	0.001
Al	-	0.01
Ba	-	0.001
Cd	0.0007	0.0001
Co	0.000005	0.001
Cr	0.0077	0.001
Cu	0.0003	0.001
Fe	-	0.01
Hg	0.0001	0.0001
Ni	0.007	0.001
Pb	0.0022	0.001
Zn	0.007	0.005
Nutrients		
TN, TKN, NOx-N	0.1# (TN), 0.004# (NOx-N)	0.2 (TN), 0.01 (NOx-N)

Analyte	Trigger Level^ (mg/L)	PQL (mg/L)
TP	0.01#	0.01
Photosynthetic pigments		
Chlorophyll a, b, c, phaeophytin	0.0009 (chl *a*) #	0.0001, 0.0002 (phaeophytin)

^: ANZECC & ARMCANZ (2000) 99% species protection trigger value for marine water.

#: ANZECC & ARMCANZ (2000) Default trigger values for physical and chemical stressors for tropical Australia for slightly disturbed ecosystems.

3.5 QA/QC

The primary objective of the data validation process is to ensure that the reported data can be used to achieve the project objectives. Analytical data were thoroughly checked by the laboratory prior to release. AECOM subsequently checked the analytical data against the data quality objectives of the project—comparing requested detection limits against PQLs, calculating Relative Percentage Differences (RPDs) and Relative Standard Deviations (RSDs) for field duplicates and replicates, respectively, and comparing RPDs and RSDs with Guideline recommendations.

Comparison of duplicates/triplicates through RPDs and RSDs may identify analytical results that appear to be unrealistically high (or low) and might prompt a request to the laboratory to reanalyse the samples as a further check of precision, or result in categorisation of those results as ‘estimates only’.

Laboratory QA/QC procedures included laboratory duplicates, method blanks, laboratory control samples and matrix spikes

4.0 Results and Discussion

This section presents the results and discussion of the physicochemical water profile data and water sample laboratory analysis.

A summary of the physicochemical water column profile data is provided in Appendix B. The laboratory analytical results are summarised in Appendix C with laboratory reports provided in Appendix D.

4.1 Physicochemical water column profiles

Water column profiles were collected at each of the sampling sites using a Seabird SBE 19 Plus V2 conductivity, temperature, depth (CTD) recorder. Measurements of temperature, salinity, DO, pH and turbidity were made every 0.5 seconds while lowering the recorder through the water column to the seabed.

Data were summarised and averaged in 10 m strata across the depth of the water column (Appendix B) and presented in depth profile plots for each parameter (Figure 4, Figure 5 and Figure 6). The following sections describe the profiles observed.

The Guidelines provide criteria levels for dissolved oxygen (> 90 % saturation), and pH values (8.2), and state that pH should not deviate more than ± 0.2 pH units among individual sampling sites. However, the Guidelines stress the need for site-specific information to enable the development of criteria that are more relevant to the system under study. The baseline data presented in this report may contribute to developing site specific criteria for future comparison.

4.1.1 Temperature

Temperature measurements were generally consistent across the sites with average surface temperatures (1 – 10 m) ranging from 30.8 to 31.3 °C. The temperature dropped consistently through the water column with no strong evidence of a thermocline.

4.1.2 Salinity

Salinity measurements were consistent across all sites. Average surface salinities (0 – 10 m) were observed between 34. 8 – 35.0 PSU with a halocline present at approximately 30 – 35 m. At this point a small drop in average salinity of approximately 0.4 PSU was observed indicating a surface layer of slightly more saline water overlying the otherwise consistent salinity of 34.5 – 34.6 PSU to the seabed.

4.1.3 Dissolved Oxygen

DO stratification in the water column was observed with a drop in DO evident at all sites, generally between 40 to 60 m but as shallow as 30 m at a small number of sites. The drop in DO was typically associated with similar occurrences in temperature and salinity which is expected (ANZECC & ARMCANZ 2000). Average surface DO (0–10 m) ranged from 87.3 – 100.4% saturation before rising slightly to a depth of approximately 30 m where DO saturation ranged from 98.2 – 100.9%. Below these surface layers, DO saturation decreased consistently through the water column.

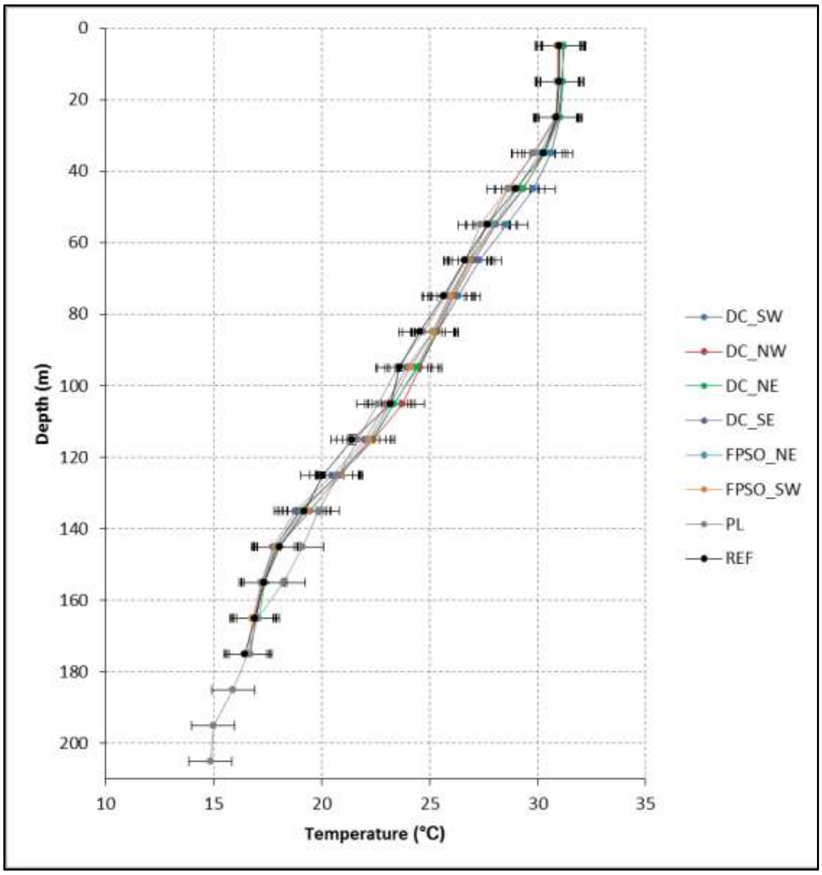
4.1.4 pH

pH levels were observed at consistent levels across all sites. Average pH was uniform in the well mixed surface layers to approximately 40 m depth where average pH was typically between 8 – 8.1. There was then a constant decrease through the water column to the seabed where pH values of 7.7 – 7.8 were observed at the deepest sites. These readings are consistent with expectations for offshore marine environments with the Guideline default trigger value for offshore marine waters set at 8.2.

4.1.5 Turbidity

Turbidity was consistently low throughout the water column (< 1 NTU), as expected for offshore marine environments. High seabed turbidity has been detected at the Prelude development site (Shell, 2015b); however there was no indication of significantly elevated turbidity close to the seabed at any of the sites in the Crux Field or along the pipeline.

Figure 4 Water column profiles for average temperature (top) and Salinity (bottom)



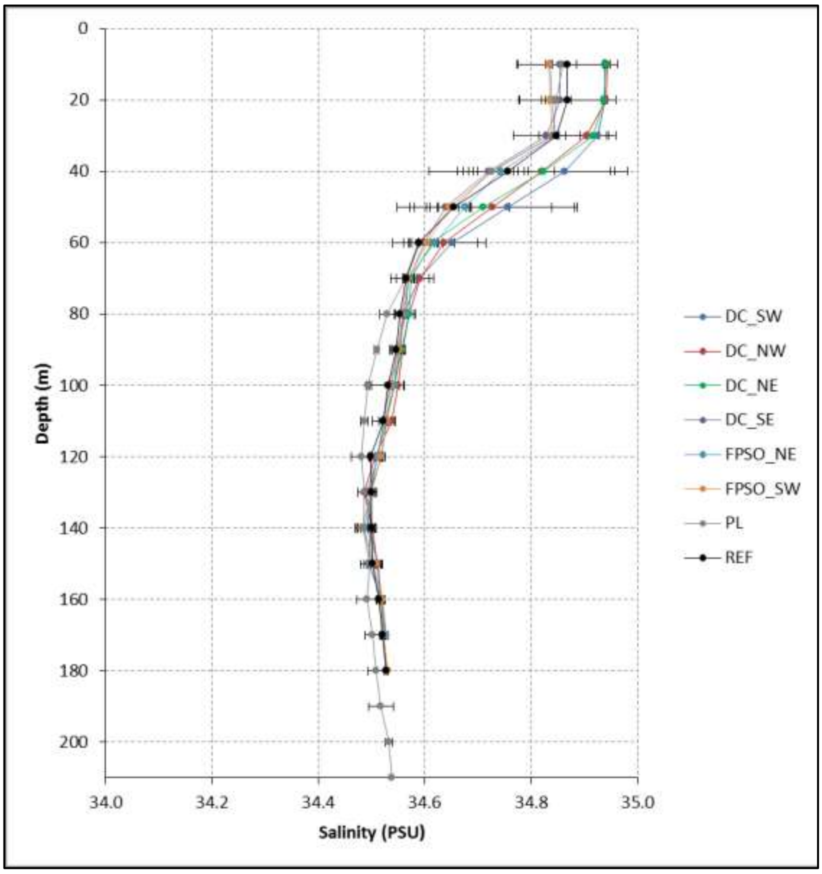
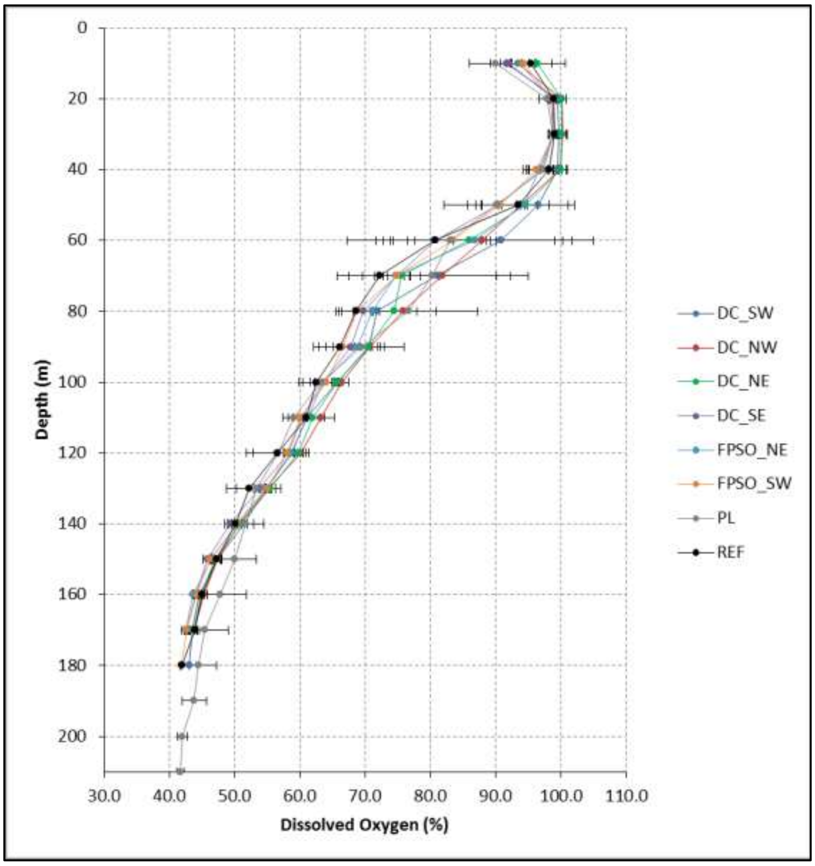


Figure 5 Water column profiles for average Dissolved Oxygen (top) and pH (bottom)



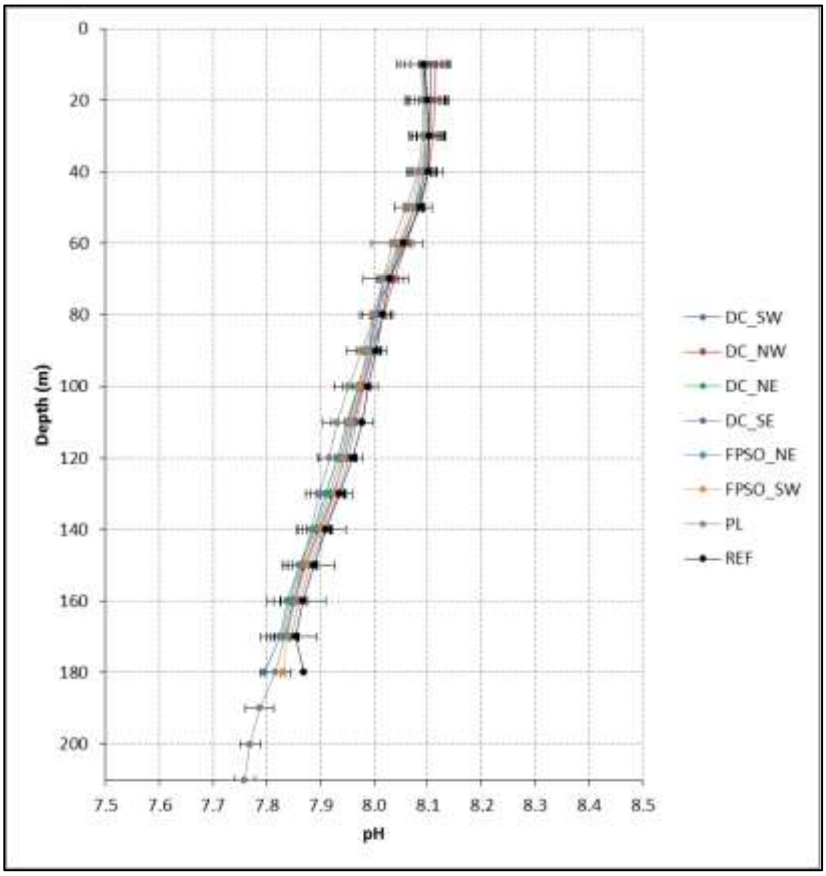
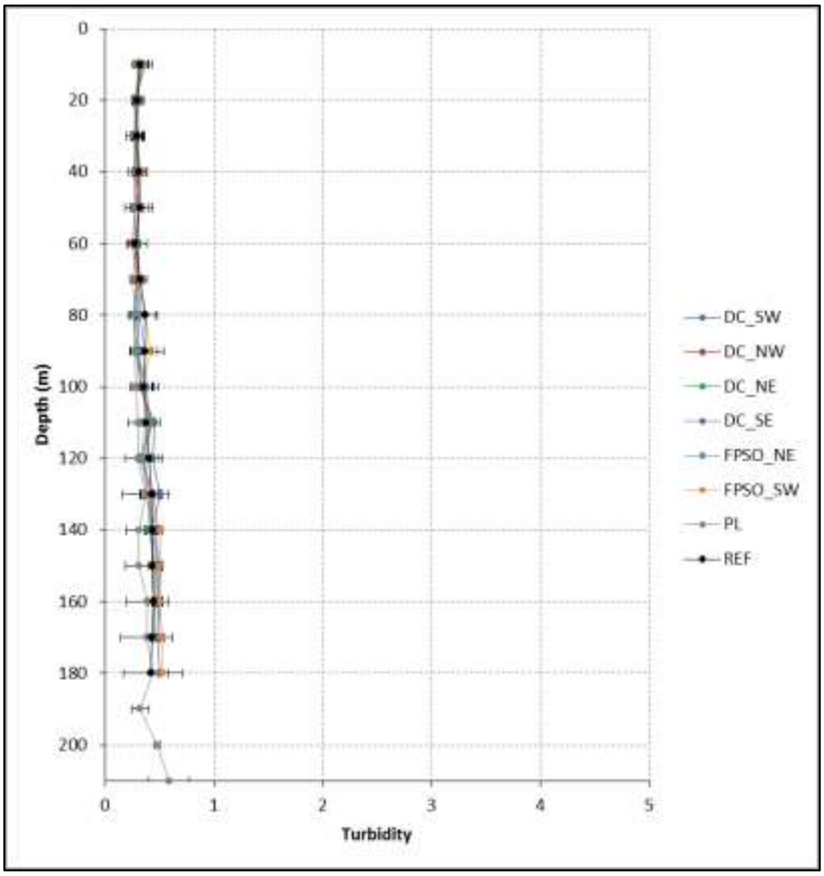


Figure 6 **Water column profiles for average turbidity**



4.2 Hydrocarbons

Water samples were analysed for TRH and BTEX. Analytical results are presented in Appendix C with laboratory reports provided in Appendix D.

TRH was not detectable above the PQL (0.01 mg/L) in any of the samples. This would be expected of a remote offshore ocean environment sufficiently distant from other existing development.

Similarly, BTEX were not detected above the applied PQLs of 0.001 mg/L (Benzene, Toluene and Ethylbenzene) and 0.003 mg/L (Xylenes). Low reliability trigger values for 99% species protection for BTEX in marine waters are suggested in the Guidelines. These are specified as 0.5 mg/L (Benzene), 0.18 mg/L (Toluene) and 0.005 mg/L (Ethylbenzene). Low reliability trigger levels for xylene isomers are suggested as 0.35 mg/L (o-xylene), 0.075 mg/L (m-xylene) and 0.2 mg/L (p-xylene).

4.3 Metals

Samples were analysed for total metals and results compared against the Guideline 99% species protection trigger values for marine waters. The metals tested for, and PQLs applied, are shown in Table 1 and the results are provided in the following sections. Analytical results are presented in Appendix C with laboratory reports provided in Appendix D.

With some exceptions, metals generally returned concentrations below the PQLs. Where this was not the case, concentrations were generally substantially below the Guideline 99% species protection trigger value for marine waters.

4.3.1 Arsenic

Arsenic concentrations were detected above the PQL of 0.001 mg/L at all sites however the concentrations were still very low with a range of 0.001 – 0.004 mg/L.

No Guideline 99% protection trigger exists for arsenic in marine waters however; low reliability guideline trigger levels of 0.0023 mg/L and 0.0045 mg/L are suggested for marine waters for As III and V species respectively. Analysis of samples for speciated arsenic was not undertaken as part of this program.

The low reliability trigger level for As III was exceeded at three sites (FPSO_NE2000, FPSO_SE2000 and REF_SW) where concentrations of 0.004, 0.003 and 0.003 mg/L for Total arsenic were recorded at each site respectively.

4.3.2 Aluminium

Aluminium concentrations were below the PQL of 0.01 mg/L in all samples. There is no Guideline trigger value for aluminium.

4.3.3 Zinc

Zinc was detected above the PQL of 0.005 mg/L at only one site (FPSO_NE2000) where a concentration of 0.021 mg/L was measured. At this concentration, it is above the Guideline 99% species protection trigger value of 0.007 mg/L however, it is unlikely to be representative of the zinc concentrations of the wider water body at the Crux Field. This may be indicative of an isolated occurrence of minor sample contamination from an undetermined source.

4.3.4 Cadmium

At all sites cadmium concentrations were below the PQL of 0.0001 mg/L and therefore below the Guideline 99% species protection trigger value of 0.0007 mg/L.

4.3.5 Cobalt

Cobalt was not detected at concentrations above the PQL of 0.001 mg/L at any of the sites sampled. It was not possible to apply a PQL sufficiently low to detect levels at the Guideline 99% species protection level trigger of 0.000005 mg/L, however, the PQL applied was sufficient to detect any exceedance of the Guideline 95% protection trigger level of 0.001 mg/L, of which none were observed.

4.3.6 Chromium

Chromium was detected above the PQL of 0.001 mg/L at one site (DC0_SW1000) where a concentration of 0.002 mg/L was measured. This is below the Guideline 99% species protection trigger level of 0.0077 mg/L.

4.3.7 Copper

Copper was detected at concentrations at or above the PQL of 0.001 mg/L at two sites (DC0_SW1000 – 0.001 mg/L and PL-1 – 0.002 mg/L).

It was not possible to apply a PQL sufficiently low to detect levels at the Guideline 99% species protection level trigger of 0.0003 mg/L, however, the PQL applied was sufficient to detect any exceedance of the 95% protection trigger level of 0.0013 mg/L.

Of the two sites where copper concentrations exceeded the PQL, one of these, PL-1 exceeded the 95% species protection trigger level by a small amount. This site is located along the proposed pipeline route some 100 km south-west of the Crux Field and, as a single sample, is an unreliable representation of copper concentrations across the Crux Field or the wider region. Rather, it may be indicative of an isolated occurrence of minor sample contamination from an undetermined source.

Further to this, copper concentrations were detected in the rinsate, field blank and trip blank samples. The source of this was identified by the analysing laboratory as the deionised water used for the blank and rinsate water. The laboratory confirmed that this would not have impacted the primary samples, which appears to be the case.

4.3.8 Iron

No Guideline trigger level is provided for iron in marine waters, in which it occurs naturally. Iron was detected above the PQL (0.01 mg/L) at 11 sites, at concentrations of 0.01 – 0.06 mg/L. At two of these sites (DC2 and FPSO_0) field duplicate samples were analysed and, in each instance, the primary sample had an iron concentration below PQL, while the duplicate sample showed a concentration above PQL (0.03 and 0.02 for DC2 and FPSO_0 respectively).

4.3.9 Lead

At all sites, lead concentrations were below the PQL of 0.001 mg/L and therefore below the Guideline 99 % species protection level of 0.0022 mg/L.

4.3.10 Nickel

Nickel concentrations exceeded the PQL of 0.001 mg/L at only one of the sites sampled (FPSO_NE2000) where a concentration of 0.001 mg/L was detected. This concentration is below the Guideline 99% species protection trigger level of 0.007 mg/L.

4.3.11 Mercury

Mercury was not detected above the PQL of 0.0001 mg/L at any of the sites sampled. The PQL is equal to the Guideline 99% species protection trigger level of 0.0001 mg/L so there were no exceedances of this trigger level.

4.3.12 Barium

Barium was not detected above the PQL of 0.01 mg/L at any of the sites sampled. While there is no Guideline water quality trigger level for barium, it is a common constituent in drilling muds and as such may become present in the water column should such materials be utilised during any future drilling.

While barium has been known to remain present in marine sediments post-drilling, it would not be expected to have any long lasting impact on water quality once drilling activities have ceased and suspended sediments have settled.

4.4 Nutrients and photosynthetic pigments

Concentrations of nutrients were analysed in all samples. Analytical results are presented in Appendix C with laboratory reports provided in Appendix D.

The Guidelines provide criteria levels for water contaminant concentrations. However, the guidelines stress the need for site-specific information to enable the development of criteria that are more relevant to the system under study.

In particular, the Guidelines note that the trigger values proposed for nutrient and chlorophyll concentrations in marine waters are not equally applicable to coastal and offshore waters. Location specific baseline information allows for more accurate assessment of these parameters due to the site-specific nature of ecosystem response to nutrient enrichment.

Therefore, the water quality parameters measured were assessed in terms of the recommendations in the Guidelines, but it is suggested that baseline data from this survey will form the basis for criteria levels for comparison in future impact assessments and monitoring.

4.4.1 Nitrogen

TN concentrations did not exceed the PQL of 0.2 mg/L at any of the sites sampled. While this PQL was not sufficiently low to detect the presence of nitrogen at the Guideline level of 0.1 mg/L, any exceedance that was undetected would not be substantially greater than 0.1 mg/L.

TKN is a measure of the total concentration of organic nitrogen and ammonia. TKN was not detected above the PQL of 0.2 mg/L. No default trigger level is provided by the Guidelines.

NOx-N was detected at or above the PQL of 0.01 mg/L at four sites (DC00, DC3, FPSO_NE1000 and FPSO_SE2000) where concentrations measured ranged from 0.01 – 0.05 mg/L. As for TN, the PQL was higher than the suggested guideline value (0.004 mg/L). As laboratories are typically unable to reliably analyse water samples to PQLs that are less than guideline values, any post-baseline comparisons of nitrogen levels will need to be between concentrations at potential impact sites and reference sites, rather than being compared back to baseline concentrations.

4.4.2 Total Phosphorus

TP concentrations did not exceed the PQL of 0.01 mg/L at any of the sites sampled. The PQL applied is equal to the Guideline default trigger value applicable to north-west WA offshore marine environments.

4.4.3 Photosynthetic pigments

Analytical results for photosynthetic pigments are presented in Appendix C with laboratory reports provided in Appendix D.

Of the four parameters analysed (Chlorophyll a, b, c and phaeophytin), only chlorophyll a was detected above the PQL of 0.0001 mg/L (0.0002 mg/L for phaeophytin). Concentrations of chlorophyll a above the PQL were detected at seven sites:

- five in the vicinity of the potential FPSO locations (FPSO_0, FPSO_NE1000 and NE2000, FPSO_SE1000 and SE2000)
- the two reference sites at the eastern end of the Crux Field (Ref_NE and REF_SE).

All detections of chlorophyll were very low, with concentrations of 0.0001 mg/L recorded at all of these sites with the exception of REF_SE where a concentration of 0.0002 mg/L was observed.

These results are below the Guideline trigger values for offshore marine waters of Northern Australia (0.0005 – 0.0009 mg/L). The lower of these two values is typical of clear coral dominated waters (e.g. Great Barrier Reef), while higher values are typical of turbid macrotidal systems (e.g. North West Shelf of WA) (ANZECC & ARMCANZ, 2000).

5.0 Conclusions

The following conclusions can be drawn from the 2016 water quality baseline survey:

- Water quality in the AC/RL9 area is generally very good and can be classified as effectively unmodified which would be expected given the remote location of the Crux Field. This is reflected in the results presented whereby all but a very small number of toxicant concentrations were observed to be below the Guideline 99% species protection (where PQLs were sufficiently low).
- Petroleum hydrocarbons were all below the detectable limit indicating no evidence of impact from petroleum development sites or natural seeps in the region. This would be expected due to the distance to neighbouring fields that have been developed.
- Metals concentrations were all within expected ranges with all but four results showing concentrations below the applicable Guideline 99% or 95% species protection levels (where the PQLs were sufficiently low). Where Guideline trigger values were not available, toxicant concentrations were observed within levels expected for open ocean marine environments.
- Nutrient concentrations were very low across all sites with all samples returning concentrations below the PQLs for both TP and TN and TKN. NOx-N concentrations were similarly low however measures above the PQL at four sites. Combined with the analytical results for chlorophyll and phaeophytin, there is no evidence of any unexpected nutrient loads.
- Photosynthetic pigments in surface waters were also very low and below the Guideline default trigger values applicable to north-west Western Australia. These concentrations may display seasonal variability, however the timing of this survey was such that it likely would have captured some of the higher concentrations that would be expected over the course of a year.
- Physical characteristics were within the expected ranges for this time of year when compared to the background data presented in previous desk top studies (Shell 2014, 2015). Baseline data collected as part of this survey are suitable for use in developing site-specific criteria against which future monitoring data could be assessed.

6.0 References

ANZECC & ARMCANZ 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment & Conservation Council and Agriculture & Resource Management Council of Australia & New Zealand, October 2000.

Shell 2009, Prelude Floating LNG Project Draft Environmental Impact Statement, Shell Development (Australia) Pty Ltd, October 2009

Shell 2014, AC/RL9 Environment Plan HSE_GEN_001004 (Revision 2), Shell Development (Australia) Pty Ltd.

Shell 2015a, Crux Field Development – Metocean Reference Document. Document Number TEC_CRU_005707. Shell Australia Pty Ltd.

Shell 2015b, Summary of studies into underwater visibility at Prelude field. Internal Report: 2000-010-S001-GE00-G00000-WA-5880, Michael Garvey, Shell Australia.

Standards Australia 1998, Water quality - Sampling Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples (AS/NZS 5667.1:1998). Homebush, NSW.

Appendix A

Water quality sonde calibration certificates

Appendix A Water quality sonde calibration certificates

RPS

CTD Reference Checks

Instrument: CTD 19plus V2

Instrument Serial Number: 6243

Calibration Date: 12/04/2016

Sensor	Reference	Value	Residual	Pass/Fail	Expected Accuracy
Salinity (PSU)	29.83526	29.77190	0.06336	Pass	+/- 0.16
	32.90661	32.75784	0.14877	Pass	
Temperature (°C)	19.10000	19.09941	0.00059	Pass	+/- 0.0192
Depth (dB)	0.49033	0.41142	0.07892	Pass	+/- 0.12
Turbidity (NTU)	0.00000	0.30000	-0.30000	Pass	+/- 5% Linearity
	20.00000	18.80000	1.20000	Pass	
	100.00000	102.90000	-2.90000	Pass	
Dissolved Oxygen (ml/L)	9.01600	9.04900	-0.03300	Pass	+/- 2%
pH	4.00000	3.99500	0.00500	Pass	pH probe was calibrated with these values.
	7.00000	7.01100	-0.01100	Pass	
	10.00000	9.99500	0.00500	Pass	

Notes:

- Salinity tests were conducted using RPS MetOcean salinity baths, the reference values of the salinity baths have been generated from averaging 20 SBE37 salinity values.
- Temperature test was conducted against calibrated digital FLUKE thermometer, with CTD instrument submerged in freshwater.
- Depth test was conducted with instrument submerged to a known height.
- Turbidity tests were conducted against 3 known turbidty standards.
- Dissolved Oxygen was cross checked against a secondary dissolved oxygen sensor.
- pH tests were conducted by Imbros (SBE contractor) the values found were used to calibrate the sensor configuration.

Technician: M. MATSON Signed: [signature] Date: 20/04/16

QC Checker: G. WARK Signed: [signature] Date: 20-4-16

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1887
CALIBRATION DATE: 03-Jul-12

SBE 43 OXYGEN CALIBRATION DATA

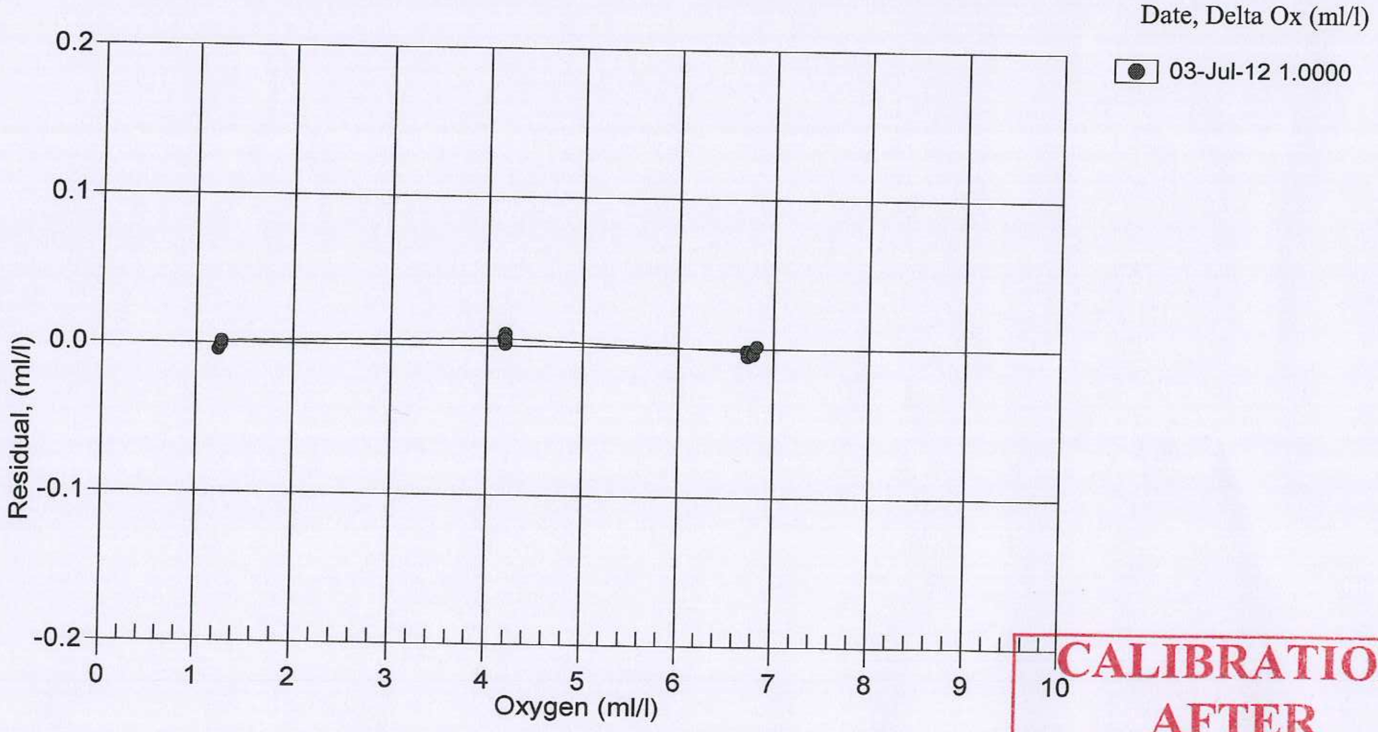
COEFFICIENTS
Soc = 0.4325
Voffset = -0.4265
Tau20 = 4.72

A = -2.2783e-003
B = 1.3259e-004
C = -2.7826e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4 H1 = -3.30000e-2
D2 = -4.64803e-2 H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.23	2.00	0.16	0.720	1.22	-0.00
1.23	6.00	0.14	0.757	1.23	-0.00
1.24	12.00	0.13	0.812	1.24	-0.00
1.25	26.00	0.09	0.947	1.25	-0.00
1.26	20.00	0.11	0.889	1.25	-0.00
1.26	30.00	0.08	0.993	1.26	0.00
4.17	2.00	0.16	1.430	4.18	0.01
4.18	26.00	0.09	2.162	4.18	0.00
4.18	30.00	0.08	2.301	4.18	0.00
4.18	12.00	0.12	1.726	4.18	0.00
4.18	6.00	0.14	1.550	4.19	0.01
4.19	20.00	0.11	1.974	4.19	0.00
6.72	12.00	0.12	2.514	6.72	-0.00
6.72	20.00	0.11	2.906	6.72	-0.00
6.74	6.00	0.14	2.235	6.74	-0.00
6.78	30.00	0.08	3.463	6.78	-0.00
6.78	2.00	0.16	2.054	6.78	-0.00
6.82	26.00	0.08	3.257	6.82	0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



CALIBRATION AFTER MODIFICATIONS

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 6243
CALIBRATION DATE: 20-Dec-08

SBE19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.006465e+000
h = 1.539737e-001
i = -1.985717e-004
j = 3.753773e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006

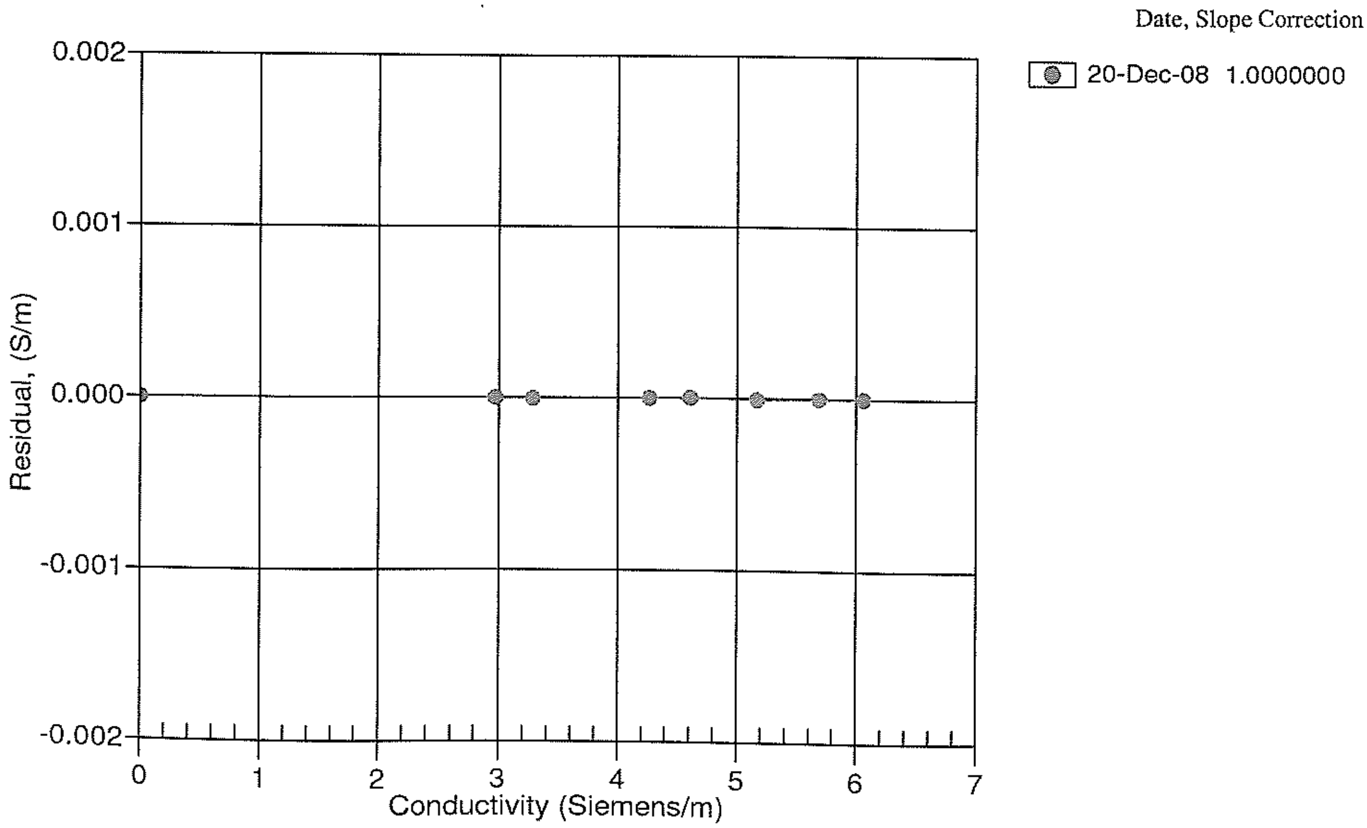
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2558.86	0.0000	0.00000
1.0000	34.7888	2.97384	5085.00	2.9738	0.00000
4.5000	34.7688	3.28068	5276.76	3.2807	-0.00000
15.0000	34.7253	4.26163	5847.09	4.2616	0.00000
18.5001	34.7150	4.60639	6034.51	4.6064	0.00001
24.0000	34.7029	5.16362	6325.43	5.1636	-0.00001
29.0000	34.6951	5.68470	6585.57	5.6847	-0.00000
32.5001	34.6889	6.05629	6764.82	6.0563	0.00000

f = INST FREQ / 1000.0

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

NTU Characterization Sheet

Date: 17/04/2012

S/N: NTURT-263

Nephelometric Turbidity Unit (NTU) Scale Factor

Turbidity units expressed in NTU can be derived using the equation:

NTU = Scale Factor x (Output - Dark Counts)

	ASV1	ASV2	ASV4		Digital	
Dark Counts	0.058	0.027	0.011	V	50	counts
NTU Solution Value	4.64	2.32	1.16	V	3800	counts
Scale Factor (SF)	47	95	189	NTU/V	0.0579	NTU/count
Maximum Output	4.97	4.97	4.97	V	16380	counts
Resolution	0.0	0.0	0.0	mV	1.0	counts
Ambient temperature during calibration	22		°C			

Dark Counts: Signal output of the meter in clean water with black tape over detector.

SF: Scale factor is determined using the following equation: SF = xx ÷ (Output - Dark Counts), where xx is the value of a Formazin concentration. For example: 12.2 ÷ (2011 - 50) = 0.0062.

Maximum Output: Maximum signal output the meter is cabable of.

Resolution: standard deviation of 1 minute of collected data.

Imbros
1059 Cambridge Road, Cambridge, Tasmania Australia 7170
info@imbros.com.au
www.imbros.com.au

ABN 29 009 525 053
Ph: (03) 6216 1500
Fax: (03) 6216 1555

SENSOR SERIAL NUMBER: 180786
CALIBRATION DATE: 14-Apr-16

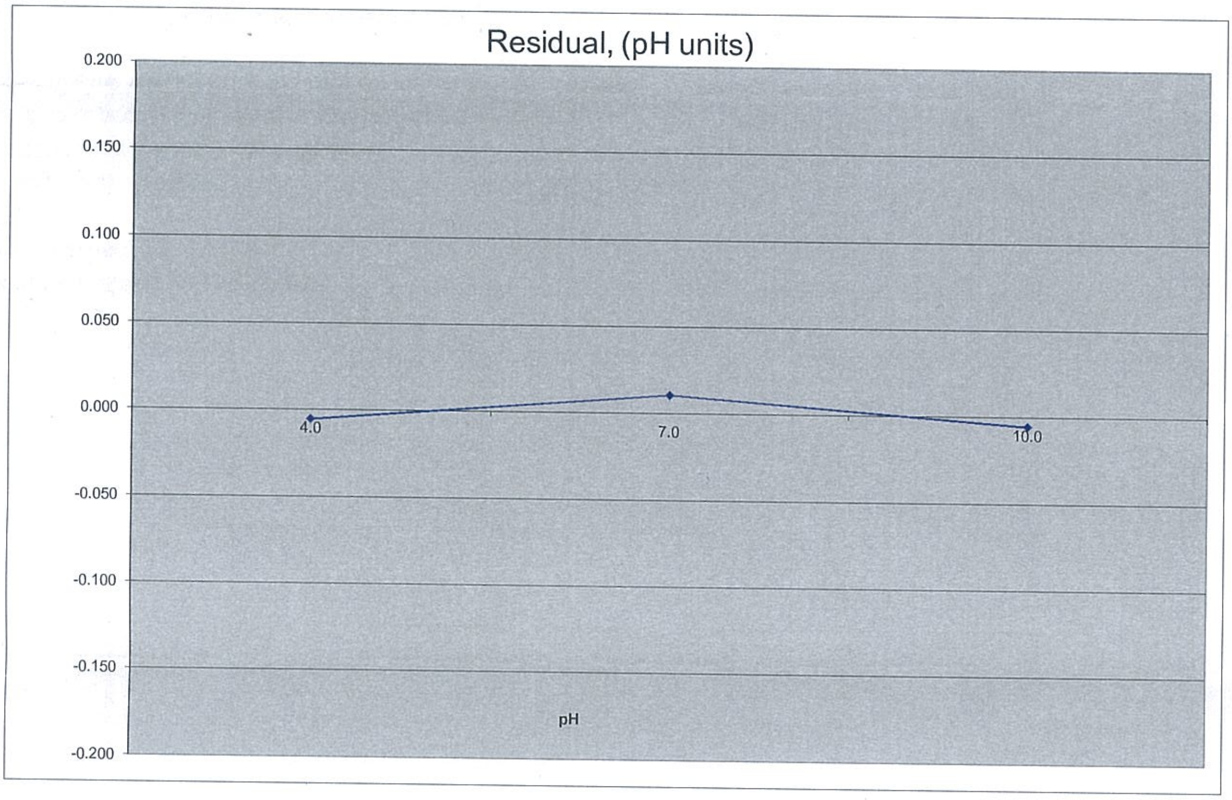
SBE18 pH CALIBRATION DATA

pH COEFFICENTS
pH slope = 4.5790
pHoffset = 2.5452

pH	Temperature (Deg C)	Vout	Instrument Output	Residual (pH units)
4.0	21.0	1.742	3.995	-0.005
7.0	21.0	2.548	7.011	0.011
10.0	21.0	3.346	9.995	-0.005

pH = 7.0 + (Vout - pHoffset) / (pHslope * K * 1.98416E-4)

Where:
Vout = pH sensor output in volts
K is the water temperature in degrees Kelvin
Risidual = instrument pH - buffer pH



SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 6243
CALIBRATION DATE: 20-Dec-08

SBE19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

a0 = 1.280611e-003
a1 = 2.605966e-004
a2 = -3.977704e-007
a3 = 1.545821e-007

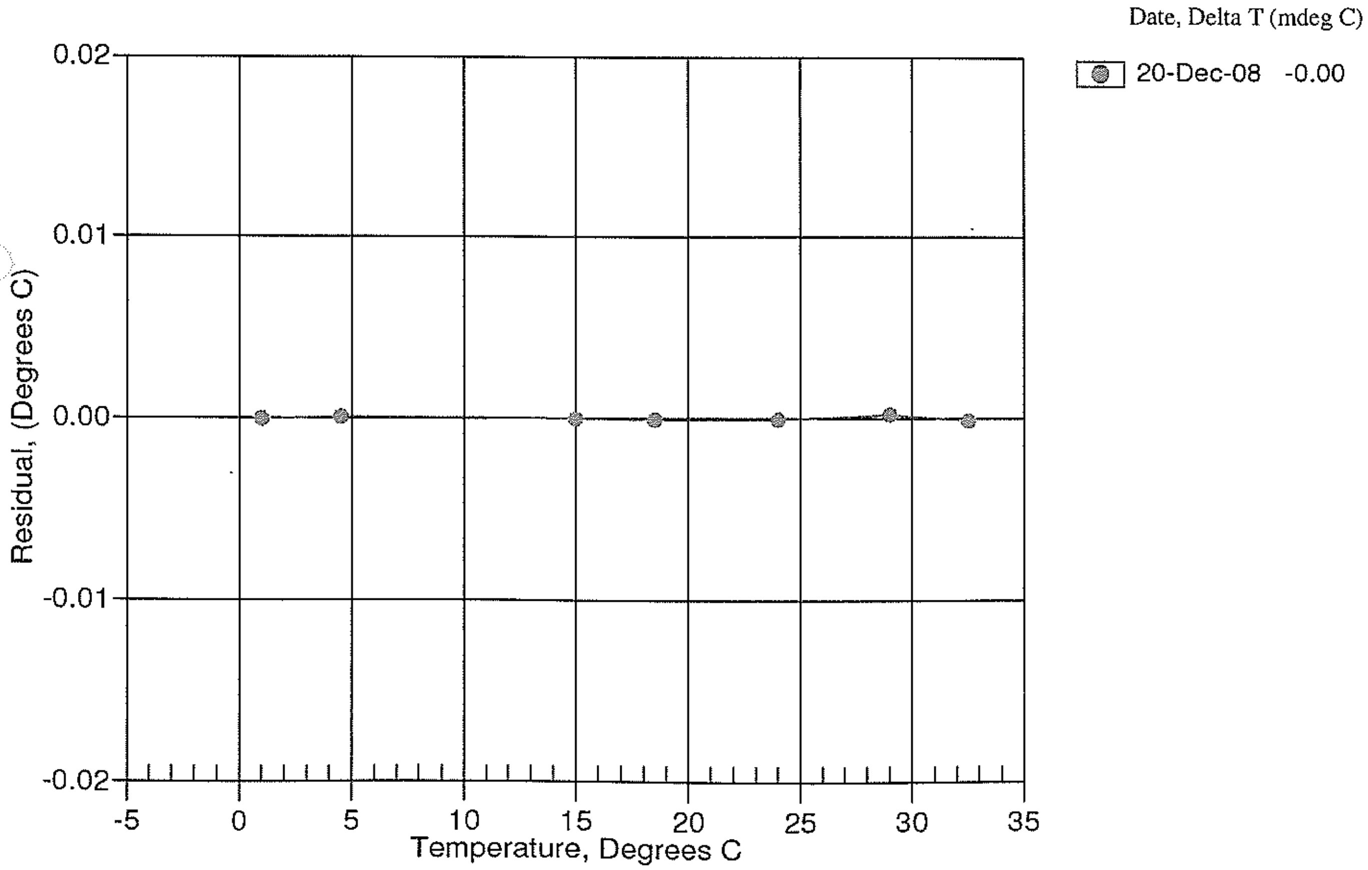
BATH TEMP (ITS-90)	INSTRUMENT OUTPUT(n)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	649730.458	1.0000	-0.0000
4.5000	576602.881	4.5001	0.0001
15.0000	394676.898	15.0000	-0.0000
18.5001	345810.576	18.5000	-0.0001
24.0000	279538.525	23.9999	-0.0001
29.0000	229187.186	29.0002	0.0002
32.5001	198841.068	32.5000	-0.0001

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

Temperature ITS-90 = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



SBE SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Pressure Test Certificate

Customer	Imbros
Job Number	69109
Date	6/20/2012
Technician	RH
Serial Number	431887

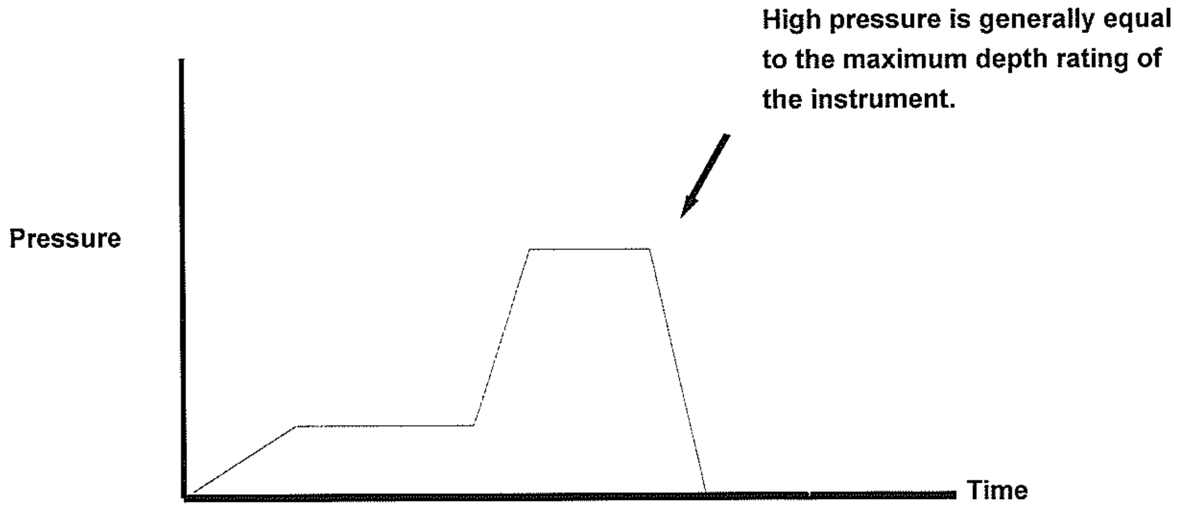
Low Pressure (PSI)	50	PSI
Time (Minutes)	15	Minutes
High Pressure (PSI)	750	PSI
Time (Minutes)	30	Minutes

Pass ☑

Fail ☐

Comments

Replaced spar, anode, getter, housing, connector and the main piston O-rings.



Typical Test Profile

Appendix B

Physicochemical water column profile data

Appendix B Physicochemical water column profile data

Table 2 Temperature (°C) / depth profiles at sites surrounding proposed Drill Centre locations

Depth	DC0	DC0_SW1000	DC0_SW2000	DC1	DC1_NW1000	DC1_NW2000	DC2	DC2_NE1000	DC2_NE2000	DC3
1 - 10 m	31.1	31.2	31.2	31.1	31.3	31.3	31.1	31.3	31.3	31.1
10 - 20 m	31.1	31.2	31.2	31.1	31.1	31.1	31.1	31.1	31.1	31.1
20 - 30 m	30.9	31.1	31.1	30.6	31.1	31.1	30.9	31.1	31.1	30.9
30 - 40 m	29.7	31.1	31.1	29.2	31.1	31.1	29.6	31.0	31.1	29.6
40 - 50 m	28.2	30.6	30.6	27.6	30.8	30.7	27.9	30.5	30.5	28.2
50 - 60 m	27.0	29.3	29.3	26.5	29.6	29.1	26.8	29.0	29.1	26.9
60 - 70 m	26.5	27.7	27.7	26.0	27.9	27.8	26.2	27.3	27.4	26.4
70 - 80 m	25.8	26.6	26.6	25.5	26.5	26.6	25.4	26.5	26.4	25.5
80 - 90 m	25.1	25.4	25.4	25.1	25.5	25.5	24.7	25.6	25.6	24.8
90 - 100 m	24.3	24.6	24.6	24.4	24.8	24.8	24.0	24.6	24.6	23.4
100 - 110 m	23.1	23.4	23.4	23.7	24.2	24.0	23.1	23.6	23.5	22.8
110 - 120 m	22.6	22.3	22.3	22.4	22.7	21.8	21.8	22.3	22.4	22.0
120 - 130 m	20.8	20.8	20.8	20.6	20.9	20.6	20.0	21.5	20.7	19.9
130 - 140 m	18.8	19.7	19.7	18.8	18.8	19.2	18.7	19.4	19.1	18.5
140 - 150 m	17.9	18.0	18.0	17.8	17.9	18.0	18.1	17.9	17.7	17.8
150 - 160 m	17.2	17.3	17.3	17.4	17.3	17.2	17.5	17.4	17.4	17.2
160 - 170 m	16.8	17.0	17.0	17.0	17.0	16.9	17.1	17.1	17.1	16.8
170 - 180 m		16.7	16.7	-	-	-	-	-	-	-
180 - 190 m	-	-	-	-	-	-	-	-	-	-
190 - 200 m	-	-	-	-	-	-	-	-	-	-
200 - 210 m	-	-	-	-	-	-	-	-	-	-

Table 3 **Temperature (°C) / depth profiles at sites surrounding proposed FPSO Locations**

Depth	FPSO_0	FPSO_SE1000	FPSO_SE2000	FPSO_NE1000	FPSO_NE2000	FPSO_SW1000	FPSO_SW2000
1 - 10 m	30.9	30.8	30.8	30.9	30.9	30.9	30.9
10 - 20 m	30.9	30.8	30.8	30.9	30.9	30.9	30.9
20 - 30 m	30.9	30.7	30.6	30.9	30.9	30.9	30.9
30 - 40 m	30.5	29.4	29.7	29.7	30.1	29.5	29.5
40 - 50 m	29.3	28.6	28.9	28.7	29.1	28.4	28.3
50 - 60 m	28.2	27.8	28.2	27.7	28.0	27.4	27.5
60 - 70 m	27.2	26.9	27.3	26.7	26.9	26.5	26.8
70 - 80 m	26.3	26.0	26.0	25.8	25.9	25.8	25.8
80 - 90 m	25.8	24.9	25.1	24.9	24.9	24.9	24.8
90 - 100 m	24.6	23.6	23.9	23.8	23.8	23.8	24.0
100 - 110 m	23.2	22.8	22.9	23.2	23.1	23.0	23.1
110 - 120 m	22.3	21.4	21.7	22.4	21.9	22.2	22.2
120 - 130 m	20.6	20.4	20.6	21.0	20.5	21.1	21.0
130 - 140 m	19.2	18.8	18.6	19.4	18.8	19.5	19.5
140 - 150 m	17.9	17.6	17.5	17.8	17.8	17.8	17.9
150 - 160 m	17.3	17.1	17.2	17.1	17.2	17.3	17.3
160 - 170 m	16.9	16.8	16.8	16.8	17.0	16.8	16.7
170 - 180 m	-	-	-	-	-	16.6	16.6
180 - 190 m	-	-	-	-	-	-	-
190 - 200 m	-	-	-	-	-	-	-
200 - 210 m	-	-	-	-	-	-	-

Table 4 **Temperature (°C) / depth profiles at sites along the Pipeline and reference sites**

Depth	PL-1	PL-2	PL-3	REF_NE	REF_SE	REF_NW	REF_SW
1 - 10 m	31.1	31.1	30.9	30.8	30.8	31.3	31.1
10 - 20 m	30.8	31.0	30.9	30.9	30.8	31.2	31.1
20 - 30 m	30.8	30.9	30.9	30.8	30.8	30.9	31.0
30 - 40 m	30.8	29.2	29.4	30.1	30.6	30.1	30.3
40 - 50 m	30.3	27.8	27.8	29.2	29.4	29.0	28.5
50 - 60 m	28.7	26.6	26.7	28.0	27.5	28.0	27.2
60 - 70 m	27.6	26.1	26.3	26.9	26.3	26.9	26.5
70 - 80 m	26.7	25.1	25.4	25.7	25.3	25.9	25.7
80 - 90 m	25.4	24.4	24.3	24.2	24.2	25.2	24.7
90 - 100 m	23.7	23.7	23.2	22.5	23.4	24.6	23.9
100 - 110 m	22.6	23.2	22.0	-	22.6	24.0	23.0
110 - 120 m	21.5	22.6	21.0	-	19.7	22.4	22.2
120 - 130 m	20.5	21.4	20.4	-	19.0	20.5	20.6
130 - 140 m	19.3	20.9	19.3	-	-	19.1	19.3
140 - 150 m	18.3	20.4	18.6	-	-	17.9	18.2
150 - 160 m	17.4	19.9	17.4	-	-	17.1	17.5
160 - 170 m	16.4	18.6	16.2	-	-	17.0	16.9
170 - 180 m	15.8	17.7	16.2	-	-	-	16.5
180 - 190 m	15.4	16.4	-	-	-	-	-
190 - 200 m	14.9	15.1	-	-	-	-	-
200 - 210 m	14.8	14.9	-	-	-	-	-

Table 5 Salinity (PSU) / depth profiles at sites surrounding proposed Drill Centre locations

Depth	DC0	DC0_SW1000	DC0_SW2000	DC1	DC1_NW1000	DC1_NW2000	DC2	DC2_NE1000	DC2_NE2000	DC3
1 - 10 m	34.94	34.94	34.94	34.94	34.94	34.95	34.94	34.94	34.94	34.94
10 - 20 m	34.94	34.94	34.94	34.94	34.94	34.94	34.94	34.94	34.94	34.93
20 - 30 m	34.90	34.94	34.94	34.83	34.94	34.94	34.89	34.94	34.94	34.87
30 - 40 m	34.73	34.93	34.93	34.68	34.93	34.94	34.71	34.93	34.93	34.71
40 - 50 m	34.61	34.83	34.83	34.58	34.88	34.84	34.59	34.82	34.82	34.60
50 - 60 m	34.58	34.69	34.69	34.58	34.71	34.67	34.57	34.65	34.65	34.57
60 - 70 m	34.57	34.60	34.60	34.58	34.60	34.62	34.56	34.59	34.59	34.56
70 - 80 m	34.56	34.56	34.56	34.57	34.58	34.57	34.56	34.58	34.58	34.55
80 - 90 m	34.56	34.55	34.55	34.56	34.56	34.55	34.56	34.55	34.56	34.54
90 - 100 m	34.53	34.55	34.55	34.56	34.56	34.55	34.54	34.55	34.55	34.53
100 - 110 m	34.53	34.52	34.52	34.53	34.55	34.54	34.52	34.52	34.53	34.53
110 - 120 m	34.52	34.52	34.52	34.51	34.51	34.49	34.49	34.52	34.51	34.51
120 - 130 m	34.48	34.50	34.50	34.47	34.49	34.50	34.50	34.51	34.50	34.49
130 - 140 m	34.50	34.50	34.50	34.51	34.50	34.50	34.51	34.48	34.47	34.51
140 - 150 m	34.51	34.49	34.49	34.51	34.51	34.51	34.51	34.51	34.52	34.52
150 - 160 m	34.51	34.52	34.52	34.52	34.52	34.51	34.51	34.52	34.52	34.51
160 - 170 m	34.52	34.52	34.52	34.53	34.53	34.53	34.52	34.52	34.53	34.53
170 - 180 m	-	34.53	34.53	-	-	-	-	-	-	-
180 - 190 m	-	-	-	-	-	-	-	-	-	-
190 - 200 m	-	-	-	-	-	-	-	-	-	-
200 - 210 m	-	-	-	-	-	-	-	-	-	-

Table 6 Salinity (PSU) / depth profiles at sites surrounding proposed FPSO Locations

Depth	FPSO_0	FPSO_SE1000	FPSO_SE2000	FPSO_NE1000	FPSO_NE2000	FPSO_SW1000	FPSO_SW2000
1 - 10 m	34.83	34.78	34.78	34.84	34.83	34.84	34.83
10 - 20 m	34.83	34.79	34.78	34.84	34.84	34.85	34.83
20 - 30 m	34.84	34.78	34.76	34.85	34.85	34.85	34.83
30 - 40 m	34.80	34.68	34.68	34.69	34.74	34.69	34.69
40 - 50 m	34.69	34.65	34.66	34.66	34.68	34.62	34.63
50 - 60 m	34.63	34.60	34.62	34.61	34.62	34.59	34.59
60 - 70 m	34.58	34.58	34.58	34.56	34.56	34.56	34.57
70 - 80 m	34.57	34.56	34.56	34.56	34.57	34.55	34.55
80 - 90 m	34.56	34.54	34.55	34.54	34.54	34.55	34.55
90 - 100 m	34.53	34.54	34.53	34.55	34.54	34.53	34.54
100 - 110 m	34.52	34.51	34.52	34.53	34.53	34.53	34.53
110 - 120 m	34.51	34.51	34.51	34.52	34.50	34.52	34.52
120 - 130 m	34.50	34.49	34.50	34.50	34.50	34.50	34.50
130 - 140 m	34.49	34.48	34.50	34.48	34.48	34.47	34.48
140 - 150 m	34.50	34.51	34.52	34.49	34.51	34.51	34.52
150 - 160 m	34.53	34.52	34.52	34.52	34.52	34.52	34.52
160 - 170 m	34.52	34.53	34.53	34.53	34.53	34.52	34.53
170 - 180 m	-	-	-	-	-	34.53	34.53
180 - 190 m	-	-	-	-	-	-	-
190 - 200 m	-	-	-	-	-	-	-
200 - 210 m	-	-	-	-	-	-	-

Table 7 Salinity (PSU) / depth profiles at sites along the Pipeline and reference sites

Depth	PL-1	PL-2	PL-3	REF_NE	REF_SE	REF_NW	REF_SW
1 - 10 m	34.86	34.88	34.83	34.79	34.79	34.96	34.94
10 - 20 m	34.86	34.86	34.82	34.79	34.79	34.96	34.93
20 - 30 m	34.86	34.84	34.81	34.78	34.77	34.90	34.93
30 - 40 m	34.86	34.67	34.65	34.75	34.75	34.74	34.78
40 - 50 m	34.78	34.60	34.58	34.67	34.67	34.67	34.61
50 - 60 m	34.64	34.56	34.56	34.59	34.56	34.63	34.58
60 - 70 m	34.59	34.55	34.55	34.57	34.55	34.59	34.56
70 - 80 m	34.54	34.53	34.52	34.54	34.55	34.57	34.56
80 - 90 m	34.51	34.51	34.51	34.53	34.55	34.56	34.55
90 - 100 m	34.49	34.50	34.50	34.49	34.54	34.55	34.55
100 - 110 m	34.48	34.49	34.49	-	34.50	34.54	34.53
110 - 120 m	34.49	34.46	34.50	-	34.49	34.49	34.52
120 - 130 m	34.49	34.48	34.50	-	34.51	34.50	34.49
130 - 140 m	34.49	34.49	34.47	-	-	34.50	34.50
140 - 150 m	34.51	34.50	34.49	-	-	34.49	34.51
150 - 160 m	34.51	34.50	34.47	-	-	34.52	34.51
160 - 170 m	34.51	34.49	34.51	-	-	34.53	34.52
170 - 180 m	34.53	34.49	34.51	-	-	-	34.53
180 - 190 m	34.53	34.50	-	-	-	-	-
190 - 200 m	34.54	34.53	-	-	-	-	-
200 - 210 m	34.54	34.54	-	-	-	-	-

Table 8 Dissolved Oxygen (% Saturation) / depth profiles at sites surrounding proposed Drill Centre locations

Depth	DC0	DC0_SW1000	DC0_SW2000	DC1	DC1_NW1000	DC1_NW2000	DC2	DC2_NE1000	DC2_NE2000	DC3
1 - 10 m	91.63	91.60	91.60	95.63	90.53	95.99	100.37	99.62	93.96	95.20
10 - 20 m	99.18	99.58	99.58	100.20	100.37	100.79	100.89	100.18	100.18	100.17
20 - 30 m	99.23	99.81	99.81	100.16	100.51	100.94	100.82	100.20	100.33	100.09
30 - 40 m	98.66	99.87	99.87	99.34	100.57	100.98	100.23	100.27	100.47	99.70
40 - 50 m	90.01	99.63	99.63	84.02	100.50	100.64	87.64	99.94	100.34	87.25
50 - 60 m	74.29	98.99	98.99	78.08	99.76	99.64	72.80	97.67	98.86	73.57
60 - 70 m	70.47	86.26	86.26	75.33	91.12	90.10	70.68	78.53	82.32	72.55
70 - 80 m	71.09	72.02	72.02	72.16	79.63	80.50	71.55	76.50	78.23	69.58
80 - 90 m	68.93	71.36	71.36	69.79	71.94	72.13	67.83	72.51	72.40	67.66
90 - 100 m	65.12	65.98	65.98	65.69	67.28	67.22	64.75	66.26	66.41	61.70
100 - 110 m	60.26	61.37	61.37	63.15	64.85	64.44	61.87	62.68	62.94	60.49
110 - 120 m	60.08	58.05	58.05	60.41	60.93	58.83	58.71	59.73	60.37	58.43
120 - 130 m	54.72	54.85	54.85	55.25	55.13	55.06	53.48	57.36	55.87	52.76
130 - 140 m	49.70	52.23	52.23	50.51	50.54	51.75	49.91	52.12	51.39	49.00
140 - 150 m	46.40	47.70	47.70	47.53	47.45	47.99	47.89	47.19	46.43	46.28
150 - 160 m	44.28	44.75	44.75	45.45	45.66	45.46	45.55	44.87	44.76	44.55
160 - 170 m	42.99	43.66	43.66	43.84	44.35	43.89	44.02	43.82	43.92	42.90
170 - 180 m	-	42.96	42.96	-	-	-	-	-	-	-
180 - 190 m	-	-	-	-	-	-	-	-	-	-
190 - 200 m	-	-	-	-	-	-	-	-	-	-
200 - 210 m	-	-	-	-	-	-	-	-	-	-

Table 9 Dissolved Oxygen (% Saturation) / depth profiles at sites surrounding proposed FPSO Locations

Depth	FPSO_0	FPSO_SE1000	FPSO_SE2000	FPSO_NE1000	FPSO_NE2000	FPSO_SW1000	FPSO_SW2000
1 - 10 m	93.47	87.34	92.87	95.28	92.47	96.18	92.94
10 - 20 m	98.30	98.44	98.38	98.57	98.54	98.63	98.82
20 - 30 m	98.67	98.19	98.31	98.72	98.79	98.88	98.94
30 - 40 m	98.11	93.57	94.36	95.08	96.63	95.24	95.37
40 - 50 m	94.87	90.42	89.66	94.15	93.82	89.02	88.01
50 - 60 m	89.95	82.34	83.93	83.32	87.15	79.37	80.85
60 - 70 m	76.11	75.66	79.67	73.70	74.15	72.48	75.93
70 - 80 m	71.27	67.80	68.79	70.97	70.92	67.17	67.52
80 - 90 m	71.37	65.62	65.06	67.12	67.54	64.55	63.36
90 - 100 m	65.99	61.67	63.04	62.26	62.56	62.67	63.30
100 - 110 m	60.97	59.79	59.73	61.03	61.17	59.15	59.72
110 - 120 m	58.53	56.32	57.21	59.07	58.17	57.82	57.58
120 - 130 m	54.42	53.15	53.34	55.45	54.12	55.34	55.13
130 - 140 m	50.27	48.80	48.25	51.02	49.53	50.52	50.30
140 - 150 m	46.38	45.21	44.82	46.49	46.05	46.05	46.26
150 - 160 m	43.70	43.53	43.89	43.43	43.62	44.10	44.43
160 - 170 m	42.61	42.36	42.29	42.18	42.62	42.66	42.43
170 - 180 m	-	-	-	-	-	41.76	41.67
180 - 190 m	-	-	-	-	-	-	-
190 - 200 m	-	-	-	-	-	-	-
200 - 210 m	-	-	-	-	-	-	-

Table 10 Dissolved Oxygen (% Saturation) / depth profiles at sites along the Pipeline and reference sites

Depth	PL-1	PL-2	PL-3	REF_NE	REF_SE	REF_NW	REF_SW
1 - 10 m	94.38	86.63	88.94	92.50	92.79	98.71	97.63
10 - 20 m	99.14	96.65	97.84	98.07	98.43	100.48	98.60
20 - 30 m	99.45	98.59	98.23	98.25	98.50	100.49	98.83
30 - 40 m	99.68	96.88	95.20	96.53	97.57	99.87	98.54
40 - 50 m	99.39	84.57	86.48	92.01	92.30	97.89	91.44
50 - 60 m	100.52	69.37	79.30	80.93	75.78	91.81	74.22
60 - 70 m	96.37	67.68	76.84	70.77	68.57	79.04	70.18
70 - 80 m	88.80	69.47	71.51	68.11	65.41	72.71	68.14
80 - 90 m	76.94	65.32	65.90	64.68	64.13	68.86	66.68
90 - 100 m	66.29	62.02	61.19	59.67	61.62	65.93	62.84
100 - 110 m	59.83	60.27	57.03	-	59.47	64.12	59.29
110 - 120 m	57.73	59.83	52.23	-	51.32	60.67	57.68
120 - 130 m	54.26	55.56	49.88	-	48.31	55.13	53.04
130 - 140 m	50.48	54.80	49.56	-	-	50.80	49.46
140 - 150 m	48.51	53.76	47.72	-	-	47.72	46.70
150 - 160 m	46.49	52.32	44.59	-	-	45.04	44.94
160 - 170 m	44.87	49.23	42.12	-	-	44.29	43.37
170 - 180 m	43.45	47.59	42.18	-	-	-	41.93
180 - 190 m	42.48	45.08	-	-	-	-	-
190 - 200 m	41.45	42.50	-	-	-	-	-
200 - 210 m	41.25	42.06	-	-	-	-	-

Table 11 pH / depth profiles at sites surrounding proposed Drill Centre locations

Depth	DC0	DC0_SW1000	DC0_SW2000	DC1	DC1_NW1000	DC1_NW2000	DC2	DC2_NE1000	DC2_NE2000	DC3
1 - 10 m	8.13	8.08	8.08	8.10	8.10	8.13	8.12	8.09	8.09	8.13
10 - 20 m	8.13	8.08	8.08	8.10	8.10	8.13	8.12	8.09	8.09	8.13
20 - 30 m	8.13	8.08	8.08	8.10	8.09	8.12	8.11	8.09	8.08	8.12
30 - 40 m	8.12	8.08	8.08	8.09	8.09	8.11	8.10	8.08	8.08	8.11
40 - 50 m	8.09	8.08	8.08	8.05	8.08	8.11	8.06	8.08	8.08	8.08
50 - 60 m	8.05	8.06	8.06	8.02	8.08	8.09	8.02	8.06	8.06	8.04
60 - 70 m	8.03	8.03	8.03	8.01	8.05	8.07	8.01	8.01	8.02	8.03
70 - 80 m	8.03	7.99	7.99	7.99	8.01	8.04	8.00	8.00	8.00	8.02
80 - 90 m	8.02	7.98	7.98	7.98	7.99	8.01	7.99	7.98	7.98	8.01
90 - 100 m	8.00	7.95	7.95	7.96	7.97	7.99	7.97	7.96	7.96	7.99
100 - 110 m	7.98	7.93	7.93	7.95	7.95	7.97	7.96	7.94	7.94	7.97
110 - 120 m	7.97	7.91	7.91	7.94	7.93	7.94	7.94	7.92	7.92	7.96
120 - 130 m	7.95	7.89	7.89	7.91	7.91	7.92	7.91	7.90	7.90	7.94
130 - 140 m	7.93	7.87	7.87	7.89	7.88	7.90	7.89	7.88	7.87	7.92
140 - 150 m	7.90	7.84	7.84	7.86	7.85	7.87	7.87	7.84	7.84	7.89
150 - 160 m	7.88	7.82	7.82	7.84	7.83	7.85	7.85	7.82	7.82	7.87
160 - 170 m	7.87	7.81	7.80	7.83	7.81	7.83	7.84	7.81	7.81	7.86
170 - 180 m	-	7.80	7.80	-	-	-	-	-	-	-
180 - 190 m	-	-	-	-	-	-	-	-	-	-
190 - 200 m	-	-	-	-	-	-	-	-	-	-
200 - 210 m	-	-	-	-	-	-	-	-	-	-

Table 12 pH / depth profiles at sites surrounding proposed FPSO Locations

Depth	FPSO_0	FPSO_SE1000	FPSO_SE2000	FPSO_NE1000	FPSO_NE2000	FPSO_SW1000	FPSO_SW2000
1 - 10 m	8.04	8.11	8.11	8.12	8.11	8.12	8.12
10 - 20 m	8.05	8.11	8.11	8.12	8.11	8.12	8.12
20 - 30 m	8.06	8.11	8.11	8.12	8.11	8.12	8.12
30 - 40 m	8.06	8.09	8.09	8.10	8.10	8.10	8.10
40 - 50 m	8.05	8.07	8.08	8.09	8.09	8.08	8.07
50 - 60 m	8.04	8.05	8.06	8.06	8.06	8.05	8.05
60 - 70 m	8.01	8.03	8.04	8.03	8.03	8.02	8.03
70 - 80 m	7.99	8.00	8.01	8.01	8.01	8.00	8.00
80 - 90 m	7.99	7.99	7.99	8.00	8.00	7.99	7.98
90 - 100 m	7.97	7.97	7.98	7.98	7.98	7.98	7.97
100 - 110 m	7.95	7.96	7.96	7.96	7.96	7.96	7.96
110 - 120 m	7.94	7.94	7.95	7.95	7.95	7.95	7.94
120 - 130 m	7.92	7.92	7.92	7.93	7.93	7.93	7.93
130 - 140 m	7.90	7.90	7.90	7.91	7.90	7.91	7.90
140 - 150 m	7.87	7.87	7.87	7.88	7.87	7.88	7.88
150 - 160 m	7.85	7.85	7.85	7.86	7.85	7.86	7.86
160 - 170 m	7.83	7.84	7.84	7.84	7.84	7.84	7.84
170 - 180 m	-	-	-	-	-	7.83	7.83
180 - 190 m	-	-	-	-	-	-	-
190 - 200 m	-	-	-	-	-	-	-
200 - 210 m	-	-	-	-	-	-	-

Table 13 pH / depth profiles at sites along the Pipeline and reference sites

Depth	PL-1	PL-2	PL-3	REF_NE	REF_SE	REF_NW	REF_SW
1 - 10 m	8.06	8.08	8.12	8.02	8.12	8.11	8.13
10 - 20 m	8.07	8.09	8.12	8.04	8.12	8.11	8.13
20 - 30 m	8.07	8.09	8.12	8.06	8.12	8.10	8.13
30 - 40 m	8.07	8.07	8.11	8.07	8.12	8.09	8.12
40 - 50 m	8.07	8.04	8.08	8.06	8.11	8.08	8.10
50 - 60 m	8.06	7.99	8.06	8.04	8.07	8.06	8.06
60 - 70 m	8.04	7.98	8.04	8.01	8.04	8.02	8.04
70 - 80 m	8.02	7.97	8.02	8.00	8.03	8.00	8.03
80 - 90 m	7.98	7.95	8.00	7.99	8.02	7.98	8.02
90 - 100 m	7.95	7.93	7.98	7.98	8.00	7.97	8.01
100 - 110 m	7.92	7.91	7.96	-	7.99	7.95	7.99
110 - 120 m	7.90	7.91	7.94	-	7.96	7.94	7.98
120 - 130 m	7.89	7.89	7.92	-	7.94	7.91	7.96
130 - 140 m	7.86	7.88	7.91	-	-	7.88	7.94
140 - 150 m	7.84	7.87	7.89	-	-	7.86	7.92
150 - 160 m	7.82	7.86	7.87	-	-	7.84	7.90
160 - 170 m	7.80	7.85	7.85	-	-	7.83	7.88
170 - 180 m	7.78	7.83	7.84	-	-	-	7.87
180 - 190 m	7.77	7.81	-	-	-	-	-
190 - 200 m	7.76	7.78	-	-	-	-	-
200 - 210 m	7.75	7.77	-	-	-	-	-

Table 14 Turbidity (NTU) / depth profiles at sites surrounding proposed Drill Centre locations

Depth	DC0	DC0_SW1000	DC0_SW2000	DC1	DC1_NW1000	DC1_NW2000	DC2	DC2_NE1000	DC2_NE2000	DC3
1 - 10 m	0.31	0.32	0.32	0.30	0.36	0.26	0.35	0.30	0.33	0.40
10 - 20 m	0.25	0.28	0.28	0.37	0.25	0.32	0.33	0.33	0.29	0.35
20 - 30 m	0.26	0.30	0.30	0.33	0.25	0.27	0.26	0.31	0.36	0.39
30 - 40 m	0.26	0.29	0.29	0.27	0.29	0.25	0.26	0.29	0.32	0.31
40 - 50 m	0.29	0.30	0.30	0.32	0.26	0.24	0.30	0.31	0.29	0.37
50 - 60 m	0.30	0.27	0.27	0.24	0.25	0.21	0.33	0.29	0.31	0.32
60 - 70 m	0.35	0.29	0.29	0.33	0.26	0.24	0.31	0.29	0.27	0.37
70 - 80 m	0.28	0.29	0.29	0.30	0.24	0.21	0.21	0.28	0.26	0.34
80 - 90 m	0.33	0.31	0.31	0.33	0.26	0.23	0.27	0.33	0.26	0.30
90 - 100 m	0.37	0.30	0.30	0.45	0.27	0.22	0.33	0.34	0.40	0.42
100 - 110 m	0.45	0.46	0.46	0.44	0.38	0.40	0.31	0.48	0.47	0.35
110 - 120 m	0.34	0.49	0.49	0.33	0.33	0.33	0.30	0.41	0.40	0.39
120 - 130 m	0.48	0.51	0.51	0.44	0.43	0.33	0.37	0.37	0.33	0.42
130 - 140 m	0.47	0.40	0.40	0.44	0.41	0.34	0.34	0.41	0.41	0.42
140 - 150 m	0.47	0.51	0.51	0.45	0.44	0.42	0.37	0.51	0.48	0.41
150 - 160 m	0.46	0.51	0.51	0.44	0.46	0.42	0.37	0.52	0.49	0.43
160 - 170 m	0.44	0.50	0.50	0.45	0.48	0.43	0.35	0.52	0.45	0.46
170 - 180 m	-	0.50	0.50	-	-	-	-	-	-	-
180 - 190 m	-	-	-	-	-	-	-	-	-	-
190 - 200 m	-	-	-	-	-	-	-	-	-	-
200 - 210 m	-	-	-	-	-	-	-	-	-	-

Table 15 Turbidity (NTU) / depth profiles at sites surrounding proposed FPSO Locations

Depth	FPSO_0	FPSO_SE1000	FPSO_SE2000	FPSO_NE1000	FPSO_NE2000	FPSO_SW1000	FPSO_SW2000
1 - 10 m	0.30	0.29	0.45	0.29	0.32	0.29	0.30
10 - 20 m	0.26	0.28	0.29	0.30	0.29	0.29	0.29
20 - 30 m	0.26	0.28	0.31	0.28	0.30	0.29	0.30
30 - 40 m	0.28	0.30	0.33	0.35	0.30	0.33	0.39
40 - 50 m	0.27	0.28	0.33	0.28	0.29	0.30	0.34
50 - 60 m	0.28	0.27	0.28	0.29	0.28	0.28	0.31
60 - 70 m	0.30	0.29	0.28	0.30	0.28	0.30	0.28
70 - 80 m	0.26	0.34	0.35	0.34	0.32	0.40	0.45
80 - 90 m	0.29	0.41	0.47	0.31	0.30	0.48	0.49
90 - 100 m	0.26	0.44	0.39	0.45	0.43	0.33	0.43
100 - 110 m	0.40	0.36	0.44	0.35	0.32	0.38	0.40
110 - 120 m	0.32	0.32	0.32	0.33	0.36	0.37	0.46
120 - 130 m	0.35	0.44	0.52	0.37	0.42	0.33	0.45
130 - 140 m	0.48	0.51	0.50	0.37	0.49	0.52	0.52
140 - 150 m	0.49	0.49	0.50	0.53	0.51	0.51	0.52
150 - 160 m	0.47	0.51	0.54	0.50	0.52	0.51	0.52
160 - 170 m	0.49	0.50	0.52	0.54	0.53	0.52	0.54
170 - 180 m	-	-	-	-	-	0.49	0.57
180 - 190 m	-	-	-	-	-	-	-
190 - 200 m	-	-	-	-	-	-	-
200 - 210 m	-	-	-	-	-	-	-

Table 16 Turbidity (NTU) / depth profiles at sites along the Pipeline and reference sites

Depth	PL-1	PL-2	PL-3	REF_NE	REF_SE	REF_NW	REF_SW
1 - 10 m	0.36	0.34	0.40	0.39	0.36	0.29	0.22
10 - 20 m	0.28	0.31	0.24	0.33	0.30	0.27	0.27
20 - 30 m	0.26	0.33	0.20	0.30	0.37	0.27	0.23
30 - 40 m	0.28	0.32	0.22	0.33	0.37	0.31	0.25
40 - 50 m	0.26	0.45	0.21	0.32	0.44	0.28	0.24
50 - 60 m	0.27	0.40	0.21	0.29	0.31	0.24	0.25
60 - 70 m	0.26	0.26	0.22	0.41	0.33	0.24	0.29
70 - 80 m	0.34	0.25	0.23	0.36	0.51	0.25	0.37
80 - 90 m	0.24	0.25	0.31	0.44	0.48	0.26	0.29
90 - 100 m	0.25	0.24	0.36	0.46	0.32	0.31	0.32
100 - 110 m	0.25	0.24	0.41	-	0.38	0.29	0.45
110 - 120 m	0.25	0.22	0.44	-	0.49	0.31	0.41
120 - 130 m	0.25	0.24	0.62	-	0.52	0.33	0.42
130 - 140 m	0.26	0.23	0.44	-	-	0.44	0.43
140 - 150 m	0.24	0.23	0.47	-	-	0.45	0.41
150 - 160 m	0.31	0.24	0.60	-	-	0.45	0.43
160 - 170 m	0.26	0.23	0.66	-	-	0.44	0.42
170 - 180 m	0.33	0.23	0.74	-	-	-	0.42
180 - 190 m	0.38	0.27	-	-	-	-	-
190 - 200 m	0.50	0.46	-	-	-	-	-
200 - 210 m	0.72	0.45	-	-	-	-	-

Appendix C

Water sample analytical results

Appendix C Water sample analytical results

Table 17 Laboratory analytical results for sample sites surrounding proposed Drill Centre locations

			Site	DC0	DC00	DC1	DC2	DC22	DC3	DC1_NW1000	DC1_NW2000	DC2_NE1000	DC2_NE2000	DC0_SW1000	DC0_SW10001	DC0_SW2000
Analyte	**Unit**	**Trigger[a]**	**PQL**													
Hydrocarbons																
TRH C6-C40 (sum)	µg/L	-	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
BTEX																
Benzene	mg/L	0.5	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Toluene	mg/L	0.18[b]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethylbenzene	mg/L	0.005[b]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Xylenes (Total)	mg/L	0.625[b]	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Metals (Total)																
Arsenic - Total	mg/L	-	0.001	**0.002**	**0.002**	**0.002**	**0.001**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**
Aluminium - Total	mg/L	-	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Barium - Total	mg/L	-	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - Total	mg/L	0.0007	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt - Total	mg/L	0.001[c]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium - Total	mg/L	0.0077	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.002**	<0.001	<0.001
Copper - Total	mg/L	0.0013[c]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.001**	<0.001	<0.001
Iron - Total	mg/L	-	0.01	**0.06**	**0.01**	**0.04**	<0.01	**0.03**	**0.02**	<0.01	**0.02**	<0.01	**0.02**	<0.01	<0.01	<0.01
Mercury - Total	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Total	mg/L	0.007	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead - Total	mg/L	0.0022	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Total	mg/L	0.007	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nutrients																
Total Nitrogen	mg/L	0.1[d]	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
TKN	mg/L	-	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
NOx-N	mg/L	0.004[d]	0.01	<0.01	**0.01**	<0.01	<0.01	<0.01	**0.04**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Phosphorus	mg/L	0.01[d]	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Photosynthetic pigments																
CHLORO 'a' 3020	µg/L	0.9[d]	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CHLORO 'b' 3020	µg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CHLORO 'c' 3020	µg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CHLOROPHYLL'a' 3000	µg/L	0.9[d]	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PHAEOPHYTIN'a' 3000	µg/L	-	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Concentrations above PQL in **bold**
a - ANZECC / ARMCANZ 99% species protection level
b - ANZECC/ARMCANZZ low reliability trigger values
c - ANZECC / ARMCANZ 95% species protection level
d -ANZECC / ARMCANZ Default trigger level. Site specific trigger level to be developed using baseline data

Table 18 Laboratory analytical results for sample sites surrounding proposed FPSO locations

			Site	FPSO_0	FPSO_00	FPSO_NE1000	FPSO_NE2000	FPSO_SW1000	FPSO_SW2000	FPSO_SE1000	FPSO_SE2000
Analyte	**Unit**	**Trigger[a]**	**PQL**								
Hydrocarbons											
TRH C6-C40 (sum)	µg/L	-	10	<10	<10	<10	<10	<10	<10	<10	<10
BTEX											
Benzene	mg/L	0.5	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Toluene	mg/L	0.18[b]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethylbenzene	mg/L	0.005[b]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Xylenes (Total)	mg/L	0.625[b]	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Metals (Total)											
Arsenic - Total	mg/L	-	0.001	**0.002**	**0.002**	**0.002**	**0.004**	**0.002**	**0.002**	**0.003**	**0.002**
Aluminium - Total	mg/L	-	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Barium - Total	mg/L	-	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - Total	mg/L	0.0007	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt - Total	mg/L	0.001[c]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium - Total	mg/L	0.0077	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper - Total	mg/L	0.0013[c]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron - Total	mg/L	-	0.01	<0.01	**0.02**	<0.01	**0.02**	**0.03**	**0.03**	<0.01	<0.01
Mercury - Total	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Total	mg/L	0.007	0.001	<0.001	<0.001	<0.001	**0.001**	<0.001	<0.001	<0.001	<0.001
Lead - Total	mg/L	0.0022	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Total	mg/L	0.007	0.005	<0.005	<0.005	<0.005	**0.021**	<0.005	<0.005	<0.005	<0.005
Nutrients											
Total Nitrogen	mg/L	0.1[d]	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
TKN	mg/L	-	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
NOx-N	mg/L	0.004[d]	0.01	<0.01	<0.01	**0.05**	<0.01	<0.01	<0.01	<0.01	**0.02**
Total Phosphorus	mg/L	0.01[d]	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Photosynthetic pigments											
CHLORO 'a' 3020	µg/L	0.9[d]	0.1	**0.1**	<0.1	**0.1**	**0.1**	<0.1	<0.1	**0.1**	**0.1**
CHLORO 'b' 3020	µg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CHLORO 'c' 3020	µg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CHLOROPHYLL'a' 3000	µg/L	0.9[d]	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.1**
PHAEOPHYTIN'a' 3000	µg/L	-	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Concentrations above PQL in **bold**

a - ANZECC / ARMCANZ 99% species protection level

b - ANZECC/ARMCANZZ low reliability trigger values

c - ANZECC / ARMCANZ 95% species protection level

d -ANZECC / ARMCANZ Default trigger level. Site specific trigger level to be developed using baseline data

Table 19 Laboratory analytical results for sample sites along the Pipeline, Reference Sites and QA/QC samples

Analyte	Unit	Trigger[a]	Site PQL	PL_1	PL_2	PL_3	REF_NW	REF_NW2	REF_SW	REF_NE	REF_SE	Rin_1	Rin_2	FB_1	Trip Blank
Hydrocarbons															
TRH C6-C40 (sum)	µg/L	-	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
BTEX															
Benzene	mg/L	0.5	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Toluene	mg/L	0.18[b]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethylbenzene	mg/L	0.005[b]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Xylenes (Total)	mg/L	0.625[b]	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Metals (Total)															
Arsenic - Total	mg/L	-	0.001	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.003**	**0.002**	**0.002**	<0.001	<0.001	<0.001	<0.001
Aluminium - Total	mg/L	-	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**0.03**	<0.01	<0.01
Barium - Total	mg/L	-	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - Total	mg/L	0.0007	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt - Total	mg/L	0.001[c]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium - Total	mg/L	0.0077	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper - Total	mg/L	0.0013[c]	0.001	**0.002**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.003**	**0.003**	**0.002**	**0.003**
Iron - Total	mg/L	-	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury - Total	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Total	mg/L	0.007	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead - Total	mg/L	0.0022	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Total	mg/L	0.007	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nutrients															
Total Nitrogen	mg/L	0.1[d]	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-	-
TKN	mg/L	-	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-	-
NOx-N	mg/L	0.004[d]	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-
Total Phosphorus	mg/L	0.01[d]	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-
Photosynthetic pigments															
CHLORO 'a' 3020	µg/L	0.9[d]	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.1**	**0.2**				
CHLORO 'b' 3020	µg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1				
CHLORO 'c' 3020	µg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1				
CHLOROPHYLL'a' 3000	µg/L	0.9[d]	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.1**	**0.1**				
PHAEOPHYTIN'a' 3000	µg/L	-	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2				

Concentrations above PQL in **bold**

a - ANZECC / ARMCANZ 99% species protection level

b - ANZECC/ARMCANZZ low reliability trigger values

c - ANZECC / ARMCANZ 95% species protection level

d -ANZECC / ARMCANZ Default trigger level. Site specific trigger level to be developed using baseline data

Appendix D

Laboratory reports

Appendix D Laboratory reports

Analytical Reference Laboratory

LABORATORY REPORT

Job Number: 16-03180
Revision: 00
Date: 12 May 2016

ADDRESS: **AECOM Services Pty Ltd**
GPO Box B59
Perth WA 6849

ATTENTION: Peter Young

DATE RECEIVED: 4/05/2016

YOUR REFERENCE: 60478944

PURCHASE ORDER:

APPROVALS:

DouglasTodd	Paul Nottle	Sam Becker
Laboratory Manager	Organics Manager	Inorganics Manager

REPORT COMMENTS:

Samples are analysed on an as received basis unless otherwise noted.

METHOD REFERENCES:

ARL No. 009	Total Petroleum Hydrocarbons (TPH) in Water
ARL No. 007	Benzene, Toluene, Ethylbenzene and Xylenes in Water
ARL No. 29/402/403	Metals in Water by AAS/ICPOES/ICPMS
ARL No. 406	Mercury by Cold Vapour Atomic Absorption Spectrophotometry
ARL No. 330	Persulphate Method for Simultaneous Determination of TN & TP
ARL No. 308	Total Phosphorus in Water by Discrete Analyser
ARL No. 313/319	NOx in Water by Discrete Analyser

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LABORATORY REPORT

AECOM Services Pty Ltd

ARL Job No: 16-03180 *Revision: 00* *Date:* 12 May 2016

TPH Low Level 1 in Water Sample No: Sample Description:	LOR	UNITS	16-03180-1 DC0	16-03180-2 DC00	16-03180-3 DC1	16-03180-4 DC2	16-03180-5 DC22
TPH Low Level 1*	10	µg/L	<10	<10	<10	<10	<10

TPH Low Level 1 in Water Sample No: Sample Description:	LOR	UNITS	16-03180-6 DC3	16-03180-7 DC1_NW1000	16-03180-8 DC1_NM2000	16-03180-9 DC2_NE1000	16-03180-10 DC2_NE2000
TPH Low Level 1*	10	µg/L	<10	<10	<10	<10	<10

TPH Low Level 1 in Water Sample No: Sample Description:	LOR	UNITS	16-03180-11 DC0_SW1000	16-03180-12 DC0_SW10001	16-03180-13 DC0_SW2000	16-03180-14 FPSO_0	16-03180-15 FPSO_00
TPH Low Level 1*	10	µg/L	<10	<10	<10	<10	<10

TPH Low Level 1 in Water Sample No: Sample Description:	LOR	UNITS	16-03180-16 FPSO_NE1000	16-03180-17 FPSO_NE2000	16-03180-18 FPSO_SW1000	16-03180-19 FPSO_SW2000	16-03180-20 FPSO_SE1000
TPH Low Level 1*	10	µg/L	<10	<10	<10	<10	<10

TPH Low Level 1 in Water Sample No: Sample Description:	LOR	UNITS	16-03180-21 FPSO_SE2000	16-03180-22 PL_1	16-03180-23 PL_2	16-03180-24 PL_3	16-03180-25 REF_NW
TPH Low Level 1*	10	µg/L	<10	<10	<10	<10	<10

TPH Low Level 1 in Water Sample No: Sample Description:	LOR	UNITS	16-03180-26 REF_NW2	16-03180-27 REF_SW	16-03180-28 REF_NE	16-03180-29 REF_SE	16-03180-30 Rin_1
TPH Low Level 1*	10	µg/L	<10	<10	<10	<10	<10

TPH Low Level 1 in Water Sample No: Sample Description:	LOR	UNITS	16-03180-31 Rin_2	16-03180-32 FB_1	16-03180-33 Trip Blank
TPH Low Level 1*	10	µg/L	<10	<10	<10

BTEX in Water Sample No: Sample Description:	LOR	UNITS	16-03180-1 DC0	16-03180-2 DC00	16-03180-3 DC1	16-03180-4 DC2	16-03180-5 DC22
Benzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Toluene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Ethylbenzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Xylenes (Total)	0.003	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003

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LABORATORY REPORT

AECOM Services Pty Ltd

ARL Job No: 16-03180 *Revision: 00* *Date:* 12 May 2016

Analytical Reference Laboratory

BTEX in Water Sample No: Sample Description:	LOR	UNITS	16-03180-6 DC3	16-03180-7 DC1_NW1000	16-03180-8 DC1_NM2000	16-03180-9 DC2_NE1000	16-03180-10 DC2_NE2000
Benzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Toluene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Ethylbenzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Xylenes (Total)	0.003	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003

BTEX in Water Sample No: Sample Description:	LOR	UNITS	16-03180-11 DC0_SW1000	16-03180-12 DC0_SW10001	16-03180-13 DC0_SW2000	16-03180-14 FPSO_0	16-03180-15 FPSO_00
Benzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Toluene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Ethylbenzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Xylenes (Total)	0.003	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003

BTEX in Water Sample No: Sample Description:	LOR	UNITS	16-03180-16 FPSO_NE1000	16-03180-17 FPSO_NE2000	16-03180-18 FPSO_SW1000	16-03180-19 FPSO_SW2000	16-03180-20 FPSO_SE1000
Benzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Toluene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Ethylbenzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Xylenes (Total)	0.003	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003

BTEX in Water Sample No: Sample Description:	LOR	UNITS	16-03180-21 FPSO_SE2000	16-03180-22 PL_1	16-03180-23 PL_2	16-03180-24 PL_3	16-03180-25 REF_NW
Benzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Toluene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Ethylbenzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Xylenes (Total)	0.003	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003

BTEX in Water Sample No: Sample Description:	LOR	UNITS	16-03180-26 REF_NW2	16-03180-27 REF_SW	16-03180-28 REF_NE	16-03180-29 REF_SE	16-03180-30 Rin_1
Benzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Toluene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Ethylbenzene	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Xylenes (Total)	0.003	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003

BTEX in Water Sample No: Sample Description:	LOR	UNITS	16-03180-31 Rin_2	16-03180-32 FB_1	16-03180-33 Trip Blank
Benzene	0.001	mg/L	<0.001	<0.001	<0.001
Toluene	0.001	mg/L	<0.001	<0.001	<0.001
Ethylbenzene	0.001	mg/L	<0.001	<0.001	<0.001
Xylenes (Total)	0.003	mg/L	<0.003	<0.003	<0.003

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LABORATORY REPORT

AECOM Services Pty Ltd

ARL Job No: 16-03180 *Revision:* 00 *Date:* 12 May 2016

Analytical Reference Laboratory

Metals in Water Sample No: Sample Description:	LOR	UNITS	16-03180-1 DC0	16-03180-2 DC00	16-03180-3 DC1	16-03180-4 DC2	16-03180-5 DC22
Arsenic - Total	0.001	mg/L	0.002	0.002	0.002	0.001	0.002
Aluminium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Barium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.001
Copper - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Iron - Total	0.01	mg/L	0.06	0.01	0.04	<0.01	0.03
Mercury - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Total	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005

Metals in Water Sample No: Sample Description:	LOR	UNITS	16-03180-6 DC3	16-03180-7 DC1_NW1000	16-03180-8 DC1_NM2000	16-03180-9 DC2_NE1000	16-03180-10 DC2_NE2000
Arsenic - Total	0.001	mg/L	0.002	0.002	0.002	0.002	0.002
Aluminium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Barium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Iron - Total	0.01	mg/L	0.02	<0.01	0.02	<0.01	0.02
Mercury - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Total	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005

Metals in Water Sample No: Sample Description:	LOR	UNITS	16-03180-11 DC0_SW1000	16-03180-12 DC0_SW10001	16-03180-13 DC0_SW2000	16-03180-14 FPSO_0	16-03180-15 FPSO_00
Arsenic - Total	0.001	mg/L	0.002	0.002	0.002	0.002	0.002
Aluminium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Barium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium - Total	0.001	mg/L	0.002	<0.001	<0.001	<0.001	<0.001
Copper - Total	0.001	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Iron - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	0.02
Mercury - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Total	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005

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LABORATORY REPORT

AECOM Services Pty Ltd

ARL Job No: *16-03180* *Revision:* *00* *Date:* 12 May 2016

Analytical Reference Laboratory

Metals in Water Sample No: Sample Description:	LOR	UNITS	16-03180-16 FPSO_NE1000	16-03180-17 FPSO_NE2000	16-03180-18 FPSO_SW1000	16-03180-19 FPSO_SW2000	16-03180-20 FPSO_SE1000
Arsenic - Total	0.001	mg/L	0.002	0.004	0.002	0.002	0.003
Aluminium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Barium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Iron - Total	0.01	mg/L	<0.01	0.02	0.03	0.03	<0.01
Mercury - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Total	0.001	mg/L	<0.001	0.001	<0.001	<0.001	<0.001
Lead - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Total	0.005	mg/L	<0.005	0.021	<0.005	<0.005	<0.005

Metals in Water Sample No: Sample Description:	LOR	UNITS	16-03180-21 FPSO_SE2000	16-03180-22 PL_1	16-03180-23 PL_2	16-03180-24 PL_3	16-03180-25 REF_NW
Arsenic - Total	0.001	mg/L	0.002	0.002	0.002	0.002	0.002
Aluminium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Barium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium - Total	0.001	mg/L	<0.001	<0.001	0.001	<0.001	<0.001
Copper - Total	0.001	mg/L	<0.001	0.002	<0.001	<0.001	<0.001
Iron - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Total	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005

Metals in Water Sample No: Sample Description:	LOR	UNITS	16-03180-26 REF_NW2	16-03180-27 REF_SW	16-03180-28 REF_NE	16-03180-29 REF_SE	16-03180-30 Rin_1
Arsenic - Total	0.001	mg/L	0.002	0.003	0.002	0.002	<0.001
Aluminium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Barium - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.003
Iron - Total	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead - Total	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Total	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005

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LABORATORY REPORT

AECOM Services Pty Ltd

ARL Job No: *16-03180* *Revision:* *00* *Date:* 12 May 2016

Analytical Reference Laboratory

Metals in Water Sample No: Sample Description:	LOR	UNITS	16-03180-31 Rin_2	16-03180-32 FB_1	16-03180-33 Trip Blank
Arsenic - Total	0.001	mg/L	<0.001	<0.001	<0.001
Aluminium - Total	0.01	mg/L	0.03	<0.01	<0.01
Barium - Total	0.01	mg/L	<0.01	<0.01	<0.01
Cadmium - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001
Cobalt - Total	0.001	mg/L	<0.001	<0.001	<0.001
Chromium - Total	0.001	mg/L	<0.001	<0.001	<0.001
Copper - Total	0.001	mg/L	0.003	0.002	0.003
Iron - Total	0.01	mg/L	<0.01	<0.01	<0.01
Mercury - Total	0.0001	mg/L	<0.0001	<0.0001	<0.0001
Nickel - Total	0.001	mg/L	<0.001	<0.001	<0.001
Lead - Total	0.001	mg/L	<0.001	<0.001	<0.001
Zinc - Total	0.005	mg/L	<0.005	<0.005	<0.005

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	16-03180-1 DC0	16-03180-2 DC00	16-03180-3 DC1	16-03180-4 DC2	16-03180-5 DC22
Total Nitrogen	0.2	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2
TKN	0.2	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	16-03180-6 DC3	16-03180-7 DC1_NW1000	16-03180-8 DC1_NM2000	16-03180-9 DC2_NE1000	16-03180-10 DC2_NE2000
Total Nitrogen	0.2	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2
TKN	0.2	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	16-03180-11 DC0_SW1000	16-03180-12 DC0_SW10001	16-03180-13 DC0_SW2000	16-03180-14 FPSO_0	16-03180-15 FPSO_00
Total Nitrogen	0.2	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2
TKN	0.2	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	16-03180-16 FPSO_NE1000	16-03180-17 FPSO_NE2000	16-03180-18 FPSO_SW1000	16-03180-19 FPSO_SW2000	16-03180-20 FPSO_SE1000
Total Nitrogen	0.2	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2
TKN	0.2	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	16-03180-21 FPSO_SE2000	16-03180-22 PL_1	16-03180-23 PL_2	16-03180-24 PL_3	16-03180-25 REF_NW
Total Nitrogen	0.2	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2
TKN	0.2	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	16-03180-26 REF_NW2	16-03180-27 REF_SW	16-03180-28 REF_NE	16-03180-29 REF_SE
Total Nitrogen	0.2	mg/L	<0.2	<0.2	<0.2	<0.2

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LABORATORY REPORT

AECOM Services Pty Ltd

ARL Job No: *16-03180* *Revision:* *00* *Date:* 12 May 2016

Total Nitrogen in Water Sample No: Sample Description:	**LOR**	**UNITS**	**16-03180-26 REF_NW2**	**16-03180-27 REF_SW**	**16-03180-28 REF_NE**	**16-03180-29 REF_SE**
TKN	0.2	mg/L	<0.2	<0.2	<0.2	<0.2

Total Phosphorus in Water Sample No: Sample Description:	**LOR**	**UNITS**	**16-03180-1 DC0**	**16-03180-2 DC00**	**16-03180-3 DC1**	**16-03180-4 DC2**	**16-03180-5 DC22**
Total Phosphorus	0.01	mg/L	<0.01	<0.01	<0.01	0.05	<0.01

Total Phosphorus in Water Sample No: Sample Description:	**LOR**	**UNITS**	**16-03180-6 DC3**	**16-03180-7 DC1_NW1000**	**16-03180-8 DC1_NM2000**	**16-03180-9 DC2_NE1000**	**16-03180-10 DC2_NE2000**
Total Phosphorus	0.01	mg/L	<0.01	0.03	<0.01	<0.01	<0.01

Total Phosphorus in Water Sample No: Sample Description:	**LOR**	**UNITS**	**16-03180-11 DC0_SW1000**	**16-03180-12 DC0_SW10001**	**16-03180-13 DC0_SW2000**	**16-03180-14 FPSO_0**	**16-03180-15 FPSO_00**
Total Phosphorus	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Total Phosphorus in Water Sample No: Sample Description:	**LOR**	**UNITS**	**16-03180-16 FPSO_NE1000**	**16-03180-17 FPSO_NE2000**	**16-03180-18 FPSO_SW1000**	**16-03180-19 FPSO_SW2000**	**16-03180-20 FPSO_SE1000**
Total Phosphorus	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Total Phosphorus in Water Sample No: Sample Description:	**LOR**	**UNITS**	**16-03180-21 FPSO_SE2000**	**16-03180-22 PL_1**	**16-03180-23 PL_2**	**16-03180-24 PL_3**	**16-03180-25 REF_NW**
Total Phosphorus	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Total Phosphorus in Water Sample No: Sample Description:	**LOR**	**UNITS**	**16-03180-26 REF_NW2**	**16-03180-27 REF_SW**	**16-03180-28 REF_NE**	**16-03180-29 REF_SE**
Total Phosphorus	0.01	mg/L	<0.01	<0.01	<0.01	<0.01

Ions by Discrete Analyser Sample No: Sample Description:	**LOR**	**UNITS**	**16-03180-1 DC0**	**16-03180-2 DC00**	**16-03180-3 DC1**	**16-03180-4 DC2**	**16-03180-5 DC22**
NOx-N	0.01	mg/L	<0.01	0.01	<0.01	<0.01	<0.01

Analytical Reference Laboratory (WA) Pty. Ltd.
46-48 Banksia Road, Welshpool, Western Australia 6106 Telephone: 08 6253 4444 Facsimile: 08 6253 4440
www.arlwa.com.au ABN: 91 050 159 898

LABORATORY REPORT

AECOM Services Pty Ltd

ARL Job No: *16-03180* *Revision:* *00* *Date:* 12 May 2016

Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	16-03180-6 DC3	16-03180-7 DC1_NW1000	16-03180-8 DC1_NM2000	16-03180-9 DC2_NE1000	16-03180-10 DC2_NE2000
NOx-N	0.01	mg/L	0.04	<0.01	<0.01	<0.01	<0.01

Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	16-03180-11 DC0_SW1000	16-03180-12 DC0_SW10001	16-03180-13 DC0_SW2000	16-03180-14 FPSO_0	16-03180-15 FPSO_00
NOx-N	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	16-03180-16 FPSO_NE1000	16-03180-17 FPSO_NE2000	16-03180-18 FPSO_SW1000	16-03180-19 FPSO_SW2000	16-03180-20 FPSO_SE1000
NOx-N	0.01	mg/L	0.05	<0.01	<0.01	<0.01	<0.01

Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	16-03180-21 FPSO_SE2000	16-03180-22 PL_1	16-03180-23 PL_2	16-03180-24 PL_3	16-03180-25 REF_NW
NOx-N	0.01	mg/L	0.02	<0.01	<0.01	<0.01	<0.01

Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	16-03180-26 REF_NW2	16-03180-27 REF_SW	16-03180-28 REF_NE	16-03180-29 REF_SE
NOx-N	0.01	mg/L	<0.01	<0.01	<0.01	<0.01

Result Definitions

LOR Limit of Reporting
[NT] Not Tested
[ND] Not Detected at indicated Limit of Reporting
[NR] Analysis Not Requested
(SS) Surrogate Standard Compound - Used for QC purposes. Acceptance Criteria is 60-120%.
* Denotes test not covered by NATA Accreditation

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46-48 Banksia Road, Welshpool, Western Australia 6106 Telephone: 08 6253 4444 Facsimile: 08 6253 4440
www.arlwa.com.au ABN: 91 050 159 898

CERTIFICATE OF ANALYSIS

Work Order	: **EP1603971**	Page	: 1 of 5
Client	: **AECOM Australia Pty Ltd**	Laboratory	: Environmental Division Perth
Contact	: PETER YOUNG	Contact	: Loren Schiavon
Address	: LEVEL 6, 3 FORREST PLACE PERTH WA 6849	Address	: 10 Hod Way Malaga WA Australia 6090
Telephone	: 6432 2000	Telephone	: +61 2 8784 8503
Project	: 60478944 Shell Crux	Date Samples Received	: 04-May-2016 15:50
Order number	: ----	Date Analysis Commenced	: 06-May-2016
C-O-C number	: ----	Issue Date	: 13-May-2016 13:41
Sampler	: PETER YOUNG		
Site	: ----		
Quote number	: ----		
No. of samples received	: 3		
No. of samples analysed	: 3		

NATA Accredited Laboratory 825
Accredited for compliance with
ISO/IEC 17025.

NATA
WORLD RECOGNISED
ACCREDITATION

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Metals Instrument Chemist	Perth Inorganics, Malaga, WA
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics, Smithfield, NSW
Jeremy Truong	Laboratory Supervisor	Perth Inorganics, Malaga, WA
Rassem Ayoubi	Senior Organic Chemist	Perth Organics, Malaga, WA
Sanjeshni Jyoti	Senior Chemist Volatiles	Sydney Organics, Smithfield, NSW

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.

- UT BTEXN/Metals conducted by ALS Sydney, NATA accreditation no. 825, site no 10911.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	REF_NW3	DC23	Trip Blank	----	----
			Client sampling date / time	01-May-2016 13:28	01-May-2016 10:30	[01-May-2016]	----	----
Compound	CAS Number	LOR	Unit	EP1603971-001	EP1603971-002	EP1603971-003	--------	--------
				Result	Result	Result	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	----	----	----
Arsenic	7440-38-2	0.5	µg/L	**1.6**	**1.4**	----	----	----
Barium	7440-39-3	1	µg/L	**6**	**15**	----	----	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	----	----	----
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	----	----	----
Cobalt	7440-48-4	0.2	µg/L	<0.2	<0.2	----	----	----
Copper	7440-50-8	1	µg/L	**2**	<1	----	----	----
Iron	7439-89-6	5	µg/L	<5	<5	----	----	----
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	----	----	----
Nickel	7440-02-0	0.5	µg/L	**1.1**	<0.5	----	----	----
Zinc	7440-66-6	5	µg/L	<5	<5	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.2**	**0.1**	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**0.2**	**0.1**	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.01	**0.01**	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	----	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	----	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	<100	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	<100	----	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**REF_NW3**	**DC23**	**Trip Blank**	**----**	**----**
			Client sampling date / time	01-May-2016 13:28	01-May-2016 10:30	[01-May-2016]	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP1603971-001**	**EP1603971-002**	**EP1603971-003**	--------	--------
				Result	Result	Result	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	----	----	----
EP125A: Monocyclic Aromatic Hydrocarbons								
Benzene	71-43-2	0.05	µg/L	<0.05	<0.05	<0.05	----	----
Toluene	108-88-3	0.5	µg/L	<0.5	<0.5	<0.5	----	----
Ethylbenzene	100-41-4	0.05	µg/L	<0.05	<0.05	<0.05	----	----
meta- & para-Xylene	108-38-3 106-42-3	0.05	µg/L	<0.05	<0.05	<0.05	----	----
Styrene	100-42-5	0.05	µg/L	<0.05	<0.05	<0.05	----	----
ortho-Xylene	95-47-6	0.05	µg/L	<0.05	<0.05	<0.05	----	----
1.3.5-Trimethylbenzene	108-67-8	0.05	µg/L	<0.05	<0.05	<0.05	----	----
1.2.4-Trimethylbenzene	95-63-6	0.05	µg/L	<0.05	<0.05	<0.05	----	----
Sum of Xylenes	1330-20-7	0.05	µg/L	<0.05	<0.05	<0.05	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**124**	**109**	**110**	----	----
Toluene-D8	2037-26-5	2	%	**120**	**101**	**100**	----	----
4-Bromofluorobenzene	460-00-4	2	%	**100**	**88.1**	**94.4**	----	----
EP125S: VOC Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**101**	**115**	**112**	----	----
Toluene-D8	2037-26-5	0.1	%	**106**	**109**	**112**	----	----
4-Bromofluorobenzene	460-00-4	0.1	%	**104**	**110**	**109**	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%)	
		Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	71	137
Toluene-D8	2037-26-5	79	131
4-Bromofluorobenzene	460-00-4	70	128
EP125S: VOC Surrogates			
1.2-Dichloroethane-D4	17060-07-0	73	129
Toluene-D8	2037-26-5	65	127
4-Bromofluorobenzene	460-00-4	68	124

Marine and Freshwater Research Laboratory Environmental Science
Tel: +61 8 93602907 Address: 90 South St, Murdoch, WA, 6150

WORLD RECOGNISED ACCREDITATION

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Peter Young
Customer: AECOM Australia Pty Ltd
Address: Level 6, 3 Forrest Place, Perth, WA, 6000

Date of Issue: 13/05/2016
Date Received: 04/05/2016
Our Reference: AEC16-1
Your Reference: 429060478944

METHOD SAMPLE CODE	Sampling Date	3020 CHLORO 'a' µg/L	3020 CHLORO 'b' µg/L	3020 CHLORO 'c' µg/L	3000 CHLOROPHYLL'a' µg/L	3000 PHAEOPHYTIN'a' µg/L
Reporting Limit		<0.1	<0.1	<0.1	<0.1	<0.2
File			16051001		16051001	
DC1	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC3	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC2	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC22	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC23	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC0	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC00	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC1_NW1000	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC1_NW2000	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC2_NE1000	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC2_NE2000	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC0_SW1000	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC0_SW1001	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
DC0_SW2000	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
FPSO_0	02/05/2016	0.1	<0.1	<0.1	<0.1	<0.2
FPSO_00	02/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
FPSO_NE1000	02/05/2016	0.1	<0.1	<0.1	<0.1	<0.2
FPSO_NE2000	02/05/2016	0.1	<0.1	<0.1	<0.1	<0.2
FPSO_SW1000	02/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
FPSO_SW2000	02/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2

Signatory: Jamie Woodward
Date: 13/05/2016

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: +61 8 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

WATER QUALITY DATA

Contact: Peter Young
Customer: AECOM Australia Pty Ltd
Address: Level 6, 3 Forrest Place, Perth, WA, 6000

Date of Issue: 13/05/2016
Date Received: 04/05/2016
Our Reference: AEC16-1
Your Reference: 429060478944

METHOD SAMPLE CODE	Sampling Date	3020 CHLORO 'a' µg/L	3020 CHLORO 'b' µg/L	3020 CHLORO 'c' µg/L	3000 CHLOROPHYLL'a' µg/L	3000 PHAEOPHYTIN'a' µg/L
Reporting Limit		**<0.1**	**<0.1**	**<0.1**	**<0.1**	**<0.2**
File			**16051001**		**16051001**	
FPSO_SE1000	02/05/2016	0.1	<0.1	<0.1	<0.1	<0.2
FPSO_SE2000	02/05/2016	0.1	<0.1	<0.1	0.1	<0.2
PL_1	30/04/2016	<0.1	<0.1	<0.1	<0.1	<0.2
PL_2	30/04/2016	<0.1	<0.1	<0.1	<0.1	<0.2
PL_3	30/04/2016	<0.1	<0.1	<0.1	<0.1	<0.2
REF_NW	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
REF_NW2	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
REF_NW3	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
REF_SW	01/05/2016	<0.1	<0.1	<0.1	<0.1	<0.2
REF_NE	01/05/2016	0.1	<0.1	<0.1	0.1	<0.2
REF_SE	01/05/2016	0.2	<0.1	<0.1	0.1	<0.2

Signatory: Jamie Woodward
Date: 13/05/2016

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Appendix B: Sediment and Water Quality Study (AECOM 2017)

AECOM

Shell Crux Baseline Surveys
Shell Australia Pty Ltd
19-May-2017
Doc No. R1841/M&C4063

Commercial-in-Confidence

Crux Field Baseline Sediment and Water Quality Assessment

Shell Crux Baseline Environmental Surveys

Crux Field Baseline Sediment and Water Quality Assessment

Shell Crux Baseline Environmental Surveys

Client: Shell Australia Pty Ltd

ABN: 14009663576

Prepared by

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ABN 20 093 846 925

19-May-2017

Job No.: 604955921

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 AS/NZS4801 and OHSAS18001.

Quality Information

Document Crux Field Baseline Sediment and Water Quality Assessment

Ref 604955921/R1841/M&C4063

Date 19-May-2017

Prepared by Peter Young

Reviewed by Ian Baxter

Revision History

Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
A	27-Apr-2017	For Review	Peter Young Principal Marine Environmental Scientist	
0	19-May-2017	For Use	Peter Young Principal Marine Environmental Scientist	

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Executive Summary

The Crux Field is located in Commonwealth waters in the Browse Basin (Timor Sea) approximately 110 km south-east of Cartier Island, 200 km off the Kimberley coast, 260 km from the Indonesian archipelago and East Timor and 600 km north-north-east of Broome, Western Australia. The field is on the Sahul Shelf in the waters of the Territory of Ashmore and Cartier Islands Adjacent Area in permit AC/RL9. Water depths in the field range from 95 m to 175 m. The approximate field dimensions are 8 km long by 5 km wide (Shell 2014).

Shell Australia Proprietary Limited plans to pipe gas from the Crux Field to the Prelude Floating Liquefied Natural Gas Development, approximately 160 km south-west of the Crux Field.

The project is in the early Select Phase and as such a number of concepts are under consideration including:

- a Floating Production Storage and Offloading (FPSO) facility or a fixed platform in the Crux Field
- a pipeline from the Crux Field to the Prelude Field.

These proposed concepts, along with drilling, subsea and pipeline infrastructure will impact on the seabed environment throughout the project area during construction and, to a lesser extent and more locally in the vicinity of infrastructure, during ongoing operations.

This report outlines the outcomes from the sediment and water quality baseline survey undertaken in the Crux Field in October/November 2016. The water quality component of the survey was a seasonal adjunct to a baseline survey conducted in April/May 2016. The survey comprised sediment sampling at 31 sites and water sampling at 10 sites around the proposed drill centres and FPSO locations, along the proposed pipeline route and at reference locations.

The survey found sediment and water quality in the AC/RL9 area to be generally very high, as indicated by the survey results which show that all but a very small number of toxicant concentrations were below ANZECC/ARMCANZ (2000) guidelines criteria.

Findings of this study included the following in relation to sediment quality:

- Metals concentrations across the AC/RL 9 area were all well below ANZECC/ARMCANZZ (2000) ISQG Low (guideline) criteria.
- Barium concentrations in some of the sediment samples in the vicinity of existing well sites in the AC/RL9 area were slightly elevated relative to samples collected at greater distances from the wells. This suggests some localised impacts from past exploration drilling activities (see Section 4.1.1.1.3).
- Elevated nickel concentrations at the Prelude end of the pipe, including one site which exceeded the guideline level. Nickel concentrations across the AC/RL9 lease area were typically within range of concentrations observed at the reference sites (see Section 4.1.1.1.11).
- Petroleum hydrocarbons were detected at very low concentrations (slightly above the laboratory practical quantitation limit [PQL]) at three sites, predominantly in the C16-C34 fraction. BTEX was not detected above the laboratory PQL in any of the samples, while naphthalene (at one site) was the only PAH detected above the PQL.
- Nitrogen was predominantly present as total kjeldahl nitrogen (TKN) with a small nitrate plus nitrite component at some sites, while phosphorus was present in higher concentrations.
- Particle size distribution composition varied, with sites across the Crux Field typically characterised by medium to fine sands with variable amounts of silt and clay between 5% and 42%, with the percentage of fines (particle size <4 – 62 µm) reducing with depth in a north easterly direction towards the shallowest part of the field. A higher percentage of fines was typical of the sites in deeper waters at the Prelude end of the proposed pipeline route.
- Benthic fauna communities were typically similar across the AC/RL9 block; however, there was some difference in community structure between this area and sites located along the proposed pipeline route.

The key findings of the water sampling component of the survey include:

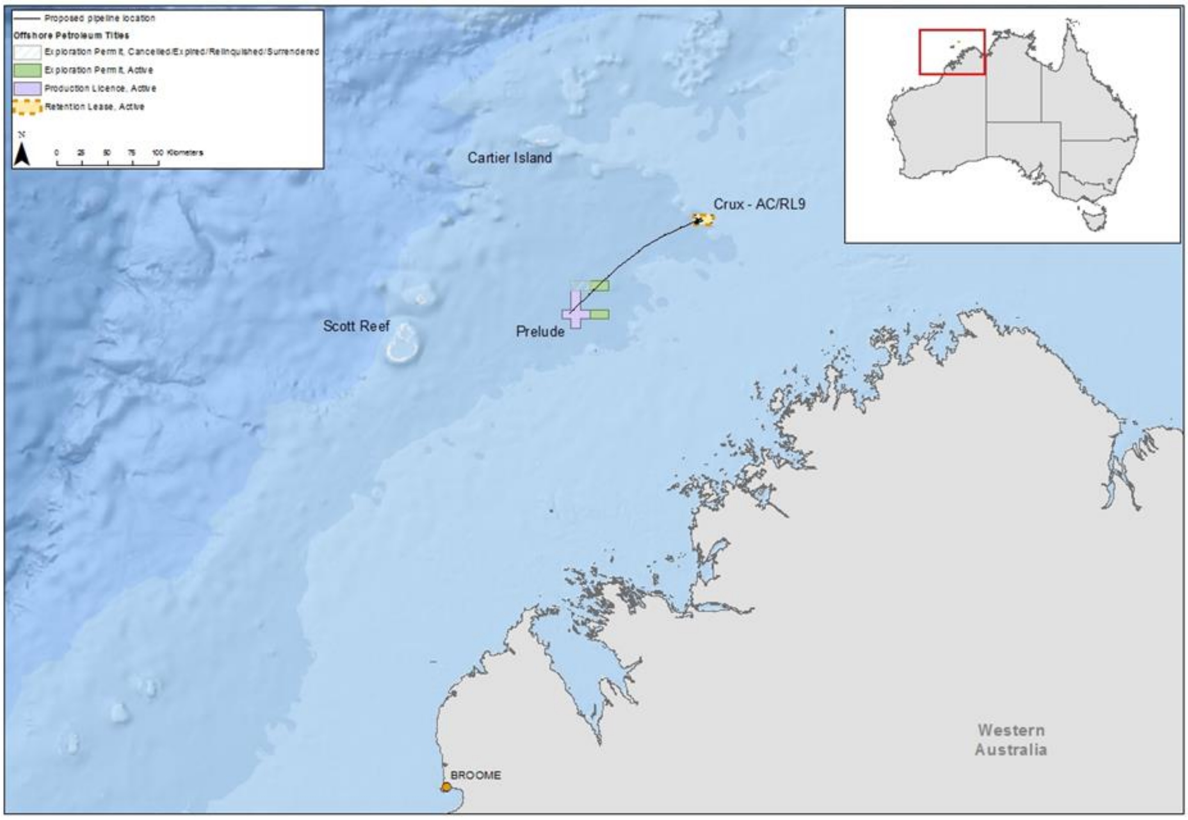
- Water quality can be considered unmodified from its natural condition, which would be expected given its remote location
- A number of subtle changes in the physicochemical attributes were observed since the May survey that may be suggestive of seasonal variation.
- Water column profiles were typically similar to those observed in the May survey with a number of subtle differences reflecting temporal variation; these included marginally higher DO through the water column, marginally lower pH through the water column, and slightly lower salinity in the upper water column.
- All but a very small number of toxicant concentrations were observed to be below the ANZECC & ARMCANZ (2000) 99% species protection levels.
- Petroleum hydrocarbons were all below the quantifiable limit indicating no evidence of impact from petroleum development sites or natural seeps in the region.
- Metals concentrations were generally comparable to those reported for the May survey and, with the exception of zinc in all samples, and cobalt at one site, were within expected ranges, below the applicable ANZECC & ARMCANZ (2000) 99% or 95% species protection levels, and within levels expected for open ocean environments.
- Zinc concentrations were all above the ANZECC & ARMCANZ (2000) 99% species protection level. A wide-spread increase in a single metal concentration across a wide geographic area would not be expected to be a result of seasonal variation and, without an obvious source, the cause of these results is not immediately apparent.
- A very small increase in TP concentrations was observed; however combined with the analytical results for chlorophyll and phaeophytin, there is no evidence of any increase in nutrient loads.
- Photosynthetic pigments in surface waters were very low and showed very little seasonal variation between the two surveys.
- Physical characteristics were within the expected ranges for this time of year when compared to the background data presented in previous desk top studies (Shell 2014, 2015a).

The baseline data presented in this report may be used for future comparison to monitor environmental impact due to construction or routine operations and provide the initial data from which a set of site specific-trigger levels may be developed as suggested by ANZECC & ARMCANZ (2000) guidelines.

1.0 Introduction

The Crux Field is located in Commonwealth waters in the Browse Basin (Timor Sea) approximately 110 km south-east of Cartier Island, 200 km off the Kimberley coast, 260 km from the Indonesian archipelago and East Timor and 600 km north-north-east of Broome, Western Australia (WA). The field is on the Sahul Shelf in the waters of the Territory of Ashmore and Cartier Islands Adjacent Area in permit area AC/RL9 (Figure 1). Water depths in the permit area range from 90 m to 180 m. The approximate dimensions of the Crux Field within AC/RL9 are 8 km by 5 km (Shell 2014).

Figure 1 Shell Crux Field retention lease AC/RL9 location



1.1 Objective

This report presents the results of the baseline sediment and water quality survey completed between 31 October and 3 November 2016 within the AC/RL9 permit area and along the proposed pipeline route to the Prelude Field (hereafter referred to as 'this survey').

The objective of this survey was to collect data to describe the existing physical and chemical sediment and water quality characteristics at locations that may potentially be impacted by development of the field with a view to:

- characterise the pre-development sediment and water quality of the AC/RL9 permit area to inform the environmental permitting process
- provide a baseline dataset against which post-impact (construction and operations) sediment and water quality measurements can be compared.

The water quality component of the survey was a seasonal adjunct to a baseline survey conducted in April/May 2016 within AC/RL9 and along the proposed pipeline route. A subset of the April/May sites was sampled on this survey to ascertain the extent of seasonal influences on water quality.

1.2 Survey overview

The survey was completed over three days in October/November 2016 on board the *MV Warrego* on completion of a metocean instrumentation servicing campaign (by RPS MetOcean) within AC/RL9 and along the proposed pipeline route.

The survey comprised:

- collection of sediment samples at 16 sites surrounding the proposed drill centres and Floating Production Storage and Offloading (FPSO) locations, nine sites along the potential pipeline route between AC/RL9 and the Prelude Field and four reference sites (one at each corner of the AC/RL9 lease)
- collection of water samples at six sites surrounding the proposed drill centres and FPSO locations, three sites along the potential pipeline route and one reference site
- measurement of physicochemical parameters through the water column, from seafloor to sea surface, at each of the water sampling sites.

A detailed description of the survey, including sample site locations, is provided in Section 3.0.

1.3 Survey HSSE

The survey was conducted in line with the HSSE standards and expectations of the three key stakeholders; Shell, AECOM and the lead contractor RPS MetOcean (RPS).

Survey planning and implementation was led by RPS MetOcean as the lead contractor to Shell with assistance from AECOM to incorporate the sediment and water quality sampling scopes of work into the survey. AECOM worked with RPS in the lead up to the survey to manage HSSE risks and implement appropriate management measures to eliminate or reduce risks to as low as possible. This included:

- Attendance at pre-survey hazard identification (HAZID) workshops
- Development of Safe Work Method Statements (SWMS)
- Attendance of pre-mobilisation meetings

AECOM's contribution to this process was underpinned by our own SH&E management systems which were incorporated into the field trip documentation and planning process.

SWMS were developed by RPS and AECOM for all survey activities undertaken in the field including:

- Sediment sampling
- Water sampling
- General survey activities

SWMS were reviewed and updated as required and signed by all survey personnel at the daily pre-start meeting. All survey activities were completed without incident.

2.0 Background

2.1 Crux Field development

Shell Australia Proprietary Limited (Shell) proposes to pipe gas from the Crux Field, within the Browse Basin, to the Prelude Floating Liquefied Natural Gas (FLNG) Development, approximately 160 km south-west of the Crux Field.

The project is in the early Select Phase and as such a number of concepts are under consideration including:

- an FPSO facility or a fixed platform in the Crux Field
- a pipeline from the Crux Field to the Prelude Field.

These proposed concepts, along with drilling, subsea and pipeline infrastructure will impact on the seabed environment throughout the project area during construction and ongoing operations.

2.2 Local environment

This study covers the Crux Field which is located on the North West Shelf, some 200 km off the Kimberley coast, and the proposed pipeline route between the Crux and Prelude Fields. A description of the environment of the field is provided below.

2.2.1 Bathymetry, seabed features and associated habitats

The seabed of the Crux Field is relatively uniform with depths varying from approximately 95 to 175 m observed during the survey. The shallower depths are found in the north-east section of the AC/RL9 lease. The seabed is typically composed of soft sediment.

The AC/RL9 permit area bathymetry and seabed features have been described in Shell (2014), and are summarised below, with some additional descriptions. Further bathymetry data will be required for the pipeline route and will be gained from hydrographic, geotechnical and habitat surveys.

- The project area is located on the Sahul Shelf; a broad shallow platform off the north-west coast of Australia that comprises the eastern part of the North West Shelf region (Wilson 2013).
- The Crux Field lies within the Northwest Shelf Transition bioregion and the pipeline route extends into the Northern Shelf Province bioregion (Baker et al 2008). From a trophic systems perspective, the Crux Field is on the western boundary of the Western Joseph Bonaparte Gulf sub-region and the pipeline route extends into the Kimberley Slope sub-region, both of which are within the Indo-Pacific Throughflow Influence trophic system (Brewer et al 2007).
- Shell (2014) describes the seabed as comprising fine clays, muds and sands; this is consistent with the sediment characteristics presented by Baker et al (2008) for the Middle Shelf physiographic division of the Northwest Shelf Transition bioregion in which the Crux Field lies. No reefs or areas of rocky substrate are known to occur within the nearby Prelude project area (Shell 2009). The present survey found similar broad seabed characteristics within the AC/RL9 permit area, though the proportion of fines (clays and silts) was typically lower than in the Prelude Field. There was also considerable variability in sediment types between different parts of the AC/RL9 permit area.
- Bathymetry of the AC/RL9 permit area is characterised by a shallow area towards the north-east corner of the lease area where depths of 90 to 100 m are typical. The depth falls to approximately 160 m in a south-westerly direction over approximately 2.5 km. The depth continues on a slight gradient until it reaches approximately 180 m depth in the south-west corner of the lease area (Figure 2).
- Single beam echo sounder bathymetry data captured during this survey reflects the above observations of bathymetry across the AC/RL9 permit area and shows a typically constant increase in depth along the proposed pipeline route.
- The major bathymetric feature along the pipeline route is a trench feature where the seabed drops from depths of approximately 210 m to a depth of approximately 270 m before returning to

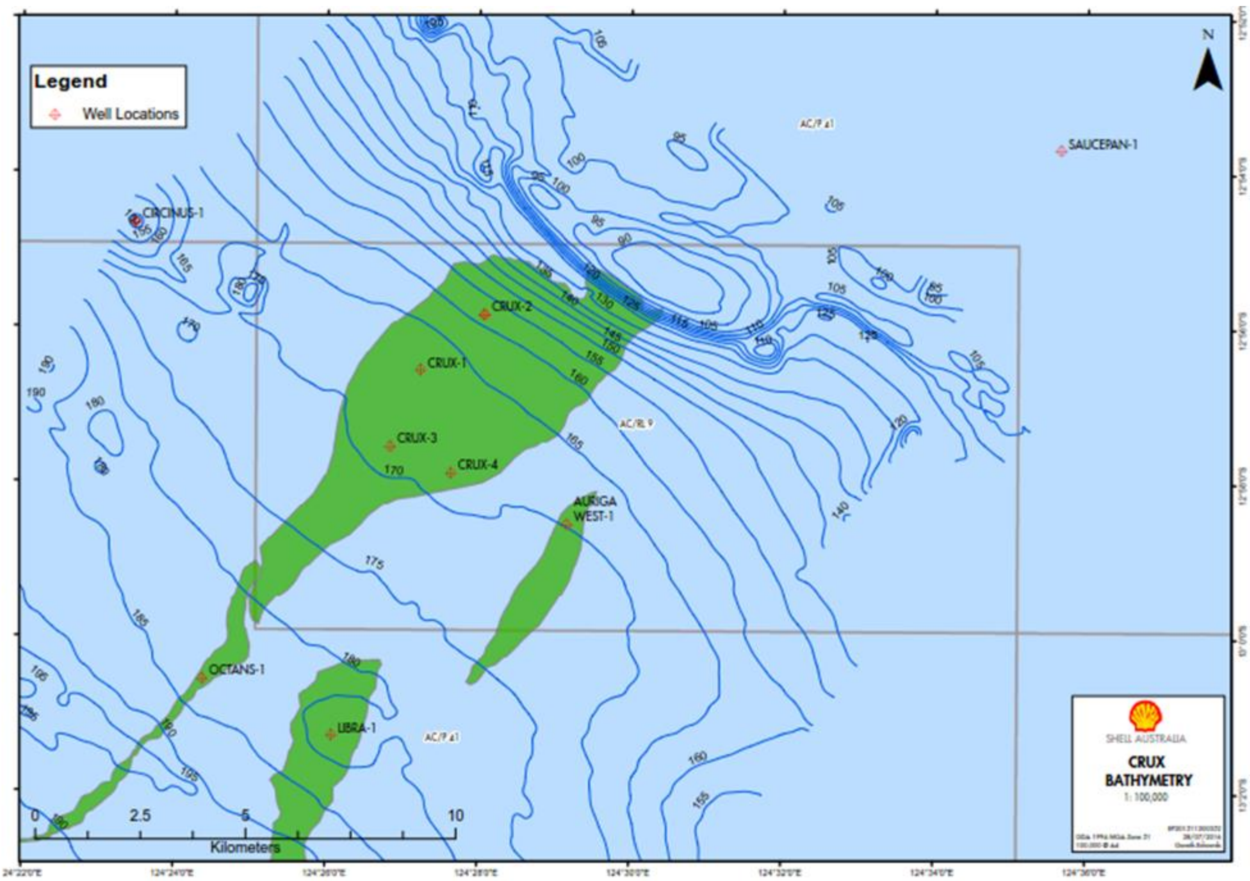
the regular depths around 250 m in the Prelude region. This feature is located closer to the Prelude Field and is some 115 km south-west of the AC/RL9 lease.

A number of shoals in the wider region present the most sensitive seabed habitats in the greater Browse Basin (Shell 2014). The closest of these to the AC/RL9 lease area include:

- Goeree Shoal (approximately 9 km north-west of AC/RL/9)
- Eugene McDermott Shoal (approximately 8 km south of AC/RL9)
- Vulcan Shoals (approximately 18 km to the north-west of AC/RL9)
- Heywood Shoal (approximately 13 km east of the pipeline and 65 km south-west of AC/RL9)
- Barracouta Shoals (approximately 58 km to the north-west)

The seabed of the Crux Field and proposed pipeline route will be described in more detail by a geophysical survey to be completed at a later date.

Figure 2 Bathymetry of the AC/RL9 lease area



2.2.2 Climate

The climate of the Browse Basin/Timor Sea region is monsoonal, and comprises two distinct seasons, winter (dry) from April to September and summer (wet) from October to March, with very rapid transition seasons, generally in April and September/October between the two main seasons (Shell 2015a).

The location of the Crux Field means that it is subjected to tropical cyclone activity, with the highest chance of such storms occurring between November and April. Data suggest the peak cyclone frequency falls in January and March, with the most intense cyclone activities observed in December and March/April (Shell 2015a).

2.2.3 Tides and currents

Local tides and currents will impact the dispersion of any discharges to the marine environment and therefore the impact that these discharges may have. The Crux Field Development Metocean Reference Document (Shell 2015a) details the key oceanographic systems at play in the region and suggests that currents at the Crux location are expected to be largely characterised by the tides.

Tides at the Crux site are predominantly semi-diurnal with successive tides generally being unequal and flowing along an approximate north-west – south-east axis (Shell 2015a).

2.2.4 Physical water parameters

Existing data describing the physical water characteristics in the region have been summarised in various desktop study reports by Shell (2014, 2015a) with additional data collected in metocean surveys currently in progress. Existing information suggests:

- Sea surface temperatures generally range between 27 °C and 30 °C annually, in waters deeper than ~150 m the temperature is approximately 19 °C (Shell 2014). Short term and long term variability is expected at the Crux site (Shell 2015a).
- Average monthly salinity profile data from the World Ocean Atlas for the Crux Filed location was presented in Shell (2015a). Salinity ranged from 34.5 – 35.1 PSU. Salinity profiles from CSIRO Marine and Atmospheric Research in the region were also referenced; these showed salinity ranging from 33.3 – 34.8 PSU. It was also noted that short and long term variability would be expected to be observed.

2.3 Marine environmental effects

The Crux Field development will potentially comprise a number of installations and vessel operations that has the potential to impact marine sediment and water quality during field development (including pipeline construction) and operations. Primarily, these potential impacts may result from routine discharges (made under the relevant regulations and licenses and covered in eventual operational environmental management plans to be developed) which could include:

- in situ overboard disposal of expended drilling mud and associated drill cuttings from drilling units
- macerated sewage and putrescible food scraps
- treated grey water from accommodation facilities and support vessels
- untreated deck drainage (deck wash and stormwater).
- treated oily water from the FPSO and marine vessels
- treated drainage water discharges
- ballast water
- treated produced formation water discharges
- cooling water containing biofouling and corrosion control chemicals
- firewater and firefighting foam discharges (during system testing).

Localised seabed disturbance during drilling, infrastructure placement and pipeline construction may also impact water quality for short periods of time due to sediment suspension.

3.0 Sediment and Water Quality Survey Methodology

3.1 Objectives

The objectives of the sediment and water quality baseline survey were to gather data to:

- inform the environmental planning and approvals process for the development of the Crux Field
- use for comparison against data from future surveys, to measure potential impacts of field development and operations.

3.2 Sediment quality assessment

3.2.1 Sampling design and site locations

Figure 3 shows the sediment sample locations within the Crux Field and along the pipeline route. Site coordinates and water depths are provided in Appendix A.

Sample locations were fundamentally aligned along four transects radiating outward from the three potential drill centres; at distances of 500, 1000 and 2000 m along north-west – south-east and north-east – south-west axes. Where sites were located in close proximity, they were merged to avoid unnecessary duplication, resulting in a small variation to these distances. Transects of sample sites from two of the drill centres (DC1 and DC3 in Figure 3) were aligned along the prevailing tidal current axis (north-west – south-east) to provide a baseline sediment quality description where impacts from drill cuttings are most likely to be observed. The two transects from the remaining drill centre (DC2 in Figure 3) are aligned along a north-east – south-west axis; sampling at these sites allows characterisation of sediments that are perpendicular to the predominant tidal current direction.

Four reference sites to monitor the prevailing background conditions during future monitoring surveys were also sampled; one in each corner of the AC/RL9 lease area. These sites are considered sufficiently distant from future field development activities that any differences in sediment analytical results between surveys are likely indicate inter-annual variability in laboratory performance.

Along the proposed pipeline route between the Crux and Prelude fields, sediment samples were collected at 10-15 km intervals to provide an indication of the variability in sediment type that occurs along the route. The data also provide a baseline against which, if necessary, an assessment can be made of sediment contamination arising from pipeline construction activities.

3.2.2 Sample numbers

3.2.2.1 Samples for physicochemical analysis

Samples of seafloor sediments were collected for physicochemical analysis at 31 sites (Figure 3):

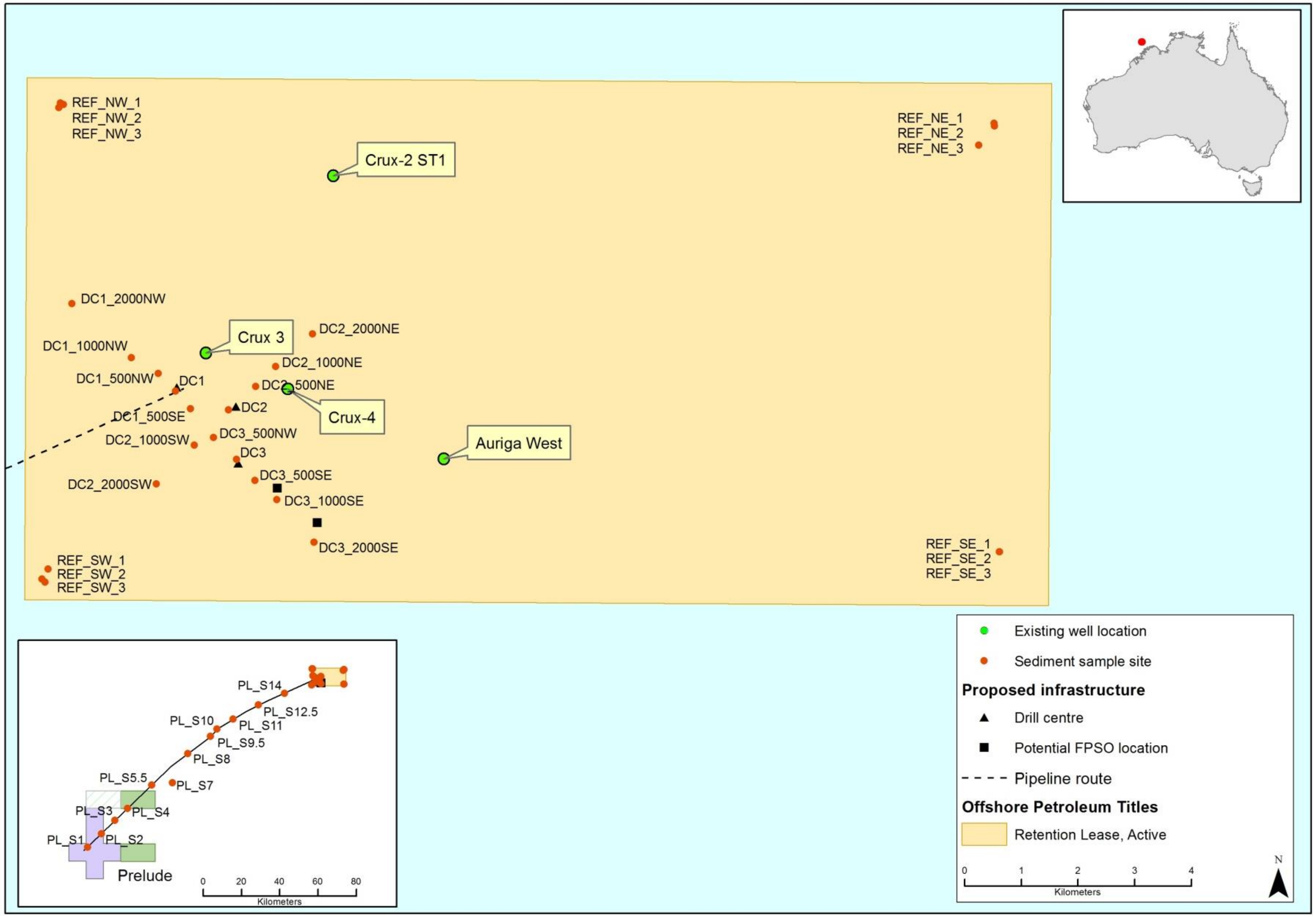
- 16 around potential future Crux Field drill centres and infrastructure
- four reference sites; one at each corner of the AC/RL9 lease area
- 11 sites along the proposed pipeline route.

Additional samples were required for QA/QC purposes in accordance with AS/NZS 4482.1 2005:

- at least 5% field replication through collection of triplicate sediment samples (i.e. three separate grab deployments) at three sites (REF_NW, REF_NE and REF_SE)
- at least 10% field duplication by extracting two subsamples from the (homogenised) sediment collected at each of four sites (DC2_0, DC3_0, DC3_1000SE and DC3_2000SE).

The QA/QC samples were labelled so as to be identifiable to AECOM as replicates, but so that they would be unrecognisable to the analysing laboratory as replicates.

Figure 3 Sediment sample sites



Also for QA/QC purposes, the following water samples were associated with the sediment sampling process:

- One trip blank sample of deionised water provided by the primary analytical laboratory. This accompanied the field sample containers throughout the survey and were analysed on arrival back at the laboratory to assess whether contamination had occurred from the sample containers or during sample transportation.
- One field blank sample effected by exposing laboratory-supplied deionised water to the atmosphere during sample collection. This was used to identify and quantify any airborne contaminants present (e.g. exhaust emissions).
- Two rinsate blanks were collected, one on each of two of the sampling days, by pouring laboratory-supplied deionised water over the sampling equipment (polycarbonate core) after it had been decontaminated between sample sites and catching the rinse water in a glass jar for laboratory analysis.

Hence the total number of samples for chemical analysis was 45 (41 sediment samples and four water samples):

- 31 primary samples
- six triplicate samples (two additional samples at each of three sites)
- four duplicate samples (one additional sample at each of four sites)
- one trip blank (water)
- one field blank (water)
- two rinsate blanks (water).

3.2.2.2 Samples for benthic fauna analysis

Samples for analysis of benthic fauna were collected at all of the 31 primary sample locations. Triplicate samples were collected from all four of the reference sites; this involved taking three separate grab samples and sieving each individually to provide three samples for each reference site. Hence 39 samples were collected for benthic fauna analysis.

3.2.3 Sample collection, processing and handling

Sediment was collected from the seabed using a Day grab supplied and operated by RPS MetOcean and *Warrego* personnel. The grab weighed 230 kg (when empty) and the jaws had a gape of 64 cm x 40 cm; hence an area of seabed of 0.256 m^2 was sampled on each deployment.

The grab was lowered to the seabed and retrieved using the deck winch and A-frame on *Warrego* (Plate 1). On reaching the surface the grab was guided to its cradle, with crew ensuring the winch cable did not come into contact with the grab; this reduced the potential for grease from the cable to contaminate the sediment sample within the grab.

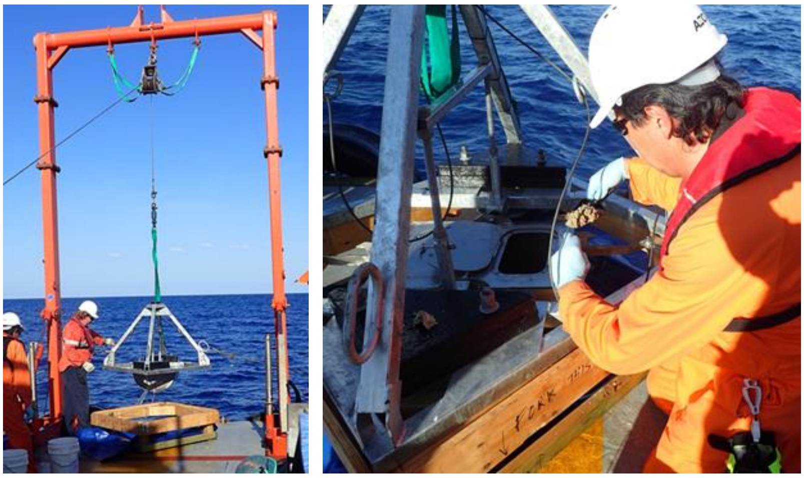


Plate 1 Day Grab operation (left) and sampling from the Day Grab inspection hatch (right)

Once the grab was secured in its cradle, one of the inspection hatches on the grab was opened and the following samples were removed (Plate 1):

- Samples to be analysed for metals, nutrients and particle size distribution (PSD) were collected by inserting a polycarbonate core into the sediments. Each sample was placed into a separate, labelled sterile plastic self-seal bag, which was in turn placed within a second labelled plastic self-seal bag for protection. Two of inter-laboratory triplicate samples were collected directly into plastic jars, as per the sampling requirements of the secondary analytical laboratory.
- Samples to be analysed for hydrocarbons and radionuclides were then collected, also through the inspection hatch. Each sample was collected by scraping a glass jar across the sediment surface. Once full, excess sediment was removed from the thread at the neck of the jar, a Teflon-lined cap was secured and the labelled jar was placed into a plastic self-seal bag.

The following precautions were implemented to reduce the potential for the introduction of contaminants into the samples:

- Sampling was undertaken in an area set aside for sample processing that had been thoroughly cleaned to remove potential contaminants such as hydrocarbon residues.
- Prior to opening the inspection hatches, *Warrego's* main engines were switched off to reduce the potential for airborne contaminants (i.e. within exhaust emissions) to enter the samples.
- Smoking was not permitted at any time in the vicinity of the sample collection and processing areas.
- Personnel involved in the removal of sediment samples from the grab wore nitrile gloves; new pairs of gloves were worn at each site.
- Care was taken to only sample sediments that were not in contact with the sides of the grab, thereby reducing the potential for the introduction of contaminants associated with the inside surfaces of the grab.

All sediment samples were frozen at the earliest opportunity. On completion of the survey the samples remained within the freezer aboard *Warrego* until demobilisation was completed in Exmouth. The samples were packed in insulated containers with freezer bricks and transported by refrigerated road freight to RPS MetOcean in Perth, then delivered by RPS MetOcean personnel to the analytical laboratories on 7 November.

Once the material for physicochemical analyses had been removed from each of the grab samples, approximately 0.0135 m^3 (e.g. 30 x 30 x 15 cm) of the remaining sediment was sieved through a 1 mm mesh to provide a sample for benthic fauna analysis. The material retained on the mesh was transferred to a calico bag and preserved in a 10% formalin solution. On completion of the survey the samples remained aboard *Warrego* until demobilisation was completed in Exmouth, then transported by refrigerated road freight to RPS MetOcean in Perth. RPS MetOcean personnel delivered the samples to The University of WA on 7 November.

3.2.4 Physicochemical analysis

3.2.4.1 Primary samples

Analysis of primary sediment samples was undertaken by ALS Environmental (ALS), a National Association of Testing Authorities (NATA) accredited laboratory for the analyses being undertaken:

- total metals (aluminium, arsenic, barium, cadmium, chromium, copper, iron, lead, mercury, nickel and zinc)
- total recoverable hydrocarbons (TRH)
- polycyclic aromatic hydrocarbons (PAH)
- oil and grease (O&G)
- benzene, toluene, ethylbenzene and xylene (BTEX)
- radionuclides (gross alpha and gross beta)
- nutrients (total nitrogen [TN], total Kjeldahl nitrogen [TKN] and total phosphorus [TP]).

Analyses were undertaken to Practical Quantitation Limits (PQLs) sufficiently low that assessment of results could be made against the sediment quality guidelines contained within the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment & Conservation Council and Agriculture & Resource Management Council of Australia and New Zealand [ANZECC & ARMCANZ] 2000), as revised by Simpson, Batley and Chariton (2013). Hereafter in this report, we refer to 'Guideline trigger levels' or 'Interim Sediment Quality Guideline Low (ISQG-Low) values', which refer to concentrations below which there exists only a low risk that adverse biological or ecological effects will occur (ANZECC & ARMCANZ 2000). Guideline trigger levels and PQLs are included in the tables of results in Section 4.1.1.

Sediment PSD was determined by Microanalysis Australia Pty Ltd using a combination of wet sieving and laser diffraction.

3.2.4.2 QA/QC samples

The duplicate sediment samples, and one of each of the triplicate sediment samples, were analysed by ALS for the analytes listed in Section 3.2.4.1. The third of the triplicate sediment samples was analysed by Analytical Reference Laboratory (ARL) for TRH, O&G and the metals and nutrients listed in Section 3.2.4.1. Analysis of the rinsate and blank samples is described in Section 3.3.4.2.

3.2.5 Benthic fauna analysis

Benthic fauna analysis was undertaken by suitably qualified and experienced biologists at the University of Western Australia. Benthic fauna were sorted and identified to the lowest possible taxa. Where possible, biota were identified to family (crustaceans and molluscs), subclass (polychaete worms), class (chordates and echinoderms) or phylum (sponges, cnidarians and sipunculid worms) level, using standard reference texts.

3.3 Water quality assessment

3.3.1 Site locations

The locations for assessment of water quality are shown in Figure 4; site coordinates and water depths are provided in Appendix F. The locations were selected to provide a spread of measurements around the sites of proposed infrastructure which includes wells, an FPSO and the pipeline to the Prelude development. Monitoring had been undertaken at each of the locations during the April/May 2016 survey.

Sample sites were located as follows:

- one site approximately equidistant to (and 1 km from) the three drill centres (DC0)

- two sites approximately 3 km from DC0, one to the north-west (DC1_2000NW) and one to the north-east (DC2_2000NE)
- one site approximately 2 km to the south-west of DC0 (DC0_2000SW)
- one site approximately midway between the two potential FPSO locations (FPSO_0), which was approximately 2 km to the south-east of DC0
- one site approximately 2 km to the north-east of FPSO_0 (FPSO_NE2000)
- a reference site in the north-east corner of the AC/RL9 lease area (REF_NE)
- three sites along the proposed pipeline route between the Crux and Prelude fields (PL_1, PL_2 and PL_3).

3.3.2 Sample numbers

Samples of surface water were collected at each of the 10 sites. Additional samples were required for QA/QC purposes in accordance with AS/NZS 4482.1 2005:

- at least 5% field replication through collection of triplicate water samples (i.e. three separate deployments of the sampling device) at one site (DC0)
- at least 10% field duplication by extracting two subsamples from the water collected in a single deployment of the sampling device (site PL_3)
- one rinsate blank, effected by pouring laboratory-supplied deionised water into the Niskin sampler (after it had been decontaminated between sample sites) and decanting the water into appropriate sample bottles.

The duplicate and triplicate samples were labelled so as to be identifiable AECOM as replicates, but so that they would be unrecognisable to the analysing laboratory as replicates.

Hence the total number of samples for chemical analysis was 14:

- 10 primary samples
- two triplicate samples (two additional samples at one site)
- one duplicate sample (one additional sample at one site)
- one rinsate blank.

3.3.3 Methods

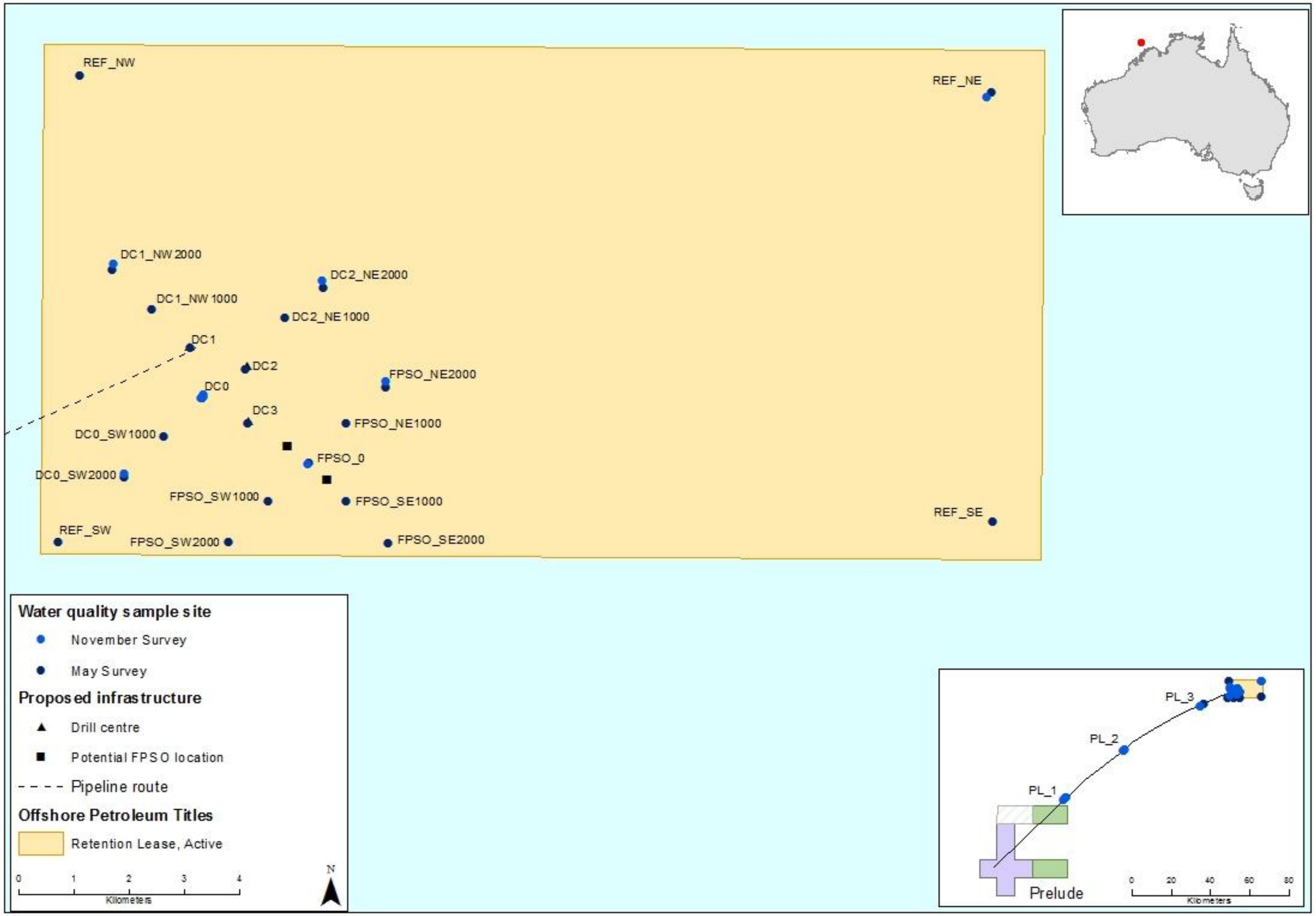
3.3.3.1 Sampling procedures

Warrego was positioned such that sampling occurred on the upstream side of the vessel (relative to prevailing currents and wind direction) to reduce the risk of contamination from the vessel wash. All vessel discharge points were closed for the duration of sampling.

Water samples were collected using a Niskin bottle deployed over the side of the vessel using the deck crane and lowered to a depth of approximately one metre below the water surface, where it was triggered to collect a sample. The sampler was brought back on board the vessel and samples were decanted directly into sample containers using the pouring mechanism on the sampler.

A decontamination procedure for the water sampler was implemented after sampling each site. A solution of Decon 90 detergent and seawater was mixed in a plastic bucket. Once a sample had been collected, the sampling equipment was thoroughly rinsed with the Decon 90 solution, then seawater.

Figure 4 Water quality baseline sample sites



3.3.3.2 Nutrients and contaminants

Water samples for analysis by the primary laboratory were decanted from the Niskin sampler into the following:

- 500 mL amber glass bottles for TPH analysis
- pairs of 40 mL glass vials for BTEX analysis
- 120 mL polyethylene bottles for metals analysis
- 500 mL polyethylene bottles for nutrient analysis.

Water samples for analysis by the secondary laboratory (trip and field blanks, rinsates and one of the triplicate samples) were decanted into the following:

- 100 mL amber glass bottles for TPH and TRH analysis
- pairs of 40 mL amber glass vials for BTEXN (BTEX plus naphthalene) analysis
- 60 mL polyethylene bottles for metals and nutrients analyses.

All water samples were refrigerated at the earliest opportunity after collection. At the completion of the survey, the samples were packed in insulated containers with freezer bricks and taken to Perth as accompanied baggage. On arrival in Perth (5 November) the samples were hand delivered to the analytical laboratories; this was achieved within three days (at most) of sample collection to meet holding time requirements (the shortest of which was seven days, for TPH).

3.3.3.3 Phytoplankton

Chlorophyll concentrations in extracts of seawater filtrate were measured as an index of phytoplankton biomass. At each site, five litres of seawater was filtered through a glass fibre filter paper (GF/C) and the filter paper frozen for subsequent pigment extraction and analysis. The filter papers were frozen at the earliest opportunity after collection, packed with the water samples and taken to Perth as accompanied baggage, then held in a freezer in Perth prior to delivery to Murdoch University on 7 November.

3.3.3.4 Vertical profiling

A Seabird SBE 19 plus V2 multi-parameter sonde was used to measure physicochemical data through vertical profiles of the water column at all 10 sampling sites. The sonde was calibrated by RPS MetOcean prior to the field survey; the calibration certificate is included as Appendix E.

The sonde was set on internal logging mode and lowered to just above the seabed using the deck winch on the survey vessel, with each parameter measured every 0.5 seconds while lowering the recorder through the water column to the seabed. The sonde measured a suite of water quality parameters - depth (m), salinity (PSU), temperature (°C), turbidity (NTU), pH and % dissolved oxygen (DO).

3.3.4 Analysis of water samples

3.3.4.1 Primary samples

Primary water sample analysis was undertaken by ARL for:

- hydrocarbons (TPH and BTEX)
- total metals (aluminium, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel and zinc)
- nutrients (TN, TKN, nitrite + nitrate [NO_x] and TP).

Where possible, analysis was undertaken to a PQL sufficiently low so as to allow assessment of results against the ANZECC & ARMCANZ (2000) guidelines. Guideline criteria levels and PQLs are included in the tables of results in Appendix G.

3.3.4.2 QA/QC samples

ALS undertook the following analyses on the blank, rinsate and inter-laboratory duplicate water samples:

- hydrocarbons (TPH, TRH, BTEX)
- nutrients (TN, TKN, NO_x and TP).

3.3.4.3 Phytoplankton

Photosynthetic pigments were extracted from the filter papers by the Marine and Freshwater Research Laboratory (MAFRL) at Murdoch University according to the Standard Methods for Examination of Water and Wastewater. Analysis was undertaken for total chlorophyll, chlorophylls 'a', 'b' and 'c', and phaeophytin. The ratio of the three forms of chlorophyll (‘a’, ‘b’ and ‘c’) can be used as an indicator of the composition of the phytoplankton assemblages. Changes in the ratio of the pigments suggest changes in assemblage structure.

3.4 Data QA/QC

The primary objective of the data validation process is to ensure that the reported data can be used to achieve the project objectives. Analytical data were thoroughly checked by the laboratory prior to release. AECOM subsequently checked the analytical data against the data quality objectives of the project—comparing requested detection limits against PQLs, calculating Relative Percentage Differences (RPDs) and Relative Standard Deviations (RSDs) for field duplicates and triplicates, respectively, and comparing RPDs and RSDs with guideline recommendations.

Comparison of duplicates/triplicates through RPDs and RSDs can identify analytical results that appear to be unrealistically high (or low) and might prompt a request to the laboratory to reanalyse the samples as a further check of precision, or result in categorisation of those results as ‘estimates only’.

Laboratory QA/QC procedures included laboratory duplicates, method blanks, laboratory control samples and matrix spikes

4.0 Results and Discussion

4.1 Sediment quality assessment

Field log sheets showing site details (coordinates, water depth, sediment description, etc.) and photos of most sediment samples are presented in Appendix A. Laboratory analytical result summaries and laboratory reports and for the sediment samples are presented in Appendix B (chemical analysis), Appendix C (physical analysis), and Appendix D (benthic fauna analysis).

4.1.1 Sediment physicochemistry

4.1.1.1 Metals in sediments

Metal concentrations in sediment samples were all below the ANZECC Guideline trigger values at all sites with the exception of nickel at site PL-S2 which, at a concentration of 21.9 mg/kg, was marginally above the ISQG-Low value of 21 mg/kg. No obvious spatial trends were observed in metal concentrations.

The concentrations of metals in the sediment samples are provided in Table 1 and summarised in the following sections. Summary statistics showing the mean concentrations of metals in the Crux Field (reference and non-reference sites) and along the proposed pipeline route are presented in Table 2.

4.1.1.1.1 Aluminium

Aluminium was detected at concentrations above the laboratory PQL of 50 mg/kg in all samples analysed ranging from 720 to 5870 mg/kg with a mean value of 2875.6 mg/kg and a standard deviation of 1032.6 mg/kg. The three sites at the Prelude end of the proposed pipeline route had the highest concentration of aluminium with the lowest concentrations shown in the reference sites at the eastern edge of the Crux Field. Aluminium concentrations in the remaining two reference sites were consistent with those observed at other samples taken from within the Crux Field. There is no Guideline trigger level for aluminium.

4.1.1.1.2 Arsenic

Arsenic was detected at concentrations above the laboratory PQL of 1 mg/kg at all sites with concentrations detected ranging from 1.17 to 13.8 mg/kg, all below the ISQG-Low value of 20 mg/kg. Concentrations of arsenic along the proposed pipeline route were generally higher than those observed around the Crux Field where concentrations all fell within the range of concentrations detected in samples collected at reference sites.

4.1.1.1.3 Barium

Barium was detected at concentrations above the laboratory PQL of 0.1 mg/kg at all sites with concentrations ranging from 6.7 to 56.2 mg/kg with an average concentration of 18.1 mg/kg and a standard deviation of 12.7 mg/kg. The highest concentrations were detected at the proposed drill centre sites (DC1 and DC2) while the concentration at DC3 was higher than that detected at reference sites, though it was only marginally higher than other samples taken from around the Crux Field. Barium concentrations were typically patchy and showed signs of a decreasing trend with distance from the proposed drill centres. This may be explained by the drilling of four exploration wells in the Crux Field in 2015 using water based muds (WBM) (Shell, 2014), two of which (Crux-3 and Crux-4, Figure 2) are in the vicinity of the sediment sampling sites sampled during this survey. Barium concentrations are indicative of the presence of WBM residues from drilling activities and that no remedial actions are necessary as barium is considered to have limited bioavailability when associated with drilling muds (Swan, Neff & Young 1994).

Table 1 Metals concentrations in sediments

Analyte	Aluminium	Arsenic	Barium	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Mercury	Nickel	Zinc
	mg/kg											
LOR	50	1	0.1	0.1	1	0.5	1	50	1	0.01	1	1
ISQG-High	NA	70	NA	10	370	NA	270	NA	220	1	52	410
ISQG-Low	NA	20	NA	1.5	80	NA	65	NA	50	0.15	21	200
DC1_0	3530	3.7	56.2	0.3	21.1	2.4	5.9	5110	2.8	0.03	10.2	20.7
DC1_500NW	3670	3.9	25.4	0.3	20.7	2.6	6	5150	2.6	0.03	11.1	20.9
DC1_1000NW	2550	4.0	24.5	0.3	19.1	2.1	4.6	4150	2.6	0.03	8.5	18
DC1_2000NW	2540	3.9	9.3	0.3	19.4	1.9	4.3	4380	2.5	0.03	7.9	18
DC1_500SE	3540	2.7	25.9	0.3	19.4	2.4	6	4670	2.5	0.03	9.8	19.4
DC2_0	3440	4.5	53	0.3	22.5	2.4	5.5	5520	2.9	0.04	10.1	21.9
DC2_0[a]	3260	4.0	47.8	0.3	19.8	2.2	5.2	5200	2.9	0.04	9.1	19.6
DC2_500NE	3060	4.6	45.1	0.3	21.5	2.2	5.1	4940	2.7	0.04	9.2	19.8
DC2_1000NE	2750	3.9	14.4	0.2	19.7	2.3	5	4420	2.5	0.04	9.1	19.7
DC2_2000NE	2580	4.0	9.4	0.3	20.2	2.7	4.2	4740	2.8	0.04	8.8	22
DC2_1000SW	3230	3.7	19.9	0.3	20.8	2.3	5.5	4790	2.8	0.04	9.6	20.1
DC2_2000SW	3140	3.0	15.8	0.3	19.5	2.2	5.2	4720	2.5	0.04	9	19.5
DC3_0	2880	3.3	9.9	0.3	20.1	2	4.7	4690	2.4	0.04	8.5	19.1
DC3_0[a]	3330	3.8	28.3	0.3	20.3	2.2	5.2	5520	3	0.04	9.3	19.7
DC3_500SE	3440	3.4	15.7	0.3	21.6	2.4	5.6	5030	2.6	0.04	9.6	21.3
DC3_1000SE	2530	4.6	11.2	0.3	20.6	2.2	4.5	4870	2.6	0.04	8.6	19.6
DC3_1000SE[a]	2640	5.0	11.1	0.3	20.4	2	4.3	5330	3	0.04	8.2	25.4
DC3_2000SE	3660	3.5	22.9	0.3	22.4	2.6	5.9	5170	2.6	0.04	10.3	21.5

Analyte	Aluminium	Arsenic	Barium	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Mercury	Nickel	Zinc
	mg/kg											
LOR	50	1	0.1	0.1	1	0.5	1	50	1	0.01	1	1
ISQG-High	NA	70	NA	10	370	NA	270	NA	220	1	52	410
ISQG-Low	NA	20	NA	1.5	80	NA	65	NA	50	0.15	21	200
DC3_2000SE[a]	3680	2.7	27.4	0.3	18.3	2.4	5.8	4900	2.5	0.04	9.6	19.4
DC3_500NW	3040	4.1	25	0.3	20.9	2.2	5.4	4820	2.7	0.04	9.4	20.3
REF_NW	2680	4.2	12.5	0.3	21.3	2	4.6	4710	2.8	0.04	8.8	19.3
REF_NW[a]	2340	2.1	16.4	0.2	13.3	1.7	4.5	3280	1.9	0.02	7.1	13.8
REF_NW[b]	2500	<5	10	0.5	15	2	17	4400	5	0.02	7	15
REF_SW	2230	6.1	8	0.3	20.1	2.7	3.5	5730	3.8	0.05	9.7	20.8
REF_NE	740	1.5	6.7	0.3	15.1	0.8	1.2	1740	<1.0	<0.01	2.9	7.3
REF_NE[a]	720	1.6	9.8	0.2	13.8	0.6	1.5	1780	1.2	0.01	2.9	6
REF_NE[b]	820	<5	7	0.4	12	<1	15	2500	4	<0.02	3	6
REF_SE	1940	1.3	12.7	0.2	13.9	1.5	3.5	2890	1.5	0.02	6.4	13.8
REF_SE[a]	1700	1.3	11.8	0.2	11.2	1.2	2.9	2680	1.6	0.02	5.2	11.6
REF_SE[b]	1780	1.2	12.9	0.2	11.1	1.3	3.1	2630	1.6	0.02	5.6	11.7
PL_S1	4680	2.7	13.3	0.2	22	4	11.6	5370	2.1	0.02	16	27.7
PL_S2	5390	7.7	10	0.3	41.3	6.1	7.7	8990	3.5	0.02	21.9	47.2
PL_S3	5870	8.7	21	0.2	43.3	6.3	7.7	16200	5.5	0.05	18.5	45.2
PL_S4	2830	2.2	28	0.3	15.9	3.4	5.9	5700	2.8	0.03	10.3	25.2
PL_S5.5	2670	11.4	10	0.5	29.8	3.7	3.6	7750	3.8	0.02	11.9	24.7
PL_S7	2240	11.3	8	0.6	31	3.6	2.4	6660	2.8	0.01	13.7	24.8
PL_S8	2870	13.4	9.4	0.5	38	4.1	5.6	8860	3.7	0.02	16.5	28.3

Analyte	Aluminium	Arsenic	Barium	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Mercury	Nickel	Zinc
	mg/kg											
LOR	50	1	0.1	0.1	1	0.5	1	50	1	0.01	1	1
ISQG-High	NA	70	NA	10	370	NA	270	NA	220	1	52	410
ISQG-Low	NA	20	NA	1.5	80	NA	65	NA	50	0.15	21	200
PL_S9.5	2170	6.8	7.6	0.3	18.1	3.1	12.8	5040	3.3	0.02	8.8	24.4
PL_S10	Three attempts to collect sample, but no sediment retained in grab due to hard substrate (a few rock shards and sponge fragments were recovered).											
PL_S11	2710	13.8	7.3	0.4	36.8	5	4.1	6800	5.4	0.02	16.1	25.9
PL_S12.5	2740	2.6	10.4	0.3	19.2	2.5	4.3	5460	1.9	0.02	8.3	21
PL_S14	3790	5.8	9.9	0.3	29.2	2.8	4.6	7120	3	0.03	11.3	26.4

a duplicate sample

b inter-laboratory duplicate sample

Concentrations above ISQG-Low value are highlighted yellow.

4.1.1.1.4 Cadmium

Cadmium was detected in concentrations above the laboratory PQL of 0.1 mg/kg at all sites with concentrations ranging from 0.2 to 0.6 mg/kg with a mean of 0.3 mg/kg and a standard deviation of 0.1 mg/kg. All concentrations were well below the ISQG-Low value of 1.5 mg/kg. Cadmium concentrations were typically even across the Crux Field with marginally higher concentrations detected along the proposed pipeline route at sites PL_S5.5, PL_S7, PL_S8, though these concentrations were similar to that returned from the analysis of the inter-laboratory duplicate sample from reference site REF_NW.

4.1.1.1.5 Chromium

Chromium was detected in concentrations above the laboratory PQL of 1 mg/kg at all sites with concentrations ranging from 11.1 to 43.3 mg/kg with a mean of 21.5 mg/kg and a standard deviation of 7.5 mg/kg. All concentrations are well below the ISQG-Low level of 80 mg/kg. Chromium concentrations across the Crux Field were typically consistent, with slightly lower concentrations detected at reference sites at the eastern end of the field. The highest concentrations were detected along the proposed pipeline route although the highest concentrations (41.3 and 43.3 mg/kg detected at sites PL_S2 and PL_S3 respectively) are still just over half of the ISQG-Low value.

4.1.1.1.6 Cobalt

Cobalt was detected above the Laboratory PQL of 0.5 mg/kg at all sites with concentrations ranging from 0.6 to 6.3 mg/kg with a mean of 2.5 mg/kg and a standard deviation of 1.2 mg/kg. There is no Guideline trigger level for cobalt however; the concentrations detected across the Crux Field were all within the range of concentrations detected at reference sites. Concentrations of cobalt at sites along the proposed pipeline route were generally higher than those across the Crux Field.

4.1.1.1.7 Copper

Copper was detected in concentrations above the laboratory PQL of 1 mg/kg at all sites with concentrations ranging from 1.2 to 17 mg/kg and a mean of 5.6 mg/kg and standard deviation of 3.2 mg/kg. At these levels copper concentrations are well below the ISQG-Low value of 65 mg/kg at all sites. Concentrations at sites across the Crux Field ranged from 4.2 – 6.0 mg/kg, slightly higher than concentrations detected at the reference sites (1.2 – 4.5 mg/kg). Concentrations at sites along the proposed pipeline route were typically similar to those across the Crux Field with the exception of PL_S1 and PL_S9.5 where notably elevated concentrations of 11.6 and 12.9 mg/kg, respectively, were present. Even at these levels, the concentrations are still well below the ISQG-Low value.

4.1.1.1.8 Iron

Iron was detected in concentrations above the laboratory PQL of 50 mg/kg at all sites with concentrations ranging from 1740 to 16200 mg/kg and a mean of 5229.5 mg/kg and standard deviation of 2357.3 mg/kg. There is no ISQG-Low value for iron however, concentrations of iron detected in samples across the Crux Field all fell within the range of concentrations detected at the reference sites while a number of samples along the proposed pipeline route showed concentrations above this range. The sample collected from site PL_S3 was almost double that of any other site.

4.1.1.1.9 Lead

Lead was detected in concentrations above the laboratory PQL of 1.0 mg/kg at all sites with the exception of one of the reference sites (REF_NE). Concentrations ranged from 1.2 to 5.5 mg/kg with a mean of 2.8 mg/kg and a standard deviation of 1.0 mg/kg. These concentrations are all well below the ISQG-Low value of 50 mg/kg. Concentrations at two sites fell outside of the rage of concentrations detected at reference sites with PL_S3 and PL_S11 returning concentrations of 5.5 and 5.4 mg/kg respectively. A lead concentration of 3.8 mg/kg, equal to that of REF_SW (the highest of the reference sites), was detected at a third site along the proposed pipeline (PL_5.5).

4.1.1.1.10 Mercury

Mercury was detected in concentrations above the laboratory PQL of 0.01 mg/kg at all sites with the exception of one of the reference sites (REF_NE). Concentrations ranged from 0.01 to 0.05 mg/kg with a mean of 0.03 mg/kg and a standard deviation of 0.01 mg/kg. Mercury concentrations were all well below the ISQG-Low value of 0.15 mg/kg and within the range of concentrations detected at the reference sites. Mercury concentrations across the Crux Field were marginally higher than those detected at sites along the proposed pipeline route with the exception of site PL_S3 which returned the highest concentration of mercury (0.05 mg/kg), the same as reference site REF_SW and still well below the ISQG-Low value.

4.1.1.1.11 Nickel

Nickel was detected at concentrations above the laboratory PQL of 1 mg/kg at all sites with concentrations ranging from 2.9 to 21.9 mg/kg with a mean of 9.7 mg/kg and a standard deviation of 3.9 mg/kg. The ISQG-Low value of 21 mg/kg was exceeded at one location (PL_S2) where a concentration of 21.9 mg/kg was detected. This site is at the Prelude end of the proposed pipeline route, distant from the Crux Field. Nickel concentrations across the Crux Field were generally within the range of concentrations at the reference sites while a number of sites along the proposed pipeline route showed elevated concentrations of nickel when compared to the reference sites.

4.1.1.1.12 Zinc

Zinc was detected at concentrations above the laboratory PQL of 1 mg/kg at all sites with concentrations ranging from 6.0 to 47.2 mg/kg with a mean of 18.1 mg/kg and a standard deviation of 7.9 mg/kg. These concentrations are all well below the ISQG-Low value of 200 mg/kg. The highest concentrations were recorded at sites PL_S2 and PL_S3, with other concentrations along the proposed pipeline route generally marginally higher than concentrations at the reference sites and sites across the Crux Field.

4.1.1.1.13 Differences between locations

A summary of the metals concentrations grouped by location (Crux Field, proposed pipeline route and reference sites) is presented in Table 2. Initial data analysis indicated that average metals concentrations were typically lower at the reference sites than at the other sites. Further analysis revealed that the average concentrations of metals at the reference sites were being skewed by the lower concentrations measured in the samples collected at REF_NE. This site is located in a shallower part of the field where sediment grain sizes are coarser. This difference in physical characteristics at the site may compromise its suitability as a reference site for future monitoring programs. The primary concern of reference site selection is to choose sites that are similar in nature to the potential impact sites so as to enable an assessment to be made of whether changes in concentrations between surveys are attributable to natural variation in the region, to inter-annual variability in laboratory performance, or to anthropogenic influences. If a reference site differs greatly in its physical characteristics from the potential impact sites, it is difficult to make such an assessment. Hence it is suggested that REF_NE can be excluded as a reference site in future surveys.

Table 2 Summary of metals in sediment at sites grouped as reference and non-reference sites

Metal	Unit	Trigger value[a]	Maximum concentration recorded	Average by location			
				Crux Field	Proposed pipeline route	Reference (All)	Reference (ex. REF_NE)
Aluminium	mg/kg	N/A	5870	3124	3450	1745	2167
Arsenic		20	13.8	3.8	7.9	1.9	2.7
Barium		N/A	56.2	24.9	12.3	10.8	12.0
Cadmium		1.5	0.6	0.3	0.4	0.3	0.3
Chromium		80	43.3	20.4	29.5	14.7	15.1
Cobalt		N/A	6.3	2.3	4.1	1.4	1.8
Copper		65	17	5.2	6.4	3.6	4.2
Iron		N/A	16200	4906	7631	1310	3760
Lead		50	5.5	2.7	3.4	1.7	2.2
Mercury		0.2	0.05	0.038	0.024	0.020	0.027
Nickel		21	21.9	9.3	13.9	5.9	7.1
Zinc		200	47.2	20.3	29.2	12.5	15.1

a = ANZECC 2000 ISQG-Low value

4.1.1.2 Hydrocarbons in sediments

The concentrations of hydrocarbons in the sediment samples (where detected above the laboratory PQL) are summarised in Table 3. TRH and TPH were detected at three sites; however, BTEX and PAHs were not detected above the laboratory PQL in any of the sediment samples collected, with the exception of DC3_1000SE where naphthalene was detected at a concentration of 5 µg/kg, equal to the laboratory PQL.

While ANZECC/ARMCANZ (2000) listed ISQG values for a number of PAHs individually, the subsequent update to the ISQG values by Simpson et al (2013) suggest a more appropriate measure of PAHs is through the use of a guideline value for the sum of PAHs (where the sum refers to the unsubstituted PAHs listed in ANZECC/ARMCANZ [2000]). The rationale suggested by Simpson et al. (2013) is that for the majority of assessments, the concentration of total PAHs represents contributions from a large number of individual PAHs, with each being a small percentage of the total. While it is recognised that the toxicities of the individual PAHs differ significantly, it is considered unlikely that an individual PAH will, by itself, dominate the total PAHs concentration. Simpson et al (2013) also provide an updated sediment quality guideline value (SQGV) for TPH.

Based on their research, Simpson et al. (2013) SQGVs of 280 mg/kg and 10 mg/kg (10,000 µg/kg) for the sum of TPHs and sum of PAHs, respectively, as an update to the ANZECC/ARMCANZ ISQG values.

When comparing the survey results to these SQGVs, the naphthalene concentration detected is well below the SQGV of 10,000 µg/kg for sum of PAHs and the ANZECC & ARMCANZ (2000) ISQG-Low value of 160 µg/kg for naphthalene.

Table 3 TRH and TPH concentrations in sediments (where detected)

TRH					
Fraction	**C6 - C10**	**>C10 - C16**	**>C16 - C34**	**>C34 - C40**	**>C10 - C40 (sum)**
	mg/kg				
LOR	**3**	**3**	**3**	**5**	**3**
REF_NW	<3	<3	<3	<5	<3
REF_NW[a]	<3	<3	**25**	<5	**25**
REF_NW[b]	<0.2	<0.2	<0.4	<0.4	<0.4
PL_S3	<3	**4**	**19**	<5	**23**
PL_S5.5	<3	<3	**12**	<5	**12**
TPH					
	C6 – C9	**C10 – C14**	**C15 – C28**	**C29 – C36**	**C10 – C36 (sum)**
	mg/kg				
LOR	**-**	**3**	**3**	**5**	**3**
REF_NW	-	<3	<3	<5	<3
REF_NW[a]	-	<3	**15**	**12**	**27**
REF_NW[b]	-	-	-	-	-
PL_S3	-	<3	**14**	**7**	**21**
PL_S5.5	-	<3	**7**	**7**	**14**

a duplicate sample

b inter-laboratory duplicate sample

It can be seen that the highest concentration of hydrocarbons was detected in one sample from REF_NW; however, TRH/TPHs were not detected above the laboratory PQL in either of the two duplicate samples also analysed from this site (including one carried out by a second laboratory). TPH/TRH concentrations at the two sites along the proposed pipeline route where they were detected (PL_S3 and PL_S5.5) were well below the SQGV for the sum of TPHs of 280 mg/kg suggested by Simpson et al (2013).

Oil and grease was detected above the PQL of 100 mg/kg at all sites with concentrations ranging from 510 – 2200 mg/kg with the average concentration being 1142.8 mg/kg. A number of sites across the Crux Field and along the proposed pipeline route were higher than the concentrations measured at the reference sites; however no apparent spatial trends were evident and higher the concentrations were spread across the Crux Field and along the proposed pipeline route.

4.1.1.3 Radionuclides

Sediment samples were analysed for gross alpha and gross beta radionuclides. Gross alpha were more commonly detected than gross beta with concentrations above the PQL of 500 Bq/kg at 20 sites ranging from 560 – 1860 Bq/kg compared to gross beta which was detected above the PQL at just one site (PL_S11) where a concentration of 640 Bq/kg was measured.

No ANZECC & ARMCANZ (2000) guidelines exist for radionuclides, as such the low screening level of 35,000 Bq/kg (for sum of gross alpha and gross beta) specified in the National Assessment Guidelines for Dredging 2009 (NAGD) (Commonwealth of Australia 2009) were applied. The sum of gross alpha and gross beta at PL_S11 (2500 Bq/kg) was the highest of any but was well below the screening level.

4.1.1.4 Nutrients in sediments

Sediment samples were analysed for nutrients (TN, NOx, TKN and TP) at all sites. While there are no Guideline trigger values for nutrients in sediments, assessing the concentrations of these nutrients at this time will provide a baseline against which project-related anthropogenic concentrations can be assessed in the future.

Nutrient concentrations are presented in Appendix B.

4.1.1.4.1 Nitrogen

Sediment samples were analysed for NOx, TKN and TN (TKN + NOx). NOx concentrations were very low where detected (concentrations exceeded the laboratory PQL of 0.1 mg/kg at 23 sites) with concentrations ranging from 0.1 to 1.8 mg/kg. TKN ranged from 210 to 1040 mg/kg which also reflected the concentration of TN given the very low concentrations of NOx detected.

No spatial pattern was evident in the concentration of nitrogen. TKN and TN concentrations were generally higher across the Crux Field and some sites along the proposed pipeline route than at the reference sites however, this was not the case for all sites. The highest NOx concentrations were obtained from sample sites located across the Crux Field and, with the exception of four sites (DC2_2000NE, DC3_0, DC3_1000SE and DC3_2000SE), NOx concentrations fell within the range of concentrations found at the reference sites.

4.1.1.4.2 Phosphorus

Phosphorus was detected above the laboratory PQL of 2 mg/kg at all sites, with concentrations ranging from 816 to 10200 mg/kg. The highest concentrations were detected along the proposed pipeline route with samples from PL_S2, PL_S5.5 and PL_S9.5 approaching or exceeding 1000 mg/kg. Phosphorus concentrations at the remaining sites fell within the range of concentrations at the reference sites.

4.1.1.5 Sediment PSD

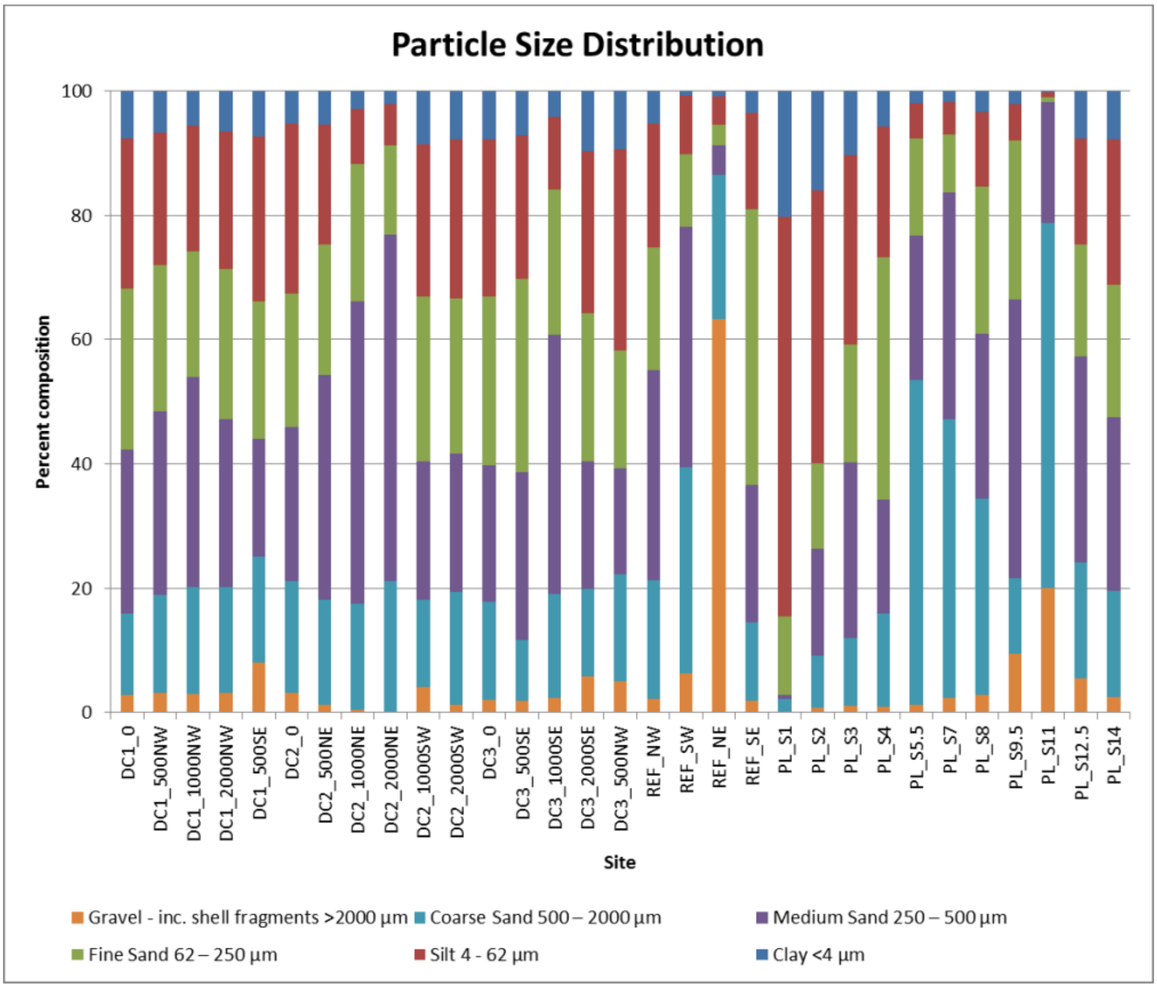
Sediment particle size distribution was assessed at each site with PSD data shown in Figure 5. Sediment PSD composition varied with sites across the Crux Field typically characterised by medium to fine sands with variable amounts of silt and clay (between 5% and 42%) with the percentage of fines (defined as the silt and clay particle fraction <4 – 62 µm) reducing with depth in a north easterly direction towards the shallowest part of the field around site REF_NE where a high gravel content (63.3%) occurred.

A number of sites along the proposed pipeline route had notably higher coarse sand fraction. The fines fraction, ranged from 0.94% (PL_S11) to 84.5% (PL_S1) with the highest fines content found at the Prelude end of the proposed pipeline route where sites PL_S1, PL_S2 and PL_S3 had fines content of 84.5%, 60% and 40.7% respectively.

The presence of a high percentage of fines is of interest due to the potential for metals to bind at greater densities to smaller, silt and clay particles with higher available surface area than to sand particles (Simpson and Batley 2016), often resulting in a higher concentration of metals present in the sediment. This was observed in a number of cases where sites with comparatively low fines content at the Prelude end of the pipeline showed the highest concentrations of a number of metals in sediment samples.

A number of metals showed a weak positive correlation between metal concertation and percent fines, suggesting that the presence of fines may not be the only factor contributing the distribution of metals in sediments of the region.

Figure 5 Sediment PSD



4.1.2 Sediment benthic fauna

A total of 39 sediment samples were analysed for benthic fauna. From these samples, 457 individuals were processed, belonging to 153 morphospecies. All samples except two contained at least one species with an average of 11.7 ± 2.51 (mean ± 1 standard error) individuals belong to 6.9 ± 1.11 morphospecies per sample.

There were 11 major taxa (phyla or sub-phyla) represented in the samples (Table 4). The most common sub-phylum (30% of individuals and 36% of morphospecies) was the Annelida, (Polychaeta), followed by Arthropoda (Crustacea) with 15% of individuals and 24% of morphospecies and Mollusca (24% of individuals and 12% of morphospecies).

Analysis was undertaken with samples grouped by direction from the central drill centre (DC) sites with the samples collected along the proposed pipeline route grouped separately (PL).There was no consistent difference between samples grouped by location (DC, SE, SW, NE, NW and PL). One-way permutational ANOVA, run in the PERMANOVA add-on to the PRIMER-E package, showed no difference in species richness (S) or abundance (N), but a significant difference in assemblage structure between locations (Table 5). Post-hoc tests between locations revealed this difference in assemblage structure to be a result of differences between assemblages at DC and PL sites, with all other locations showing no difference between each other, or with DC or PL. This lack of difference is almost certainly due to the small sample sizes at the reference sites (SE, SW, NE and NW).

Further analysis of DC sites and the SE, SW, NE and NW references sites showed no difference in species richness, abundance or assemblage structure between the five locations (Table 6), even though DC sites appeared to have more species and individuals than the reference sites (Figure 6 and Figure 7).

Table 4 Benthic fauna abundance

Phylum	# individuals	% total	#morphospecies	% total
Porifera	50	10.94	8	5.23
Nemertea	8	1.75	2	1.31
Annelida (Echiura)	2	0.44	2	1.31
Annelida (Sipunculida)	31	6.78	10	6.53
Annelida (Polychaeta)	137	30.0	55	35.95
Mollusca	108	23.62	18	11.76
Bryozoa	5	1.09	3	1.96
Nematoda	16	3.50	4	2.61
Arthropoda (Crustacea)	70	15.3	37	24.2
Echinodermata	29	6.35	13	8.50
Chordata	1	0.21	1	0.65
Total	**457**		**153**	

Table 5 Results of permutational analyses of variance testing the effect of one fixed factor (Location) with six levels (DC, SE, SW, NE, NW and PL) on species richness, abundance and assemblage structure.

Variable	Mean Square	Pseudo-F	P(perm)	Unique permutations
Species richness	21.56	0.3236	0.9027	8158
Abundance	116.1	0.4378	0.823	9569
Assemblage structure	3095.9	1.3148	**0.0188**	9784

Table 6 Results of permutational analyses of variance testing the effect of one fixed factor (Location) with five levels (DC, SE, SW, NE, NW) on species richness, abundance and assemblage structure.

Variable	Mean Square	Pseudo-F	P(perm)	Unique permutations
Species richness	22.121	0.4282	0.8358	4130
Abundance	144.3	0.4770	0.7247	7812
Assemblage structure	3355.6	1.0363	0.3578	9828

Figure 6 Mean number of species per sample from five locations in the AC/RL9 lease area.

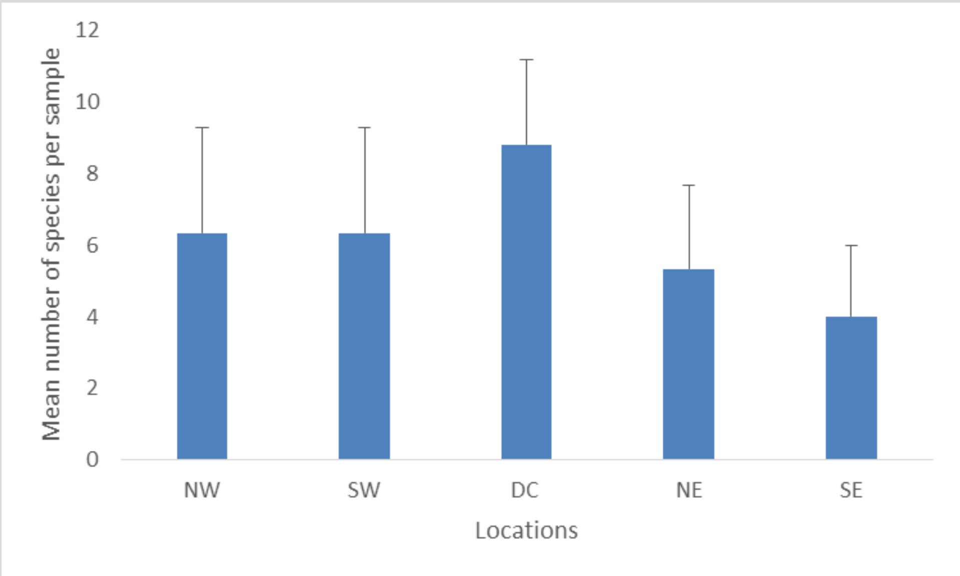
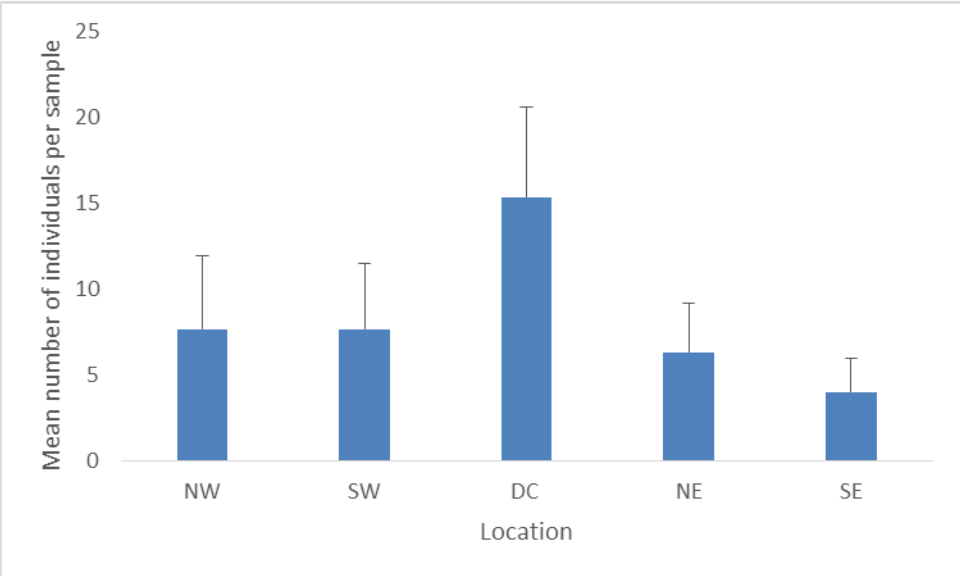


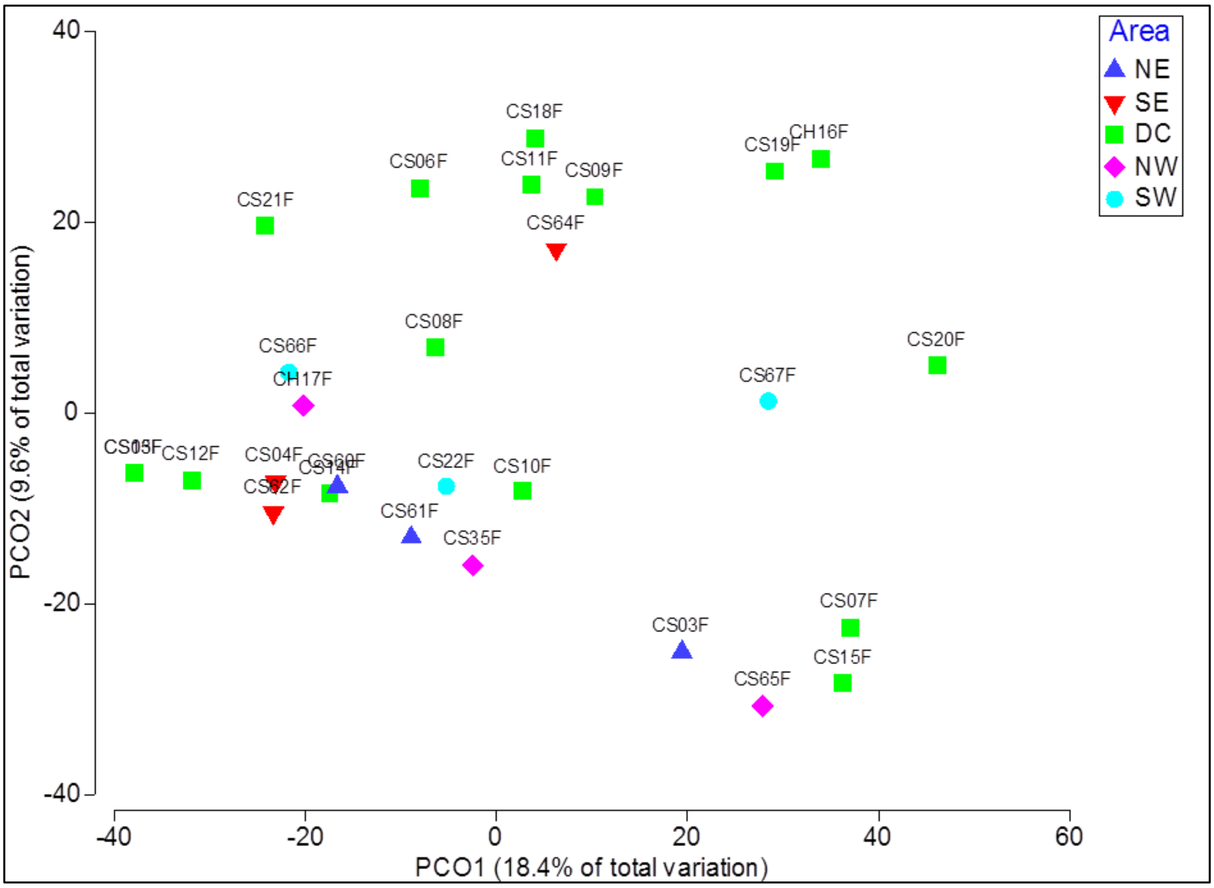
Figure 7 Mean number of individuals per sample from five locations in the AC/RL9 lease area.



Principal coordinate analysis shows a complete overlap of locations, although it should be noted that the two axes displayed account for only 28% of the variance among samples (Figure 8). Data were square root transformed prior to analysis. Each point in Figure 8represents one sample, labelled with its sample code with location identified by the colour and shape of the symbol.

The water depth at the site and %fines in the sample differed between DC sites and all the reference sites. Distance-based Linear Modelling showed that depth and %fines explained only 7% of the variation in assemblage structure and that models containing either or both of these variables had higher akaike information criterion (AIC) values (228.16 – 229.25) than the null model (AIC = 227.45), suggesting neither variable was useful in explaining assemblage structure.

Figure 8 Analysis of principle coordinates based on a Bray-Curtis similarity matrix of assemblage data of the benthic fauna from sediment samples.



In summary, the statistical analysis of the data show there are no distinct groupings of sites, patterns of distribution or variation with physical seabed attributes (water depth, % fines). Similarly, a qualitative analysis of the infauna data indicates that:

There is a high degree of variability in species richness, abundance, diversity and composition between the replicate samples at each reference site. Such variability is not unexpected in soft sediment habitats, where patchiness in distribution of benthic fauna is typically apparent on spatial scales of metres, to tens of metres, to hundreds of metres. This indicates that a high intensity of fauna sampling would be required to generate sufficiently high statistical power in the event that monitoring of impacts on the basis of changes in community characteristics was to be required as a part of project approvals.

- High abundances of individual morphospecies can occur at single sites but be poorly represented or absent at most other sites, for example:
  - Demospongia sponge species at sites DC1_500NW and DC1_1000NW. There was no clear correlation between the presence of sponges and sediment type; many of the samples collected within the Crux Field had similar PSD, but few or no sponges were contained within them.
  - One polychaete species at sites DC2_1000SW. Samples with almost identical PSDs (from other sites within Crux Field) contained either few or none of these species. There was also no clear correlation between total polychaete abundances and sediment type.

  - One species of polychaete (Polynoidae), one species of gastropod (Crepidula sp.) and a gammarid crustacean species at site DC3_500SE. The sediment sample from this site did not have any distinctive physico-chemical characteristics relative to those of sediments at nearby sites, yet overall benthic fauna abundances and diversities at the nearby sites were substantially lower.

- Along the proposed pipeline route, there were some sites at which benthic fauna characteristics may have been related to seabed characteristics:
  - The highest proportion of fines (84% silt and clay) in any of the samples collected during the survey was at site PL_S1 (at the Prelude Field end of the route); the benthic fauna within the sample comprised only two individuals of a single species of sipunculid worm.
  - At the south-western end of the route (sites PL_S1 to PL_S5.5) there was a general increase in fauna abundance with decreasing fines content.
  - The highest fauna abundance along the route was at site PL_S5.5, where a single species of bivalve mollusc accounted for 85% of the fauna in the sample. This was the site with the highest proportion of coarse sand of all sites sampled. However, at site PL_S7 the sediment PSD was similar to that at PL_S5.5, yet fauna abundance was substantially lower.
  - The lowest fauna abundance along the route (a single bivalve) was recorded in the sample from site PL_S11, in which the proportion of fines (1%) was the lowest, and the proportion of coarse sand (60%) the highest, of any of the samples collected during the survey.
- Across all sites, with some exceptions, species richness was typically highest in sediments with 25-35% fines content. As the predominant morphospecies at these sites were burrowing species (worms and bivalve molluscs), this may be indicative of an ‘optimal’ sediment structure for these fauna. Where the fines content was much greater (e.g. site PL_S11) it is possible that the greater density of sediments may preclude many burrowing species. Where the fines content is low (<10%), burrowing species may have difficulty in maintaining competent burrows, especially in coarse sand habitats.

4.2 Physicochemical water column profiles

A summary of the physicochemical water column profile data is provided in Appendix F; data from the April/May survey are included for comparative purposes. Data have been averaged in 10 m strata across the depth of the water column at all sites; these are presented below in depth profile plots for each parameter (Figure 9). Depth profile plots comparing each parameter at each site individually for both surveys are also presented in Appendix F.

The ANZECC & ARMCANZ (2000) guidelines provide criteria levels for DO (> 90% saturation) and pH values (8.2), and state that pH should not deviate more than ± 0.2 pH units among individual sampling sites. However, the guidelines stress the need for site-specific information to enable the development of criteria that are more relevant to the system under study. The baseline data presented in this report may contribute to developing site specific criteria for future comparison.

4.2.1 Temperature

Temperature measurements were generally consistent across the sites with average surface temperatures (1 – 10 m) generally slightly lower (ranging from 30.1 to 30.9 °C) compared to the May survey, when the average surface water temperature ranged from 30.8 to 31.3 °C. Temperatures in the lower water column (below approximately 50 – 60 m depth) recorded during the second survey were slightly cooler than those recorded at the same sites during the May survey. As was the case at the time of the May survey, the temperature dropped consistently through the water column with no strong evidence of a distinct thermocline.

4.2.2 Salinity

Salinity measurements were consistent across all sites. Average surface salinities (0 – 10 m) were observed between 34. 4 – 34.8 PSU compared with a range of 34.8 – 35.0 PSU observed at the same sites during the May survey. In contrast to the salinity profiles observed at the time of the May survey (when a halocline was evident at approximately 30 – 35 m), surface salinities in October were lower in the surface waters and increased slowly to about mid-way through the water column before falling slightly again with depth through the water column to the sea bed.

4.2.3 Dissolved Oxygen

DO concentrations were lower at the time of the October survey than in May, but generally followed the same trend, with higher DO in the upper water column which decreased consistently with depth to the seabed. Average surface DO (0–10 m) ranged from 102.4 – 109.4% compared to a range of 91.6 – 96.0% saturation at the time of the May survey. DO did not typically increase in the shallow surface water (<20 m) as it did during the May survey; however, beyond this depth DO generally decreased consistently through the water column in a manner similar to that observed in the May survey.

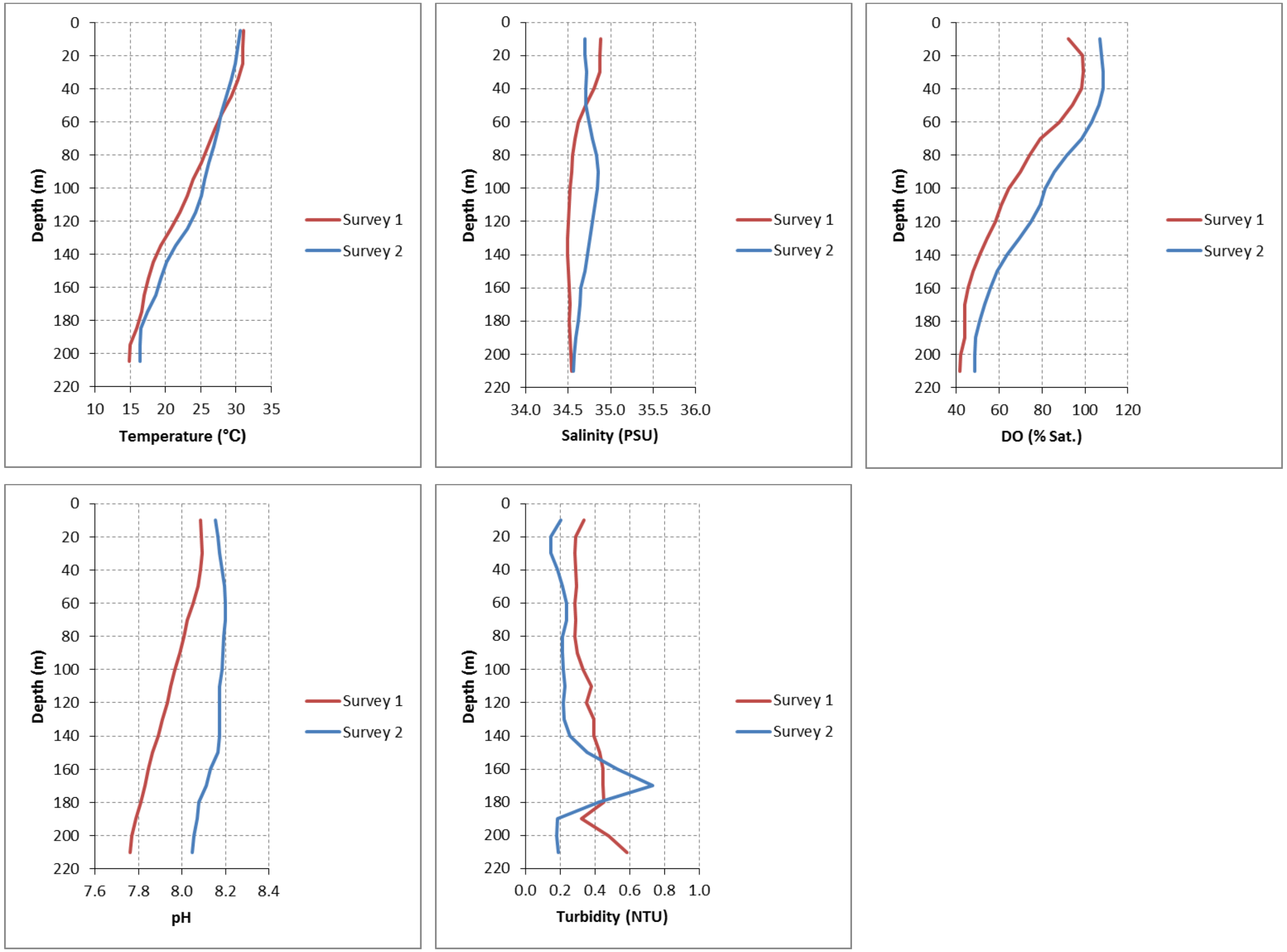
4.2.4 pH

pH levels were generally marginally higher than those recoded during the May survey; however, they were consistent across all sites with the exception of DC_SW2000, which had a slightly lower pH (approximately 0.2) throughout the water column compared to other sites measured on the October survey. pH in surface waters to 40 – 60 m increased slightly before stabilising at a pH of approximately 8.2. At 150 m depth, average pH was recorded at approximately 8.15 – 8.17 before dropping slightly through the remaining water column to the seabed, where an average pH of approximately 8 was recorded. These readings are consistent with expectations for offshore marine environments with the Guideline default trigger value for offshore marine waters set at 8.2.

4.2.5 Turbidity

Consistent with the results obtained during the May survey, turbidity was low throughout the water column (< 1 NTU), as expected for offshore marine environments. High seabed turbidity has been detected at the Prelude development site (Shell, 2015b); however there was no indication of significantly elevated turbidity close to the seabed at any of the sites in the Crux Field or along the proposed pipeline route during the May survey. This was in contrast to the October survey during which elevated turbidity was observed at a number of the sites across the Crux Field. This elevated turbidity was observed up to approximately 20 m above the seabed.

Figure 9 Water column profiles for average temperature, average salinity, average DO, average pH and average turbidity



4.3 Water chemistry

Laboratory analytical results for the water samples are presented in Appendix G with laboratory reports provided in Appendix H. The majority of analyte concentrations were below laboratory PQLs; those that exceeded the PQLs are presented in Table 7.

Table 7 Analytes with concentrations exceeding PQL

	Aluminium	Barium	Chromium	Cobalt	Iron	Nickel	Zinc	Total Phosphorus
PQL	**0.01**	**0.01**	**0.001**	**0.001**	**0.01**	**0.001**	**0.005**	**0.005**
Trigger	**-**	**-**	**0.0077[a]**	**0.001[b]**	**-**	**0.007[a]**	**0.007[a]**	**0.01[c]**
REF_NE	<0.01	**0.02**	<0.001	**0.002**	**0.2**	<0.001	**0.046**	**0.012**
DCO_SW2000	<0.01	**0.01**	<0.001	**0.001**	**0.1**	<0.001	**0.035**	**0.011**
DCO	<0.01	**0.01**	<0.001	**0.001**	**0.06**	**0.001**	**0.029**	**0.012**
DCO	<0.01	**0.01**	**0.002**	**0.001**	**0.05**	**0.001**	**0.029**	**0.011**
FPSO_0	<0.01	**0.02**	<0.001	**0.001**	**0.04**	**0.001**	**0.026**	**0.011**
FPSO_NE2000	**0.06**	**0.01**	<0.001	**0.001**	**0.04**	<0.001	**0.026**	**0.01**
DC2_NE2000	<0.01	<0.01	<0.001	**0.001**	**0.09**	**0.001**	**0.011**	**0.011**
DC1_NW2000	<0.01	**0.02**	<0.001	**0.001**	**0.04**	**0.001**	**0.01**	**0.011**
PL_3	<0.01	<0.01	<0.001	**0.001**	**0.03**	**0.001**	**0.02**	**0.01**
PL_3	<0.01	<0.01	<0.001	**0.001**	**0.03**	**0.001**	**0.02**	**0.01**
PL_2	**0.01**	<0.01	<0.001	**0.001**	**0.02**	**0.001**	**0.015**	**0.011**
PL_1	**0.02**	<0.01	<0.001	**0.001**	**0.02**	**0.001**	**0.014**	**0.01**

a = ANZECC/ARMCANZ 99% species protection level
b = ANZECC/ARMCANZ 95% species protection level
c = ANZECC / ARMCANZ Default trigger level. Site specific trigger level to be developed using baseline data
Bold = concentration above PQL
Yellow = exceeded trigger level

4.3.1 Hydrocarbons

As was the case for results of the May survey, TRH was not detectable above the PQL (0.01 mg/L) in any of the samples. This would be expected of a remote offshore ocean environment distant from existing developments.

Similarly, BTEX were again not detected above the applied PQLs of 0.001 mg/L (Benzene, Toluene and Ethylbenzene) and 0.003 mg/L (Xylenes). Low reliability trigger levels for 99% species protection for BTEX in marine waters are suggested in the ANZECC & ARMCANZ (2000) guidelines. These are specified as 0.5 mg/L (Benzene), 0.18 mg/L (Toluene) and 0.005 mg/L (Ethylbenzene). Low reliability trigger levels for xylene isomers are suggested as 0.35 mg/L (o-xylene), 0.075 mg/L (m-xylene) and 0.2 mg/L (p-xylene).

4.3.2 Metals

Samples were analysed for total metals and the results were compared against the ANZECC & ARMCANZ (2000) 99% species protection trigger values for marine waters. In May 2016, metals concentrations were generally below the PQLs, with some exceptions. Where this was not the case, concentrations were generally substantially below the guideline 99% species protection trigger levels for marine waters. The results from this survey showed similarly low concentrations of metals in water samples and, while there were a number of metal concentrations above the laboratory PQLs, these were (with the exception of zinc) generally very close to the PQLs and below the ANZECC/ARMCANZ 99% species protection levels.

4.3.2.1 Aluminium

Aluminium concentrations above the PQL of 0.01 mg/L were detected at four sites, ranging from 0.01 – 0.07 mg/L. There is no Guideline trigger level for aluminium. During the May survey, aluminium was not detected above the PQL at any sites.

4.3.2.2 Arsenic

Arsenic was not detected above the laboratory PQL of 0.001 mg/L at any site during the October survey. This is consistent with the May survey where all sites returned concentrations slightly above the PQL (with a range of 0.001 – 0.004 mg/L).

No ANZECC & ARMCANZ (2000) 99% protection trigger level exists for arsenic in marine waters however; low reliability guideline trigger levels of 0.0023 mg/L and 0.0045 mg/L are suggested for marine waters for As III and V species respectively. Given the evidently low concentrations of arsenic,, analysis of samples for speciated arsenic was not warranted as part of this program.

4.3.2.3 Barium

Barium was detected above the PQL of 0.01 mg/L at seven sites, with concentrations ranging from 0.01 – 0.02 mg/L. While there is no Guideline trigger level for comparison, these very low concentrations are consistent with the results from the May survey, where barium was not detected at any sites.

4.3.2.4 Cadmium

In line with the results of the May survey, cadmium concentrations were again below the PQL of 0.0001 mg/L at all sites and therefore below the ANZECC & ARMCANZ (2000) 99% species protection trigger level of 0.0007 mg/L.

4.3.2.5 Chromium

Chromium was detected above the PQL of 0.001 mg/L at one site (DC0) where a concentration of 0.002 mg/L was measured. This is below the ANZECC & ARMCANZ (2000) 99% species protection trigger level of 0.0077 mg/L. These results are in line with those from the May survey, in which chromium was only reported at one site (DC0_SW1000) at a concentration of 0.002 mg/L.

4.3.2.6 Cobalt

Cobalt was detected in all samples at a concertation equal to the laboratory PQL of 0.001 mg/kg except at the reference site REF_NE where a concentration of 0.002 mg/L was detected. During the May survey, cobalt was not detected at concentrations above the PQL at any of the sites sampled. It was not possible to apply a PQL sufficiently low to detect levels at the ANZECC & ARMCANZ (2000) 99% species protection level trigger of 0.000005 mg/L; however, the PQL applied was sufficient to detect any exceedance of the Guideline 95% protection trigger level of 0.001 mg/L, which was exceeded only at the REF_NE site.

4.3.2.7 Copper

Copper was not detected above the PQL of 0.001 mg/L at any site during the October survey.

It was not possible to apply a PQL sufficiently low to detect levels at the ANZECC & ARMCANZ (2000) 99% species protection level trigger of 0.0003 mg/L, however, the PQL applied was sufficient to detect any exceedance of the Guideline 95% protection trigger level of 0.0013 mg/L. Two sites exceeded this level during the May survey, by a very small amount however, both of these sites (DC0_SW1000 and PL-1) returned concentrations below the PQL during the October survey.

4.3.2.8 Iron

No ANZECC & ARMCANZ (2000) trigger level is provided for iron in marine waters, in which it occurs naturally. Iron was detected above the PQL (0.01 mg/L) at all sites, at concentrations of 0.01 – 0.09 mg/L. Concentrations were typically in line with those detected during the May survey.

4.3.2.9 Lead

As was the case during the May survey, lead concentrations were below the PQL of 0.001 mg/L and therefore below the ANZECC & ARMCANZ (2000) 99% species protection level of 0.0022 mg/L during this survey.

4.3.2.10 Mercury

Mercury was not detected above the PQL of 0.0001 mg/L at any of the sites sampled during this survey. The PQL is equal to the ANZECC & ARMCANZ (2000) 99% species protection trigger level of 0.0001 mg/L so there were no exceedances of this trigger level. This was also the case during the May survey.

4.3.2.11 Nickel

Nickel concentrations were equal to the PQL of 0.001 mg/L at seven sites during this survey compared to only one site during the May survey. During this survey nickel was not detected above the PQL at the site where nickel was detected during the May survey (FPSO_NE2000, 0.001 mg/L). At 0.001 mg/L, the maximum concentration detected is below the ANZECC & ARMCANZ (2000) 99% species protection trigger level of 0.007 mg/L.

4.3.2.12 Zinc

Zinc was detected above the PQL of 0.005 mg/L at all sites sampled during this survey, with concentrations detected ranging from 0.01 – 0.046 mg/L. This is in contrast to the May survey, when the PQL was exceeded at only one site (FPSO_NE2000), where a concentration of 0.021 mg/L was measured. At these concentrations, zinc is above the ANZECC & ARMCANZ (2000) 99% species protection trigger value of 0.007 mg/L.

Zinc was not detected in either of the two inter laboratory duplicates; however, it was detected at a concentration of 0.006 mg/L in a rinsate sample. This suggests that the elevated zinc levels may be due to laboratory processes and/or (to a limited extent) sample contamination during collection. Hence the reported concentrations may not be representative of the actual concentrations within the water samples collected during the survey. This would render the data unsuitable for use in determining site-specific trigger levels for zinc in the study area.

4.3.3 Nutrients and photosynthetic pigments

The ANZECC & ARMCANZ (2000) guidelines provide criteria levels for water contaminant concentrations. However, the guidelines stress the need for site-specific information to enable the development of criteria that are more relevant to the system under study. In particular, the guidelines note that the trigger levels proposed for nutrient and chlorophyll concentrations in marine waters are not equally applicable to coastal and offshore waters. Location-specific baseline information allows for more accurate assessment of these parameters due to the site-specific nature of ecosystem responses to nutrient enrichment.

Therefore, the water quality parameters measured were assessed in terms of the recommendations in the guidelines, but it is suggested that baseline data from this survey and the May survey will form the basis for criteria levels for comparison in future impact assessments and monitoring.

4.3.3.1 Nitrogen

TN concentrations did not exceed the PQL of 0.2 mg/L at any of the sites sampled during the May survey. This PQL was not sufficiently low to detect the presence of nitrogen at the ANZECC & ARMCANZ (2000) trigger level of 0.1 mg/L. The PQL was lowered for the October survey and no detections above the lower PQL of 0.1 mg/L were measured.

NOx was not detected above the laboratory PQL of 0.002 mg/L. This is consistent with the May survey, in which NOx was not detected above the higher PQL of 0.01 mg/L applied to that analysis. The PQL was lowered to 0.002 mg/L for this survey; which is closer to the suggested guideline value of 0.001 mg/L (suggested to be typical of clear offshore waters).

4.3.3.2 Phosphorus

In contrast to the May survey when TP concentrations did not exceed the PQL of 0.01 mg/L at any of the sites sampled, results from this survey returned concentrations of TP which exceeded a lower PQL of 0.005 mg/L. Concentrations of TP measured during the October survey ranged from 0.01 – 0.012 mg/L. The ANZECC & ARMCANZ (2000) default trigger level applicable to offshore marine environments is 0.01 mg/L; hence all sites either equalled, or marginally exceeded, this Guideline level.

4.3.3.3 Photosynthetic pigments

For the four parameters analysed (Chlorophyll a, b, c and phaeophytin), no sites registered a result above the laboratory PQL of 0.0001 mg/L (0.0002 mg/L for phaeophytin). This is marginally different to the May survey results, where concentrations of chlorophyll a were measured above the PQL at seven sites, three of which were re-sampled during the October survey (FPSO_0, FPSO_NE2000 and REF_NE). In May, all detections of total chlorophyll were very low. The measured concentration of total chlorophyll at all sites re-sampled on this survey was 0.0001 mg/L.

These results are below the ANZECC & ARMCANZ (2000) trigger levels for offshore marine waters of Northern Australia (0.0005 – 0.0009 mg/L). The lower of these two values is typical of clear coral dominated waters (e.g. Great Barrier Reef), while higher values are typical of turbid macrotidal systems (e.g. North West Shelf of WA) (ANZECC & ARMCANZ 2000).

4.4 Data QA/QC

4.4.1 Sediment samples

Field triplicate and duplicate samples were taken at three and four sites respectively. The calculated RPD and RSD values for metals from the field QA/QC samples exceeded the guideline of ±50% for a number of analytes. Exceedances of RPD/RSD in a number of these samples were at very low levels and where both primary and duplicate samples were < 10 times the PQL. At these concentrations, the RPD is not considered to be significant due to the very low concentrations detected.

A small number of RPDs fell outside of these criteria:

- Barium at DC3_0
- NOx at DC3_0, DC3_1000SE and DC3_2000SE

The RSD for Copper at REF_NE and REF_NW also fell outside of these criteria.

Barium at site DC3_0 may have fallen outside of these limits if drilling muds containing barium have been used in the area. This may result in a heterogeneous sediment sample composition resulting in this breach of the RPD target. This is conceivable given that a well was drilled at this location and elevated Barium concentrations were found at a number of surrounding sites compared to Reference sites and sites further afield.

NOx were analysed to a low level PQL of 0.1 mg/kg. At the very low levels detected in the duplicate samples (1.1 – 1.8 mg/L) and the relatively small component of TN that this NOx makes up (with TKN shown to be the dominant nitrogen component in all samples), these exceedances in RPD are not seen to invalidate the overall assessment of nitrogen in sediment samples.

The RSD for copper fell outside of the guideline criteria due to the result for from the secondary laboratory being notably higher than the two samples from the primary laboratory (which met the RPD criteria). These samples were referred back to the laboratory and re-analysed. The revised results showed concentrations in line with the primary sample and the revised RSD. The result for REF_NW fell within the criteria and, while the RSD for the revised result for REF_NE remained outside the ±50% guideline, all results were less than 10 times the LOR and so is deemed satisfactory.

Laboratory QA/QC data were all within the acceptable laboratory levels for duplicates, method blanks, laboratory control samples and matrix spikes.

4.4.2 Water samples

One duplicate and one triplicate water sample were taken during the October survey. In all cases, the RPDs and RSDs were within the guideline criteria of ±50%.

Laboratory QA/QC data were all within the acceptable laboratory levels for duplicates, method blanks, laboratory control samples and matrix spikes.

5.0 Summary and Conclusions

5.1 Summary

The outcomes from the October 2016 sediment quality assessment are as follows:

- Metals concentrations across the AC/RL 9 area were all well below the Guideline ISQG-Low levels. The only exceedance of an ISQG-Low level was at site PL_S2, at the Prelude end of the proposed pipeline route.
- Petroleum hydrocarbons were detected at very low concentrations (slightly above the laboratory PQL) at three sites, predominantly in the C16-C34 fraction. One of these sites was a reference site at which the duplicate and triplicate samples did not register any TPH above the PQL. The concentrations detected were well below the SQGV level for TPH.
- BTEX was not detected above the laboratory PQL in any of the samples, while naphthalene was the only PAH detected above the PQL - at one site where the concentration was equal to the PQL and well below the Guideline level.
- Oil and grease were detected at all sites with no apparent spatial trends in the distribution of concentrations.
- Radionuclides were detected at 20 sites with gross alpha more prevalent than gross beta. Concentrations were well below the screening level applied.
- Nitrogen was predominantly present as TKN with a small NOx component at some sites, while phosphorus was present in higher concentrations.
- PSD composition varied, with sites across the Crux Field typically characterised by medium to fine sands with variable amounts of silt and clay between 5% and 42%, with the percentage of fines (particle size <4 – 62 µm) reducing with depth in a north easterly direction towards the shallowest part of the field. A higher percentage of fines was typical of the sites in deeper waters at the Prelude end of the proposed pipeline route.
- Species richness within benthic fauna communities was typically higher in sediments with 25-35% fines content than those with very high (>80%) or very low (<10%) fines. However, there were many exceptions within the AC/RL9 block and along the proposed pipeline route.
- At the sites where benthic fauna abundance within the samples was greatest, this was typically attributable to a high abundance of a single morphospecies. These species were typically absent, or present at much lower abundances, in samples from neighbouring sites and from sites with similar seabed characteristics.

The key outcomes from the November 2016 water quality assessment, where a number of subtle changes in the physicochemical attributes were observed since the May survey that may be suggestive of seasonal variation, were as follows:

- Water column profiles were typically similar to those observed in the May survey with a number of subtle differences reflecting temporal variation these include:
  - marginally higher DO through the water column
  - marginally lower pH through the water column
  - slightly lower salinity in the upper water column which increased to be higher than the May survey in the mid water column before falling consistently to similar concentrations at the seabed
- All but a very small number of toxicant concentrations were observed to be below the ANZECC & ARMCANZ (2000) 99% species protection levels (where PQLs were sufficiently low).
- Petroleum hydrocarbons were all below the quantifiable limit indicating no evidence of impact from petroleum development sites or natural seeps in the region.

- Metals concentrations were generally comparable to those reported for the May survey and, with the exception of zinc, were all within expected ranges with all but one result (cobalt at REF_NE) showing concentrations below the applicable ANZECC & ARMCANZ (2000) guidelines 99% or 95% species protection levels. Where guideline trigger values were not available, toxicant concentrations were observed within levels expected for open ocean marine environments.
- Zinc concentrations were above the Guideline level of 0.007 mg/L in all samples. Zinc was not detected in either of the two inter laboratory duplicates; however, it was detected at a concentration of 0.006 mg/L in a rinsate sample. This suggests that the elevated zinc levels may be due to laboratory processes and/or (to a limited extent) sample contamination during collection. Hence the reported concentrations may not be representative of the actual concentrations within the water samples collected during the survey. This would render the data unsuitable for use in determining site-specific trigger levels for zinc in the study area
- Nutrient concentrations were very low across all sites with all samples returning concentrations below the PQLs for both TN and NOx consistent with the results at the same set of sites sampled during the May survey. Samples were tested for TP to a lower PQL in October (PQL = 0.005 mg/L) compared to the May survey (PQL = 0.01 mg/L) with concentrations all slightly above the previously applied 0.01 mg/L PQL. This suggests a very small increase in TP concentrations during the October survey. Combined with the analytical results for chlorophyll and phaeophytin, there is no evidence of any increase in nutrient loads even with the small observed increase in TP.
- Photosynthetic pigments in surface waters were below the laboratory PQL at all sites. This is consistent with the May survey where chlorophyll concentrations equalled the PQL of 0.1 mg/L at three of the sites that were resampled in October. These results suggest very little seasonal variation in photosynthetic pigments in the surface waters between the two surveys.
- Physical characteristics were within the expected ranges for this time of year when compared to the background data presented in previous desk top studies (Shell 2014, 2015a).

5.2 Conclusion

No evidence was found to suggest that the marine environment across the Crux Field or along the proposed pipeline route has been impacted adversely to date from natural or anthropogenic sources.

The results of the October survey supports the assertion that water quality in the AC/RL9 area can be classified as effectively unmodified, which would be expected given the remote location of the Crux Field and the distance to neighbouring fields that have been developed.

Little seasonal variation was observed in the limited number of sites sampled in both the May survey and this survey. Notable differences were all in the physical parameters rather than chemical characteristics of the waterbody. Baseline data relating to the physical water characteristics collected as part of this survey are suitable for use in developing site-specific criteria against which future monitoring data could be assessed. With the exception of the zinc data from this survey, the baseline dataset could also be used to develop site-specific criteria

Similarly, there is generally little evidence of substantial widespread impacts upon sediment quality from anthropogenic sources; however it is possible that the higher concentrations of metals at the Prelude end of the proposed pipeline route may be due to a combination of the higher proportion of finer particles and the activities associated with the Prelude development. Some increased levels of barium in the vicinity of exploration wells drilled in 2015 appear to be evident, but this is expected of drilling activities and would be anticipated to attenuate naturally over time. Detections of hydrocarbons in sediment samples were dispersed across a wide area suggesting that it is unlikely that these results are due to large scale or wide spread anthropogenic sources.

Average concentrations of metals at the reference sites were being skewed by the lower concentrations measured in the samples collected at REF_NE. This site is located in a shallower part of the field where sediment grain sizes are coarser. This difference in physical characteristics at the site may compromise its suitability as a reference site for future monitoring programs. Hence it is suggested that REF_NE can be excluded as a reference site in future surveys.

The water and sediment quality data collected during the baseline surveys provide a snapshot of the marine environment at these locations and will allow future comparisons to identify any impacts due to the development and/or operation of the Crux Field.

The high degree of variability in benthic community characteristics between the replicate samples at each reference site, and between sites with similar physical sediment characteristics (e.g. PSD, water depth) is indicative of the patchiness in benthic fauna distribution typically found in soft sediment habitats. This precludes the effective use of benthic fauna monitoring to detect impacts from development activities.

Any future comparisons that are made to this baseline data should be done considering the surrounding field activities (development and operations activities which could potentially impact sediment and water quality either temporarily or longer term) and natural medium to long-term climatic cycles and temporal variation associated with these systems (which may result in natural variation in water quality parameters such as nutrients, pH, temperature, DO and salinity etc.).

6.0 References

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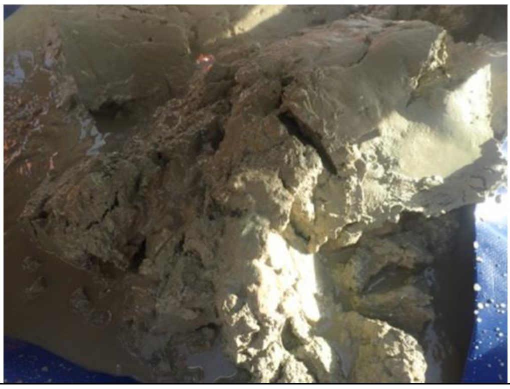
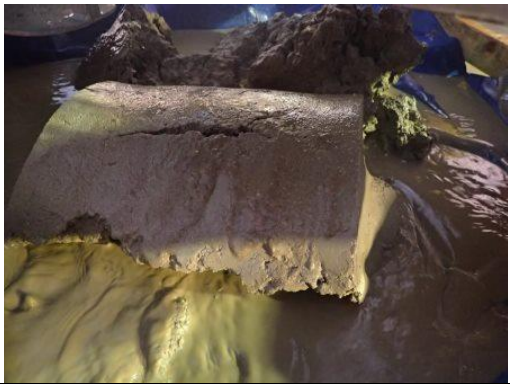
Appendix A

Field Log - Sediments

Appendix A Field Log - Sediments

Table 8 Sediment sample field sampling data sheets

Table 9 Sediment sample photographic record

Sample ID	Site name	Image
CS01	PL_S1	
CS02	PL_S2	
CS03	REF_NE	
CS04	REF_SE	

Sample ID	Site name	Image
CS51	DC3_1000SE	
CS07	DC3_500SE	
CS08	DC3_0	
CS09	DC3_500NW	

Sample ID	Site name	Image
CS10	DC2_0	
CS11	DC2_500NE	
CS12	DC2_1000NE	
CS13	DC2_2000NE	

Sample ID	Site name	Image
CS14	DC1_0	
CS15	DC1_500NW	
CS16	DC1_1000NW	
CS17	REF_NW	

Sample ID	Site name	Image
CS35	REF_NW	
CS65	REF_NW	
CS18	DC1_2000NW	
CS19	DC1_500SE	

Sample ID	Site name	Image
CS20	DC2_1000SW	
CS21	DC2_2000SW	
CS22	REF_SW	
CS66	REF_SW	

Sample ID	Site name	Image
CS67	REF_SW	
CS23	PL_S14	
CS24	PL_S12.5	
CS25	PL_S11	

Sample ID	Site name	Image
CS26	PL_S9.5	
CS27	PL_S8	
CS28	PL_S7	
CS31	PL_S3	

Appendix B

Laboratory reports – Sediment Chemistry

Appendix B Analysis results and Laboratory reports – Sediment Chemistry

Table 10 Sediment sample chemical analysis results for sites around the proposed drill centres

Table 11 Sediment sample chemical analysis results for reference sites and sites along the proposed pipeline route

Appendix C

Laboratory report - Particle Size Distribution

Appendix D

Laboratory report - Benthic fauna

Appendix D Laboratory report - Benthic fauna

Table 12 Benthic Fauna sample data

Appendix E

Water quality sonde calibration certificates

Appendix E Water quality sonde calibration certificates

Appendix F

Physicochemical water column profile data

Appendix F Physicochemical water column profile data

Table 13 Water column profile site locations

Site	Latitude/ Longitude (GDA94)	Water depth (MSL)	Deployed (WST)
DC0	12°58.341'S 124°26.680'E	166m	1606 02/11/16
DC0_SW2000	12°59.106'S 124°25.914'E	165m	1505 02/11/16
DC1_NW2000	12°57.113'S 124°25.749'E	166m	1812 02/11/16
DC2_NE2000	12°57.233'S 124°27.866'E	166m	1736 02/11/16
FPSO_0	12°58.941'S 124°27.773'E	166m	1631 02/11/16
FPSO_NE2000	12°58.236'S 124°28.492'E	160m	1705 02/11/16
PL-1 (KP103)	13°27.578'S 123°39.726'E	210m	1553 30/10/16
PL-2 (KP65)	13°14.413'S 123°56.000'E	200m	1245 30/10/16
PL-3 (KP18)	13°01.841'S 124°18.380'E	180m	0640 30/10/16
REF_NE	12°55.310'S 124°34.543'E	95m	0640 02/11/16

Table 14 Temperature (°C) / depth profiles at sites surrounding proposed Drill Centre locations

Depth	DC0		DC0_SW2000		DC1_NW2000		DC2_NE2000	
	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov
1 - 10 m	31.1	30.7	31.2	30.6	31.3	30.5	31.3	30.8
10 - 20 m	31.1	30.4	31.2	30.4	31.1	30.3	31.1	30.3
20 - 30 m	30.9	29.8	31.1	30.3	31.1	29.6	31.1	30.0
30 - 40 m	29.7	28.9	31.1	29.4	31.1	28.7	31.1	29.6
40 - 50 m	28.2	28.2	30.6	28.8	30.7	28.4	30.5	28.9
50 - 60 m	27.0	28.0	29.3	28.4	29.1	27.6	29.1	27.8
60 - 70 m	26.5	27.4	27.7	27.8	27.8	26.8	27.4	27.3
70 - 80 m	25.8	26.6	26.6	27.1	26.6	26.4	26.4	26.9
80 - 90 m	25.1	26.2	25.4	26.5	25.5	25.9	25.6	26.2
90 - 100 m	24.3	25.5	24.6	26.1	24.8	25.5	24.6	25.5
100 - 110 m	23.1	24.8	23.4	25.3	24.0	25.0	23.5	24.9
110 - 120 m	22.6	24.0	22.3	24.3	21.8	24.4	22.4	24.0
120 - 130 m	20.8	22.4	20.8	23.6	20.6	23.6	20.7	22.7
130 - 140 m	18.8	20.7	19.7	22.3	19.2	22.2	19.1	20.8
140 - 150 m	17.9	19.5	18.0	20.3	18.0	20.3	17.7	20.2
150 - 160 m	17.2	19.2	17.3	19.1	17.2	18.5	17.4	19.9
160 - 170 m	16.8	19.2	17.0	18.6	16.9	17.8	17.1	19.6
170 - 180 m	-	-	16.7	18.5	-	-	-	-

Table 15 Temperature (°C) / depth profiles at sites surrounding proposed FPSO Locations

Depth	FPSO_0		FPSO_NE2000	
	Apr/May	Nov	Apr/May	Nov
1 - 10 m	30.9	30.6	30.9	30.9
10 - 20 m	30.9	30.4	30.9	30.2
20 - 30 m	30.9	30.1	30.9	30.0
30 - 40 m	30.5	29.6	30.1	29.6
40 - 50 m	29.3	28.5	29.1	28.7
50 - 60 m	28.2	27.5	28.0	27.6
60 - 70 m	27.2	27.3	26.9	27.2
70 - 80 m	26.3	26.8	25.9	26.6
80 - 90 m	25.8	26.2	24.9	26.3
90 - 100 m	24.6	25.5	23.8	25.9
100 - 110 m	23.2	24.9	23.1	25.3
110 - 120 m	22.3	23.9	21.9	24.3
120 - 130 m	20.6	21.9	20.5	22.0
130 - 140 m	19.2	20.2	18.8	19.9
140 - 150 m	17.9	19.3	17.8	19.7
150 - 160 m	17.3	19.2	17.2	19.6
160 - 170 m	16.9	19.1	17.0	19.6

Table 16 Temperature (°C) / depth profiles at sites along the Pipeline and reference sites

Depth	PL-1		PL-2		PL-3		REF_NE	
	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov
1 - 10 m	31.1	30.9	31.1	30.4	30.9	30.2	30.8	30.1
10 - 20 m	30.8	30.2	31.0	30.2	30.9	30.2	30.9	30.0
20 - 30 m	30.8	29.7	30.9	30.2	30.9	30.2	30.8	29.6
30 - 40 m	30.8	28.9	29.2	30.0	29.4	29.9	30.1	28.9
40 - 50 m	30.3	28.4	27.8	29.6	27.8	28.6	29.2	27.9
50 - 60 m	28.7	27.8	26.6	29.0	26.7	27.7	28.0	27.5
60 - 70 m	27.6	27.2	26.1	28.4	26.3	27.6	26.9	27.2
70 - 80 m	26.7	26.8	25.1	27.8	25.4	26.7	25.7	26.6
80 - 90 m	25.4	26.5	24.4	26.8	24.3	26.0	24.2	25.3
90 - 100 m	23.7	26.3	23.7	26.0	23.2	25.2	22.5	24.1
100 - 110 m	22.6	25.9	23.2	25.5	22.0	24.3	-	-
110 - 120 m	21.5	25.0	22.6	24.9	21.0	23.6	-	-
120 - 130 m	20.5	24.2	21.4	24.2	20.4	22.8	-	-
130 - 140 m	19.3	21.8	20.9	22.9	19.3	22.2	-	-
140 - 150 m	18.3	20.1	20.4	20.7	18.6	21.5	-	-
150 - 160 m	17.4	18.6	19.9	19.5	17.4	20.4	-	-
160 - 170 m	16.4	17.0	18.6	17.8	16.2	18.7	-	-
170 - 180 m	15.8	16.7	17.7	16.8	16.2	17.8	-	-
180 - 190 m	15.4	16.3	16.4	16.7	-	-	-	-
190 - 200 m	14.9	16.1	15.1	16.6	-	-	-	-
200 - 210 m	14.8	16.1	14.9	16.6	-	-	-	-

Figure 10 Temperature (°C) / depth profiles plots for each site sampled during May (survey 1) and November (survey 2)

Table 17 Salinity (PSU) / depth profiles at sites surrounding proposed Drill Centre locations

Depth	DC0		DC0_SW2000		DC1_NW2000		DC2_NE2000	
	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov
1 - 10 m	34.94	34.76	34.94	34.75	34.95	34.75	34.94	34.72
10 - 20 m	34.94	34.75	34.94	34.75	34.94	34.74	34.94	34.65
20 - 30 m	34.90	34.71	34.94	34.74	34.94	34.72	34.94	34.76
30 - 40 m	34.73	34.64	34.93	34.72	34.94	34.65	34.93	34.77
40 - 50 m	34.61	34.68	34.83	34.72	34.84	34.77	34.82	34.71
50 - 60 m	34.58	34.81	34.69	34.80	34.67	34.85	34.65	34.68
60 - 70 m	34.57	34.83	34.60	34.87	34.62	34.83	34.59	34.72
70 - 80 m	34.56	34.84	34.56	34.83	34.57	34.84	34.58	34.82
80 - 90 m	34.56	34.84	34.55	34.86	34.55	34.81	34.56	34.81
90 - 100 m	34.53	34.80	34.55	34.88	34.55	34.80	34.55	34.80
100 - 110 m	34.53	34.77	34.52	34.80	34.54	34.75	34.53	34.74
110 - 120 m	34.52	34.75	34.52	34.79	34.49	34.74	34.51	34.76
120 - 130 m	34.48	34.73	34.50	34.78	34.50	34.76	34.50	34.77
130 - 140 m	34.50	34.72	34.50	34.73	34.50	34.75	34.47	34.72
140 - 150 m	34.51	34.67	34.49	34.70	34.51	34.69	34.52	34.68
150 - 160 m	34.51	34.64	34.52	34.66	34.51	34.60	34.52	34.65
160 - 170 m	34.52	34.62	34.52	34.63	34.53	34.57	34.53	34.65
170 - 180 m	-	-	34.53	34.61	-	-	-	-

Table 18 Salinity (PSU) / depth profiles at sites surrounding proposed FPSO Locations

Depth	FPSO_0		FPSO_NE2000	
	Apr/May	Nov	Apr/May	Nov
1 - 10 m	34.83	34.75	34.83	34.72
10 - 20 m	34.83	34.75	34.84	34.67
20 - 30 m	34.84	34.75	34.85	34.76
30 - 40 m	34.80	34.74	34.74	34.75
40 - 50 m	34.69	34.66	34.68	34.71
50 - 60 m	34.63	34.62	34.62	34.69
60 - 70 m	34.58	34.66	34.56	34.68
70 - 80 m	34.57	34.75	34.57	34.70
80 - 90 m	34.56	34.82	34.54	34.76
90 - 100 m	34.53	34.78	34.54	34.78
100 - 110 m	34.52	34.77	34.53	34.77
110 - 120 m	34.51	34.76	34.50	34.76
120 - 130 m	34.50	34.74	34.50	34.72
130 - 140 m	34.49	34.71	34.48	34.72
140 - 150 m	34.50	34.67	34.51	34.66
150 - 160 m	34.53	34.64	34.52	34.64
160 - 170 m	34.52	34.63	34.53	34.64

Table 19 Salinity (PSU) / depth profiles at sites along the Pipeline and reference sites

Depth	PL-1		PL-2		PL-3		REF_NE	
	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov
1 - 10 m	34.86	34.68	34.88	34.69	34.83	34.73	34.79	34.39
10 - 20 m	34.86	34.71	34.86	34.73	34.82	34.73	34.79	34.48
20 - 30 m	34.86	34.69	34.84	34.74	34.81	34.73	34.78	34.53
30 - 40 m	34.86	34.72	34.67	34.76	34.65	34.70	34.75	34.63
40 - 50 m	34.78	34.72	34.60	34.87	34.58	34.68	34.67	34.58
50 - 60 m	34.64	34.77	34.56	34.99	34.56	34.70	34.59	34.57
60 - 70 m	34.59	34.82	34.55	35.01	34.55	34.81	34.57	34.58
70 - 80 m	34.54	35.08	34.53	35.02	34.52	34.85	34.54	34.63
80 - 90 m	34.51	35.08	34.51	35.00	34.51	34.88	34.53	34.70
90 - 100 m	34.49	35.06	34.50	34.92	34.50	34.88	34.49	34.73
100 - 110 m	34.48	34.98	34.49	34.84	34.49	34.86	-	-
110 - 120 m	34.49	34.87	34.46	34.79	34.50	34.81	-	-
120 - 130 m	34.49	34.80	34.48	34.72	34.50	34.79	-	-
130 - 140 m	34.49	34.72	34.49	34.71	34.47	34.77	-	-
140 - 150 m	34.51	34.69	34.50	34.73	34.49	34.75	-	-
150 - 160 m	34.51	34.66	34.50	34.65	34.47	34.73	-	-
160 - 170 m	34.51	34.64	34.49	34.65	34.51	34.70	-	-
170 - 180 m	34.53	34.59	34.49	34.61	34.51	34.66	-	-
180 - 190 m	34.53	34.58	34.50	34.59	-	-	-	-
190 - 200 m	34.54	34.57	34.53	34.57	-	-	-	-
200 - 210 m	34.54	34.56	34.54	34.56	-	-	-	-

Figure 11 Salinity (PSU) / depth profiles plots for each site sampled during May (survey 1) and November (survey 2)

Table 20 Dissolved Oxygen (% Saturation) / depth profiles at sites surrounding proposed Drill Centre locations

Depth	DC0		DC0_SW2000		DC1_NW2000		DC2_NE2000	
	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov
1 - 10 m	91.63	102.4	91.60	108.3	95.99	106.3	93.96	106.6
10 - 20 m	99.18	107.3	99.58	108.1	100.79	106.5	100.18	107.1
20 - 30 m	99.23	108.5	99.81	108.1	100.94	108.5	100.33	107.9
30 - 40 m	98.66	107.6	99.87	110.0	100.98	106.4	100.47	108.3
40 - 50 m	90.01	105.8	99.63	108.9	100.64	106.0	100.34	107.3
50 - 60 m	74.29	106.0	98.99	108.1	99.64	102.0	98.86	101.0
60 - 70 m	70.47	99.8	86.26	104.8	90.10	91.0	82.32	95.7
70 - 80 m	71.09	89.9	72.02	96.7	80.50	86.7	78.23	92.9
80 - 90 m	68.93	85.6	71.36	87.0	72.13	83.9	72.40	86.4
90 - 100 m	65.12	83.0	65.98	84.1	67.22	81.5	66.41	82.0
100 - 110 m	60.26	78.9	61.37	81.4	64.44	79.8	62.94	79.4
110 - 120 m	60.08	74.8	58.05	75.4	58.83	76.6	60.37	74.0
120 - 130 m	54.72	67.3	54.85	71.0	55.06	72.1	55.87	66.9
130 - 140 m	49.70	61.5	52.23	67.7	51.75	65.8	51.39	61.7
140 - 150 m	46.40	57.2	47.70	60.6	47.99	59.6	46.43	58.6
150 - 160 m	44.28	55.5	44.75	56.2	45.46	51.3	44.76	57.7
160 - 170 m	42.99	55.2	43.66	53.3	43.89	48.2	43.92	55.9
170 - 180 m	-	-	42.96	53.0	-	-	-	-

Table 21 Dissolved Oxygen (% Saturation) / depth profiles at sites surrounding proposed FPSO Locations

Depth	FPSO_0		FPSO_NE2000	
	Apr/May	Nov	Apr/May	Nov
1 - 10 m	93.47	107.1	92.47	106.9
10 - 20 m	98.30	107.3	98.54	107.5
20 - 30 m	98.67	108.0	98.79	108.0
30 - 40 m	98.11	108.3	96.63	108.3
40 - 50 m	94.87	105.7	93.82	106.8
50 - 60 m	89.95	97.7	87.15	99.5
60 - 70 m	76.11	95.3	74.15	95.2
70 - 80 m	71.27	89.5	70.92	88.1
80 - 90 m	71.37	86.5	67.54	86.2
90 - 100 m	65.99	82.9	62.56	84.8
100 - 110 m	60.97	79.2	61.17	81.5
110 - 120 m	58.53	74.0	58.17	76.1
120 - 130 m	54.42	66.3	54.12	67.4
130 - 140 m	50.27	59.6	49.53	57.8
140 - 150 m	46.38	56.0	46.05	56.2
150 - 160 m	43.70	54.8	43.62	56.0
160 - 170 m	42.61	54.6	42.62	55.7

Table 22 Dissolved Oxygen (% Saturation) / depth profiles at sites along the Pipeline and reference sites

Depth	PL-1		PL-2		PL-3		REF_NE	
	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov
1 - 10 m	94.38	109.4	86.63	108.9	88.94	108.2	92.50	105.8
10 - 20 m	99.14	109.5	96.65	109.3	97.84	108.2	98.07	106.3
20 - 30 m	99.45	110.3	98.59	109.1	98.23	108.0	98.25	107.1
30 - 40 m	99.68	111.4	96.88	109.4	95.20	108.5	96.53	104.8
40 - 50 m	99.39	109.8	84.57	110.6	86.48	109.1	92.01	96.6
50 - 60 m	100.52	107.3	69.37	111.1	79.30	106.1	80.93	91.4
60 - 70 m	96.37	99.4	67.68	109.2	76.84	104.2	70.77	88.8
70 - 80 m	88.80	86.0	69.47	105.5	71.51	93.0	68.11	85.8
80 - 90 m	76.94	81.8	65.32	93.0	65.90	83.7	64.68	80.8
90 - 100 m	66.29	78.5	62.02	85.7	61.19	75.6	59.67	75.3
100 - 110 m	59.83	77.2	60.27	82.3	57.03	71.3	-	-
110 - 120 m	57.73	75.9	59.83	77.0	52.23	71.2	-	-
120 - 130 m	54.26	72.4	55.56	72.6	49.88	67.4	-	-
130 - 140 m	50.48	64.7	54.80	67.4	49.56	64.9	-	-
140 - 150 m	48.51	57.3	53.76	61.8	47.72	62.5	-	-
150 - 160 m	46.49	54.1	52.32	58.4	44.59	58.8	-	-
160 - 170 m	44.87	50.9	49.23	54.2	42.12	52.6	-	-
170 - 180 m	43.45	49.9	47.59	50.6	42.18	50.1	-	-
180 - 190 m	42.48	48.6	45.08	49.6	-	-	-	-
190 - 200 m	41.45	48.0	42.50	49.3	-	-	-	-
200 - 210 m	41.25	47.7	42.06	49.2	-	-	-	-

Figure 12 DO (% saturation) / depth profiles plots for each site sampled during May (survey 1) and November (survey 2)

Table 23 pH / depth profiles at sites surrounding proposed Drill Centre locations

Depth	DC0		DC0_SW2000		DC1_NW2000		DC2_NE2000	
	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov
1 - 10 m	8.13	8.13	8.08	7.94	8.13	8.24	8.09	8.20
10 - 20 m	8.13	8.14	8.08	7.94	8.13	8.25	8.09	8.22
20 - 30 m	8.13	8.15	8.08	7.95	8.12	8.27	8.08	8.23
30 - 40 m	8.12	8.16	8.08	7.97	8.11	8.28	8.08	8.25
40 - 50 m	8.09	8.17	8.08	7.99	8.11	8.28	8.08	8.26
50 - 60 m	8.05	8.17	8.06	7.99	8.09	8.29	8.06	8.27
60 - 70 m	8.03	8.17	8.03	8.00	8.07	8.28	8.02	8.27
70 - 80 m	8.03	8.17	7.99	8.01	8.04	8.27	8.00	8.26
80 - 90 m	8.02	8.17	7.98	8.01	8.01	8.27	7.98	8.25
90 - 100 m	8.00	8.16	7.95	8.00	7.99	8.26	7.96	8.25
100 - 110 m	7.98	8.16	7.93	8.01	7.97	8.26	7.94	8.25
110 - 120 m	7.97	8.16	7.91	8.01	7.94	8.26	7.92	8.25
120 - 130 m	7.95	8.16	7.89	8.01	7.92	8.25	7.90	8.24
130 - 140 m	7.93	8.17	7.87	8.01	7.90	8.25	7.87	8.25
140 - 150 m	7.90	8.16	7.84	8.02	7.87	8.25	7.84	8.23
150 - 160 m	7.88	8.14	7.82	8.01	7.85	8.06	7.82	8.21
160 - 170 m	7.87	8.13	7.80	7.99	7.83	7.97	7.81	8.20
170 - 180 m	-	-	7.80	7.98	-	-	-	-

Table 24 pH / depth profiles at sites surrounding proposed FPSO Locations

Depth	FPSO_0		FPSO_NE2000	
	Apr/May	Nov	Apr/May	Nov
1 - 10 m	8.04	8.20	8.11	8.17
10 - 20 m	8.05	8.21	8.11	8.19
20 - 30 m	8.06	8.22	8.11	8.20
30 - 40 m	8.06	8.22	8.10	8.21
40 - 50 m	8.05	8.24	8.09	8.23
50 - 60 m	8.04	8.24	8.06	8.23
60 - 70 m	8.01	8.23	8.03	8.22
70 - 80 m	7.99	8.23	8.01	8.22
80 - 90 m	7.99	8.22	8.00	8.21
90 - 100 m	7.97	8.22	7.98	8.21
100 - 110 m	7.95	8.22	7.96	8.21
110 - 120 m	7.94	8.22	7.95	8.21
120 - 130 m	7.92	8.22	7.93	8.22
130 - 140 m	7.90	8.22	7.90	8.22
140 - 150 m	7.87	8.20	7.87	8.19
150 - 160 m	7.85	8.18	7.85	8.18
160 - 170 m	7.83	8.17	7.84	8.16

Table 25 pH / depth profiles at sites along the Pipeline and reference sites

Depth	PL-1		PL-2		PL-3		REF_NE	
	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov
1 - 10 m	8.06	8.14	8.08	8.03	8.12	8.25	8.02	8.25
10 - 20 m	8.07	8.15	8.09	8.04	8.12	8.25	8.04	8.25
20 - 30 m	8.07	8.16	8.09	8.05	8.12	8.25	8.06	8.25
30 - 40 m	8.07	8.17	8.07	8.06	8.11	8.26	8.07	8.26
40 - 50 m	8.07	8.18	8.04	8.08	8.08	8.27	8.06	8.26
50 - 60 m	8.06	8.18	7.99	8.09	8.06	8.28	8.04	8.25
60 - 70 m	8.04	8.18	7.98	8.10	8.04	8.27	8.01	8.24
70 - 80 m	8.02	8.16	7.97	8.11	8.02	8.26	8.00	8.24
80 - 90 m	7.98	8.15	7.95	8.11	8.00	8.25	7.99	8.24
90 - 100 m	7.95	8.14	7.93	8.11	7.98	8.23	7.98	8.24
100 - 110 m	7.92	8.13	7.91	8.10	7.96	8.22	-	-
110 - 120 m	7.90	8.14	7.91	8.10	7.94	8.21	-	-
120 - 130 m	7.89	8.14	7.89	8.10	7.92	8.20	-	-
130 - 140 m	7.86	8.16	7.88	8.10	7.91	8.19	-	-
140 - 150 m	7.84	8.14	7.87	8.11	7.89	8.18	-	-
150 - 160 m	7.82	8.13	7.86	8.11	7.87	8.17	-	-
160 - 170 m	7.80	8.12	7.85	8.10	7.85	8.16	-	-
170 - 180 m	7.78	8.10	7.83	8.07	7.84	8.15	-	-
180 - 190 m	7.77	8.09	7.81	8.05	-	-	-	-
190 - 200 m	7.76	8.07	7.78	8.04	-	-	-	-
200 - 210 m	7.75	8.06	7.77	8.03	-	-	-	-

Figure 13 pH / depth profiles plots for each site sampled during May (survey 1) and November (survey 2)

Table 26 Turbidity (NTU) / depth profiles at sites surrounding proposed Drill Centre locations

Depth	DC0		DC0_SW2000		DC1_NW2000		DC2_NE2000	
	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov
1 - 10 m	0.31	0.13	0.32	0.11	0.26	0.35	0.33	0.16
10 - 20 m	0.25	0.09	0.28	0.08	0.32	0.29	0.29	0.11
20 - 30 m	0.26	0.16	0.30	0.14	0.27	0.23	0.36	0.11
30 - 40 m	0.26	0.22	0.29	0.12	0.25	0.25	0.32	0.24
40 - 50 m	0.29	0.22	0.30	0.14	0.24	0.34	0.29	0.28
50 - 60 m	0.30	0.23	0.27	0.19	0.21	0.32	0.31	0.28
60 - 70 m	0.35	0.22	0.29	0.21	0.24	0.32	0.27	0.27
70 - 80 m	0.28	0.15	0.29	0.20	0.21	0.26	0.26	0.21
80 - 90 m	0.33	0.19	0.31	0.18	0.23	0.30	0.26	0.27
90 - 100 m	0.37	0.15	0.30	0.16	0.22	0.31	0.40	0.26
100 - 110 m	0.45	0.20	0.46	0.20	0.40	0.31	0.47	0.27
110 - 120 m	0.34	0.17	0.49	0.21	0.33	0.34	0.40	0.24
120 - 130 m	0.48	0.19	0.51	0.23	0.33	0.31	0.33	0.26
130 - 140 m	0.47	0.21	0.40	0.22	0.34	0.38	0.41	0.26
140 - 150 m	0.47	0.23	0.51	0.22	0.42	0.38	0.48	0.26
150 - 160 m	0.46	0.55	0.51	0.21	0.42	0.46	0.49	0.46
160 - 170 m	0.44	0.81	0.50	0.63	0.43	0.49	0.45	0.97
170 - 180 m	-	-	0.50	0.58	-	-	-	-

Table 27 Turbidity (NTU) / depth profiles at sites surrounding proposed FPSO Locations

Depth	FPSO_0		FPSO_NE2000	
	Apr/May	Nov	Apr/May	Nov
1 - 10 m	0.30	0.25	0.32	0.24
10 - 20 m	0.26	0.18	0.29	0.18
20 - 30 m	0.26	0.11	0.30	0.16
30 - 40 m	0.28	0.13	0.30	0.24
40 - 50 m	0.27	0.23	0.29	0.28
50 - 60 m	0.28	0.28	0.28	0.27
60 - 70 m	0.30	0.24	0.28	0.28
70 - 80 m	0.26	0.22	0.32	0.27
80 - 90 m	0.29	0.09	0.30	0.25
90 - 100 m	0.26	0.16	0.43	0.28
100 - 110 m	0.40	0.20	0.32	0.27
110 - 120 m	0.32	0.17	0.36	0.29
120 - 130 m	0.35	0.25	0.42	0.27
130 - 140 m	0.48	0.24	0.49	0.48
140 - 150 m	0.49	0.39	0.51	1.19
150 - 160 m	0.47	0.92	0.52	1.52
160 - 170 m	0.49	0.95	0.53	1.98

Table 28 Turbidity (NTU) / depth profiles at sites along the Pipeline and reference sites

Depth	PL-1		PL-2		PL-3		REF_NE	
	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov	Apr/May	Nov
1 - 10 m	0.36	0.25	0.34	0.05	0.40	0.18	0.39	0.28
10 - 20 m	0.28	0.13	0.31	0.02	0.24	0.14	0.33	0.20
20 - 30 m	0.26	0.15	0.33	0.01	0.20	0.14	0.30	0.25
30 - 40 m	0.28	0.15	0.32	0.01	0.22	0.16	0.33	0.31
40 - 50 m	0.26	0.14	0.45	0.02	0.21	0.13	0.32	0.32
50 - 60 m	0.27	0.26	0.40	0.01	0.21	0.16	0.29	0.34
60 - 70 m	0.26	0.28	0.26	0.04	0.22	0.14	0.41	0.33
70 - 80 m	0.34	0.32	0.25	0.03	0.23	0.13	0.36	0.33
80 - 90 m	0.24	0.32	0.25	0.04	0.31	0.16	0.44	0.33
90 - 100 m	0.25	0.32	0.24	0.02	0.36	0.16	0.46	0.34
100 - 110 m	0.25	0.32	0.24	0.04	0.41	0.23	-	-
110 - 120 m	0.25	0.33	0.22	0.04	0.44	0.16	-	-
120 - 130 m	0.25	0.31	0.24	0.01	0.62	0.14	-	-
130 - 140 m	0.26	0.33	0.23	0.02	0.44	0.13	-	-
140 - 150 m	0.24	0.34	0.23	0.06	0.47	0.13	-	-
150 - 160 m	0.31	0.33	0.24	0.04	0.60	0.21	-	-
160 - 170 m	0.26	0.32	0.23	0.03	0.66	0.42	-	-
170 - 180 m	0.33	0.32	0.23	0.05	0.74	0.73	-	-
180 - 190 m	0.38	0.32	0.27	0.04	-	-	-	-
190 - 200 m	0.50	0.30	0.46	0.05	-	-	-	-
200 - 210 m	0.72	0.34	0.45	0.04	-	-	-	-

Figure 14 Turbidity (NTU) / depth profiles plots for each site sampled during May (survey 1) and November (survey 2)

Appendix G

Water sample analytical results

Appendix G Water sample analytical results

Table 29 Water sampling site locations

Location	Latitude/Longitude (GDA94)	Collected (WST)
DC0_1	12°58.356'S 124°26.691'E	1530 02/11/16
DC0_2 (triplicate)	12°58.374'S 124°26.667'E	1542 02/11/16
DC0_3 (triplicate)	12°58.336'S 124°26.690'E	1554 02/11/16
DC0_SW2000	12°59.119'S 124°25.906'E	1440 02/11/16
DC1_NW2000	12°57.058'S 124°25.786'E	1825 02/11/16
DC2_NE2000	12°57.215'S 124°27.874'E	1750 02/11/16
FPSO_0	12°59.017'S 124°27.735'E	1647 02/11/16
FPSO_NE2000	12°58.200'S 124°28.518'E	1720 02/11/16
PL-1 (KP103)	13°28.178'S 123°39.023'E	1515 03/11/16
PL-2 (KP65)	13°14.513'S 123°55.937'E	1103 03/11/16
PL-3_1 (KP18)	13°02.199'S 124°17.316'E	0628 03/11/16
PL-3_2 (KP18) (duplicate)	13°02.159'S 124°17.364'E	0640 03/11/16
REF_NE	12°55.374'S 124°34.499'E	0710 02/11/16

Table 30 Laboratory analytical results summary

				DCO_SW2000	DCO	DCO	FPSO_0	FPSO_NE2000	DC2_NE2000	DC1_NW2000	PL_3	PL_3	PL_2	PL_1	REF_NE
Analyte	**Unit**	**Trigger[a]**	**PQL**												
Hydrocarbons															
TPH Low Level	µg/L	-	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
BTEX															
Benzene	mg/L	0.5	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Toluene	mg/L	0.18[b]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethylbenzene	mg/L	0.005[b]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Xylenes (Total)	mg/L	0.625[b]	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Metals															
Aluminium - Total	mg/L	-	0.01	<0.01	<0.01	<0.01	<0.01	**0.06**	<0.01	<0.01	<0.01	<0.01	**0.01**	**0.02**	<0.01
Arsenic - Total	mg/L	-	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium - Total	mg/L	-	0.01	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	<0.01	**0.02**	<0.01	<0.01	<0.01	<0.01	**0.02**
Iron - Total	mg/L	-	0.01	**0.1**	**0.06**	**0.05**	**0.04**	**0.04**	**0.09**	**0.04**	**0.03**	**0.03**	**0.02**	**0.02**	**0.2**
Cadmium - Total	mg/L	0.0007	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt - Total	mg/L	0.001[c]	0.001	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.002**
Chromium - Total	mg/L	0.0077	0.001	<0.001	<0.001	**0.002**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper - Total	mg/L	0.0013[c]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury - Total	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Total	mg/L	0.007	0.001	<0.001	**0.001**	**0.001**	**0.001**	<0.001	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	<0.001
Lead - Total	mg/L	0.0022	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Total	mg/L	0.007	0.005	**0.035**	**0.029**	**0.029**	**0.026**	**0.026**	**0.011**	**0.01**	**0.02**	**0.02**	**0.015**	**0.014**	**0.046**
Nutrients															
Total Nitrogen	mg/L	0.1[d]	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Phosphorus	mg/L	0.01[d]	0.005	**0.011**	**0.012**	**0.011**	**0.011**	**0.01**	**0.011**	**0.011**	**0.01**	**0.01**	**0.011**	**0.01**	**0.012**
NOx-N	mg/L	0.004[d]	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Photosynthetic pigments															
CHLORO 'a'	µg/L	0.9[d]	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CHLORO 'b'	µg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CHLORO 'c'	µg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CHLOROPHYLL'a'	µg/L	0.9[d]	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PHAEOPHYTIN'a'	µg/L	-	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Concentrations above PQL in **bold**
a - ANZECC / ARMCANZ 99% species protection level
b - ANZECC / ARMCANZ low reliability trigger vlaues
c - ANZECC / ARMCANZ 95% species protection level
d - ANZECC / ARMCANZ Default trigger level. Site specific trigger level to be developed using baseline data

Appendix H

Laboratory reports – Water Chemistry

Appendix H Laboratory reports – Water Chemistry

Appendix C: Benthic Habitat Study (Fugro 2017a)

FUGRO SURVEY PTY LTD

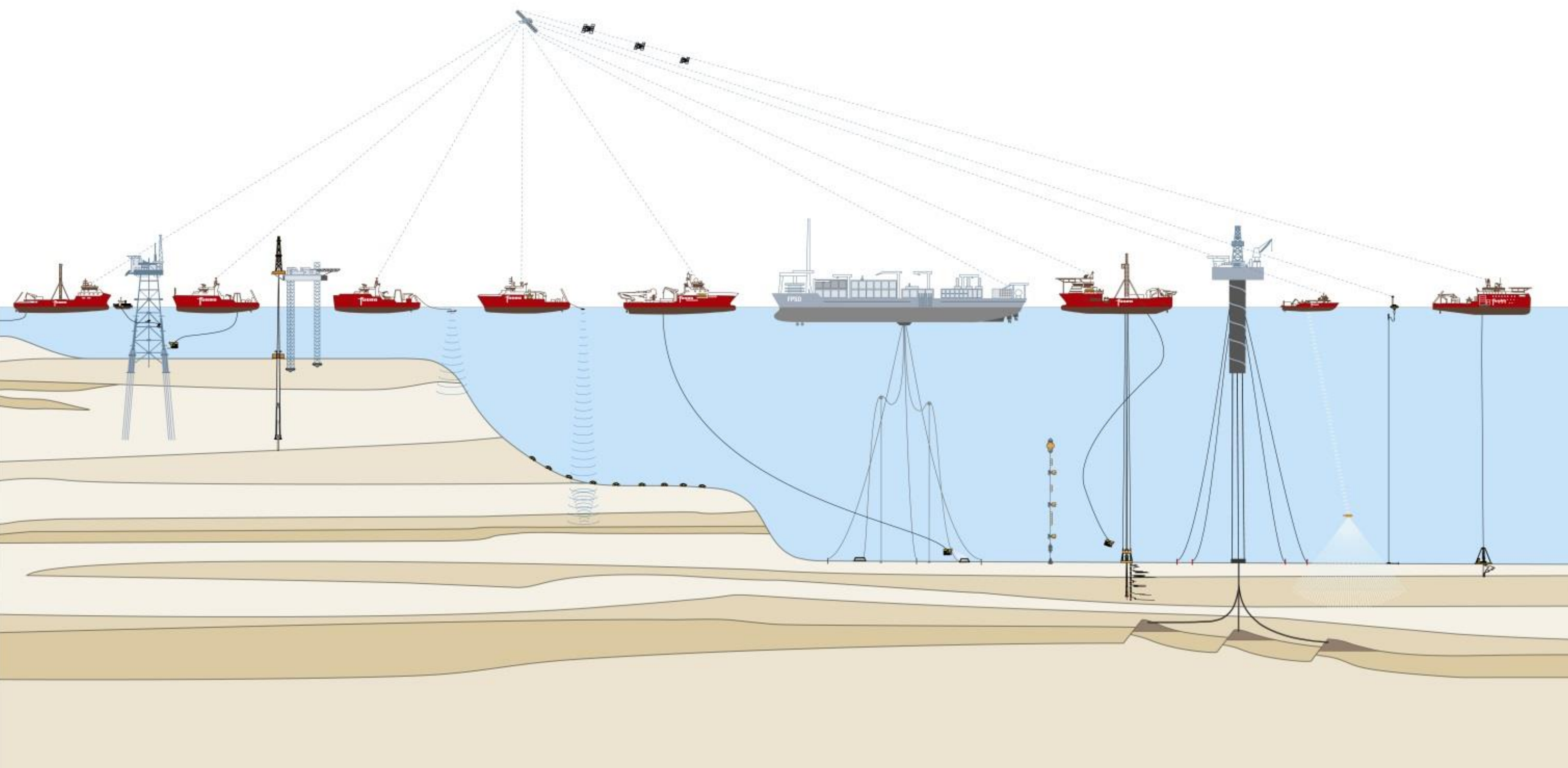
Provision of Geomatic Services (Crux Development)

Volume 1D – Environmental Habitat

Survey Period: 7 April to 3 May 2017

Fugro Document No: FRPT GP1569

Shell Australia Pty Ltd



Provision of Geomatic Services (Crux Development)

Volume 1D – Environmental Habitat

Survey Period: 7 April – 3 May 2017

Fugro Document No. FRPT GP1569

Prepared For: Shell Australia Pty Ltd
562 Wellington St
Perth, WA, 6000

Shell Contract No. IG73840

2	Revised final, incorporating client's comments	R. Parsotan	L. Bush	J. Shottin	04 July 2018
1	Final, incorporating client's comments	S. Ballard	P. Falkner		20 July 2017
0	Draft final for client's comments	S. Ballard	R. Parsotan	P. Falkner	16 June 2017
Rev	**Description**	**Prepared**	**Checked**	**Approved**	**Date**

CONTENTS

TABLES IN THE MAIN TEXT

FIGURES IN THE MAIN TEXT

ABBREVIATIONS

AGDEE	Australian Government Department of the Environment and Energy
BPP	Benthic Primary Producers
BMS	Business Management System
Cm	Centimetre
Cu in	Cubic inch
DVD	Digital Versatile Disc
EOL	End of Line
Fugro	Fugro Survey Pty Ltd and all Fugro entities involved with this project
GNSS	Global Navigation Satellite System
INPEX	INPEX Corporation
IUCN	International Union for Conservation of Nature
kHz	Kilohertz
KM	Kilometre(s)
kts	Knots
KP	Kilometre Point
LAT	Lowest Astronomical Tide
MBES	Multibeam Echo Sounder
Ms	Milliseconds
MV	Motor Vessel
psi	Pounds Per Square Inch
QC	Quality Control
RIGSS	Remote Intelligent Geotechnical Seabed Surveys
SBP	Sub-Bottom Profiler
Shell	Shell Australia Pty Ltd
SOL	Start of Line
SSS	Sidescan Sonar
USBL	Ultra Short Baseline
UTM	Universal Transverse Mercator

1. INTRODUCTION

1.1 Report Structure

The report structure for the project is summarised in Table 1.1.

Table 1.1: Report Structure

Fugro Report No.	Volume	Report Titles
FRPT GP1569	1A	Crux Site Geophysical Results and Drawings
FRPT GP1569	1B	Crux to Prelude Geophysical Results and Drawings
FRPT GP1569	1C	Geotechnical Factual Data
FRPT GP1569	**1D (this report)**	**Environmental Habitat**
FRPT GP1569	2	Geophysical, Geotechnical and Environmental Survey Operations

1.2 Project Description

Shell Australia Pty Ltd (Shell) contracted Fugro Survey Pty Ltd (Fugro) to carry out geophysical geotechnical and environmental survey services for the Crux Field development. The Crux Field is located approximately 620 km to the north-east of Broome and 740 km to the west of Darwin. It is seen as a possible tie-in to the Prelude Field which is located 160 km to the south-west of the Crux Field. An overview of the proposed Crux Field development is shown as Figure 1.1.

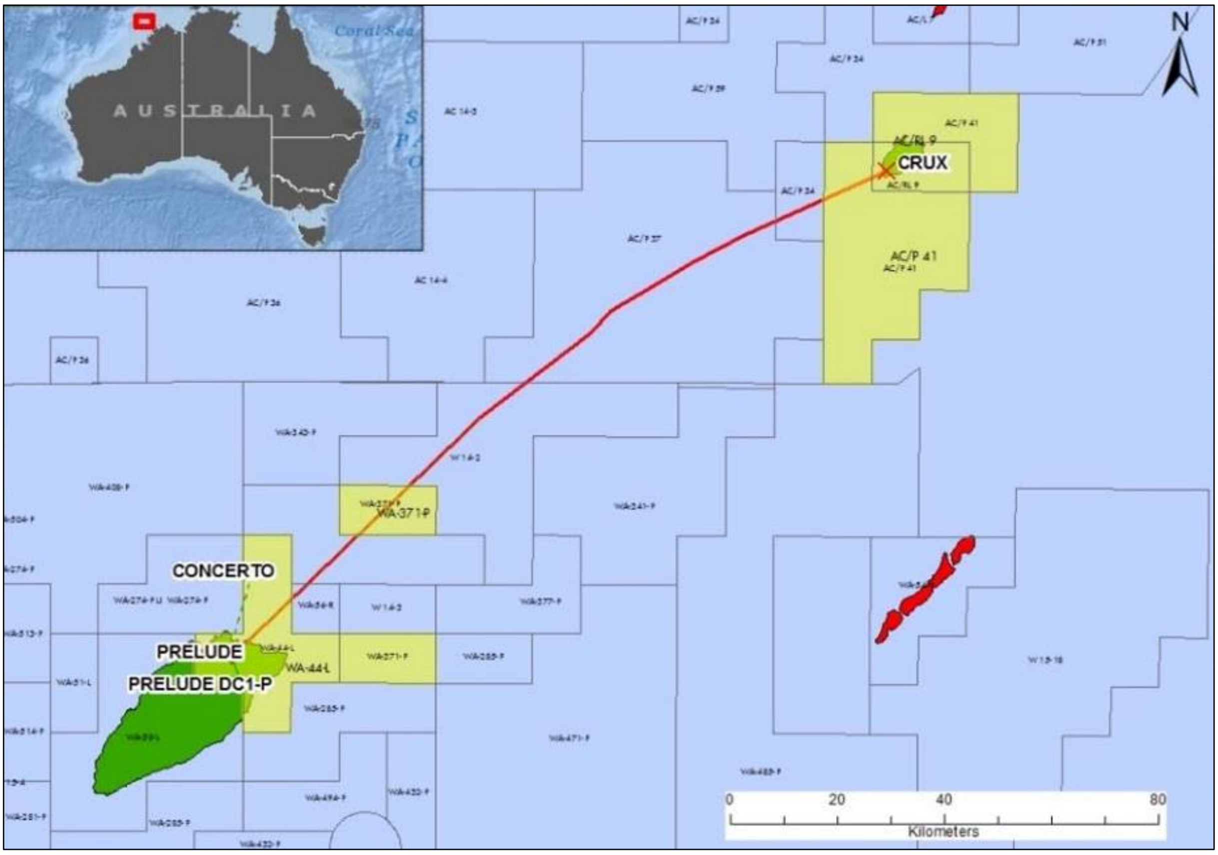


Figure 1.1: General location diagram

The survey was carried out between 06 April and 02 May 2017 on the MV Fugro Equator. Fugro were contracted to undertake the survey, which comprised a combination of geophysical data acquisition, geotechnical sampling and testing and environmental camera operations. Additional sample field testing and sub-sampling was conducted by the Remote Intelligent Geotechnical Seabed Surveys (RIGSS) division of the University of Western Australia (UWA) on behalf of RPS Group.

The full range of geophysical, geotechnical and environmental survey information collected included:

- Survey positioning;
- Multibeam Bathymetry Echo Sounding (MBES);
- Side Scan Sonar (SSS);
- Magnetometer;
- Chirp Sub-Bottom Profiling (SBP);
- Airgun multi-channel seismic reflection;
- Gravity Piston Core (GPC) and Box Core (BC) sampling;
- Offshore geotechnical laboratory testing;
- Riggs in situ sample testing (conducted by UWA);
- Sediment sub-sampling (conducted by UWA on behalf of RPS);
- Seabed photography and video transects.

This document reports the results of the habitat assessment conducted at the Crux site and provisional pipeline route to connect the Crux Field with the Prelude Field. The proposed well locations at the Crux site are provided in Table 1.2 and displayed spatially in Figure 4.1. All survey related works were carried out in accordance with Shell technical specifications and the Fugro Business Management System (BMS).

Table 1.2: Proposed Well Locations

GDA94, MGA94, UTM Zone 51, CM123 °East		
Name	**Easting [m]**	**Northing [m]**
DC-C1	656 470	8 566 340
DC-CA1	657 510	8 566 000
DC-CAL1	657 550	8 565 000

2. SCOPE OF WORK

2.1 Survey Area

A provisional pipeline route was surveyed to connect the Crux Field back to the Prelude Field. This survey included a primary route 160 km in length and an alternate route at the southwestern end where the route crosses a seabed ridge. Two areas of further development were surveyed where the primary route and the alternate route transverse the seabed ridge. A site survey of 8 km by 14.6 km was also conducted at the Crux Field.

2.2 Survey Objectives

The survey objectives are shown in Table 2.1.

Table 2.1: Survey Objectives

Priority	Acquisition/Reporting Objective	Project Objective
1.1	Mapping of seabed features, sediments, bathymetry and morphology across the survey site. This is to be achieved through the acquisition of MBES and SSS data from a hull mounted or towed survey platform, augmented by seabed soil samples	○ General mapping of seabed; ○ Identification and mapping of seafloor geohazards throughout the site; ○ Narrowing of site selection for drill centre and preferred foundation concepts; ○ Support exploratory pipeline routing and optimisation; ○ Optimise placement and/or assess risks for future geotechnical program.
1.2	Mapping of the shallow soil units, geological features and anomalies at least in the top 200 m (below seafloor) across the site. This is to be achieved through the acquisition of SBP data augmented where possible by shallow soil samples and piston cores. Where possible using the use of two SBP systems would be preferred as to optimise the shallow imaging as well as achieving the deeper penetration of 200 m required by the project for concept decisions	○ General mapping of shallow soil units and geology across site; ○ Perform tie lines at well and legacy seismic locations within the Crux field; ○ Identification and mapping of sub-surface geohazards; ○ Narrowing of site selection for drill centre and preferred foundation concepts; ○ Assess top soil unit thickness along indicative pipeline route and optimise; ○ Optimise placement and/or assess risks to the future geotechnical program; ○ Provide a dataset that can be used to map geotechnical soil units across the site (provide a basis for narrowing of concepts for future geotechnical campaigns).
1.3	Sampling and classification of seabed and shallow soils across the Crux site. This is to be achieved through the acquisition of box and/or piston cores in support of the above objectives	○ Provide basis and ground truth data for mapping objectives defined above; ○ Provide early, basic geotechnical information to the project prior to the execution of the detailed geotechnical campaign.
2	Sampling, testing and classification of shallow soils along the indicative Crux pipeline route. This is to be achieved through the acquisition of box cores along the route. Seabed soil profiles along the route are to be generated through interpolation using SSS, SBP and MBES data	○ Assess soil unit thickness and properties along indicative pipeline route and optimise were possible with the available time and data gathered; ○ Integrate with geophysical datasets to develop seabed soil profiles along the pipeline route.

Priority	Acquisition/Reporting Objective	Project Objective
3	Identification and mapping of shallow localised magnetic anomalies. This is to be achieved through the acquisition of data from a vessel-towed magnetometer or gradiometer. Anomalies are to be reviewed in context with supporting SBP, MBES and SSS data	○ Integrate magnetic data with MBES, SSS and SBP datasets to identify any possible anthropogenic hazards such as dropped objects, remnants of war or unexploded ordnance (buried or on seabed).
4	Visual identification of seabed anomalies and benthic environment. This is to be achieved through the use of an eyeball camera that can be lowered from the vessel and positioned using USBL and an attached transponder	○ Identify benthic environment with video evidence; ○ Visual confirmation of any anomalies found with site survey; ○ Help with the SSS seabed classifications.
5	RIGSS JIP – Testing	○ R&D: First field tests of RIGSS equipment, testing methodology and comparison of results of standard testing. If successful data can be used for pipeline design.
6	Sedimentology Studies	○ R&D: Gain a better understanding of sediment transport in the region and its effects on near seafloor visibility.

2.3 Environmental Background Information

The Kimberley Commonwealth Marine Reserve is a 74,469 km^2 protected area located approximately 90 km south-east of the Crux site (AGDEE, 2017).

Protected areas in Australia are assigned one of six categories as outlined in the International Union for Conservation of Nature (IUCN) document (Dudley, 2008). The Kimberley Commonwealth protected area consists of three zones. The largest zone (66,563 km^2) is a multiple use zone (IUCN VI) which is a protected area with sustainable use of natural resources, located approximately 90 km from Crux site. The next largest zone (6,777 km^2) is the Marine National Park Zone (IUCN II) which is approximately 250 km away from the Crux site. The National Park is a protected area managed mainly for ecosystem conservation and recreation. The smallest area of the reserve (1,129 km^2) is a Habitat Protection Zone (IUCN VI) located approximately 350 km from Crux site. A habitat/species management area is where the protected area is managed mainly for conservation through management intervention.

2.4 Geodetic Parameters

All coordinates detailed in this report are referenced to the International Terrestrial Reference Frame 2008, projected to the Geocentric Datum of Australia 1994, Central Meridian 123°East (UTM Zone 51). Detailed geodetic and projection parameters are provided in Table 2.2.

Table 2.2: Project Geodetic and Projection Parameters

Global Navigation Satellite System (GNSS) Geodetic Parameters [1)]		
Datum:	International Terrestrial Reference Frame 2008 (ITRF2008)	EPSG Code: 1061
Ellipsoid:	Geodetic Reference System 1980 (GRS80)	
Semi-major Axis:	a = 6 378 137.000 m	
Inverse Flattening:	$^1/_f$ = 298.257 222 101	
Local Datum Geodetic Parameters [2)]		
Datum:	Geocentric Datum of Australia 1994 (GDA94)	EPSG Code: 6283
Ellipsoid:	Geodetic Reference System 1980 (GRS80)	
Semi-major Axis:	a = 6 378 137.000 m	
Inverse Flattening:	$^1/_f$ = 298.257 222 101	
Datum Transformation Parameters [3)] from ITRF2008 to GDA94		
Shift dX: -0.05131 m	Rotation rX: +0.0359080 arcsec	Scale Factor: +0.01227150 ppm
Shift dY: +0.01207 m	Rotation rY: +0.0300348 arcsec	Coordinate Frame Rotation
Shift dZ: +0.05316 m	Rotation rZ: +0.0295464 arcsec	EPSG Code: 41357
Project Projection Parameters		
Map Projection:	Transverse Mercator	
Grid System:	Map Grid of Australia 1994 (MGA94)	EPSG Code: 17351
Central Meridian:	123° East (UTM Zone 51)	
Latitude of Origin:	0° (Equator)	
False Easting:	500 000 m	
False Northing:	10 000 000 m	
Scale Factor on Central Meridian:	0.9996	
Units:	Metres	
Project Coordinate Reference System (CRS)		
Projected:	GDA94/MGA Zone 51	EPSG Code: 28351

Notes:
1. The geodetic datum of Fugro's global GNSS correction data is ITRF2008.
2. Source: Client.
3. Transformation parameters from ITRF2008 to GDA94 calculated for Epoch 2017.5 in accordance with the paper ITRF to GDA94 Coordinate Transformations, John Dawson and Alex Woods, Journal of Applied Geodesy 4 (2010).

3. METHODS

3.1 Habitat Assessment

3.1.1 Ground-Truthing Rationale

The habitat survey was required to establish broad characterisation of benthic habitats across the project area. To identify the specific regions for ground-truthing with the camera system, sidescan sonar and bathymetric data were reviewed by environmental scientists in conjunction with the onboard geophysicist. Individual sidescan sonar lines were viewed. Particular emphasis was placed on locating potential reefs and anomalous features, on boundaries between areas of differing sonar reflectivity and changes in bathymetry as well as areas characteristic of background conditions of the survey area. The client's request to cover previously sampled locations were also incorporated into the survey design. The potential occurrence of sensitive species and habitats was also taken into account.

The survey strategy was devised and prioritised based on the following:

- Areas of different acoustic facies (high and low reflectivity) on the sidescan sonar data which are indicative of broad changes in substrate type or the presence of areas that may support ecological diverse benthic communities;
- Bathymetric features such as mound or ridge features.

3.1.2 Survey Strategy

Twenty-nine camera transects were proposed. Ten transects were proposed at the Crux site, two of which covered previously sampled locations (DC3_500SE and DC1_500_NW), one covered the abandoned well CRUX 1 and seven which were chosen from the reviewed geophysical data. Fifteen transects were proposed along the primary route, one of which covered a previously sampled location (PLS10). The fourteen other stations along the primary route were chosen on review of the geophysical data and for coverage along the entire pipeline route. Four transects were proposed along the alternate pipeline route.

The coordinates, data to be acquired and rationale for each camera transect is provided in Table 3.1.

At the client's request, all transects were given the prefix 'SA1702_' as shown in Table 3.1. However, for ease of reporting and clarity of figures and tables, this prefix will not be used hereon in.

Table 3.1: Proposed Environmental Camera Transects

GDA94, MGA94, UTM Zone 51, CM123 °East				
Transects	**Easting [m]**	**Northing [m]**	**Rationale**	**Sample Acquisition**
SA1702_ENV01 SOL	663 691.15	8 570 765.95	Mottled area north-east of site, possible reef structure	Stills, Video
SA1702_ENV01 EOL	663 576.92	8 570 588.16		
SA1702_ENV02 SOL	661 424.09	8 571 313.14	Down slope	Stills, Video
SA1702_ENV02 EOL	661 206.69	8 571 036.78		
SA1702_ENV03 SOL	657 564.76	8 568 835.13	Sand waves and passing over abandoned well CRUX 1	Stills, Video
SA1702_ENV03 EOL	657 766.50	8 568 726.43		
SA1702_ENV04 SOL	656 182.05	8 566 616.90		Stills, Video

GDA94, MGA94, UTM Zone 51, CM123 °East				
Transects	Easting [m]	Northing [m]	Rationale	Sample Acquisition
SA1702_ENV04 EOL	656 105.59	8 566 554.26	Hard substrate passing through previous survey station DC1_500_NW	
SA1702_ENV05 SOL	656 436.82	8 565 655.97	Area of high reflectivity changing to sand	Stills, Video
SA1702_ENV05 EOL	656 727.20	8 565 838.78		
SA1702_ENV06 SOL	657 811.18	8 564 660.75	Area of hard substrate passing through previous survey station DC3_500SE	Stills, Video
SA1702_ENV06 EOL	657 889.94	8 564 727.53		
SA1702_ENV07 SOL	654 237.87	8 562 349.02	Area of high and low reflectivity changing to sand waves	Stills, Video
SA1702_ENV07 EOL	654 463.56	8 562 215.44		
SA1702_ENV08 SOL	656 192.87	8 559 557.34	Depressions in area of variable reflectivity	Stills, Video
SA1702_ENV08 EOL	656 281.77	8 559 506.91		
SA1702_ENV09 SOL	629 648.25	8 554 221.82	Sand with high reflectivity contacts	Stills, Video
SA1702_ENV09 EOL	629 526.17	8 554 255.25		
SA1702_ENV10 SOL	618 604.16	8 548 495.23	Transition between area of ripples to high reflectivity area, possible soft sediment	Stills, Video
SA1702_ENV10 EOL	618 423.74	8 548 495.23		
SA1702_ENV11 SOL	604 623.81	8 540 007.26	Down ridge to hard substrate passing through previous survey station PLS10	Stills, Video
SA1702_ENV11 EOL	604 565.12	8 539 852.62		
SA1702_ENV12 SOL	602 414.35	8 537 228.10	Area of mottled high reflectivity. Rough hard sediment	Stills, Video
SA1702_ENV12 EOL	602 289.06	8 537 028.20		
SA1702_ENV13 SOL	597 069.10	8 533 025.79	Sand waves with sand ripples	Stills, Video
SA1702_ENV13 EOL	597 102.77	8 532 836.93		
SA1702_ENV14 SOL	585 583.41	8 524 299.65	Undulating sand seabed with depressions	Stills, Video
SA1702_ENV14 EOL	585 552.71	8 524 174.52		
SA1702_ENV15 SOL	579 249.33	8 519 395.76	Depressions	Stills, Video
SA1702_ENV15 EOL	579 237.63	8 519 243.68		
SA1702_ENV16 SOL	572 916.72	8 513 079.05	Sand waves	Stills, Video
SA1702_ENV16 EOL	572 812.90	8 513 081.57		
SA1702_ENV17 SOL	564 544.02	8 504 942.07	Area of high reflectivity and sand waves	Stills, Video
SA1702_ENV17 EOL	564 338.17	8 504 920.40		
SA1702_ENV18 SOL	559 546.59	8 500 658.78	Top of ridge, mottled areas of reflectivity and raised outcropping	Stills, Video
SA1702_ENV18 EOL	559 410.52	8 500 556.73		
SA1702_ENV19 SOL	558 524.61	8 499 087.33	Outcropping on slope of ridge, potential reef. Transect passes through area of high and low reflectivity and two raised areas	Stills, Video
SA1702_ENV19 EOL	558 211.51	8 499 163.72		
SA1702_ENV20 SOL	556 578.81	8 498 053.76	Raised area, potential reef structure transitioning to soft sediment	Stills, Video
SA1702_ENV20 EOL	556 899.50	8 497 755.83		
SA1702_ENV21 SOL	551 906.91	8 492 893.77	Soft sediment	Stills, Video
SA1702_ENV21 EOL	552 010.42	8 492 893.27		
SA1702_ENV22 EOL	546 438.14	8 487 540.79	Soft sediment with two areas of potential outcropping	Stills, Video
SA1702_ENV22 SOL	546 322.32	8 487 638.26		
SA1702_ENV23 EOL	539 807.25	8 481 170.65	Soft sediment with potential rocky outcropping	Stills, Video
SA1702_ENV23 SOL	539 893.33	8 481 246.60		
SA1702_ENV24 EOL	549 157.34	8 484 632.54	Soft sediment - characterisation of alternative pipeline route	Stills, Video
SA1702_ENV24 SOL	549 274.78	8 484 603.90		
SA1702_ENV25 EOL	557 379.21	8 490 677.78	Hard substrate to Soft sediment	Stills, Video
SA1702_ENV25 SOL	557 284.48	8 490 608.82		

GDA94, MGA94, UTM Zone 51, CM123 °East				
Transects	**Easting [m]**	**Northing [m]**	**Rationale**	**Sample Acquisition**
SA1702_ENV26 EOL	559 072.19	8 491 572.02	Down ridge	Stills, Video
SA1702_ENV26 SOL	558 711.46	8 491 371.95		
SA1702_ENV27 EOL	566 442.70	8 504 748.69	Soft flat sediment transitioning to sand waves	Stills, Video
SA1702_ENV27 SOL	566 474.02	8 504 645.98		
SA1702_ENV28 EOL	657 941.64	8 561 882.37	Area of variable reflectivity coverage to south-east of site	Stills, Video
SA1702_ENV28 SOL	658 101.15	8 561 953.77		
SA1702_ENV29 EOL	661 390.26	8 566 820.76	Low reflectivity coverage to east of site	Stills, Video
SA1702_ENV29 SOL	661 489.73	8 566 820.76		

3.2 Survey Methods

3.2.1 Geophysical survey

Multibeam echo sounder (MBES) bathymetry data were recorded using two different hull-mounted MBES systems – a Kongsberg EM2040 and a Kongsberg EM302, which were operated at nominal frequencies of 200 kHz to 300 kHz and 30 kHz, respectively.

Two different sidescan sonar systems were deployed during the geophysical surveys. Along the pipeline route, an EdgeTech 4200 MP digital sidescan sonar was utilised simultaneously acquiring data at 300 kHz and 600 kHz with nominal slant ranges of 250 m and 125 m for the low and high frequency channels. However, signal attenuation in the water column reduced the interpretable slant range to approximately 170 m and 100 m, respectively.

The same system was used during the Crux site survey for all crosslines whilst data along the mainlines were acquired by a GeoAcoustics 159D analogue sidescan sonar with a lower frequency of 100 kHz and a slant range of 325 m.

Sub-bottom profiler (SBP) data were recorded with a Kongsberg SBP300. After assessing various settings a frequency band of 2.5 kHz to 6.5 kHz with a pulse length of 2 ms was chosen in order to optimise the signal quality and resolution in the near-surface sector. The maximum vertical resolution was approximately 0.25 m (i.e. only horizons with a thickness of at least 0.25 m could be resolved). Depth penetration was up to 45 ms, which corresponds to approximately 35 m, dependent on the prevailing shallow geological conditions. Initial data quality control (QC) and preliminary interpretation was conducted offshore in order to guide the determination of geotechnical sampling and environmental camera transect locations.

Multi-channel seismic reflection data were acquired for the Crux site using a small volume airgun and a 24-channel hydrophone streamer. The airgun used was either a 5 cu in mini-airgun or a 10 cu in sleeve gun. The hydrophone streamer uses a single element per channel with an interval of 2 m giving an active length of 46 m. Shots were fired with a pressure of 1000 psi at a fixed distance interval of 2 m (equivalent to approximately 1.3 s at a survey speed of 3.2 kts) providing half-fold data. Both the source and the hydrophone streamer were towed off stern about 0.7 m below water surface. The offsets between source and the first receiver channel were initially about 3.4 m across-track and 8 m along-track but changed to about 5.9 m across-track and 16 m along-track late in the survey. Recording delays were set between

0 ms and 100 ms and record lengths varied between 400 ms and 500 ms in order to log the required 200 m of sub-seabed data.

3.2.2 Environmental Survey

Seabed photography was acquired using a Seatronics DTS 6000 towed system mounted within a purpose-built camera frame fitted with a Kongsberg OE14-208 digital stills camera and a Kongsberg OE14-366 colour zoom video camera, a separate strobe, laser and four underwater LED lamps.

Seabed video footage was displayed on a computer monitor and recorded directly onto the hard drive of the DVD recorder with photographic stills being stored on the camera and then transferred to the computer. A video overlay was used to display a navigation string from an attached USBL beacon, including the time, date, depth and location (easting and northing) of the camera system. The survey location and station number were also displayed (manually updated). Footage was viewed in real-time, assisting in the control of the camera in the water. The laser was measured as 52 cm.

Operational procedures for seabed photography were as follows:

- The camera was setup on deck prior to deployment and a test photograph taken;
- The camera was deployed into the water just below the sea surface and lamps and laser turned on;
- The camera was lowered to the seabed using the winch and when the seabed was visible recording started. The camera system was suspended approximately 0.5 m off the seabed and allowed to drift around at the start of line (SOL). Adjustments to the vessel could then be made to ensure the camera was within horizontal tolerance for the transect line before proceeding;
- The vessel manoeuvred along the line at approximately 0.4 knots with the winch adjusted to keep the seabed visible on the live feed;
- Still photography commenced with the environmental scientist manually triggering the camera while the camera moved over the seabed. Whenever a photograph was taken the surveyor captured a position fix. Photographs were taken at regular intervals when seabed conditions allowed, additional photographs were taken when new fauna was present or the habitat changed;
- The camera was recovered to the deck and washed down to prevent personnel coming into contact with any marine stingers that may have been on the equipment.
- On completion, video footage was copied to digital versatile disc (DVD) and backed up onto the ship's system. Photographs were downloaded and backed up onto the ship's system and an external hard drive.

3.3 Interpretation Methods

To assess the habitats within the survey area, analysis of video and stills photographic data was undertaken by experienced Fugro marine biologists/taxonomists. Video photographic data were reviewed in conjunction with the still photographs, noting the location of any observed changes in the sediment type and/or associated faunal community.

As the requirement for this survey was to provide general habitat descriptions to characterise the benthic habitats of the region rather than to provide detailed transect analysis and species level data, a classification system was used. The classification system applied was based on the that used by INPEX

(INPEX 2012) during the habitat survey for the Ichthys Project in the Browse Basin, with the following modifications:

- Near shore habitats such as seagrasses and macroalgae communities were removed from the habitat classification as they were not encountered;
- Soft sediment habitats ‘burrowing macrofauna’ was added as a biota class.

The classification provides a hierarchical system that groups low level classes (Figure 3.1) into broader higher level classes. Using a hierarchical system allows habitat types and any associated benthic communities to be described in a consistent and comparable way.

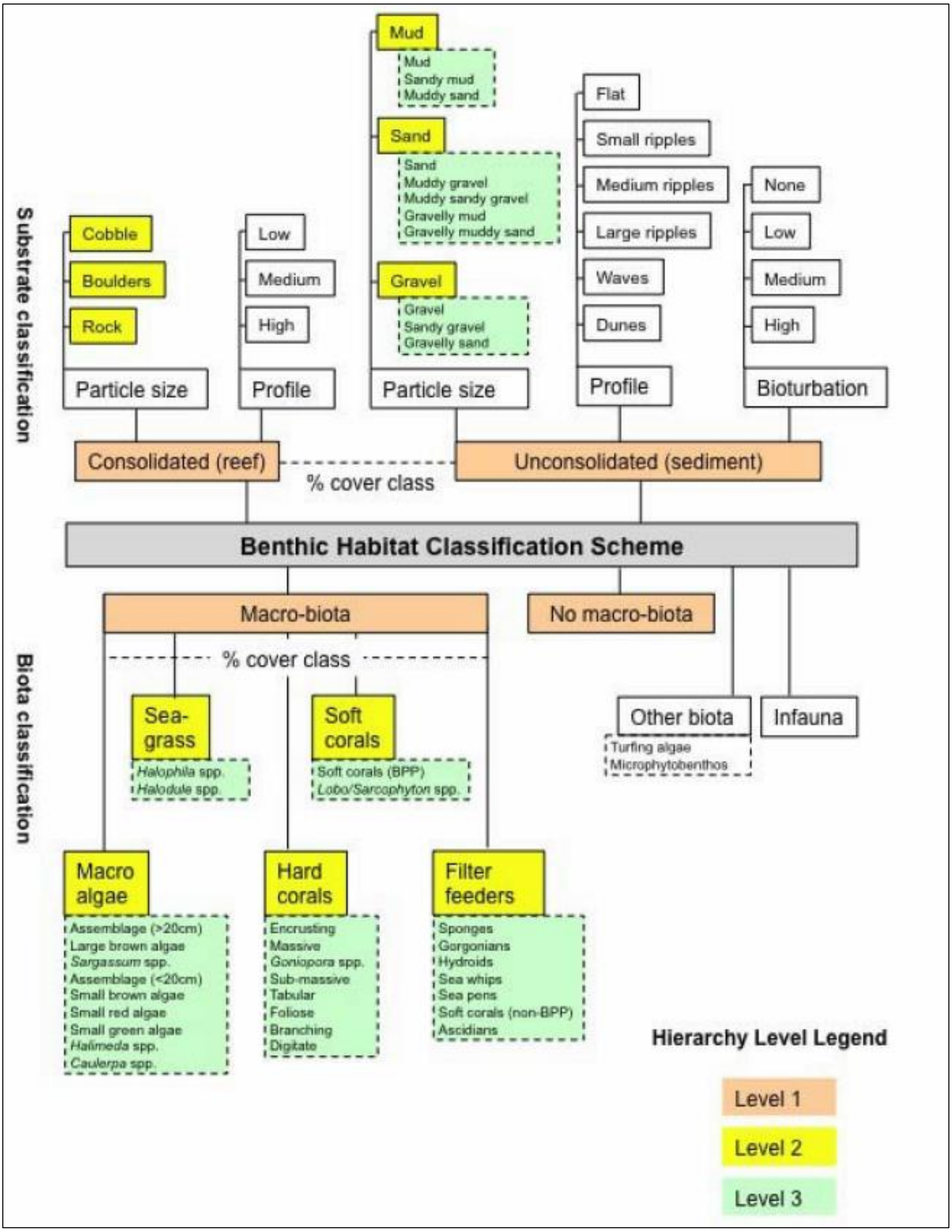


Figure 3.1: Habitat classification scheme hierarchical flow chart (from INPEX, 2012)

3.3.1 Sediment Particle Size

Seabed sediments have been described based on observations on seabed video/photographic data and the interpretation of geophysical data. Due to the difficulty in interpreting sediment particle sizes from video and photographic data, descriptions are based on the Folk classification (Folk, 1954) which uses the descriptive terms ‘mud’, ‘sand’ and ‘gravel’ in combinations depending on the estimated proportions of each component (Figure 3.2).

The terms pebble, cobble and boulder have also been used to described larger sized sediment, which are terms used in the Wentworth classification (Wentworth, 1922) where sediment particles are graded depending on their size (in millimetres).

Additional information such as reef particle size (rock, boulders, cobbles), reef profile (low, medium, high) and sediment profile, flat, low ripples, medium, ripples, high ripples) were also recorded according to the decision rules outlined in Table 3.2. Levels of bioturbation were estimated from the burrows and tracks observed on the seabed per metre.

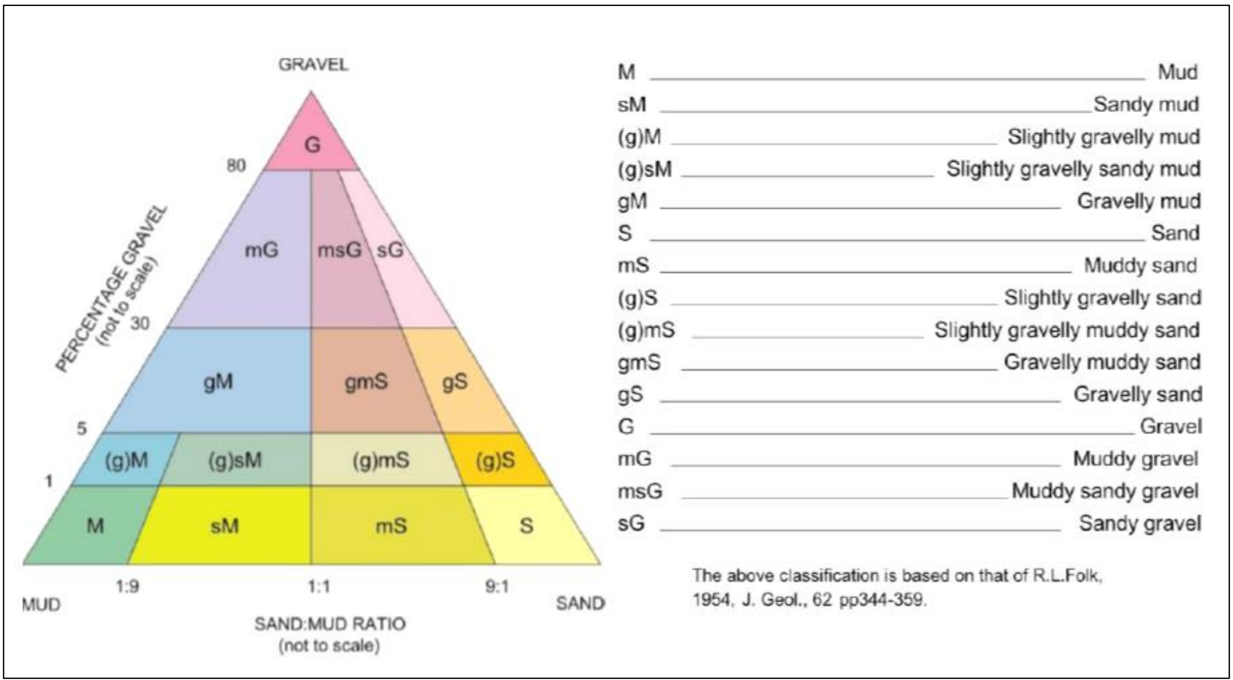


Figure 3.2: Sediment classification triangle (Folk, 1954)

Table 3.2: Substrate Class Definitions (Adapted from INPEX, 2012)

Substrate Type	Decision Rules
Consolidated Reef	Substrate predominantly made up of particles of cobble size (> 64 mm diameter) or larger
Unconsolidated (sediment)	Substrate predominantly made up of particles of pebble size (< 64 mm diameter) or smaller
Substrate Composition	
All sediment	Sediment 100 %
Mixed sediment and reef	Reef 1 – 24 % (i.e. sand 76 – 99 %)
	Reef 25 – 49 %
	Reef 50 %
	Reef 51 – 74 %
	Reef 75 – 99 %
All reef	Reef 100 %
Reef	
Reef Particle Size	
Cobble	Particles 64 – 256 mm
Boulder	Particles > 256 mm
Rock (unbroken)	Unbroken rock substrate
Reef Profile	
High	> 4 m rise over 2 m
Medium	1 – 4 m rise over 2 m
Low	< 1 m rise over 2 m
Sediment	
Sediment Particle Size	
Pebble	Particle 4 – 64 mm
Gravel	Particle 2 – 4 mm
Sand	Particles 63 µm – 2 mm
Mud	Particles < 63 µm
Sediment Profile	
Flat	No profile (undulations < 1 cm)
Small ripples	Undulations 1 – 10 cm high
Medium ripples	Undulations 10 – 50 cm high
Large ripples	Undulations 50 – 100 cm high
Waves	Undulations 1 – 5 m high
Dunes	Undulations > 5 m high
Bioturbation	
None	No evidence of bioturbation
Low	1 – 2 disturbances (e.g. burrows or mounds) per meter
Medium	3 – 10 disturbances per meter
High	> 10 disturbances per meter

3.3.2 Seabed Habitats/Biotope Classification

The video and still images were analysed using qualitative community class per cent cover estimates consistent with the habitat classification scheme in Table 3.3. Biota classes (Table 3.4) were used to group observed epifauna. Fauna not categorised under a biota class were recorded as present and left at a higher taxonomic level.

Table 3.3: Biota Coverage Classification Definitions (Adapted from INPEX, 2012)

Biota Cover Class	Decision Rules
> 80 %	No substrate visible
60 – 80 %	Some substrate visible
40 – 60 %	Substrate is clearly visible but biota dominates the image frame
20 – 40 %	Substrate dominates most of the image
10 – 20 %	Substrate dominates most of the image
5 – 10 %	Substrate dominates most of the image
1 – 5 %	Trace densities
0 – 1 %	No significant macrobiota

Table 3.4: Habitat Classification Definitions (Adapted from INPEX, 2012)

Biota Classes	Morphological Groups	Definitions and Examples
Hard coral assemblages > 10 % over 10 m^2	Branching	At least 20 branching (e.g. *Seriatopora hystrix*)
	Digitate	Less than 20 branching (e.g. *Acropora digitifera*)
	Tabular	Horizontal flattened plates (e.g. *Acropora hyacinthus*)
	Encrusting	Major portion attached to substrate as a laminar plate (e.g. *Porites vaughani*)
	Foliose	Coral attached at one or more points, leaf like appearance (e.g. *Turbinaria* spp.)
	Massive	Solid boulder or mound (e.g. *Favites* spp.)
	Submassive	Tends to small columns, knobs or wedges
Soft coral (BPP) assemblages > 10 % over 10 m^2	Sarco-/lobo- phyton sp. *Sinularia* sp.	Photosynthetic soft corals (e.g. Alcyonidae spp.)
Filter feeders (non BPP) assemblages > 10 % over 10 m^2		Ahermatypic animals (not defined as BPP)
	Soft coral (non-BPP)	Non-photosynthetic soft corals (e.g. Gorgonian fans, Alcyoniidae (non-BPP) Dendronepthia spp.)
	Sponges	Can note morphological groups
	Ascidians	Stalked, encrusting, solitary
	Hydroids	
	Sea Whips	
	Gorgonian fans	
	Sea pens	
	Bryozoan	Foliose, stalked
	Anemones	Tube, solitary
	Polychaetes	
Burrowing Macrofauna	Polychaetes Crustacea	1-2 burrows (low bioturbation) or higher per meter

Where biota coverage exceeded 10 % over 10 m^2, a community type was assigned. The community types were defined by the dominant and codominant biota classes, as summarised in Table 3.5.

Table 3.5: Community Type Classification and Rules Nomenclature

Community Type Classification	Example	Biota Class Composition
Dominated by biota class	Hard coral	Biota class is > 90 % composition of total biota
Dominant biota class *with* other biota classes present	Hard coral *with* macroalgae	Dominant biota class < 90 % with other biota 10 % to 30 % composition of total biota
Codominant biota classes (*and*)	Hard coral *and* macroalgae	Codominant biota classes each > 30 % composition of total biota

Habitats based on their geophysical characteristics were described in line with the hierarchy (Figure 3.1) and their characterising fauna recorded.

4. RESULTS

4.1 Field Operations

Video footage was successfully acquired at 25 of the 29 proposed locations. Transect ENV28 was removed from the survey plan at the client's request. Transects ENV29, ENV27 and ENV17 were aborted due to insufficient visibility at the seabed for camera operations.

Digital still images were acquired at 23 of the 25 completed transects. No digital stills were acquired at transects ENV06 and ENV07 due to a technical fault, therefore screen captures were captured from the video footage at these locations.

Transects ENV05 and ENV09 were completed in two sections due to an equipment fault part way along the transect. A 30 m overlap ensured coverage across each of the transects. The resumed transects are labelled ENV05A and ENV09A respectively, and are referred to as two separate transects at each location in the following sections. A full list of the completed camera transects is shown in Table 4.1.

Poor visibility was encountered during several transects especially nearer the Prelude end of the pipeline route where the sediment was finer. Tropical Cyclone Frances passed over the survey area on 28 April 2017, and seabed visibility was noticeably worse after this event.

Table 4.1: Completed Camera Transects

GDA94, MGA94, UTM Zone 51, CM123 °East						
Station	**Easting [m]**	**Northing [m]**	**Depth [m]**	**Length [m]**	**Video footage [HH:MM:SS]**	**No. of Stills**
ENV01_SOL	663 708.71	8 570 789.01	89	252	00:25:15	36
ENV01_EOL	663 570.85	8 570 578.62	93			
ENV02_SOL	661 531.53	8 571 433.04	104	515	00:49:25	53
ENV02_EOL	661 202.72	8 571 033.20	132			
ENV03_SOL	657 509.58	8 568 862.76	166	345	00:32:51	35
ENV03_EOL	657 814.66	8 568 700.43	167			
ENV04_SOL	656 229.20	8 566 668.33	170	204	00:15:59	21
ENV04_EOL	656 078.04	8 566 531.18	171			
ENV05_SOL	656 387.08	8 565 625.02	171	277	00:25:35	32
ENV05_EOL	656 619.49	8 565 775.63	167			
ENV05A_SOL	656 566.11	8 565 740.66	168	198	00:18:39	33
ENV05A_EOL	656 735.03	8 565 844.19	171			
ENV06_SOL	657 760.40	8 564 621.35	172	185	00:14:08	0
ENV06_EOL	657 902.12	8 564 740.05	172			
ENV07_SOL	654 189.30	8 562 374.60	178	332	00:31:42	0
ENV07_EOL	654 475.98	8 562 207.63	178			
ENV08_SOL	656 141.51	8 559 588.55	180	183	00:19:25	28
ENV08_EOL	656 298.64	8 559 495.57	179			
ENV09_SOL	629 714.45	8 554 194.01	197	63	00:10:42	11
ENV09_EOL	629 653.94	8 554 211.67	198			

ENV09A_SOL	629 457.86	8 554 276.82	198	213	00:17:35	22
ENV09A_EOL	629 663.36	8 554 219.02	198			
ENV10_SOL	618 673.46	8 548 464.64	209	127	00:26:04	40
ENV10_EOL	618 386.56	8 548 508.30	206			
ENV11_SOL	604 638.61	8 540 051.69	212	276	00:22:06	35
ENV11_EOL	604 559.80	8 539 839.63	214			
ENV12_SOL	602 451.71	8 537 279.04	204	312	00:29:39	49
ENV12_EOL	602 283.90	8 537 016.35	204			
ENV13_SOL	597 039.12	8 533 100.50	203	287	00:30:14	33
ENV13_EOL	597 117.33	8 532 824.13	204			
ENV14_SOL	585 598.47	8 524 336.86	210	181	00:20:09	28
ENV14_EOL	585 551.40	8 524 163.03	210			
ENV15_SOL	579 254.05	8 519 450.22	211	236	00:21:49	36
ENV15_EOL	579 313.23	8 519 224.71	210			
ENV16_SOL	572 970.58	8 513 099.97	206	173	00:16:45	25
ENV16_EOL	572 799.07	8 513 078.15	207			
ENV18_SOL	559 581.08	8 500 701.19	223	234	00:30:05	52
ENV18_EOL	559 399.17	8 500 553.92	229			
ENV19_SOL	558 593.31	8 499 068.71	234	408	00:31:49	56
ENV19_EOL	558 197.58	8 499 170.16	241			
ENV20_SOL	556 518.21	8 498 104.46	247	529	00:47:16	82
ENV20_EOL	556 905.36	8 497 744.97	245			
ENV21_SOL	551 827.71	8 492 890.98	270	194	00:19:25	28
ENV21_EOL	552 021.36	8 492 888.26	270			
ENV22_SOL	546 512.10	8 487 478.14	266	265	00:27:53	44
ENV22_EOL	546 309.53	8 487 649.05	267			
ENV23_SOL	539 749.30	8 481 133.38	257	196	00:21:15	36
ENV23_EOL	539 902.12	8 481 255.46	256			
ENV24_SOL	549 099.63	8 484 644.79	261	196	00:19:28	32
ENV24_EOL	549 290.68	8 484 600.66	260			
ENV25_SOL	557 436.38	8 490 735.70	266	211	00:21:53	30
ENV25_EOL	557 278.17	8 490 595.75	271			
ENV26_SOL	559 082.60	8 491 595.79	220	446	01:03:20	95
ENV26_EOL	558 942.68	8 491 495.02	244			

4.2 Bathymetry

The bathymetry of the survey area is displayed with the environmental transect locations in Figure 4.1.

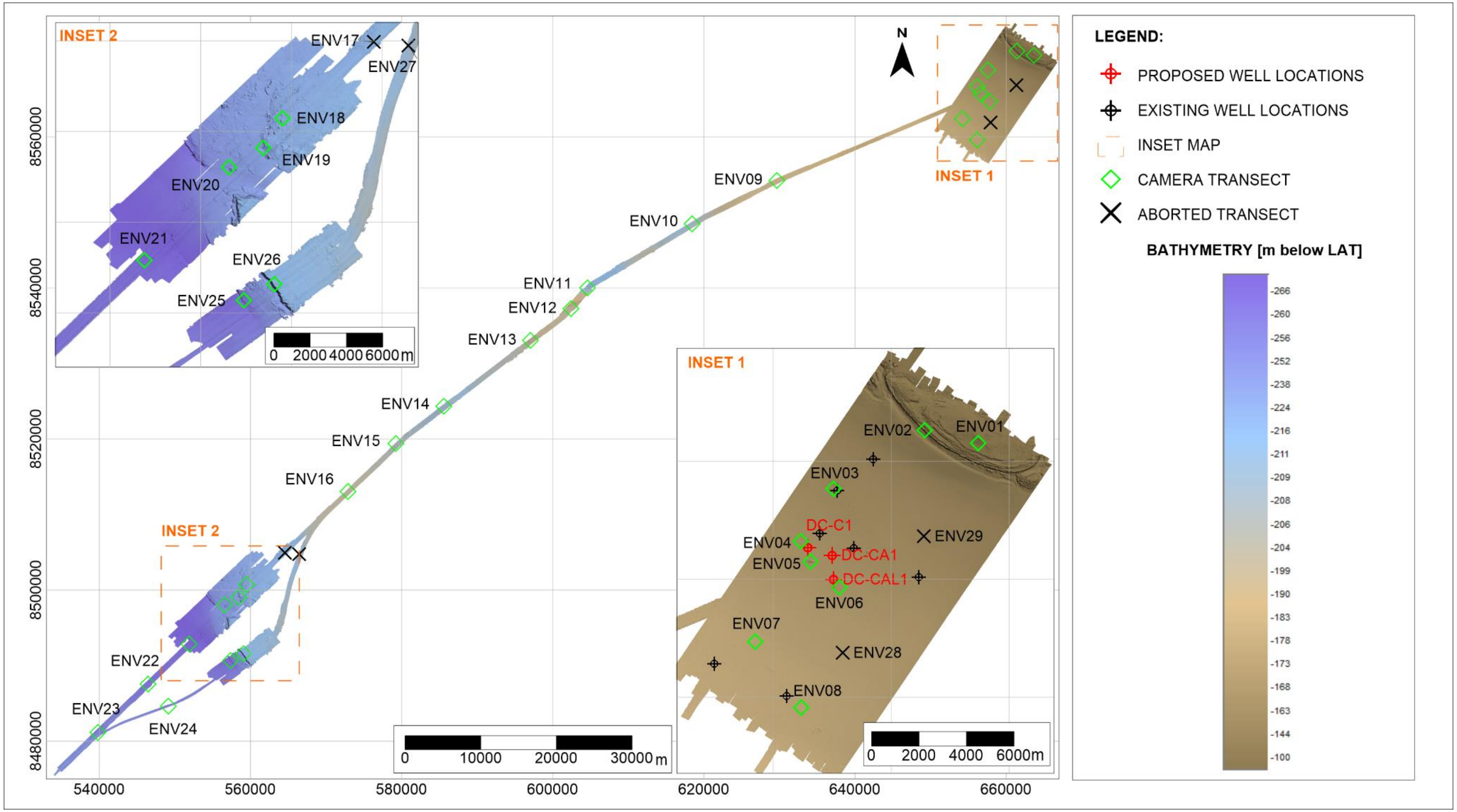


Figure 4.1: Environmental transect locations and bathymetry of survey

4.2.1 Crux Site

Water depths across the Crux site range between a minimum depth of 84.4 m in the north-eastern part and a maximum depth of 186.5 m in the southwestern corner. The majority of the site is gently dipping towards the south-west with general seabed gradients of approximately 0.1°.

In the north-east a large outcropping reef complex stretches across the whole width of the survey area with a steep southern wall and scouring along the foot of the slope. Gradients exceed 50° in some places and commonly the seabed rises by 10 m to 20 m over a distance of 30 m along the steepest sections. Several minor escarpments along the reef flank are interpreted as different stages of growth and erosion. Further, smaller reef developments in the shallow section on top of the main structure contribute to very irregular morphology. Two additional build-ups to the west and south-east of the main complex are observed. Overall, this reef structure is considered to be of similar origin to the many shoals in this region, such as Scott Reef or Heywood Shoal. A bathymetric image of the reef area is presented in Figure 4.2.

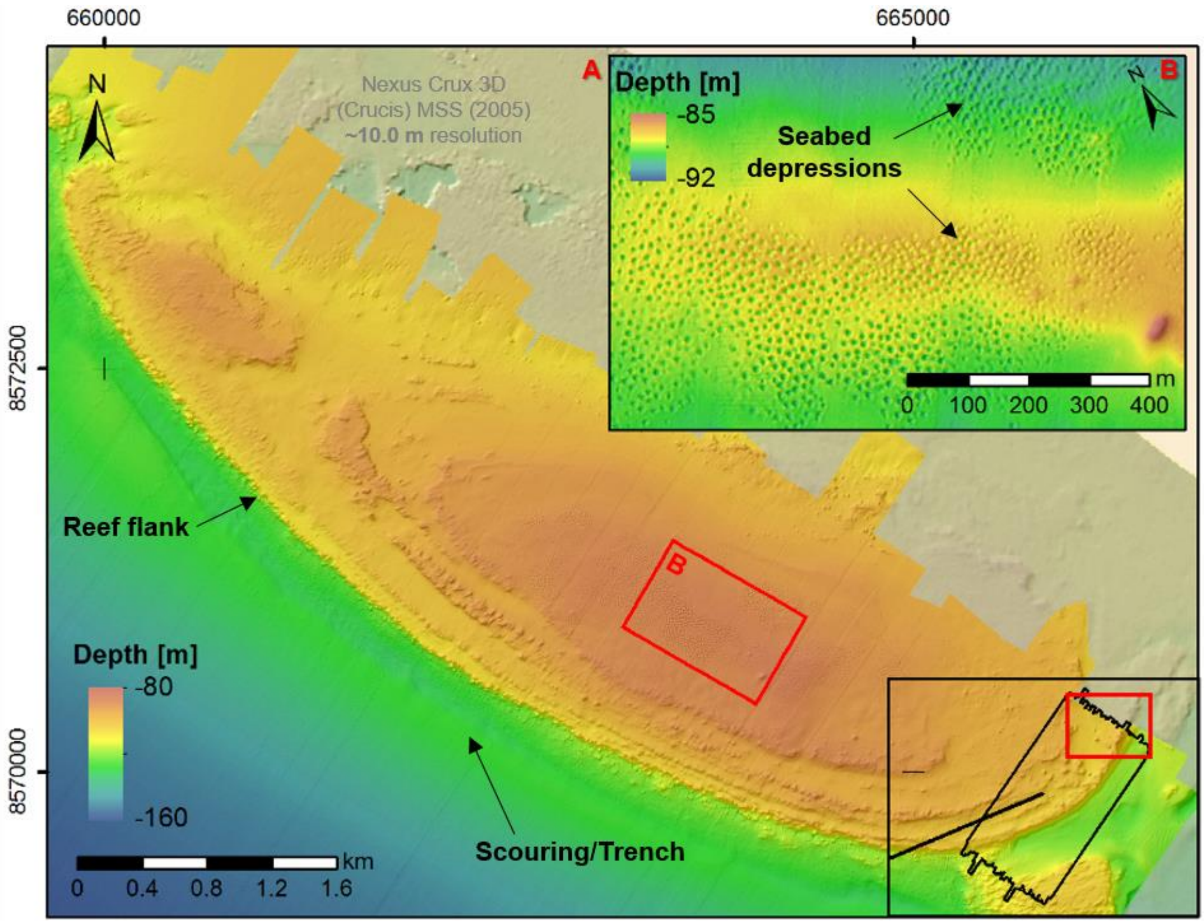


Figure 4.2: (A) Reef complex in northern part of the Crux site and (B) close-up view of seabed depressions

An area of approximately 3.2 km by 1.2 km on top of the reef complex exhibits numerous seabed depressions or pits that appear to be arranged in clusters. These are usually of nearly circular shape, about 10 m to 15 m wide and 0.8 m to 1.3 m deep but can reach diameters of up to 20 m and depths of up to 2 m in some places.

A second area of seabed depressions is found in the south-eastern part of the Crux site in water depths between 177.0 m and 183.0 m. Here, several pockmark clusters up to 550 m across feature slightly oval-shaped individual depressions between 10 and 15 m in diameter. The pockmark depths are beyond the resolution of the MBES data and, hence, are not expected to exceed a few tens of centimetres. Nevertheless, they show up clearly in the sidescan sonar data (see Figure 4.3) due to a rim of sediment around the edge of the depression. See Volume 1A - Crux Site Results and Drawings – for more details.

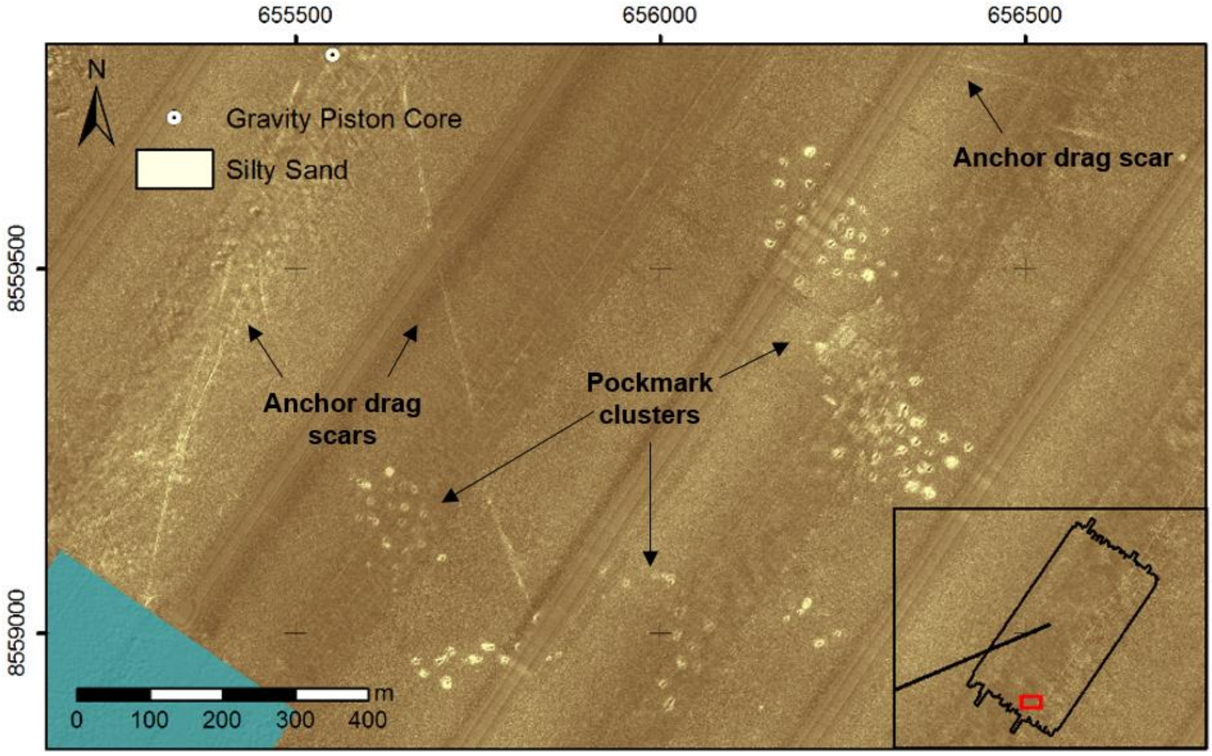


Figure 4.3: Pockmark clusters are clearly visible in sidescan sonar data

4.2.2 Route P1/P1S: KP 0 to KP 105.3

Water depths along this part of the proposed P1/P1S route range from 165.1 m below LAT within the Crux site to 216.9 m below LAT near KP 55.5. Overall, the seabed is gently dipping in the first half of this section with general seabed gradients between 0.1° and 0.2° corresponding to a change in water depth of a few metres over 1 km. See Volume 1B – Crux to Prelude Survey Results and Drawings – for more details.

The route crosses a morphological escarpment or ridge between KP 61 and KP 62, where the seabed shoals to 191.7 m. The escarpment features localised seabed gradients of up to 9.7° representing a change in water depth of 6 m over 80 m. For the remaining section of the route the water depth varies between 196.9 m and 212.0 m with gradients of less than 0.1°. See Volume 1B – Crux to Prelude Survey Results and Drawings – for more details.

4.2.3 Route P1: KP 105.3 to KP 154.1 (end of route) Including PD2

The seabed is gently dipping with general gradients of less than 0.1° until KP 118.9 and water depths decreasing from 204.0 m at KP 105.3 and 226.0 m at KP 118.9. Megaripples, running in a north-south direction, occur along or in vicinity of the route until KP 117.2 while sandwaves are limited to the area between KP 109.1 and 110.7. Between KP 117.3 and KP 118.3 the route traverses through irregular, outcropping terrain that features elevations of up to 5 m compared to the surrounding seabed. Local seabed gradient are up to 20° is this segment.

Immediately after, the pipeline route crosses an area of seabed depressions. These are of similar dimensions as the ones observed 30 km further north, usually featuring diameters in the order of tens of metres and depths of up to 1.5 m, but are thought to have developed due to erosion of the sub-cropping seabed with subsequent sediment deposition.

From KP 118.9 onwards, the seabed slightly steepens but general seabed gradients do not exceed 1.0°. The deepest point along the pipeline route is reached at approximately KP 128.5. Subsequently the seabed gently rises until the end of the route at KP 154.1, where the water depth is approximately 248.0 m. Undulations due to sub-cropping or outcropping cemented sediments are observed towards the end of the route between KP 144.0 and KP 151.0 m.

The area of PD2 as shown in Figure 4.4A, presents the most complex segment of the P1 pipeline route in regards to its morphology. Widely abundant subcropping and outcropping seabed as well as current-induced bedforms such as sandwaves and megaripples result in highly variable morphology with steep seabed gradients of up to 45°. The two most pronounced feature are a trench in the northern central part of PD2, where the seabed drops by up to 25 m over a distance of 50 m, and a sharply rising platform in the southern central part. The platform marks an elevation of 20 m to 30 m in relation to the surrounding seabed and widens towards the south-east. The tip is aligned with the trench although not directly connected. Both features, the trench and the platform, extend beyond the coverage of this survey. However, the revised pipeline route evades both features and does not cross any of the steep flanks. See Volume 1B – Crux to Prelude Survey Results and Drawings – for more details.

4.3 Route P1S: KP 105.3 to KP 156.5 (end of Route) including PD1

Route P1S separates from P1 at KP 105.3 and continues in south-south-westerly direction before turning south-west at KP 124.0, eventually reconnecting with P1 at KP 151.6 (P1 KP 149.2). Additional data were acquired between KP 122.5 and KP 132.5 (PD1) widening the survey corridor to approximately 2500 m in order to identify the best route through this area of difficult and irregular terrain.

From KP 105.3 until KP 112.0 the route passes through areas of megaripples and sandwaves trending in a north-south direction. Apart from that, the seabed is generally smooth and gently dipping with gradients of less than 0.1° until approximately KP 127.4. At KP 127.4 the P1S route passes the southern flank of the platform where the seabed abruptly drops approximately 35 m over a distance of 120 m (~ 23° slope angle). This feature may present an obstruction for the proposed pipeline and cannot be avoided within the PD1 area (Figure 4.5). Furthermore, historical bathymetry data suggest a continuation of the escarpment towards the north, into the PD2 area, and to the south for at least 14 km.

Scouring is observed along the entire south-western side of the platform resulting in a parallel running trench about 170 m wide and 8 m deep. Locally, seabed gradients on the south-western flank of the trench exceed 10° corresponding to a depth change of several metres over a distance of 20 m (Figure 4.5 B and C).

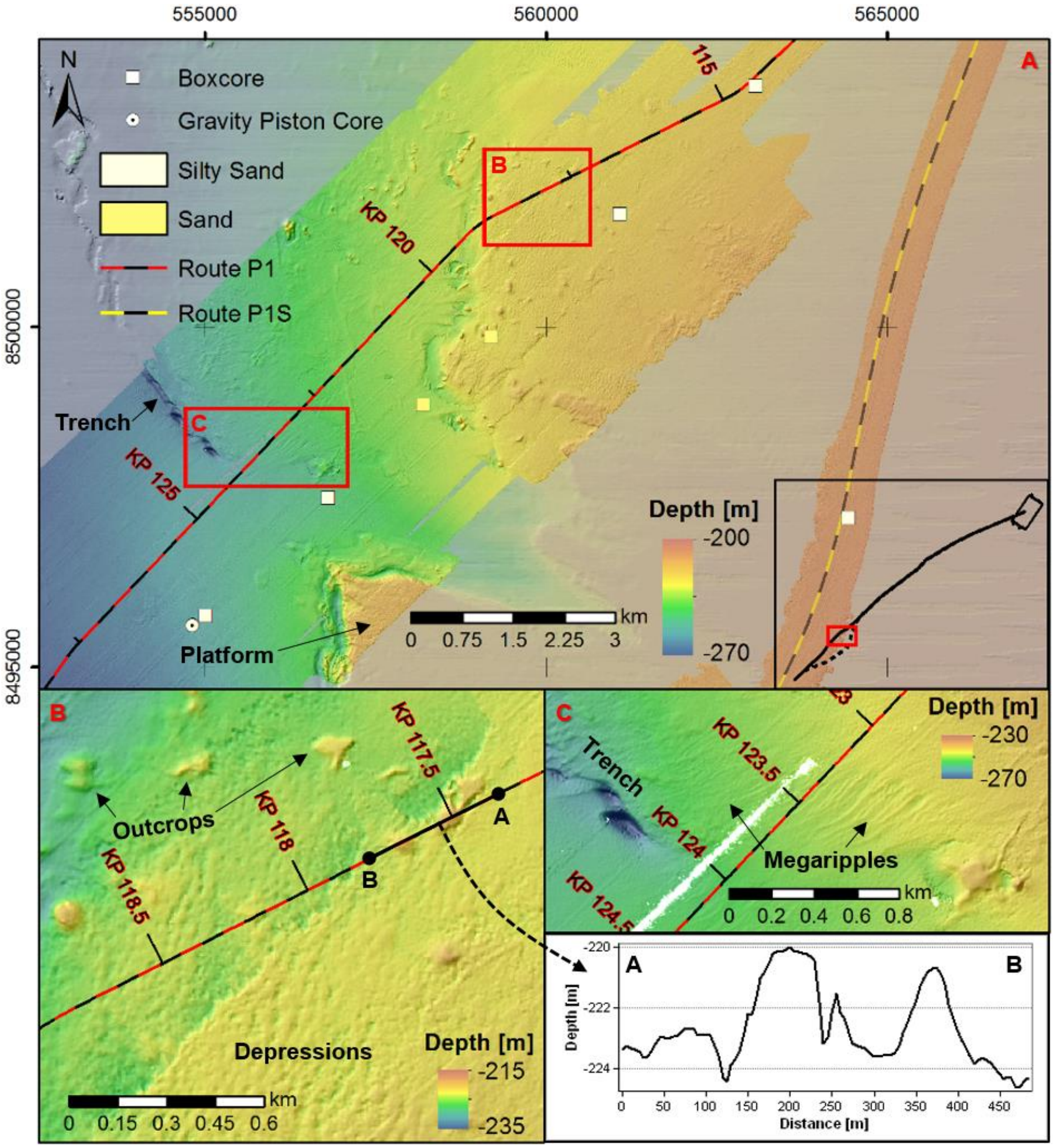


Figure 4.4: Bathymetry data of the (A) PD2 area demonstrating complex seabed morphology with close up views of (B) seabed depressions, outcrops crossed by the pipeline route including (D) cross section and (C) the north-west trending trench

After the trench, the seabed starts to dip gently and water depth increases from 240.0 m to 262.0 m over a distance of approximately 1300 m. The remaining section until KP 151.6, where the P1S route merges with P1 again, is nearly flat with water depths slightly decreasing to 252.5 m. The last segment from KP 148.2 to KP 151.6 features irregular seabed surface due to subcropping and outcropping strata. See Volume 1B - Crux to Prelude Survey Results and Drawings - for more details.

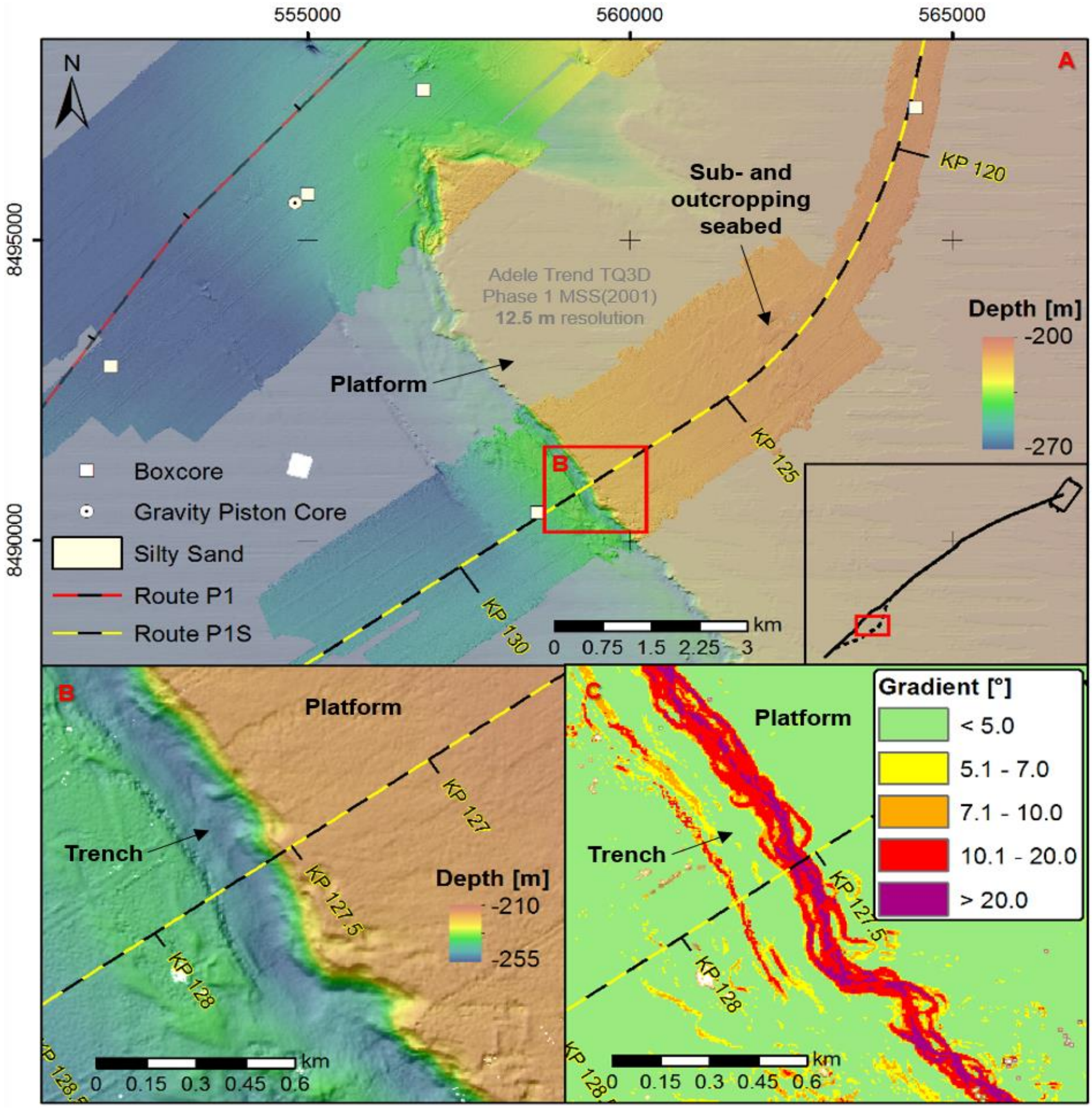


Figure 4.5: Multibeam echo sounder data examples showing (A) an overview of the PD1 area and surroundings, (B) the crossing of the southern flank of the platform and (C) a gradient map of the same section as (B)

4.4 Seabed Features

The seabed features of the survey area are displayed with the environmental transect locations in Figure 4.6.

4.4.1 Crux Site

The surface sediment throughout the majority of the Crux site consists of fine to medium or fine to coarse carbonate sand with different proportions of silt and, in many cases, gravel-sized shells and shell fragments. For simplicity reasons “silty sand” (silt component larger than 12 %) and “sand with silt” (silt component between 5 % and 12 %) are jointly described as “silty sand” in both report and drawings.

On top of the reef complex in the north-east the seabed composition varies between silty sand, sand and outcropping reef facies. In between individual reef structures the seabed is usually covered with sandy sediments and a surface layer of very poorly sorted shells, shell fragments and coral fragments of various sizes eroded from adjacent reefs. The seabed depressions are concentrated on the top central part of the outcrop, where a layer of loose sediment has been deposited.

Seven wellheads are found within the site. Their as-found positions and surface expressions in relation to the surrounding seabed based on MBES data are provided in Table 4.2. See Volume 1A – Crux Site Results and Drawings – for more details.

Table 4.2: As-Found Positions of Seabed Elevations of Existing Wells

GDA94, MGA94, UTM Zone 51, CM123 °East			
Name	**Easting [m]**	**Northing [m]**	**Elevation [m]**
Crux-1	657 707	8 568 755	1.3
Crux-2	659 237	8 570 083	1.1
Crux-3	656 982	8 566 947	1.0
Crux-4	658 430	8 566 317	2.0
Auriga West-1	661 183	8 565 082	0.6
Libra-1	655 572	8 560 056	0.2
Octans-1	652 504	8 561 424	Not measurable

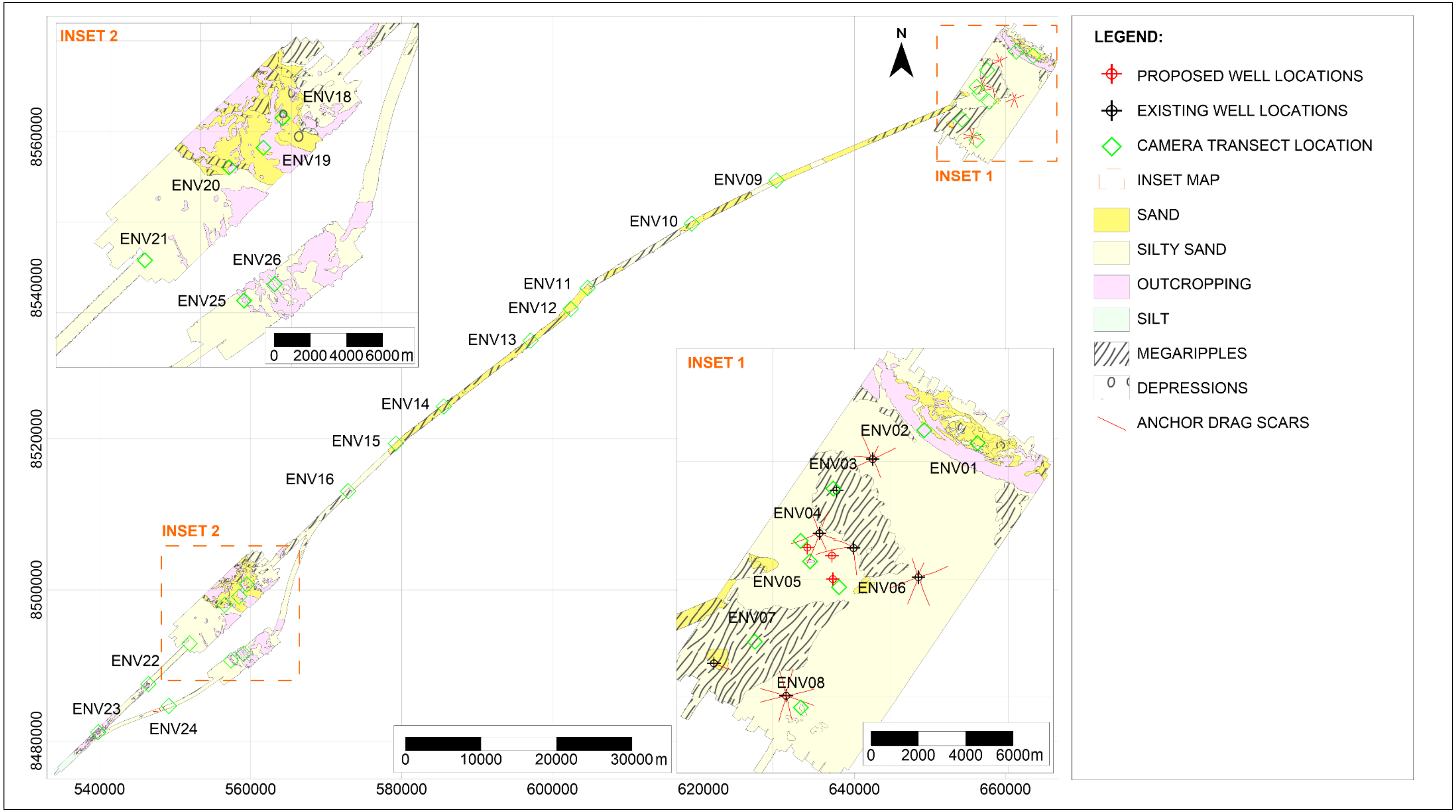


Figure 4.6: Environmental transect locations and seabed features

4.4.2 Route P1/P1S: KP 0 to KP 105.3

Surface sediments along this segment of the route comprise a variety of sand (approximately 70 %) and silty sand (approximately 30 %) usually with a fraction of up to coarse gravel sized shells and shell fragments. Apart from sand waves and megaripples, no other natural or anthropogenic seabed features were identified within this route segment. See Volume 1B – Crux to Prelude Survey Results and Drawings – for more details.

4.4.3 Route P1: KP 105.3 to KP 154.1 (end of route) Including PD2

Along this segment of the route the seabed is composed of silty sand (approximately 70 %), fine to medium sand (approximately 12 %), outcrops and subcrops (approximately 12 %) and silt (approximately 6 %).

Apart from areas of cemented seabed between KP 112.6 and KP 113.4, silty sand with a small fraction of coarse sand and fine gravel sized shells and shell fragments prevails from KP 105.3 to KP 117.4. Towards the centre of PD2, from KP 117.4 to KP 124.4, the route traverses a few areas of subcropping or outcropping reef/calcarenite. Here, the silt component disappears and the coarse fraction of gravel sized shells and shell fragments increases.

After KP124.4 fine sediments become more dominant. The seabed comprises silty sand with decreased or without a coarser fraction of shells and shell fragments. The route crosses two sections of sub- and outcropping calcarenite between KP 137.7 and KP 141.0 and between KP 143.4 and KP 151.3. Within this section a slight increase in the gravel component of the surface sediment was noted. Beyond the outcropping area, silty sediment prevails until the end of the route at KP 154.1. The alternative pipeline route P1S ties in with P1 at KP 149.204. See Volume 1B – Crux to Prelude Survey Results and Drawings – for more details.

4.4.4 Route P1S: KP 105.3 to KP 156.5 (end of route) Including PD1

Along this section of the route the seabed is composed of silty sand (approximately 81 %), outcrops and subcrops (approximately 14 %) and silt (approximately 5 %).

Except for the sandwaves and megaripples observed in the beginning of the route, the seabed is benign and featureless until KP 120.4. The prevailing sediment type in this section is silty fine to medium sand. Between KP 120.4 and KP 129.1, located within the PD1 area, the seabed composition alternates between silty fine to medium sand and outcropping or subcropping cemented sediments. After the scarp the dominating surface sediment is silty fine to medium sand and the seabed is mostly featureless and benign until KP 148.0. From this point on outcrops and subcrops are the dominant seabed type, intersected by layers of silty fine to medium sand. The last segment from KP 153.8 to KP 156.5 is characterised by a mostly featureless silty seabed. See Volume 1B – Crux to Prelude Survey Results and Drawings – for more details.

4.5 Overview of Seabed Habitats and Fauna

The review of the seabed video and digital stills (Appendix B) showed a very low abundance of epifauna across the survey area. Eight different habitats were identified based on geomorphological structures and the sediments they comprised (Figure 4.8). Table 4.3 displays the criteria of the classification system adopted and the distribution of the habitats identified across the completed transects.

A threshold of 10 % cover by macrobiota was defined by the classification scheme before a community type could be assigned. Macrobenthic epifauna only exceeded this threshold in sections of three transects (ENV02, ENV05A and ENV18), all located in the 'Consolidated Unbroken Rock' habitat. Although some epifauna were observed along other transects, all other transects had epifauna coverage below 10 % and thus were classed as either 'no macrobiota' or 'burrowing macrofauna' dependent on the associated presence of burrows (Figure 4.8). Details of fauna observed in areas of <10 % coverage are included in Section 4.6.1 to 4.6.8, divided by habitat type.

The community classification of 'Filter feeders' was given to a 140 m section of ENV02, a 68 m section of ENV05A and a 60 m section of ENV18. The filter feeders along ENV02 and ENV05A consisted of sponges (Porifera), hydroids (Hydrozoa), branching coral (Alcyonacea) and sea whips (Alcyonacea). The filter feeders along ENV18 consisted of crinoids (Crinoidea), soft coral (Alcyonaria) and sea pens (Pennatulacea). Example photographs of filter feeder are presented in Figure 4.7.

Mixed sediments were present along many of the transects and were split into consolidated or unconsolidated sediments based on the proportion of hard substrate present (> 50 % consolidated, > 50 % unconsolidated). The amount of hard substrate present appeared to have the greatest effect on the benthic community present as the hard substrate provides a surface for sessile epifauna to attach and increases the biodiversity present. Therefore, the faunal assemblages found in consolidated sediment (Section 4.6.1) were not greatly influenced by the presence of unconsolidated sediments. However, within the unconsolidated habitats even a small amount of reef substrate (1 % to 24 %) has a noticeable effect on the epifaunal composition and unconsolidated sediments with hard substrate have been described as separate habitats (Section 4.6.4, Section 4.6.6 and Section 4.6.8).

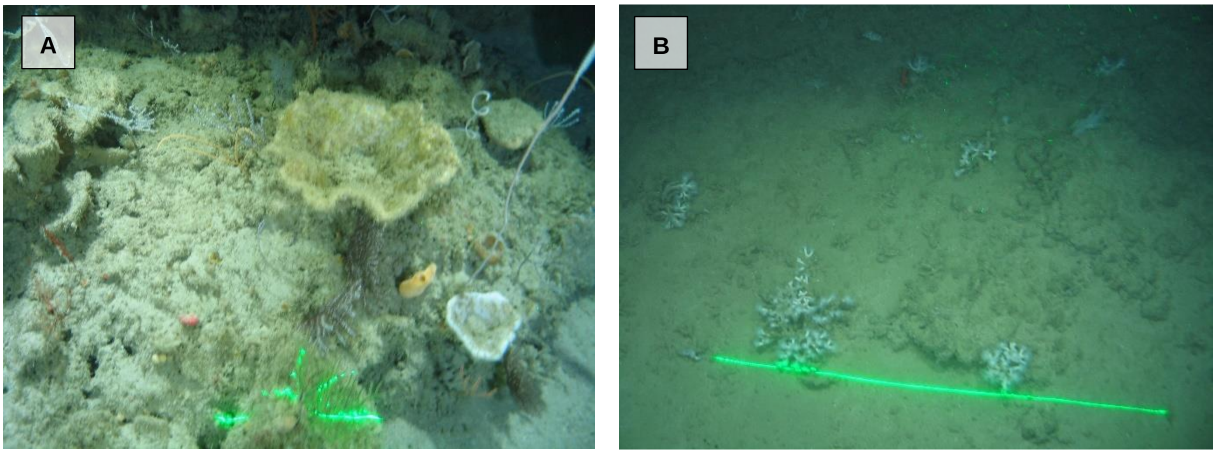


Photo A: SA1702_ENV02_14 Filter feeders (soft coral and sea whips (Alcyonaria), hydrozoa)
Photo B: SA1702_ENV11_11 Filter feeders (soft coral (Alcyonaria))

Figure 4.7: Example photographs of 'Filter feeders'

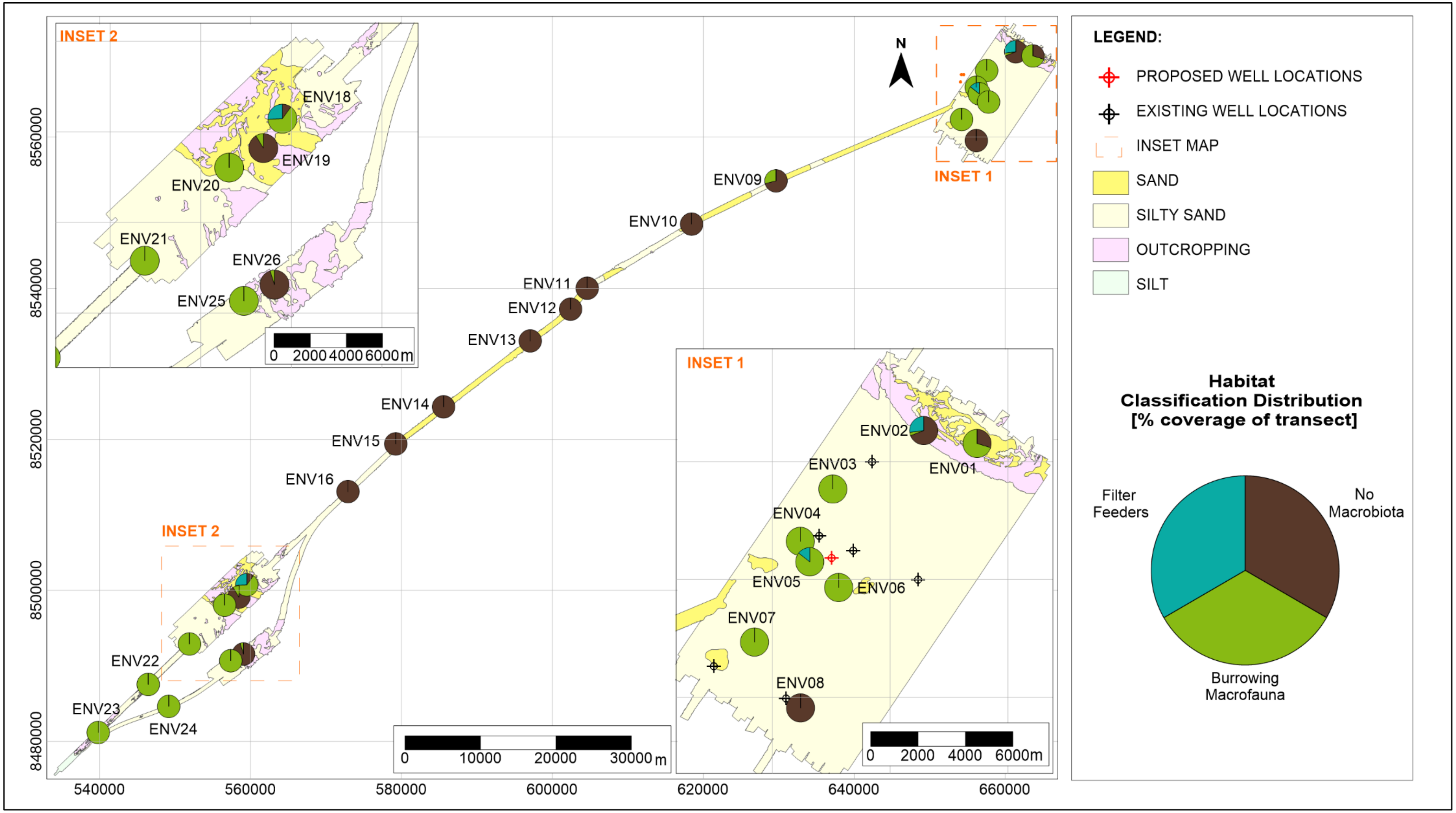


Figure 4.8: Habitat classification distribution

Table 4.3: Habitat Classification Hierarchy

<table>
<tr><th>Level 1</th><th>Level 2</th><th colspan="4">Level 3</th><th rowspan="2">Distribution</th></tr>
<tr><th>Substrate Type</th><th>Particle Size</th><th>Sediment Particle Size</th><th>Sediment Description</th><th>Profile</th><th>Characterising Fauna</th></tr>
<tr><td rowspan="3">Consolidated</td><td rowspan="3">Rock</td><td rowspan="3">Rock (unbroken)</td><td>Reef with sand veneer high relief</td><td>High</td><td>Burrows, soft coral (Alcyonaria), sponge (Porifera), sea anemone (Actiniaria), branching coral (Alcyonacea),</td><td>ENV19</td></tr>
<tr><td>Reef with sand veneer, medium relief</td><td>Medium</td><td>Sea whips (Alcyonacea), Branching coral (Alcyonacea), sponges</td><td>ENV02, ENV18, ENV19</td></tr>
<tr><td>Reef with veneer of sediment, low relief</td><td>Low</td><td>Hydroids (Hydrozoa, sponge (Porifera), branching coral (Alcyonacea)</td><td>ENV01, ENV02, ENV05A, ENV11, ENV12</td></tr>
<tr><td rowspan="13">Unconsolidated</td><td rowspan="5">Gravel</td><td>Sandy gravel</td><td>Sandy gravel</td><td>Flat</td><td>Sparse to no visible fauna</td><td>ENV11</td></tr>
<tr><td rowspan="3">Gravelly sand</td><td rowspan="3">Gravelly Sand</td><td rowspan="3">Flat to small ripples</td><td>Soft coral (Alcyonacea), hydroids (Hydrozoa)</td><td>ENV01, ENV05, ENV05A, ENV26</td></tr>
<tr><td>Faunal Burrows</td><td>ENV09A</td></tr>
<tr><td>Sparse to no visible fauna</td><td>ENV09, ENV09A, ENV11,</td></tr>
<tr><td>Gravelly sand over hard substrate</td><td>1 % – 49 % reef</td><td>Flat</td><td>Sea whips (Alcyonacea), hydroids (Hydrozoa), sponge (Porifera)</td><td>ENV02, ENV09A, ENV15</td></tr>
<tr><td rowspan="5">Sand</td><td rowspan="3">Sand</td><td rowspan="3">Sand</td><td rowspan="3">Flat to medium ripples</td><td>Faunal burrows</td><td>ENV02, ENV03, ENV07, ENV18, ENV19, ENV26</td></tr>
<tr><td>Sea anemones (Actiniaria), tubular glass sponges (Porifera), sea urchin (Echinoidea)</td><td>ENV04, ENV06, ENV08,</td></tr>
<tr><td>Sparse to no visible fauna</td><td>ENV11, ENV10, ENV16, ENV02, ENV13, ENV14, ENV15</td></tr>
<tr><td rowspan="2">Sand with hard substrate</td><td>1 % – 49 % reef</td><td>Flat</td><td>Sponges (Porifera) crinoids (Crinoidea), faunal burrows</td><td>ENV05, ENV05A, ENV14, ENV18, ENV19, ENV26</td></tr>
<tr><td>Volcanic rock</td><td>Small to medium waves</td><td>Sparse to no visible fauna</td><td>ENV10</td></tr>
<tr><td rowspan="2">Mud</td><td>Muddy sand</td><td>Muddy sand</td><td>Flat</td><td>Faunal burrows</td><td>ENV18, ENV20, ENV25, ENV21, ENV22, ENV24, ENV23</td></tr>
<tr><td>Muddy sand with hard substrate</td><td>1 % – 24 % Reef</td><td>Flat</td><td>Sponges (Porifera), faunal burrows</td><td>ENV20, ENV25</td></tr>
</table>

4.6 Habitat Descriptions

4.6.1 Consolidated Unbroken Rock

Table 4.4 summarises the classification and characteristics of this habitat.

Table 4.4: Summary Classification and Characteristics of 'Consolidated Unbroken Rock'

Hierarchical Classification				
Level 1	**Substrate Type**	**Consolidated**		
Level 2	Particle size	Rock (51 % – 99 %) with sediment veneer (1 % – 49 %)		
Level 3	Sediment particle size	Unbroken rock		
	Sediment description	Reef with sediment veneer		
	Profile	Low	Medium	High
	Characteristic fauna	Burrows, soft coral (Alcyonaria), sponge (Porifera), sea anemone (Actiniaria), branching coral (Alcyonacea),	Sea whips (Alcyonacea), Branching coral (Alcyonacea), sponges (Porifera)	Hydroids (Hydrozoa), sponge (Porifera), branching coral (Alcyonacea)
Physical Characteristics				
Depth [m]		66 m – 242 m		

This habitat was observed at several locations across the survey area; in the shallower waters to the north of the Crux site (66 m to 94 m), a raised mound in the centre of the Crux site (168 m to 170 m) and at the escarpments along the pipeline route (204 m to 242 m). Although predominantly hard substrate a veneer of sediment was still present partially covering the hard substrate. The presence of unconsolidated sediments in this habitat had a smaller influence on the community structure than the hard substrate. Therefore, a similar faunal assemblage was present in areas of nearly 100 % reef to areas which were 51 % reef to 49 % soft sediment. The faunal composition in this habitat varied little with depth.

'Consolidated unbroken rock' was the only habitat where the community type 'Filter feeders' was observed as this was the only habitat where epifauna exceeded 10 % coverage. All Fauna, including fauna below 10 % coverage, were split into three different biological assemblages which changed with the relief that was recorded for the rock substrate (see Table 4.4). Table 4.3 details the transects where each of these faunal assemblages were found. The majority of the rock substrate observed with the camera was low profile (<1 m over 2 m) which allowed the attachment of soft corals (Alcyonaria), sponge (Porifera), sea anemones (Actiniaria) and branching coral (Alcyonacea) as well as faunal burrows present in the unconsolidated sediment between the rock substrate. Areas of medium profile (1 m to 4 m over 2 m) were characterised by sea whips (Alcyonacea), branching coral (Alcyonacea) and sponges (Porifera). One area of high profile reef (>2 m over 2 m) was present during transect ENV19 and was characterised by Hydroids (Hydrozoa), sponges (Porifera) and branching coral (Alcyonacea). The community type 'Filter feeders' was present in low and medium relief areas.

Example photographs of the different fauna identified in the three biotopes within the habitat 'Consolidated unbroken rock' and displayed in Figure 4.9.

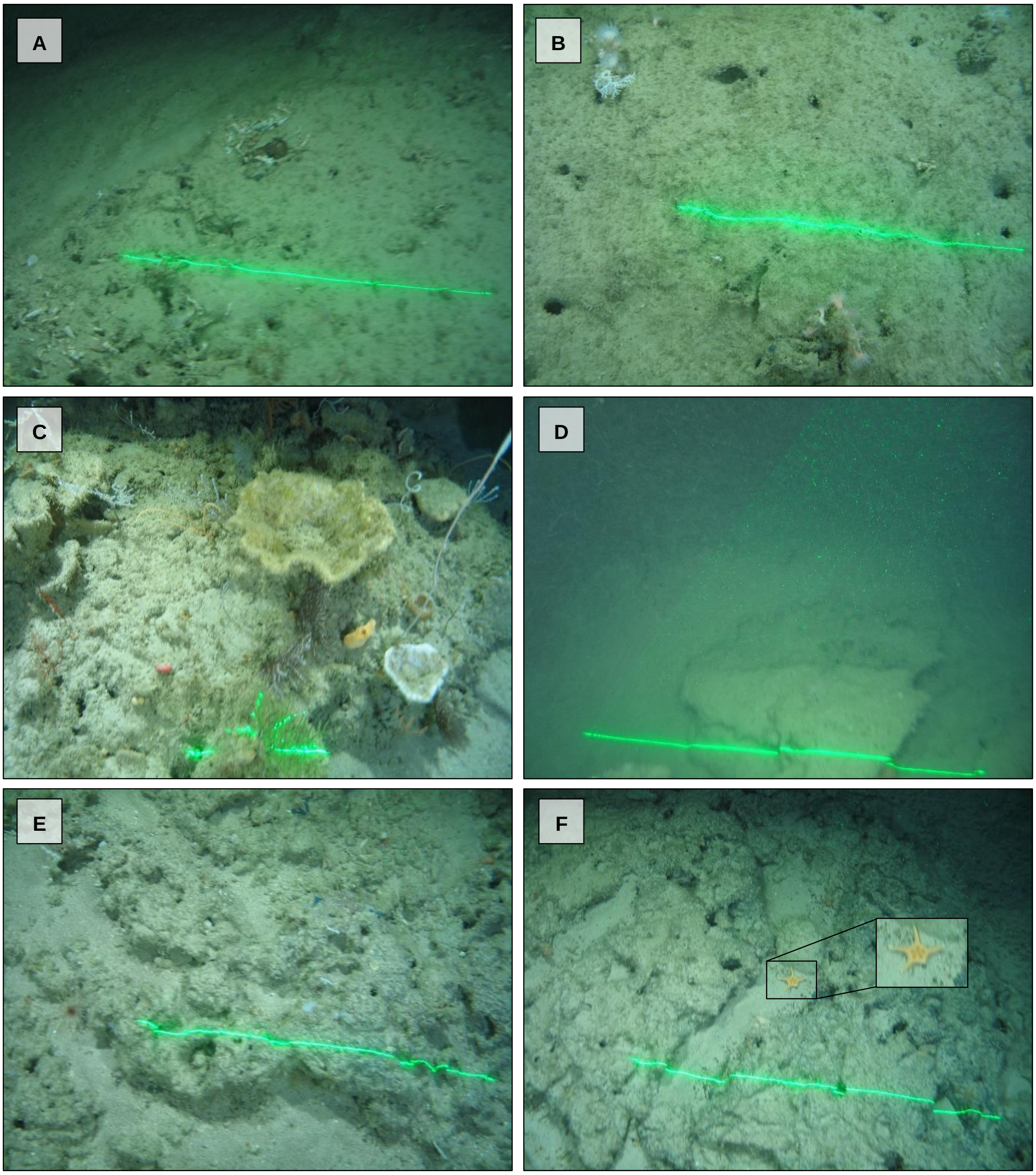


Photo A:	SA1702_ENV19_14 Unbroken rock substrate with sand veneer, faunal burrows;
Photo B:	SA1702_ENV19_18 Unbroken rock substrate with sand veneer, faunal burrows, soft corals (Alcyonaria), bryozoan;
Photo C:	SA1702_ENV02_14 Unbroken rock substrate with sand veneer, sponges (Porifera), hydroids (Hydrozoa), bryozoan, sea whips (Alcyonacea);
Photo D:	SA1702_ENV19_46 Unbroken rock substrate with sand veneer, no visible fauna;
Photo E:	SA1702_ENV11_29 Unbroken rock substrate with sand veneer, faunal burrows;
Photo F:	SA1702_ENV12_41 Unbroken rock substrate with sand veneer, faunal burrows, starfish (Asteroidea).

Figure 4.9: Example photographs of ‘Consolidated Unbroken Rock’ and associated fauna

4.6.2 Unconsolidated Sandy Gravel

Table 4.5 summarises the classification and characteristics of this habitat.

Table 4.5: Summary Classification and Characteristics of 'Unconsolidated Sandy Gravel'

Hierarchical Classification		
Level 1	**Substrate Type**	**Unconsolidated**
Level 2	Particle size	Gravel
Level 3	Sediment particle size	Sandy Gravel
	Sediment description	Sandy Gravel
	Profile	Flat
	Characteristic fauna	Sparse to no visible fauna
Physical Characteristics		
Depth [m]		212 m – 215 m

Although only identified from a single transect (ENV11) during the survey, it is possible that this habitat occurs more widely within the Crux site. This sediment occurred adjacent to the 'Unconsolidated Gravelly Sand' habitat discussed in Section 4.6.3.

The sediment within this habitat appeared, from seabed photographic data, to principally comprise of gravel and shell material with some sand content.

No benthic macrofauna were observed within this habitat. An unidentified fish was observed on the video footage.

Example photographs of this habitat are provided in Figure 4.10.

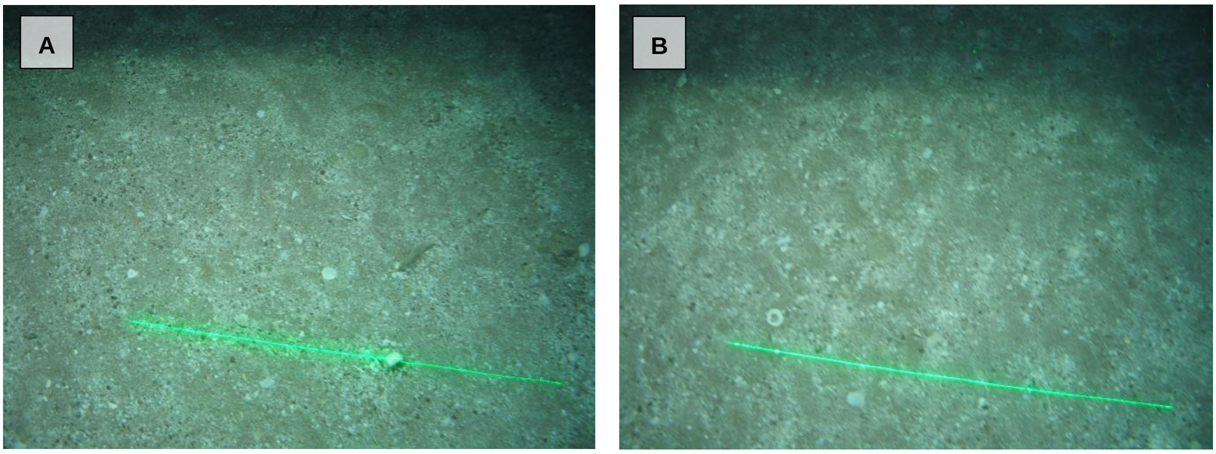


Photo A: SA1702_ENV11_02 Sandy Gravel, no visible fauna;
Photo B: SA1702_ENV11_11 Sandy Gravel, no visible fauna.

Figure 4.10: Example photographs of 'Unconsolidated Sandy Gravel'

4.6.3 Unconsolidated Gravelly Sand

Table 4.6 summarises the classification and characteristics of this habitat.

Table 4.6: Summary Classification and Characteristics of 'Unconsolidated Gravelly Sand'

Hierarchical Classification				
Level 1	**Substrate Type**	**Unconsolidated**		
Level 2	Particle size	Gravel		
Level 3	Sediment particle size	Gravelly sand		
	Sediment description	Gravelly sand		
	Profile	Flat to small ripples		
	Characteristic fauna	Soft coral (Alcyonacea), hydroids (Hydrozoa)	Faunal burrows	Sparse to no visible fauna
Physical Characteristics				
Depth [m]		89 m – 249 m		

This habitat was observed at several locations, three transects at the Crux site (transects ENV01, ENV05 and ENV05A) and four transects along the pipeline route (transects ENV09, ENV09A, ENV11 and ENV26).

Three different faunal assemblages were observed. Four transects (ENV01, ENV05, ENV05A and ENV26) showed faunal assemblages consisting of sporadic soft corals (Alcyonacea) and hydroids (Hydrozoa) with sea cucumbers (Holothuroidea), sea pens (Pennatulacea), sea urchins (Echinoidea), sea anemones (Actiniaria) and sea whips (Alcyonacea) also present. The attached sessile epifauna may indicate that a harder substrate is present beneath the gravelly sand sediment. One section of transect (ENV09A) was characterised by the presence of faunal burrows but most observations of this habitat showed no bioturbation indicating the sediment was not cohesive enough to provide a stable environment for burrows. Sections of transects ENV09, ENV09A and ENV15 showed little evidence of epifauna or faunal burrows however a few unidentified fish were observed.

Water depths at which this habitat was observed ranged from 89 m (ENV01) to 249 m (ENV26).

Example photographs of the 'Unconsolidated Gravelly Sand' habitat are displayed in Figure 4.11.

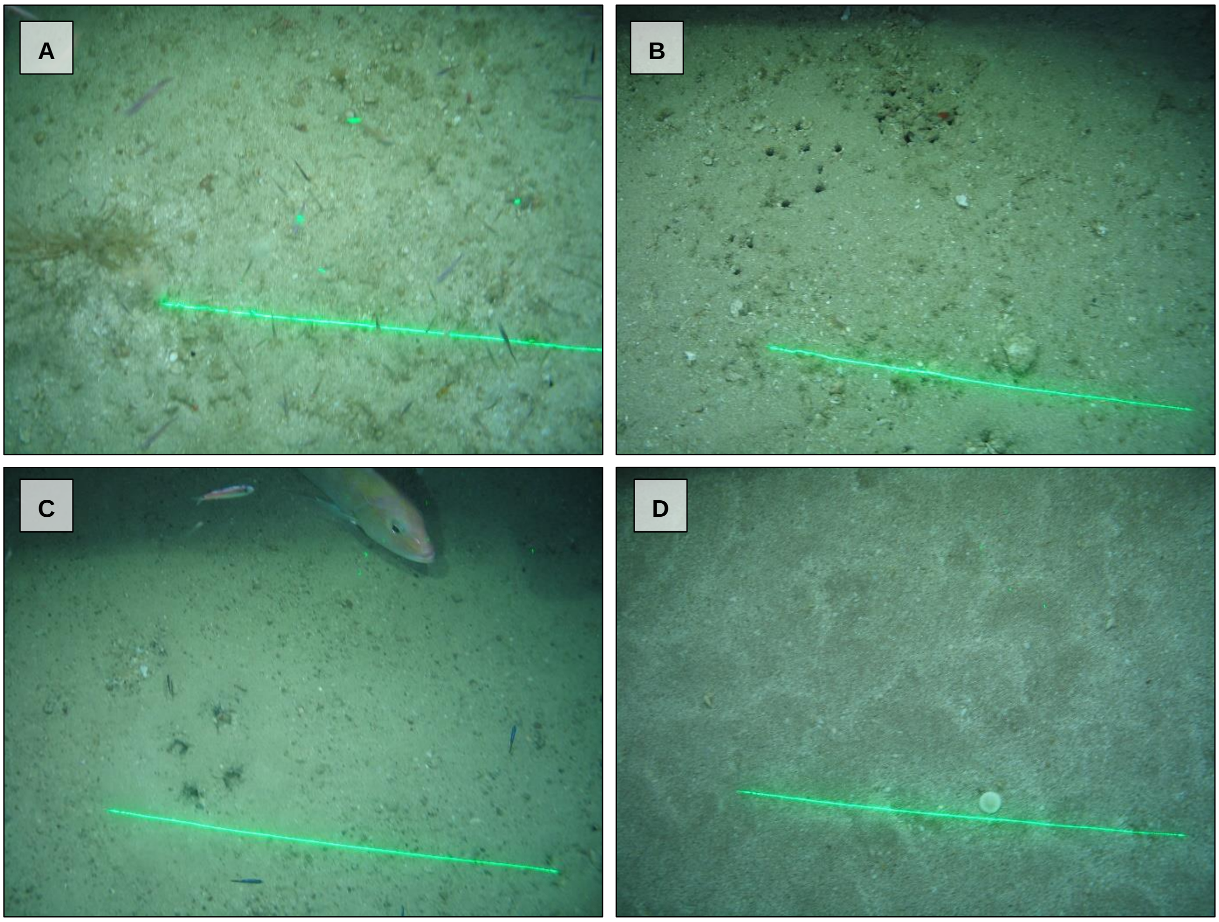


Photo A:	SA1702_ENV01_15 Gravelly sand, hydroids (Hydrozoa), fish;
Photo B:	SA1702_ENV05_56 Gravelly sand, faunal burrows;
Photo C:	SA1702_ENV09A_30 Gravelly sand, faunal burrows, unidentified fish;
Photo D:	SA1702_ENV11_7 Gravelly sand, no visible fauna.

Figure 4.11: Example photographs of 'Unconsolidated Gravelly Sand'

4.6.4 Unconsolidated Gravelly Sand over Hard Substrate

Table 4.7 summarises the classification and characteristics of this habitat.

Table 4.7: Summary Classification and Characteristics of 'Unconsolidated Gravelly Sand over Hard Substrate'

Hierarchical Classification		
Level 1	**Substrate Type**	**Unconsolidated**
Level 2	Particle size	Gravel
Level 3	Sediment particle size	Gravelly sand
	Sediment description	Gravelly sand forming veneer over reef material (1 – 49 %)
	Profile	Flat sediment, low reef
	Characteristic fauna	Sea whips (Alcyonacea), sponge (Porifera), hydroids (Hydrozoa)
Physical Characteristics		
Depth [m]		66 m – 214 m

This habitat was observed at three locations (transects ENV02, ENV09A and ENV15). This habitat consisted of a mixed sediment with predominantly gravelly sand (> 50 %) with patches of unbroken reef and reef rubble (cobbles). The water depths at which this habitat occurred ranged from 66 m (transect ENV02) to 214 m (transect ENV15).

The habitat was characterised by the epifaunal community growing on the hard substrate, including sea whips (Alcyonacea), hydroids (Hydrozoa) and sponges (Porifera). Stalked crinoids (Isselicrinidae) were also present in this habitat. No bioturbation was apparent in the unconsolidated gravelly sand between the hard substrate, indicating a sediment unsuitable for faunal burrows.

Example photographs of the 'Unconsolidated Gravelly Sand over Hard Substrate' habitat are displayed in Figure 4.12.

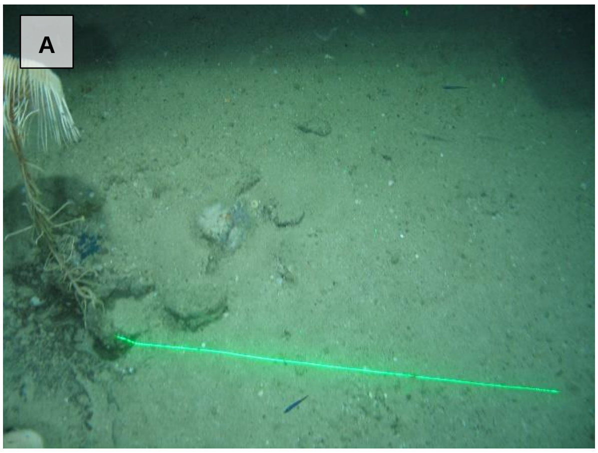


Photo A: SA1702_ENV09A_24 Gravelly sand with reef rubble (cobbles), stalked crinoid (Isselicrinidae);
Photo B: SA1702_ENV15_18 Gravelly sand with reef rubble (cobbles), unidentified fish.

Figure 4.12: Example photographs of 'Unconsolidated Gravelly Sand over Hard Substrate'

4.6.5 Unconsolidated Sand

Table 4.8 summarises the classification and characteristics of this habitat.

Table 4.8: Summary Classification and Characteristics of 'Unconsolidated Sand'

<table>
<tr><th colspan="5">Hierarchical Classification</th></tr>
<tr><th>Level 1</th><th>Substrate Type</th><th colspan="3">Unconsolidated</th></tr>
<tr><td>Level 2</td><td>Particle size</td><td colspan="3">Sand</td></tr>
<tr><td rowspan="4">Level 3</td><td>Sediment particle size</td><td colspan="3">Sand</td></tr>
<tr><td>Sediment description</td><td colspan="3">Sand (100 %)</td></tr>
<tr><td>Profile</td><td colspan="3">Flat to medium ripples</td></tr>
<tr><td>Characteristic fauna</td><td>Faunal burrows</td><td>Sea anemones (Actiniaria), tubular glass sponges (Porifera), sea urchin (Echinoidea)</td><td>Sparse to no visible fauna</td></tr>
<tr><th colspan="5">Physical Characteristics</th></tr>
<tr><td colspan="2">Depth [m]</td><td colspan="3">66 m – 247 m</td></tr>
</table>

This was the predominant sediment type observed across the survey area and consisted areas of flat sand or sand forming small (1 cm to 10 cm high) to medium ripples (10 cm to 50 cm high).

Based on the fauna observed three different biological assemblages were observed. Seven transects showed areas where there was little to no evidence of epifauna and faunal burrows (< 1 disturbance per meter) indicating the sand in these areas was not cohesive enough for to provide a stable environment for burrows. Sections of six transects showed higher levels of bioturbation ranging from low (1 to 2 disturbances per meter) to medium (3 to 10 disturbances per meter). The bioturbation consisted largely of faunal burrows although the occasional faunal track was also observed. Three transects showed sessile fauna associated with the sand substrate with sea anemones (Actiniaria) and glass tubular sponges (Porifera) being present in low abundance. Sand is not usually a suitable substratum for sessile attaching fauna so they may be indicative of a hard substrate beneath a thin sand layer.

Example photographs of this 'Unconsolidated Sand' habitat and associated fauna are displayed in Figure 4.13.

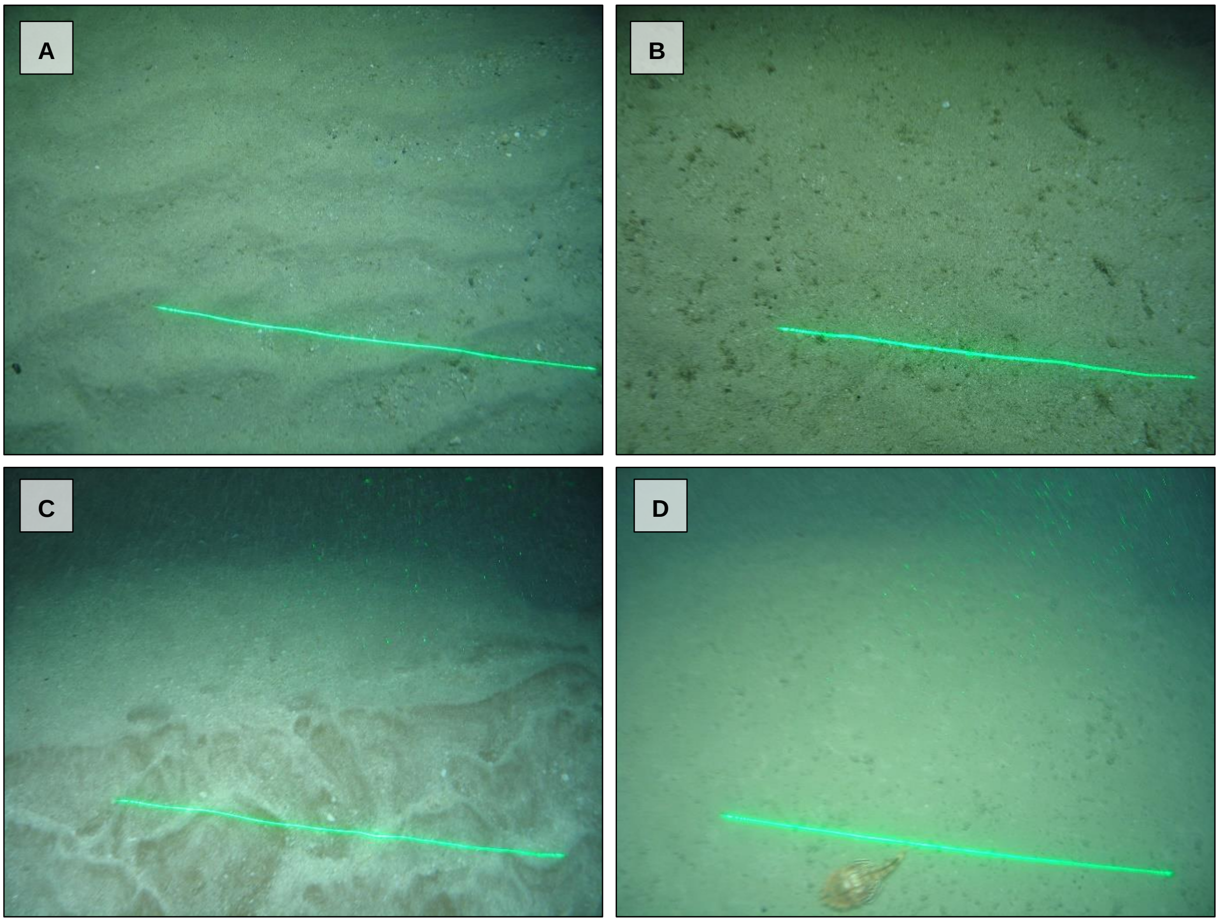


Photo A: SA1702_ENV02_23 Sand forming sand waves, no visible fauna;
Photo B: SA1702_ENV04_11 Sand, hydroids (Hydrozoa);
Photo C: SA1702_ENV13_19 Sand forming sand waves, no visible fauna;
Photo D: SA1702_ENV18_13 Sand, unidentified fish.

Figure 4.13: Example photographs of 'Unconsolidated Sand'

4.6.6 Unconsolidated Sand with Hard Substrate

Table 4.9 summarises the classification and characteristics of this habitat.

Table 4.9: Summary Classification and Characteristics of 'Unconsolidated Sand with Hard Substrate'

Hierarchical Classification			
Level 1	**Substrate Type**	**Unconsolidated**	
Level 2	Particle size	Sand	
Level 3	Sediment particle size	Sand	
	Sediment description	Sand (41 % – 99 %) forming veneer over reef material (1 % – 49 %)	Sand forming veneer over volcanic rock
	Profile	Flat sediment, low reef	Small to medium ripples, low rock
	Characteristic fauna	Sponges (Porifera) crinoids (Crinoidea), faunal burrows	No visible fauna
Physical Characteristics			
Depth [m]		167 m – 257 m	

This habitat was only observed at two transect at the Crux site (ENV05, ENV05A) and five transects along the pipeline route (ENV14, ENV18, ENV19, ENV26 and ENV10). The habitat consisted predominantly of sand sediment with a smaller proportion (< 49 %) of hard substrate. Two types of hard substrate were identified. Old unbroken reef and reef rubble was the same as that observed in other habitats across the survey area (Section 4.6.1, Section 4.6.4 and Section 4.6.8). A different hard substrate was observed at transect ENV10 and appeared to be of volcanic origin. On the sidescan sonar data, the acoustic return of this habitat was similar to that of rippled sand seen elsewhere across the survey area.

The volcanic sediment covered by a veneer of sand sediment had no visible fauna present. This may indicate a mobile and dynamic environment with the sand scouring the surface of the hard substrate and preventing epifauna from attaching. Low to medium sand waves were also present and are indicative of mobile shifting sediments.

The presence of hard reef substrate among the sand sediment provided a surface for attachment for a variety of sessile epifauna, predominantly sponges (Porifera) but including soft corals (Alcyonacea), hydroids (Hydrozoa), branching coral (Alcyonacea) and sea pens (Pennatulacea) as well as mobile epifauna such as crinoids (Crinoidea), starfish (Asteroidea), crabs (Decapoda) and sea urchins (Echinoidea).

Example photographs of this 'Unconsolidated Sand with Hard Substrate' habitat and associated fauna are displayed in Figure 4.14.

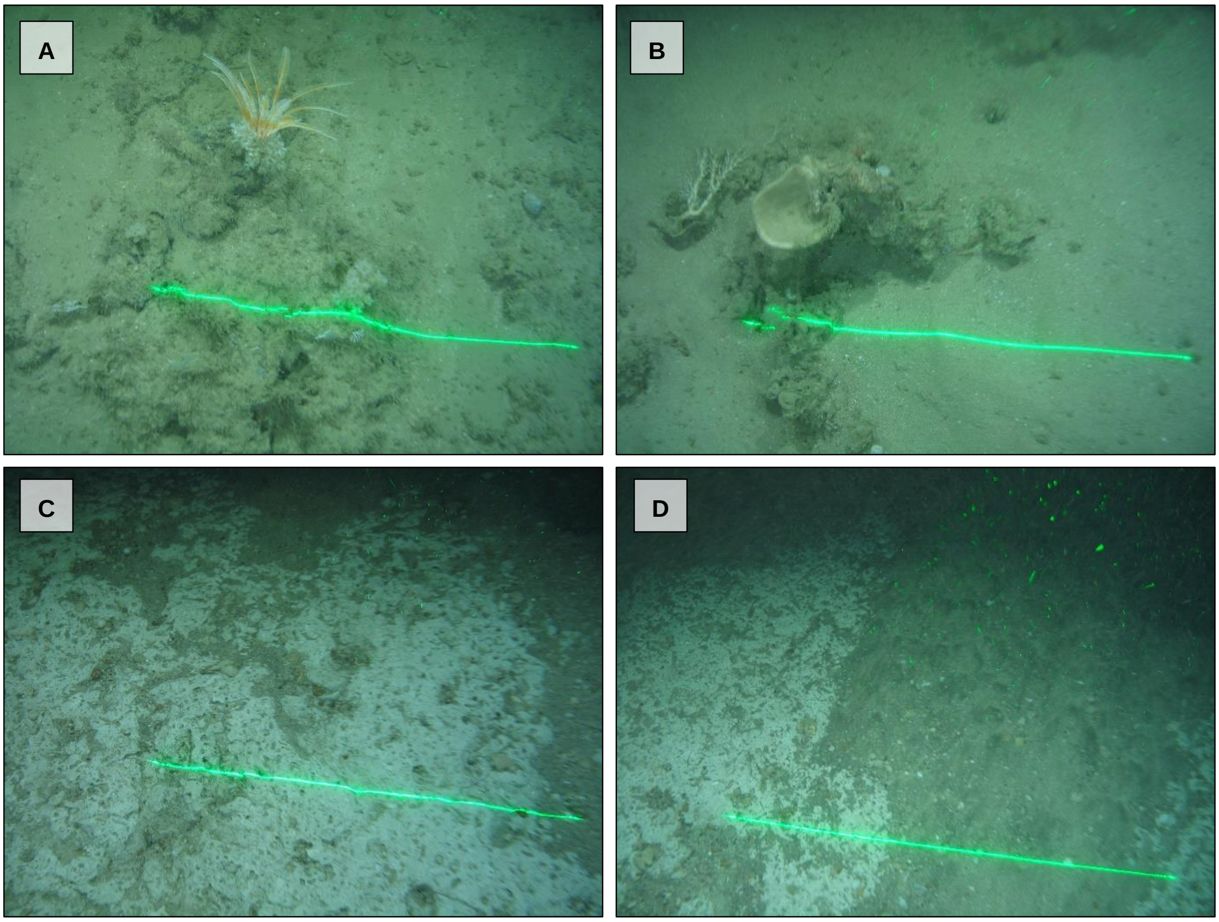


Photo A: SA1702_ENV18_42 Sand veneer over reef, crinoid (Crinoidea);
Photo B: SA1702_ENV26_93 Sand veneer over reef, sponge (Porifera);
Photo C: SA1702_ENV10_32 Sand veneer over volcanic rock, no visible fauna;
Photo D: SA1702_ENV10_35 Sand veneer over volcanic rock, no visible fauna.

Figure 4.14: Example photographs of 'Unconsolidated Sand with Hard Substrate'

4.6.7 Unconsolidated Muddy Sand

Table 4.10 summarises the classification and characteristics of this habitat.

Table 4.10: Summary Classification and Characteristics of 'Unconsolidated Muddy Sand'

Hierarchical Classification		
Level 1	**Substrate Type**	**Unconsolidated**
Level 2	Particle size	Muddy Sand
Level 3	Sediment particle size	Muddy Sand
	Sediment description	Muddy Sand (100 %)
	Profile	Flat
	Characteristic fauna	Faunal burrows
Physical Characteristics		
Depth [m]		228 m – 272 m

This habitat was only recorded at the deepest transects (ENV18, ENV20, ENV21, ENV22, ENV23, ENV24 and ENV25) surveyed along the pipeline route and was the second most common habitat observed during the survey after 'Unconsolidated Sand' (Section 4.6.5).

The high degree of turbidity limited the visibility during data acquisition along several of these transects but, where visible, the habitat comprised of muddy sand. Bioturbation in this habitat was recorded as low (1 to 2 disturbances per meter) to medium (3 to 10 disturbances per meter). The bioturbation consisted largely of faunal burrows, suggesting an abundant infaunal community as burrows increase the oxygen in the surface sediment often resulting in a greater abundance of infauna. The occasional faunal track was also observed. Epifuana was sparse in this habitat although hydroids (Hydrozoa), sponges (Porifera), hermit crabs (Paguroidea) and sea pens (Pennatulacea) were also observed in this habitat.

Example photographs of this habitat are shown in Figure 4.15.

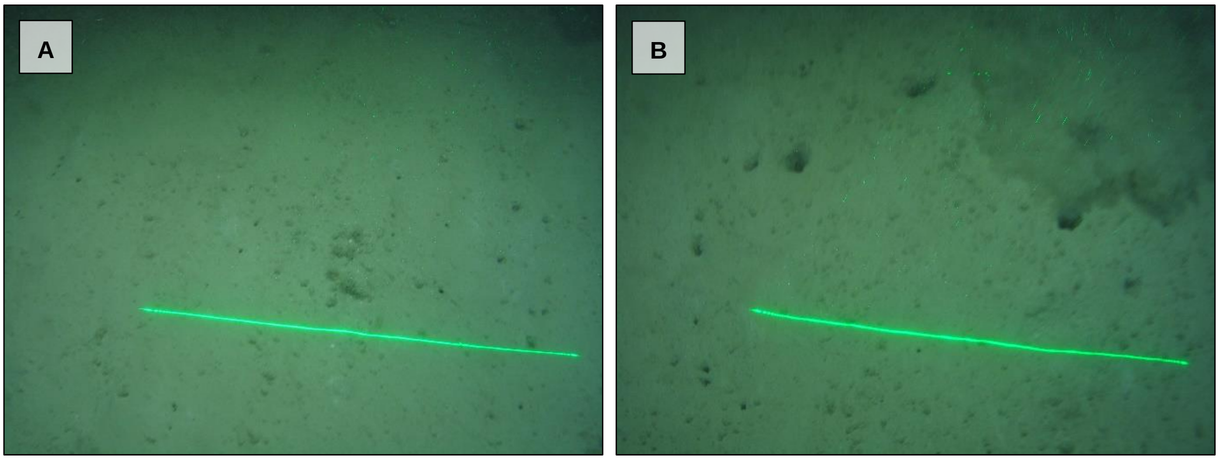


Photo A:	SA1702_ENV20_73, Muddy sand, faunal burrows;
Photo B:	SA1702_ENV25_27, Muddy sand, faunal burrows.

Figure 4.15: Example photographs of 'Unconsolidated Muddy Sand'

4.6.8 Unconsolidated Muddy Sand with Hard Substrate

Table 4.11 summarises the classification and characteristics of this habitat.

Table 4.11: Summary Classification and Characteristics of 'Unconsolidated Muddy Sand with Hard Substrate

Hierarchical Classification		
Level 1	**Substrate Type**	**Unconsolidated**
Level 2	Particle size	Muddy Sand
Level 3	Sediment particle size	Muddy Sand
	Sediment description	Muddy sand (76 % – 99 %) over hard substrate (1 % – 24 %)
	Profile	Flat with low reef
	Characteristic fauna	Sponges (Porifera), faunal burrows
Physical Characteristics		
Depth [m]		242 m – 269 m

This 'Unconsolidated Muddy Sand with Hard Substrate' habitat was observed at two transects, located at the bottom of the escarpments along the pipeline route (ENV20) and the alternative pipeline route (ENV25). This habitat was only recorded in the deeper water (242 m – 269 m) and was recorded alongside the 'Unconsolidated Muddy Sand' habitat described in Section 4.6.7.

The presence of hard substrate allowed the attachment of sessile epifauna. Sponges (Porifera) were characteristic of this habitat. Sea anemones (Actiniaria), sea whips (Alcyonacea), soft corals (Alcyonaria) and hydroids (Hydrozoa) were also present. However, some sessile attaching taxa that had been recorded in other areas where hard substrate had been present were not recorded in this habitat. The high levels of suspended material in the water column at this location may inhibit colonisation by other filter feeding species (e.g. soft corals and sponges), as these suspended particles may clog the filter feeding apparatus.

Example photographs of this habitat are shown in Figure 4.16.

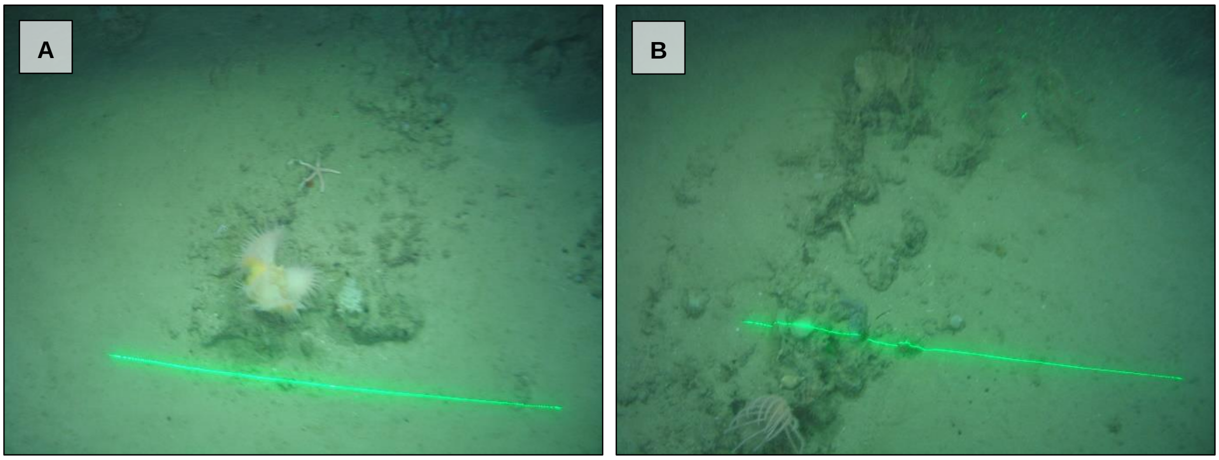


Photo A:	SA1702_ENV20_13, Muddy sand with reef rubble (cobbles), starfish (Asteroidea), sea anemones (Actinaria), sponge (Porifera);
Photo B:	SA1702_ENV25_9, Muddy sand with reef rubble (cobbles), soft coral (Ellisellidae), faunal burrows.

Figure 4.16: Example photographs of ‘Unconsolidated Muddy Sand with Hard Substrate’

5. CONCLUSIONS

A broad range of habitat types were seen across the survey area, with eight separate habitats identified based on geomorphological structures and the sediments. Water depths ranged from 84.4 m to 262.0 m and decreased from the Crux site in the north-east of the survey area to the Prelude end of the pipeline in the south-west of the survey area. Two escarpments were evident on the video transects within the survey area: one to the north-east of Crux site and one along the pipeline route.

Areas of potential reef and mixed sediment were targeted for camera transects based on review of the sidescan sonar and bathymetry data. Sediment types observed on the camera varied across the survey area. Muddy sand was observed on the video to the south of the survey area at the Prelude end of the pipeline route, while gravelly sand with hard substrate was observed in the shallower areas of the Crux site. This was broadly consistent with the geophysical data interpretation which identified the predominant sediment type as silty sand at the Crux site with sand being the predominant sediment type along the pipeline route.

Overall epifaunal abundance was low with some habitats having little to no visible fauna. Most habitats had low faunal abundance with a few characterising taxa. Unconsolidated sediments with no hard substrate for attachment had fewer epifaunal taxa present. Sea pens (Pennatulacea), crinoids (Crinoidea) including the stalked crinoids (Isselicrinidae) and sea urchins (Echinoidea) were observed. Unconsolidated sediments had a higher level of bioturbation mainly in the form of faunal burrows, although the presence of faunal burrows depended on the sediment type and cohesiveness of the sediment.

The greatest influence on epifaunal communities was the presence of consolidated hard substrate, even in habitats where unconsolidated sediment was the dominant sediment type. Habitats containing a proportion of hard substrate for attachment had soft corals and sea whips (Alcyonacea) sea anemones (Actiniaria), hydroids (Hydrozoa) and sponges (Porifera) present. Sections of three transects (ENV02, ENV05A and ENV18), were recorded as having an abundance greater than 10 % coverage which was the threshold applied to the habitat classification applied. Sections of three transects were assigned the community classification of ‘Filter Feeders’ (ENV02, ENV05A and ENV18).

6. REFERENCES

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Wentworth, C.K., 1922. A Scale of Grade and Class Terms for Clastic Sediments. *Journal of Geology,* 30, pp. 377-392.

7. DISTRIBUTION

A copy of this report has been distributed as follows:

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Attn: Gareth Edwards and Nick Lake : 1 x electronic copy

APPENDICES

A. LOGS

A.1 SURVEY LOGS

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
22/04/2016	05:28:06	SA1702_ENV02	Still	SA1702_ENV	108	66.9	661424.09	8571313.14	661527.17	8571429.94	155.8	
22/04/2016		SA1702_ENV02	Still	SA1702_ENV	NO FIX							
22/04/2016	05:28:31	SA1702_ENV02	Still	SA1702_ENV	109	66.6	661424.09	8571313.14	661525.11	8571428.07	153.0	
22/04/2016	05:29:31	SA1702_ENV02	Still	SA1702_ENV	110	66.1	661424.09	8571313.14	661519.69	8571423.25	145.8	
22/04/2016	05:31:03	SA1702_ENV02	Still	SA1702_ENV	111	66.5	661424.09	8571313.14	661512.10	8571414.79	134.5	
22/04/2016	05:32:15	SA1702_ENV02	Still	SA1702_ENV	112	67.4	661424.09	8571313.14	661503.82	8571406.13	122.5	
22/04/2016		SA1702_ENV02		SA1702_ENV	NO FIX							
22/04/2016	05:33:13	SA1702_ENV02	Still	SA1702_ENV	113	66.6	661424.09	8571313.14	661497.72	8571398.49	112.7	
22/04/2016	05:35:21	SA1702_ENV02	Still	SA1702_ENV	114	67.5	661424.09	8571313.14	661481.55	8571381.69	89.4	
22/04/2016	05:35:37	SA1702_ENV02	Still	SA1702_ENV	115	67.8	661424.09	8571313.14	661481.05	8571379.88	87.7	
22/04/2016	05:37:49	SA1702_ENV02	Still	SA1702_ENV	116	71.4	661424.09	8571313.14	661466.80	8571361.85	64.8	
22/04/2016	05:40:26	SA1702_ENV02	Still	SA1702_ENV	117	71.6	661424.09	8571313.14	661450.09	8571340.75	37.9	
22/04/2016	05:41:31	SA1702_ENV02	Still	SA1702_ENV	118	71.6	661424.09	8571313.14	661439.90	8571329.55	22.8	
22/04/2016	05:41:38	SA1702_ENV02	Still	SA1702_ENV	119	71.7	661424.09	8571313.14	661438.80	8571328.21	21.1	
22/04/2016	05:43:54	SA1702_ENV02	Still	SA1702_ENV	120	72.1	661424.09	8571313.14	661423.13	8571308.77	4.5	
22/04/2016	05:44:35	SA1702_ENV02	Still	NO STILL	121	73.9	661424.09	8571313.14	661418.84	8571303.42	11.0	
22/04/2016	05:45:24	SA1702_ENV02	Still	SA1702_ENV	122	75.0	661424.09	8571313.14	661412.49	8571296.20	20.5	
22/04/2016	05:46:26	SA1702_ENV02	Still	SA1702_ENV	123	80.3	661424.09	8571313.14	661404.62	8571287.10	32.5	
22/04/2016	05:46:49	SA1702_ENV02	Still	SA1702_ENV	124	82.6	661424.09	8571313.14	661401.94	8571283.80	36.8	
22/04/2016	05:47:15	SA1702_ENV02	Still	SA1702_ENV	125	83.6	661424.09	8571313.14	661398.63	8571280.44	41.4	
22/04/2016	05:48:08	SA1702_ENV02	Still	SA1702_ENV	126	86.0	661424.09	8571313.14	661392.55	8571272.89	51.1	
22/04/2016	05:48:31	SA1702_ENV02	Still	SA1702_ENV	127	86.1	661424.09	8571313.14	661389.97	8571269.69	55.2	
22/04/2016	05:49:27	SA1702_ENV02	Still	SA1702_ENV	128	86.4	661424.09	8571313.14	661383.85	8571262.12	65.0	
22/04/2016	05:49:57	SA1702_ENV02	Still	SA1702_ENV	129	88.1	661424.09	8571313.14	661379.77	8571258.13	70.6	
22/04/2016	05:50:41	SA1702_ENV02	Still	SA1702_ENV	130	87.1	661424.09	8571313.14	661375.16	8571252.73	77.7	
22/04/2016	05:51:46	SA1702_ENV02	Still	SA1702_ENV	131	88.7	661424.09	8571313.14	661368.27	8571243.88	89.0	
22/04/2016	05:52:08	SA1702_ENV02	Still	SA1702_ENV	132	89.0	661424.09	8571313.14	661366.30	8571240.70	92.7	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transcect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
22/04/2016	05:52:45	SA1702_ENV02	Still	SA1702_ENV	133	90.0	661424.09	8571313.14	661361.80	8571236.14	99.0	
22/04/2016	05:54:08	SA1702_ENV02	Still	SA1702_ENV	134	89.8	661424.09	8571313.14	661351.95	8571224.16	114.5	
22/04/2016	05:54:56	SA1702_ENV02	Still	SA1702_ENV	135	89.8	661424.09	8571313.14	661346.21	8571217.28	123.5	
22/04/2016	05:55:44	SA1702_ENV02	Still	SA1702_ENV	136	90.3	661424.09	8571313.14	661340.33	8571210.03	132.8	
22/04/2016	05:56:23	SA1702_ENV02	Still	SA1702_ENV	137	90.8	661424.09	8571313.14	661335.30	8571204.09	140.6	
22/04/2016	05:57:17	SA1702_ENV02	Still	SA1702_ENV	138	90.5	661424.09	8571313.14	661328.69	8571196.05	151.0	
22/04/2016	05:57:50	SA1702_ENV02	Still	SA1702_ENV	139	92.2	661424.09	8571313.14	661324.79	8571191.05	157.4	
22/04/2016	05:58:28	SA1702_ENV02	Still	SA1702_ENV	140	91.0	661424.09	8571313.14	661320.42	8571185.98	164.1	
22/04/2016	05:59:49	SA1702_ENV02	Still	SA1702_ENV	141	92.7	661424.09	8571313.14	661311.94	8571174.87	178.0	
22/04/2016	06:00:58	SA1702_ENV02	Still	SA1702_ENV	142	91.5	661424.09	8571313.14	661303.64	8571165.79	190.3	
22/04/2016	06:02:02	SA1702_ENV02	Still	SA1702_ENV	143	92.8	661424.09	8571313.14	661296.60	8571157.29	201.4	
22/04/2016	06:02:42	SA1702_ENV02	Still	SA1702_ENV	144	92.6	661424.09	8571313.14	661292.36	8571151.82	208.3	
22/04/2016	06:04:20	SA1702_ENV02	Still	SA1702_ENV	145	93.3	661424.09	8571313.14	661281.41	8571137.33	226.4	
22/04/2016	06:04:52	SA1702_ENV02	Still	SA1702_ENV	146	93.8	661424.09	8571313.14	661277.68	8571133.00	232.1	
22/04/2016	06:05:43	SA1702_ENV02	Still	SA1702_ENV	147	93.8	661424.09	8571313.14	661271.56	8571125.41	241.9	
22/04/2016	06:07:02	SA1702_ENV02	Still	SA1702_ENV	148	94.5	661424.09	8571313.14	661262.43	8571115.51	255.3	
22/04/2016	06:07:33	SA1702_ENV02	Still	SA1702_ENV	149	95.0	661424.09	8571313.14	661258.75	8571111.07	261.1	
22/04/2016	06:08:17	SA1702_ENV02	Still	SA1702_ENV	150	94.9	661424.09	8571313.14	661254.12	8571105.02	268.7	
22/04/2016	06:08:56	SA1702_ENV02	Still	SA1702_ENV	151	95.2	661424.09	8571313.14	661250.18	8571099.74	275.3	
22/04/2016	06:09:10	SA1702_ENV02	Still	SA1702_ENV	152	95.3	661424.09	8571313.14	661248.74	8571097.83	277.7	
22/04/2016	06:09:48	SA1702_ENV02	Still	SA1702_ENV	153	95.3	661424.09	8571313.14	661245.15	8571092.13	284.4	
22/04/2016	06:10:32	SA1702_ENV02	Still	SA1702_ENV	154	95.9	661424.09	8571313.14	661239.94	8571085.03	293.2	
22/04/2016	06:11:39	SA1702_ENV02	Still	SA1702_ENV	155	95.9	661424.09	8571313.14	661233.13	8571075.11	305.2	
22/04/2016	06:12:17	SA1702_ENV02	Still	SA1702_ENV	156	96.3	661424.09	8571313.14	661229.26	8571069.98	311.6	
22/04/2016	06:13:54	SA1702_ENV02	Still	SA1702_ENV	157	95.1	661424.09	8571313.14	661219.67	8571055.68	328.7	
22/04/2016	06:14:53	SA1702_ENV02	Still	SA1702_ENV	158	95.0	661424.09	8571313.14	661213.53	8571047.17	339.2	
22/04/2016	06:15:50	SA1702_ENV02	Still	SA1702_ENV	159	94.2	661424.09	8571313.14	661207.38	8571038.84	349.6	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
22/04/2016	11:06:15	SA1702_ENV01	Still	SA1702_ENV	201	91.0	663691.15	8570765.95	663701.98	8570780.05	17.8	
22/04/2016	11:06:35	SA1702_ENV01	Still	SA1702_ENV	202	89.0	663691.15	8570765.95	663699.00	8570776.82	13.4	
22/04/2016	11:07:19	SA1702_ENV01	Still	SA1702_ENV	203	91.0	663691.15	8570765.95	663693.65	8570768.76	3.8	
22/04/2016	11:07:57	SA1702_ENV01	Still	SA1702_ENV	204	91.0	663691.15	8570765.95	663690.37	8570762.75	3.3	
22/04/2016	11:08:39	SA1702_ENV01	Still	SA1702_ENV	205	91.0	663691.15	8570765.95	663685.94	8570755.19	12.0	
22/04/2016	11:08:47	SA1702_ENV01	Still	SA1702_ENV	206	91.0	663691.15	8570765.95	663685.25	8570754.01	13.3	
22/04/2016	11:09:35	SA1702_ENV01	Still	SA1702_ENV	207	90.0	663691.15	8570765.95	663680.64	8570747.10	21.6	
22/04/2016	11:10:26	SA1702_ENV01	Still	SA1702_ENV	208	91.0	663691.15	8570765.95	663676.51	8570740.77	29.1	
22/04/2016	11:11:24	SA1702_ENV01	Still	SA1702_ENV	209	90.0	663691.15	8570765.95	663670.77	8570733.91	38.0	
22/04/2016	11:11:56	SA1702_ENV01	Still	SA1702_ENV	210	92.0	663691.15	8570765.95	663667.68	8570729.16	43.6	
22/04/2016	11:12:14	SA1702_ENV01	Still	SA1702_ENV	211	91.0	663691.15	8570765.95	663666.45	8570727.24	45.9	
22/04/2016	11:13:09	SA1702_ENV01	Still	SA1702_ENV	212	92.0	663691.15	8570765.95	663660.33	8570717.83	57.1	
22/04/2016	11:13:41	SA1702_ENV01	Still	SA1702_ENV	213	93.0	663691.15	8570765.95	663656.38	8570713.00	63.3	
22/04/2016	11:13:56	SA1702_ENV01	Still	SA1702_ENV	214	94.0	663691.15	8570765.95	663654.77	8570710.43	66.4	
22/04/2016	11:14:41	SA1702_ENV01	Still	SA1702_ENV	215	92.0	663691.15	8570765.95	663650.59	8570702.24	75.5	
22/04/2016	11:15:07	SA1702_ENV01	Still	SA1702_ENV	216	92.0	663691.15	8570765.95	663648.82	8570697.23	80.7	
22/04/2016	11:15:56	SA1702_ENV01	Still	SA1702_ENV	217	93.0	663691.15	8570765.95	663645.20	8570690.65	88.2	
22/04/2016	11:16:56	SA1702_ENV01	Still	SA1702_ENV	218	92.0	663691.15	8570765.95	663638.02	8570679.85	101.2	
22/04/2016	11:17:48	SA1702_ENV01	Still	SA1702_ENV	219	93.0	663691.15	8570765.95	663632.13	8570671.40	111.5	
22/04/2016	11:18:17	SA1702_ENV01	Still	SA1702_ENV	220	93.0	663691.15	8570765.95	663629.56	8570667.45	116.2	
22/04/2016	11:18:32	SA1702_ENV01	Still	SA1702_ENV	221	93.0	663691.15	8570765.95	663628.33	8570665.52	118.5	
22/04/2016	11:19:11	SA1702_ENV01	Still	SA1702_ENV	222	93.0	663691.15	8570765.95	663624.71	8570659.70	125.3	
22/04/2016	11:20:17	SA1702_ENV01	Still	SA1702_ENV	223	93.0	663691.15	8570765.95	663618.02	8570650.12	137.0	
22/04/2016	11:21:19	SA1702_ENV01	Still	SA1702_ENV	224	92.0	663691.15	8570765.95	663612.22	8570640.03	148.6	
22/04/2016	11:21:56	SA1702_ENV01	Still	SA1702_ENV	225	92.0	663691.15	8570765.95	663607.94	8570634.64	155.5	
22/04/2016	11:22:39	SA1702_ENV01	Still	SA1702_ENV	226	92.0	663691.15	8570765.95	663602.24	8570627.28	164.7	
22/04/2016	11:23:25	SA1702_ENV01	Still	SA1702_ENV	227	92.0	663691.15	8570765.95	663597.17	8570619.28	174.2	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
22/04/2016	11:23:33	SA1702_ENV01	Still	SA1702_ENV	228	93.0	663691.15	8570765.95	663596.48	8570618.00	175.6	
22/04/2016	11:24:43	SA1702_ENV01	Still	SA1702_ENV	229	92.0	663691.15	8570765.95	663590.82	8570608.16	187.0	
22/04/2016	11:25:11	SA1702_ENV01	Still	SA1702_ENV	230	93.0	663691.15	8570765.95	663588.76	8570604.59	191.1	
22/04/2016	11:25:47	SA1702_ENV01	Still	SA1702_ENV	231	92.0	663691.15	8570765.95	663585.39	8570600.35	196.5	
22/04/2016	11:26:20	SA1702_ENV01	Still	SA1702_ENV	232	93.0	663691.15	8570765.95	663582.93	8570596.06	201.4	
22/04/2016	11:27:08	SA1702_ENV01	Still	SA1702_ENV	233	92.0	663691.15	8570765.95	663578.55	8570589.92	209.0	
22/04/2016	11:30:03	SA1702_ENV01	Still	SA1702_ENV	234	92.0	663691.15	8570765.95	663570.15	8570578.80	222.9	
22/04/2016	11:30:13	SA1702_ENV01	Still	SA1702_ENV	235	92.0	663691.15	8570765.95	663570.39	8570578.42	223.1	
22/04/2016	11:30:28	SA1702_ENV01	Still	SA1702_ENV	236	92.0	663691.15	8570765.95	663570.87	8570578.68	222.6	
23/04/2017	00:38:54	SA1702_ENV03	Still	NO STILL	300	166.3	657564.76	8568835.13	657488.25	8568874.61	86.1	
23/04/2017	00:44:14	SA1702_ENV03	Still	NO STILL	301	166.3	657564.76	8568835.13	657527.92	8568855.59	42.1	
23/04/2017	00:44:44	SA1702_ENV03	Still	SA1702_ENV	302	166.5	657564.76	8568835.13	657533.01	8568852.72	36.3	
23/04/2017	00:46:52	SA1702_ENV03	Still	SA1702_ENV	303	166.5	657564.76	8568835.13	657553.15	8568839.87	12.5	
23/04/2017	00:47:34	SA1702_ENV03	Still	SA1702_ENV	304	167.0	657564.76	8568835.13	657559.40	8568836.23	5.5	
23/04/2017	00:48:49	SA1702_ENV03	Still	SA1702_ENV	305	167.3	657564.76	8568835.13	657570.10	8568830.25	7.2	
23/04/2017	00:49:14	SA1702_ENV03	Still	SA1702_ENV	306	166.6	657564.76	8568835.13	657574.87	8568828.28	12.2	
23/04/2017	00:50:22	SA1702_ENV03	Still	SA1702_ENV	307	166.5	657564.76	8568835.13	657586.60	8568824.12	24.5	
23/04/2017	00:51:52	SA1702_ENV03	Still	SA1702_ENV	308	166.9	657564.76	8568835.13	657601.77	8568815.67	41.8	
23/04/2017	00:52:18	SA1702_ENV03	Still	SA1702_ENV	309	166.5	657564.76	8568835.13	657606.23	8568813.58	46.7	
23/04/2017	00:52:59	SA1702_ENV03	Still	SA1702_ENV	310	166.7	657564.76	8568835.13	657613.41	8568810.11	54.7	
23/04/2017	00:54:08	SA1702_ENV03	Still	SA1702_ENV	311	166.5	657564.76	8568835.13	657624.66	8568803.84	67.6	
23/04/2017	00:54:48	SA1702_ENV03	Still	SA1702_ENV	312	165.9	657564.76	8568835.13	657631.11	8568800.74	74.7	
23/04/2017	00:55:21	SA1702_ENV03	Still	SA1702_ENV	313	166.3	657564.76	8568835.13	657636.43	8568798.04	80.7	
23/04/2017	00:57:10	SA1702_ENV03	Still	SA1702_ENV	314	166.4	657564.76	8568835.13	657653.01	8568788.52	99.8	
23/04/2017	00:58:22	SA1702_ENV03	Still	SA1702_ENV	315	166.5	657564.76	8568835.13	657664.18	8568782.57	112.5	
23/04/2017	00:58:45	SA1702_ENV03	Still	SA1702_ENV	316	167.1	657564.76	8568835.13	657667.76	8568780.37	116.7	
23/04/2017	00:59:49	SA1702_ENV03	Still	SA1702_ENV	317	166.8	657564.76	8568835.13	657677.22	8568773.75	128.1	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transcept	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
23/04/2017	01:00:34	SA1702_ENV03	Still	SA1702_ENV	318	166.6	657564.76	8568835.13	657685.26	8568769.98	137.0	
23/04/2017	01:01:06	SA1702_ENV03	Still	SA1702_ENV	319	166.8	657564.76	8568835.13	657690.68	8568767.28	143.0	
23/04/2017	01:01:18	SA1702_ENV03	Still	SA1702_ENV	320	166.9	657564.76	8568835.13	657692.54	8568766.42	145.1	
23/04/2017	01:02:03	SA1702_ENV03	Still	SA1702_ENV	321	166.3	657564.76	8568835.13	657700.16	8568762.63	153.6	
23/04/2017	01:02:32	SA1702_ENV03	Still	SA1702_ENV	322	165.9	657564.76	8568835.13	657704.87	8568759.31	159.3	
23/04/2017	01:03:16	SA1702_ENV03	Still	SA1702_ENV	323	165.3	657564.76	8568835.13	657712.16	8568755.63	167.5	
23/04/2017	01:03:34	SA1702_ENV03	Still	SA1702_ENV	324	165.9	657564.76	8568835.13	657714.68	8568754.26	170.3	
23/04/2017	01:04:19	SA1702_ENV03	Still	SA1702_ENV	325	166.6	657564.76	8568835.13	657721.68	8568751.55	177.8	
23/04/2017	01:05:05	SA1702_ENV03	Still	SA1702_ENV	326	166.7	657564.76	8568835.13	657728.40	8568747.27	185.7	
23/04/2017	01:06:14	SA1702_ENV03	Still	SA1702_ENV	327	167.3	657564.76	8568835.13	657738.56	8568741.04	197.6	
23/04/2017	01:07:08	SA1702_ENV03	Still	SA1702_ENV	328	166.2	657564.76	8568835.13	657747.35	8568736.84	207.4	
23/04/2017	01:07:50	SA1702_ENV03	Still	SA1702_ENV	329	166.8	657564.76	8568835.13	657754.70	8568733.33	215.5	
23/04/2017	01:08:02	SA1702_ENV03	Still	SA1702_ENV	330	167.2	657564.76	8568835.13	657756.18	8568732.99	217.0	
23/04/2017	01:09:03	SA1702_ENV03	Still	SA1702_ENV	331	167.3	657564.76	8568835.13	657766.88	8568727.74	228.9	
23/04/2017	01:10:00	SA1702_ENV03	Still	SA1702_ENV	332	167.0	657564.76	8568835.13	657776.28	8568722.48	239.6	
23/04/2017	01:11:00	SA1702_ENV03	Still	SA1702_ENV	333	167.5	657564.76	8568835.13	657786.11	8568717.20	250.8	
23/04/2017	01:12:18	SA1702_ENV03	Still	SA1702_ENV	334	166.9	657564.76	8568835.13	657797.59	8568708.62	265.0	
23/04/2017	01:13:09	SA1702_ENV03	Still	SA1702_ENV	335	166.8	657564.76	8568835.13	657806.00	8568704.95	274.1	
23/04/2017	01:13:52	SA1702_ENV03	Still	SA1702_ENV	336	167.5	657564.76	8568835.13	657811.81	8568701.83	280.7	
23/04/2017	03:17:53	SA1702_ENV04	Still	NO STILL	400	170.0	656182.05	8566616.90	656228.89	8566657.82	62.2	
23/04/2017	03:23:51	SA1702_ENV04	Still	SA1702_ENV	401	170.0	656182.05	8566616.90	656229.11	8566658.39	62.7	
23/04/2017	03:25:00	SA1702_ENV04	Still	SA1702_ENV	402	171.0	656182.05	8566616.90	656224.11	8566653.33	55.6	
23/04/2017	03:25:13	SA1702_ENV04	Still	SA1702_ENV	403	171.3	656182.05	8566616.90	656221.75	8566651.49	52.7	
23/04/2017	03:25:43	SA1702_ENV04	Still	NO STILL	404	170.6	656182.05	8566616.90	656215.54	8566646.98	45.0	
23/04/2017	03:25:58	SA1702_ENV04	Still	SA1702_ENV	405	170.7	656182.05	8566616.90	656212.48	8566644.71	41.2	
23/04/2017	03:26:32	SA1702_ENV04	Still	SA1702_ENV	406	170.8	656182.05	8566616.90	656205.33	8566638.86	32.0	
23/04/2017	03:27:07	SA1702_ENV04	Still	SA1702_ENV	407	171.6	656182.05	8566616.90	656198.68	8566633.34	23.4	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
23/04/2017	03:28:04	SA1702_ENV04	Still	SA1702_ENV	408	171.6	656182.05	8566616.90	656189.81	8566625.70	11.7	
23/04/2017	03:29:02	SA1702_ENV04	Still	SA1702_ENV	409	171.2	656182.05	8566616.90	656179.99	8566618.26	2.5	
23/04/2017	03:29:17	SA1702_ENV04	Still	SA1702_ENV	410	171.7	656182.05	8566616.90	656177.21	8566616.36	4.9	
23/04/2017	03:31:52	SA1702_ENV04	Still	SA1702_ENV	411	171.1	656182.05	8566616.90	656149.45	8566592.69	40.6	
23/04/2017	03:32:34	SA1702_ENV04	Still	SA1702_ENV	412	171.8	656182.05	8566616.90	656141.32	8566586.73	50.7	
23/04/2017	03:33:59	SA1702_ENV04	Still	SA1702_ENV	413	171.2	656182.05	8566616.90	656127.91	8566576.73	67.4	
23/04/2017	03:34:16	SA1702_ENV04	Still	SA1702_ENV	414	171.1	656182.05	8566616.90	656125.18	8566574.14	71.2	
23/04/2017	03:34:56	SA1702_ENV04	Still	SA1702_ENV	415	171.3	656182.05	8566616.90	656118.92	8566568.39	79.6	
23/04/2017	03:35:20	SA1702_ENV04	Still	SA1702_ENV	416	171.4	656182.05	8566616.90	656114.28	8566565.10	85.3	
23/04/2017	03:35:49	SA1702_ENV04	Still	SA1702_ENV	417	171.7	656182.05	8566616.90	656110.28	8566561.29	90.8	
23/04/2017	03:36:23	SA1702_ENV04	Still	SA1702_ENV	418	171.2	656182.05	8566616.90	656106.56	8566555.90	97.1	
23/04/2017	03:36:49	SA1702_ENV04	Still	SA1702_ENV	419	171.4	656182.05	8566616.90	656102.88	8566552.01	102.4	
23/04/2017	03:37:20	SA1702_ENV04	Still	NO STILL	420	171.9	656182.05	8566616.90	656097.95	8566547.62	109.0	
23/04/2017	03:37:59	SA1702_ENV04	Still	SA1702_ENV	421	171.3	656182.05	8566616.90	656091.53	8566542.41	117.2	
23/04/2017	03:38:49	SA1702_ENV04	Still	SA1702_ENV	422	171.0	656182.05	8566616.90	656082.73	8566536.05	128.1	
23/04/2017	03:39:15	SA1702_ENV04	Still	SA1702_ENV	423	171.4	656182.05	8566616.90	656078.76	8566531.96	133.7	
23/04/2017	04:46:43	SA1702_ENV05	Still	SA1702_ENV	501	171.0	656436.82	8565655.97	656390.80	8565627.87	53.9	
23/04/2017	04:47:26	SA1702_ENV05	Still	SA1702_ENV	502	171.0	656436.82	8565655.97	656398.17	8565632.61	45.2	
23/04/2017	04:48:04	SA1702_ENV05	Still	SA1702_ENV	503	171.9	656436.82	8565655.97	656405.47	8565637.31	36.5	
23/04/2017	04:49:43	SA1702_ENV05	Still	SA1702_ENV	504	171.8	656436.82	8565655.97	656420.96	8565647.23	18.1	
23/04/2017	04:50:13	SA1702_ENV05	Still	SA1702_ENV	505	171.3	656436.82	8565655.97	656424.78	8565649.77	13.5	
23/04/2017	04:50:40	SA1702_ENV05	Still	SA1702_ENV	506	170.8	656436.82	8565655.97	656428.35	8565652.24	9.3	
23/04/2017	04:51:17	SA1702_ENV05	Still	SA1702_ENV	507	170.8	656436.82	8565655.97	656432.94	8565654.93	4.0	
23/04/2017	04:52:09	SA1702_ENV05	Still	SA1702_ENV	508	171.7	656436.82	8565655.97	656440.36	8565660.08	5.4	
23/04/2017	04:52:57	SA1702_ENV05	Still	SA1702_ENV	509	170.3	656436.82	8565655.97	656447.56	8565665.02	14.0	
23/04/2017	04:53:42	SA1702_ENV05	Still	SA1702_ENV	510	171.0	656436.82	8565655.97	656454.93	8565669.27	22.5	
23/04/2017	04:54:49	SA1702_ENV05	Still	SA1702_ENV	511	170.5	656436.82	8565655.97	656465.30	8565676.49	35.1	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
23/04/2017	04:55:04	SA1702_ENV05	Still	SA1702_ENV	512	170.7	656436.82	8565655.97	656468.01	8565678.24	38.3	
23/04/2017	04:56:14	SA1702_ENV05	Still	SA1702_ENV	513	170.1	656436.82	8565655.97	656479.26	8565684.62	51.2	
23/04/2017	04:56:44	SA1702_ENV05	Still	SA1702_ENV	514	169.7	656436.82	8565655.97	656523.07	8565730.90	114.2	
23/04/2017	04:57:19	SA1702_ENV05	Still	SA1702_ENV	515	169.8	656436.82	8565655.97	656488.85	8565690.40	62.4	
23/04/2017	04:58:08	SA1702_ENV05	Still	SA1702_ENV	516	170.4	656436.82	8565655.97	656495.71	8565695.25	70.8	
23/04/2017	04:58:26	SA1702_ENV05	Still	SA1702_ENV	517	170.5	656436.82	8565655.97	656498.42	8565697.00	74.0	
23/04/2017	04:59:23	SA1702_ENV05	Still	SA1702_ENV	518	170.1	656436.82	8565655.97	656506.26	8565702.33	83.5	
23/04/2017	04:59:53	SA1702_ENV05	Still	SA1702_ENV	519	170.3	656436.82	8565655.97	656510.78	8565705.24	88.9	
23/04/2017	05:00:33	SA1702_ENV05	Still	SA1702_ENV	520	170.3	656436.82	8565655.97	656516.56	8565708.53	95.5	
23/04/2017	05:02:18	SA1702_ENV05	Still	SA1702_ENV	521	168.3	656436.82	8565655.97	656531.33	8565718.73	113.4	
23/04/2017	05:02:42	SA1702_ENV05	Still	SA1702_ENV	522	169.3	656436.82	8565655.97	656534.76	8565721.08	117.6	
23/04/2017	05:03:19	SA1702_ENV05	Still	SA1702_ENV	523	169.7	656436.82	8565655.97	656540.51	8565724.39	124.2	
23/04/2017	05:03:54	SA1702_ENV05	Still	SA1702_ENV	524	168.4	656436.82	8565655.97	656545.33	8565727.97	130.2	
23/04/2017	05:04:24	SA1702_ENV05	Still	SA1702_ENV	525	169.2	656436.82	8565655.97	656550.45	8565730.14	135.7	
23/04/2017	05:04:46	SA1702_ENV05	Still	SA1702_ENV	526	167.6	656436.82	8565655.97	656553.99	8565732.14	139.8	
23/04/2017	05:05:18	SA1702_ENV05	Still	NO STILL	527	167.3	656436.82	8565655.97	656558.86	8565735.82	145.8	
23/04/2017	05:05:29	SA1702_ENV05	Still	NO STILL	528	167.7	656436.82	8565655.97	656560.45	8565736.97	147.8	
23/04/2017	05:06:02	SA1702_ENV05	Still	SA1702_ENV	529	167.2	656436.82	8565655.97	656565.42	8565740.44	153.9	
23/04/2017	05:07:12	SA1702_ENV05	Still	SA1702_ENV	530	167.2	656436.82	8565655.97	656576.36	8565746.62	166.4	
23/04/2017	05:07:48	SA1702_ENV05	Still	SA1702_ENV	531	167.5	656436.82	8565655.97	656581.72	8565750.86	173.2	
23/04/2017	05:09:27	SA1702_ENV05	Still	NO STILL	532	166.7	656436.82	8565655.97	656596.90	8565761.29	191.6	
23/04/2017	05:09:45	SA1702_ENV05	Still	SA1702_ENV	533	167.1	656436.82	8565655.97	656599.38	8565763.20	194.7	
23/04/2017	05:10:41	SA1702_ENV05	Still	SA1702_ENV	534	166.5	656436.82	8565655.97	656608.35	8565769.17	205.5	
23/04/2017	05:11:04	SA1702_ENV05	Still	SA1702_ENV	535	167.5	656436.82	8565655.97	656612.10	8565771.73	210.1	
23/04/2017	11:21:51	SA1702_ENV05A	Still	SA1702_ENV	536	168.2	656436.82	8565655.97	656567.86	8565741.92	156.7	
23/04/2017	11:23:04	SA1702_ENV05A	Still	SA1702_ENV	537	167.8	656436.82	8565655.97	656581.82	8565748.54	172.0	
23/04/2017	11:23:13	SA1702_ENV05A	Still	SA1702_ENV	538	168.5	656436.82	8565655.97	656583.41	8565749.25	173.8	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
23/04/2017	11:23:26	SA1702_ENV05A	Still	SA1702_ENV	539	168.7	656436.82	8565655.97	656586.06	8565750.78	176.8	
23/04/2017	11:24:20	SA1702_ENV05A	Still	SA1702_ENV	540	168.5	656436.82	8565655.97	656595.80	8565756.76	188.2	
23/04/2017	11:24:54	SA1702_ENV05A	Still	SA1702_ENV	541	168.4	656436.82	8565655.97	656600.06	8565759.84	193.5	
23/04/2017	11:25:15	SA1702_ENV05A	Still	SA1702_ENV	542	168.4	656436.82	8565655.97	656602.36	8565761.77	196.5	
23/04/2017	11:25:23	SA1702_ENV05A	Still	SA1702_ENV	543	168.9	656436.82	8565655.97	656603.17	8565762.27	197.4	
23/04/2017	11:25:50	SA1702_ENV05A	Still	SA1702_ENV	544	168.7	656436.82	8565655.97	656606.28	8565764.27	201.1	
23/04/2017	11:25:57	SA1702_ENV05A	Still	SA1702_ENV	545	168.2	656436.82	8565655.97	656607.20	8565764.83	202.2	
23/04/2017	11:26:34	SA1702_ENV05A	Still	SA1702_ENV	546	168.7	656436.82	8565655.97	656611.87	8565768.03	207.8	
23/04/2017	11:27:11	SA1702_ENV05A	Still	SA1702_ENV	547	168.7	656436.82	8565655.97	656617.48	8565770.98	214.2	
23/04/2017	11:27:30	SA1702_ENV05A	Still	SA1702_ENV	548	168.8	656436.82	8565655.97	656620.19	8565772.80	217.4	
23/04/2017	11:28:39	SA1702_ENV05A	Still	SA1702_ENV	549	168.1	656436.82	8565655.97	656632.24	8565780.12	231.5	
23/04/2017	11:29:26	SA1702_ENV05A	Still	SA1702_ENV	550	169.0	656436.82	8565655.97	656641.48	8565785.62	242.3	
23/04/2017	11:29:52	SA1702_ENV05A	Still	SA1702_ENV	551	169.3	656436.82	8565655.97	656646.23	8565788.91	248.0	
23/04/2017	11:30:34	SA1702_ENV05A	Still	SA1702_ENV	552	170.0	656436.82	8565655.97	656653.62	8565793.42	256.7	
23/04/2017	11:30:45	SA1702_ENV05A	Still	SA1702_ENV	553	169.9	656436.82	8565655.97	656655.48	8565794.61	258.9	
23/04/2017	11:31:42	SA1702_ENV05A	Still	SA1702_ENV	554	171.0	656436.82	8565655.97	656664.97	8565800.03	269.8	
23/04/2017	11:31:50	SA1702_ENV05A	Still	SA1702_ENV	555	170.6	656436.82	8565655.97	656666.06	8565800.80	271.2	
23/04/2017	11:32:37	SA1702_ENV05A	Still	SA1702_ENV	556	171.5	656436.82	8565655.97	656671.65	8565805.52	278.4	
23/04/2017	11:32:44	SA1702_ENV05A	Still	SA1702_ENV	557	170.2	656436.82	8565655.97	656672.53	8565806.07	279.4	
23/04/2017	11:32:54	SA1702_ENV05A	Still	SA1702_ENV	558	170.4	656436.82	8565655.97	656673.76	8565806.96	281.0	
23/04/2017	11:33:29	SA1702_ENV05A	Still	SA1702_ENV	559	171.8	656436.82	8565655.97	656677.98	8565810.04	286.2	
23/04/2017	11:33:51	SA1702_ENV05A	Still	SA1702_ENV	560	171.5	656436.82	8565655.97	656681.02	8565812.16	289.9	
23/04/2017	11:34:28	SA1702_ENV05A	Still	SA1702_ENV	561	171.8	656436.82	8565655.97	656686.29	8565815.35	296.0	
23/04/2017	11:35:23	SA1702_ENV05A	Still	SA1702_ENV	562	171.9	656436.82	8565655.97	656695.28	8565820.46	306.4	
23/04/2017	11:36:01	SA1702_ENV05A	Still	SA1702_ENV	563	171.2	656436.82	8565655.97	656701.85	8565824.35	314.0	
23/04/2017	11:36:43	SA1702_ENV05A	Still	SA1702_ENV	564	171.5	656436.82	8565655.97	656708.42	8565828.13	321.6	
23/04/2017	11:37:19	SA1702_ENV05A	Still	SA1702_ENV	565	172.2	656436.82	8565655.97	656714.88	8565831.62	328.9	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
23/04/2017	11:37:57	SA1702_ENV05A	Still	SA1702_ENV	566	172.5	656436.82	8565655.97	656721.55	8565835.35	336.5	
23/04/2017	11:38:13	SA1702_ENV05A	Still	SA1702_ENV	567	171.9	656436.82	8565655.97	656724.05	8565836.91	339.5	
23/04/2017	11:39:16	SA1702_ENV05A	Still	SA1702_ENV	568	172.4	656436.82	8565655.97	656733.53	8565843.21	350.8	
24/04/2017	03:46:54	SA1702_ENV06	Vid				657811.18	8564660.75	657760.40	8564621.35	64.3	
24/04/2017	04:01:01	SA1702_ENV06	Vid				657889.94	8564727.53	657902.12	8564740.05	17.5	
24/04/2017	06:27:28	SA1702_ENV07	Vid				654237.87	8562349.02	654189.32	8562374.58	54.9	
24/04/2017	06:59:10	SA1702_ENV07	Vid				654463.56	8562215.44	654475.98	8562207.63	14.7	
24/04/2017		SA1702_ENV09	Still	SA1702_ENV	NO FIX		629648.25	8554221.82				
24/04/2017	12:08:26	SA1702_ENV09	Still	SA1702_ENV	601	198.3	629648.25	8554221.82	629706.50	8554196.05	63.7	
24/04/2017	12:08:47	SA1702_ENV09	Still	SA1702_ENV	602	198.1	629648.25	8554221.82	629702.24	8554197.24	59.3	
24/04/2017	12:09:00	SA1702_ENV09	Still	SA1702_ENV	603	198.6	629648.25	8554221.82	629700.03	8554197.44	57.2	
24/04/2017	12:09:57	SA1702_ENV09	Still	SA1702_ENV	604	198.0	629648.25	8554221.82	629689.10	8554201.47	45.6	
24/04/2017	12:10:19	SA1702_ENV09	Still	SA1702_ENV	605	197.5	629648.25	8554221.82	629685.08	8554202.92	41.4	
24/04/2017	12:11:18	SA1702_ENV09	Still	SA1702_ENV	606	197.1	629648.25	8554221.82	629675.50	8554206.61	31.2	
24/04/2017	12:12:08	SA1702_ENV09	Still	SA1702_ENV	607	197.4	629648.25	8554221.82	629667.39	8554208.55	23.3	
24/04/2017	12:12:33	SA1702_ENV09	Still	SA1702_ENV	608	199.0	629648.25	8554221.82	629662.94	8554209.55	19.1	
24/04/2017	12:42:49	SA1702_ENV09A	Still	SA1702_ENV	609	199.1	629648.25	8554221.82	629464.80	8554273.87	190.7	
24/04/2017	12:45:15	SA1702_ENV09A	Still	SA1702_ENV	610	199.4	629648.25	8554221.82	629489.96	8554264.14	163.8	
24/04/2017	12:45:32	SA1702_ENV09A	Still	NO STILL	611	197.9	629648.25	8554221.82	629492.78	8554263.19	160.9	
24/04/2017	12:46:22	SA1702_ENV09A	Still	SA1702_ENV	612	199.0	629648.25	8554221.82	629501.37	8554260.97	152.0	
24/04/2017	12:47:54	SA1702_ENV09A	Still	SA1702_ENV	613	198.9	629648.25	8554221.82	629517.08	8554255.37	135.4	
24/04/2017	12:48:43	SA1702_ENV09A	Still	SA1702_ENV	614	198.5	629648.25	8554221.82	629528.85	8554251.48	123.0	
24/04/2017	12:49:48	SA1702_ENV09A	Still	SA1702_ENV	615	198.9	629648.25	8554221.82	629543.11	8554248.52	108.5	
24/04/2017	12:50:34	SA1702_ENV09A	Still	SA1702_ENV	616	198.8	629648.25	8554221.82	629552.04	8554244.34	98.8	
24/04/2017	12:51:19	SA1702_ENV09A	Still	SA1702_ENV	618	198.5	629648.25	8554221.82	629559.94	8554241.70	90.5	
24/04/2017	12:52:07	SA1702_ENV09A	Still	SA1702_ENV	619	198.1	629648.25	8554221.82	629568.78	8554238.06	81.1	
24/04/2017	12:52:37	SA1702_ENV09A	Still	SA1702_ENV	620	197.5	629648.25	8554221.82	629574.36	8554234.78	75.0	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
24/04/2017	12:53:04	SA1702_ENV09A	Still	SA1702_ENV	621	199.0	629648.25	8554221.82	629578.84	8554233.58	70.4	
24/04/2017	12:53:12	SA1702_ENV09A	Still	SA1702_ENV	622	197.8	629648.25	8554221.82	629580.23	8554233.28	69.0	
24/04/2017	12:53:20	SA1702_ENV09A	Still	SA1702_ENV	623	198.7	629648.25	8554221.82	629581.93	8554232.84	67.2	
24/04/2017	12:54:24	SA1702_ENV09A	Still	SA1702_ENV	624	198.8	629648.25	8554221.82	629593.28	8554231.34	55.8	
24/04/2017	12:54:47	SA1702_ENV09A	Still	SA1702_ENV	625	197.5	629648.25	8554221.82	629598.38	8554229.58	50.5	
24/04/2017	12:54:53	SA1702_ENV09A	Still	SA1702_ENV	626	197.8	629648.25	8554221.82	629599.80	8554229.33	49.0	
24/04/2017	12:55:07	SA1702_ENV09A	Still	SA1702_ENV	627	198.1	629648.25	8554221.82	629602.58	8554228.52	46.2	
24/04/2017	12:55:34	SA1702_ENV09A	Still	SA1702_ENV	628	198.6	629648.25	8554221.82	629609.73	8554227.05	38.9	
24/04/2017	12:56:37	SA1702_ENV09A	Still	SA1702_ENV	629	198.4	629648.25	8554221.82	629623.50	8554223.05	24.8	
24/04/2017	12:57:44	SA1702_ENV09A	Still	SA1702_ENV	630	198.6	629648.25	8554221.82	629637.57	8554220.91	10.7	
24/04/2017	12:58:07	SA1702_ENV09A	Still	SA1702_ENV	631	198.5	629648.25	8554221.82	629641.76	8554219.78	6.8	
24/04/2017	12:58:39	SA1702_ENV09A	Still	SA1702_ENV	632	198.6	629648.25	8554221.82	629648.46	8554218.82	3.0	
24/04/2017	12:58:46	SA1702_ENV09A	Still	SA1702_ENV	633	197.8	629648.25	8554221.82	629649.97	8554218.71	3.6	
24/04/2017	12:59:16	SA1702_ENV09A	Still	SA1702_ENV	634	199.5	629648.25	8554221.82	629656.58	8554218.59	8.9	
24/04/2017	22:33:00	SA1702_ENV11	Still	SA1702_ENV	701	214.0	604623.81	8540007.26	604634.27	8540046.13	40.3	
24/04/2017	22:33:33	SA1702_ENV11	Still	SA1702_ENV	702	215.4	604623.81	8540007.26	604630.92	8540041.00	34.5	
24/04/2017	22:34:30	SA1702_ENV11	Still	SA1702_ENV	703	214.9	604623.81	8540007.26	604625.36	8540032.57	25.4	
24/04/2017	22:34:55	SA1702_ENV11	Still	SA1702_ENV	704	215.1	604623.81	8540007.26	604624.43	8540029.33	22.1	
24/04/2017	22:35:49	SA1702_ENV11	Still	SA1702_ENV	705	215.3	604623.81	8540007.26	604622.98	8540022.03	14.8	
24/04/2017	22:36:11	SA1702_ENV11	Still	SA1702_ENV	706	213.6	604623.81	8540007.26	604623.26	8540019.07	11.8	
24/04/2017	22:37:07	SA1702_ENV11	Still	SA1702_ENV	707	213.4	604623.81	8540007.26	604621.54	8540010.90	4.3	
24/04/2017	22:37:59	SA1702_ENV11	Still	SA1702_ENV	708	211.1	604623.81	8540007.26	604620.40	8540002.25	6.1	
24/04/2017	22:39:03	SA1702_ENV11	Still	SA1702_ENV	709	213.6	604623.81	8540007.26	604617.60	8539991.43	17.0	
24/04/2017	22:39:10	SA1702_ENV11	Still	SA1702_ENV	710	212.1	604623.81	8540007.26	604617.28	8539990.32	18.2	
24/04/2017	22:39:50	SA1702_ENV11	Still	SA1702_ENV	711	214.5	604623.81	8540007.26	604614.56	8539982.71	26.2	
24/04/2017	22:40:22	SA1702_ENV11	Still	SA1702_ENV	712	215.1	604623.81	8540007.26	604611.69	8539978.29	31.4	
24/04/2017	22:41:18	SA1702_ENV11	Still	SA1702_ENV	713	213.1	604623.81	8540007.26	604609.39	8539967.83	42.0	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
24/04/2017	22:41:30	SA1702_ENV11	Still	SA1702_ENV	714	212.6	604623.81	8540007.26	604609.21	8539964.78	44.9	
24/04/2017	22:42:52	SA1702_ENV11	Still	SA1702_ENV	715	213.4	604623.81	8540007.26	604604.85	8539951.34	59.1	
24/04/2017	22:43:17	SA1702_ENV11	Still	SA1702_ENV	716	212.4	604623.81	8540007.26	604603.16	8539946.93	63.8	
24/04/2017	22:44:00	SA1702_ENV11	Still	SA1702_ENV	717	212.8	604623.81	8540007.26	604599.47	8539941.01	70.6	
24/04/2017	22:44:53	SA1702_ENV11	Still	SA1702_ENV	718	211.9	604623.81	8540007.26	604595.37	8539933.58	79.0	
24/04/2017	22:45:35	SA1702_ENV11	Still	SA1702_ENV	719	212.2	604623.81	8540007.26	604592.24	8539926.48	86.7	
24/04/2017	22:46:32	SA1702_ENV11	Still	SA1702_ENV	720	214.0	604623.81	8540007.26	604590.25	8539915.33	97.9	
24/04/2017	22:47:26	SA1702_ENV11	Still	SA1702_ENV	721	213.4	604623.81	8540007.26	604586.57	8539907.29	106.7	
24/04/2017	22:48:04	SA1702_ENV11	Still	SA1702_ENV	722	213.6	604623.81	8540007.26	604583.89	8539901.98	112.6	
24/04/2017	22:49:30	SA1702_ENV11	Still	SA1702_ENV	723	214.2	604623.81	8540007.26	604577.34	8539888.24	127.8	
24/04/2017	22:49:48	SA1702_ENV11	Still	SA1702_ENV	724	214.1	604623.81	8540007.26	604575.55	8539884.65	131.8	
24/04/2017	22:50:37	SA1702_ENV11	Still	SA1702_ENV	725	214.4	604623.81	8540007.26	604572.72	8539876.80	140.1	
24/04/2017	22:50:50	SA1702_ENV11	Still	SA1702_ENV	726	214.5	604623.81	8540007.26	604572.02	8539875.12	141.9	
24/04/2017	22:51:01	SA1702_ENV11	Still	SA1702_ENV	727	214.7	604623.81	8540007.26	604571.01	8539873.46	143.8	
24/04/2017	22:51:23	SA1702_ENV11	Still	SA1702_ENV	728	214.6	604623.81	8540007.26	604570.27	8539869.47	147.8	
24/04/2017	22:51:34	SA1702_ENV11	Still	SA1702_ENV	729	214.8	604623.81	8540007.26	604569.48	8539867.88	149.6	
24/04/2017	22:51:49	SA1702_ENV11	Still	SA1702_ENV	730	215.2	604623.81	8540007.26	604569.20	8539865.30	152.1	
24/04/2017	22:52:07	SA1702_ENV11	Still	SA1702_ENV	731	214.6	604623.81	8540007.26	604568.39	8539861.62	155.8	
24/04/2017	22:52:25	SA1702_ENV11	Still	SA1702_ENV	732	214.4	604623.81	8540007.26	604567.93	8539857.98	159.4	
24/04/2017	22:53:06	SA1702_ENV11	Still	SA1702_ENV	733	214.7	604623.81	8540007.26	604565.22	8539851.82	166.1	
24/04/2017	22:53:33	SA1702_ENV11	Still	SA1702_ENV	734	213.6	604623.81	8540007.26	604563.03	8539846.94	171.5	
24/04/2017	22:54:08	SA1702_ENV11	Still	SA1702_ENV	735	214.2	604623.81	8540007.26	604560.22	8539841.35	177.7	
25/04/2017	00:49:22	SA1702_ENV12	Still	SA1702_ENV	801	204.1	602414.35	8537228.10	602452.22	8537279.87	64.1	
25/04/2017	00:50:46	SA1702_ENV12	Still	SA1702_ENV	802	204.5	602414.35	8537228.10	602446.91	8537270.51	53.5	
25/04/2017	00:51:22	SA1702_ENV12	Still	SA1702_ENV	803	203.8	602414.35	8537228.10	602442.51	8537264.49	46.0	
25/04/2017	00:52:12	SA1702_ENV12	Still	SA1702_ENV	804	204.9	602414.35	8537228.10	602436.72	8537255.86	35.7	
25/04/2017	00:53:09	SA1702_ENV12	Still	SA1702_ENV	805	204.4	602414.35	8537228.10	602431.30	8537248.19	26.3	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
25/04/2017	00:53:31	SA1702_ENV12	Still	SA1702_ENV	806	205.4	602414.35	8537228.10	602429.37	8537245.43	22.9	
25/04/2017	00:54:08	SA1702_ENV12	Still	SA1702_ENV	807	204.2	602414.35	8537228.10	602426.62	8537240.94	17.8	
25/04/2017	00:54:52	SA1702_ENV12	Still	SA1702_ENV	808	205.1	602414.35	8537228.10	602422.91	8537235.27	11.2	
25/04/2017	00:55:05	SA1702_ENV12	Still	SA1702_ENV	809	205.0	602414.35	8537228.10	602421.70	8537233.03	8.9	
25/04/2017	00:55:55	SA1702_ENV12	Still	SA1702_ENV	810	204.6	602414.35	8537228.10	602417.02	8537225.70	3.6	
25/04/2017	00:56:07	SA1702_ENV12	Still	SA1702_ENV	811	204.5	602414.35	8537228.10	602415.80	8537223.78	4.6	
25/04/2017	00:57:02	SA1702_ENV12	Still	SA1702_ENV	812	205.1	602414.35	8537228.10	602409.83	8537214.99	13.9	
25/04/2017	00:57:21	SA1702_ENV12	Still	SA1702_ENV	813	204.4	602414.35	8537228.10	602407.98	8537212.00	17.3	
25/04/2017	00:57:33	SA1702_ENV12	Still	SA1702_ENV	814	205.2	602414.35	8537228.10	602406.81	8537209.84	19.7	
25/04/2017	00:57:49	SA1702_ENV12	Still	SA1702_ENV	815	204.1	602414.35	8537228.10	602404.90	8537207.36	22.8	
25/04/2017	00:58:23	SA1702_ENV12	Still	SA1702_ENV	816	205.6	602414.35	8537228.10	602401.56	8537201.69	29.3	
25/04/2017	00:58:50	SA1702_ENV12	Still	SA1702_ENV	817	206.4	602414.35	8537228.10	602398.95	8537197.62	34.1	
25/04/2017	00:59:37	SA1702_ENV12	Still	SA1702_ENV	818	206.2	602414.35	8537228.10	602394.83	8537190.42	42.4	
25/04/2017	00:59:52	SA1702_ENV12	Still	SA1702_ENV	819	204.7	602414.35	8537228.10	602393.38	8537188.10	45.2	
25/04/2017	01:00:26	SA1702_ENV12	Still	SA1702_ENV	820	205.7	602414.35	8537228.10	602390.27	8537183.51	50.7	
25/04/2017	01:01:00	SA1702_ENV12	Still	SA1702_ENV	821	204.8	602414.35	8537228.10	602387.55	8537178.75	56.2	
25/04/2017	01:01:31	SA1702_ENV12	Still	SA1702_ENV	822	205.7	602414.35	8537228.10	602384.79	8537174.57	61.1	
25/04/2017	01:02:04	SA1702_ENV12	Still	SA1702_ENV	823	203.9	602414.35	8537228.10	602381.47	8537169.69	67.0	
25/04/2017	01:02:57	SA1702_ENV12	Still	SA1702_ENV	824	205.1	602414.35	8537228.10	602375.86	8537160.59	77.7	
25/04/2017	01:03:46	SA1702_ENV12	Still	SA1702_ENV	825	205.2	602414.35	8537228.10	602370.25	8537152.35	87.6	
25/04/2017	01:04:32	SA1702_ENV12	Still	SA1702_ENV	826	205.3	602414.35	8537228.10	602365.15	8537145.24	96.4	
25/04/2017	01:05:11	SA1702_ENV12	Still	SA1702_ENV	827	205.5	602414.35	8537228.10	602360.64	8537138.99	104.0	
25/04/2017	01:06:00	SA1702_ENV12	Still	SA1702_ENV	828	205.5	602414.35	8537228.10	602355.80	8537132.65	112.0	
25/04/2017	01:06:22	SA1702_ENV12	Still	SA1702_ENV	829	205.7	602414.35	8537228.10	602353.61	8537129.93	115.4	
25/04/2017	01:06:52	SA1702_ENV12	Still	SA1702_ENV	830	205.8	602414.35	8537228.10	602351.07	8537125.91	120.2	
25/04/2017	01:07:11	SA1702_ENV12	Still	SA1702_ENV	831	206.3	602414.35	8537228.10	602349.81	8537123.22	123.1	
25/04/2017	01:07:36	SA1702_ENV12	Still	SA1702_ENV	832	205.2	602414.35	8537228.10	602347.59	8537119.47	127.5	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
25/04/2017	01:08:23	SA1702_ENV12	Still	SA1702_ENV	833	205.8	602414.35	8537228.10	602344.02	8537112.50	135.3	
25/04/2017	01:09:07	SA1702_ENV12	Still	SA1702_ENV	834	206.7	602414.35	8537228.10	602340.02	8537105.87	143.1	
25/04/2017	01:09:48	SA1702_ENV12	Still	SA1702_ENV	835	206.4	602414.35	8537228.10	602336.42	8537099.52	150.3	
25/04/2017	01:10:22	SA1702_ENV12	Still	SA1702_ENV	836	205.2	602414.35	8537228.10	602333.30	8537094.08	156.6	
25/04/2017	01:10:55	SA1702_ENV12	Still	SA1702_ENV	837	204.3	602414.35	8537228.10	602330.03	8537088.96	162.7	
25/04/2017	01:11:43	SA1702_ENV12	Still	SA1702_ENV	838	205.4	602414.35	8537228.10	602325.68	8537081.58	171.3	
25/04/2017	01:12:31	SA1702_ENV12	Still	SA1702_ENV	839	206.0	602414.35	8537228.10	602321.35	8537073.99	180.0	
25/04/2017	01:12:39	SA1702_ENV12	Still	SA1702_ENV	840	205.8	602414.35	8537228.10	602320.53	8537072.63	181.6	
25/04/2017	01:13:39	SA1702_ENV12	Still	SA1702_ENV	841	206.4	602414.35	8537228.10	602315.51	8537063.57	191.9	
25/04/2017	01:14:23	SA1702_ENV12	Still	SA1702_ENV	842	207.4	602414.35	8537228.10	602310.48	8537055.42	201.5	
25/04/2017	01:15:02	SA1702_ENV12	Still	SA1702_ENV	843	205.8	602414.35	8537228.10	602305.96	8537048.94	209.4	
25/04/2017	01:15:30	SA1702_ENV12	Still	SA1702_ENV	844	205.9	602414.35	8537228.10	602302.47	8537044.77	214.8	
25/04/2017	01:16:15	SA1702_ENV12	Still	SA1702_ENV	845	206.1	602414.35	8537228.10	602297.79	8537038.97	222.2	
25/04/2017	01:16:48	SA1702_ENV12	Still	SA1702_ENV	846	206.1	602414.35	8537228.10	602294.48	8537034.44	227.8	
25/04/2017	01:17:38	SA1702_ENV12	Still	SA1702_ENV	847	206.2	602414.35	8537228.10	602290.36	8537027.51	235.8	
25/04/2017	01:17:50	SA1702_ENV12	Still	SA1702_ENV	848	206.6	602414.35	8537228.10	602289.28	8537025.58	238.0	
25/04/2017	01:18:35	SA1702_ENV12	Still	SA1702_ENV	849	206.3	602414.35	8537228.10	602285.08	8537018.01	246.7	
25/04/2017	04:16:25	SA1702_ENV13	Still	SA1702_ENV	901	207.7	597069.10	8533025.79	597038.42	8533093.72	74.5	
25/04/2017	04:17:10	SA1702_ENV13	Still	SA1702_ENV	902	205.5	597069.10	8533025.79	597037.92	8533086.86	68.6	
25/04/2017	04:17:56	SA1702_ENV13	Still	SA1702_ENV	903	205.4	597069.10	8533025.79	597037.62	8533079.92	62.6	
25/04/2017	04:19:27	SA1702_ENV13	Still	SA1702_ENV	904	205.8	597069.10	8533025.79	597039.49	8533069.06	52.4	
25/04/2017	04:21:07	SA1702_ENV13	Still	SA1702_ENV	905	204.7	597069.10	8533025.79	597040.37	8533054.94	40.9	
25/04/2017	04:22:00	SA1702_ENV13	Still	SA1702_ENV	906	204.5	597069.10	8533025.79	597043.16	8533044.50	32.0	
25/04/2017	04:23:39	SA1702_ENV13	Still	SA1702_ENV	907	204.5	597069.10	8533025.79	597047.05	8533025.31	22.1	
25/04/2017	04:24:46	SA1702_ENV13	Still	SA1702_ENV	908	205.4	597069.10	8533025.79	597048.49	8533014.06	23.7	
25/04/2017	04:25:42	SA1702_ENV13	Still	SA1702_ENV	909	204.3	597069.10	8533025.79	597049.10	8533004.43	29.3	
25/04/2017	04:26:19	SA1702_ENV13	Still	SA1702_ENV	910	204.2	597069.10	8533025.79	597049.96	8532998.23	33.6	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
25/04/2017	04:27:05	SA1702_ENV13	Still	SA1702_ENV	911	202.7	597069.10	8533025.79	597051.15	8532990.93	39.2	
25/04/2017	04:28:42	SA1702_ENV13	Still	SA1702_ENV	912	204.5	597069.10	8533025.79	597053.55	8532976.00	52.2	
25/04/2017	04:29:30	SA1702_ENV13	Still	SA1702_ENV	913	204.5	597069.10	8533025.79	597055.76	8532967.28	60.0	
25/04/2017	04:29:47	SA1702_ENV13	Still	SA1702_ENV	914	204.2	597069.10	8533025.79	597057.20	8532963.53	63.4	
25/04/2017	04:30:43	SA1702_ENV13	Still	SA1702_ENV	915	204.5	597069.10	8533025.79	597060.91	8532952.29	74.0	
25/04/2017	04:31:08	SA1702_ENV13	Still	SA1702_ENV	916	204.7	597069.10	8533025.79	597062.07	8532948.12	78.0	
25/04/2017	04:31:31	SA1702_ENV13	Still	SA1702_ENV	917	204.4	597069.10	8533025.79	597062.92	8532944.16	81.9	
25/04/2017	04:31:50	SA1702_ENV13	Still	SA1702_ENV	918	204.0	597069.10	8533025.79	597063.19	8532940.69	85.3	
25/04/2017	04:32:24	SA1702_ENV13	Still	SA1702_ENV	919	204.3	597069.10	8533025.79	597065.12	8532935.65	90.2	
25/04/2017	04:33:02	SA1702_ENV13	Still	SA1702_ENV	920	203.9	597069.10	8533025.79	597067.02	8532929.07	96.7	
25/04/2017	04:33:36	SA1702_ENV13	Still	SA1702_ENV	921	203.5	597069.10	8533025.79	597068.35	8532923.18	102.6	
25/04/2017	04:34:41	SA1702_ENV13	Still	SA1702_ENV	922	203.0	597069.10	8533025.79	597071.84	8532912.62	113.2	
25/04/2017	04:35:32	SA1702_ENV13	Still	SA1702_ENV	923	202.5	597069.10	8533025.79	597073.70	8532905.03	120.9	
25/04/2017	04:35:49	SA1702_ENV13	Still	SA1702_ENV	924	202.8	597069.10	8533025.79	597075.14	8532902.12	123.8	
25/04/2017	04:37:51	SA1702_ENV13	Still	SA1702_ENV	925	202.7	597069.10	8533025.79	597084.72	8532890.72	136.0	
25/04/2017	04:39:15	SA1702_ENV13	Still	SA1702_ENV	926	203.3	597069.10	8533025.79	597093.85	8532888.70	139.3	
25/04/2017	04:40:18	SA1702_ENV13	Still	SA1702_ENV	927	202.8	597069.10	8533025.79	597097.07	8532879.77	148.7	
25/04/2017	04:41:26	SA1702_ENV13	Still	SA1702_ENV	928	203.5	597069.10	8533025.79	597101.73	8532869.41	159.7	
25/04/2017	04:42:32	SA1702_ENV13	Still	SA1702_ENV	929	204.5	597069.10	8533025.79	597105.85	8532859.40	170.4	
25/04/2017	04:43:03	SA1702_ENV13	Still	SA1702_ENV	930	205.8	597069.10	8533025.79	597108.41	8532854.36	175.9	
25/04/2017	04:43:53	SA1702_ENV13	Still	SA1702_ENV	931	206.4	597069.10	8533025.79	597111.89	8532844.49	186.3	
25/04/2017	04:44:42	SA1702_ENV13	Still	SA1702_ENV	932	205.2	597069.10	8533025.79	597114.72	8532835.56	195.6	
25/04/2017	04:45:26	SA1702_ENV13	Still	SA1702_ENV	933	204.4	597069.10	8533025.79	597116.40	8532827.32	204.0	
25/04/2017	09:15:18	SA1702_ENV14	Still	SA1702_ENV	1001	209.1	585583.41	8524299.65	585599.53	8524334.59	38.5	
25/04/2017	09:16:18	SA1702_ENV14	Still	SA1702_ENV	1002	210.2	585583.41	8524299.65	585599.17	8524327.21	31.7	
25/04/2017	09:17:08	SA1702_ENV14	Still	SA1702_ENV	1003	209.5	585583.41	8524299.65	585597.04	8524322.95	27.0	
25/04/2017	09:18:22	SA1702_ENV14	Still	SA1702_ENV	1004	210.2	585583.41	8524299.65	585591.51	8524318.09	20.1	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
25/04/2017	09:18:38	SA1702_ENV14	Still	SA1702_ENV	1005	208.8	585583.41	8524299.65	585591.06	8524316.62	18.6	
25/04/2017	09:19:51	SA1702_ENV14	Still	SA1702_ENV	1006	209.7	585583.41	8524299.65	585587.22	8524306.87	8.2	
25/04/2017	09:20:21	SA1702_ENV14	Still	SA1702_ENV	1007	209.3	585583.41	8524299.65	585585.07	8524302.97	3.7	
25/04/2017	09:21:00	SA1702_ENV14	Still	SA1702_ENV	1008	210.3	585583.41	8524299.65	585582.97	8524297.51	2.2	
25/04/2017	09:22:14	SA1702_ENV14	Still	SA1702_ENV	1009	210.0	585583.41	8524299.65	585579.24	8524289.21	11.2	
25/04/2017	09:22:52	SA1702_ENV14	Still	SA1702_ENV	1010	211.2	585583.41	8524299.65	585577.71	8524282.94	17.7	
25/04/2017	09:23:06	SA1702_ENV14	Still	SA1702_ENV	1011	211.6	585583.41	8524299.65	585576.68	8524281.35	19.5	
25/04/2017	09:23:16	SA1702_ENV14	Still	SA1702_ENV	1012	211.4	585583.41	8524299.65	585576.28	8524279.80	21.1	
25/04/2017	09:23:36	SA1702_ENV14	Still	SA1702_ENV	1013	212.1	585583.41	8524299.65	585576.02	8524276.03	24.7	
25/04/2017	09:23:46	SA1702_ENV14	Still	SA1702_ENV	1014	211.5	585583.41	8524299.65	585575.24	8524274.48	26.5	
25/04/2017	09:24:08	SA1702_ENV14	Still	SA1702_ENV	1015	212.1	585583.41	8524299.65	585574.51	8524270.64	30.3	
25/04/2017	09:24:30	SA1702_ENV14	Still	SA1702_ENV	1016	210.8	585583.41	8524299.65	585574.57	8524267.28	33.6	
25/04/2017	09:25:02	SA1702_ENV14	Still	SA1702_ENV	1017	208.7	585583.41	8524299.65	585574.46	8524260.18	40.5	
25/04/2017	09:26:00	SA1702_ENV14	Still	SA1702_ENV	1018	208.9	585583.41	8524299.65	585571.71	8524249.86	51.2	
25/04/2017	09:27:22	SA1702_ENV14	Still	SA1702_ENV	1019	209.7	585583.41	8524299.65	585569.44	8524237.37	63.8	
25/04/2017	09:29:31	SA1702_ENV14	Still	SA1702_ENV	1020	211.2	585583.41	8524299.65	585566.35	8524220.99	80.5	
25/04/2017	09:30:22	SA1702_ENV14	Still	SA1702_ENV	1021	212.7	585583.41	8524299.65	585563.97	8524214.21	87.6	
25/04/2017	09:31:17	SA1702_ENV14	Still	SA1702_ENV	1022	210.1	585583.41	8524299.65	585562.39	8524203.71	98.2	
25/04/2017	09:31:41	SA1702_ENV14	Still	SA1702_ENV	1023	209.3	585583.41	8524299.65	585561.50	8524198.68	103.3	
25/04/2017	09:32:16	SA1702_ENV14	Still	SA1702_ENV	1024	209.1	585583.41	8524299.65	585559.87	8524191.67	110.5	
25/04/2017	09:33:07	SA1702_ENV14	Still	SA1702_ENV	1025	210.1	585583.41	8524299.65	585557.11	8524182.87	119.7	
25/04/2017	09:33:30	SA1702_ENV14	Still	SA1702_ENV	1026	210.0	585583.41	8524299.65	585555.78	8524178.85	123.9	
25/04/2017	09:34:06	SA1702_ENV14	Still	SA1702_ENV	1027	210.8	585583.41	8524299.65	585554.14	8524173.29	129.7	
25/04/2017	09:34:45	SA1702_ENV14	Still	SA1702_ENV	1028	209.7	585583.41	8524299.65	585552.44	8524166.81	136.4	
25/04/2017	13:10:05	SA1702_ENV15	Still	SA1702_ENV	1101	210.5	579249.33	8519395.76	579251.97	8519441.41	45.7	
25/04/2017	13:11:06	SA1702_ENV15	Still	SA1702_ENV	1102	211.3	579249.33	8519395.76	579254.29	8519429.56	34.2	
25/04/2017	13:11:43	SA1702_ENV15	Still	SA1702_ENV	1103	212.5	579249.33	8519395.76	579254.50	8519423.18	27.9	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transcect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
25/04/2017	13:12:28	SA1702_ENV15	Still	SA1702_ENV	1104	211.7	579249.33	8519395.76	579253.21	8519416.15	20.7	
25/04/2017	13:12:41	SA1702_ENV15	Still	SA1702_ENV	1105	211.5	579249.33	8519395.76	579253.29	8519413.97	18.6	
25/04/2017	13:12:54	SA1702_ENV15	Still	SA1702_ENV	1106	210.4	579249.33	8519395.76	579252.74	8519411.87	16.5	
25/04/2017	13:13:29	SA1702_ENV15	Still	SA1702_ENV	1107	210.9	579249.33	8519395.76	579252.95	8519408.92	13.6	
25/04/2017	13:14:01	SA1702_ENV15	Still	SA1702_ENV	1108	212.7	579249.33	8519395.76	579253.57	8519406.36	11.4	
25/04/2017	13:14:35	SA1702_ENV15	Still	SA1702_ENV	1109	212.6	579249.33	8519395.76	579253.89	8519400.28	6.4	
25/04/2017	13:14:41	SA1702_ENV15	Still	SA1702_ENV	1110	210.8	579249.33	8519395.76	579253.79	8519399.09	5.6	
25/04/2017	13:14:52	SA1702_ENV15	Still	SA1702_ENV	1111	211.3	579249.33	8519395.76	579253.69	8519397.05	4.5	
25/04/2017	13:15:02	SA1702_ENV15	Still	SA1702_ENV	1112	211.5	579249.33	8519395.76	579253.66	8519395.81	4.3	
25/04/2017	13:15:14	SA1702_ENV15	Still	SA1702_ENV	1113	211.7	579249.33	8519395.76	579253.70	8519393.53	4.9	
25/04/2017	13:15:24	SA1702_ENV15	Still	SA1702_ENV	1114	211.8	579249.33	8519395.76	579254.16	8519391.78	6.3	
25/04/2017	13:15:40	SA1702_ENV15	Still	SA1702_ENV	1115	211.5	579249.33	8519395.76	579255.06	8519388.96	8.9	
25/04/2017	13:15:57	SA1702_ENV15	Still	SA1702_ENV	1116	211.3	579249.33	8519395.76	579255.84	8519385.69	12.0	
25/04/2017	13:16:06	SA1702_ENV15	Still	SA1702_ENV	1117	212.7	579249.33	8519395.76	579256.43	8519383.62	14.1	
25/04/2017	13:16:22	SA1702_ENV15	Still	SA1702_ENV	1118	212.4	579249.33	8519395.76	579257.07	8519380.39	17.2	
25/04/2017	13:17:18	SA1702_ENV15	Still	SA1702_ENV	1119	213.8	579249.33	8519395.76	579258.64	8519372.87	24.7	
25/04/2017	13:18:01	SA1702_ENV15	Still	SA1702_ENV	1120	214.4	579249.33	8519395.76	579257.99	8519365.96	31.0	
25/04/2017	13:18:14	SA1702_ENV15	Still	SA1702_ENV	1121	214.5	579249.33	8519395.76	579258.68	8519363.65	33.4	
25/04/2017	13:19:18	SA1702_ENV15	Still	SA1702_ENV	1122	211.0	579249.33	8519395.76	579261.46	8519353.77	43.7	
25/04/2017	13:20:36	SA1702_ENV15	Still	SA1702_ENV	1123	211.2	579249.33	8519395.76	579267.36	8519336.85	61.6	
25/04/2017	13:21:11	SA1702_ENV15	Still	SA1702_ENV	1124	211.4	579249.33	8519395.76	579270.29	8519330.08	68.9	
25/04/2017	13:21:54	SA1702_ENV15	Still	SA1702_ENV	1125	210.7	579249.33	8519395.76	579272.66	8519321.29	78.0	
25/04/2017	13:22:38	SA1702_ENV15	Still	SA1702_ENV	1126	210.9	579249.33	8519395.76	579276.99	8519311.13	89.0	
25/04/2017	13:23:53	SA1702_ENV15	Still	SA1702_ENV	1127	211.5	579249.33	8519395.76	579283.40	8519293.87	107.4	
25/04/2017	13:24:40	SA1702_ENV15	Still	SA1702_ENV	1128	211.1	579249.33	8519395.76	579286.61	8519281.20	120.5	
25/04/2017	13:25:12	SA1702_ENV15	Still	SA1702_ENV	1129	210.5	579249.33	8519395.76	579289.55	8519274.71	127.6	
25/04/2017	13:25:54	SA1702_ENV15	Still	SA1702_ENV	1130	211.7	579249.33	8519395.76	579292.46	8519268.08	134.8	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
25/04/2017	13:26:30	SA1702_ENV15	Still	SA1702_ENV	1131	212.1	579249.33	8519395.76	579293.80	8519259.13	143.7	
25/04/2017	13:26:59	SA1702_ENV15	Still	SA1702_ENV	1132	211.5	579249.33	8519395.76	579296.69	8519252.95	150.5	
25/04/2017	13:28:41	SA1702_ENV15	Still	SA1702_ENV	1133	211.8	579249.33	8519395.76	579304.08	8519251.37	154.4	
25/04/2017	13:29:41	SA1702_ENV15	Still	SA1702_ENV	1134	211.0	579249.33	8519395.76	579305.40	8519246.14	159.8	
25/04/2017	13:30:24	SA1702_ENV15	Still	SA1702_ENV	1135	211.6	579249.33	8519395.76	579308.41	8519237.63	168.8	
25/04/2017	13:30:48	SA1702_ENV15	Still	SA1702_ENV	1136	211.5	579249.33	8519395.76	579310.70	8519231.72	175.1	
26/04/2017	00:44:04	SA1702_ENV18	Still	SA1702_ENV	1201	227.6	559546.59	8500658.78	559575.263	8500695.911	46.9	
26/04/2017	00:44:38	SA1702_ENV18	Still	SA1702_ENV	1202	228.3	559546.59	8500658.78	559572.408	8500692.719	42.6	
26/04/2017	00:45:32	SA1702_ENV18	Still	SA1702_ENV	1203	228.0	559546.59	8500658.78	559567.835	8500689.915	37.7	
26/04/2017	00:45:44	SA1702_ENV18	Still	SA1702_ENV	1204	227.7	559546.59	8500658.78	559567.06	8500689.007	36.5	
26/04/2017	00:46:18	SA1702_ENV18	Still	SA1702_ENV	1205	228.4	559546.59	8500658.78	559564.457	8500685.978	32.5	
26/04/2017	00:46:50	SA1702_ENV18	Still	SA1702_ENV	1206	228.0	559546.59	8500658.78	559562.221	8500683.414	29.2	
26/04/2017	00:47:14	SA1702_ENV18	Still	SA1702_ENV	1207	228.5	559546.59	8500658.78	559560.569	8500681.364	26.6	
26/04/2017	00:47:48	SA1702_ENV18	Still	SA1702_ENV	1208	227.8	559546.59	8500658.78	559558.216	8500678.717	23.1	
26/04/2017	00:48:00	SA1702_ENV18	Still	SA1702_ENV	1209	227.6	559546.59	8500658.78	559557.486	8500678.005	22.1	
26/04/2017	00:48:17	SA1702_ENV18	Still	SA1702_ENV	1210	228.8	559546.59	8500658.78	559556.17	8500676.885	20.5	
26/04/2017	00:48:35	SA1702_ENV18	Still	NO STILL	1211	227.6	559546.59	8500658.78	559554.742	8500675.992	19.0	
26/04/2017	00:48:55	SA1702_ENV18	Still	SA1702_ENV	1212	228.3	559546.59	8500658.78	559552.647	8500674.704	17.0	
26/04/2017	00:49:22	SA1702_ENV18	Still	SA1702_ENV	1213	228.1	559546.59	8500658.78	559550.232	8500672.513	14.2	
26/04/2017	00:50:04	SA1702_ENV18	Still	SA1702_ENV	1214	227.8	559546.59	8500658.78	559546.313	8500668.752	10.0	
26/04/2017	00:51:29	SA1702_ENV18	Still	SA1702_ENV	1215	228.3	559546.59	8500658.78	559539.551	8500661.366	7.5	
26/04/2017	00:52:46	SA1702_ENV18	Still	SA1702_ENV	1216	228.2	559546.59	8500658.78	559533.96	8500654.219	13.4	
26/04/2017	00:52:57	SA1702_ENV18	Still	SA1702_ENV	1217	228.0	559546.59	8500658.78	559533.022	8500653.287	14.6	
26/04/2017	00:53:29	SA1702_ENV18	Still	SA1702_ENV	1218	228.5	559546.59	8500658.78	559529.721	8500650.622	18.7	
26/04/2017	00:53:42	SA1702_ENV18	Still	SA1702_ENV	1219	228.2	559546.59	8500658.78	559528.315	8500649.01	20.7	
26/04/2017	00:54:24	SA1702_ENV18	Still	SA1702_ENV	1220	227.6	559546.59	8500658.78	559523.847	8500645.674	26.2	
26/04/2017	00:55:29	SA1702_ENV18	Still	SA1702_ENV	1221	228.0	559546.59	8500658.78	559517.536	8500640.147	34.5	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	00:56:21	SA1702_ENV18	Still	SA1702_ENV	1222	226.5	559546.59	8500658.78	559511.888	8500635.191	42.0	
26/04/2017	00:56:36	SA1702_ENV18	Still	SA1702_ENV	1223	226.9	559546.59	8500658.78	559510.398	8500634.02	43.8	
26/04/2017	00:57:05	SA1702_ENV18	Still	SA1702_ENV	1224	227.2	559546.59	8500658.78	559507.409	8500630.735	48.2	
26/04/2017	00:57:28	SA1702_ENV18	Still	SA1702_ENV	1225	227.2	559546.59	8500658.78	559505.409	8500628.686	51.0	
26/04/2017	00:58:42	SA1702_ENV18	Still	SA1702_ENV	1226	226.2	559546.59	8500658.78	559496.412	8500620.797	62.9	
26/04/2017	00:59:05	SA1702_ENV18	Still	SA1702_ENV	1227	225.7	559546.59	8500658.78	559493.154	8500618.538	66.9	
26/04/2017	00:59:16	SA1702_ENV18	Still	SA1702_ENV	1228	225.1	559546.59	8500658.78	559491.865	8500617.827	68.3	
26/04/2017	00:59:26	SA1702_ENV18	Still	SA1702_ENV	1229	225.0	559546.59	8500658.78	559490.718	8500616.529	70.0	
26/04/2017	00:59:39	SA1702_ENV18	Still	SA1702_ENV	1230	224.2	559546.59	8500658.78	559489.22	8500615.157	72.1	
26/04/2017	00:59:49	SA1702_ENV18	Still	SA1702_ENV	1231	223.9	559546.59	8500658.78	559487.765	8500613.955	74.0	
26/04/2017	01:00:00	SA1702_ENV18	Still	SA1702_ENV	1232	223.4	559546.59	8500658.78	559486.099	8500612.707	76.0	
26/04/2017	01:00:16	SA1702_ENV18	Still	SA1702_ENV	1233	223.3	559546.59	8500658.78	559484.048	8500611.189	78.6	
26/04/2017	01:00:44	SA1702_ENV18	Still	SA1702_ENV	1234	222.9	559546.59	8500658.78	559480.844	8500609.247	82.3	
26/04/2017	01:00:44	SA1702_ENV18	Still	NO STILL	1235	222.9	559546.59	8500658.78	559480.844	8500609.247	82.3	
26/04/2017	01:01:00	SA1702_ENV18	Still	SA1702_ENV	1236	222.8	559546.59	8500658.78	559478.485	8500609.021	84.3	
26/04/2017	01:01:37	SA1702_ENV18	Still	SA1702_ENV	1237	222.0	559546.59	8500658.78	559473.778	8500607.365	89.1	
26/04/2017	01:02:03	SA1702_ENV18	Still	SA1702_ENV	1238	222.7	559546.59	8500658.78	559471.01	8500604.772	92.9	
26/04/2017	01:03:18	SA1702_ENV18	Still	SA1702_ENV	1239	222.7	559546.59	8500658.78	559462.644	8500597.835	103.7	
26/04/2017	01:03:47	SA1702_ENV18	Still	SA1702_ENV	1240	223.3	559546.59	8500658.78	559459.567	8500595.606	107.5	
26/04/2017	01:04:43	SA1702_ENV18	Still	SA1702_ENV	1241	224.0	559546.59	8500658.78	559453.761	8500591.335	114.7	
26/04/2017	01:04:52	SA1702_ENV18	Still	SA1702_ENV	1242	223.5	559546.59	8500658.78	559452.849	8500590.757	115.8	
26/04/2017	01:05:25	SA1702_ENV18	Still	SA1702_ENV	1243	224.7	559546.59	8500658.78	559448.637	8500587.534	121.1	
26/04/2017	01:05:51	SA1702_ENV18	Still	SA1702_ENV	1244	225.6	559546.59	8500658.78	559445.482	8500585.496	124.9	
26/04/2017	01:06:56	SA1702_ENV18	Still	SA1702_ENV	1245	226.2	559546.59	8500658.78	559438.28	8500581.51	133.0	
26/04/2017	01:07:43	SA1702_ENV18	Still	SA1702_ENV	1246	226.2	559546.59	8500658.78	559470.843	8500538.776	141.9	
26/04/2017	01:07:58	SA1702_ENV18	Still	SA1702_ENV	1247	226.3	559546.59	8500658.78	559431.729	8500577.952	140.4	
26/04/2017	01:08:40	SA1702_ENV18	Still	SA1702_ENV	1248	227.1	559546.59	8500658.78	559427.261	8500575.282	145.6	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	01:09:13	SA1702_ENV18	Still	SA1702_ENV	1249	227.7	559546.59	8500658.78	559423.605	8500573.015	149.9	
26/04/2017	01:09:39	SA1702_ENV18	Still	SA1702_ENV	1250	227.8	559546.59	8500658.78	559420.813	8500570.905	153.4	
26/04/2017	01:10:21	SA1702_ENV18	Still	SA1702_ENV	1251	228.6	559546.59	8500658.78	559415.909	8500567.545	159.4	
26/04/2017	01:11:20	SA1702_ENV18	Still	SA1702_ENV	1252	229.0	559546.59	8500658.78	559409.648	8500562.984	167.1	
26/04/2017	01:11:58	SA1702_ENV18	Still	SA1702_ENV	1253	228.3	559546.59	8500658.78	559405.606	8500559.908	172.2	
26/04/2017	01:12:42	SA1702_ENV18	Still	SA1702_ENV	1254	228.9	559546.59	8500658.78	559400.567	8500555.209	179.0	
26/04/2017	02:11:19	SA1702_ENV19	Still	SA1702_ENV	1301	235.9	558524.61	8499087.33	558592.51	8499070.52	70.0	
26/04/2017	02:12:27	SA1702_ENV19	Still	SA1702_ENV	1302	235.5	558524.61	8499087.33	558589.07	8499070.69	66.6	
26/04/2017	02:13:29	SA1702_ENV19	Still	SA1702_ENV	1303	237.0	558524.61	8499087.33	558579.83	8499072.97	57.1	
26/04/2017	02:13:52	SA1702_ENV19	Still	SA1702_ENV	1304	236.4	558524.61	8499087.33	558575.75	8499074.41	52.7	
26/04/2017	02:14:45	SA1702_ENV19	Still	SA1702_ENV	1305	236.8	558524.61	8499087.33	558566.51	8499076.76	43.2	
26/04/2017	02:15:44	SA1702_ENV19	Still	SA1702_ENV	1306	237.4	558524.61	8499087.33	558554.86	8499080.13	31.1	
26/04/2017	02:16:16	SA1702_ENV19	Still	SA1702_ENV	1307	238.0	558524.61	8499087.33	558548.86	8499081.83	24.9	
26/04/2017	02:16:44	SA1702_ENV19	Still	SA1702_ENV	1308	237.6	558524.61	8499087.33	558543.92	8499083.29	19.7	
26/04/2017	02:17:23	SA1702_ENV19	Still	SA1702_ENV	1309	237.5	558524.61	8499087.33	558535.85	8499085.65	11.4	
26/04/2017	02:18:32	SA1702_ENV19	Still	SA1702_ENV	1310	237.8	558524.61	8499087.33	558520.89	8499089.45	4.3	
26/04/2017	02:19:29	SA1702_ENV19	Still	SA1702_ENV	1311	238.6	558524.61	8499087.33	558508.04	8499092.42	17.3	
26/04/2017	02:20:31	SA1702_ENV19	Still	SA1702_ENV	1312	237.7	558524.61	8499087.33	558494.01	8499096.24	31.9	
26/04/2017	02:20:47	SA1702_ENV19	Still	SA1702_ENV	1313	237.7	558524.61	8499087.33	558490.65	8499096.89	35.3	
26/04/2017	02:21:17	SA1702_ENV19	Still	SA1702_ENV	1314	237.5	558524.61	8499087.33	558484.01	8499098.12	42.0	
26/04/2017	02:21:28	SA1702_ENV19	Still	SA1702_ENV	1315	236.6	558524.61	8499087.33	558481.38	8499098.88	44.7	
26/04/2017	02:21:59	SA1702_ENV19	Still	SA1702_ENV	1316	234.4	558524.61	8499087.33	558474.29	8499101.07	52.2	
26/04/2017	02:22:10	SA1702_ENV19	Still	SA1702_ENV	1317	233.8	558524.61	8499087.33	558471.79	8499101.94	54.8	
26/04/2017	02:22:31	SA1702_ENV19	Still	SA1702_ENV	1318	233.3	558524.61	8499087.33	558467.27	8499102.82	59.4	
26/04/2017	02:22:57	SA1702_ENV19	Still	SA1702_ENV	1319	231.6	558524.61	8499087.33	558462.01	8499104.41	64.9	
26/04/2017	02:23:09	SA1702_ENV19	Still	SA1702_ENV	1320	230.3	558524.61	8499087.33	558459.54	8499104.72	67.4	
26/04/2017	02:23:41	SA1702_ENV19	Still	NO STILL	1321	230.0	558524.61	8499087.33	558454.29	8499107.27	73.1	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	02:24:32	SA1702_ENV19	Still	SA1702_ENV	1322	229.3	558524.61	8499087.33	558443.54	8499109.41	84.0	
26/04/2017	02:24:43	SA1702_ENV19	Still	SA1702_ENV	1323	231.2	558524.61	8499087.33	558440.82	8499110.06	86.8	
26/04/2017	02:24:53	SA1702_ENV19	Still	SA1702_ENV	1324	232.3	558524.61	8499087.33	558438.49	8499110.40	89.2	
26/04/2017	02:25:09	SA1702_ENV19	Still	SA1702_ENV	1325	234.7	558524.61	8499087.33	558434.26	8499111.44	93.5	
26/04/2017	02:25:30	SA1702_ENV19	Still	SA1702_ENV	1326	237.8	558524.61	8499087.33	558428.97	8499112.57	98.9	
26/04/2017	02:25:47	SA1702_ENV19	Still	SA1702_ENV	1327	239.2	558524.61	8499087.33	558424.44	8499113.50	103.5	
26/04/2017	02:26:13	SA1702_ENV19	Still	SA1702_ENV	1328	239.5	558524.61	8499087.33	558417.55	8499115.22	110.6	
26/04/2017	02:26:43	SA1702_ENV19	Still	SA1702_ENV	1329	240.0	558524.61	8499087.33	558409.91	8499116.74	118.4	
26/04/2017	02:26:58	SA1702_ENV19	Still	SA1702_ENV	1330	240.7	558524.61	8499087.33	558406.50	8499117.46	121.9	
26/04/2017	02:27:21	SA1702_ENV19	Still	SA1702_ENV	1331	241.2	558524.61	8499087.33	558401.56	8499118.72	127.0	
26/04/2017	02:27:48	SA1702_ENV19	Still	SA1702_ENV	1332	241.0	558524.61	8499087.33	558395.72	8499120.35	133.0	
26/04/2017	02:28:10	SA1702_ENV19	Still	SA1702_ENV	1333	241.5	558524.61	8499087.33	558390.25	8499121.79	138.7	
26/04/2017	02:28:22	SA1702_ENV19	Still	SA1702_ENV	1334	241.1	558524.61	8499087.33	558387.85	8499122.49	141.2	
26/04/2017	02:28:52	SA1702_ENV19	Still	SA1702_ENV	1335	240.6	558524.61	8499087.33	558380.96	8499124.34	148.3	
26/04/2017	02:29:12	SA1702_ENV19	Still	SA1702_ENV	1336	241.8	558524.61	8499087.33	558376.37	8499125.73	153.1	
26/04/2017	02:29:37	SA1702_ENV19	Still	SA1702_ENV	1337	242.0	558524.61	8499087.33	558370.66	8499127.16	159.0	
26/04/2017	02:30:18	SA1702_ENV19	Still	SA1702_ENV	1338	242.0	558524.61	8499087.33	558361.06	8499129.48	168.9	
26/04/2017	02:30:43	SA1702_ENV19	Still	SA1702_ENV	1339	242.1	558524.61	8499087.33	558354.94	8499131.18	175.2	
26/04/2017	02:31:06	SA1702_ENV19	Still	SA1702_ENV	1340	242.9	558524.61	8499087.33	558351.12	8499132.20	179.2	
26/04/2017	02:31:17	SA1702_ENV19	Still	SA1702_ENV	1341	242.3	558524.61	8499087.33	558348.46	8499132.61	181.9	
26/04/2017	02:32:09	SA1702_ENV19	Still	SA1702_ENV	1342	242.0	558524.61	8499087.33	558335.98	8499135.30	194.6	
26/04/2017	02:32:40	SA1702_ENV19	Still	SA1702_ENV	1343	242.8	558524.61	8499087.33	558327.66	8499137.23	203.2	
26/04/2017	02:33:13	SA1702_ENV19	Still	SA1702_ENV	1344	242.7	558524.61	8499087.33	558319.67	8499139.30	211.4	
26/04/2017	02:33:53	SA1702_ENV19	Still	NO STILL	1345	242.8	558524.61	8499087.33	558309.96	8499141.70	221.4	
26/04/2017	02:34:27	SA1702_ENV19	Still	SA1702_ENV	1346	243.5	558524.61	8499087.33	558301.96	8499143.68	229.7	
26/04/2017	02:34:54	SA1702_ENV19	Still	SA1702_ENV	1347	242.0	558524.61	8499087.33	558296.07	8499145.29	235.8	
26/04/2017	02:35:08	SA1702_ENV19	Still	SA1702_ENV	1348	240.8	558524.61	8499087.33	558292.64	8499146.12	239.3	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	02:35:29	SA1702_ENV19	Still	SA1702_ENV	1349	241.1	558524.61	8499087.33	558288.25	8499147.46	243.9	
26/04/2017	02:36:45	SA1702_ENV19	Still	SA1702_ENV	1350	240.2	558524.61	8499087.33	558270.16	8499152.04	262.6	
26/04/2017	02:37:32	SA1702_ENV19	Still	SA1702_ENV	1351	242.1	558524.61	8499087.33	558259.63	8499154.94	273.5	
26/04/2017	02:38:20	SA1702_ENV19	Still	SA1702_ENV	1352	240.8	558524.61	8499087.33	558249.25	8499157.46	284.1	
26/04/2017	02:38:38	SA1702_ENV19	Still	SA1702_ENV	1353	240.7	558524.61	8499087.33	558245.43	8499158.60	288.1	
26/04/2017	02:38:56	SA1702_ENV19	Still	SA1702_ENV	1354	239.1	558524.61	8499087.33	558241.59	8499160.11	292.2	
26/04/2017	02:39:20	SA1702_ENV19	Still	NO STILL	1355	239.5	558524.61	8499087.33	558237.27	8499160.96	296.6	
26/04/2017	02:39:53	SA1702_ENV19	Still	NO STILL	1356	240.6	558524.61	8499087.33	558229.86	8499162.79	304.3	
26/04/2017	02:40:01	SA1702_ENV19	Still	NO STILL	1357	240.7	558524.61	8499087.33	558229.18	8499162.98	305.0	
26/04/2017	02:40:41	SA1702_ENV19	Still	SA1702_ENV	1358	241.4	558524.61	8499087.33	558219.72	8499165.25	314.7	
26/04/2017	02:41:07	SA1702_ENV19	Still	SA1702_ENV	1359	241.9	558524.61	8499087.33	558213.52	8499166.80	321.1	
26/04/2017	02:41:28	SA1702_ENV19	Still	SA1702_ENV	1360	242.0	558524.61	8499087.33	558208.40	8499167.73	326.3	
26/04/2017	02:42:02	SA1702_ENV19	Still	SA1702_ENV	1361	242.1	558524.61	8499087.33	558200.06	8499169.47	334.8	
26/04/2017	06:32:24	SA1702_ENV20	Still	SA1702_ENV	1401	248.1	556578.81	8498053.76	556523.66	8498100.90	72.6	
26/04/2017	06:33:15	SA1702_ENV20	Still	SA1702_ENV	1402	248.2	556578.81	8498053.76	556528.21	8498096.72	66.4	
26/04/2017	06:34:51	SA1702_ENV20	Still	SA1702_ENV	1403	247.6	556578.81	8498053.76	556537.35	8498086.83	53.0	
26/04/2017	06:35:18	SA1702_ENV20	Still	SA1702_ENV	1404	248.7	556578.81	8498053.76	556539.76	8498084.14	49.5	
26/04/2017	06:37:39	SA1702_ENV20	Still	SA1702_ENV	1405	248.3	556578.81	8498053.76	556556.25	8498068.17	26.8	
26/04/2017	06:38:16	SA1702_ENV20	Still	SA1702_ENV	1406	249.2	556578.81	8498053.76	556561.27	8498063.87	20.2	
26/04/2017	06:39:34	SA1702_ENV20	Still	SA1702_ENV	1407	248.5	556578.81	8498053.76	556571.57	8498053.90	7.2	
26/04/2017	06:40:23	SA1702_ENV20	Still	SA1702_ENV	1408	248.7	556578.81	8498053.76	556578.41	8498048.64	5.1	
26/04/2017	06:40:44	SA1702_ENV20	Still	SA1702_ENV	1409	249.0	556578.81	8498053.76	556581.41	8498046.31	7.9	
26/04/2017	06:41:29	SA1702_ENV20	Still	SA1702_ENV	1410	248.9	556578.81	8498053.76	556587.13	8498040.90	15.3	
26/04/2017	06:42:03	SA1702_ENV20	Still	SA1702_ENV	1411	248.6	556578.81	8498053.76	556591.57	8498037.04	21.0	
26/04/2017	06:42:44	SA1702_ENV20	Still	SA1702_ENV	1412	247.9	556578.81	8498053.76	556596.99	8498031.79	28.5	
26/04/2017	06:42:54	SA1702_ENV20	Still	SA1702_ENV	1413	248.3	556578.81	8498053.76	556598.35	8498030.72	30.2	
26/04/2017	06:43:14	SA1702_ENV20	Still	SA1702_ENV	1414	247.8	556578.81	8498053.76	556600.97	8498028.21	33.8	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	06:44:01	SA1702_ENV20	Still	SA1702_ENV	1415	247.1	556578.81	8498053.76	556607.40	8498022.76	42.2	
26/04/2017	06:44:14	SA1702_ENV20	Still	SA1702_ENV	1416	248.1	556578.81	8498053.76	556609.04	8498021.22	44.4	
26/04/2017	06:44:25	SA1702_ENV20	Still	SA1702_ENV	1417	248.5	556578.81	8498053.76	556610.51	8498020.10	46.2	
26/04/2017	06:44:59	SA1702_ENV20	Still	SA1702_ENV	1418	247.3	556578.81	8498053.76	556616.48	8498016.86	52.7	
26/04/2017	06:45:32	SA1702_ENV20	Still	SA1702_ENV	1419	247.4	556578.81	8498053.76	556620.95	8498015.46	57.0	
26/04/2017	06:45:55	SA1702_ENV20	Still	SA1702_ENV	1420	247.7	556578.81	8498053.76	556623.67	8498014.35	59.7	
26/04/2017	06:46:38	SA1702_ENV20	Still	SA1702_ENV	1421	247.7	556578.81	8498053.76	556630.16	8498010.89	66.9	
26/04/2017	06:46:58	SA1702_ENV20	Still	SA1702_ENV	1422	247.6	556578.81	8498053.76	556633.58	8498008.66	70.9	
26/04/2017	06:47:13	SA1702_ENV20	Still	SA1702_ENV	1423	245.4	556578.81	8498053.76	556635.56	8498007.42	73.3	
26/04/2017	06:47:45	SA1702_ENV20	Still	SA1702_ENV	1424	247.2	556578.81	8498053.76	556639.45	8498004.12	78.4	
26/04/2017	06:48:10	SA1702_ENV20	Still	SA1702_ENV	1425	247.7	556578.81	8498053.76	556642.19	8498001.67	82.0	
26/04/2017	06:48:22	SA1702_ENV20	Still	SA1702_ENV	1426	246.9	556578.81	8498053.76	556643.23	8498000.62	83.5	
26/04/2017	06:49:02	SA1702_ENV20	Still	SA1702_ENV	1427	246.5	556578.81	8498053.76	556647.25	8497998.35	88.1	
26/04/2017	06:49:47	SA1702_ENV20	Still	SA1702_ENV	1428	247.8	556578.81	8498053.76	556651.62	8497996.25	92.8	
26/04/2017	06:50:25	SA1702_ENV20	Still	SA1702_ENV	1429	246.5	556578.81	8498053.76	556655.88	8497992.89	98.2	
26/04/2017	06:51:18	SA1702_ENV20	Still	SA1702_ENV	1430	246.5	556578.81	8498053.76	556662.47	8497988.21	106.3	
26/04/2017	06:52:04	SA1702_ENV20	Still	SA1702_ENV	1431	246.1	556578.81	8498053.76	556668.47	8497983.36	114.0	
26/04/2017	06:52:30	SA1702_ENV20	Still	SA1702_ENV	1432	245.6	556578.81	8498053.76	556671.77	8497980.23	118.5	
26/04/2017	06:53:04	SA1702_ENV20	Still	SA1702_ENV	1433	245.7	556578.81	8498053.76	556676.75	8497975.39	125.4	
26/04/2017	06:53:32	SA1702_ENV20	Still	SA1702_ENV	1434	244.6	556578.81	8498053.76	556680.45	8497971.59	130.7	
26/04/2017	06:53:55	SA1702_ENV20	Still	SA1702_ENV	1435	244.1	556578.81	8498053.76	556684.07	8497968.62	135.4	
26/04/2017	06:54:20	SA1702_ENV20	Still	SA1702_ENV	1436	244.0	556578.81	8498053.76	556687.55	8497965.11	140.3	
26/04/2017	06:55:03	SA1702_ENV20	Still	SA1702_ENV	1437	243.1	556578.81	8498053.76	556693.58	8497959.29	148.6	
26/04/2017	06:55:18	SA1702_ENV20	Still	SA1702_ENV	1438	243.1	556578.81	8498053.76	556695.11	8497957.29	151.1	
26/04/2017	06:55:47	SA1702_ENV20	Still	SA1702_ENV	1439	242.4	556578.81	8498053.76	556698.92	8497952.91	156.8	
26/04/2017	06:55:57	SA1702_ENV20	Still	SA1702_ENV	1440	242.6	556578.81	8498053.76	556700.63	8497951.63	159.0	
26/04/2017	06:56:22	SA1702_ENV20	Still	SA1702_ENV	1441	242.5	556578.81	8498053.76	556703.86	8497948.12	163.7	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	06:56:29	SA1702_ENV20	Still	SA1702_ENV	1442	242.3	556578.81	8498053.76	556705.07	8497947.08	165.3	
26/04/2017	06:56:56	SA1702_ENV20	Still	SA1702_ENV	1443	243.1	556578.81	8498053.76	556708.81	8497943.51	170.5	
26/04/2017	06:57:20	SA1702_ENV20	Still	SA1702_ENV	1444	243.0	556578.81	8498053.76	556711.96	8497940.40	174.9	
26/04/2017	06:57:56	SA1702_ENV20	Still	SA1702_ENV	1445	242.9	556578.81	8498053.76	556717.28	8497935.84	181.9	
26/04/2017	06:58:07	SA1702_ENV20	Still	SA1702_ENV	1446	242.5	556578.81	8498053.76	556718.62	8497934.19	184.0	
26/04/2017	06:58:23	SA1702_ENV20	Still	SA1702_ENV	1447	242.7	556578.81	8498053.76	556721.22	8497931.69	187.6	
26/04/2017	06:59:22	SA1702_ENV20	Still	SA1702_ENV	1448	242.2	556578.81	8498053.76	556729.70	8497924.44	198.7	
26/04/2017	06:59:29	SA1702_ENV20	Still	SA1702_ENV	1449	242.6	556578.81	8498053.76	556730.79	8497923.22	200.3	
26/04/2017	07:00:03	SA1702_ENV20	Still	SA1702_ENV	1450	241.9	556578.81	8498053.76	556735.88	8497918.93	207.0	
26/04/2017	07:00:21	SA1702_ENV20	Still	SA1702_ENV	1451	242.5	556578.81	8498053.76	556738.53	8497916.23	210.8	
26/04/2017	07:00:37	SA1702_ENV20	Still	SA1702_ENV	1452	242.8	556578.81	8498053.76	556740.69	8497914.41	213.6	
26/04/2017	07:01:20	SA1702_ENV20	Still	SA1702_ENV	1453	241.9	556578.81	8498053.76	556747.15	8497908.56	222.3	
26/04/2017	07:01:42	SA1702_ENV20	Still	SA1702_ENV	1454	242.2	556578.81	8498053.76	556750.56	8497905.58	226.8	
26/04/2017	07:02:04	SA1702_ENV20	Still	SA1702_ENV	1455	242.2	556578.81	8498053.76	556753.56	8497902.68	231.0	
26/04/2017	07:02:32	SA1702_ENV20	Still	SA1702_ENV	1456	241.9	556578.81	8498053.76	556757.06	8497898.47	236.4	
26/04/2017	07:03:06	SA1702_ENV20	Still	SA1702_ENV	1457	242.6	556578.81	8498053.76	556762.06	8497893.23	243.6	
26/04/2017	07:03:17	SA1702_ENV20	Still	SA1702_ENV	1458	243.0	556578.81	8498053.76	556763.39	8497891.75	245.6	
26/04/2017	07:03:52	SA1702_ENV20	Still	SA1702_ENV	1459	242.3	556578.81	8498053.76	556768.04	8497886.68	252.4	
26/04/2017	07:04:46	SA1702_ENV20	Still	SA1702_ENV	1460	243.3	556578.81	8498053.76	556776.25	8497877.80	264.5	
26/04/2017	07:04:52	SA1702_ENV20	Still	SA1702_ENV	1461	242.7	556578.81	8498053.76	556777.32	8497876.18	266.3	
26/04/2017	07:05:26	SA1702_ENV20	Still	SA1702_ENV	1462	243.8	556578.81	8498053.76	556782.83	8497871.44	273.6	
26/04/2017	07:05:52	SA1702_ENV20	Still	SA1702_ENV	1463	243.9	556578.81	8498053.76	556786.60	8497867.58	279.0	
26/04/2017	07:06:14	SA1702_ENV20	Still	SA1702_ENV	1464	244.4	556578.81	8498053.76	556789.95	8497864.46	283.6	
26/04/2017	07:06:53	SA1702_ENV20	Still	SA1702_ENV	1465	245.3	556578.81	8498053.76	556795.52	8497858.79	291.5	
26/04/2017	07:07:21	SA1702_ENV20	Still	SA1702_ENV	1466	245.2	556578.81	8498053.76	556800.06	8497854.48	297.8	
26/04/2017	07:08:10	SA1702_ENV20	Still	SA1702_ENV	1467	245.8	556578.81	8498053.76	556807.76	8497846.81	308.6	
26/04/2017	07:08:32	SA1702_ENV20	Still	SA1702_ENV	1468	245.3	556578.81	8498053.76	556811.52	8497843.03	313.9	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	07:09:20	SA1702_ENV20	Still	SA1702_ENV	1469	245.9	556578.81	8498053.76	556819.40	8497835.39	324.9	
26/04/2017	07:10:05	SA1702_ENV20	Still	SA1702_ENV	1470	245.6	556578.81	8498053.76	556827.10	8497828.13	335.5	
26/04/2017	07:10:57	SA1702_ENV20	Still	SA1702_ENV	1471	245.7	556578.81	8498053.76	556835.94	8497820.09	347.4	
26/04/2017	07:11:31	SA1702_ENV20	Still	SA1702_ENV	1472	246.6	556578.81	8498053.76	556841.47	8497814.66	355.2	
26/04/2017	07:12:15	SA1702_ENV20	Still	SA1702_ENV	1473	246.7	556578.81	8498053.76	556848.95	8497807.48	365.6	
26/04/2017	07:13:01	SA1702_ENV20	Still	SA1702_ENV	1474	246.4	556578.81	8498053.76	556857.27	8497800.03	376.7	
26/04/2017	07:13:45	SA1702_ENV20	Still	SA1702_ENV	1475	246.7	556578.81	8498053.76	556864.56	8497792.80	387.0	
26/04/2017	07:14:03	SA1702_ENV20	Still	SA1702_ENV	1476	246.5	556578.81	8498053.76	556866.82	8497790.24	390.4	
26/04/2017	07:14:42	SA1702_ENV20	Still	SA1702_ENV	1477	246.6	556578.81	8498053.76	556873.32	8497782.90	400.1	
26/04/2017	07:15:40	SA1702_ENV20	Still	SA1702_ENV	1478	246.4	556578.81	8498053.76	556882.76	8497773.30	413.6	
26/04/2017	07:16:07	SA1702_ENV20	Still	SA1702_ENV	1479	246.6	556578.81	8498053.76	556886.77	8497768.26	419.9	
26/04/2017	07:16:46	SA1702_ENV20	Still	SA1702_ENV	1480	246.7	556578.81	8498053.76	556892.70	8497761.36	429.0	
26/04/2017	07:17:34	SA1702_ENV20	Still	SA1702_ENV	1481	246.7	556578.81	8498053.76	556899.73	8497752.45	440.2	
26/04/2017	07:17:54	SA1702_ENV20	Still	SA1702_ENV	1482	246.2	556578.81	8498053.76	556902.00	8497748.94	444.3	
26/04/2017	12:55:24	SA1702_ENV26	Still	SA1702_ENV	1501	220.9	559072.19	8491572.02	559082.55	8491595.24	25.4	
26/04/2017	12:55:40	SA1702_ENV26	Still	SA1702_ENV	1502	220.5	559072.19	8491572.02	559082.22	8491594.27	24.4	
26/04/2017	12:56:24	SA1702_ENV26	Still	SA1702_ENV	1503	220.6	559072.19	8491572.02	559081.54	8491590.24	20.5	
26/04/2017	12:56:49	SA1702_ENV26	Still	SA1702_ENV	1504	221.0	559072.19	8491572.02	559080.46	8491586.99	17.1	
26/04/2017	12:57:56	SA1702_ENV26	Still	SA1702_ENV	1505	221.5	559072.19	8491572.02	559078.46	8491575.87	7.4	
26/04/2017	12:58:49	SA1702_ENV26	Still	SA1702_ENV	1506	220.9	559072.19	8491572.02	559074.59	8491570.24	3.0	
26/04/2017	12:59:12	SA1702_ENV26	Still	SA1702_ENV	1507	220.8	559072.19	8491572.02	559073.15	8491568.66	3.5	
26/04/2017	12:59:31	SA1702_ENV26	Still	SA1702_ENV	1508	221.2	559072.19	8491572.02	559071.71	8491567.34	4.7	
26/04/2017	13:01:14	SA1702_ENV26	Still	SA1702_ENV	1509	221.2	559072.19	8491572.02	559063.26	8491558.13	16.5	
26/04/2017	13:01:59	SA1702_ENV26	Still	SA1702_ENV	1510	221.8	559072.19	8491572.02	559059.23	8491554.80	21.5	
26/04/2017	13:02:30	SA1702_ENV26	Still	SA1702_ENV	1511	222.2	559072.19	8491572.02	559055.82	8491551.69	26.1	
26/04/2017	13:03:49	SA1702_ENV26	Still	SA1702_ENV	1512	221.8	559072.19	8491572.02	559045.71	8491545.84	37.2	
26/04/2017	13:04:16	SA1702_ENV26	Still	SA1702_ENV	1513	221.2	559072.19	8491572.02	559042.98	8491544.00	40.5	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	13:05:00	SA1702_ENV26	Still	SA1702_ENV	1514	221.8	559072.19	8491572.02	559039.21	8491541.78	44.7	
26/04/2017	13:05:47	SA1702_ENV26	Still	SA1702_ENV	1515	221.7	559072.19	8491572.02	559034.31	8491542.21	48.2	
26/04/2017	13:06:46	SA1702_ENV26	Still	SA1702_ENV	1516	221.4	559072.19	8491572.02	559030.68	8491541.84	51.3	
26/04/2017	13:07:32	SA1702_ENV26	Still	SA1702_ENV	1517	222.3	559072.19	8491572.02	559025.31	8491542.07	55.6	
26/04/2017	13:08:31	SA1702_ENV26	Still	SA1702_ENV	1518	222.9	559072.19	8491572.02	559020.70	8491542.42	59.4	
26/04/2017	13:09:02	SA1702_ENV26	Still	SA1702_ENV	1519	222.4	559072.19	8491572.02	559019.26	8491545.01	59.4	
26/04/2017	13:10:15	SA1702_ENV26	Still	SA1702_ENV	1520	224.9	559072.19	8491572.02	559014.05	8491544.95	64.1	
26/04/2017	13:10:52	SA1702_ENV26	Still	SA1702_ENV	1521	225.4	559072.19	8491572.02	559011.24	8491544.71	66.8	
26/04/2017	13:11:20	SA1702_ENV26	Still	SA1702_ENV	1522	227.3	559072.19	8491572.02	559008.89	8491543.53	69.4	
26/04/2017	13:12:11	SA1702_ENV26	Still	NO STILL	1523	229.0	559072.19	8491572.02	559004.90	8491541.54	73.9	
26/04/2017	13:13:21	SA1702_ENV26	Still	SA1702_ENV	1524	230.2	559072.19	8491572.02	558999.19	8491538.51	80.3	
26/04/2017	13:13:38	SA1702_ENV26	Still	SA1702_ENV	1525	230.4	559072.19	8491572.02	558997.25	8491537.30	82.6	
26/04/2017	13:14:07	SA1702_ENV26	Still	SA1702_ENV	1526	230.8	559072.19	8491572.02	558994.30	8491536.00	85.8	
26/04/2017	13:14:48	SA1702_ENV26	Still	SA1702_ENV	1527	232.1	559072.19	8491572.02	558990.36	8491534.47	90.0	
26/04/2017	13:15:29	SA1702_ENV26	Still	SA1702_ENV	1528	231.0	559072.19	8491572.02	558987.20	8491532.53	93.7	
26/04/2017	13:15:39	SA1702_ENV26	Still	SA1702_ENV	1529	234.7	559072.19	8491572.02	558986.05	8491533.29	94.4	
26/04/2017	13:16:01	SA1702_ENV26	Still	SA1702_ENV	1530	235.6	559072.19	8491572.02	558985.05	8491530.69	96.4	
26/04/2017	13:16:50	SA1702_ENV26	Still	SA1702_ENV	1531	237.2	559072.19	8491572.02	558980.85	8491526.20	102.2	
26/04/2017	13:17:40	SA1702_ENV26	Still	SA1702_ENV	1532	240.1	559072.19	8491572.02	558975.74	8491523.53	107.9	
26/04/2017	13:18:10	SA1702_ENV26	Still	SA1702_ENV	1533	241.2	559072.19	8491572.02	558972.20	8491520.81	112.3	
26/04/2017	13:18:59	SA1702_ENV26	Still	SA1702_ENV	1534	243.1	559072.19	8491572.02	558966.99	8491516.42	119.0	
26/04/2017	13:19:34	SA1702_ENV26	Still	SA1702_ENV	1535	244.5	559072.19	8491572.02	558964.74	8491513.81	122.2	
26/04/2017	13:20:15	SA1702_ENV26	Still	SA1702_ENV	1536	244.0	559072.19	8491572.02	558964.18	8491492.91	133.9	
26/04/2017	13:20:38	SA1702_ENV26	Still	SA1702_ENV	1537	245.6	559072.19	8491572.02	558959.00	8491508.57	129.8	
26/04/2017	13:20:58	SA1702_ENV26	Still	SA1702_ENV	1538	245.1	559072.19	8491572.02	558958.03	8491506.53	131.6	
26/04/2017	13:22:41	SA1702_ENV26	Still	SA1702_ENV	1539	247.1	559072.19	8491572.02	558951.00	8491500.43	140.8	
26/04/2017	13:23:25	SA1702_ENV26	Still	SA1702_ENV	1540	247.8	559072.19	8491572.02	558948.45	8491498.61	143.9	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	13:23:36	SA1702_ENV26	Still	SA1702_ENV	1541	248.3	559072.19	8491572.02	558947.51	8491498.42	144.8	
26/04/2017	13:24:26	SA1702_ENV26	Still	SA1702_ENV	1542	248.9	559072.19	8491572.02	558965.94	8491467.63	149.0	
26/04/2017	13:25:11	SA1702_ENV26	Still	SA1702_ENV	1543	249.2	559072.19	8491572.02	558941.66	8491494.41	151.9	
26/04/2017	13:26:12	SA1702_ENV26	Still	NO STILL	1544	250.2	559072.19	8491572.02	558937.84	8491490.91	156.9	
26/04/2017	13:26:35	SA1702_ENV26	Still	SA1702_ENV	1545	252.0	559072.19	8491572.02	558936.24	8491489.25	159.2	
26/04/2017	13:27:24	SA1702_ENV26	Still	SA1702_ENV	1546	253.3	559072.19	8491572.02	558931.09	8491486.98	164.7	
26/04/2017	13:27:49	SA1702_ENV26	Still	SA1702_ENV	1547	254.4	559072.19	8491572.02	558928.44	8491486.16	167.4	
26/04/2017	13:28:32	SA1702_ENV26	Still	SA1702_ENV	1548	255.2	559072.19	8491572.02	558923.94	8491485.62	171.6	
26/04/2017	13:29:37	SA1702_ENV26	Still	SA1702_ENV	1549	255.6	559072.19	8491572.02	558916.79	8491485.67	177.8	
26/04/2017	13:29:57	SA1702_ENV26	Still	SA1702_ENV	1550	255.8	559072.19	8491572.02	558914.34	8491485.18	180.2	
26/04/2017	13:30:19	SA1702_ENV26	Still	SA1702_ENV	1551	256.7	559072.19	8491572.02	558912.28	8491485.03	182.0	
26/04/2017	13:30:57	SA1702_ENV26	Still	SA1702_ENV	1552	256.2	559072.19	8491572.02	558907.54	8491484.29	186.6	
26/04/2017	13:31:41	SA1702_ENV26	Still	SA1702_ENV	1553	256.5	559072.19	8491572.02	558903.04	8491483.49	190.9	
26/04/2017	13:32:35	SA1702_ENV26	Still	SA1702_ENV	1554	256.1	559072.19	8491572.02	558898.87	8491484.12	194.3	
26/04/2017	13:33:11	SA1702_ENV26	Still	SA1702_ENV	1555	256.6	559072.19	8491572.02	558895.52	8491481.63	198.4	
26/04/2017	13:33:31	SA1702_ENV26	Still	SA1702_ENV	1556	255.4	559072.19	8491572.02	558893.36	8491480.27	201.0	
26/04/2017	13:33:54	SA1702_ENV26	Still	SA1702_ENV	1557	255.8	559072.19	8491572.02	558891.89	8491479.13	202.8	
26/04/2017	13:35:23	SA1702_ENV26	Still	SA1702_ENV	1558	255.7	559072.19	8491572.02	558884.25	8491475.29	211.4	
26/04/2017	13:35:33	SA1702_ENV26	Still	SA1702_ENV	1559	257.1	559072.19	8491572.02	558882.95	8491474.35	213.0	
26/04/2017	13:35:42	SA1702_ENV26	Still	SA1702_ENV	1560	255.7	559072.19	8491572.02	558882.34	8491473.98	213.7	
26/04/2017	13:35:50	SA1702_ENV26	Still	SA1702_ENV	1561	255.6	559072.19	8491572.02	558881.05	8491473.39	215.1	
26/04/2017	13:36:21	SA1702_ENV26	Still	SA1702_ENV	1562	255.8	559072.19	8491572.02	558878.87	8491472.65	217.4	
26/04/2017	13:36:50	SA1702_ENV26	Still	SA1702_ENV	1563	255.6	559072.19	8491572.02	558875.29	8491471.71	221.0	
26/04/2017	13:36:58	SA1702_ENV26	Still	SA1702_ENV	1564	254.3	559072.19	8491572.02	558874.72	8491471.23	221.7	
26/04/2017	13:37:47	SA1702_ENV26	Still	SA1702_ENV	1565	254.2	559072.19	8491572.02	558869.16	8491467.14	228.5	
26/04/2017	13:38:03	SA1702_ENV26	Still	SA1702_ENV	1566	254.8	559072.19	8491572.02	558867.68	8491465.45	230.6	
26/04/2017	13:38:25	SA1702_ENV26	Still	SA1702_ENV	1567	254.9	559072.19	8491572.02	558864.95	8491463.45	234.0	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transcect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	13:39:30	SA1702_ENV26	Still	SA1702_ENV	1568	254.5	559072.19	8491572.02	558858.90	8491458.01	241.8	
26/04/2017	13:40:11	SA1702_ENV26	Still	SA1702_ENV	1569	254.8	559072.19	8491572.02	558854.87	8491454.28	247.2	
26/04/2017	13:41:05	SA1702_ENV26	Still	SA1702_ENV	1570	252.8	559072.19	8491572.02	558861.30	8491459.13	239.2	
26/04/2017	13:41:44	SA1702_ENV26	Still	SA1702_ENV	1571	252.8	559072.19	8491572.02	558844.69	8491445.93	260.1	
26/04/2017	13:42:08	SA1702_ENV26	Still	SA1702_ENV	1572	253.1	559072.19	8491572.02	558841.53	8491444.27	263.7	
26/04/2017	13:42:35	SA1702_ENV26	Still	SA1702_ENV	1573	253.4	559072.19	8491572.02	558838.56	8491442.98	266.9	
26/04/2017	13:43:23	SA1702_ENV26	Still	SA1702_ENV	1574	254.1	559072.19	8491572.02	558832.58	8491439.81	273.7	
26/04/2017	13:43:34	SA1702_ENV26	Still	SA1702_ENV	1575	254.1	559072.19	8491572.02	558831.43	8491439.01	275.1	
26/04/2017	13:44:36	SA1702_ENV26	Still	SA1702_ENV	1576	253.6	559072.19	8491572.02	558822.21	8491435.12	285.0	
26/04/2017	13:44:50	SA1702_ENV26	Still	SA1702_ENV	1577	253.7	559072.19	8491572.02	558819.43	8491433.93	288.0	
26/04/2017	13:44:55	SA1702_ENV26	Still	SA1702_ENV	1578	253.2	559072.19	8491572.02	558819.11	8491433.52	288.5	
26/04/2017	13:45:32	SA1702_ENV26	Still	NO STILL	1579	253.1	559072.19	8491572.02	558813.95	8491431.57	294.0	
26/04/2017	13:46:07	SA1702_ENV26	Still	SA1702_ENV	1580	253.1	559072.19	8491572.02	558808.75	8491428.75	299.9	
26/04/2017	13:46:18	SA1702_ENV26	Still	SA1702_ENV	1581	252.8	559072.19	8491572.02	558807.61	8491428.17	301.2	
26/04/2017	13:47:19	SA1702_ENV26	Still	SA1702_ENV	1582	250.8	559072.19	8491572.02	558801.62	8491407.52	316.6	
26/04/2017	13:47:52	SA1702_ENV26	Still	SA1702_ENV	1583	250.1	559072.19	8491572.02	558792.40	8491421.22	317.8	
26/04/2017	13:48:53	SA1702_ENV26	Still	NO STILL	1584	248.1	559072.19	8491572.02	558783.00	8491413.59	329.7	
26/04/2017	13:49:42	SA1702_ENV26	Still	SA1702_ENV	1585	246.6	559072.19	8491572.02	558775.26	8491409.04	338.7	
26/04/2017	13:50:31	SA1702_ENV26	Still	SA1702_ENV	1586	246.4	559072.19	8491572.02	558767.17	8491405.23	347.6	
26/04/2017	13:51:34	SA1702_ENV26	Still	SA1702_ENV	1587	247.3	559072.19	8491572.02	558758.90	8491400.50	357.2	
26/04/2017	13:52:09	SA1702_ENV26	Still	SA1702_ENV	1588	248.2	559072.19	8491572.02	558752.79	8491397.04	364.2	
26/04/2017	13:52:18	SA1702_ENV26	Still	SA1702_ENV	1589	248.7	559072.19	8491572.02	558751.37	8491395.93	366.0	
26/04/2017	13:52:59	SA1702_ENV26	Still	SA1702_ENV	1590	247.8	559072.19	8491572.02	558743.10	8491391.81	375.2	
26/04/2017	13:53:32	SA1702_ENV26	Still	SA1702_ENV	1591	246.6	559072.19	8491572.02	558737.48	8491389.57	381.2	
26/04/2017	13:54:07	SA1702_ENV26	Still	SA1702_ENV	1592	244.4	559072.19	8491572.02	558731.80	8491387.60	387.1	
26/04/2017	13:54:29	SA1702_ENV26	Still	SA1702_ENV	1593	244.7	559072.19	8491572.02	558728.33	8491386.61	390.7	
26/04/2017	13:54:55	SA1702_ENV26	Still	SA1702_ENV	1594	243.8	559072.19	8491572.02	558724.30	8491384.31	395.3	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	13:56:06	SA1702_ENV26	Still	SA1702_ENV	1595	243.9	559072.19	8491572.02	558715.43	8491374.93	407.6	
26/04/2017	13:56:20	SA1702_ENV26	Still	SA1702_ENV	1596	244.2	559072.19	8491572.02	558713.47	8491373.16	410.1	
26/04/2017	13:56:31	SA1702_ENV26	Still	SA1702_ENV	1597	244.7	559072.19	8491572.02	558711.78	8491372.03	412.2	
26/04/2017	13:57:10	SA1702_ENV26	Still	SA1702_ENV	1598	244.1	559072.19	8491572.02	558706.20	8491368.83	418.6	
26/04/2017	13:57:26	SA1702_ENV26	Still	SA1702_ENV	1599	244.1	559072.19	8491572.02	558704.11	8491367.73	421.0	
26/04/2017	14:54:46	SA1702_ENV25	Still	SA1702_ENV	1601	265.7	557379.21	8490677.78	557442.14	8490717.79	74.6	
26/04/2017	14:55:56	SA1702_ENV25	Still	SA1702_ENV	1602	266.1	557379.21	8490677.78	557440.26	8490708.33	68.3	
26/04/2017	14:56:12	SA1702_ENV25	Still	SA1702_ENV	1603	265.5	557379.21	8490677.78	557439.27	8490706.97	66.8	
26/04/2017	14:57:27	SA1702_ENV25	Still	SA1702_ENV	1604	266.5	557379.21	8490677.78	557431.35	8490704.19	58.4	
26/04/2017	14:57:47	SA1702_ENV25	Still	SA1702_ENV	1605	262.7	557379.21	8490677.78	557428.82	8490702.96	55.6	
26/04/2017	14:57:57	SA1702_ENV25	Still	SA1702_ENV	1606	266.3	557379.21	8490677.78	557427.50	8490702.01	54.0	
26/04/2017	14:59:21	SA1702_ENV25	Still	SA1702_ENV	1607	266.7	557379.21	8490677.78	557417.03	8490691.72	40.3	
26/04/2017	14:59:32	SA1702_ENV25	Still	SA1702_ENV	1608	266.1	557379.21	8490677.78	557415.44	8490690.22	38.3	
26/04/2017	15:00:01	SA1702_ENV25	Still	SA1702_ENV	1609	266.5	557379.21	8490677.78	557411.09	8490687.16	33.2	
26/04/2017	15:00:58	SA1702_ENV25	Still	SA1702_ENV	1610	266.6	557379.21	8490677.78	557403.54	8490682.75	24.8	
26/04/2017	15:01:06	SA1702_ENV25	Still	SA1702_ENV	1611	266.2	557379.21	8490677.78	557401.96	8490681.99	23.1	
26/04/2017	15:01:14	SA1702_ENV25	Still	SA1702_ENV	1612	266.1	557379.21	8490677.78	557400.87	8490681.52	22.0	
26/04/2017	15:01:59	SA1702_ENV25	Still	SA1702_ENV	1613	266.1	557379.21	8490677.78	557392.68	8490678.99	13.5	
26/04/2017	15:03:03	SA1702_ENV25	Still	SA1702_ENV	1614	266.5	557379.21	8490677.78	557380.94	8490676.35	2.2	
26/04/2017	15:03:46	SA1702_ENV25	Still	SA1702_ENV	1615	266.6	557379.21	8490677.78	557371.67	8490674.02	8.4	
26/04/2017	15:04:27	SA1702_ENV25	Still	SA1702_ENV	1616	267.6	557379.21	8490677.78	557362.89	8490670.45	17.9	
26/04/2017	15:05:39	SA1702_ENV25	Still	SA1702_ENV	1617	267.4	557379.21	8490677.78	557348.84	8490662.09	34.2	
26/04/2017	15:06:10	SA1702_ENV25	Still	SA1702_ENV	1618	267.9	557379.21	8490677.78	557343.05	8490658.36	41.0	
26/04/2017	15:06:47	SA1702_ENV25	Still	SA1702_ENV	1619	268.8	557379.21	8490677.78	557336.59	8490654.33	48.6	
26/04/2017	15:07:37	SA1702_ENV25	Still	SA1702_ENV	1620	269.7	557379.21	8490677.78	557329.05	8490647.86	58.4	
26/04/2017	15:08:33	SA1702_ENV25	Still	SA1702_ENV	1621	270.8	557379.21	8490677.78	557320.01	8490641.17	69.6	
26/04/2017	15:09:34	SA1702_ENV25	Still	SA1702_ENV	1622	272.0	557379.21	8490677.78	557310.28	8490635.76	80.7	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	15:10:26	SA1702_ENV25	Still	SA1702_ENV	1623	272.3	557379.21	8490677.78	557300.92	8490630.13	91.6	
26/04/2017	15:11:18	SA1702_ENV25	Still	SA1702_ENV	1624	272.7	557379.21	8490677.78	557294.07	8490624.05	100.7	
26/04/2017	15:11:48	SA1702_ENV25	Still	SA1702_ENV	1625	271.9	557379.21	8490677.78	557292.17	8490619.88	104.5	
26/04/2017	15:11:58	SA1702_ENV25	Still	SA1702_ENV	1626	271.9	557379.21	8490677.78	557291.57	8490618.28	105.9	
26/04/2017	15:12:11	SA1702_ENV25	Still	SA1702_ENV	1627	272.8	557379.21	8490677.78	557290.84	8490616.12	107.8	
26/04/2017	15:12:58	SA1702_ENV25	Still	SA1702_ENV	1628	272.3	557379.21	8490677.78	557288.87	8490607.65	114.4	
26/04/2017	15:13:20	SA1702_ENV25	Still	SA1702_ENV	1629	272.9	557379.21	8490677.78	557287.22	8490605.27	117.1	
26/04/2017	15:13:55	SA1702_ENV25	Still	SA1702_ENV	1630	271.5	557379.21	8490677.78	557283.21	8490600.02	123.5	
26/04/2017	19:23:33	SA1702_ENV21	Still	SA1702_ENV	1701	269.9	551906.91	8492893.77	551829.53	8492890.30	77.5	
26/04/2017	19:24:19	SA1702_ENV21	Still	SA1702_ENV	1702	269.4	551906.91	8492893.77	551832.75	8492890.16	74.2	
26/04/2017	19:24:42	SA1702_ENV21	Still	SA1702_ENV	1703	270.8	551906.91	8492893.77	551834.99	8492890.33	72.0	
26/04/2017	19:26:18	SA1702_ENV21	Still	SA1702_ENV	1704	269.9	551906.91	8492893.77	551845.82	8492890.37	61.2	
26/04/2017	19:27:35	SA1702_ENV21	Still	SA1702_ENV	1705	270.0	551906.91	8492893.77	551856.29	8492889.81	50.8	
26/04/2017	19:28:20	SA1702_ENV21	Still	SA1702_ENV	1706	270.6	551906.91	8492893.77	551863.85	8492890.81	43.2	
26/04/2017	19:28:44	SA1702_ENV21	Still	SA1702_ENV	1707	270.0	551906.91	8492893.77	551868.18	8492891.03	38.8	
26/04/2017	19:29:01	SA1702_ENV21	Still	SA1702_ENV	1708	269.5	551906.91	8492893.77	551871.46	8492891.11	35.5	
26/04/2017	19:29:53	SA1702_ENV21	Still	SA1702_ENV	1709	270.5	551906.91	8492893.77	551880.54	8492891.10	26.5	
26/04/2017	19:30:22	SA1702_ENV21	Still	SA1702_ENV	1710	270.5	551906.91	8492893.77	551886.32	8492891.29	20.7	
26/04/2017	19:30:41	SA1702_ENV21	Still	SA1702_ENV	1711	270.6	551906.91	8492893.77	551890.18	8492891.55	16.9	
26/04/2017	19:31:26	SA1702_ENV21	Still	SA1702_ENV	1712	270.8	551906.91	8492893.77	551898.87	8492891.54	8.3	
26/04/2017	19:31:40	SA1702_ENV21	Still	SA1702_ENV	1713	270.6	551906.91	8492893.77	551901.77	8492891.32	5.7	
26/04/2017	19:32:29	SA1702_ENV21	Still	SA1702_ENV	1714	270.2	551906.91	8492893.77	551910.81	8492890.25	5.3	
26/04/2017	19:33:22	SA1702_ENV21	Still	SA1702_ENV	1715	270.4	551906.91	8492893.77	551921.30	8492889.80	14.9	
26/04/2017	19:33:50	SA1702_ENV21	Still	SA1702_ENV	1716	270.0	551906.91	8492893.77	551926.77	8492889.67	20.3	
26/04/2017	19:34:22	SA1702_ENV21	Still	SA1702_ENV	1717	271.0	551906.91	8492893.77	551932.59	8492889.46	26.0	
26/04/2017	19:35:34	SA1702_ENV21	Still	SA1702_ENV	1718	270.3	551906.91	8492893.77	551946.59	8492889.42	39.9	
26/04/2017	19:35:45	SA1702_ENV21	Still	SA1702_ENV	1719	270.4	551906.91	8492893.77	551948.96	8492889.53	42.3	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
26/04/2017	19:36:29	SA1702_ENV21	Still	SA1702_ENV	1720	270.8	551906.91	8492893.77	551957.55	8492889.79	50.8	
26/04/2017	19:37:26	SA1702_ENV21	Still	SA1702_ENV	1721	270.2	551906.91	8492893.77	551969.25	8492889.49	62.5	
26/04/2017	19:37:50	SA1702_ENV21	Still	SA1702_ENV	1722	270.0	551906.91	8492893.77	551974.61	8492889.38	67.8	
26/04/2017	19:38:57	SA1702_ENV21	Still	SA1702_ENV	1723	270.7	551906.91	8492893.77	551988.04	8492888.45	81.3	
26/04/2017	19:39:34	SA1702_ENV21	Still	SA1702_ENV	1724	270.8	551906.91	8492893.77	551995.93	8492888.58	89.2	
26/04/2017	19:40:06	SA1702_ENV21	Still	SA1702_ENV	1725	270.8	551906.91	8492893.77	552002.66	8492888.51	95.9	
26/04/2017	19:40:35	SA1702_ENV21	Still	SA1702_ENV	1726	271.0	551906.91	8492893.77	552008.18	8492888.00	101.4	
26/04/2017	19:40:56	SA1702_ENV21	Still	SA1702_ENV	1727	270.9	551906.91	8492893.77	552012.49	8492887.98	105.7	
26/04/2017	19:41:31	SA1702_ENV21	Still	SA1702_ENV	1728	270.5	551906.91	8492893.77	552018.91	8492888.15	112.1	
27/04/2017	00:48:58	SA1702_ENV22	Still	SA1702_ENV	1801	265.2	546438.14	8487540.79	546512.93	8487480.74	95.9	
27/04/2017	00:49:46	SA1702_ENV22	Still	SA1702_ENV	1802	266.5	546438.14	8487540.79	546513.28	8487482.89	94.9	
27/04/2017	00:50:53	SA1702_ENV22	Still	SA1702_ENV	1803	266.3	546438.14	8487540.79	546508.17	8487486.94	88.3	
27/04/2017	00:52:15	SA1702_ENV22	Still	SA1702_ENV	1804	266.0	546438.14	8487540.79	546498.12	8487494.86	75.5	
27/04/2017	00:52:30	SA1702_ENV22	Still	SA1702_ENV	1805	265.8	546438.14	8487540.79	546496.42	8487496.40	73.3	
27/04/2017	00:52:35	SA1702_ENV22	Still	NO STILL	1806	267.0	546438.14	8487540.79	546496.31	8487496.58	73.1	
27/04/2017	00:53:28	SA1702_ENV22	Still	SA1702_ENV	1807	267.0	546438.14	8487540.79	546492.02	8487500.89	67.0	
27/04/2017	00:54:10	SA1702_ENV22	Still	SA1702_ENV	1808	266.4	546438.14	8487540.79	546487.69	8487505.11	61.1	
27/04/2017	00:54:28	SA1702_ENV22	Still	SA1702_ENV	1809	266.9	546438.14	8487540.79	546485.99	8487507.00	58.6	
27/04/2017	00:56:09	SA1702_ENV22	Still	SA1702_ENV	1810	266.7	546438.14	8487540.79	546475.86	8487516.81	44.7	
27/04/2017	00:57:04	SA1702_ENV22	Still	SA1702_ENV	1811	266.0	546438.14	8487540.79	546469.93	8487520.91	37.5	
27/04/2017	00:59:11	SA1702_ENV22	Still	SA1702_ENV	1812	266.0	546438.14	8487540.79	546453.10	8487529.71	18.6	
27/04/2017	00:59:27	SA1702_ENV22	Still	SA1702_ENV	1813	265.9	546438.14	8487540.79	546450.78	8487531.06	15.9	
27/04/2017	01:01:23	SA1702_ENV22	Still	SA1702_ENV	1814	265.8	546438.14	8487540.79	546432.89	8487542.82	5.6	
27/04/2017	01:01:29	SA1702_ENV22	Still	SA1702_ENV	1815	266.4	546438.14	8487540.79	546432.14	8487543.63	6.6	
27/04/2017	01:02:01	SA1702_ENV22	Still	SA1702_ENV	1816	266.5	546438.14	8487540.79	546427.03	8487547.53	13.0	
27/04/2017	01:02:14	SA1702_ENV22	Still	SA1702_ENV	1817	266.7	546438.14	8487540.79	546425.15	8487549.38	15.6	
27/04/2017	01:03:03	SA1702_ENV22	Still	SA1702_ENV	1818	266.5	546438.14	8487540.79	546419.52	8487554.65	23.2	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
27/04/2017	01:03:13	SA1702_ENV22	Still	SA1702_ENV	1819	266.3	546438.14	8487540.79	546418.28	8487555.72	24.8	
27/04/2017	01:03:30	SA1702_ENV22	Still	SA1702_ENV	1820	265.5	546438.14	8487540.79	546415.91	8487557.71	27.9	
27/04/2017	01:03:41	SA1702_ENV22	Still	SA1702_ENV	1821	266.7	546438.14	8487540.79	546414.12	8487558.98	30.1	
27/04/2017	01:03:51	SA1702_ENV22	Still	SA1702_ENV	1822	266.7	546438.14	8487540.79	546412.69	8487560.38	32.1	
27/04/2017	01:04:08	SA1702_ENV22	Still	SA1702_ENV	1823	266.5	546438.14	8487540.79	546410.51	8487562.85	35.4	
27/04/2017	01:04:56	SA1702_ENV22	Still	SA1702_ENV	1824	266.8	546438.14	8487540.79	546403.65	8487569.08	44.6	
27/04/2017	01:05:54	SA1702_ENV22	Still	SA1702_ENV	1825	266.6	546438.14	8487540.79	546395.39	8487575.37	55.0	
27/04/2017	01:06:07	SA1702_ENV22	Still	SA1702_ENV	1826	266.5	546438.14	8487540.79	546393.82	8487576.90	57.2	
27/04/2017	01:06:51	SA1702_ENV22	Still	SA1702_ENV	1827	266.4	546438.14	8487540.79	546387.82	8487582.43	65.3	
27/04/2017	01:07:53	SA1702_ENV22	Still	SA1702_ENV	1828	267.3	546438.14	8487540.79	546377.68	8487590.64	78.4	
27/04/2017	01:08:03	SA1702_ENV22	Still	SA1702_ENV	1829	267.2	546438.14	8487540.79	546376.10	8487591.81	80.3	
27/04/2017	01:08:30	SA1702_ENV22	Still	SA1702_ENV	1830	266.8	546438.14	8487540.79	546372.36	8487595.02	85.3	
27/04/2017	01:09:20	SA1702_ENV22	Still	SA1702_ENV	1831	266.4	546438.14	8487540.79	546365.81	8487600.30	93.7	
27/04/2017	01:09:55	SA1702_ENV22	Still	SA1702_ENV	1832	267.2	546438.14	8487540.79	546360.70	8487604.43	100.2	
27/04/2017	01:10:23	SA1702_ENV22	Still	SA1702_ENV	1833	266.2	546438.14	8487540.79	546357.06	8487607.85	105.2	
27/04/2017	01:10:45	SA1702_ENV22	Still	SA1702_ENV	1834	267.5	546438.14	8487540.79	546353.44	8487610.93	110.0	
27/04/2017	01:11:11	SA1702_ENV22	Still	SA1702_ENV	1835	267.4	546438.14	8487540.79	546349.57	8487614.42	115.2	
27/04/2017	01:11:38	SA1702_ENV22	Still	SA1702_ENV	1836	267.2	546438.14	8487540.79	546345.18	8487617.66	120.6	
27/04/2017	01:11:54	SA1702_ENV22	Still	SA1702_ENV	1837	266.7	546438.14	8487540.79	546342.91	8487619.40	123.5	
27/04/2017	01:12:18	SA1702_ENV22	Still	SA1702_ENV	1838	266.2	546438.14	8487540.79	546339.24	8487622.57	128.3	
27/04/2017	01:12:32	SA1702_ENV22	Still	SA1702_ENV	1839	266.8	546438.14	8487540.79	546336.89	8487624.20	131.2	
27/04/2017	01:12:48	SA1702_ENV22	Still	SA1702_ENV	1840	266.8	546438.14	8487540.79	546334.67	8487626.10	134.1	
27/04/2017	01:13:05	SA1702_ENV22	Still	SA1702_ENV	1841	266.4	546438.14	8487540.79	546332.48	8487628.05	137.0	
27/04/2017	01:14:13	SA1702_ENV22	Still	SA1702_ENV	1842	267.1	546438.14	8487540.79	546323.73	8487636.11	148.9	
27/04/2017	01:14:32	SA1702_ENV22	Still	SA1702_ENV	1843	267.0	546438.14	8487540.79	546321.19	8487638.25	152.2	
27/04/2017	01:15:06	SA1702_ENV22	Still	SA1702_ENV	1844	267.2	546438.14	8487540.79	546316.14	8487642.88	159.1	
27/04/2017	01:15:53	SA1702_ENV22	Still	SA1702_ENV	1845	267.2	546438.14	8487540.79	546310.57	8487648.11	166.7	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
27/04/2017	02:40:30	SA1702_ENV24	Still	SA1702_ENV	1901	261.3	549157.34	8484632.54	549100.29	8484646.15	58.7	
27/04/2017	02:41:13	SA1702_ENV24	Still	SA1702_ENV	1902	261.5	549157.34	8484632.54	549103.51	8484645.58	55.4	
27/04/2017	02:41:33	SA1702_ENV24	Still	SA1702_ENV	1903	261.4	549157.34	8484632.54	549105.90	8484644.60	52.8	
27/04/2017	02:42:09	SA1702_ENV24	Still	SA1702_ENV	1904	262.4	549157.34	8484632.54	549112.34	8484643.70	46.4	
27/04/2017	02:43:01	SA1702_ENV24	Still	SA1702_ENV	1905	261.8	549157.34	8484632.54	549124.64	8484641.45	33.9	
27/04/2017	02:43:33	SA1702_ENV24	Still	SA1702_ENV	1906	262.0	549157.34	8484632.54	549130.88	8484638.88	27.2	
27/04/2017	02:43:38	SA1702_ENV24	Still	SA1702_ENV	1907	261.8	549157.34	8484632.54	549131.87	8484638.51	26.2	
27/04/2017	02:44:25	SA1702_ENV24	Still	SA1702_ENV	1908	262.0	549157.34	8484632.54	549138.30	8484636.35	19.4	
27/04/2017	02:44:37	SA1702_ENV24	Still	SA1702_ENV	1909	262.0	549157.34	8484632.54	549139.54	8484636.23	18.2	
27/04/2017	02:44:59	SA1702_ENV24	Still	SA1702_ENV	1910	261.9	549157.34	8484632.54	549141.38	8484636.31	16.4	
27/04/2017	02:46:43	SA1702_ENV24	Still	SA1702_ENV	1911	262.0	549157.34	8484632.54	549150.68	8484635.25	7.2	
27/04/2017	02:46:54	SA1702_ENV24	Still	SA1702_ENV	1912	262.2	549157.34	8484632.54	549152.82	8484634.87	5.1	
27/04/2017	02:47:35	SA1702_ENV24	Still	SA1702_ENV	1913	261.5	549157.34	8484632.54	549160.82	8484633.27	3.5	
27/04/2017	02:48:14	SA1702_ENV24	Still	SA1702_ENV	1914	261.3	549157.34	8484632.54	549170.04	8484631.33	12.8	
27/04/2017	02:48:43	SA1702_ENV24	Still	SA1702_ENV	1915	261.5	549157.34	8484632.54	549176.85	8484629.63	19.7	
27/04/2017	02:49:05	SA1702_ENV24	Still	SA1702_ENV	1916	262.3	549157.34	8484632.54	549182.30	8484628.59	25.3	
27/04/2017	02:49:44	SA1702_ENV24	Still	SA1702_ENV	1917	262.1	549157.34	8484632.54	549191.19	8484627.02	34.3	
27/04/2017	02:50:29	SA1702_ENV24	Still	SA1702_ENV	1918	261.8	549157.34	8484632.54	549199.84	8484623.94	43.4	
27/04/2017	02:51:01	SA1702_ENV24	Still	SA1702_ENV	1919	261.9	549157.34	8484632.54	549204.49	8484621.97	48.3	
27/04/2017	02:51:11	SA1702_ENV24	Still	SA1702_ENV	1920	261.2	549157.34	8484632.54	549205.73	8484621.47	49.6	
27/04/2017	02:51:59	SA1702_ENV24	Still	NO STILL	1921	262.5	549157.34	8484632.54	549211.45	8484620.32	55.5	
27/04/2017	02:53:18	SA1702_ENV24	Still	SA1702_ENV	1922	261.8	549157.34	8484632.54	549224.27	8484617.38	68.6	
27/04/2017	02:54:05	SA1702_ENV24	Still	SA1702_ENV	1923	261.7	549157.34	8484632.54	549230.60	8484614.80	75.4	
27/04/2017	02:54:44	SA1702_ENV24	Still	SA1702_ENV	1924	261.0	549157.34	8484632.54	549236.67	8484613.57	81.6	
27/04/2017	02:55:56	SA1702_ENV24	Still	SA1702_ENV	1925	261.1	549157.34	8484632.54	549249.19	8484610.92	94.4	
27/04/2017	02:56:30	SA1702_ENV24	Still	SA1702_ENV	1926	261.3	549157.34	8484632.54	549256.61	8484609.41	101.9	
27/04/2017	02:56:57	SA1702_ENV24	Still	SA1702_ENV	1927	261.6	549157.34	8484632.54	549262.08	8484608.15	107.5	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
27/04/2017	02:57:17	SA1702_ENV24	Still	SA1702_ENV	1928	261.9	549157.34	8484632.54	549266.15	8484607.47	111.7	
27/04/2017	02:57:47	SA1702_ENV24	Still	SA1702_ENV	1929	261.6	549157.34	8484632.54	549272.30	8484605.99	118.0	
27/04/2017	02:58:00	SA1702_ENV24	Still	SA1702_ENV	1930	261.7	549157.34	8484632.54	549274.91	8484605.29	120.7	
27/04/2017	02:58:08	SA1702_ENV24	Still	SA1702_ENV	1931	261.8	549157.34	8484632.54	549276.63	8484604.79	122.5	
27/04/2017	02:58:39	SA1702_ENV24	Still	SA1702_ENV	1932	261.4	549157.34	8484632.54	549282.15	8484602.69	128.3	
27/04/2017	02:58:57	SA1702_ENV24	Still	SA1702_ENV	1933	261.4	549157.34	8484632.54	549285.58	8484601.67	131.9	
27/04/2017	09:02:18	SA1702_ENV23	Still	SA1702_ENV	2001	257.6	539807.25	8481170.65	539753.84	8481136.11	63.6	
27/04/2017	09:02:33	SA1702_ENV23	Still	SA1702_ENV	2002	257.1	539807.25	8481170.65	539755.33	8481137.46	61.6	
27/04/2017	09:03:23	SA1702_ENV23	Still	SA1702_ENV	2003	257.3	539807.25	8481170.65	539761.04	8481141.09	54.9	
27/04/2017	09:03:54	SA1702_ENV23	Still	SA1702_ENV	2004	257.1	539807.25	8481170.65	539764.22	8481143.37	51.0	
27/04/2017	09:04:02	SA1702_ENV23	Still	SA1702_ENV	2005	257.4	539807.25	8481170.65	539765.05	8481144.06	49.9	
27/04/2017	09:04:23	SA1702_ENV23	Still	SA1702_ENV	2006	257.8	539807.25	8481170.65	539767.24	8481145.72	47.1	
27/04/2017	09:04:38	SA1702_ENV23	Still	SA1702_ENV	2007	257.0	539807.25	8481170.65	539768.58	8481146.85	45.4	
27/04/2017	09:05:11	SA1702_ENV23	Still	NO STILL	2008	257.3	539807.25	8481170.65	539768.58	8481146.85	45.4	
27/04/2017	09:08:11	SA1702_ENV23	Still	SA1702_ENV	2009	256.8	539807.25	8481170.65	539795.84	8481163.49	13.5	
27/04/2017	09:08:51	SA1702_ENV23	Still	SA1702_ENV	2010	257.2	539807.25	8481170.65	539800.19	8481164.33	9.5	
27/04/2017	09:09:46	SA1702_ENV23	Still	SA1702_ENV	2011	257.3	539807.25	8481170.65	539806.22	8481167.11	3.7	
27/04/2017	09:10:23	SA1702_ENV23	Still	SA1702_ENV	2012	257.4	539807.25	8481170.65	539810.25	8481170.85	3.0	
27/04/2017	09:10:49	SA1702_ENV23	Still	SA1702_ENV	2013	257.4	539807.25	8481170.65	539812.87	8481173.34	6.2	
27/04/2017	09:11:01	SA1702_ENV23	Still	SA1702_ENV	2014	257.2	539807.25	8481170.65	539814.52	8481174.72	8.3	
27/04/2017	09:11:35	SA1702_ENV23	Still	SA1702_ENV	2015	256.5	539807.25	8481170.65	539819.51	8481178.32	14.5	
27/04/2017	09:11:43	SA1702_ENV23	Still	SA1702_ENV	2016	257.9	539807.25	8481170.65	539820.88	8481179.24	16.1	
27/04/2017	09:12:26	SA1702_ENV23	Still	SA1702_ENV	2017	256.8	539807.25	8481170.65	539827.09	8481183.83	23.8	
27/04/2017	09:13:06	SA1702_ENV23	Still	SA1702_ENV	2018	256.4	539807.25	8481170.65	539831.74	8481188.00	30.0	
27/04/2017	09:13:51	SA1702_ENV23	Still	SA1702_ENV	2019	256.3	539807.25	8481170.65	539838.24	8481192.85	38.1	
27/04/2017	09:14:03	SA1702_ENV23	Still	SA1702_ENV	2020	255.9	539807.25	8481170.65	539839.35	8481194.14	39.8	
27/04/2017	09:14:54	SA1702_ENV23	Still	SA1702_ENV	2021	255.3	539807.25	8481170.65	539845.02	8481201.86	49.0	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
27/04/2017	09:15:02	SA1702_ENV23	Still	SA1702_ENV	2022	255.4	539807.25	8481170.65	539845.91	8481202.94	50.4	
27/04/2017	09:15:30	SA1702_ENV23	Still	SA1702_ENV	2023	255.4	539807.25	8481170.65	539848.81	8481206.76	55.1	
27/04/2017	09:15:55	SA1702_ENV23	Still	SA1702_ENV	2024	255.9	539807.25	8481170.65	539851.98	8481210.04	59.6	
27/04/2017	09:16:04	SA1702_ENV23	Still	SA1702_ENV	2025	255.6	539807.25	8481170.65	539853.02	8481211.32	61.2	
27/04/2017	09:16:33	SA1702_ENV23	Still	SA1702_ENV	2026	255.1	539807.25	8481170.65	539856.41	8481215.50	66.5	
27/04/2017	09:16:57	SA1702_ENV23	Still	SA1702_ENV	2027	255.8	539807.25	8481170.65	539858.70	8481218.21	70.1	
27/04/2017	09:17:52	SA1702_ENV23	Still	SA1702_ENV	2028	255.8	539807.25	8481170.65	539865.29	8481223.96	78.8	
27/04/2017	09:18:50	SA1702_ENV23	Still	SA1702_ENV	2029	256.6	539807.25	8481170.65	539872.47	8481231.31	89.1	
27/04/2017	09:19:20	SA1702_ENV23	Still	SA1702_ENV	2030	256.6	539807.25	8481170.65	539875.85	8481234.76	93.9	
27/04/2017	09:19:46	SA1702_ENV23	Still	SA1702_ENV	2031	257.1	539807.25	8481170.65	539878.86	8481237.98	98.3	
27/04/2017	09:20:34	SA1702_ENV23	Still	SA1702_ENV	2032	256.8	539807.25	8481170.65	539885.73	8481243.28	106.9	
27/04/2017	09:21:02	SA1702_ENV23	Still	SA1702_ENV	2033	257.1	539807.25	8481170.65	539889.86	8481246.23	112.0	
27/04/2017	09:21:18	SA1702_ENV23	Still	SA1702_ENV	2034	257.1	539807.25	8481170.65	539892.07	8481247.33	114.3	
27/04/2017	09:21:48	SA1702_ENV23	Still	SA1702_ENV	2035	257.2	539807.25	8481170.65	539895.98	8481250.28	119.2	
27/04/2017	09:22:12	SA1702_ENV23	Still	SA1702_ENV	2036	257.4	539807.25	8481170.65	539898.96	8481252.58	123.0	
27/04/2017	09:22:30	SA1702_ENV23	Still	SA1702_ENV	2037	257.3	539807.25	8481170.65	539900.81	8481254.14	125.4	
30/04/2017	14:32:16	SA1702_ENV29	Still	SA1702_ENV	2101	165.0	661390.26	8566820.76	661323.45	8566816.04	67.0	
30/04/2017	14:32:20	SA1702_ENV29	Still	SA1702_ENV	2102	165.1	661390.26	8566820.76	661323.46	8566816.05	67.0	
30/04/2017	14:32:27	SA1702_ENV29	Still	SA1702_ENV	2103	164.8	661390.26	8566820.76	661323.50	8566816.20	66.9	
30/04/2017	14:32:57	SA1702_ENV29	Still	SA1702_ENV	2104	164.5	661390.26	8566820.76	661323.78	8566817.17	66.6	
30/04/2017	14:33:18	SA1702_ENV29	Still	SA1702_ENV	2105	164.7	661390.26	8566820.76	661324.88	8566817.93	65.4	
30/04/2017	14:34:49	SA1702_ENV29	Still	SA1702_ENV	2106	164.4	661390.26	8566820.76	661335.89	8566818.92	54.4	
30/04/2017	14:36:22	SA1702_ENV29	Still	SA1702_ENV	2107	164.5	661390.26	8566820.76	661351.64	8566819.78	38.6	
30/04/2017	14:36:41	SA1702_ENV29	Still	SA1702_ENV	2108	164.4	661390.26	8566820.76	661355.16	8566820.65	35.1	
30/04/2017	14:37:20	SA1702_ENV29	Still	SA1702_ENV	2109	164.4	661390.26	8566820.76	661363.63	8566820.68	26.6	
30/04/2017	14:37:51	SA1702_ENV29	Still	SA1702_ENV	2110	164.9	661390.26	8566820.76	661370.66	8566820.64	19.6	
30/04/2017	20:56:40	SA1702_ENV08	Still	SA1702_ENV	2201	180.1	656192.87	8559557.34	656141.77	8559588.03	59.6	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
30/04/2017	20:57:26	SA1702_ENV08	Still	SA1702_ENV	2202	180.0	656192.87	8559557.34	656144.63	8559587.79	57.0	
30/04/2017	20:58:03	SA1702_ENV08	Still	SA1702_ENV	2203	180.5	656192.87	8559557.34	656150.85	8559587.17	51.5	
30/04/2017	20:58:30	SA1702_ENV08	Still	SA1702_ENV	2204	180.1	656192.87	8559557.34	656155.36	8559585.77	47.1	
30/04/2017	20:58:38	SA1702_ENV08	Still	SA1702_ENV	2205	180.8	656192.87	8559557.34	656156.24	8559585.16	46.0	
30/04/2017	20:59:34	SA1702_ENV08	Still	SA1702_ENV	2206	179.7	656192.87	8559557.34	656163.22	8559579.76	37.2	
30/04/2017	21:01:04	SA1702_ENV08	Still	SA1702_ENV	2207	180.6	656192.87	8559557.34	656175.11	8559569.69	21.6	
30/04/2017	21:01:54	SA1702_ENV08	Still	SA1702_ENV	2208	179.9	656192.87	8559557.34	656181.84	8559564.47	13.1	
30/04/2017	21:02:28	SA1702_ENV08	Still	SA1702_ENV	2209	179.5	656192.87	8559557.34	656187.18	8559560.85	6.7	
30/04/2017	21:04:34	SA1702_ENV08	Still	SA1702_ENV	2210	179.4	656192.87	8559557.34	656200.04	8559552.38	8.7	
30/04/2017	21:04:47	SA1702_ENV08	Still	SA1702_ENV	2211	179.6	656192.87	8559557.34	656202.00	8559551.92	10.6	
30/04/2017	21:05:19	SA1702_ENV08	Still	SA1702_ENV	2212	179.3	656192.87	8559557.34	656206.92	8559550.80	15.5	
30/04/2017	21:05:44	SA1702_ENV08	Still	SA1702_ENV	2213	179.7	656192.87	8559557.34	656211.32	8559549.45	20.1	
30/04/2017	21:05:50	SA1702_ENV08	Still	SA1702_ENV	2214	179.5	656192.87	8559557.34	656211.96	8559549.34	20.7	
30/04/2017	21:05:55	SA1702_ENV08	Still	NO STILL	2215	180.3	656192.87	8559557.34	656212.66	8559549.15	21.4	
30/04/2017	21:07:46	SA1702_ENV08	Still	SA1702_ENV	2216	179.9	656192.87	8559557.34	656230.40	8559541.80	40.6	
30/04/2017	21:08:34	SA1702_ENV08	Still	SA1702_ENV	2217	180.0	656192.87	8559557.34	656238.58	8559537.68	49.8	
30/04/2017	21:09:02	SA1702_ENV08	Still	SA1702_ENV	2218	179.4	656192.87	8559557.34	656243.22	8559534.52	55.3	
30/04/2017	21:09:13	SA1702_ENV08	Still	SA1702_ENV	2219	179.8	656192.87	8559557.34	656244.99	8559533.15	57.5	
30/04/2017	21:10:32	SA1702_ENV08	Still	SA1702_ENV	2220	179.8	656192.87	8559557.34	656257.67	8559525.35	72.3	
30/04/2017	21:11:26	SA1702_ENV08	Still	SA1702_ENV	2221	179.6	656192.87	8559557.34	656265.72	8559519.65	82.0	
30/04/2017	21:11:50	SA1702_ENV08	Still	SA1702_ENV	2222	179.4	656192.87	8559557.34	656269.10	8559516.81	86.3	
30/04/2017	21:12:05	SA1702_ENV08	Still	SA1702_ENV	2223	179.5	656192.87	8559557.34	656271.25	8559515.25	89.0	
30/04/2017	21:12:25	SA1702_ENV08	Still	SA1702_ENV	2224	179.6	656192.87	8559557.34	656274.06	8559513.49	92.3	
30/04/2017	21:13:03	SA1702_ENV08	Still	SA1702_ENV	2225	179.3	656192.87	8559557.34	656279.98	8559509.09	99.6	
30/04/2017	21:13:28	SA1702_ENV08	Still	SA1702_ENV	2226	179.1	656192.87	8559557.34	656283.96	8559506.73	104.2	
30/04/2017	21:13:58	SA1702_ENV08	Still	SA1702_ENV	2227	179.8	656192.87	8559557.34	656288.03	8559503.30	109.4	
30/04/2017	21:14:27	SA1702_ENV08	Still	SA1702_ENV	2228	179.2	656192.87	8559557.34	656292.05	8559500.67	114.2	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
30/04/2017	21:15:09	SA1702_ENV08	Still	SA1702_ENV	2229	180.0	656192.87	8559557.34	656297.45	8559496.00	121.2	
01/05/2017	01:41:40	SA1702_ENV10	Still	SA1702_ENV	2301	209.0	618604.16	8548495.23	618683.31	8548453.19	89.6	
01/05/2017	01:42:42	SA1702_ENV10	Still	SA1702_ENV	2302	209.8	618604.16	8548495.23	618683.01	8548449.17	91.3	
01/05/2017	01:46:41	SA1702_ENV10	Still	SA1702_ENV	2303	209.3	618604.16	8548495.23	618663.95	8548456.38	71.3	
01/05/2017	01:48:04	SA1702_ENV10	Still	SA1702_ENV	2304	211.0	618604.16	8548495.23	618648.22	8548469.12	51.2	
01/05/2017	01:48:50	SA1702_ENV10	Still	SA1702_ENV	2305	210.1	618604.16	8548495.23	618639.44	8548476.50	39.9	
01/05/2017	01:49:31	SA1702_ENV10	Still	SA1702_ENV	2306	209.6	618604.16	8548495.23	618632.06	8548482.61	30.6	
01/05/2017	01:49:35	SA1702_ENV10	Still	SA1702_ENV	2307	209.7	618604.16	8548495.23	618631.22	8548483.00	29.7	
01/05/2017	01:49:38	SA1702_ENV10	Still	NO STILL	2308	209.7	618604.16	8548495.23	618630.75	8548483.70	29.0	
01/05/2017	01:50:19	SA1702_ENV10	Still	SA1702_ENV	2309	210.4	618604.16	8548495.23	618623.05	8548488.64	20.0	
01/05/2017	01:51:10	SA1702_ENV10	Still	SA1702_ENV	2310	209.9	618604.16	8548495.23	618613.54	8548494.61	9.4	
01/05/2017	01:52:05	SA1702_ENV10	Still	SA1702_ENV	2311	209.4	618604.16	8548495.23	618601.95	8548498.38	3.8	
01/05/2017	01:52:41	SA1702_ENV10	Still	SA1702_ENV	2312	210.6	618604.16	8548495.23	618594.15	8548501.68	11.9	
01/05/2017	01:53:06	SA1702_ENV10	Still	SA1702_ENV	2313	210.3	618604.16	8548495.23	618590.15	8548502.32	15.7	
01/05/2017	01:53:45	SA1702_ENV10	Still	SA1702_ENV	2314	210.5	618604.16	8548495.23	618583.90	8548501.62	21.2	
01/05/2017	01:55:05	SA1702_ENV10	Still	SA1702_ENV	2315	209.4	618604.16	8548495.23	618570.61	8548496.42	33.6	
01/05/2017	01:55:37	SA1702_ENV10	Still	SA1702_ENV	2316	209.6	618604.16	8548495.23	618563.37	8548495.89	40.8	
01/05/2017	01:56:06	SA1702_ENV10	Still	SA1702_ENV	2317	209.8	618604.16	8548495.23	618555.81	8548494.13	48.4	
01/05/2017	01:56:29	SA1702_ENV10	Still	SA1702_ENV	2318	210.6	618604.16	8548495.23	618550.04	8548493.73	54.1	
01/05/2017	01:57:00	SA1702_ENV10	Still	SA1702_ENV	2319	209.9	618604.16	8548495.23	618541.85	8548492.39	62.4	
01/05/2017	01:57:57	SA1702_ENV10	Still	SA1702_ENV	2320	210.2	618604.16	8548495.23	618523.30	8548494.06	80.9	
01/05/2017	01:58:04	SA1702_ENV10	Still	SA1702_ENV	2321	211.0	618604.16	8548495.23	618521.61	8548493.37	82.6	
01/05/2017	01:58:41	SA1702_ENV10	Still	SA1702_ENV	2322	211.0	618604.16	8548495.23	618509.84	8548494.50	94.3	
01/05/2017	01:58:53	SA1702_ENV10	Still	SA1702_ENV	2323	210.5	618604.16	8548495.23	618504.83	8548496.31	99.3	
01/05/2017	01:59:46	SA1702_ENV10	Still	SA1702_ENV	2324	210.2	618604.16	8548495.23	618488.25	8548501.03	116.1	
01/05/2017	02:00:19	SA1702_ENV10	Still	SA1702_ENV	2325	210.2	618604.16	8548495.23	618478.53	8548502.39	125.8	
01/05/2017	02:00:39	SA1702_ENV10	Still	SA1702_ENV	2326	210.1	618604.16	8548495.23	618473.00	8548502.92	131.4	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
01/05/2017	02:00:56	SA1702_ENV10	Still	SA1702_ENV	2327	210.7	618604.16	8548495.23	618467.35	8548503.95	137.1	
01/05/2017	02:01:07	SA1702_ENV10	Still	SA1702_ENV	2328	210.7	618604.16	8548495.23	618464.38	8548504.31	140.1	
01/05/2017	02:01:36	SA1702_ENV10	Still	SA1702_ENV	2329	210.7	618604.16	8548495.23	618455.47	8548506.01	149.1	
01/05/2017	02:01:54	SA1702_ENV10	Still	SA1702_ENV	2330	210.8	618604.16	8548495.23	618450.83	8548506.59	153.8	
01/05/2017	02:02:21	SA1702_ENV10	Still	SA1702_ENV	2331	210.3	618604.16	8548495.23	618444.18	8548506.70	160.4	
01/05/2017	02:02:43	SA1702_ENV10	Still	NO STILL	2332	210.3	618604.16	8548495.23	618438.29	8548506.75	166.3	
01/05/2017	02:03:03	SA1702_ENV10	Still	SA1702_ENV	2333	210.0	618604.16	8548495.23	618433.20	8548506.01	171.3	
01/05/2017	02:03:33	SA1702_ENV10	Still	SA1702_ENV	2334	210.6	618604.16	8548495.23	618425.19	8548506.09	179.3	
01/05/2017	02:03:47	SA1702_ENV10	Still	SA1702_ENV	2335	210.8	618604.16	8548495.23	618421.71	8548505.85	182.8	
01/05/2017	02:04:05	SA1702_ENV10	Still	SA1702_ENV	2336	211.2	618604.16	8548495.23	618416.68	8548505.49	187.8	
01/05/2017	02:04:14	SA1702_ENV10	Still	SA1702_ENV	2337	211.1	618604.16	8548495.23	618414.16	8548506.14	190.3	
01/05/2017	02:04:21	SA1702_ENV10	Still	SA1702_ENV	2338	210.8	618604.16	8548495.23	618412.54	8548506.30	191.9	
01/05/2017	02:04:35	SA1702_ENV10	Still	SA1702_ENV	2339	211.3	618604.16	8548495.23	618407.98	8548506.54	196.5	
01/05/2017	02:04:50	SA1702_ENV10	Still	SA1702_ENV	2340	211.6	618604.16	8548495.23	618402.88	8548507.47	201.7	
01/05/2017	02:05:01	SA1702_ENV10	Still	SA1702_ENV	2341	211.6	618604.16	8548495.23	618399.86	8548508.09	204.7	
01/05/2017	02:05:29	SA1702_ENV10	Still	SA1702_ENV	2342	210.4	618604.16	8548495.23	618392.59	8548508.28	212.0	
01/05/2017	07:42:25	SA1702_ENV16	Still	SA1702_ENV	2401	171.6	572916.72	8513079.05	572969.77	8513096.64	55.9	
01/05/2017	07:43:00	SA1702_ENV16	Still	SA1702_ENV	2402	172.2	572916.72	8513079.05	572968.18	8513091.77	53.0	
01/05/2017	07:43:14	SA1702_ENV16	Still	SA1702_ENV	2403	172.6	572916.72	8513079.05	572967.86	8513090.59	52.4	
01/05/2017	07:44:41	SA1702_ENV16	Still	SA1702_ENV	2404	171.6	572916.72	8513079.05	572960.81	8513084.27	44.4	
01/05/2017	07:45:00	SA1702_ENV16	Still	NO STILL	2405	171.2	572916.72	8513079.05	572957.91	8513083.05	41.4	
01/05/2017	07:45:58	SA1702_ENV16	Still	SA1702_ENV	2406	170.8	572916.72	8513079.05	572951.46	8513080.97	34.8	
01/05/2017	07:47:20	SA1702_ENV16	Still	SA1702_ENV	2407	171.6	572916.72	8513079.05	572940.84	8513078.40	24.1	
01/05/2017	07:47:57	SA1702_ENV16	Still	SA1702_ENV	2408	172.4	572916.72	8513079.05	572934.01	8513077.60	17.4	
01/05/2017	07:48:30	SA1702_ENV16	Still	SA1702_ENV	2409	171.5	572916.72	8513079.05	572927.73	8513077.44	11.1	
01/05/2017	07:49:04	SA1702_ENV16	Still	NO STILL	2410	170.8	572916.72	8513079.05	572922.40	8513078.47	5.7	
01/05/2017	07:50:16	SA1702_ENV16	Still	SA1702_ENV	2411	171.1	572916.72	8513079.05	572908.79	8513079.51	7.9	

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Time [UTC]	Transect	Type	ID	Fix No.	Water Depth [m]	Proposed Location		Actual Location		Offset [m]	Notes
							Easting [m]	Northing [m]	Easting [m]	Northing [m]		
01/05/2017	07:50:54	SA1702_ENV16	Still	SA1702_ENV	2412	170.9	572916.72	8513079.05	572900.12	8513079.59	16.6	
01/05/2017	07:50:59	SA1702_ENV16	Still	SA1702_ENV	2413	172.0	572916.72	8513079.05	572898.66	8513079.78	18.1	
01/05/2017	07:51:29	SA1702_ENV16	Still	SA1702_ENV	2414	170.6	572916.72	8513079.05	572891.47	8513080.13	25.3	
01/05/2017	07:52:29	SA1702_ENV16	Still	SA1702_ENV	2415	170.8	572916.72	8513079.05	572877.64	8513081.73	39.2	
01/05/2017	07:52:56	SA1702_ENV16	Still	SA1702_ENV	2416	171.2	572916.72	8513079.05	572872.18	8513082.63	44.7	
01/05/2017	07:53:10	SA1702_ENV16	Still	SA1702_ENV	2417	171.0	572916.72	8513079.05	572869.95	8513083.09	46.9	
01/05/2017	07:53:55	SA1702_ENV16	Still	SA1702_ENV	2418	170.9	572916.72	8513079.05	572863.09	8513084.66	53.9	
01/05/2017	07:54:27	SA1702_ENV16	Still	SA1702_ENV	2419	171.7	572916.72	8513079.05	572857.41	8513084.99	59.6	
01/05/2017	07:54:44	SA1702_ENV16	Still	SA1702_ENV	2420	171.2	572916.72	8513079.05	572854.85	8513085.53	62.2	
01/05/2017	07:55:32	SA1702_ENV16	Still	SA1702_ENV	2421	171.3	572916.72	8513079.05	572846.40	8513085.30	70.6	
01/05/2017	07:55:58	SA1702_ENV16	Still	SA1702_ENV	2422	171.5	572916.72	8513079.05	572841.08	8513084.04	75.8	
01/05/2017	07:56:02	SA1702_ENV16	Still	SA1702_ENV	2423	171.9	572916.72	8513079.05	572840.15	8513083.96	76.7	
01/05/2017	07:56:12	SA1702_ENV16	Still	NO STILL	2424	170.9	572916.72	8513079.05	572838.26	8513083.62	78.6	
01/05/2017	07:57:09	SA1702_ENV16	Still	SA1702_ENV	2425	171.7	572916.72	8513079.05	572823.82	8513079.35	92.9	
01/05/2017	07:57:51	SA1702_ENV16	Still	SA1702_ENV	2426	171.9	572916.72	8513079.05	572813.29	8513078.33	103.4	
01/05/2017	07:58:10	SA1702_ENV16	Still	SA1702_ENV	2427	171.6	572916.72	8513079.05	572808.28	8513077.48	108.5	
01/05/2017	07:58:21	SA1702_ENV16	Still	NO STILL	2428	171.9	572916.72	8513079.05	572805.81	8513077.88	110.9	
01/05/2017	07:58:48	SA1702_ENV16	Still	SA1702_ENV	2429	171.7	572916.72	8513079.05	572800.23	8513078.02	116.5	

A.2 VIDEO/PHOTOGRAPHIC LOG

GDA94, MGA94, UTM Zone 51, CM123 °East									
Date	Transect	Video File	Time [UTC]	Video Coordinates		Length [m]	Still Nos.	Sediment Description	Fauna/Bioturbation/Debris
				Easting [m]	Northing [m]				
22/04/2017	SA1702_ENV02	20170422052614_1	05:26:13	661531.53	8571433.04	16	3	Reef with gravelly sand veneer	Sea whip (Alcyonacea), fan coral (Alcyonacea), branching coral (Alcyonacea), hydroids (Hydrozoa), sea anemones (Actiniaria)
			05:28:49	661519.01	8571422.76				
22/04/2017	SA1702_ENV02	20170422052614_1	05:28:49	661519.01	8571422.76	10	1	Sand	Burrows, hydroids (Hydrozoa)
			05:30:07	661512.76	8571415.31				
22/04/2017	SA1702_ENV02	20170422052614_1	05:30:07	661512.76	8571415.31	140	10	Reef with gravelly sand veneer	Sea whip (Alcyonacea), fan coral (Alcyonacea), hydroids (Hydrozoa), branching coral (Alcyonacea), sponges (Porifera), barrel sponges (Porifera), sea cucumber, fish, cryptic coral
			05:43:08	661422.80	8571308.30				
22/04/2017	SA1702_ENV02	20170422052614_1	05:43:08	661422.80	8571308.30	149	17	Reef with sand veneer	Sea whip (Alcyonacea), fan coral (Alcyonacea), hydroids (Hydrozoa), branching coral (Alcyonacea), sponges (Porifera), fish, dead coral
			05:56:42	661326.94	8571193.89				
22/04/2017	SA1702_ENV02	20170422052614_2	05:56:42	661326.94	8571193.89	101	10	Reef with sand veneer	Fish, fan coral (Alcyonacea), branching coral (Alcyonacea), hydroids (Hydrozoa), sea whip (Alcyonacea), dead coral
			06:06:07	661262.88	8571115.98				
22/04/2017	SA1702_ENV02	20170422052614_2	06:06:07	661262.88	8571115.98	20	2	Sand	Burrows, hydroids (Hydrozoa)
			06:08:04	661250.56	8571100.11				
22/04/2017	SA1702_ENV02	20170422052614_2	06:08:04	661250.56	8571100.11	8	1	Reef boulders with sand veneer	Hydroids (Hydrozoa), branching coral (Alcyonacea), fan coral (Alcyonacea), fish
			06:08:49	661246.25	8571093.52				
22/04/2017	SA1702_ENV02	20170422052614_2	06:08:49	661246.25	8571093.52	74	9	Sand forming ripples	Burrows, hydroids (Hydrozoa), faunal tracks
			06:15:39	661202.72	8571033.20				
22/04/2017	SA1702_ENV01	20170424034654	11:05:22	663708.71	8570789.01	49	6	Gravelly sand	Soft coral (Alcyonaria), sea cucumber (Holothuridae), hydroids (Hydrozoa), fish, flat fish
			11:09:28	663681.20	8570747.95				
22/04/2017	SA1702_ENV01	20170424034654	11:09:28	663681.20	8570747.95	25	5	Reef with gravelly sand veneer	Fish, hydroids (Hydrozoa)
			11:12:14	663666.45	8570727.24				
22/04/2017	SA1702_ENV01	20170424034654	11:12:14	663666.45	8570727.24	177	25	Gravelly sand	Soft coral (Alcyonaria), hydroids (Hydrozoa), sea cucumber? (Holothuridae), fish, sea pen
			11:30:37	663570.85	8570578.62				

GDA94, MGA94, UTM Zone 51, CM123 °East									
Date	Transect	Video File	Time [UTC]	Video Coordinates Easting [m]	Video Coordinates Northing [m]	Length [m]	Still Nos.	Sediment Description	Fauna/Bioturbation/Debris
									(Pennatulacea), burrows, sea urchin (Echinoidea), sea whip (Alcyonacea), burrows, sea anemones (Actiniaria)
23/04/2017	SA1702_ENV03	20170423004121_1	00:41:21	657509.58	8568862.76	321	32	Sand forming ripples	Burrows, sea pen (Pennatulacea), sea urchin (Echinoidea), hydroids (Hydrozoa)
			01:11:49	657793.18	8568711.71				
23/04/2017	SA1702_ENV03	20170423004121_2	01:11:50	657793.50	8568711.42	24	3	Sand forming ripples	Burrows
			01:14:11	657814.66	8568700.43				
23/04/2017	SA1702_ENV04	20170423032326	03:23:25	656229.20	8566668.33	204	21	Sand forming ripples	Sea anemones (Actiniaria), tubular glass sponges (Porifera), burrows, stalked crinoid (Isselicrinidae), sea urchin (Echinoidea), fish, hydroids (Hydrozoa)
			03:39:24	656078.04	8566531.18				
23/04/2017	SA1702_ENV05	20170423044616	04:46:16	656387.08	8565625.02	178	22	Gravelly sand	burrows, sea anemones (Actiniaria), hydroids (Hydrozoa), tubular glass sponges (Porifera), soft coral (Alcyonaria), sea whip (Alcyonacea)
			05:02:51	656536.53	8565722.02				
23/04/2017	SA1702_ENV05	20170423044616	05:02:51	656536.53	8565722.02	99	10	Reef covered by gravelly sand veneer	Soft coral (Alcyonaria), sponges (Porifera), hydroids (Hydrozoa), stalked crinoids (Isselicrinidae), fish, burrows, laminar sponge (Porifera), sea urchin (Echinoidea)
			05:11:51	656619.49	8565775.63				
23/04/2017	SA1702_ENV05A	20170423112046	11:20:46	656566.11	8565740.66	40	6	Gravelly sand	Stalked crinoids (Isselicrinidae), hydroids (Hydrozoa), sea urchin, fish, sponge (Porifera), soft coral (Nephtheidae), bryozoan, burrows
			11:25:00	656600.83	8565760.34				
23/04/2017	SA1702_ENV05A	20170423112046	11:25:00	656600.83	8565760.34	68	12	Outcropping of hard substrate	Stalked crinoids (Isselicrinidae), hydroids (Hydrozoa), sea urchin (Echinoidea), fish, sponge, branching coral (Alcyonacea), bryozoan, burrows, tubular sponges (Porifera), sea whips (Alcyonacea)
			11:31:01	656658.56	8565796.47				
23/04/2017	SA1702_ENV05A	20170423112046	11:31:01	656658.56	8565796.47	90	15	Gravelly sand	Burrows, sponge, branching coral (Alcyonacea), sea anemone (Actiniaria), hydroids (Hydrozoa), crinoids (Crinoidea), sea urchins (Echinoidea)
			11:39:25	656735.03	8565844.19				
24/04/2017	SA1702_ENV06	20170423034654	03:46:54	657760.40	8564621.35	185	10*	Sand	

GDA94, MGA94, UTM Zone 51, CM123 °East									
Date	Transect	Video File	Time [UTC]	Video Coordinates		Length [m]	Still Nos.	Sediment Description	Fauna/Bioturbation/Debris
				Easting [m]	Northing [m]				
			04:01:01	657902.12	8564740.05				sea anemones (Actiniaria), burrows, fish, hydroids (Hydrozoa), tubular glass sponge (Porifera), sea urchin (Echinoidea)
24/04/2017	SA1702_ENV07	20170424062728_1	06:27:28	654189.3	8562374.6	320	13*	Sand forming ripples	Burrows, hermit crab (Paguroidea), sea potato (Echinoidea), fish, sea urchin (Echinoidea)
			06:58:06	654465.85	8562213.90				
24/04/2017	SA1702_ENV07	20170424062728_2	06:58:06	654465.85	8562213.90	12	3*	Sand forming ripples	Burrows
			06:59:10	654475.98	8562207.63				
24/04/2017	SA1702_ENV09	20170424120541	12:05:40	629714.45	8554194.01	63	9	Gravelly sand	Fish, sea anemones (Actiniaria)
			12:13:30	629653.94	8554211.67				
24/04/2017	SA1702_ENV09A	20170424124209	12:42:08	629457.86	8554276.82	148	14	Gravelly sand	Fish, burrows
			12:54:43	629598.00	8554229.66				
24/04/2017	SA1702_ENV09A	20170424124209	12:54:43	629598.00	8554229.66	5	3	Reef rubble with gravelly sand veneer	Stalked crinoids (Isselicrinidae), sponges (Porifera), hydroids (Hydrozoa), fish
			12:55:04	629602.41	8554228.59				
24/04/2017	SA1702_ENV09A	20170424124209	12:55:04	629602.41	8554228.59	62	7	Gravelly sand	Fish, burrows
			12:59:43	629663.36	8554219.02				
24/04/2017	SA1702_ENV11	20170424223209	22:32:08	604638.61	8540051.69	36	6	Sandy gravel	Fish
			22:36:12	604623.92	8540018.48				
24/04/2017	SA1702_ENV11	20170424223209	22:36:12	604623.92	8540018.48	22	2	Gravelly sand forming ripples	Fish
			22:38:29	604619.19	8539996.51				
24/04/2017	SA1702_ENV11	20170424223209	22:38:29	604619.19	8539996.51	27	4	Sandy gravel	No visible fauna
			22:41:00	604609.38	8539971.82				
24/04/2017	SA1702_ENV11	20170424223209	22:41:00	604609.38	8539971.82	28	4	Sand forming ripples	No visible fauna
			22:43:35	604601.34	8539944.58				
24/04/2017	SA1702_ENV11	20170424223209	22:43:35	604601.34	8539944.58	70	8	Gravelly sand	No visible fauna
			22:50:16	604573.48	8539880.46				
24/04/2017	SA1702_ENV11	20170424223209	22:50:16	604573.48	8539880.46	43	11	Reef with sand veneer	Sea pen (Pennatulacea), crinoid (Crinoidea), sponge (Porifera)
			22:54:15	604559.80	8539839.63				

GDA94, MGA94, UTM Zone 51, CM123 °East									
Date	Transect	Video File	Time [UTC]	Video Coordinates		Length [m]	Still Nos.	Sediment Description	Fauna/Bioturbation/Debris
				Easting [m]	Northing [m]				
25/04/2017	SA1702_ENV12	20170425004905	00:49:04	602451.71	8537279.04	312	49	Reef with sand veneer	Stalked crinoid (Isselicrinidae), sponge (Porifera), starfish (Asteroidea), sea anemone (Actiniaria), branched coral (Alcyonacea), crinoids (Crinoidea), sea urchins (Echinoidea), burrows
			01:18:43	602283.90	8537016.35				
25/04/2017	SA1702_ENV13	20170425041526	04:15:25	597039.12	8533100.50	287	33	Sand forming ripples, shell fragments	Burrows, fish
			04:45:39	597117.33	8532824.13				
25/04/2017	SA1702_ENV14	20170425041526	09:14:57	585598.47	8524336.86	56	9	Sand	fish, burrows, faunal tracks
			09:22:41	585577.81	8524284.77				
25/04/2017	SA1702_ENV14	20170425041526	09:22:41	585577.81	8524284.77	14	5	Depression, reef rubble with sand veneer	No visible fauna
			09:24:02	585574.56	8524271.51				
25/04/2017	SA1702_ENV14	20170425041526	09:24:02	585574.56	8524271.51	111	14	Sand	Sea urchin (Echinoidea), fish, burrows,
			09:35:06	585551.40	8524163.03				
25/04/2017	SA1702_ENV15	20170425130924	13:09:23	579254.05	8519450.22	34	3	Sand	Burrows, fish
			13:12:24	579253.35	8519416.68				
25/04/2017	SA1702_ENV15	20170425130924	13:12:24	579253.35	8519416.68	53	17	Depression, reef rubble with gravelly sand veneer	Sea whip (Alcyonacea), hydroids (Hydrozoa), fish, sponge (Porifera), stalked crinoid (Isselicrinidae), burrows,
			13:18:13	579258.68	8519363.65				
25/04/2017	SA1702_ENV15	20170425130924	13:18:13	579258.68	8519363.65	149	16	Sand	Burrows, sea pen? (Pennatulacea), fish
			13:31:12	579313.23	8519224.71				
26/04/2017	SA1702_ENV18	20170426004247	00:42:47	559581.08	8500701.19	23	5	Muddy sand	Burrows, branching coral (Alcyonacea), fish
			00:46:20	559564.19	8500685.63				
26/04/2017	SA1702_ENV18	20170426004247	00:46:20	559564.19	8500685.63	23	6	Reef rubble with sand veneer	Sponge, crinoid (Crinoidea), sea anemone (Actiniaria), Soft coral (Alcyonaria), fish
			00:49:53	559547.20	8500669.63				
26/04/2017	SA1702_ENV18	20170426004247	00:49:53	559547.20	8500669.63	74	13	Sand	Burrows, sand dollar (Echinoidea), fish
			00:58:58	559493.79	8500619.12				
26/04/2017	SA1702_ENV18	20170426004247	00:58:58	559493.79	8500619.12	60	17	Reef outcropping	Crinoids (Crinoidea), soft coral (Alcyonaria), sea anemones (Actiniaria), branching coral (Alcyonacea), sea pen
			01:05:58	559444.49	8500584.63				

GDA94, MGA94, UTM Zone 51, CM123 °East									
Date	**Transect**	**Video File**	**Time [UTC]**	**Video Coordinates**		**Length [m]**	**Still Nos.**	**Sediment Description**	**Fauna/Bioturbation/Debris**
				Easting [m]	**Northing [m]**				
									(Pennatulacea), stalked crinoid (Isselicrinidae), fan coral (Alcyonacea), squat lobsters (Anomura), fish, sea urchin (Echinoidea)
26/04/2017	SA1702_ENV18	20170426004247	01:05:58	559444.49	8500584.63	55	10	Reef rubble with sand veneer	Fish, burrows, soft coral (Alcyonaria), stalked crinoid (Isselicrinidae), bryozoan
			01:12:52	559399.17	8500553.92				
26/04/2017	SA1702_ENV19	20170426021026_1	02:10:25	558593.31	8499068.71	111	13	Reef rubble with sand veneer	Fan worms (Sabellidae), burrows, soft coral (Alcyonaria), crinoid (Crinoidea), branching coral (Alcyonacea), sponge (Porifera), sea pen (Pennatulacea), bryozoan, starfish (Asteroidea)
			02:21:08	558485.98	8499097.89				
26/04/2017	SA1702_ENV19	20170426021026_1	02:21:08	558485.98	8499097.89	60	12	Reef with sand veneer, high relief	Burrows, soft coral (Alcyonaria), fan coral (Alcyonacea), sponge (Porifera), sea anemone (Actiniaria), branching coral (Alcyonacea),
			02:25:33	558427.98	8499112.97				
26/04/2017	SA1702_ENV19	20170426021026_1	02:25:33	558427.98	8499112.97	135	19	Reef with sand veneer	Soft coral (Alcyonaria), sponges (Porifera), sea urchin (Echinoidea), fan coral (Alcyonacea), fan worms (Sabellidae), sea pen (Pennatulacea), acorn worm casing (Enteropneusta), sea anemone (Actiniaria), faunal tracks, burrows
			02:34:49	558296.46	8499145.13				
26/04/2017	SA1702_ENV19	20170426021026_1	02:34:49	558296.46	8499145.13	67	8	Reef with sand veneer, medium relief	Sponges (Porifera), sea urchin (Echinoidea), branching coral (Alcyonacea), burrows, crab (Decapoda)
			02:39:42	558231.89	8499162.33				
26/04/2017	SA1702_ENV19	20170426021026_1	02:39:42	558231.89	8499162.33	18	1	Sand	Burrows, hermit crab (Paguroidae), sea anemone (Actiniaria)
			02:41:00	558214.84	8499166.55				
26/04/2017	SA1702_ENV19	20170426021026_2	02:41:01	558214.62	8499166.58	17	3	Reef with sand veneer	Burrows, sea anemone (Actiniaria)
			02:42:14	558197.58	8499170.16				
26/04/2017	SA1702_ENV20	20170426063102_1	06:31:02	556518.21	8498104.46	45	4	Muddy sand forming ripples	Burrows, sea urchin (Echinoidea), faunal tracks, hydroids (Hydrozoa)
			06:36:54	556550.93	8498073.26				
26/04/2017	SA1702_ENV20	20170426063102_1	06:36:54	556550.93	8498073.26	64	8	Muddy sand	Burrows, sea pen (Pennatulacea)
			06:42:51	556598.25	8498030.83				

GDA94, MGA94, UTM Zone 51, CM123 °East									
Date	Transect	Video File	Time [UTC]	Video Coordinates Easting [m]	Video Coordinates Northing [m]	Length [m]	Still Nos.	Sediment Description	Fauna/Bioturbation/Debris
26/04/2017	SA1702_ENV20	20170426063102_1	06:42:51	556598.25	8498030.83	193	40	Reef rubble with veneer of muddy sand	Laminar sponge (Porifera), soft coral (Alcyonaria), sea anemone (Actiniaria), burrows, hydroids (Hydrozoa), sea whip (Alcyonacea), sponge (Porifera), stalked crinoid (Isselicrinidae), sea cucumber (Holothuridae), starfish (Asteroidea)
			07:01:19	556747.26	8497908.49				
26/04/2017	SA1702_ENV20	20170426063102_2	07:01:20	556747.26	8497908.49	73	13	Reef rubble with veneer of muddy sand	Sponge (Porifera), branching coral (Alcyonacea), starfish (Asteroidea), laminar sponge (Porifera), burrows
			07:07:05	556797.92	8497856.37				
26/04/2017	SA1702_ENV20	20170426063102_2	07:07:05	556797.92	8497856.37	155	17	Muddy sand	Burrows, fan worm (Sabellidae), sponge (Porifera)
			07:18:18	556905.36	8497744.97				
26/04/2017	SA1702_ENV26	20170426125427_1	12:54:27	559082.60	8491595.79	172	41	Reef with veneer of sand	Sponge (Porifera), hydroids (Hydrozoa), sea anemones (Actiniaria), branching coral (Alcyonacea), tubular sponges (Porifera), sea whip (Alcyonacea), crab (Decapoda), burrows, soft coral (Alcyonaria), crinoids (Crinoidea)
			13:24:50	558942.68	8491495.02				
26/04/2017	SA1702_ENV26	20170426125427_2	13:24:51	558942.76	8491494.65	176	39	Reef with veneer of sand	Sponge (Porifera), starfish (Asteroidea), burrows, fish, sea anemone (Actiniaria), foliose sponge (Porifera), crinoids (Crinoidea), sea snail (Trochidae), squat lobster (Decapoda), lobster (Decapoda), starfish (Asteroidea)
			13:48:36	558785.33	8491415.74				
26/04/2017	SA1702_ENV26	20170426125427_2	13:48:36	558785.33	8491415.74	30	2	Sand forming sand ripples	Hydroids (Hydrozoa), burrows
			13:51:30	558759.19	8491400.81				
26/04/2017	SA1702_ENV26	20170426125427_2	13:51:30	558759.19	8491400.81	29	6	Gravelly sand	Hydroids (Hydrozoa), burrows, crinoids (Crinoidea)
			13:53:59	558732.86	8491388.15				
26/04/2017	SA1702_ENV26	20170426125427_2	13:53:59	558732.86	8491388.15	16	3	Reef with veneer of sand	Sponges (Porifera), sea anemone (Actiniaria), basket star (Phrynophiurida)
			13:55:30	558719.54	8491378.94				
26/04/2017	SA1702_ENV26	20170426125427_3	13:55:30	558719.54	8491378.94	22	5	Reef with veneer of sand	Sea pens (Pennatulacea), burrows, sea cucumber (Holothuridae), sponge (laminar) (Porifera), hydroids (Hydrozoa), soft coral (Alcyonaria),
			13:57:47	558701.54	8491365.67				

GDA94, MGA94, UTM Zone 51, CM123 °East									
Date	Transect	Video File	Time [UTC]	Video Coordinates Easting [m]	Video Coordinates Northing [m]	Length [m]	Still Nos.	Sediment Description	Fauna/Bioturbation/Debris
26/04/2017	SA1702_ENV25	20170426145238	14:52:38 14:59:19	557436.38 557417.03	8490735.70 8490691.71	48	8	Muddy sand	Burrows, hydroids (Hydrozoa), fish, hermit crab (Paguroidea), sea pen (Pennatulacea)
26/04/2017	SA1702_ENV25	20170426145238	14:59:19 15:07:22	557417.03 557330.77	8490691.71 8490649.12	96	11	Reef rubble with sand veneer	Soft coral (Alcyonaria), hydroids (Hydrozoa), fish, sponges (Porifera), burrows, sea urchins (Echinoidea), crinoid (Crinoidea)
26/04/2017	SA1702_ENV25	20170426145238	15:07:22 15:14:31	557330.77 557278.17	8490649.12 8490595.75	75	11	Muddy sand	Burrows, fish
26/04/2017	SA1702_ENV21	20170426192216	19:22:16 19:41:41	551827.71 552021.36	8492890.98 8492888.26	194	28	Muddy sand	Fish, sea anemone (Actiniaria), sea pens (Pennatulacea), ray (Torpediniformes), hermit crab (Paguroidea)
27/04/2017	SA1702_ENV22	20170427004806	00:48:05 01:12:13	546512.10 546339.73	8487478.14 8487622.17	225	36	Muddy sand	Burrows, fish
27/04/2017	SA1702_ENV22	20170427004806	01:12:13 01:15:59	546339.73 546309.53	8487622.17 8487649.05	40	8	Reef rubble with muddy sand veneer	Soft coral (Alcyonaria), stalked crinoid (Isselicrinidae)
27/04/2017	SA1702_ENV24	20170427023955	02:39:54 02:59:21	549099.63 549290.68	8484644.79 8484600.66	196	32	Muddy sand	Burrows, fish, sea urchin (Echinoidea), hydroids (Hydrozoa),
27/04/2017	SA1702_ENV23	20170427090124	09:01:24 09:22:39	539749.30 539902.12	8481133.38 8481255.46	196	36	Muddy sand	Burrows, sea urchin (Echinoidea)
30/04/2017	SA1702_ENV29	20170430143123	14:31:23 14:38:02	661324.94 661373.54	8566814.76 8566820.59	49	10	Transect aborted due to visibility - footage recorded to show conditions	
30/04/2017	SA1702_ENV08	20170430205550	20:55:50 21:15:14	656141.51 656298.64	8559588.55 8559495.57	183	28	Sand, occasional cobble	Fish, sea anemone (Actiniaria), soft coral (Alcyonaria), sea urchins (Echinoidea), hydroids (Hydrozoa), stalked crinoids (Isselicrinidae)
01/05/2017	SA1702_ENV10	20170501013944	01:39:44 01:46:05	618673.46 618668.63	8548464.64 8548453.50	12	2	Sand	No visible fauna
01/05/2017	SA1702_ENV10	20170501013944	01:46:05 01:58:31	618668.63 618512.53	8548453.50 8548493.93	161	19	Hard substrate (possibly volcanic) with sand veneer forming small sand ripples	No visible fauna

GDA94, MGA94, UTM Zone 51, CM123 °East									
Date	**Transect**	**Video File**	**Time [UTC]**	**Video Coordinates**		**Length [m]**	**Still Nos.**	**Sediment Description**	**Fauna/Bioturbation/Debris**
				Easting [m]	**Northing [m]**				
01/05/2017	SA1702_ENV10	20170501013944	01:58:31	618512.53	8548493.93	127	19	Hard substrate (possibly volcanic) with sand veneer forming medium sand ripples	No visible fauna
			02:05:49	618386.56	8548508.30				
01/05/2017	SA1702_ENV16	20170501074207	07:42:07	572970.58	8513099.97	173	25	Sand	Starfish (Asteroidea)
			07:58:51	572799.07	8513078.15				

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Transect	Video File	Time [UTC]	Classification		Substrate Type	Substrate Composition	Reef Particle Size	Reef Profile	Sediment Particle Size	Sediment Profile	Bioturbation
				Community Type	Habitat Type							
22/04/2017	SA1702_ENV02	20170422052614_1	05:26:13 05:28:49	No macrobiota	Mixed reef	Unconsolidated	Reef 25-49%	Rock (unbroken)	Low	Gravelly sand	Flat	None
22/04/2017	SA1702_ENV02	20170422052614_1	05:28:49 05:30:07	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	Flat	None
22/04/2017	SA1702_ENV02	20170422052614_1	05:30:07 05:43:08	Filter feeders	Filter-feeders: reef	Consolidated	Reef 51-75%	Rock (unbroken)	Medium	Gravelly sand	Flat	None
22/04/2017	SA1702_ENV02	20170422052614_1	05:43:08 05:56:42	No macrobiota	Mixed reef	Consolidated	Reef 51-75%	Rock (unbroken)	Medium	Sand	Flat	None
22/04/2017	SA1702_ENV02	20170422052614_2	05:56:42 06:06:07	No macrobiota	Mixed reef	Consolidated	Reef 51-75%	Rock (unbroken)	Medium	Sand	Flat	None
22/04/2017	SA1702_ENV02	20170422052614_2	06:06:07 06:08:04	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	Flat	Medium
22/04/2017	SA1702_ENV02	20170422052614_2	06:08:04 06:08:49	No macrobiota	Mixed reef	Consolidated	Reef 51-75%	Boulder	Low	Sand	Flat	None
22/04/2017	SA1702_ENV02	20170422052614_2	06:08:49 06:15:39	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	small ripples	None
22/04/2017	SA1702_ENV01	20170424034654	11:05:22 11:09:28	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Gravelly sand	Flat	None
22/04/2017	SA1702_ENV01	20170424034654	11:09:28 11:12:14	No macrobiota	Mixed reef	Consolidated	Reef 51-75%	Rock (unbroken) with boulders	Low	Gravelly sand	Flat	None
22/04/2017	SA1702_ENV01	20170424034654	11:12:14 11:30:37	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Gravelly sand	Flat	Low
23/04/2017	SA1702_ENV03	20170423004121_1	00:41:21 01:11:49	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	small ripples	Low
23/04/2017	SA1702_ENV03	20170423004121_2	01:11:50 01:14:11	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	small ripples	Low

GDA94, MGA94, UTM Zone 51, CM123 °East													
Date	Transect	Video File	Time [UTC]	Classification		Substrate Type	Substrate Composition	Reef Particle Size	Reef Profile	Sediment Particle Size	Sediment Profile	Bioturbation
				Community Type	Habitat Type							
23/04/2017	SA1702_ENV04	20170423032326	03:23:25 03:39:24	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	small ripples	Low
23/04/2017	SA1702_ENV05	20170423044616	04:46:16 05:02:51	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Gravelly sand	small ripples	Medium
23/04/2017	SA1702_ENV05	20170423044616	05:02:51 05:11:51	Burrowing macrofauna	Mixed reef	Unconsolidated	Reef 1-24%	Cobbles	Low	Sand	Flat	Medium
23/04/2017	SA1702_ENV05A	20170423112046	11:20:46 11:25:00	Burrowing macrofauna	Mixed reef	Unconsolidated	Reef 1-24%	Cobbles	Low	Sand	Flat	Medium
23/04/2017	SA1702_ENV05A	20170423112046	11:25:00 11:31:01	Filter feeders	Filter-feeders: reef	Consolidated	Reef 51-75%	Rock (unbroken) with cobbles	Low	Sand	Flat	None
23/04/2017	SA1702_ENV05A	20170423112046	11:31:01 11:39:25	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Gravelly Sand	Flat	Medium
24/04/2017	SA1702_ENV06	20170423034654	03:46:54 04:01:01	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	Flat	Medium
24/04/2017	SA1702_ENV07	20170424062728_1	06:27:28 06:58:06	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	small ripples	Low
24/04/2017	SA1702_ENV07	20170424062728_2	06:58:06 06:59:10	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	small ripples	Low
24/04/2017	SA1702_ENV09	20170424120541	12:05:40 12:13:30	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Gravelly sand	Flat	None
24/04/2017	SA1702_ENV09A	20170424124209	12:42:08 12:54:43	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Gravelly sand	Flat	None
24/04/2017	SA1702_ENV09A	20170424124209	12:54:43 12:55:04	No macrobiota	Mixed reef	Unconsolidated	Reef 25-49%	Cobbles	Low	Gravelly sand	Flat	None
24/04/2017	SA1702_ENV09A	20170424124209	12:55:04 12:59:43	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Gravelly sand	Flat	Low
24/04/2017	SA1702_ENV11	20170424223209	22:32:08			Unconsolidated	Sediment 100%	n/a	n/a		Flat	None

GDA94, MGA94, UTM Zone 51, CM123 °East													
Date	Transect	Video File	Time [UTC]	Classification		Substrate Type	Substrate Composition	Reef Particle Size	Reef Profile	Sediment Particle Size	Sediment Profile	Bioturbation
				Community Type	Habitat Type							
			22:36:12	No macrobiota	Soft bottom benthos; sediment					Sandy Gravel		
24/04/2017	SA1702_ENV11	20170424223209	22:36:12 22:38:29	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Gravelly sand	small ripples	None
24/04/2017	SA1702_ENV11	20170424223209	22:38:29 22:41:00	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sandy Gravel	Flat	None
24/04/2017	SA1702_ENV11	20170424223209	22:41:00 22:43:35	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	small ripples	None
24/04/2017	SA1702_ENV11	20170424223209	22:43:35 22:50:16	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Gravelly sand	Flat	None
24/04/2017	SA1702_ENV11	20170424223209	22:50:16 22:54:15	No macrobiota	Mixed reef	Consolidated	Reef 51-75%	Rock (unbroken)	Low	Sand	Flat	None
25/04/2017	SA1702_ENV12	20170425004905	00:49:04 01:18:43	No macrobiota	Mixed reef	Consolidated	Reef 51-75%	Rock (unbroken)	Low	Sand	Flat	None
25/04/2017	SA1702_ENV13	20170425041526	04:15:25 04:45:39	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	Medium ripples	None
25/04/2017	SA1702_ENV14	20170425041526	09:14:57 09:22:41	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	small ripples	None
25/04/2017	SA1702_ENV14	20170425041526	09:22:41 09:24:02	No macrobiota	Mixed reef	Unconsolidated	Reef 1-24%	Cobbles	Low	Sand	Flat	None
25/04/2017	SA1702_ENV14	20170425041526	09:24:02 09:35:06	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	small ripples	None
25/04/2017	SA1702_ENV15	20170425130924	13:09:23 13:12:24	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	Flat	None
25/04/2017	SA1702_ENV15	20170425130924	13:12:24 13:18:13	No macrobiota	Mixed reef	Unconsolidated	Reef 1-24%	Cobbles	Low	Gravelly sand	Flat	None
25/04/2017	SA1702_ENV15	20170425130924	13:18:13			Unconsolidated	Sediment 100%	n/a	n/a	Sand	small ripples	None

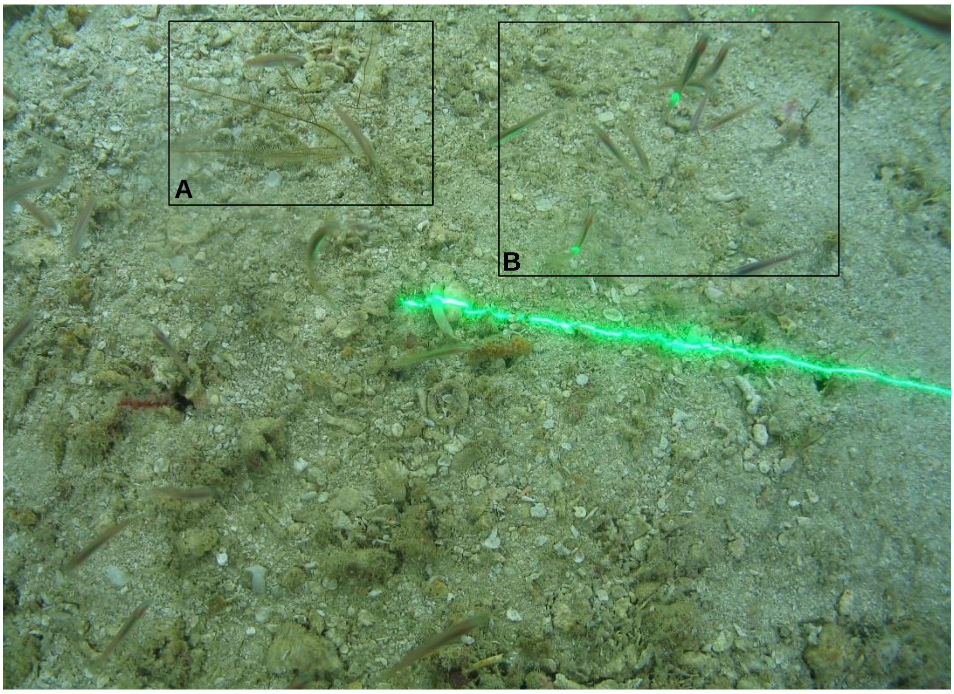
GDA94, MGA94, UTM Zone 51, CM123 °East													
Date	Transect	Video File	Time [UTC]	Classification		Substrate Type	Substrate Composition	Reef Particle Size	Reef Profile	Sediment Particle Size	Sediment Profile	Bioturbation
				Community Type	Habitat Type							
			13:31:12	No macrobiota	Soft bottom benthos; sediment							
26/04/2017	SA1702_ENV18	20170426004247	00:42:47 00:46:20	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Muddy sand	Flat	Low
26/04/2017	SA1702_ENV18	20170426004247	00:46:20 00:49:53	No macrobiota	Mixed reef	Unconsolidated	Reef 1-24%	Cobble	Low	Sand	Flat	None
26/04/2017	SA1702_ENV18	20170426004247	00:49:53 00:58:58	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	Flat	Low
26/04/2017	SA1702_ENV18	20170426004247	00:58:58 01:05:58	Filter feeders	Filter-feeders: reef	Consolidated	Reef 75-99%	Rock (unbroken)	Medium	Sand	Flat	None
26/04/2017	SA1702_ENV18	20170426004247	01:05:58 01:12:52	Burrowing macrofauna	Mixed reef	Unconsolidated	Reef 25-49%	Rock (unbroken) with cobbles	Low	Sand	Flat	Low
26/04/2017	SA1702_ENV19	20170426021026_1	02:10:25 02:21:08	No macrobiota	Mixed reef	Unconsolidated	Reef 25-49%	Cobble	Low	Sand	Flat	None
26/04/2017	SA1702_ENV19	20170426021026_1	02:21:08 02:25:33	No macrobiota	Mixed reef	Consolidated	Reef 75-99%	Rock (unbroken)	High	Sand	Flat	None
26/04/2017	SA1702_ENV19	20170426021026_1	02:25:33 02:34:49	No macrobiota	Mixed reef	Unconsolidated	Reef 25-49%	Rock (unbroken)	Low	Sand	Flat	None
26/04/2017	SA1702_ENV19	20170426021026_1	02:34:49 02:39:42	No macrobiota	Mixed reef	Consolidated	Reef 75-99%	Rock (unbroken)	Medium	Sand	Flat	None
26/04/2017	SA1702_ENV19	20170426021026_1	02:39:42 02:41:00	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	n	n/a	Low	Sand	Flat	Low
26/04/2017	SA1702_ENV19	20170426021026_2	02:41:01 02:42:14	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	n	n/a	Low	Sand	Flat	Low
26/04/2017	SA1702_ENV20	20170426063102_1	06:31:02 06:36:54	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	n	n/a	Low	Muddy sand	Flat	Low
26/04/2017	SA1702_ENV20	20170426063102_1	06:36:54			Unconsolidated	n	n/a	Low	Muddy sand	Flat	Medium

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Transect	Video File	Time [UTC]	Classification		Substrate Type	Substrate Composition	Reef Particle Size	Reef Profile	Sediment Particle Size	Sediment Profile	Bioturbation
				Community Type	Habitat Type							
			06:42:51	Burrowing macrofauna	Soft bottom benthos; sediment							
26/04/2017	SA1702_ENV20	20170426063102_1	06:42:51 07:01:19	Burrowing macrofauna	Mixed reef	Unconsolidated	Reef 1-24%	Cobble	Low	Muddy sand	Flat	Low
26/04/2017	SA1702_ENV20	20170426063102_2	07:01:20 07:07:05	Burrowing macrofauna	Mixed reef	Unconsolidated	Reef 1-24%	Cobble	Low	Muddy sand	Flat	Low
26/04/2017	SA1702_ENV20	20170426063102_2	07:07:05 07:18:18	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	n	n/a	Low	Muddy sand	Flat	Medium
26/04/2017	SA1702_ENV26	20170426125427_1	12:54:27 13:24:50	No macrobiota	Mixed reef	Unconsolidated	Reef 25-49%	Rock (unbroken) with cobbles	Low	Sand	Flat	None
26/04/2017	SA1702_ENV26	20170426125427_2	13:24:51 13:48:36	No macrobiota	Mixed reef	Unconsolidated	Reef 25-49%	Rock (unbroken) with cobbles	Low	Sand	Flat	None
26/04/2017	SA1702_ENV26	20170426125427_2	13:48:36 13:51:30	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	small ripples	None
26/04/2017	SA1702_ENV26	20170426125427_2	13:51:30 13:53:59	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Gravelly sand	Flat	None
26/04/2017	SA1702_ENV26	20170426125427_2	13:53:59 13:55:30	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Reef 1-24%	Cobble	Low	Sand	Flat	None
26/04/2017	SA1702_ENV26	20170426125427_3	13:55:30 13:57:47	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Reef 1-24%	Cobble	Low	Sand	Flat	Low
26/04/2017	SA1702_ENV25	20170426145238	14:52:38 14:59:19	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Muddy sand	Flat	Low
26/04/2017	SA1702_ENV25	20170426145238	14:59:19 15:07:22	Burrowing macrofauna	Mixed reef	Unconsolidated	Reef 1-24%	Cobble	Low	Muddy sand	Flat	Low
26/04/2017	SA1702_ENV25	20170426145238	15:07:22 15:14:31	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Muddy sand	Flat	Medium
26/04/2017	SA1702_ENV21	20170426192216	19:22:16			Unconsolidated	Sediment 100%	n/a	n/a	Muddy sand	Flat	Medium

GDA94, MGA94, UTM Zone 51, CM123 °East												
Date	Transect	Video File	Time [UTC]	Classification		Substrate Type	Substrate Composition	Reef Particle Size	Reef Profile	Sediment Particle Size	Sediment Profile	Bioturbation
				Community Type	Habitat Type							
			19:41:41	Burrowing macrofauna	Soft bottom benthos; sediment							
27/04/2017	SA1702_ENV22	20170427004806	00:48:05 01:12:13	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Muddy sand	Flat	Medium
27/04/2017	SA1702_ENV22	20170427004806	01:12:13 01:15:59	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Muddy sand	Flat	Medium
27/04/2017	SA1702_ENV24	20170427023955	02:39:54 02:59:21	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Muddy sand	Flat	Medium
27/04/2017	SA1702_ENV23	20170427090124	09:01:24 09:22:39	Burrowing macrofauna	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Muddy sand	Flat	Medium
30/04/2017	SA1702_ENV29	20170430143123	14:31:23 14:38:02	-	-	-	-	-	-	-	-	-
30/04/2017	SA1702_ENV08	20170430205550	20:55:50 21:15:14	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	Flat	None
01/05/2017	SA1702_ENV10	20170501013944	01:39:44 01:46:05	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	Flat	None
01/05/2017	SA1702_ENV10	20170501013944	01:46:05 01:58:31	No macrobiota	Hard substrate non-reef	Unconsolidated	Hard substrate 25-49%	Rock (unbroken)	Low	Sand	small ripples	None
01/05/2017	SA1702_ENV10	20170501013944	01:58:31 02:05:49	No macrobiota	Hard substrate non-reef	Unconsolidated	Hard substrate 25-49%	Rock (unbroken)	Low	Sand	Medium ripples	None
01/05/2017	SA1702_ENV16	20170501074207	07:42:07 07:58:51	No macrobiota	Soft bottom benthos; sediment	Unconsolidated	Sediment 100%	n/a	n/a	Sand	Flat	None

B. SEABED PHOTOGRAPHS

SA1702_ENV01

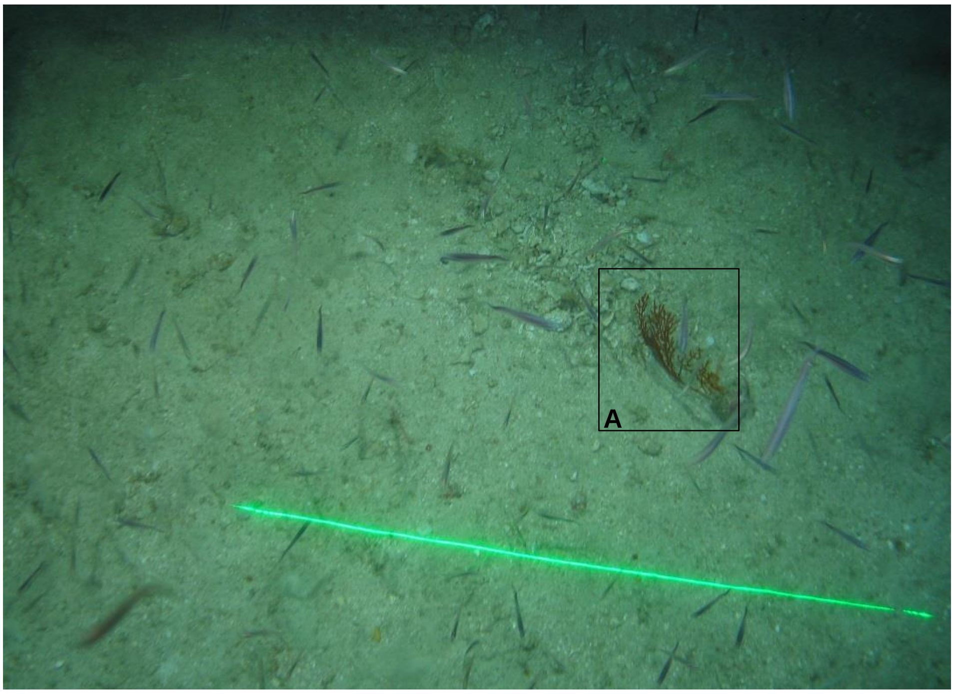


Photograph:
SA1702_ENV01_22

Easting: 663624.71 mE
Northing: 8570659.70 mN
Depth: 93 m

Sediment Type:
Gravelly sand

Fauna:
A: Hydroids (Hydrozoa)
B: Unidentified fish



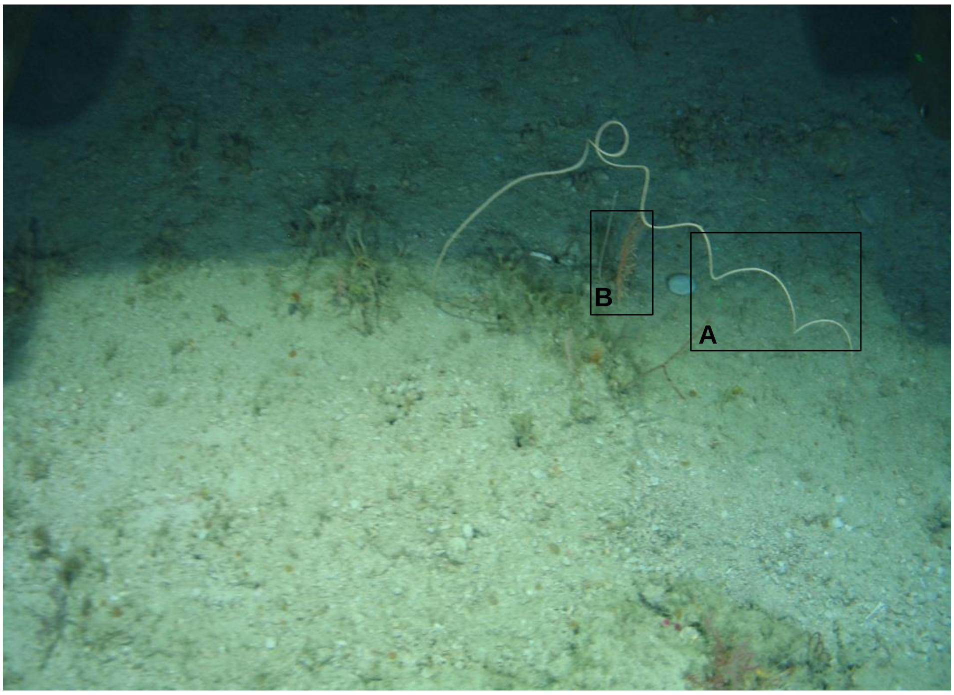
Photograph:
SA1702_ENV01_10

Easting: 663667.683 mE
Northing: 8570729.16 mN
Depth: 92 m

Sediment Type:
Reef rubble with sand veneer

Fauna:
A: Sea fan (Alcyonacea)
Unidentified fish

SA1702_ENV02

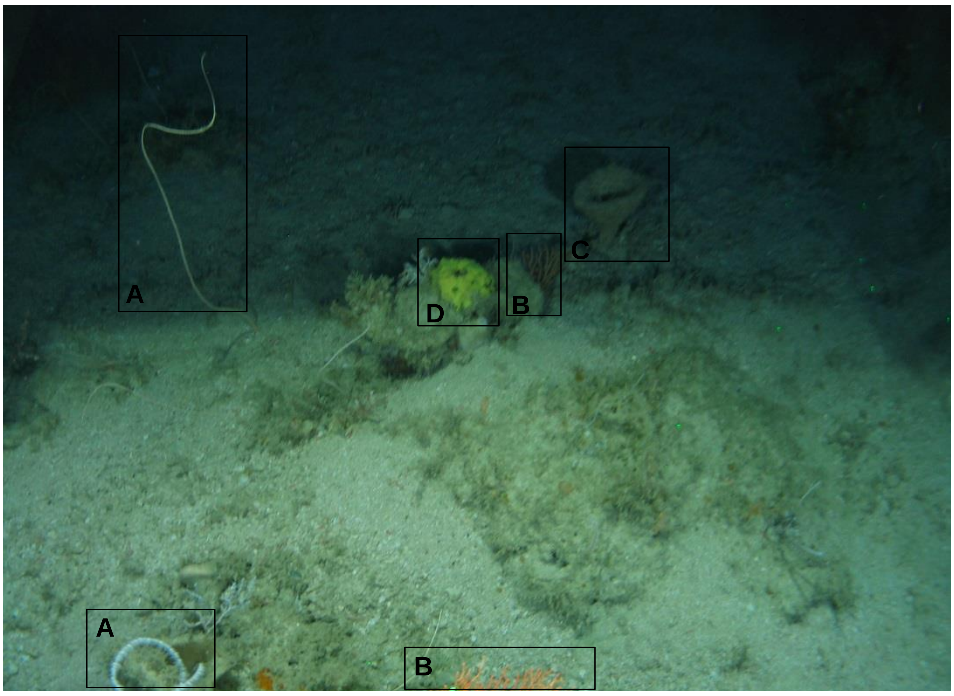


Photograph:
SA1702_ENV02_6

Easting: 661503.82 mE
Northing: 8571406.13 mN
Depth: 67.42m

Sediment Type:
Reef rubble with sand veneer

Fauna:
A: Sea Whip (Alcyonacea)
B: Hydroids (Hydrozoa)



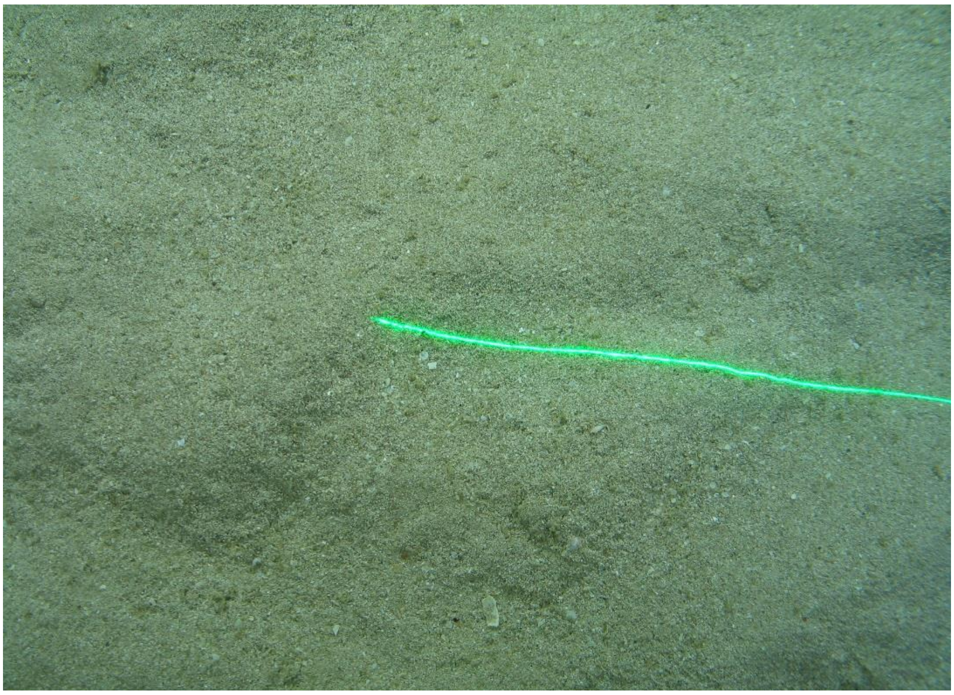
Photograph:
SA1702_ENV02_12

Easting: 661450.09 mE
Northing: 8571340.75 mN
Depth: 71.61 m

Sediment Type:
Reef with sand veneer

Fauna:
A: Sea Whip (Alcyonacea)
B: Sea Fan (Alcyonacea)
C: Barrel Sponge (Porifera)
D: Encrusting sponge (Porifera)
Hydroids (Hydrozoa)

SA1702_ENV03

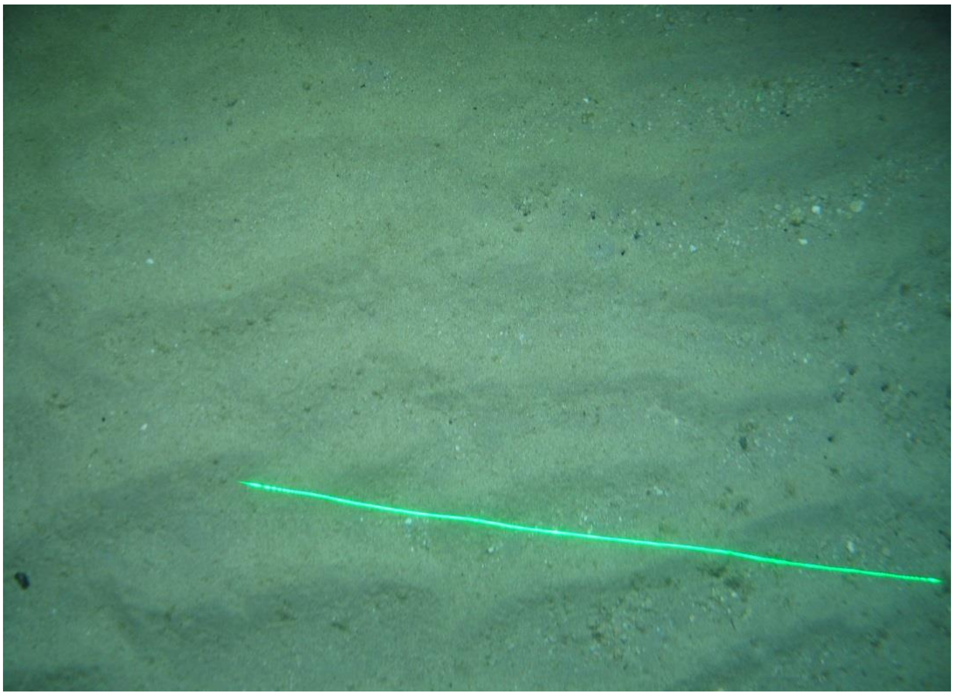


Photograph:
SA1702_ENV03_19

Easting: 657692.54 mE
Northing: 8568766.42 mN
Depth: 166.9 m

Sediment Type:
Rippled sand

Fauna:
No visible fauna



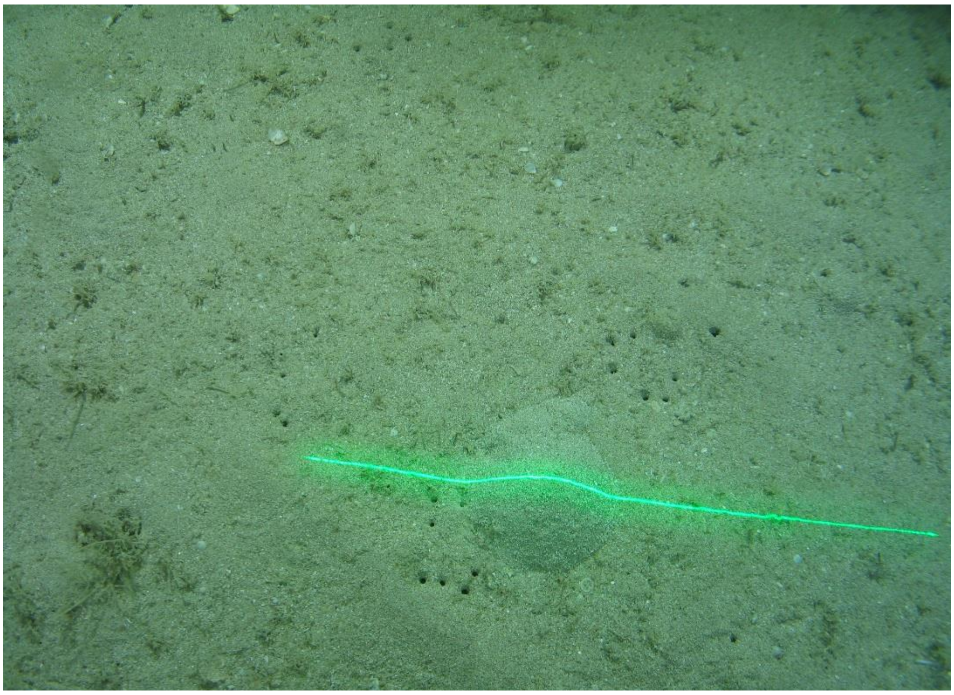
Photograph:
SA1702_ENV03_23

Easting: 657714.68 mE
Northing: 8568754.26 mN
Depth: 165.9 m

Sediment Type:
Rippled sand

Fauna:
Faunal burrows

SA1702_ENV04

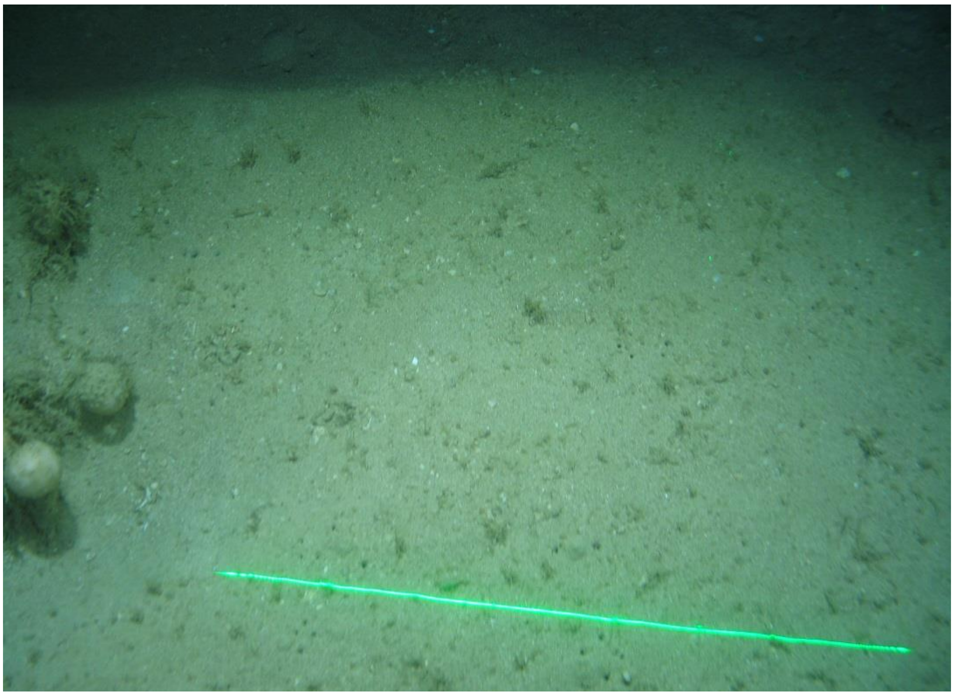


Photograph:
SA1702_ENV04_07

Easting: 656189.81 mE
Northing: 8566625.70 mN
Depth: 171.6 m

Sediment Type:
Sand

Fauna:
Faunal burrows
Hydroids (Hydrozoa)



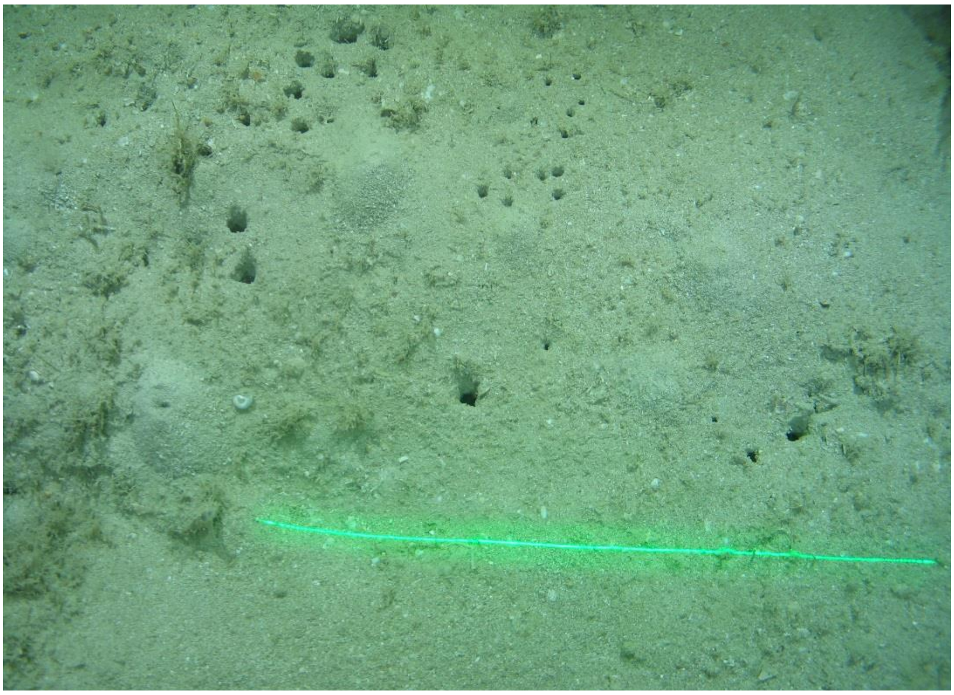
Photograph:
SA1702_ENV04_16

Easting: 656110.28 mE
Northing: 8566561.29 mN
Depth: 171.7 m

Sediment Type:
Sand

Fauna:
A: Sponges (Porifera)
B: Hydroids (Hydrozoa)

SA1702_ENV05

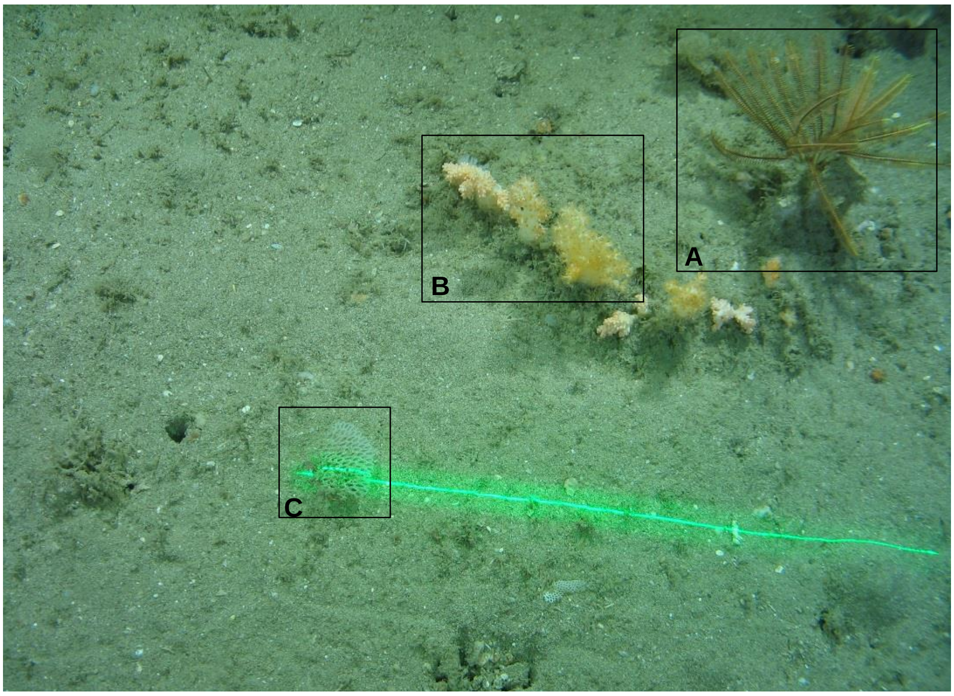


Photograph:
SA1702_ENV05_06

Easting: 656424.78 mE
Northing: 8565649.77 mN
Depth: 171.3 m

Sediment Type:
Gravelly sand

Fauna:
Faunal burrows
Hydroids (Hydrozoa)



Photograph:
SA1702_ENV05A_40

Easting: 656603.17 mE
Northing: 8565762.27 mN
Depth: 168.9 m

Sediment Type:
Reef rubble with veneer of gravelly sand

Fauna:
A: Crinoid (Crinoidea)
B: Soft Coral (Alcyonaria)
C: Bryozoa

SA1702_ENV06

Photograph:
SA1702_ENV06_05
(Screen grab from video)

Easting: 657811.87 mE
Northing: 8564667.23 mN
Depth: 172.8 m

Sediment Type:
Sand

Fauna:
Tubular glass sponge (Porifera)

Photograph:
SA1702_ENV06_06
(Screen grab from video)

Easting: 657818.11 mE
Northing: 8564672.98 mN
Depth: 172.4 m

Sediment Type:
Sand

Fauna:
Faunal burrows

SA1702_ENV07

Photograph:
SA1702_ENV05_06
(Screen grab from video)

Easting: 656424.78 mE
Northing: 8565649.77 mN
Depth: 171.3 m

Sediment Type:
Sand

Fauna:
Faunal burrows

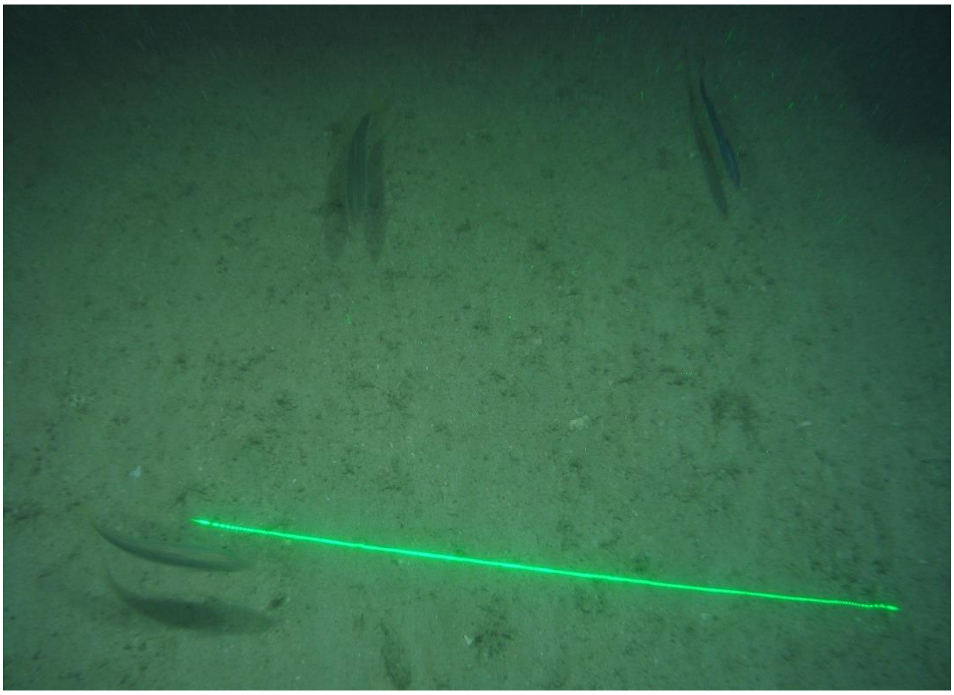
Photograph:
SA1702_ENV05A_40
(Screen grab from video)

Easting: 656603.17 mE
Northing: 8565762.27 mN
Depth: 168.9 m

Sediment Type:
Sand forming ripples

Fauna:
A: Sea Urchin (Echinoidea)

SA1702_ENV08

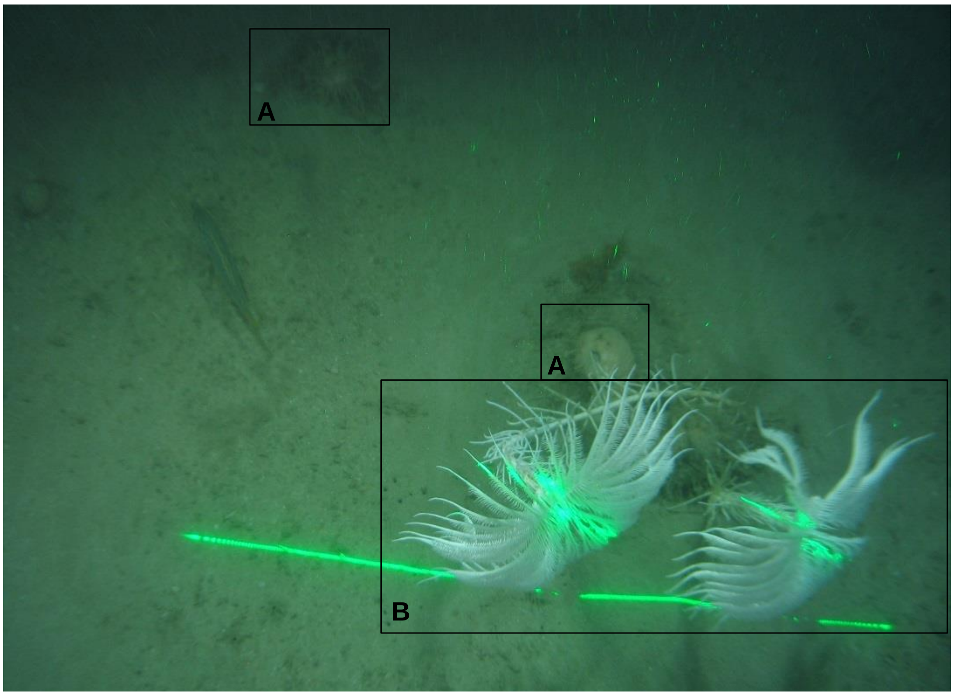


Photograph:
SA1702_ENV08_19

Easting: 656257.67mE
Northing: 8559525.35 mN
Depth: 179.8 m

Sediment Type:
Sand

Fauna:
Unidentified fish



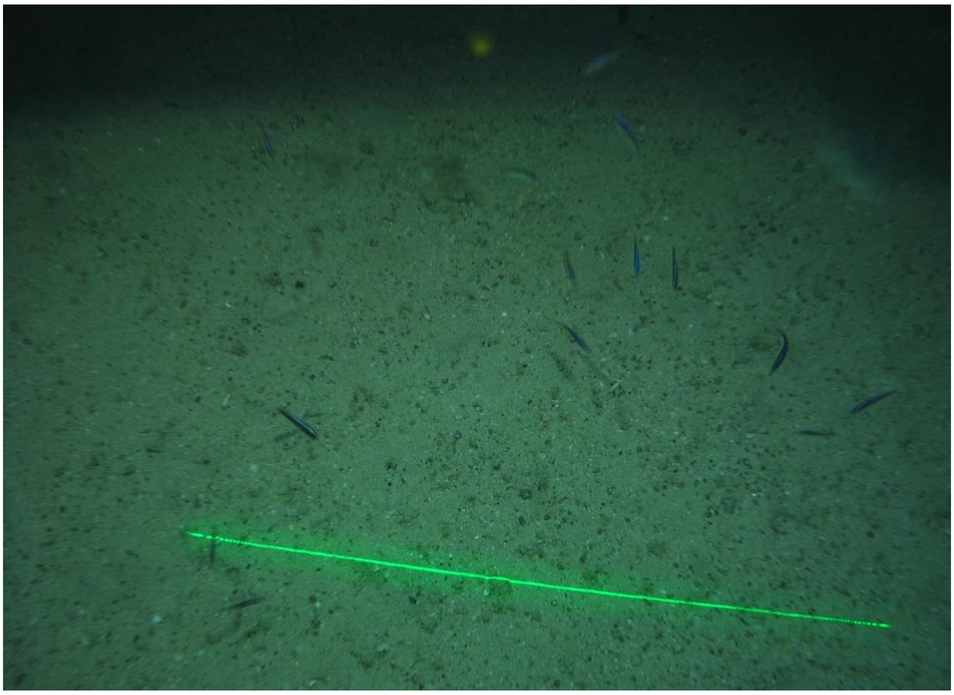
Photograph:
SA1702_ENV08_26

Easting: 656288.03 mE
Northing: 8568741.04 mN
Depth: 167.3 m

Sediment Type:
Sand

Fauna:
A: Sea anemone (Actiniaria)
B: Stalked crinoid (Isselicrinoidea)
Unidentified fish

SA1702_ENV09

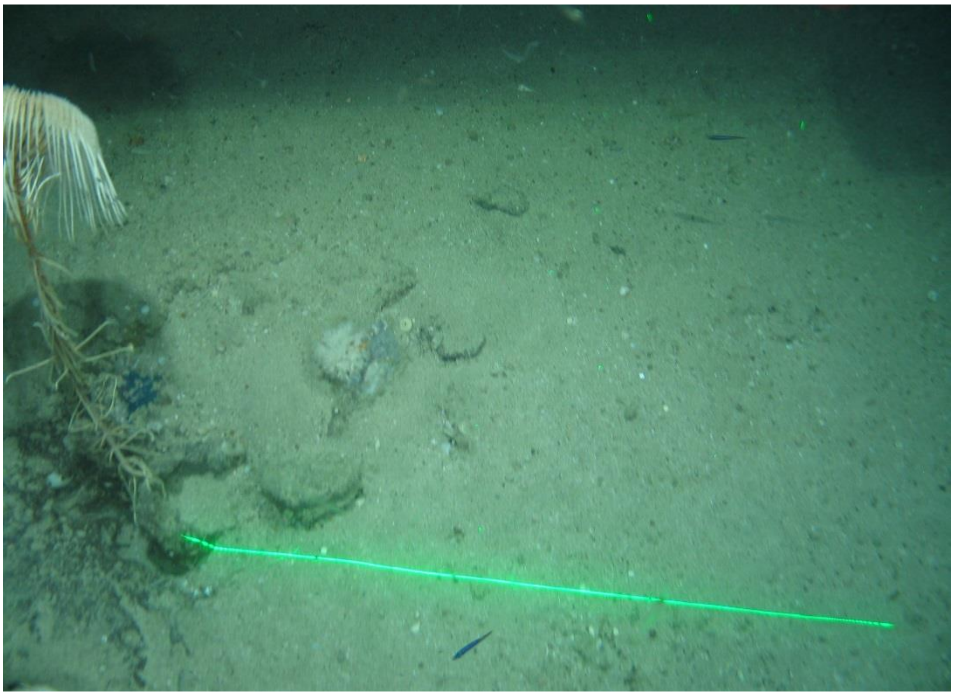


Photograph:
SA1702_ENV09A_15

Easting: 629543.11 mE
Northing: 8554248.52 mN
Depth: 198.9 m

Sediment Type:
Gravelly sand

Fauna:
Unidentified fish



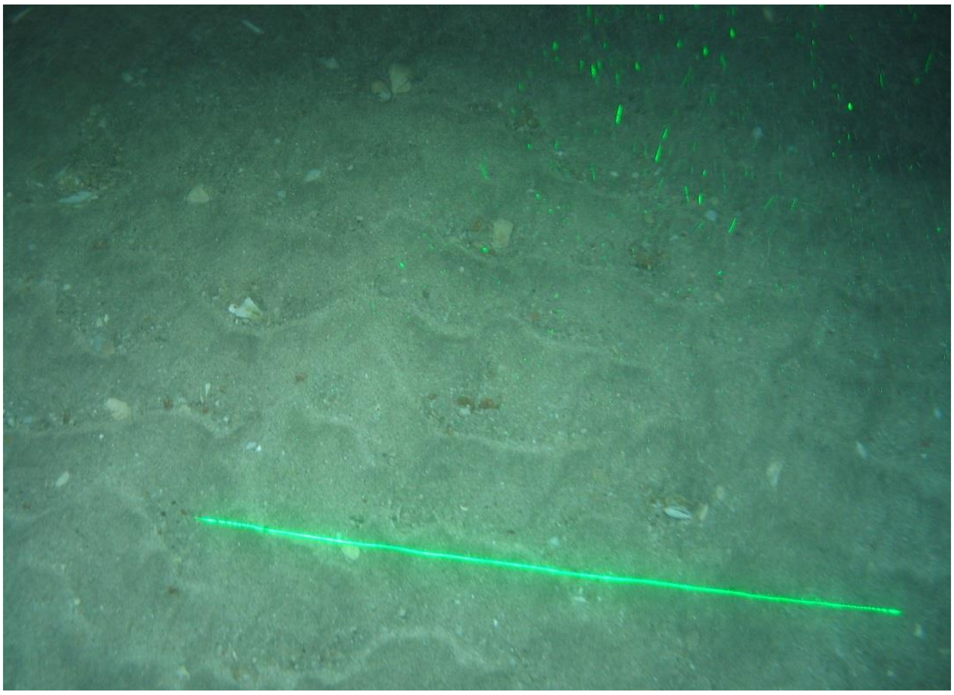
Photograph:
SA1702_ENV09A_24

Easting: 629598.38 mE
Northing: 8554229.58 mN
Depth: 197.5 m

Sediment Type:
Reef rubble with gravelly sand veneer

Fauna:
A: Stalked crinoid (Isselicrinoidea)
Unidentified fish

SA1702_ENV10

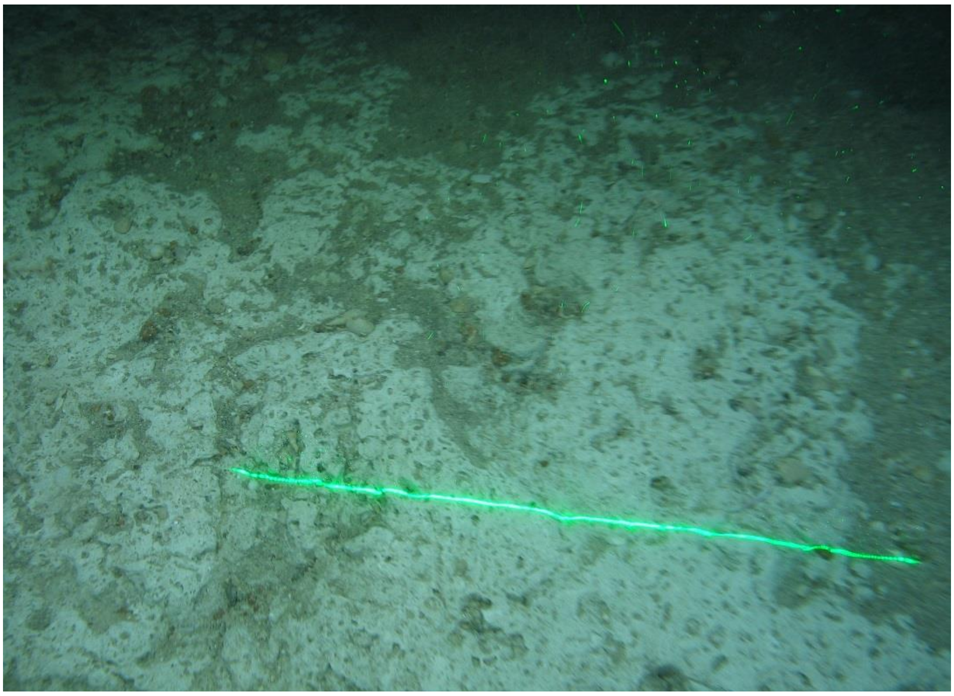


Photograph:
SA1702_ENV10_10

Easting: 618601.95 mE
Northing: 8548498.38 mN
Depth: 209.4 m

Sediment Type:
Sand forming ripples

Fauna:
No visible fauna



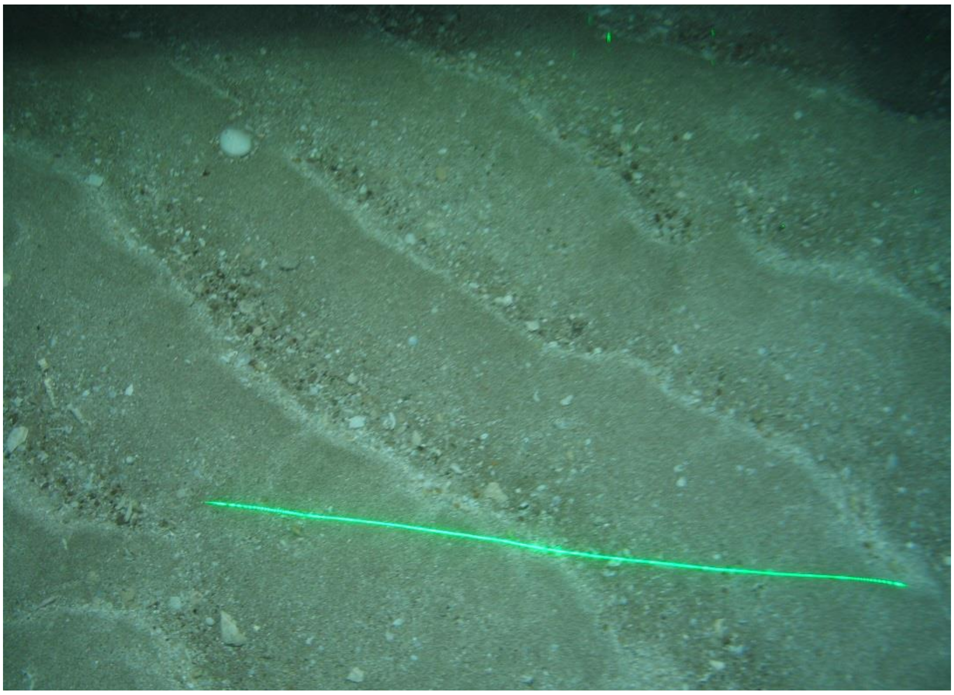
Photograph:
SA1702_ENV10_32

Easting: 618425.19 mE
Northing: 8548506.09 mN
Depth: 210.6 m

Sediment Type:
Hard substrate (volcanic rock) with sand veneer

Fauna:
No visible fauna

SA1702_ENV11

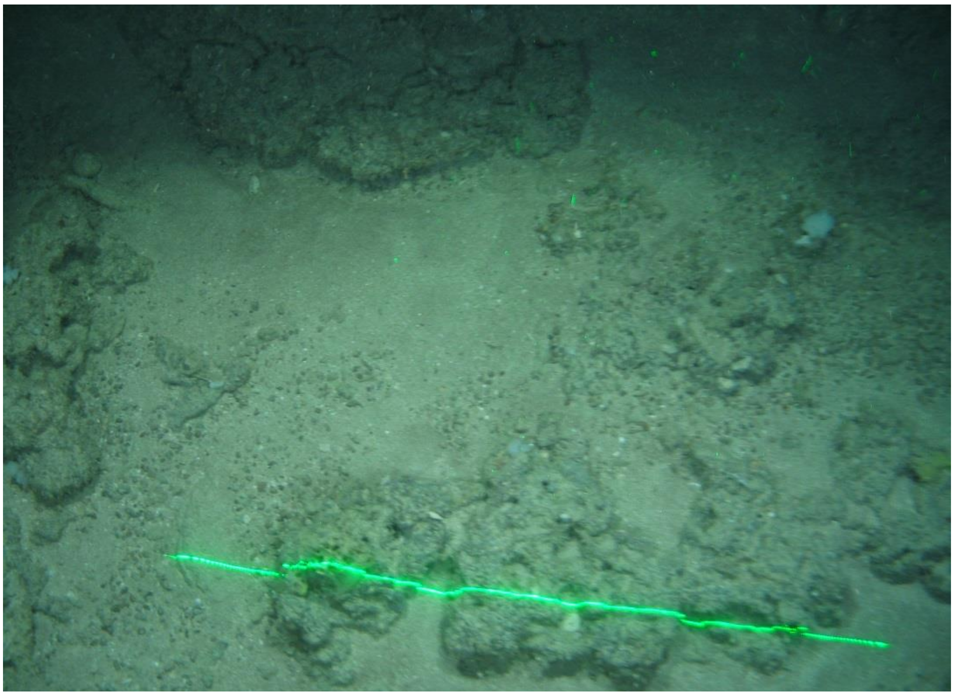


Photograph:
SA1702_ENV11_15

Easting: 618563.37 mE
Northing: 8548495.89 mN
Depth: 209.6 m

Sediment Type:
Rippled sand with some shell fragments

Fauna:
No visible fauna



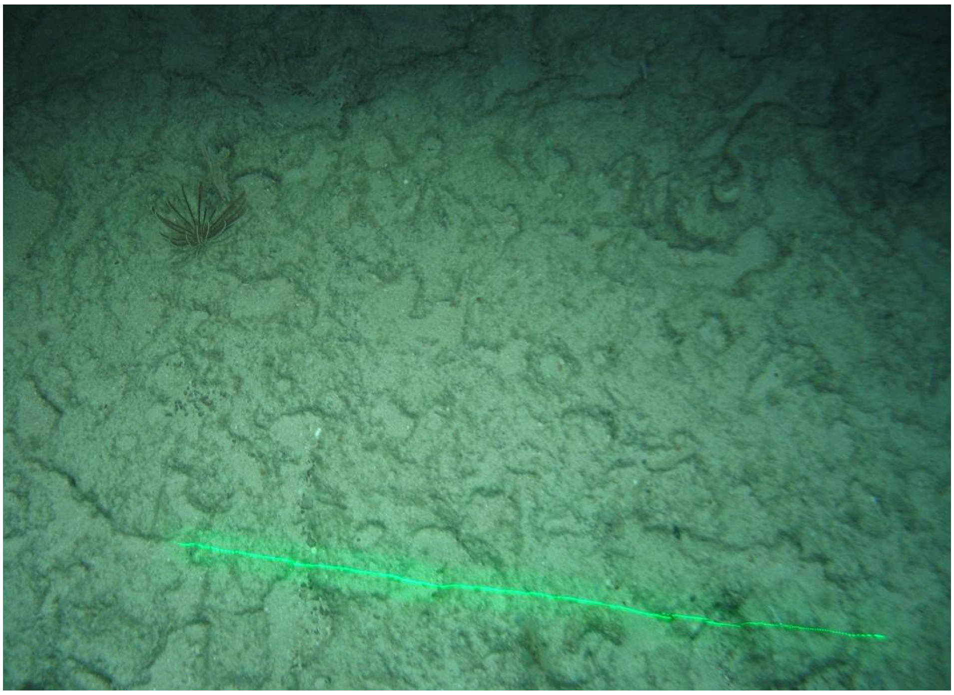
Photograph:
SA1702_ENV11_33

Easting: 618421.71 mE
Northing: 8548505.85 mN
Depth: 210.8 m

Sediment Type:
Reef rubble with sand veneer

Fauna:
No visible fauna

SA1702_ENV12

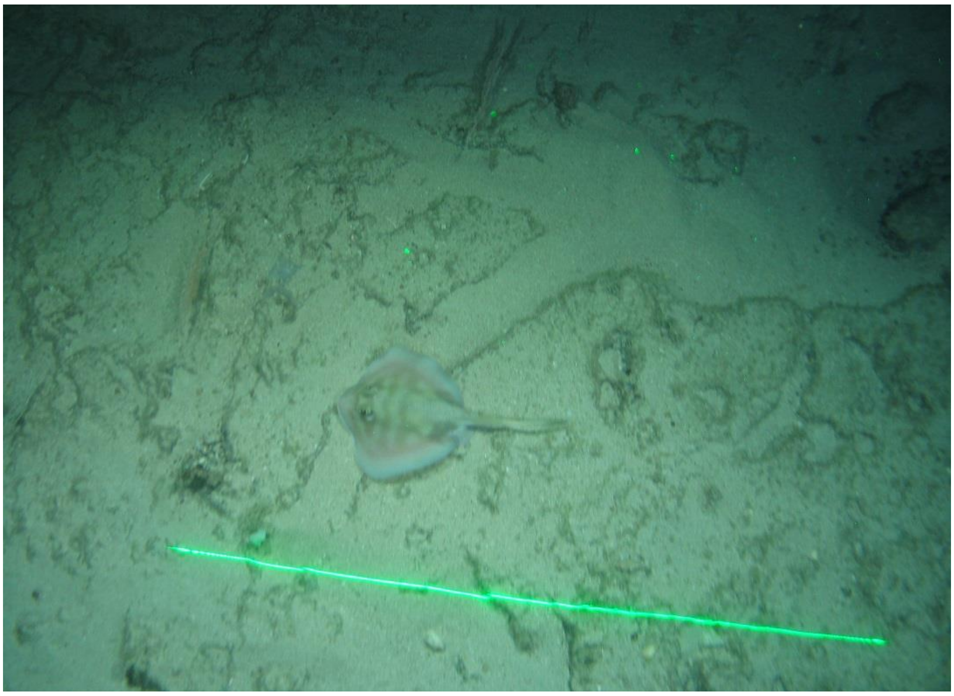


Photograph:
SA1702_ENV12_06

Easting: 618563.37 mE
Northing: 8537245.43 mN
Depth: 205.4 m

Sediment Type:
Reef rubble with sand veneer

Fauna:
Crinoid (Crinoidea)



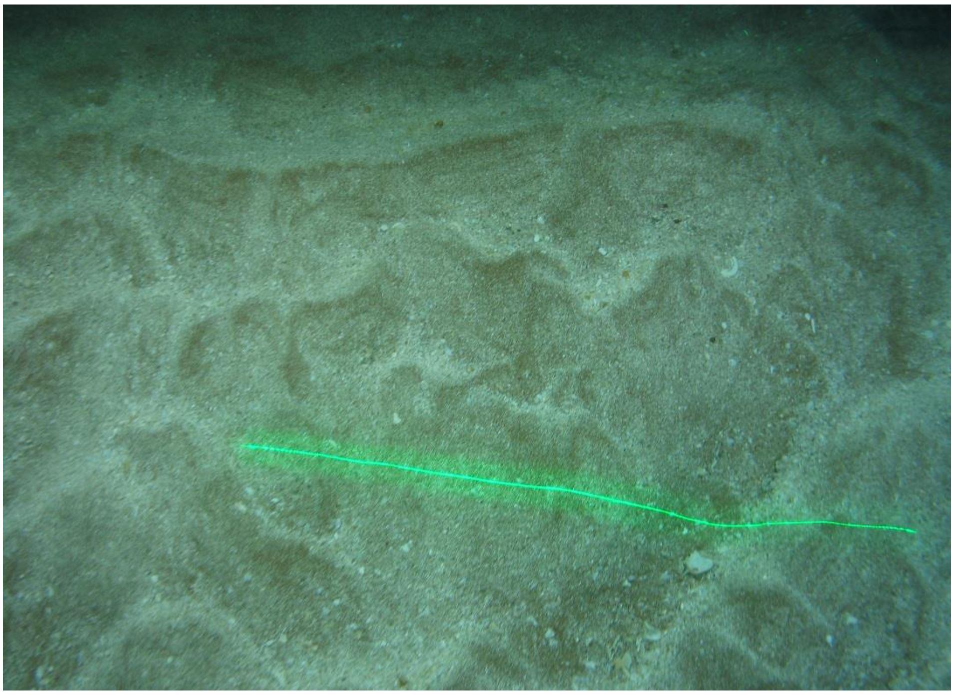
Photograph:
SA1702_ENV12_35

Easting: 602336.42 mE
Northing: 8537099.52 mN
Depth: 206.4 m

Sediment Type:
Reef rubble with sand veneer

Fauna:
A: Sea fan (Alcyonacea)
B: Ray (Batoidea)

SA1702_ENV13

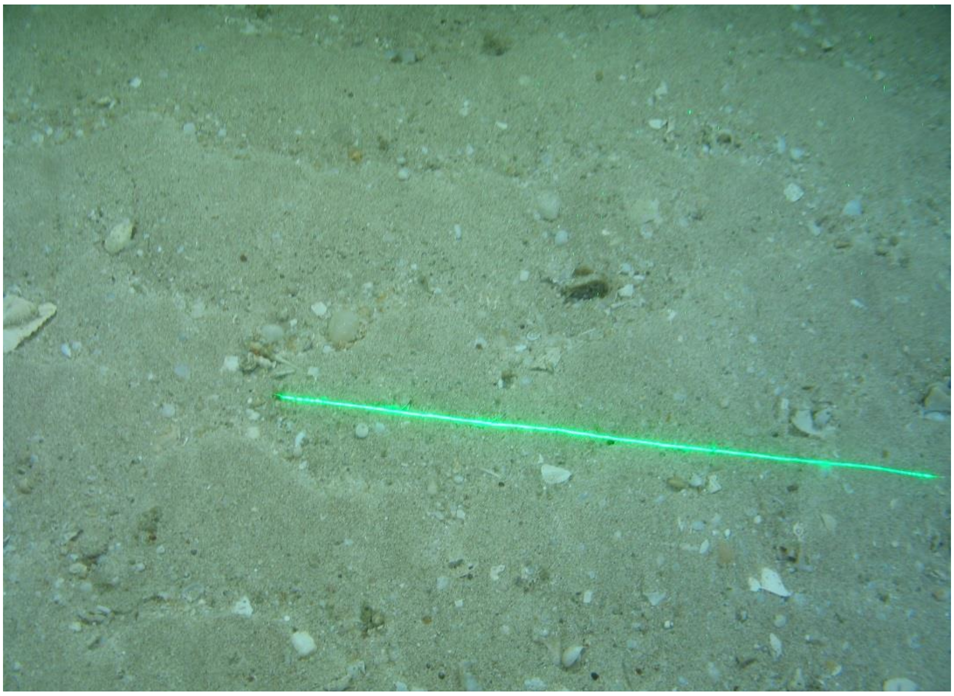


Photograph:
SA1702_ENV13_03

Easting: 597037.62 mE
Northing: 8533079.92 mN
Depth: 205.4 m

Sediment Type:
Sand forming ripples

Fauna:
No visible fauna



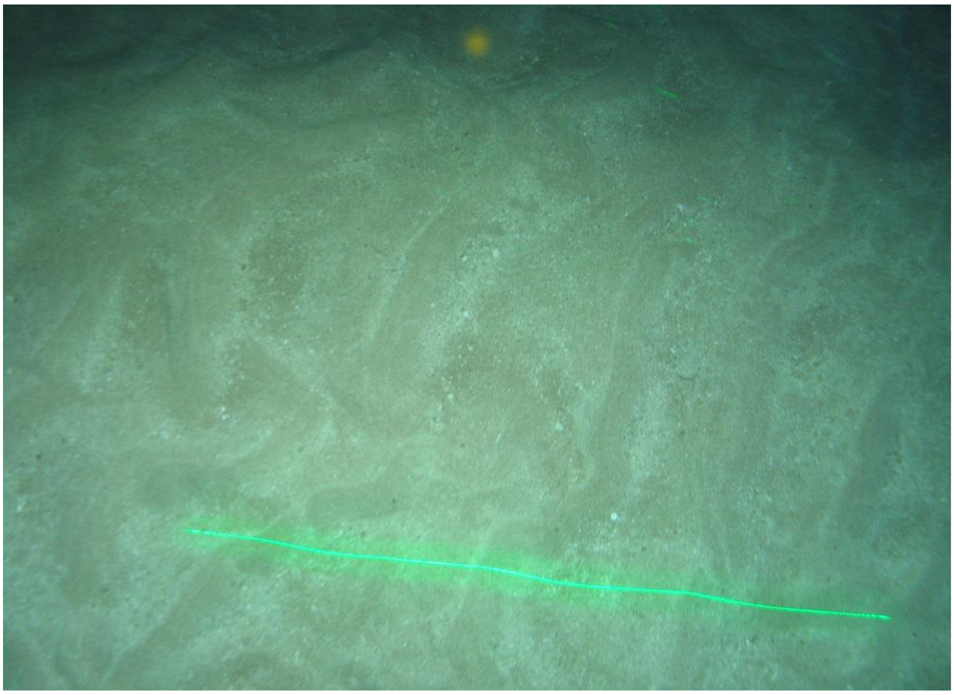
Photograph:
SA1702_ENV13_31

Easting: 597111.89 mE
Northing: 8532844.49 mN
Depth: 206.4 m

Sediment Type:
Sand forming ripples with shell fragments

Fauna:
No visible fauna

SA1702_ENV14

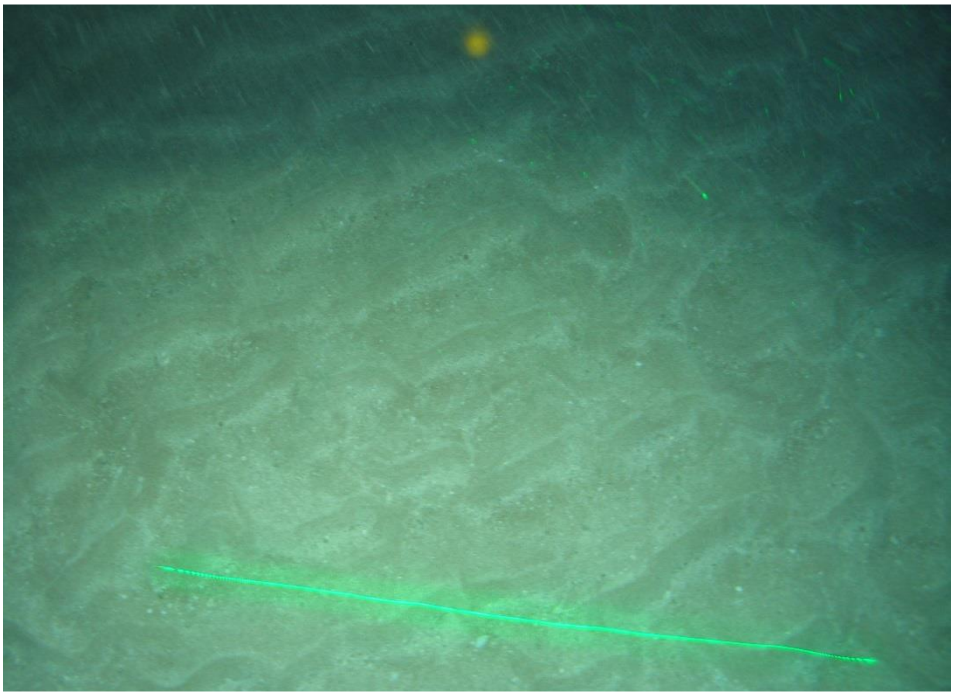


Photograph:
SA1702_ENV14_02

Easting: 585599.17 mE
Northing: 8524327.21 mN
Depth: 210.2 m

Sediment Type:
Sand forming ripples

Fauna:
No visible fauna



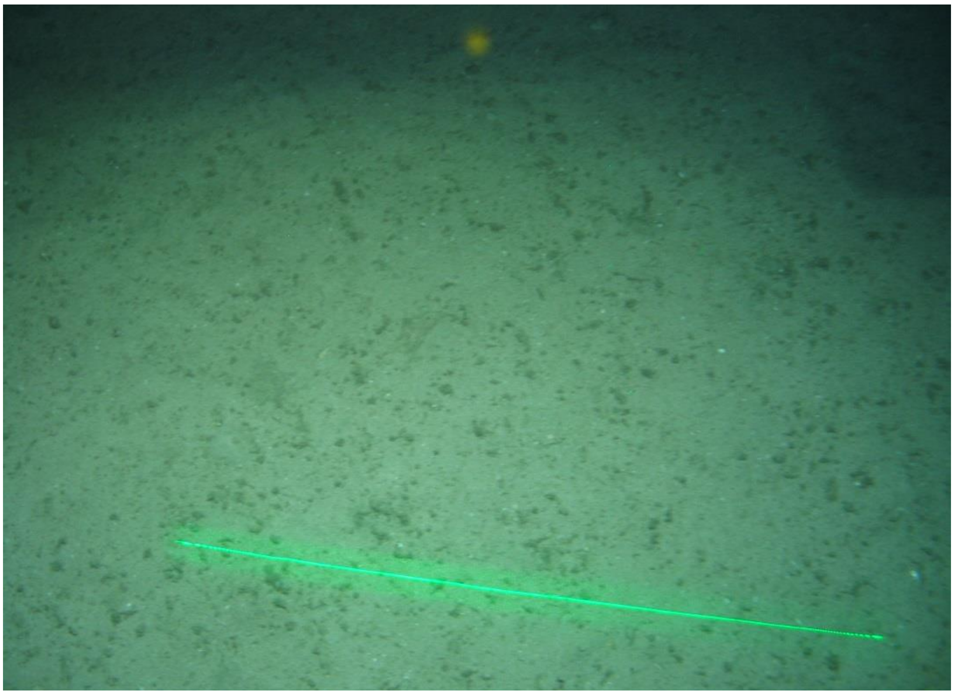
Photograph:
SA1702_ENV14_03

Easting: 585597.04 mE
Northing: 8524322.95 mN
Depth: 210.2 m

Sediment Type:
Sand forming ripples

Fauna:
No visible fauna

SA1702_ENV15

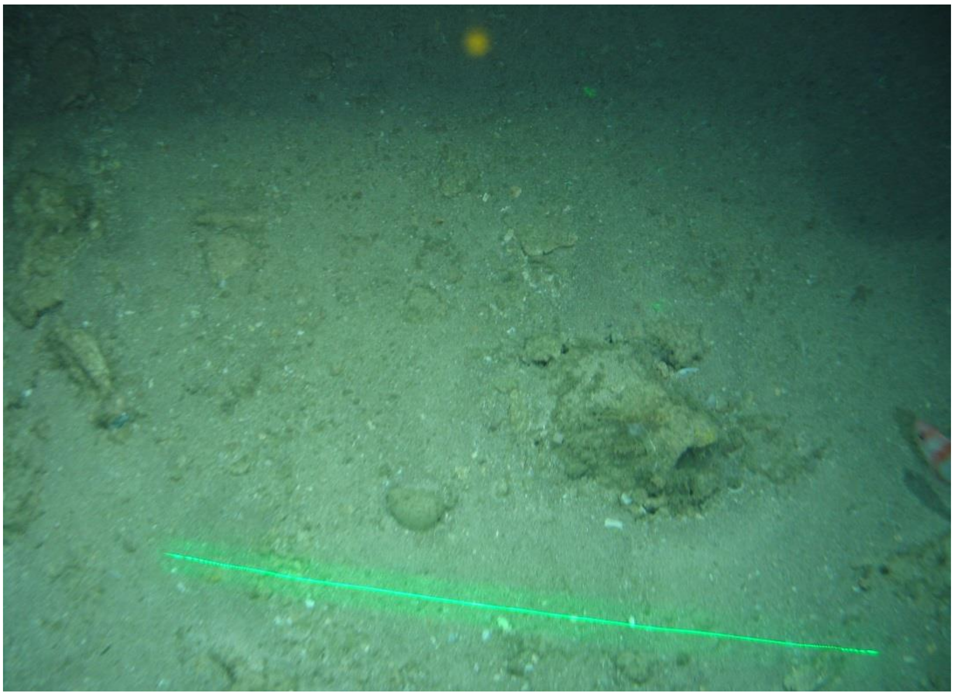


Photograph:
SA1702_ENV15_03

Easting: 579254.50 mE
Northing:8519423.18 mN
Depth: 212.5 m

Sediment Type:
Gravelly sand

Fauna:
No visible fauna



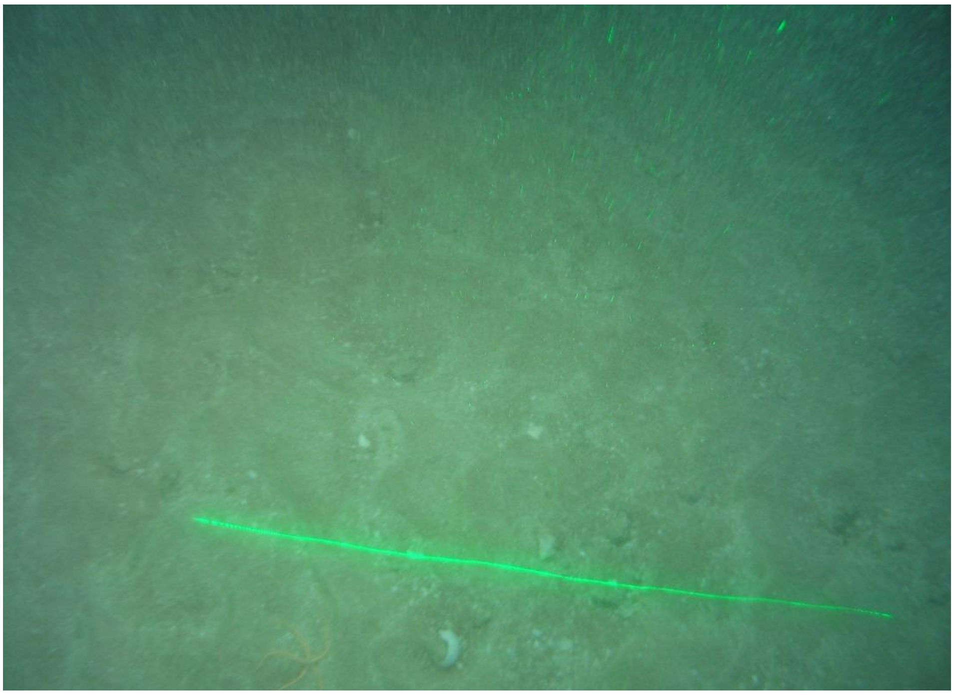
Photograph:
SA1702_ENV15_14

Easting: 579254.16 mE
Northing: 8519391.78 mN
Depth: 211.8 m

Sediment Type:
Reef rubble with gravelly sand veneer

Fauna:
Saddle Grouper (*Cephalopholis sexmaculata*)

SA1702_ENV16

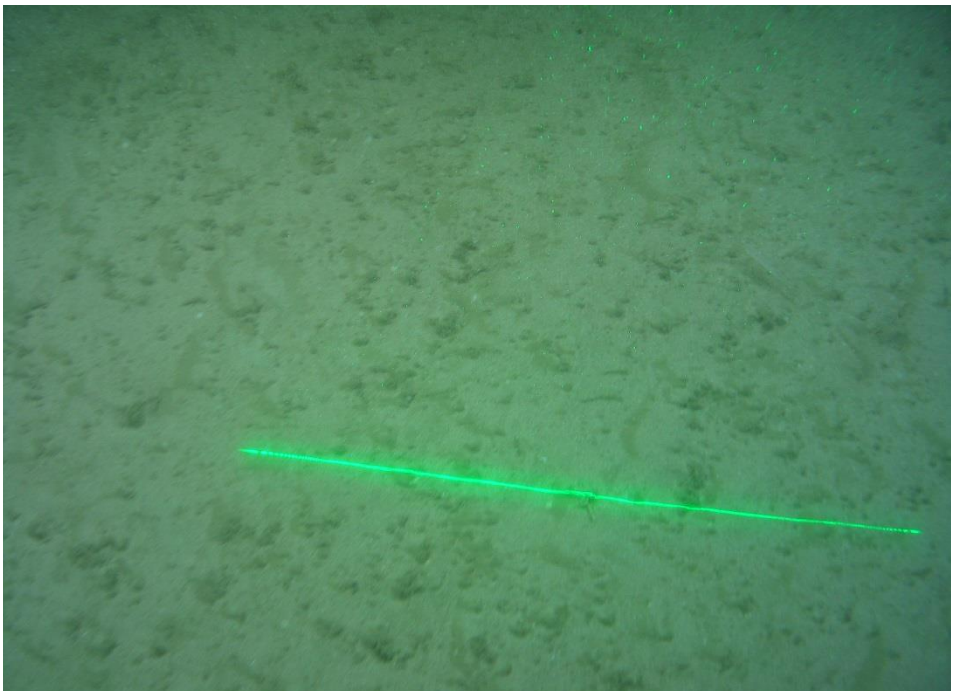


Photograph:
SA1702_ENV16_14

Easting: 572872.18 mE
Northing: 8513082.63 mN
Depth: -171.25 m

Sediment Type:
Sand forming ripples

Fauna:
No visible fauna



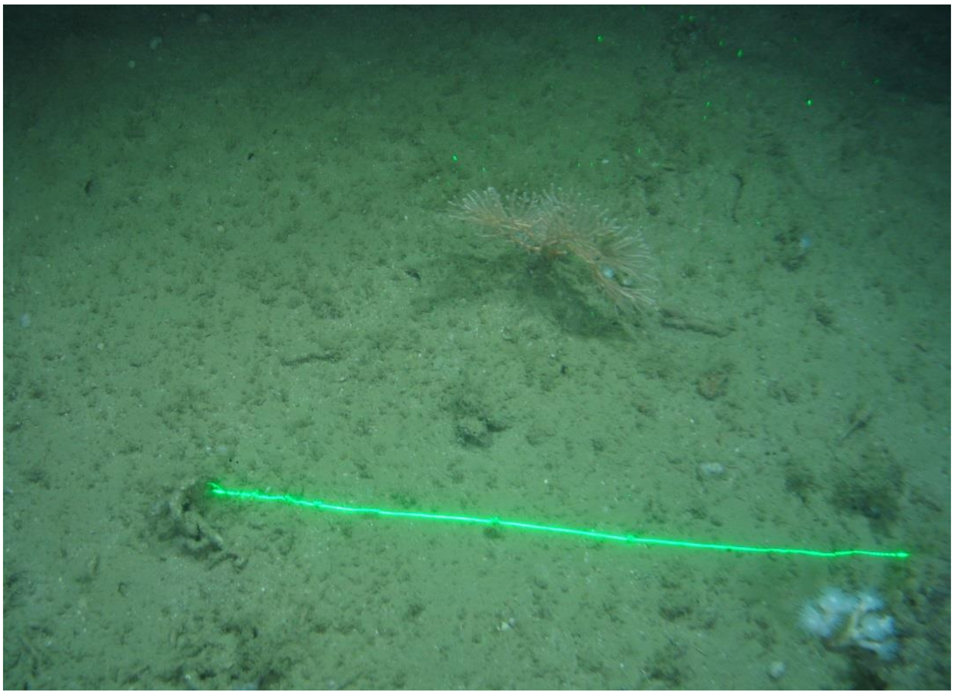
Photograph:
SA1702_ENV16_20

Easting: 572841.08 mE
Northing: 8513084.04 mN
Depth: -171.55 m

Sediment Type:
Sand

Fauna:
Hydroids (Hydrozoa)

SA1702_ENV18

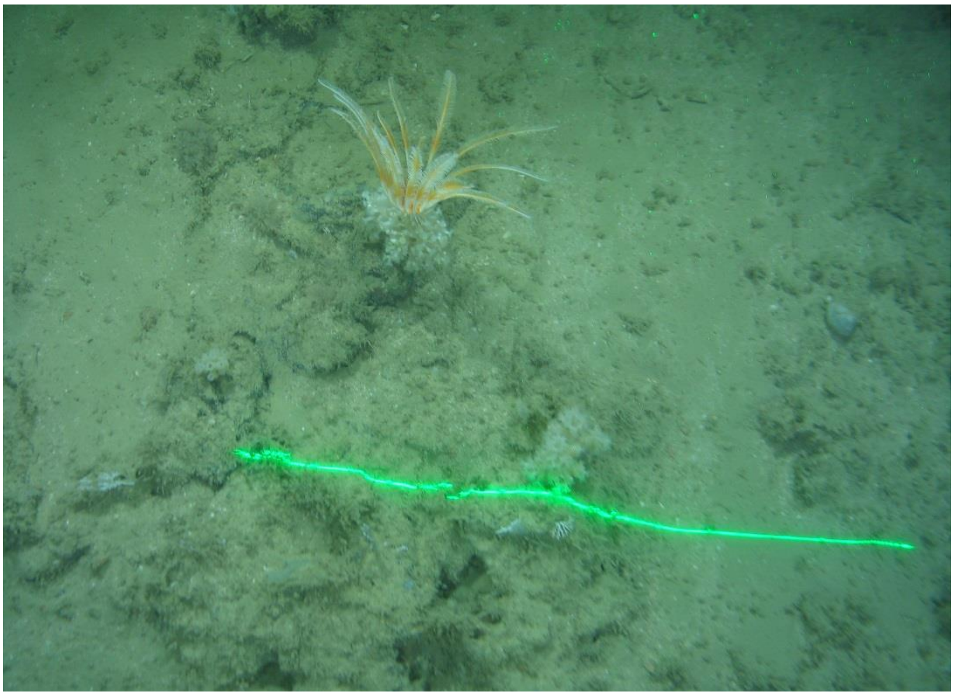


Photograph:
SA1702_ENV18_33

Easting: 559480.844 mE
Northing: 8500609.25 mN
Depth: 222.9 m

Sediment Type:
Reef with sand veneer

Fauna:
A: Sea fan (Alcyonacea)
B: Soft coral (Alcyonaria)
Hydroids (Hydrozoa)



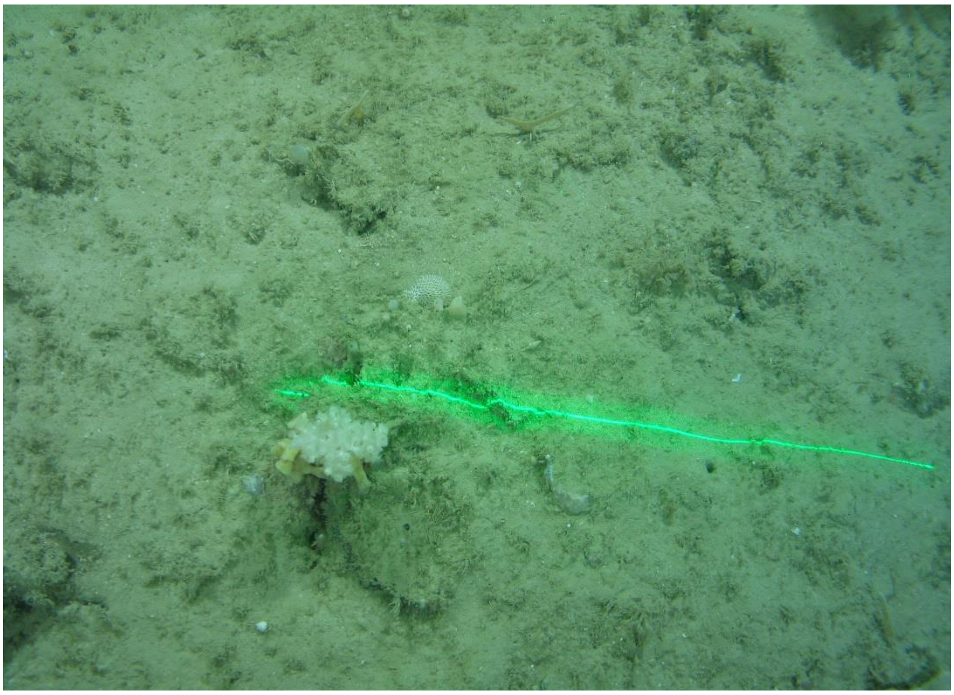
Photograph:
SA1702_ENV18_42

Easting: 559445.482 mE
Northing: 8500585.50 mN
Depth: 225.6 m

Sediment Type:
Reef rubble with sand veneer

Fauna:
Crinoid (Crinoidea)

SA1702_ENV19

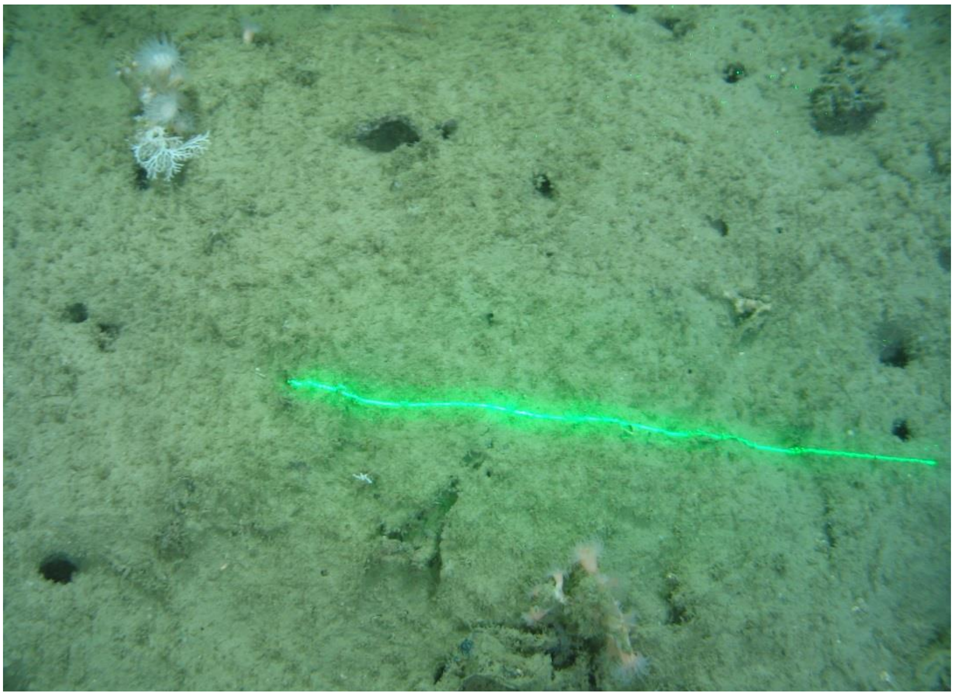


Photograph:
SA1702_ENV19_07

Easting: 558548.86 mE
Northing: 8499081.83 mN
Depth: 238 m

Sediment Type:
Reef rubble with sand veneer

Fauna:
Soft coral (Alcyonaria)
Bryozoa
Hydroids (Hydrozoa)



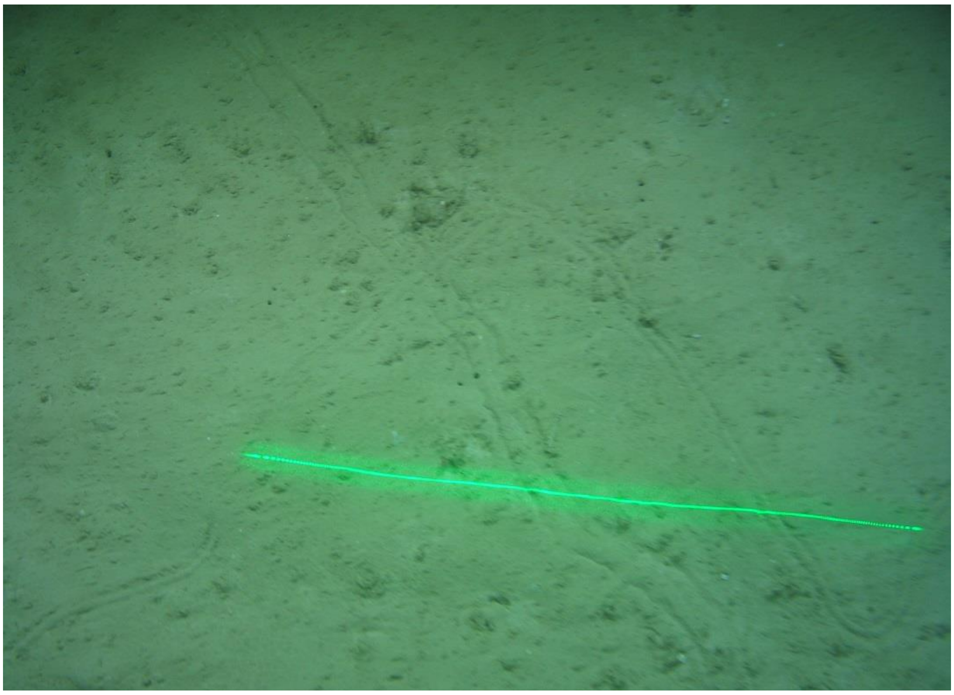
Photograph:
SA1702_ENV19_18

Easting: 558467.27 mE
Northing: 8499102.82 mN
Depth: 233.3 m

Sediment Type:
Reef rubble with sand veneer

Fauna:
Soft coral (Alcyonaria)
Bryozoa
Faunal burrows

SA1702_ENV20

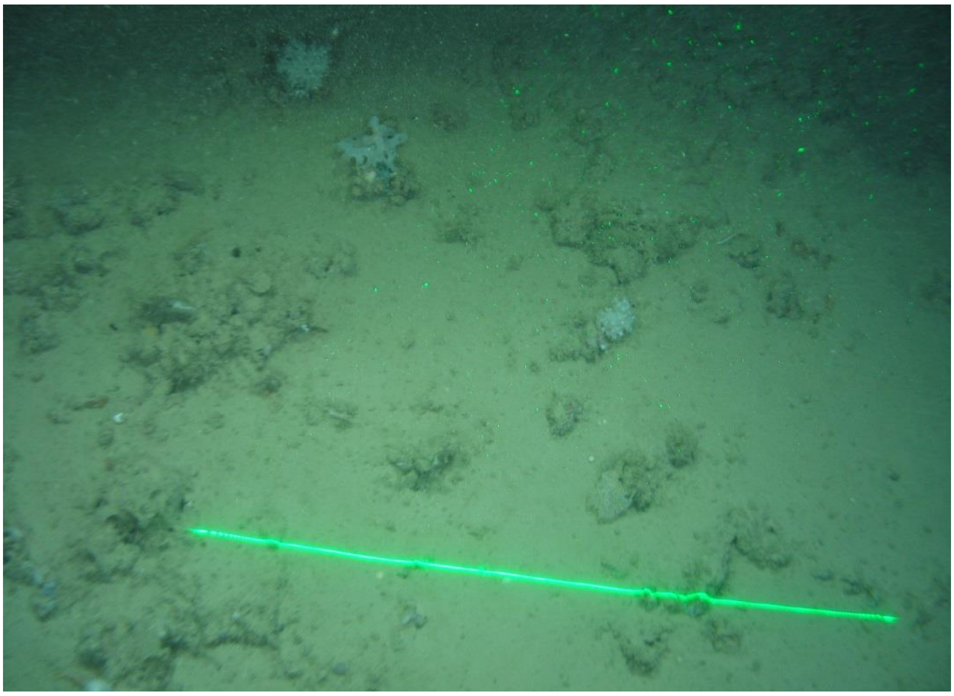


Photograph:
SA1702_ENV20_06

Easting: 556561.27 mE
Northing: 8498063.87 mN
Depth: 249.2 m

Sediment Type:
Muddy sand

Fauna:
Faunal tracks
Faunal burrows



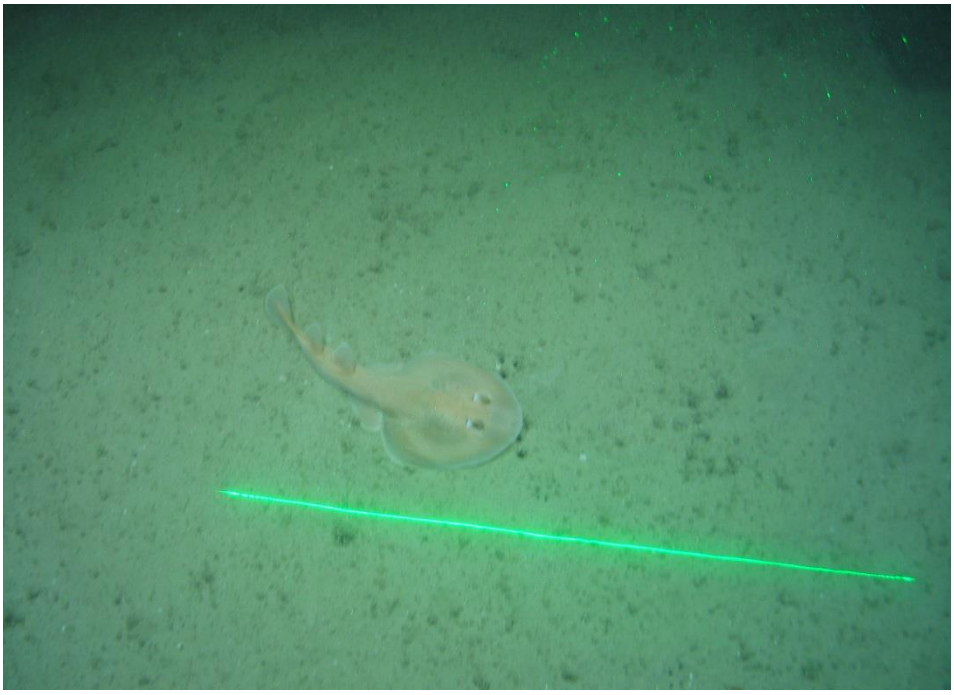
Photograph:
SA1702_ENV20_43

Easting: 556708.81 mE
Northing: 8497943.51 mN
Depth: 243.1 m

Sediment Type:
Reef rubble with muddy sand veneer

Fauna:
Sponges (Porifera)
Hydroids (Hydrozoa)

SA1702_ENV21

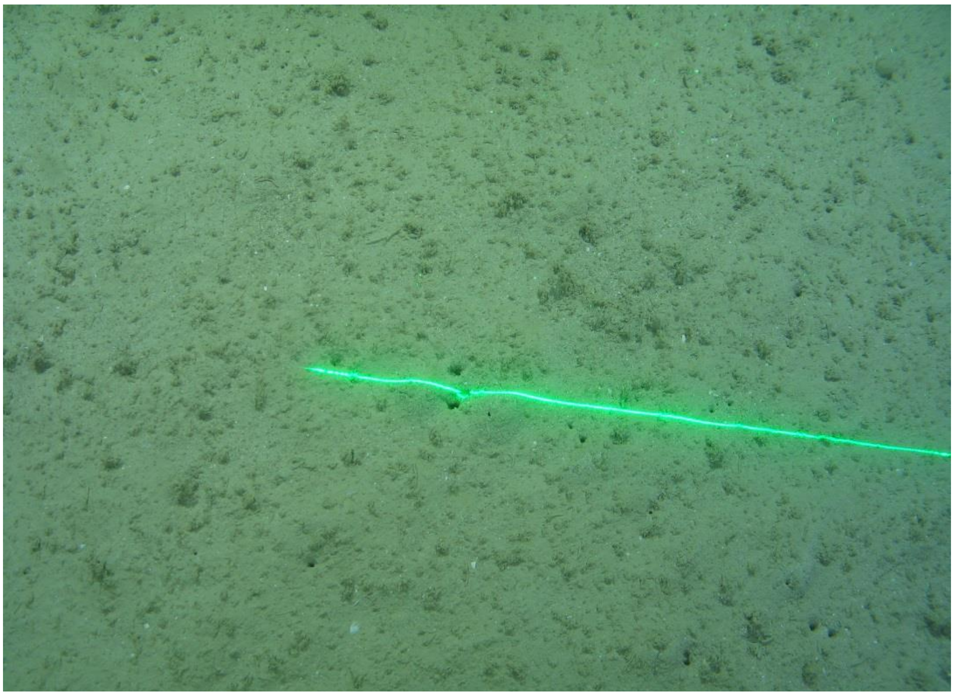


Photograph:
SA1702_ENV21_13

Easting: 551901.77 mE
Northing: 8492891.32 mN
Depth: 270.6 m

Sediment Type:
Muddy sand

Fauna:
Ray (Torpediniformes)



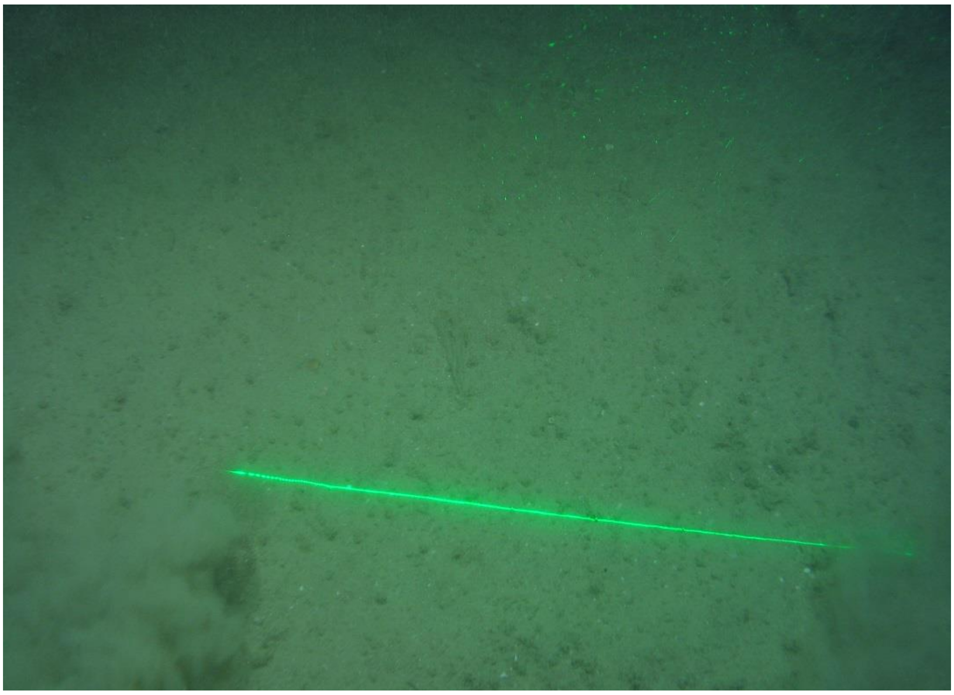
Photograph:
SA1702_ENV21_17

Easting: 551932.59 mE
Northing: 8492889.46 mN
Depth: 271 m

Sediment Type:
Muddy sand

Fauna:
Faunal burrows
Hydroids (Hydrozoa)

SA1702_ENV22

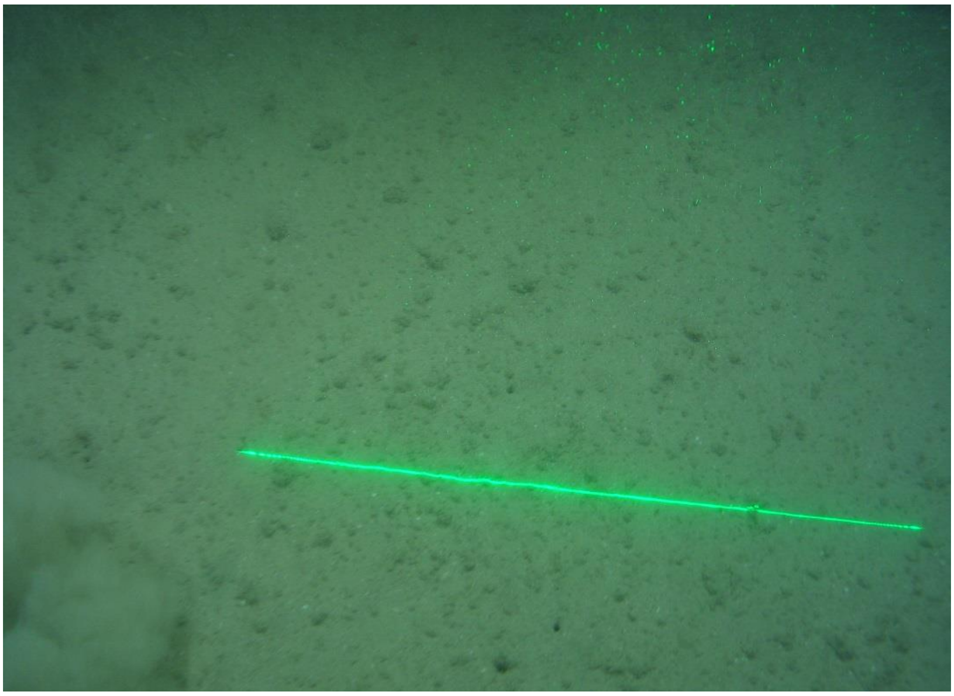


Photograph:
SA1702_ENV22_21

Easting: 546412.69 mE
Northing: 8487560.38 mN
Depth: 266.7 m

Sediment Type:
Muddy sand

Fauna:
No visible fauna



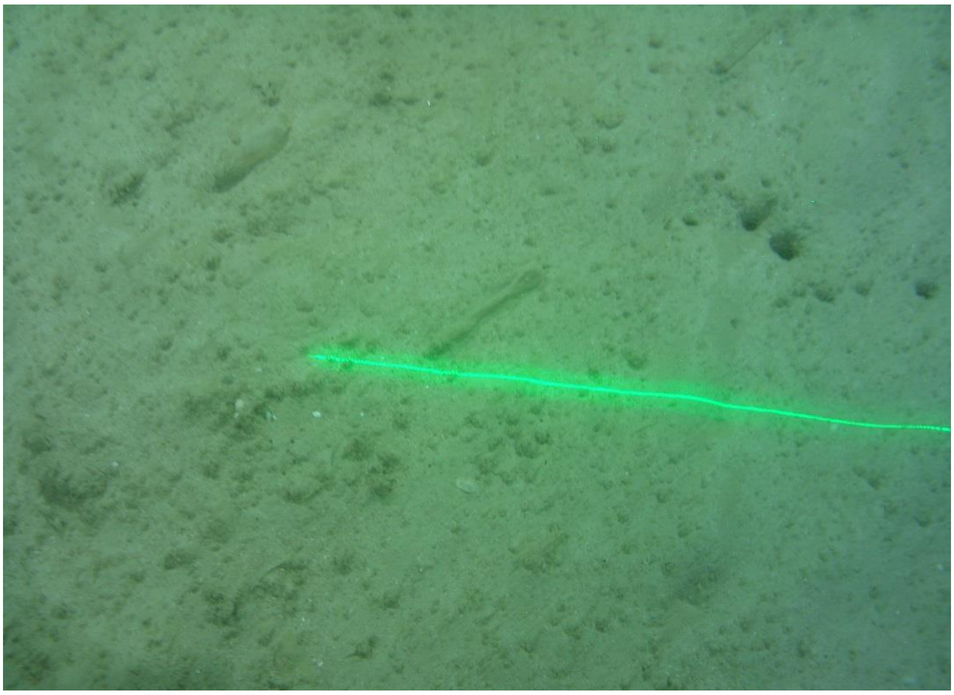
Photograph:
SA1702_ENV22_28

Easting: 546376.10 mE
Northing: 8487591.81 mN
Depth: 267.2 m

Sediment Type:
Muddy sand

Fauna:
No visible fauna

SA1702_ENV23

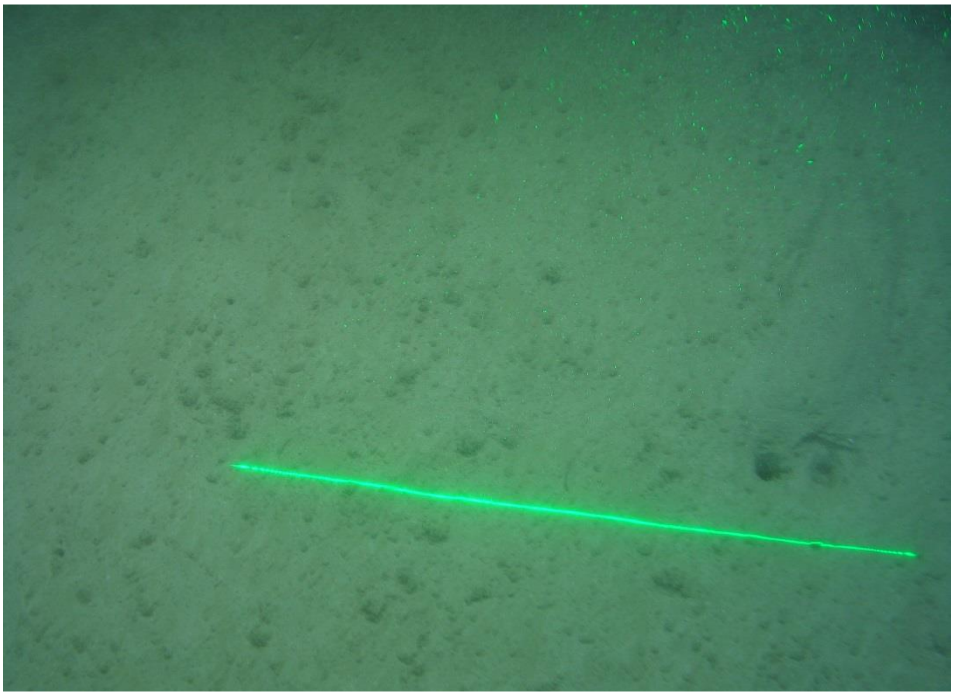


Photograph:
SA1702_ENV23_06

Easting: 539767.24 mE
Northing: 8481145.72 mN
Depth: 257.8 m

Sediment Type:
Muddy sand

Fauna:
Faunal burrows



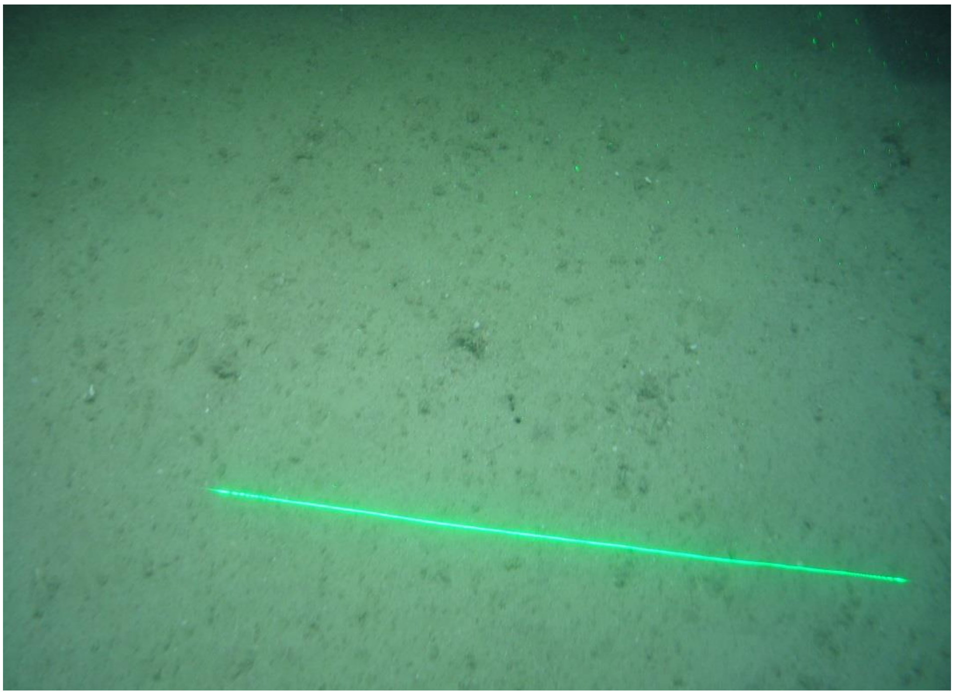
Photograph:
SA1702_ENV23_35

Easting: 539898.96 mE
Northing: 8481252.58 mN
Depth: 257.4 m

Sediment Type:
Muddy sand

Fauna:
Faunal burrows

SA1702_ENV24

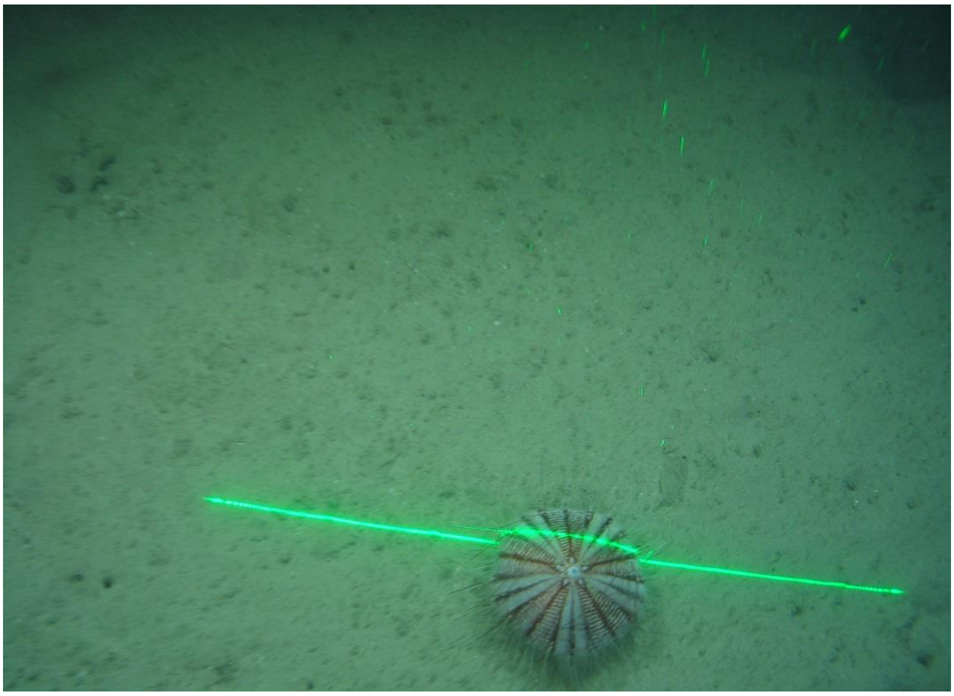


Photograph:
SA1702_ENV24_27

Easting: 549266.15 mE
Northing: 8484607.47 mN
Depth: 261.9 m

Sediment Type:
Muddy sand

Fauna:
Faunal burrows



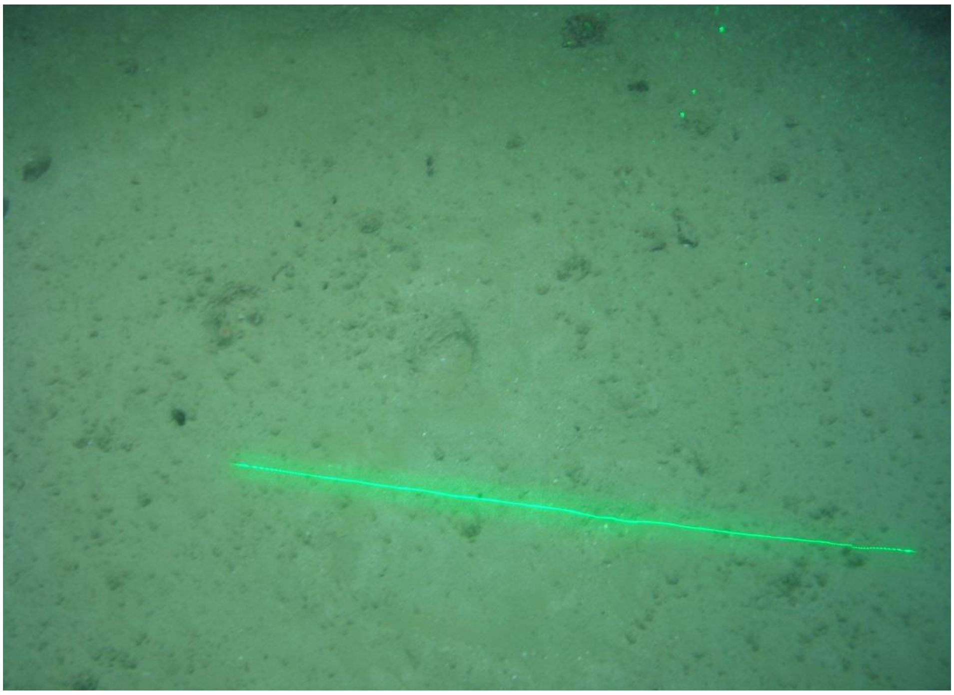
Photograph:
SA1702_ENV24_32

Easting: 549285.58 mE
Northing: 8484601.67 mN
Depth: 261.4 m

Sediment Type:
Muddy sand

Fauna:
Sea urchin (Echinoidea)
Faunal burrows

SA1702_ENV25

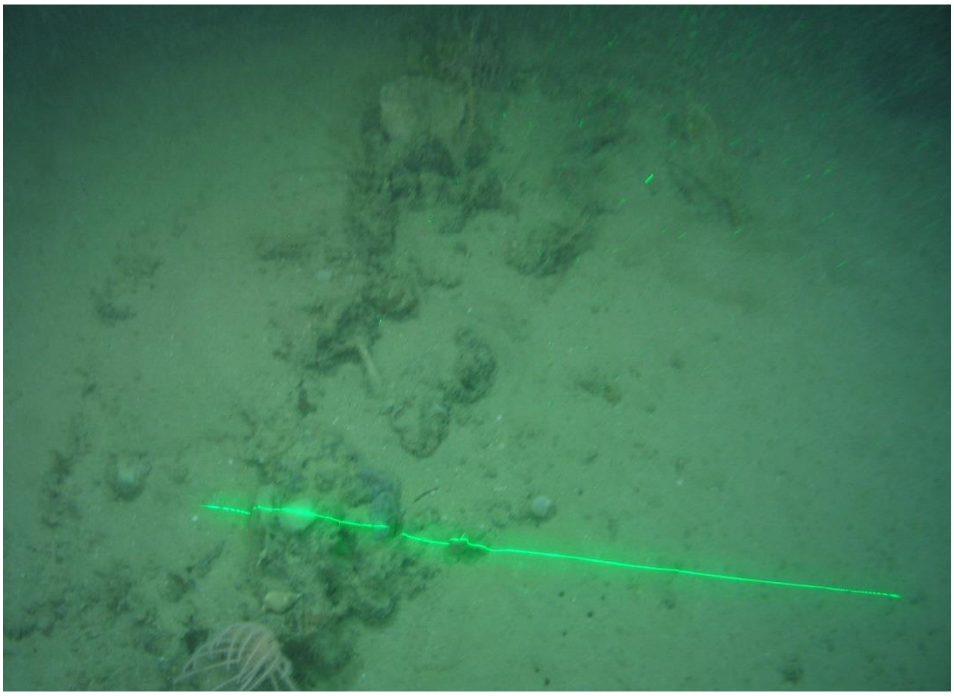


Photograph:
SA1702_ENV25_02

Easting: 557440.26 mE
Northing: 8490708.33 mN
Depth: 266.1 m

Sediment Type:
Muddy Sand

Fauna:
Faunal burrows



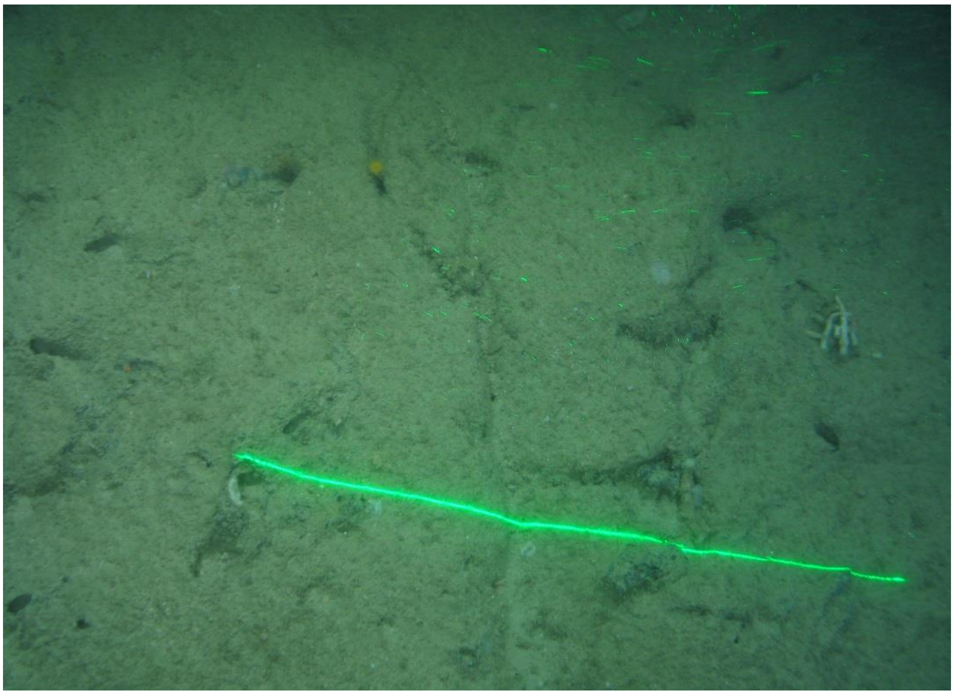
Photograph:
SA1702_ENV25_09

Easting: 557411.09 mE
Northing: 8490687.16 mN
Depth: 266.5 m

Sediment Type:
Reef rubble with muddy sand veneer

Fauna:
Sponge (Porifera)
Hydroids (Hydrozoa)
Soft coral (Alcyonaria)

SA1702_ENV26

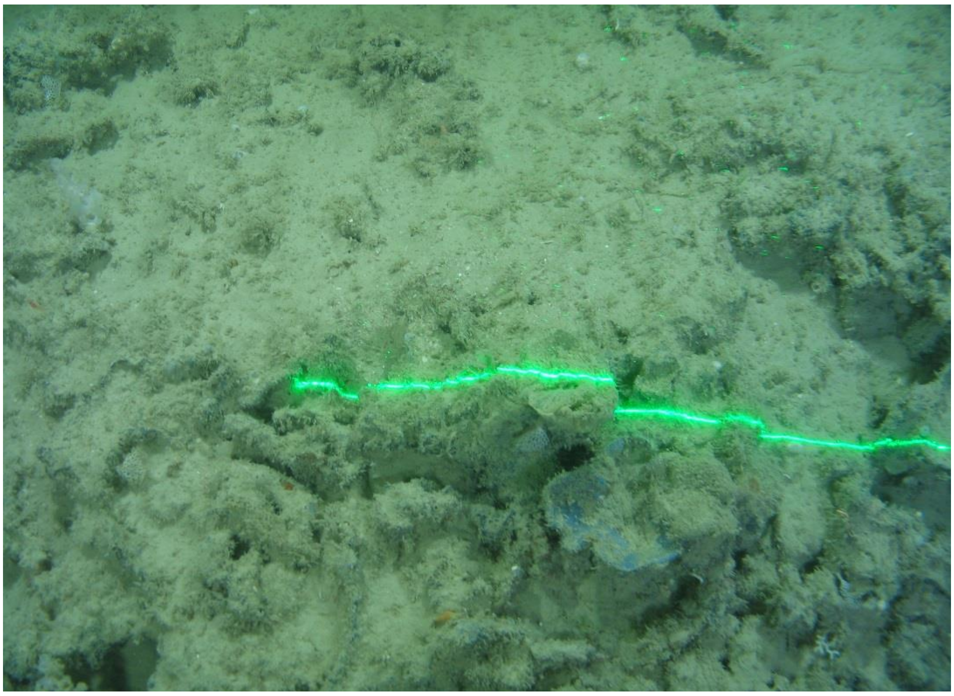


Photograph:
SA1702_ENV26_42

Easting: 558941.66 mE
Northing: 8491494.41 mN
Depth: 249.2 m

Sediment Type:
Reef with sand veneer

Fauna:
Sponges (Porifera)
Soft coral (Alcyonaria)



Photograph:
SA1702_ENV26_60

Easting: 558878.87 mE
Northing: 8491472.65 mN
Depth: 255.8 m

Sediment Type:
Reef with sand veneer

Fauna:
Sponges (Porifera)
Soft coral (Alcyonaria)
Hydroids (Hydrozoa)
Bryozoa

Appendix D: Drill Cuttings and Drilling Muds Dispersion Modelling Study (RPS 2018a)

REPORT

Shell Crux Project

Sediment Dispersion Modelling of Drill Cuttings and Fluids Discharges

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No.:	MAW0633J		
Version:	2-Fig		
Date:	12 July 2018		

Document Status

Version	Purpose of Document	Prepared by	Reviewed by	Review Date
A	Issued for internal review	M. Zapata	D. Wright	27/04/2018
0	Issued for Client review	M. Zapata	D. Wright	01/05/2018
1	Issued for Client review	M. Zapata	D. Wright	28/06/2018
2	Final	M. Zapata	D. Wright	12/07/2018

Approval for Issue

Name	Signature	Date
Sasha Zigic	S. Zigic	12/07/2018

RPS

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1 Introduction

1.1 Background

RPS has been commissioned by CDM Smith Australia Pty Ltd (CDM Smith), on behalf of Shell Australia Pty Ltd (Shell), to undertake a sediment dispersion modelling study of discharged cuttings and fluids during drilling of the development wells within the Crux field (Table 1.1 and Figure 1.1). The Crux field is located in the northern Browse Basin in offshore Commonwealth marine waters, approximately 190 km offshore north-west Australia and 620 km north-north-east of Broome.

The principal aim of the study was to calculate the fate of discharged drill cuttings and unrecoverable drilling muds, quantify the likely area of coverage and levels of suspended sediments and bottom deposition (thickness and accumulated load), and assess the risk to sensitive receptors of contact from cuttings and muds discharged during the operation.

During the Crux drilling campaign, Shell intends to drill five wells all from one drill centre (one location), with each well currently proposed to be drilled as five intervals using conventional drilling techniques. Based on the current well design and information from previous drilling campaigns undertaken by Shell for Prelude and the Auriga-1 well, the Crux drilling programme is expected to result in the discharge of an estimated 891 m^3 of cuttings and 247 m^3 of mud solids over 33.5 days per well. In total, 167.5 days will be required to drill all five wells.

The potential area that may be influenced by the discharge of drill cuttings and drilling fluids was assessed on both a monthly and annualised basis.

Table 1.1 Location of the proposed Crux Development Well used as the release site for the drill cuttings and drilling fluids dispersion modelling assessment.

Release Site	Latitude (°S)	Longitude (°E)	Water Depth (m)
Crux Development Well	12° 57’ 52.46”	124° 26’ 33.21”	170

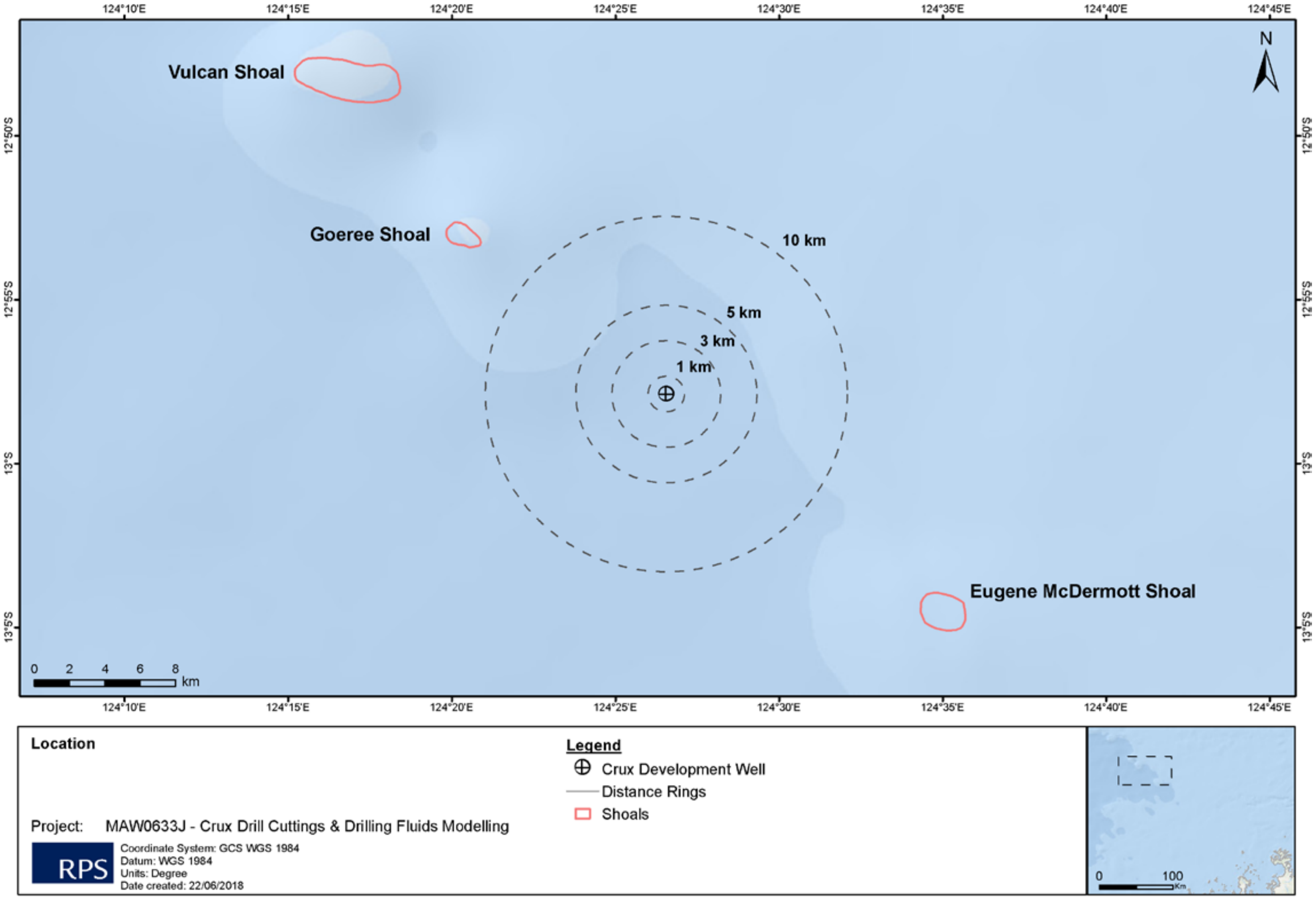

Figure 1.1 Location of the proposed Crux Development Well relative to the nearest submerged shoals.

1.2 Modelling Scope

The scope of the modelling included the following components:

1. Collation of a suitable three-dimensional, spatially-varying current data set surrounding the proposed Crux Development Well location for a ten-year (2008-2017) hindcast period. The current data set included the combined influence of drift and tidal currents, and was suitably long as to be indicative of interannual variability in ocean currents. The current data set was validated against the metocean data collected in the Crux development area.
2. Collation of seasonally-varying vertical water density profiles at the Crux development area for use as input to the sediment dispersion model.
3. Summary of the drilling plan as discrete discharge characteristics representing each stage of the drilling programme for input to the sediment dispersion model.
4. Establishment of a sediment dispersion model to repeatedly simulate all stages of the drilling programme under different sample conditions, with each sample represented by a time sequence of current flow commencing on the first day of each calendar month within the ten-year hindcast of currents (i.e. 120 simulations from January 2008 to December 2017).
5. Analysis of the results of all simulations to map the distribution and thicknesses of discharged drill cuttings and drilling muds in the water column and on the sea floor.

2 Regional Ocean Currents

2.1 Overview

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region of the Kimberley Coast. However, the offshore regions with water depths exceeding 100-200 m experience significant large-scale drift 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 sediment plumes over time scales exceeding a few hours.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (hours to days) and result in long trajectories. Hence, the current-induced transport of plumes can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is important to consider all these potential advective mechanisms to rigorously understand patterns of potential transport from a given discharge location.

To appropriately allow for temporal and spatial variation in the current field, dispersion modelling requires the current speed and direction over a spatial grid covering the potential migration zone of plumes. Estimates of the net currents were derived by combining predictions of the drift currents, available from a mesoscale ocean model, with estimates of the tidal currents generated by an RPS model set up for the study area. These estimates are considered representative of the oceanographic currents that influence the Crux development area. Shell has also collected 12 months of metocean data in the Crux development area, with this data being used to validate the hydrodynamic model used in this modelling study. Refer to Section 2.4 for further discussion of the tidal and current model validation.

A composite modelled ocean current data product was derived by combining predictions of mesoscale circulation currents, available at daily resolution from global ocean models, with predictions of the hourly tidal currents generated by the RPS HYDROMAP model. By combining a drift current model with a tidal model, the influences of inter-annual and seasonal drift patterns, and the more regular variations in tide, were included.

2.2 Mesoscale Circulation

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 2.1. They are characterised as follows:

- **Buoyancy driven circulation**. The main buoyancy-driven feature in the region is the Indonesian Throughflow (ITF) 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.

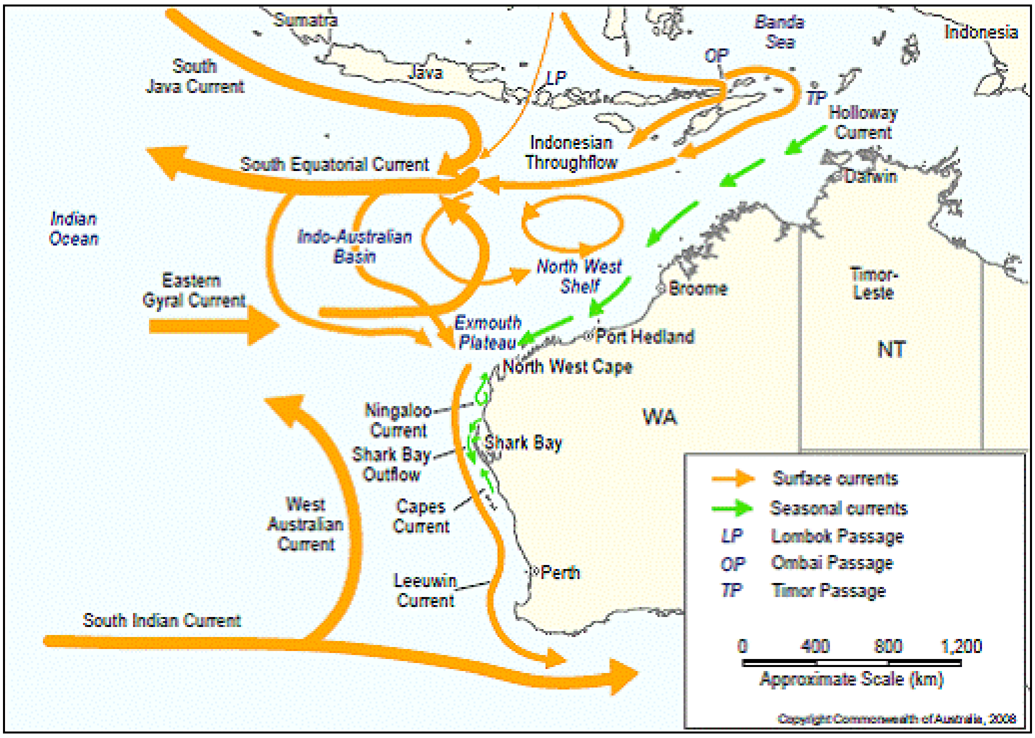

Figure 2.1 **A map of the major currents off the West Australian coast (DEWHA, 2008).**

2.2.1 Description of 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 2008 to 2017 (inclusive).

2.3 Tidal Currents

2.3.1 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) (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 particular 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).

2.3.2 Tidal Grid Setup

A HYDROMAP model was established over a domain that extended approximately 3,300 km east-west by 3,100 km north-south over the eastern Indian Ocean. The grid extends beyond Eucla in the south and beyond Bathurst Island in the north (Figure 2.2).

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 98,600 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.

2.3.3 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.

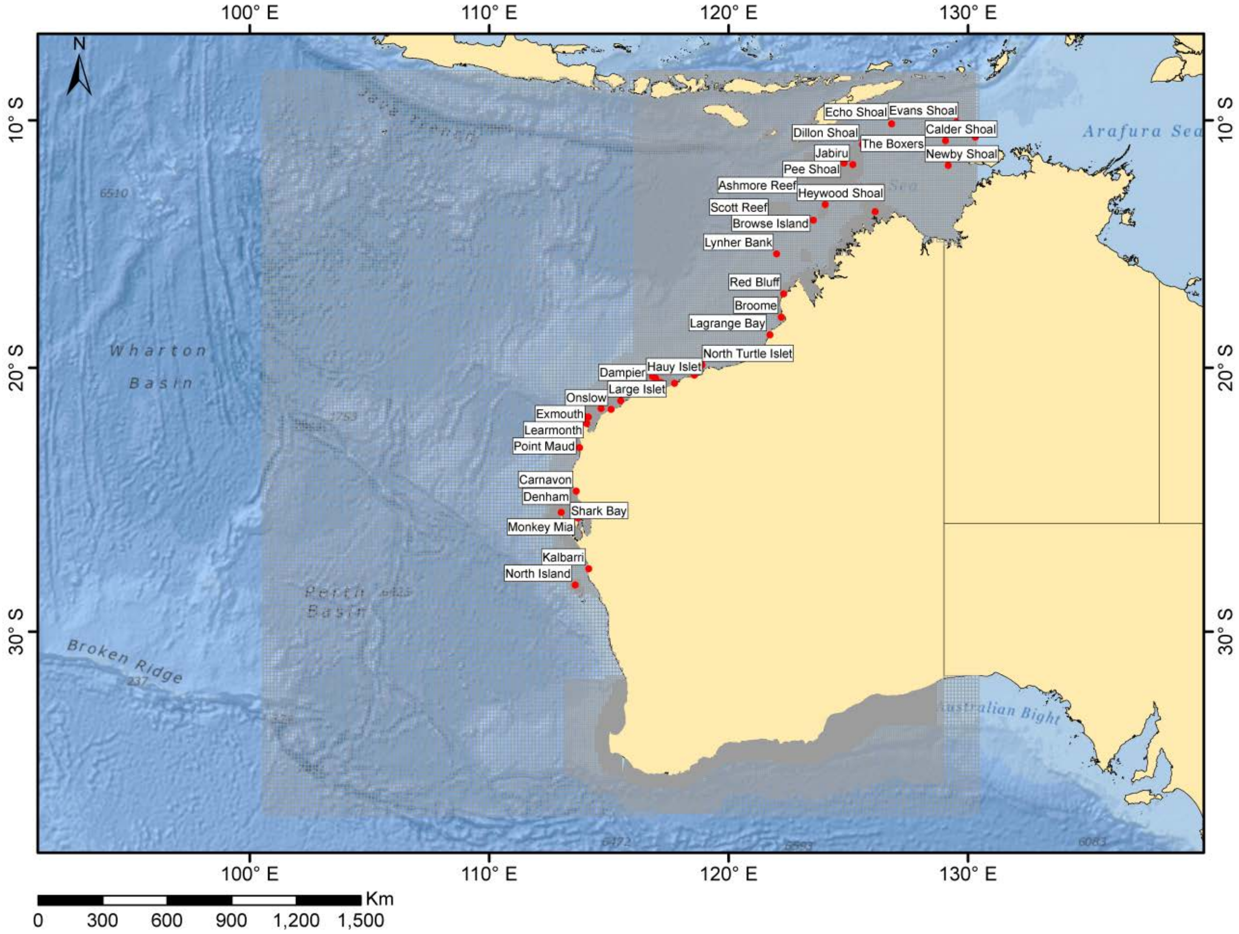

Figure 2.2 Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing the full domain in context with the continental land mass and the locations available for tidal comparisons (red labelled dots). Higher-resolution areas are indicated by the denser mesh zones.

2.4 Tidal and Current Model Validation

The suitability of the modelled tidal and drift current data products was evaluated by comparing the predicted currents to those measured at the Crux development area. The following sections describe the sources of both the modelled and measured data, the comparison methodology, and the outcomes of the comparisons for both the tidal and drift current components.

2.4.1 Data Sources

A tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP. HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. This model is described in Section 2.3.

A mesoscale ocean current data sets was selected for the study: HYCOM (Hybrid Coordinate Ocean Model) Consortium's global ocean model, HYCOM. This model is described in Section 0.

A data set of measured currents was collected by RPS at the Crux development area between April 2016 and May 2017 (RPS, 2017). This data set includes a series of point current measurements made at six depths through the water column using CM04 current meters mounted on a floating mooring. The measurement depths are approximately 20 m, 70 m, 110 m, 150 m, 165 m and 167 m below the water surface. The temporal resolution of the data is 1 minute. The raw data was quality-controlled by RPS and only data identified as high-quality was used for comparison to model data. For the measurements at a 20 m water depth, there is approximately a 7-week gap in the data between early September and late October 2016.

2.4.2 Model Validation Skills

2.4.2.1 Overview

The mesoscale and tidal current models were validated through quantitative and visual comparisons of measured and modelled data.

2.4.2.2 Statistics

A quantitative analysis of a model's skill at replicating the environmental conditions was conducted using the Index of Agreement (IOA), presented in Willmott (1981), and the Mean Absolute Error (MAE), discussed in Willmott (1982) and Willmott & Matsuura (2005). Other traditional error estimates, such as the correlation coefficient and the root mean square error (RMSE) are problematic and prone to ambiguities and bias (Willmott & Matsuura, 2005; Willmott, 1982). Consequently, they are not reported in isolation here.

The MAE is simply the average of the absolute values of the differences between the observed and modelled values. MAE is a more natural measure of average error (Willmott & Matsuura, 2005) and more readily understood. The IOA is determined using the following formula:

$$\text{IOA} = 1 - \frac{\sum |X_{\text{model}} - X_{\text{obs}}|^2}{\sum \left(|X_{\text{model}} - \overline{X_{\text{obs}}}| + |X_{\text{obs}} - \overline{X_{\text{obs}}}| \right)^2}$$

In this equation, X represents the variable being compared and $\bar{X}$ represents the mean of that variable over time.

A perfect agreement can be said to exist between the model and field observations if the IOA gives a measure of one, and complete disagreement will produce an IOA measure of zero (Wilmott, 1981). Although it is difficult to find guidelines for what values of the IOA might represent a good agreement, Willmott *et al.* (1985) suggests that values meaningfully larger than 0.5 represent good model performance. Clearly, the higher the IOA and the lower the MAE, the better the model performance.

An important point to note regarding both, and in fact most, measures of model performance, is that slight phase differences in the series can result in a seemingly poor statistical comparison, particularly in rapidly changing series such as tidal direction or water elevation where the tidal range is large. It is therefore always important to consider both the statistics <u>and</u> the visual representation of the comparison (Willmott *et al.*, 1985). Statistical comparison of current direction can be misleading; skill measures of direction can become biased where the directional fluctuations are near 0-360°. Therefore, we have based the quantitative assessment on the U and V current components and not magnitude and direction.

RPS

2.4.2.3 Time Series

In addition to bulk statistical measures, model performance for the measurement period was assessed visually with the aid of scatterplots and rose plots. The scatterplots show the correlation between the x- and y-components of the measured and modelled data. The rose plots show the frequency of current direction by sector, and magnitude by colour, to allow comparison of current direction between modelled and measured data.

The model performance was also evaluated against time series plots of water level, U (east-west) velocity component, V (north/south) velocity component, current speed and current direction data. This approach is valuable because statistical measures of model skill can heavily penalise errors in phase (i.e. time lags) even when the dynamics of flow are broadly reproduced.

2.4.3 Tidal Elevation Validation

For verification of the tidal elevation 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 Crux development area were used for comparison.

Time series comparisons were completed for a six-month period from January to June 2010. The statistics are summarised in Table 2.1, and indicate excellent model performance in this region. Water level time series for these locations are shown in Figure 2.3, Figure 2.4 and Figure 2.5 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.

For the purposes of understanding the limitations in accuracy of the tidal predictions, the RMSE and MAE in Table 2.1 should be noted. On average, the model predictions are within 0.1-0.3 m of XTide predictions based on known constituent data at any point in time. Often the error is mostly attributable to errors of phase in the tidal signal, with the magnitude of the tidal rise and fall over each tide well represented. However, in the application of the data predictions to operational circumstances, the potential errors should be considered.

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 2.6. The red line on each plot shows the 1:1 line, which would indicate a perfect match between the modelled and observed data. Note that the data is generally closely aligned to the 1:1 line demonstrating the high quality of the model performance.

RPS

Table 2.1 Statistical comparison of predicted surface elevation data from HYDROMAP and XTide at 18 locations in the tidal model domain (January to July 2010).

Tide Station	Longitude (°E)	Latitude (°S)	IOA	CC	MAE (m)	RMSE (m)
Ashmore Reef	123.02	12.22	0.99	0.99	0.14	0.18
Browse Island	123.55	14.10	0.97	0.97	0.36	0.45
Calder Shoal	129.07	10.85	0.97	0.97	0.17	0.21
Cape Legendre	116.83	20.35	0.99	0.99	0.12	0.14
Dillon Shoal	125.60	11.00	0.97	0.95	0.18	0.22
Echo Shoal	126.82	10.15	0.97	0.94	0.17	0.21
Evans Shoal	129.53	10.08	0.98	0.98	0.11	0.14
Goodrich Bank	130.32	10.70	0.99	0.97	0.13	0.16
Heywood Shoal	124.05	13.47	0.98	0.96	0.27	0.33
Jabiru	125.20	11.83	097	0.95	0.22	0.27
Loxton Shoal	128.72	09.60	0.99	0.98	0.10	0.13
Lynedoch Bank	130.82	10.03	0.98	0.98	0.12	0.15
Lynher Bank	122.02	15.47	0.98	0.97	0.26	0.31
Newby Shoal	129.18	11.87	0.98	0.96	0.23	0.27
Pee Shoal	124.83	11.77	0.97	0.94	0.23	0.27
Scott Reef	121.80	14.05	0.99	0.98	0.16	0.19
The Boxers	128.35	11.45	0.97	0.96	0.16	0.20
Troughton Island	126.13	13.75	0.97	0.95	0.27	0.33

Notes: *IOA* *Index of Agreement – values close to 1 represent a high level of agreement.*
CC *Correlation Coefficient – values close to 1 represent very good correlation.*
MAE *Mean Absolute Error – the lower the value, the smaller the error.*
RMSE *Root Mean Square Error – the lower the value, the smaller the error.*

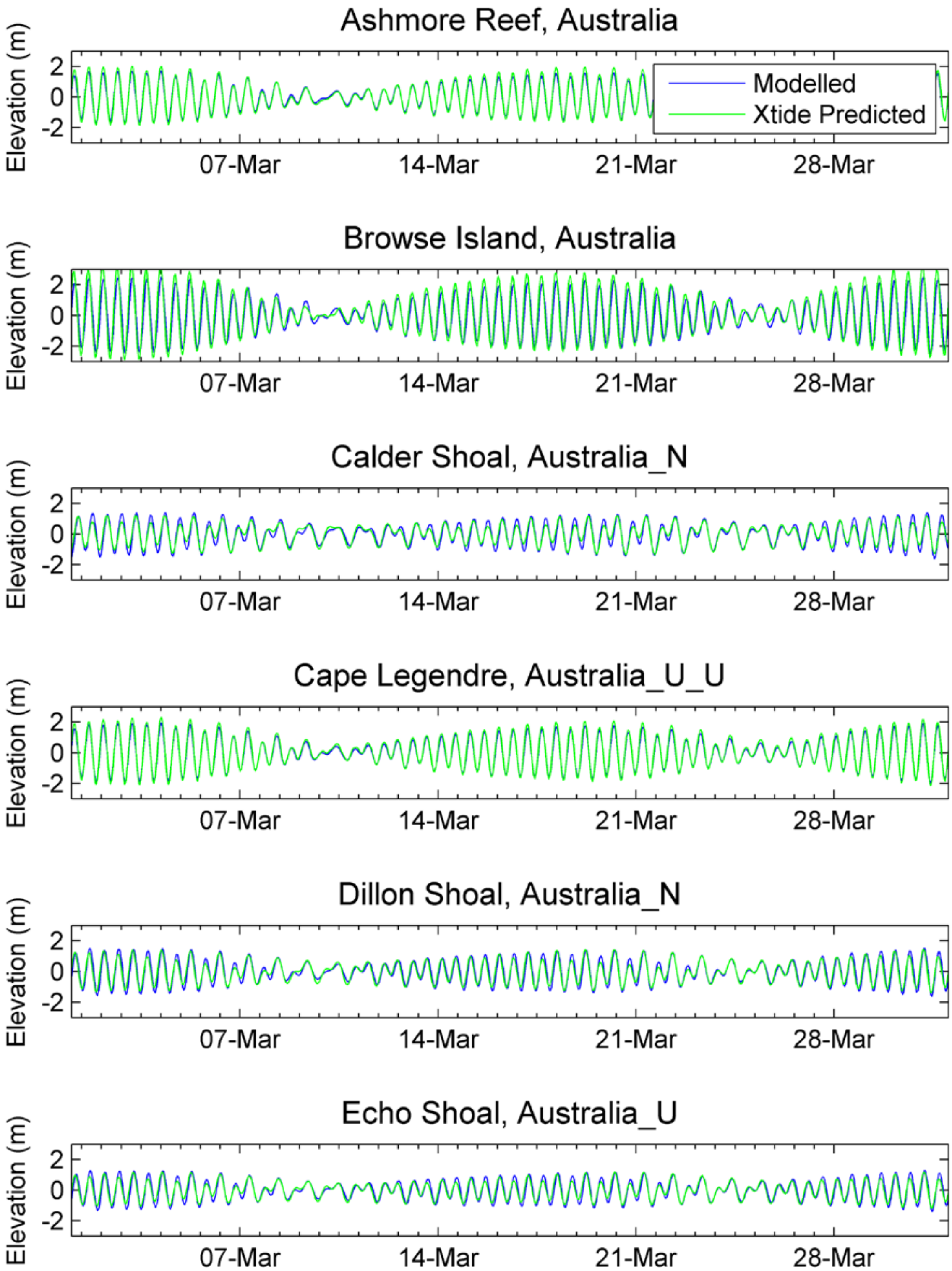

Figure 2.3 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

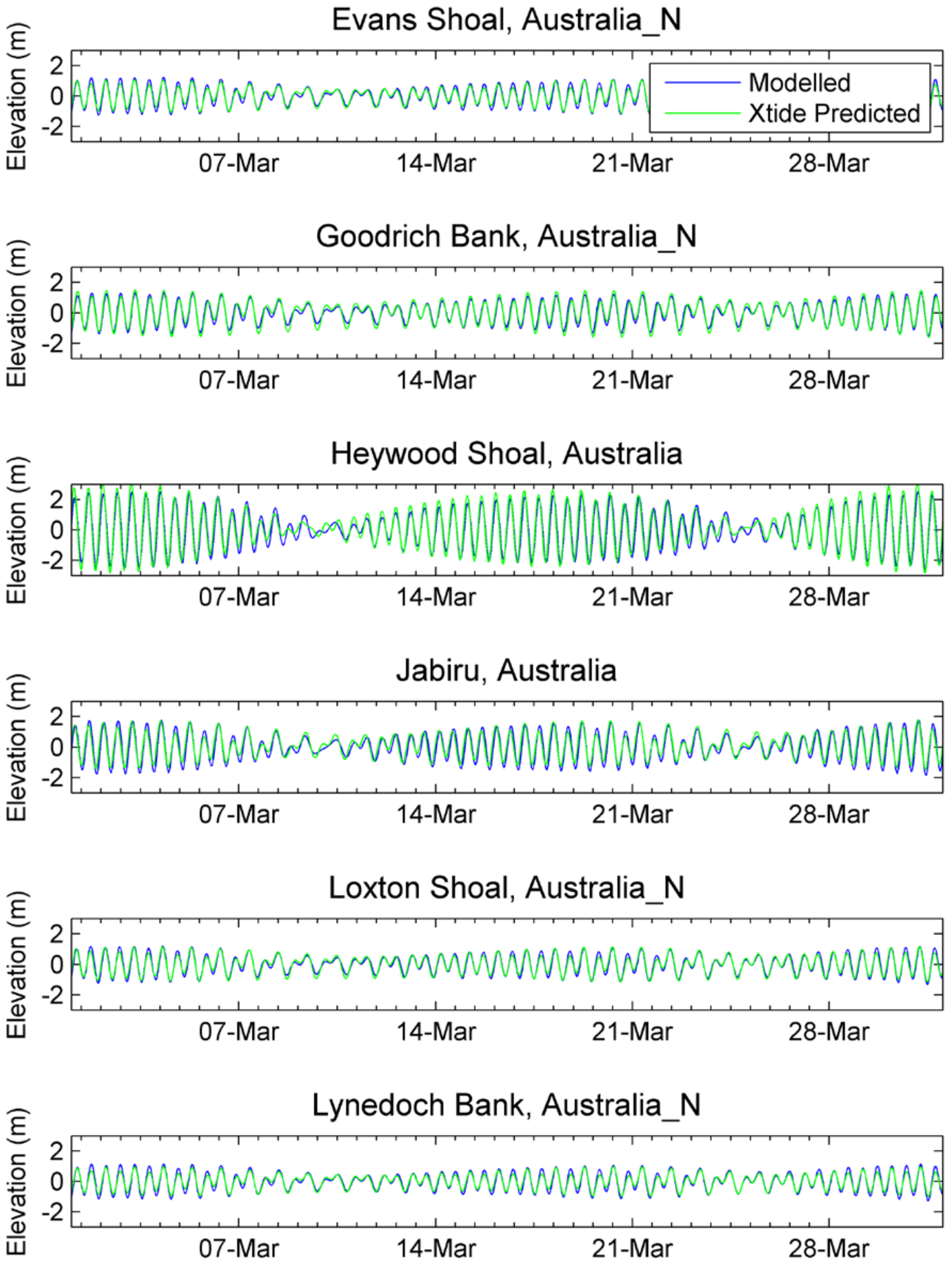

Figure 2.4 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

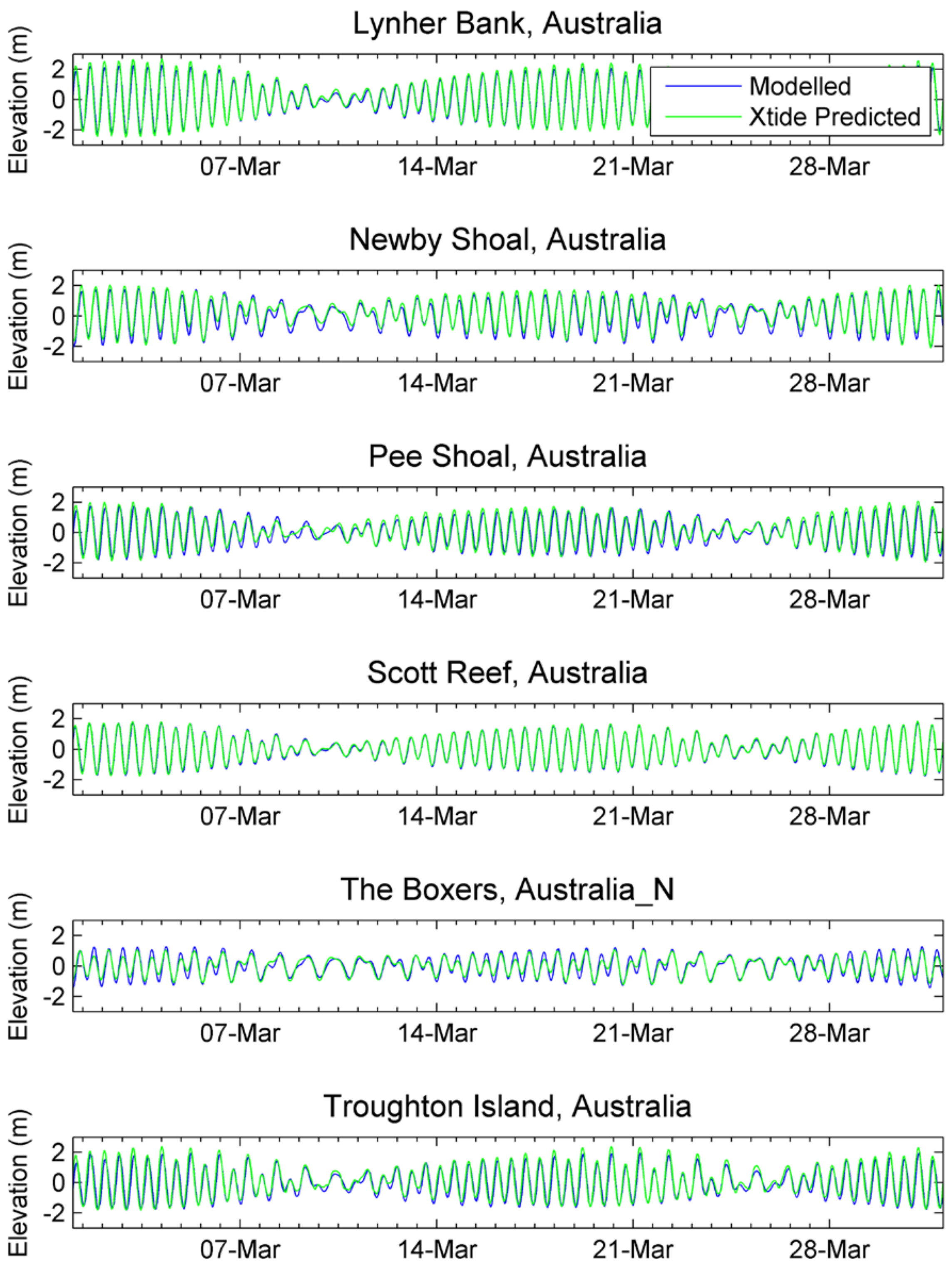

Figure 2.5 **Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).**

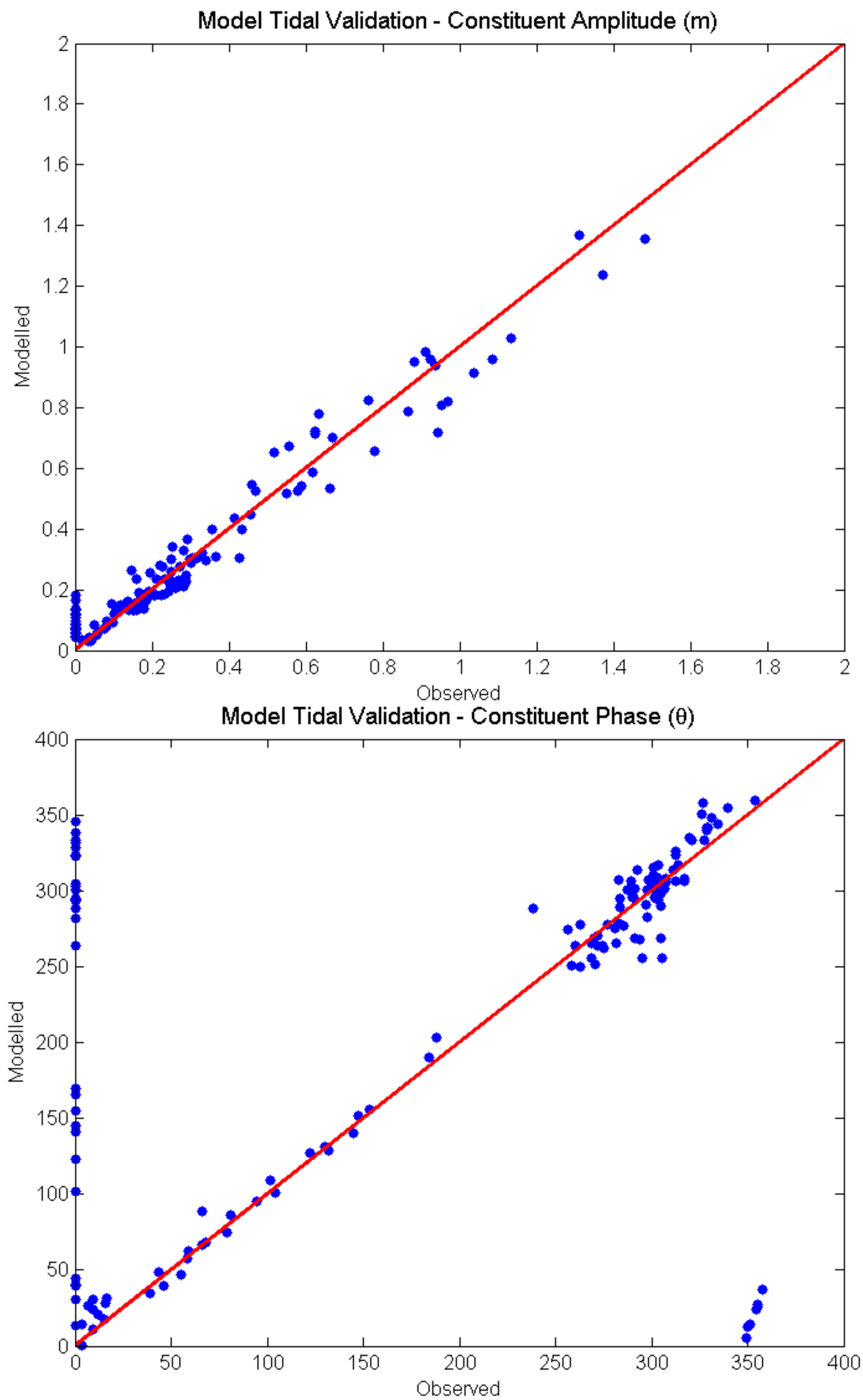

Figure 2.6 Comparisons between predicted tidal constituent amplitudes (top) and phases (bottom) from HYDROMAP and XTide at all stations in the tidal model domain. The red line indicates a 1:1 correlation between the respective data sets.

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2.4.4 Composite Current Data Set Validation: HYDROMAP + HYCOM

A composite modelled ocean current data product was derived by combining predictions of mesoscale circulation currents, available at daily resolution from the HYCOM ocean model, with predictions of the hourly tidal currents generated by the RPS HYDROMAP model.

To verify the modelled current predictions, the composite model outputs at the Crux development area were compared against the unfiltered site-specific current measurements. The model results were validated through both quantitative and visual comparisons between measured and modelled data at each depth where both data sets were available.

Time series comparison of composite model outputs and measured current magnitude, direction, and U/V velocity components at water depths of 20 m, 70 m and 110 m are presented in Figure 2.7, Figure 2.8 and Figure 2.9, respectively, for one month during winter (June 2016) and summer (December 2016). The time series comparisons reveal that the composite model offers a good match with the measured U/V velocity components at all water depths in both winter and summer, with the magnitudes and timings of the peaks and troughs matching well.

The IOA and MAE values derived from comparisons of the U/V velocity components at water depths of 20 m, 70 m and 110 m over the full measurement period are presented in Table 2.2. The IOA for each velocity component is high at all water depths, reflecting the good match in the magnitudes and timings of the peaks and troughs in the composite model data and measured data. The MAE for the U/V velocity components is relatively low at approximately 0.1 m/s for all water depths, indicating that the magnitude and range of the velocity components match well; however, a slight overprediction of the current magnitude is evident at times.

To compare directionality, roses for the composite model outputs and measured currents at 20 m, 70 m and 110 m water depths over the full measurement period are shown in Figure 2.9. The roses show that the composite model current direction is a good match with the measured direction. A shift in the dominant current direction from a north/south alignment in the measured data set to a northwest/southeast alignment in the composite model data set is evident at the 20 m water depth, and to a lesser extent also at the 70 m water depth. However, the range and variability in the measured current direction is captured by the composite model data, which matches best with the measured data at the water depth of 110 m.

Based on the validation performance, the composite model data set is a good model of standard conditions at the Crux development area and will adequately resolve local and regional circulation patterns. As such, the model is considered suitable for use in the numerical modelling studies conducted as part of the Crux project.

Table 2.2 Statistical comparison of predicted (HYDROMAP+HYCOM) and observed current speeds along orthogonal component axes at the Crux development area (2016-2017).

Skill Measure	Index of Agreement (IOA)			Mean Absolute Error (MAE) (m/s)		
Depth (m)	20	70	110	20	70	110
U Component	0.72	0.75	0.76	0.11	0.11	0.11
V Component	0.82	0.80	0.78	0.11	0.10	0.10

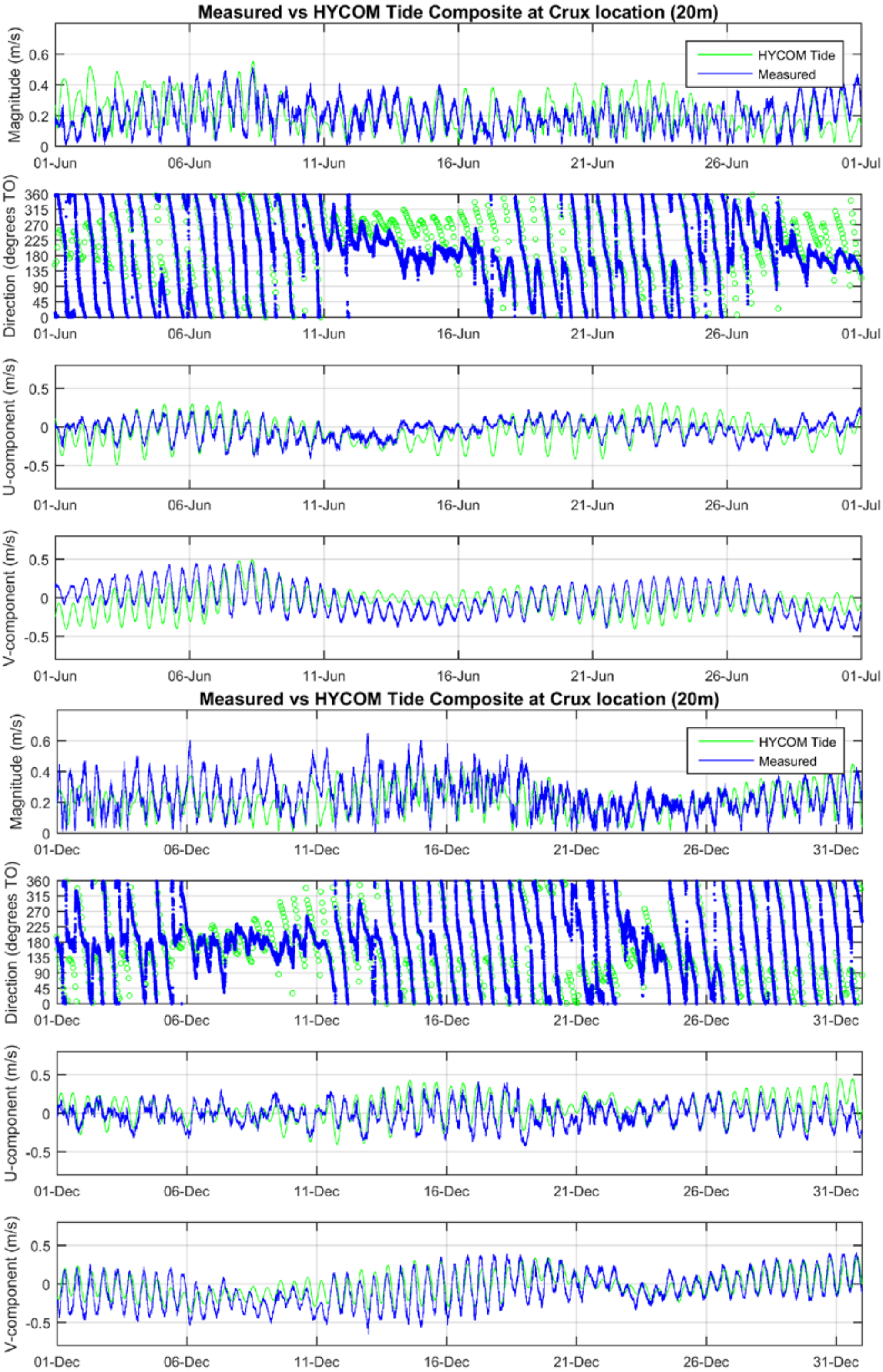

Figure 2.7 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 20 m for June 2016 (top panel) and December 2016 (bottom panel).

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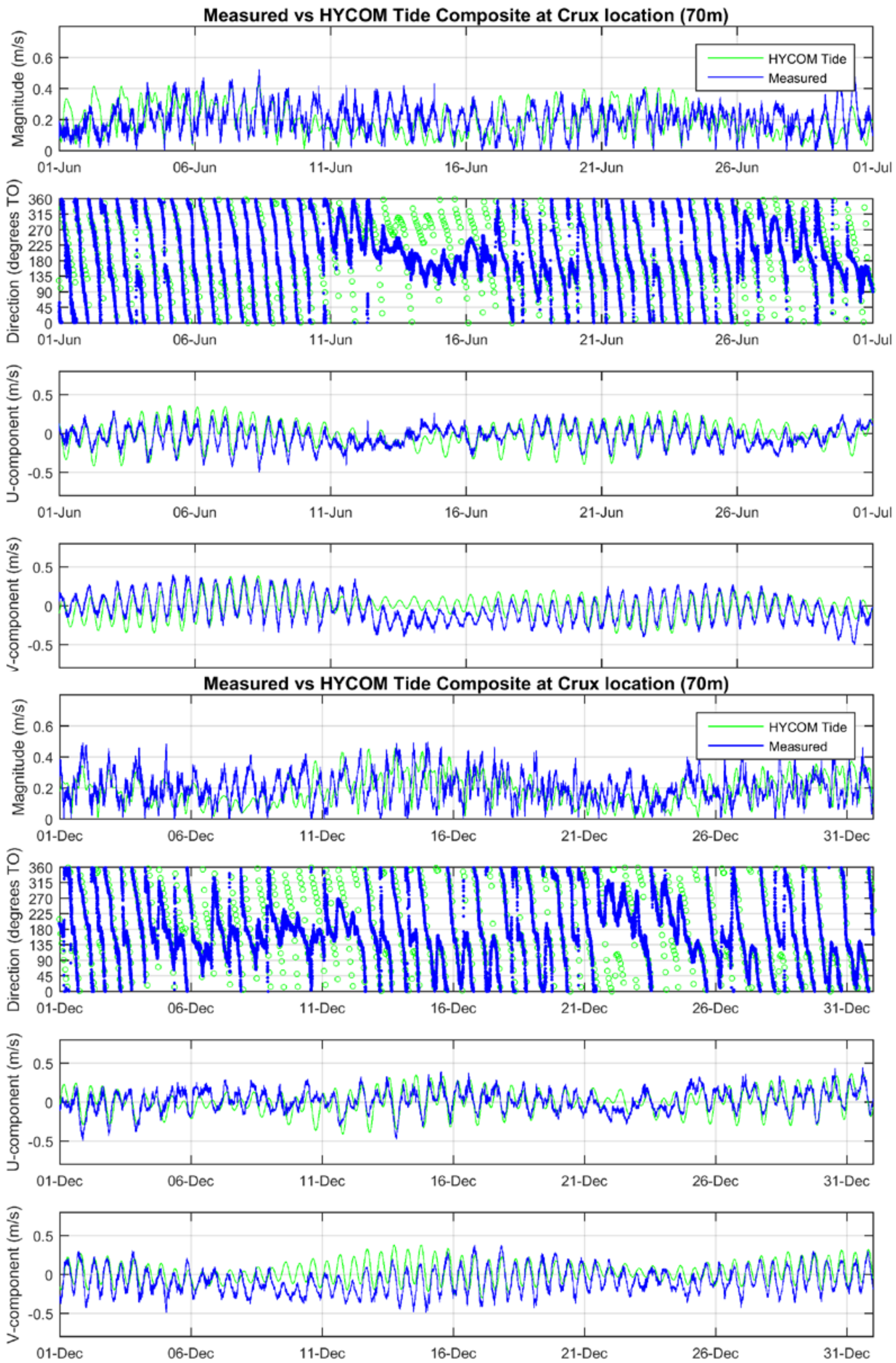

Figure 2.8 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 70 m for June 2016 (top panel) and December 2016 (bottom panel).

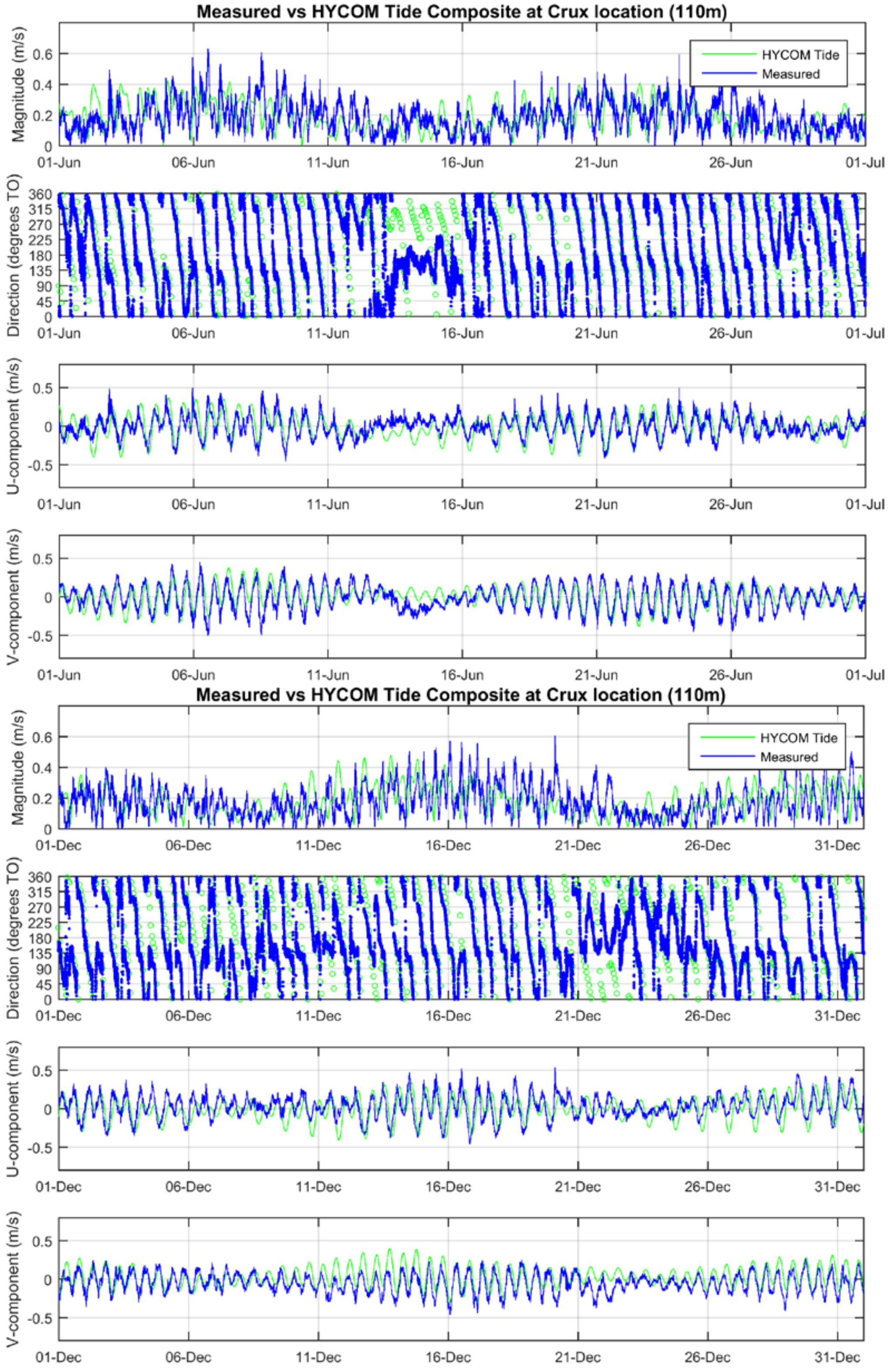

Figure 2.9 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 110 m for June 2016 (top panel) and December 2016 (bottom panel).

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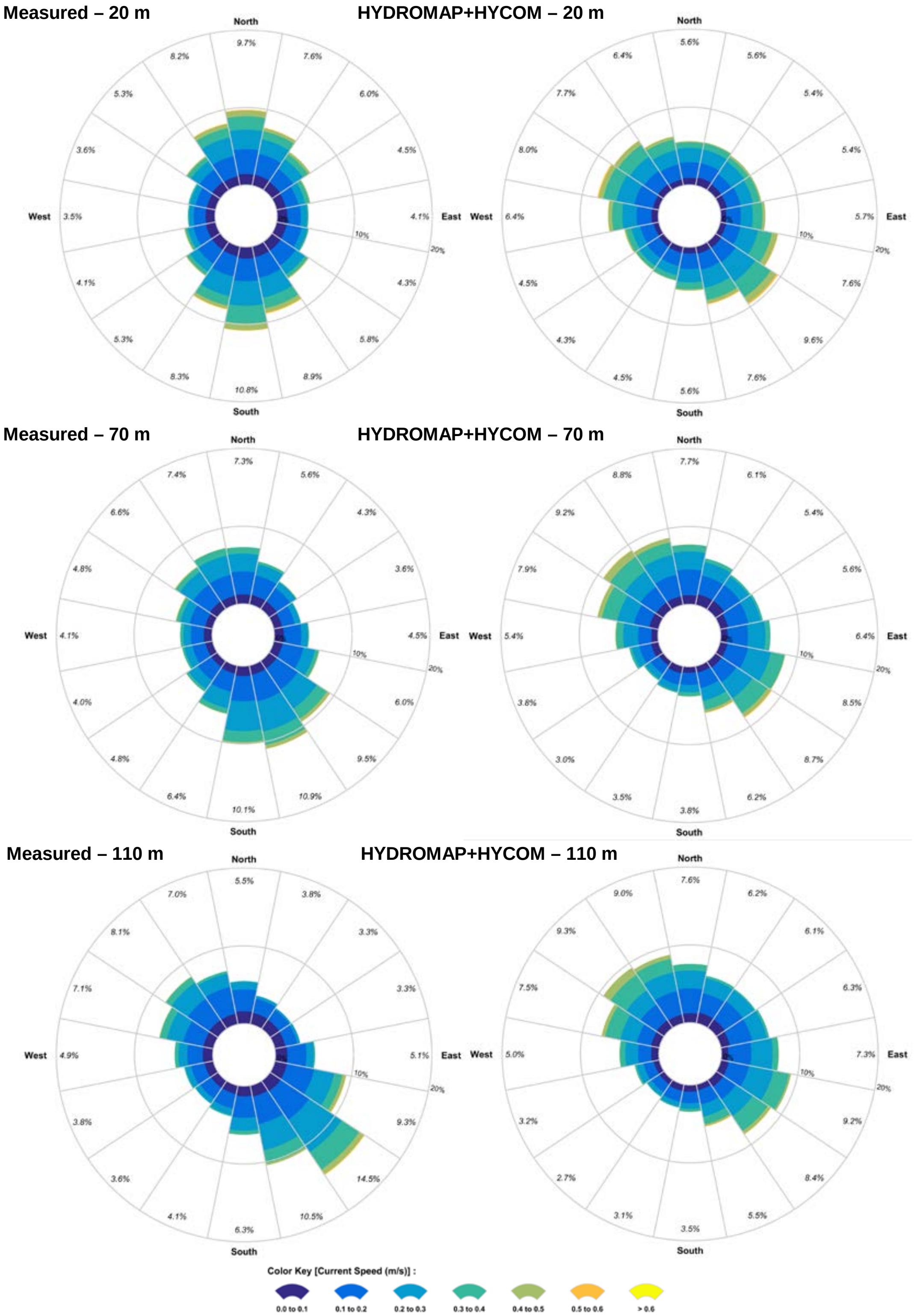

Figure 2.10 Comparative distributions for measured (left column) and predicted (HYDROMAP+HYCOM, right column) current data at the Crux development area (2016-2017) at depths of approximately 20 m (top row), 70 m (middle row) and 110 m (bottom row). The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

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2.5 Currents at Crux Development Well

Table 2.3 displays the monthly average and maximum near-surface and near-seabed current speeds calculated from the combination of HYCOM ocean currents and HYDROMAP tidal currents near the Crux Development Well location. Figure 2.11 and Figure 2.12 show the monthly near-surface and near-seabed current roses, respectively.

The data shows that the current speeds vary between seasons. In general, during summer (December to February) both near-surface and near-seabed currents are strongest (maximum near-surface speed of 1.51 m/s in January and maximum near-seabed speed of 0.60 m/s in December).

Table 2.3 Monthly average and maximum near-surface and near-seabed current speeds (2008-2017, inclusive) derived from the combined HYCOM and HYDROMAP databases near to the Crux Development Well location.

Month	Near-Surface Current Speed		Near-Seabed Current Speed	
	Average (m/s)	Maximum (m/s)	Average (m/s)	Maximum (m/s)
January	0.28	1.51	0.19	0.53
February	0.27	0.86	0.21	0.57
March	0.25	0.71	0.22	0.52
April	0.24	0.82	0.21	0.57
May	0.23	0.68	0.20	0.58
June	0.23	0.67	0.19	0.55
July	0.22	0.77	0.20	0.50
August	0.23	0.67	0.21	0.50
September	0.23	0.60	0.21	0.50
October	0.23	0.61	0.21	0.52
November	0.22	0.65	0.19	0.53
December	0.24	0.70	0.19	0.60
Maximum	**0.28**	**1.51**	**0.22**	**0.60**
Minimum	**0.22**	**0.60**	**0.19**	**0.50**

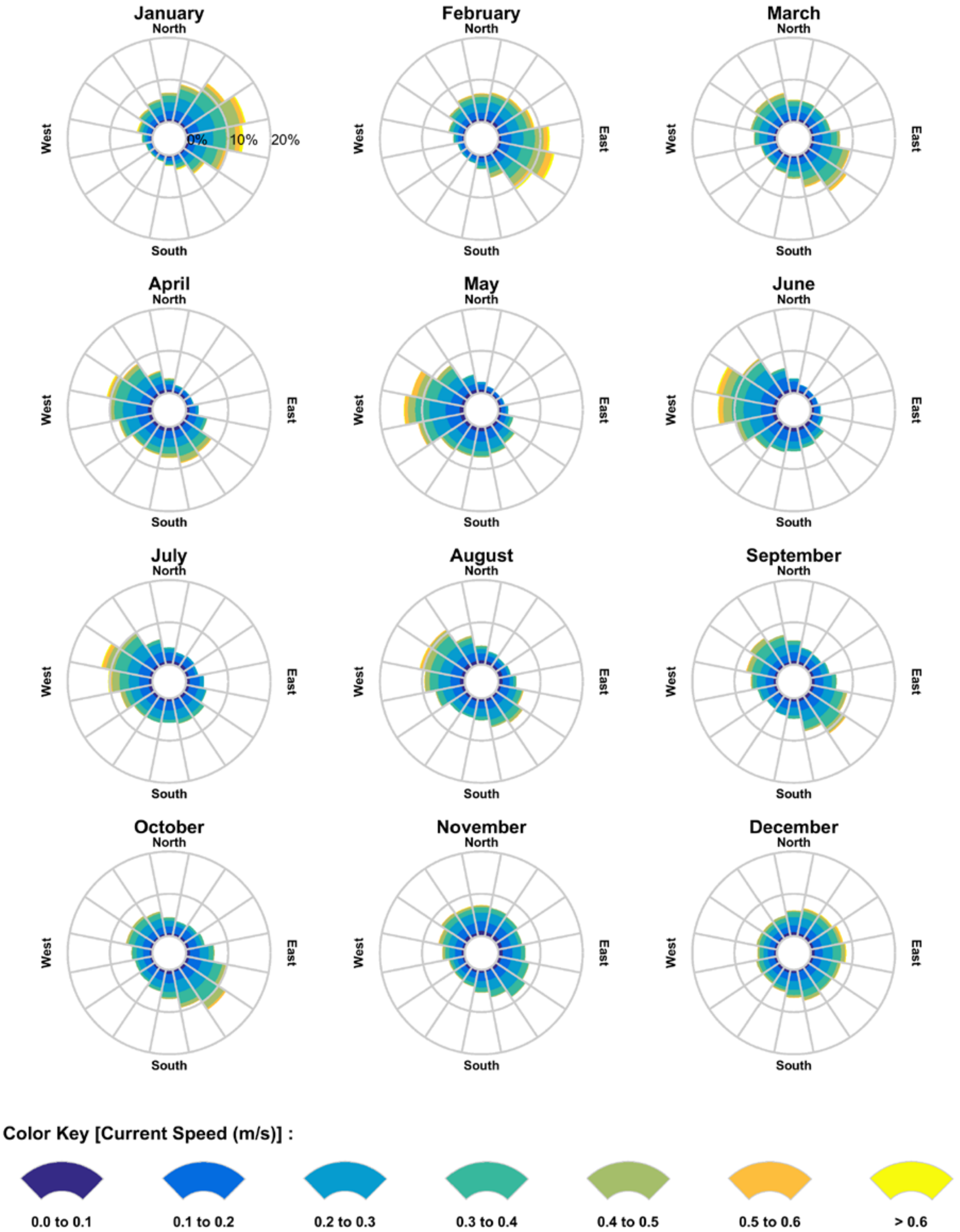

Figure 2.11 Monthly near-surface current distribution (2008-2017, inclusive) derived from the combined HYCOM and HYDROMAP databases near to the Crux Development Well location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

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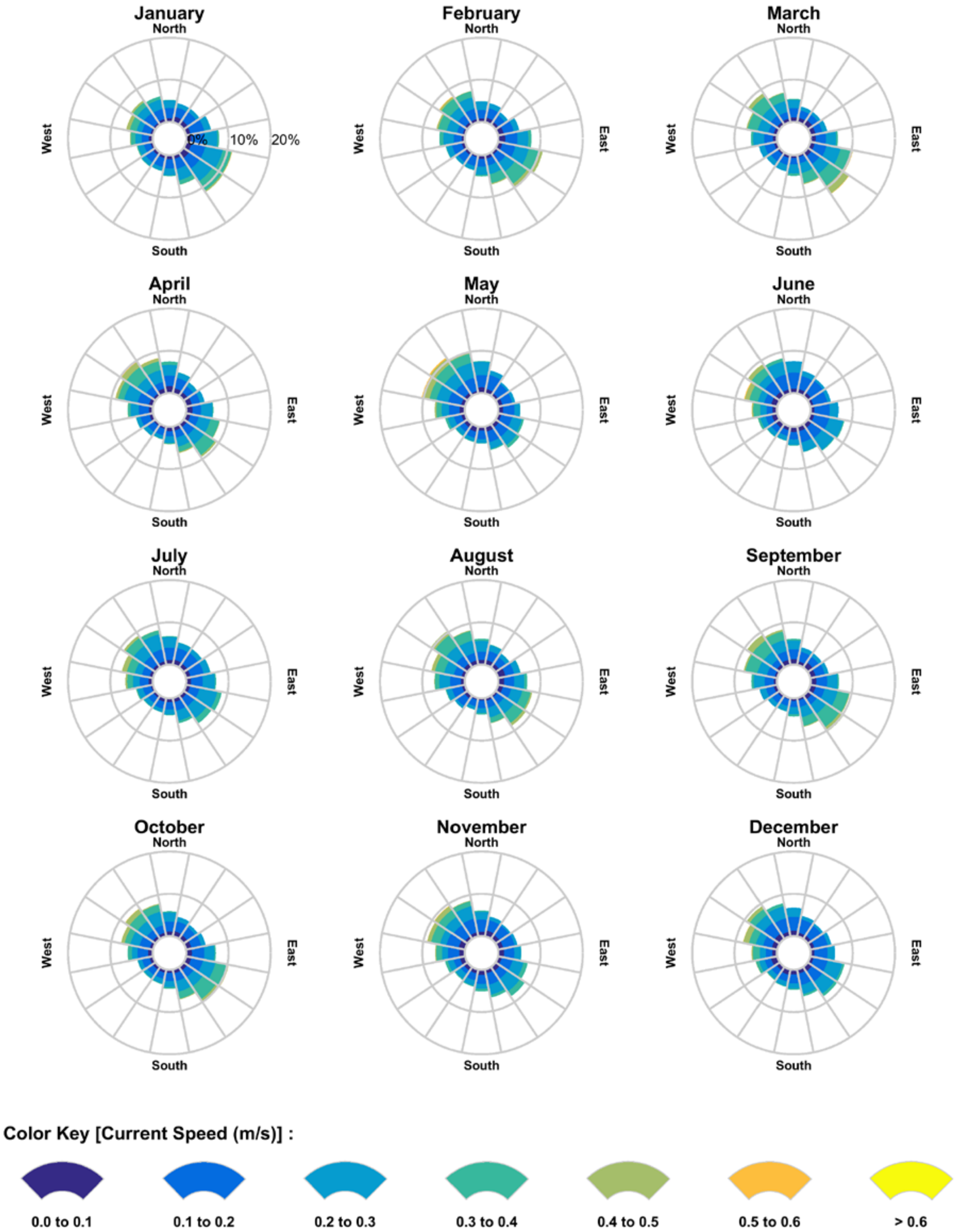

Figure 2.12 Monthly near-seabed current distribution (2008-2017, inclusive) derived from the combined HYCOM and HYDROMAP databases near to the Crux Development Well location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

3 Modelling Methods

3.1 Sediment Dispersion Model: MUDMAP

MUDMAP is a three-dimensional plume model used by industry and regulators to aid in assessing the potential environmental effects from operational discharges such as drill cuttings, drilling fluids and produced formation water. The model has been applied to hundreds of assessments in over 35 countries, including Australia.

The model itself is an enhancement of the Offshore Operators Committee (OOC) model and calculates the fates of discharges through three distinct stages, as defined by laboratory and field studies (Koh & Chang, 1973; Khondaker, 2000):

- Stage 1: **Convective descent stage** – free fall of the combined mass of fluids and cuttings;
- Stage 2: **Dynamic collapse stage** – the collapse of the combined mass as it meets the seabed (or water surface); and
- Stage 3: **Passive dispersion stage** – the transport and dispersion of discharged fluids and particles by local currents. For drill cuttings and mud particles that have higher density than seawater, this phase also calculates sinking and settlement to the seabed.

Each stage plays an integral role on different time and distance scales. The governing equations and solutions of MUDMAP were built on the formulae originally developed by Koh & Chang (1973) and extended by the work of Brandsma & Sauer Jr (1983), known as the OOC model, for Stages 1 and 2 of plume motion.

The far-field calculation (passive dispersion stage) employs a particle-based, random walk procedure. The model predicts the dynamics of the discharge material and resulting seabed concentrations and bottom thicknesses over the near-field (i.e. the immediate area of the discharge) and the far-field (the wider region). Figure 3.1 shows a conceptual diagram of the dispersion and fates of drill cuttings and fluids discharge to the ocean and an idealised representation of the three discharge phases.

Settling under currents is selective for particle size, with the larger particles (rocks, gravel to sand) tending to settle quickly, forming a pile that aligns with the predominant current axis. Smaller particles (especially silts and clays) tend to remain suspended for exponentially longer time periods and will therefore be dispersed more widely by local currents. Dispersion of the finer discharged material will tend to be enhanced with increased current speeds and water depth, and with greater variation in current direction over time and depth.

MUDMAP can simulate up to six classes of material (each with up to 6 sub-categories, for a total of 36 sub-categories). Each material class can be set up with a unique density and particle-size distribution. During the dispersion stage, particles are transported in three dimensions according to the current data and horizontal and vertical dispersion coefficients at each time step, following the governing equations.

MUDMAP has been extensively validated and applied for discharge operations in Australian coastal and ocean waters, and around the world (e.g. Burns *et al.*, 1999; Spaulding, 1994; King & McAllister, 1997, 1998).

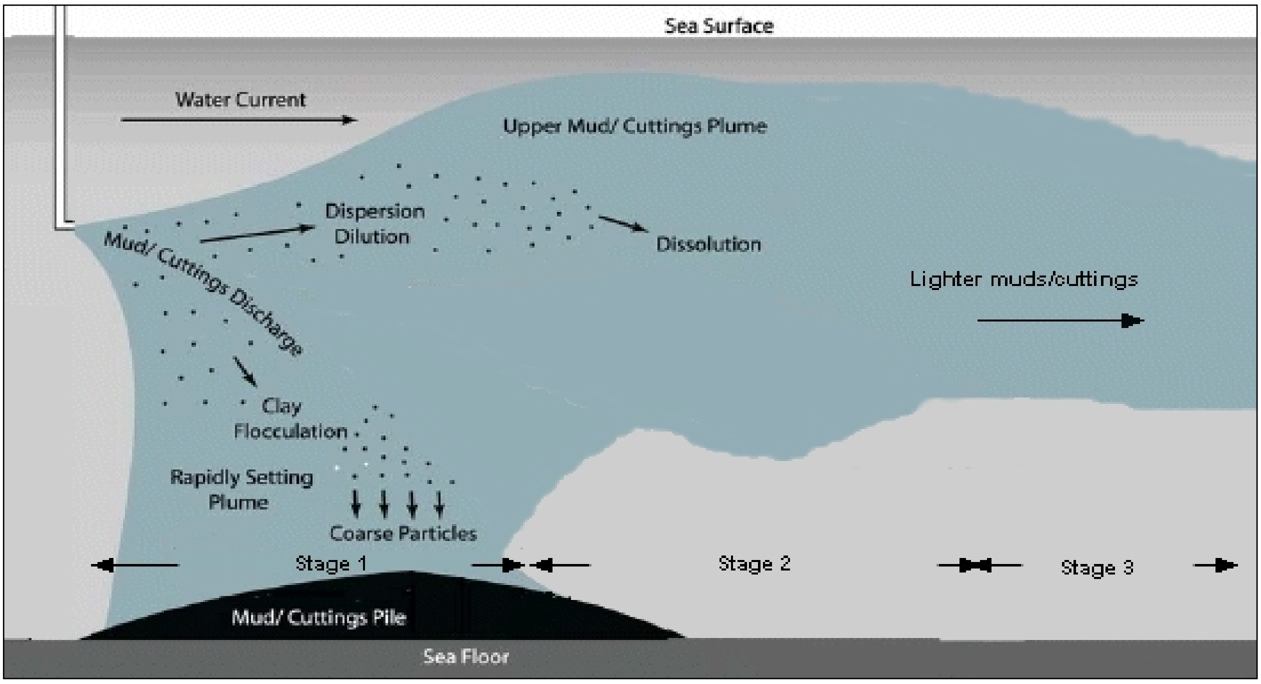

Figure 3.1 Conceptual diagram showing the general behaviour of cuttings and muds discharged to the ocean and the idealised representation of the three discharge phases (Neff, 2005).

3.2 Discharge Program

Based on the current well design and consistent with other similar industry standard drilling programs, the Crux wells are expected to comprise five drilling intervals (Table 3.1). A total of five wells of identical profile will be drilled from one drill centre (one location).

The Conductor and Surface intervals (42” and 32” bore diameters, respectively) will be drilled using seawater with bentonite sweeps. The extracted drill cuttings and drilling muds will be discharged directly to the seafloor. A riser will then be installed for the remainder of the drilling to circulate the cuttings and muds to the drilling rig where cuttings will be separated then discharged to the sea surface. With the riser in place, water based mud (WBM) will be used in the drilling of the Intermediate 1 (17 ½” bore diameter) interval, then synthetic based mud (SBM) will be used in the drilling of the Intermediate 2 (12 ¼” bore diameter) and Production (8 ½” bore diameter) intervals.

Estimates for the volumes of mud discharged during each interval are based on assumed rates of loss from the separation/dryer system, where fluids can adhere to cuttings. It is expected that the percentage volume of solids within the drilling mud is 3% when drilling with seawater/gel sweeps, 6% when drilling with WBM, and 10% when drilling with SBM. The drill cuttings and WBM/SBM will be discharged overboard from the rig above the sea surface from a vertically downward orientated discharge pipe. The drilling plan for the Crux foundation wells involves 33.5 days of drilling per well, comprising 2 days for the near seabed discharges and 31.5 days for the surface discharges. In total, 167.5 days of actual drilling will be required to complete all 5 proposed wells.

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Table 3.1 Summary of the estimated volumes of discharged drill cuttings and unrecoverable mud solids for each well interval.

Well Interval	Hole Diameter (inches)	Discharge Method	Cuttings Volume Discharged (m^3)	Muds (Solids Only)		Discharge Duration (days)
				Type	Volume Discharged (m^3)	
Conductor	36	Returned directly to the seafloor	72	Seawater/Gel	12	1
Surface	32	Returned directly to the seafloor	119	Seawater/Gel	18	1
Intermediate 1	17½	Cuttings and WBM brought to drilling rig, then discharged to surface	477	WBM	208	11.5
Intermediate 2	12¼	Cuttings and SBM brought to drilling rig, separated/dried, then discharged to surface	191	SBM	4	9
Production	8½	Cuttings and SBM brought to drilling rig, separated/dried, then discharged to surface	32	SBM	5	11
Totals			**891**	**-**	**247**	**33.5**

Note: Only discharged solids used as model input.

WBM – Water Based Mud.

SBM – Synthetic Based Mud.

3.3 Discharge Input Data

The input data used to set up the MUDMAP dispersion model included, for each well interval:

- Volume and discharge duration of the cuttings and unrecovered muds;
- Particle size distribution and settling velocities of discharged cuttings and unrecoverable muds;
- Bulk density of the discharged cuttings and unrecoverable muds;
- Temperature and salinity profiles of the receiving waters;
- Diameter and orientation of the discharge pipe;
- Height/depth of the discharge point relative to mean sea level; and
- Depth-varying current data to represent local physical forcing.

Table 3.2 provides a summary of the discharge configuration and the estimated volumes of cuttings and muds used as input into the discharge model. The modelling inputs for the Crux drilling programme are based on the current well design and information from previous drilling campaigns undertaken by Shell for the Prelude FLNG project, and the Auriga-1 exploration well which was targeting the Crux field. Considering this, the estimated volumes of drill cuttings and mud are considered representative of that expected to be discharged from drilling of the Crux development wells. The discharges for all five wells incorporated totals of 4,455 m^3 of drill cuttings and 1,235 m^3 of drilling muds over a period of 167.5 days.

Each model simulation represented the sequential completion of all well intervals, with rates and depth of discharge varying to represent the drilling program. Discharge was represented in the model to occur over the defined discharge duration; however, the simulations were run for an additional "run-on" period of 6.5 days to allow for assessment of dispersion of the finer sediment fractions.

In configuring the model, bulk densities of 2,601 kg/m^3 and 4,200 kg/m^3 were assumed for the cuttings and muds, respectively, following Nedwed (2004).

It is proposed that conventional drilling methods will be used, so the particle size distributions for cuttings and drilling muds were represented by literature data for conventional drilling which suggest particle sizes would be expected to vary between 0.016 mm and 6 mm in diameter. The model was set up with four main particle classes to represent large, medium and light cuttings, and drilling fluid solids (i.e. mud particles). The proportion of each size class was adjusted for each well interval according to the proposed proportion of muds and cuttings, as shown in Table 3.3.

It is worth noting that particle size has a greater influence on the rate of settling than density (Neff, 2005). Therefore, when setting up the material for discharge in the model, each particle size class was distributed across up to six sub-categories with specific settling velocities. The settling velocities for the various size sub-categories were derived from empirical data provided by Dyer (1986), as summarised in Table 3.4.

Table 3.2 Key inputs to the drill cuttings and unrecoverable mud solids dispersion modelling.

Parameter	Crux Development Well
Volume of cuttings discharged (m^3)	891 (single 1-well discharge)
Volume of muds discharged (m^3)	247 (single 1-well discharge)
Total volume of cuttings discharged (m^3)	4,455 (multiple 5-well discharge)
Total volume of muds discharged (m^3)	1,235 (multiple 5-well discharge)
Density of drill cuttings (kg/m^3)	2,601
Density of drilling synthetic base mud (kg/m^3)	4,200
Near seabed discharge duration	10 days (multiple 5-well discharge)
Sea surface discharge duration	167.5 days (multiple 5-well discharge)
Depth of near seabed discharges	2 m above seabed
Depth of sea surface discharges	Above mean sea level (168.5 m water depth)
Sea surface discharge pipe orientation	Vertically downwards
Sea surface discharge pipe diameter (inches)	8

Table 3.3 Proportional contribution of the particle size classes for each well interval.

Material Class	Conductor Interval (%)	Surface Interval (%)	Intermediate 1 Interval (%)	Intermediate 2 Interval (%)	Production Interval (%)
Large Cuttings (0.45 mm – 6 mm)	48	40	39	55	49
Medium Cuttings (0.15 mm – 0.40 mm)	21	21	17	20	21
Light Cuttings (0.02 mm – 0.10 mm)	17	17	14	19	17
Drilling Fluid Solids (0.016 mm – 0.063 mm)	14	13	30	2	12

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Table 3.4 Discharge particle characteristics and size distribution of cuttings, water based mud (WBM) and synthetic based mud (SBM) assumed for modelling of the well intervals.

Sediment Characteristic			Particle Size Distribution (%)				
Class	Grain Size (mm)	Settling velocity (cm/s)	Conductor Interval	Surface Interval	Intermediate 1 Interval	Intermediate 2 Interval	Production Interval
Large Cuttings	6	54	10	10	8	12	11
	5	50	10	10	8	12	11
	2	29	10	10	8	12	11
	1	13	7	7	6	8	7
	0.5	8	7	7	6	8	7
	0.45	7	3	4	3	4	4
Medium Cuttings	0.4	6	3	4	3	4	4
	0.35	5	3	4	3	4	4
	0.3	4	3	4	3	4	4
	0.25	3	3	4	3	4	4
	0.2	2	3	4	3	4	4
	0.15	2	3	4	3	4	4
Light Cuttings	0.1	0.80	3	4	3	4	4
	0.05	0.22	3	4	3	4	4
	0.04	0.15	3	4	3	4	4
	0.03	0.08	3	4	3	8	6
	0.02	0.04	3	4	3	0	0
Drilling Fluid Solids	0.063	0.34	0.20	0.19	0.43	0	0
	0.05	0.22	0.81	0.75	2	0.11	1
	0.035	0.11	2	2	4	0.27	2
	0.026	0.06	3	3	6	2	10
	0.02	0.04	4	4	8	0	0
	0.016	0.03	5	4	10	0	0

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3.4 Grid Configuration

A uniformly sized rectangular grid covering a 20 km (longitude, x-direction) by 20 km (latitude, y-direction) region around the well location was employed to calculate the concentration of drill cuttings and muds in the water column and on the seafloor. The resolution of each grid cell was approximately 20 m (x) x 20 m (y) x 10 m (z).

3.5 Mixing Parameters

The horizontal and vertical dispersion coefficients are used in dispersion modelling to represent the mixing and diffusion processes caused by turbulence, which are sub-grid processes at the scale of the hydrodynamic model drivers. The dispersion coefficients are expressed in units of rate of area change (m^2/s). Increasing the horizontal dispersion coefficient will increase the horizontal spread of the discharge plume and decrease the centreline concentrations. Increasing the vertical dispersion coefficient spreads the discharge further across the vertical layers.

The horizontal turbulent diffusion of the plume is dependent on the hydrodynamic conditions (i.e. wind, wave and current) and the physical scale of the plume compared to the scales of the oceanic processes that disperse the plume. For a plume of approximately 10-100 m width, dispersion occurs primarily through small-scale horizontal swirling motions and vertical mixing, with a horizontal dispersion rate of the order of 0.1 m^2/s. As the plume grows to a scale of 1-10 km, it begins to be subject to mesoscale eddies and horizontal dispersion rate becomes of the order of a few to tens of m^2/s. At even larger scales, the plume would be larger than the mesoscale eddies and eddy mixing becomes the dominant mechanism, with a rate of horizontal dispersion of 100-1,000 m^2/s.

For this project, with an open ocean environment and length scales of 10 m to 1 km, a horizontal diffusion rate of 0.25 m^2/s was applied. A value of 0.10 cm^2/s was set for the vertical dispersion coefficient to account for the influence of turbulence within the water column, as well as wave-induced turbulence. The values are based on previous experience and informed by studies by Copeland (1996).

3.6 Stochastic Outcomes

A stochastic modelling approach was followed for the assessment of drill cuttings and fluids discharge in this study, with 120 replicate simulations carried out over the ten-year hindcast period (one per calendar month). The results of all replicate simulations for each calendar month were combined and statistically analysed to develop the distribution of outcomes based on time and event. These statistics were then presented as contours of maximum occurrence.

Note: considering the stochastic modelling methodology applied, the contour figures of water column concentration do not represent the location of the plume at any point in time but are a statistical summary of the range of outcomes across all replicate simulations and time steps. Similarly, sedimentation results are presented as a statistical summary of the range of final outcomes of maximum bottom thickness and bottom concentration levels across all replicate simulations for each month assessed.

3.7 Reporting Thresholds

The MUDMAP model can track and predict sediment concentrations and thickness to very low levels that may not be of practical and ecological significance; therefore, a series of minimum detectable levels and impact thresholds were defined for reporting of the model-predicted outcomes.

Table 3-5 presents a summary of the natural and impact threshold levels used in this study for assessment of sedimentation.

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Table 3-5 Natural and impact threshold levels for bottom thickness.

Parameter	Natural Threshold Level (mm)	Impact Threshold Level (mm)	
		Low Exposure	High Exposure
Bottom Thickness – single (1) well discharge	0.015	1	10
Bottom Thickness – multiple (5) well discharge	0.07		

A study by Glen (1997) found that the maximum natural sedimentation rate for Northwest Australia is 223.21 cm/thousand years (ka). As a conservative measure, a minimum threshold thickness of 0.015 mm was calculated from the maximum natural sedimentation rate of 2.23 mm/year (or 0.0061 mm/day) multiplied by the discharge duration (33.5 days/well).

Impact thresholds of 1 mm (low exposure) and 10 mm (high exposure) have been applied in this study and are based on available literature and are considered industry standard. A study by Trannum et al. (2009) showed a significant decrease of species, abundance of individuals, Shannon-Wiener diversity, and biomass of marine animals with increasing depth of WBM cuttings (3-24 mm) on sediment in the microcosms. Therefore, a conservative 1 mm impact threshold was selected as representative of low exposure. A study by Kjeilen-Eilertsen *et al.* (2004) showed that deposition greater than 9.6 mm is likely to cause smothering impacts on benthic ecosystems, including corals. It is also worth noting that a study by Smit *et al.* (2008) established a thickness threshold of greater than 6.5 mm would be needed before potential harm to benthic macrofauna. This sediment thickness threshold is based on data from shallow-water fauna.

It is important to note that the predicted sedimentation is quoted as the level above any background sedimentation process relevant to the Crux Development Well location. Moderate levels of sediment mobility are expected in this region due to the drift and tidal current magnitudes, and therefore it is expected that these results are conservative (i.e. more sedimentation predicted than would be the case).

4 Modelling Results

4.1 Overview

Discharges of drill cuttings and drilling muds were modelled for the Crux well design, which is expected to comprise five well sections: Conductor, Surface, Intermediate 1, Intermediate 2 and Production. Discharges from the Conductor and Surface sections will occur near the seabed, whereas discharges from the remaining sections will occur at the surface (see Section 3.2). The drilling programme was assumed to have a total duration of 33.5 days per well. Shell intends to drill five wells from one drill centre (one location), requiring approximately 167.5 days in total to drill.

The modelling results for a single well (drill cuttings and drilling muds), single well (drill cuttings only), and five wells (drill cuttings and drilling muds) are presented in Section 4.2, Section 4.3 and Section 4.4, respectively. Each of the results sections presents the monthly model results and the integration (annualised) of all model results to assess the regional coverage of all discharge operations.

If drilling were to occur at alternative locations within the Crux development area, similar sedimentation outcomes may be expected given the likelihood of similar metocean conditions. However, drilling in areas of more complex bathymetry, particularly in close proximity to the shoals within the Crux development area, may result in patterns of sedimentation being more clearly influenced by that bathymetry.

4.2 Drill Cuttings and Drilling Muds (Single Well)

4.2.1 Discussion of Annualised Results

The results for each month were integrated to define the likely coverage area of bottom thickness above the thresholds for ‘any time’ or current conditions modelled.

Figure 4.1 shows the annualised distribution of sediment thickness calculated for deposits of drill cuttings and drilling muds. The results presented in the figure are aggregates of all stochastic simulations commencing throughout the ten-year hindcast period.

The modelling results demonstrated that larger particles (greater than 0.25 mm diameter) were predicted to settle typically within 250 m from the well, while the currents transported the smaller sediments (less than 0.25 mm) further away from the well.

Table 4.1 shows the predicted maximum bottom thickness, area of coverage and the maximum distance well location to the drill cuttings and drilling muds thresholds (0.015 mm, 1 mm and 10 mm).

The maximum thickness (or height of mound) was predicted to be 377.5 mm adjacent to the well location (Table 4.1).

Modelling predicted a zone of potential influence at the natural threshold level, with thicknesses of 0.015 mm or greater expected up to ~2 km from the well location while covering an area ~7.96 km^2 (796 ha). This potential zone of influence was more localised at the low (1 mm) and high (10 mm) exposure thresholds, with drill cuttings and drilling muds not expected beyond 326 m and 68 m, respectively. Total areas of coverage at the low (1 mm) and high (10 mm) exposure threshold were 0.008 km^2 (0.8 ha) and 0.194 km^2 (19.4 ha), respectively.

Modelling indicates that sedimentation resulting from discharges of drill cuttings and drilling fluids is not likely to have any impact above the natural threshold (0.015 mm) at the shoals closest to the well site.

4.2.2 Discussion of Monthly Results

The outcomes of the sediment dispersion modelling assessment are summarised, for each month, in Table 4.2, with maximum values presented for sediment bottom thickness, area of coverage above the 0.015 mm, 1 mm and 10 mm thresholds, and maximum distance from the well to these thresholds.

Figure 5.1 to Figure 5.12 show the distributions of sediment thickness calculated for deposits of drill cuttings and drilling muds on the seafloor for operations commencing on the first day of each calendar month (January to December). The results presented in each monthly figure are aggregates of all stochastic simulations commencing in all corresponding months during the ten-year hindcast period.

Sediments larger than 0.25 mm in diameter are predicted to typically settle out within 250 m of the well, with displacement occurring on either side of the well in response to the prevailing currents. Finer sediments are forecast to disperse more widely, with the finest sediments contributing a lower proportion of sediment to deposits greater than 0.015 mm (natural threshold) thick. Deposits exceeding the 0.015 mm minimum thickness are calculated to extend up to between 1,710 m (July) and 2,002 m (January) from the well site. At the low (1 mm) exposure threshold, drill cuttings and drilling muds are expected to extend up to between 229 m (December) and 326 m (February) for the well site. Drill cuttings and drilling muds were modelled to extend up to between 47 m (February) and 68 m (November) at the high (10 mm) threshold.

Deposits of finer sediments are consistently calculated to build up along the tidal axis on either side of the source rather than displace to a particular side, indicating that tidal currents will have influence over movement of the finer particles and that ocean currents will have a small impact on the net movement direction and distance travelled before settlement occurs. The directions in which sediments are calculated to settle vary only slightly among the monthly simulations, which is indicative of the high influence of tidal currents at the source and the relative lack of variation in ocean current conditions over the ten-year hindcast period.

The maximum thickness (or height of mound) calculated at any location in any simulation is forecast to fall in the range of 276 mm (November) to 378 mm (January), adjacent to the well location, and quickly decrease with distance from the well. The minimum and maximum predicted areas of sediment coverage at thicknesses greater than 0.015 mm are ~4.6 km^2 (May) and ~6.5 km^2 (November), respectively. At the low (1 mm) exposure threshold, the minimum and maximum predicted areas are predicted to be greatly reduced and range between 0.114 km^2 (June) and 0.140 km^2 (February), respectively. At the high (10 mm) exposure threshold, this is reduced further, with minimum and maximum predicted areas ranging from 0.004 km^2 (February) and 0.007 km^2 (November), respectively.

Modelling indicates that sedimentation resulting from discharges of drill cuttings and drilling fluids is not likely to have any impact above the natural threshold (0.015 mm) at the shoals closest to the well site.

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4.2.3 Results Tables and Figures

Table 4.1 Predicted maximum bottom thickness, area of coverage above the 0.015 mm, 1 mm and 10 mm thresholds, and maximum distance to these thresholds resulting from the drill cuttings and drilling muds discharge programme. The results are calculated across all simulations during the period 2008-2017.

Period	Maximum Bottom Thickness (mm)	Total Area of Coverage (km^2) above Threshold			Maximum Distance (m) from Well to Threshold		
		0.015 mm	1 mm	10 mm	0.015 mm	1 mm	10 mm
Annualised	377.5	7.96	0.194	0.008	2,002	326	68

Table 4.2 Predicted maximum bottom thickness, area of coverage above the 0.015 mm, 1 mm and 10 mm thresholds, and maximum distance to these thresholds resulting from the drill cuttings and drilling muds discharge programme. The results are calculated across all simulations commencing on the first day of each calendar month during the period 2008-2017.

Month	Maximum Bottom Thickness (mm)	Total Area of Coverage (km^2) above Threshold			Maximum Distance (m) from Well to Threshold		
		0.015 mm	1 mm	10 mm	0.015 mm	1 mm	10 mm
January	377.5	5.42	0.138	0.005	2,002	298	50
February	281.0	5.16	0.140	0.004	1,884	326	47
March	282.0	5.25	0.133	0.005	1,944	290	45
April	285.6	5.52	0.129	0.004	1,829	257	47
May	279.0	4.60	0.120	0.005	1,786	278	49
June	277.2	4.91	0.114	0.005	1,728	270	47
July	280.8	5.01	0.122	0.006	1,710	259	48
August	277.9	5.52	0.127	0.005	1,865	258	53
September	278.3	5.70	0.130	0.005	1,800	270	48
October	282.8	5.09	0.125	0.005	1,917	271	50
November	276.2	6.45	0.126	0.007	1,919	248	68
December	277.1	5.68	0.124	0.005	1,853	229	49
Minimum	**276.2**	**4.60**	**0.114**	**0.004**	**1,710**	**229**	**47**
Maximum	**377.5**	**6.45**	**0.140**	**0.007**	**2,002**	**326**	**68**

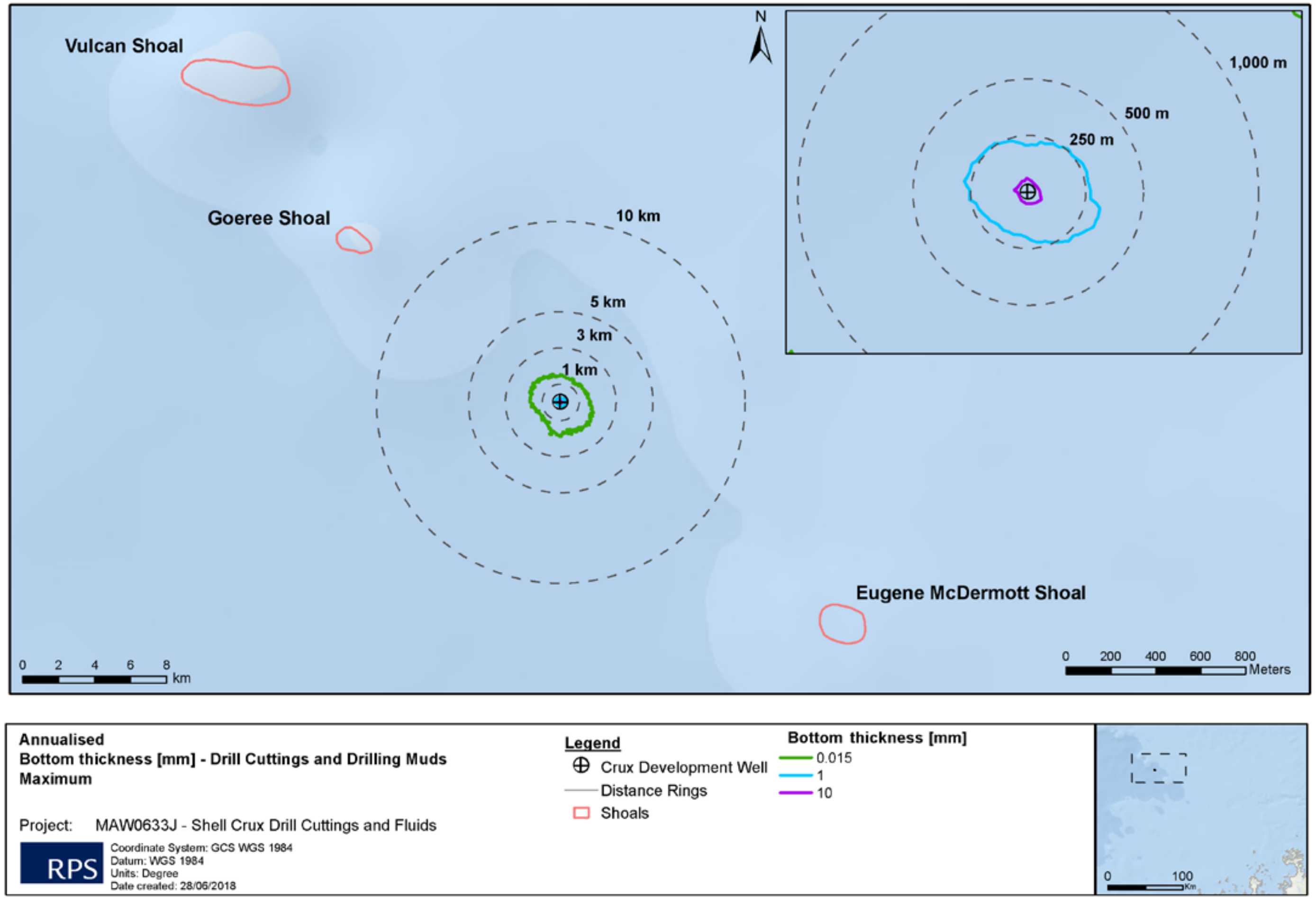

Figure 4.1 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations during the period 2008-2017.**

4.3 Drill Cuttings Only (Single Well)

4.3.1 Discussion of Annualised Results

The results for each month were integrated to define the likely coverage area of bottom thickness above the thresholds for 'any time' or current conditions modelled.

Figure 4.2 shows the annualised distribution of sediment thickness calculated for deposits of drill cuttings. The results presented in the figure are aggregates of all stochastic simulations commencing throughout the ten-year hindcast period.

The modelling results demonstrated that larger particles (greater than 0.25 mm diameter) were predicted to settle typically within 250 m from the well, while the currents transported the smaller sediments (less than 0.25 mm) further away from the well.

Table 4.3 shows the predicted maximum bottom thickness, area of coverage and the maximum distance well location to the drill cuttings and drilling muds thresholds (0.015 mm, 1 mm and 10 mm).

The maximum thickness (or height of mound) was predicted to be 374.3 mm adjacent to the well location (Table 4.3).

Modelling predicted a zone of potential influence at the natural threshold level, with thicknesses of 0.015 mm or greater expected up to ~1.9 km from the well location while covering an area ~6.77 km^2 (677 ha). This potential zone of influence was more localised at the low (1 mm) and high (10 mm) exposure thresholds, with drill cuttings not expected beyond 326 m and 62 m, respectively. Total areas of coverage at the low (1 mm) and high (10 mm) exposure threshold were 0.007 km^2 (0.7 ha) and 0.188 km^2 (18.8 ha), respectively.

Modelling indicates that sedimentation resulting from discharges of drill cuttings is not likely to have any impact above the natural threshold (0.015 mm) at the shoals closest to the well site.

4.3.2 Discussion of Monthly Results

The outcomes of the sediment dispersion modelling assessment are summarised, for each month, in Table 4.4, with maximum values presented for sediment bottom thickness, area of coverage above the 0.015 mm, 1 mm and 10 mm thresholds, and maximum distance from the well to these thresholds.

Figure 5.13 to Figure 5.24 show the distributions of sediment thickness calculated for deposits of only drill cuttings on the seafloor for operations commencing on the first day of each calendar month (January to December). The results presented in each monthly figure are aggregates of all stochastic simulations commencing in all corresponding months during the ten-year hindcast period.

The outcomes of this analysis, where the finer sediments associated with drilling muds are excluded, indicate that the maximum thicknesses and spatial extents will be slightly reduced, reflecting the reduced proportion of fines within the overall discharge.

Deposits exceeding the 0.015 mm minimum thickness are calculated to extend up to between 1,624 m (December) and 1,928 m (March) from the well site. At the low (1 mm) exposure threshold, drill cuttings are expected to extend up to between 228 m (December) and 326 m (February) for the well site. Drill cuttings were modelled to extend up to between 44 m (March) and 62 m (November) at the high (10 mm) threshold.

The maximum thickness (or height of mound) calculated at any location in any simulation is forecast to fall in the range of ~275 mm (November) to ~374 mm (January), adjacent to the well location and quickly decrease with distance from the well. The minimum and maximum predicted areas of sediment coverage at thicknesses greater than 0.015 mm are ~4.3 km^2 (May) and ~5.3 km^2 (November), respectively. At the low (1 mm) exposure threshold, the minimum and maximum predicted areas are predicted to be greatly reduced and range between 0.109 km^2 (June) and 0.132 km^2 (February), respectively. At the high (10 mm) exposure threshold, this is reduced further, with minimum and maximum predicted areas ranging from 0.004 km^2 (February) and 0.006 km^2 (November), respectively.

Modelling indicates that sedimentation resulting from discharges of drill cuttings is not likely to have any impact above the natural threshold (0.015 mm) at the shoals closest to the well site.

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4.3.3 Results Tables and Figures

Table 4.3 Predicted maximum bottom thickness, area of coverage above the 0.015, mm 1 mm and 10 mm thresholds, and maximum distance to these thresholds resulting from only the drill cuttings volumes of the discharge programme. The results are calculated across all simulations during the period 2008-2017.

Period	Maximum Bottom Thickness (mm)	Total Area of Coverage (km^2) above Threshold			Maximum Distance (m) from Well to Threshold		
		0.015 mm	1 mm	10 mm	0.015 mm	1 mm	10 mm
Annualised	374.3	6.77	0.188	0.007	1,928	326	62

Table 4.4 Predicted maximum bottom thickness, area of coverage above the 0.015 mm, 1 mm and 10 mm thresholds, and maximum distance to these thresholds resulting from only the drill cuttings volumes of the discharge programme. The results are calculated across all simulations commencing on the first day of each calendar month during the period 2008-2017.

Month	Maximum Bottom Thickness (mm)	Total Area of Coverage (km^2) above Threshold			Maximum Distance (m) from Well to Threshold		
		0.015 mm	1 mm	10 mm	0.015 mm	1 mm	10 mm
January	374.3	4.92	0.129	0.005	1,731	287	45
February	278.4	4.94	0.132	0.004	1,821	318	46
March	279.5	4.94	0.125	0.004	1,928	284	44
April	281.8	4.84	0.119	0.004	1,698	248	45
May	277.0	4.33	0.111	0.004	1,722	277	45
June	275.9	4.44	0.109	0.005	1,694	269	47
July	278.5	4.62	0.117	0.005	1,704	241	46
August	276.3	4.97	0.120	0.005	1,785	252	48
September	276.5	4.81	0.122	0.004	1,764	255	47
October	280.4	4.75	0.119	0.004	1,775	259	45
November	274.8	5.31	0.120	0.006	1,663	241	62
December	275.9	4.87	0.117	0.005	1,624	228	50
Minimum	**274.8**	**4.33**	**0.109**	**0.004**	**1,624**	**228**	**44**
Maximum	**374.3**	**5.31**	**0.132**	**0.006**	**1,928**	**326**	**62**

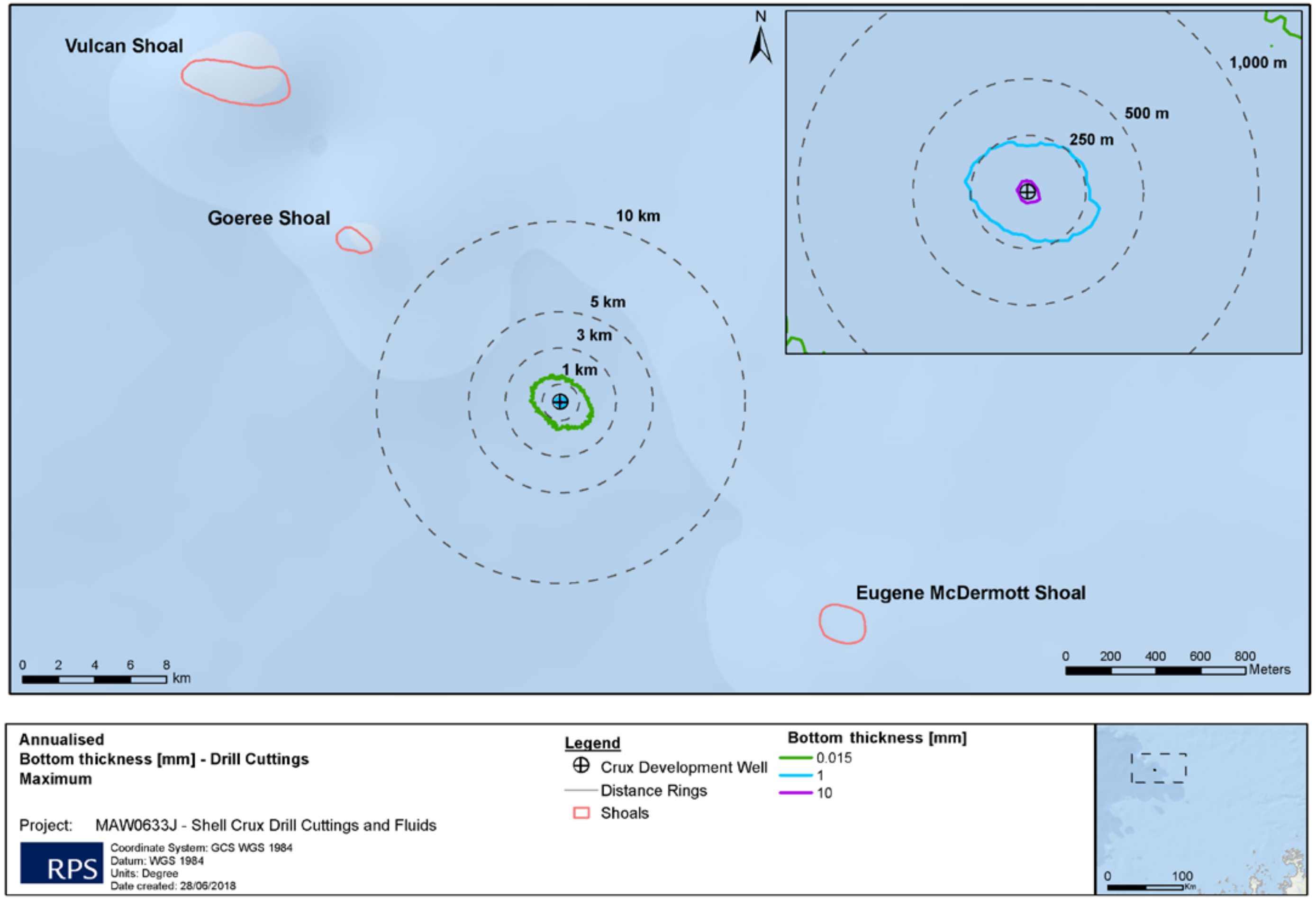

Figure 4.2 **Predicted maximum bottom thickness resulting from the drill cuttings discharge programme. The maximum concentrations are calculated across all simulations during the period 2008-2017.**

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4.4 Drill Cuttings and Drilling Muds (Five Wells)

4.4.1 Discussion of Annualised Results

The results for each month were integrated to define the likely coverage area of bottom thickness above the thresholds for 'any time' or current conditions modelled.

Table 4.5 shows the annualised distribution of sediment thickness calculated for deposits of drill cuttings. The results presented in the figure are aggregates of all stochastic simulations commencing throughout the ten-year hindcast period.

The modelling results demonstrated that larger particles (greater than 0.25 mm diameter) were predicted to settle typically within 250 m from the well, while the currents transported the smaller sediments (less than 0.25 mm) further away from the well.

Table 4.5 shows the predicted maximum bottom thickness, area of coverage and the maximum distance well location to the minimum drill cuttings and drilling muds thresholds (0.07 mm, 1 mm and 10 mm).

The maximum thickness (or height of mound) was predicted to be 1,888 mm adjacent to the well location (Table 4.5).

Modelling predicted a relatively wide zone of potential influence at the natural threshold level, with thicknesses of 0.07 mm or greater expected up to ~2 km from the well location while covering an area ~8.61 km^2 (861 ha). This potential zone of influence was more localised at the low (1 mm) and high (10 mm) exposure thresholds, with drill cuttings and drilling muds not expected beyond 658 m and 248 m, respectively. Total areas of coverage at the low (1 mm) and high (10 mm) exposure threshold were 0.115 km^2 (11.5 ha) and 0.875 km^2 (87.5 ha), respectively.

Modelling indicates that sedimentation resulting from discharges of drill cuttings and drilling fluids is not likely to have any impact above the natural threshold (0.015 mm) at the shoals closest to the well site.

4.4.2 Discussion of Monthly Results

The outcomes of the sediment dispersion modelling assessment are summarised, for each month, in Table 4.4, with maximum values presented for sediment bottom thickness, area of coverage above the 0.07 mm, 1 mm and 10 mm thresholds, and maximum distance from the well to these thresholds.

Figure 5.25 to Figure 5.36 show the distributions of sediment thickness calculated for deposits of drill cuttings and drilling muds on the seafloor for operations commencing on the first day of each calendar month (January to December). The results presented in each monthly figure are aggregates of all stochastic simulations commencing in all corresponding months during the ten-year hindcast period.

Sediments larger than 0.25 mm in diameter are predicted to typically settle out within 250 m of the well, with displacement occurring on either side of the well in response to the prevailing currents. Finer sediments are forecast to disperse more widely, with the finest sediments contributing a lower proportion of sediment to deposits greater than 0.07 mm (natural threshold) thick. Deposits exceeding the 0.07 mm minimum thickness are calculated to extend up to between 1,832 m (July) and 2,057 m (February) from the well site. At the low (1 mm) exposure threshold, drill cuttings and drilling muds are expected to extend up to between 528 m (August) and 658 m (February) for the well site. Drill cuttings and drilling muds were modelled to extend up to between 188 m (July) and 233 m (February) at the high (10 mm) threshold.

Deposits of finer sediments are consistently calculated to build up along the tidal axis on either side of the source rather than displace to a particular side, indicating that tidal currents will have influence over movement of the finer particles and that ocean currents will have a small impact on the net movement direction and distance travelled before settlement occurs. The directions in which sediments are calculated to settle vary only slightly among the monthly simulations, which is indicative of the high influence of tidal currents at the source and the relative lack of variation in ocean current conditions over the ten-year hindcast period.

The maximum thickness (or height of mound) calculated at any location in any simulation is forecast to fall in the range of 1,381 mm (November) to 1,888 mm (January), adjacent to the well location and quickly decrease with distance from the well. The minimum and maximum predicted areas of sediment coverage at thicknesses greater than 0.07 mm are ~4.9 km^2 (May) and ~7.1 km^2 (November), respectively. At the low (1 mm) exposure threshold, the minimum and maximum predicted areas are predicted to be greatly reduced and range between 0.482 km^2 (May) and 0.613 km^2 (January), respectively. At the high (10 mm) exposure threshold, this is reduced further, with minimum and maximum predicted areas ranging from 0.068 km^2 (May) and 0.082 km^2 (February), respectively.

Modelling indicates that sedimentation resulting from discharges of drill cuttings and drilling fluids is not likely to have any impact above the natural threshold (0.07 mm) at the shoals closest to the well site.

4.4.3 Results Tables and Figures

Table 4.5 Predicted maximum bottom thickness, area of coverage above the 0.07 mm, 1 mm and 10 mm thresholds, and maximum distance to these thresholds resulting from the drill cuttings and drilling muds discharge programme. The results are calculated across all simulations during the period 2008-2017.

Period	Maximum Bottom Thickness (mm)	Total Area of Coverage (km^2) above Threshold			Maximum Distance (m) from Well to Threshold		
		0.07 mm	1 mm	10 mm	0.07 mm	1 mm	10 mm
Annualised	1,888	8.61	0.875	0.115	2,057	658	248

Table 4.6 Predicted maximum bottom thickness, area of coverage above the 0.07 mm, 1 mm and 10 mm thresholds, and maximum distance to these thresholds resulting from the drill cuttings and drilling muds discharge programme. The results are calculated across all simulations commencing on the first day of each calendar month during the period 2008-2017.

Month	Maximum Bottom Thickness (mm)	Total Area of Coverage (km^2) above Threshold			Maximum Distance (m) from Well to Threshold		
		0.07 mm	1 mm	10 mm	0.07 mm	1 mm	10 mm
January	1,888	5.77	0.613	0.080	2,035	647	208
February	1,405	5.44	0.562	0.082	2,057	658	233
March	1,410	5.57	0.505	0.074	1,925	597	227
April	1,428	5.90	0.512	0.072	1,901	548	191
May	1,395	4.89	0.482	0.068	1,849	571	212
June	1,386	5.25	0.503	0.068	1,900	595	207
July	1,404	5.30	0.511	0.072	1,832	541	188
August	1,390	5.88	0.507	0.077	1,950	528	207
September	1,392	6.13	0.525	0.076	1,830	533	213
October	1,414	5.39	0.522	0.077	1,882	594	216
November	1,381	7.10	0.570	0.071	2,047	528	197
December	1,386	6.13	0.559	0.069	1,911	537	179
Minimum	**1,381**	**4.89**	**0.482**	**0.069**	**1,832**	**528**	**188**
Maximum	**1,888**	**7.10**	**0.613**	**0.082**	**2,057**	**658**	**233**

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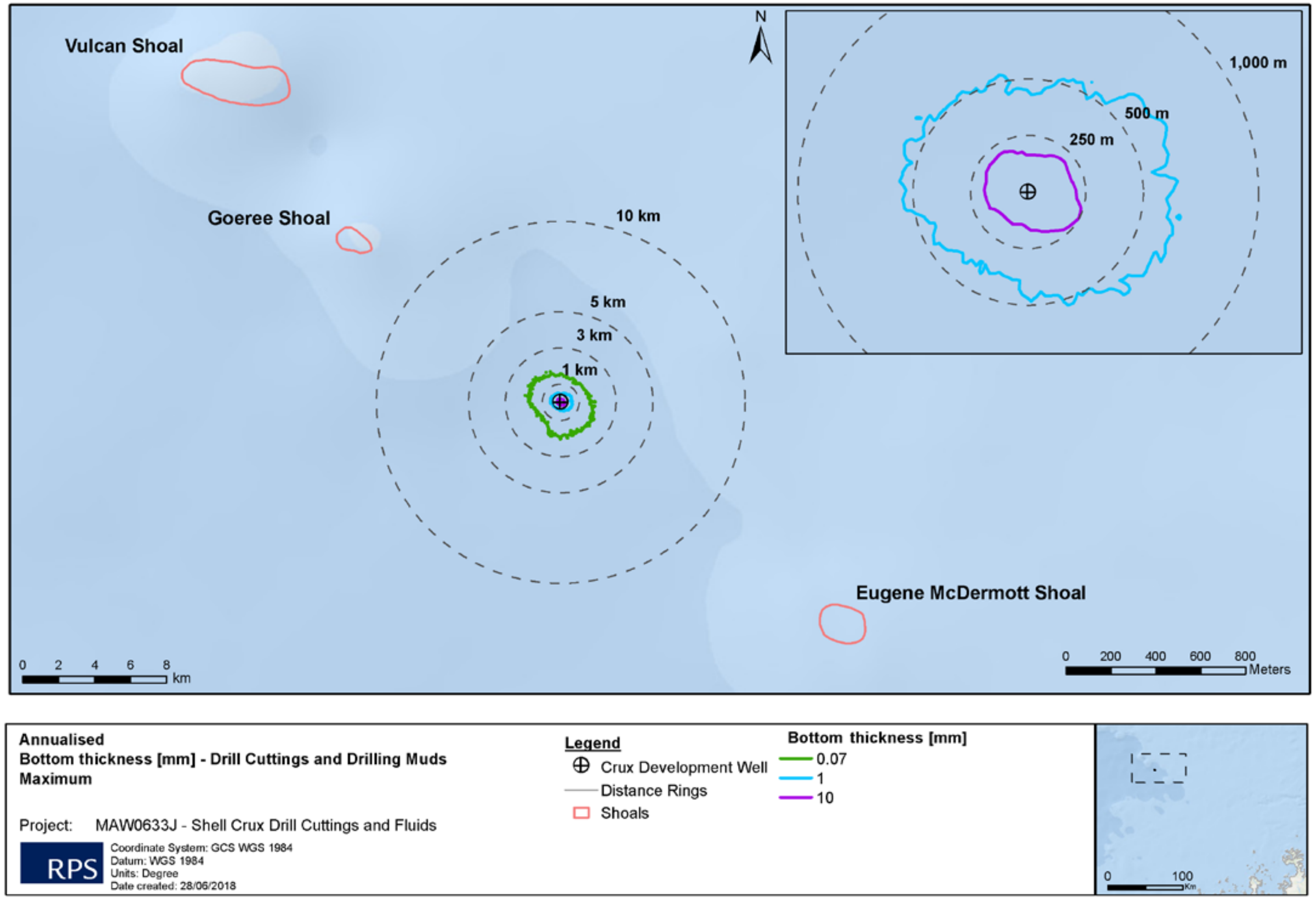

Figure 4.3 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations during the period 2008-2017.**

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Appendix A

Monthly Figures

Drill Cuttings & Drilling Muds (Single Well)

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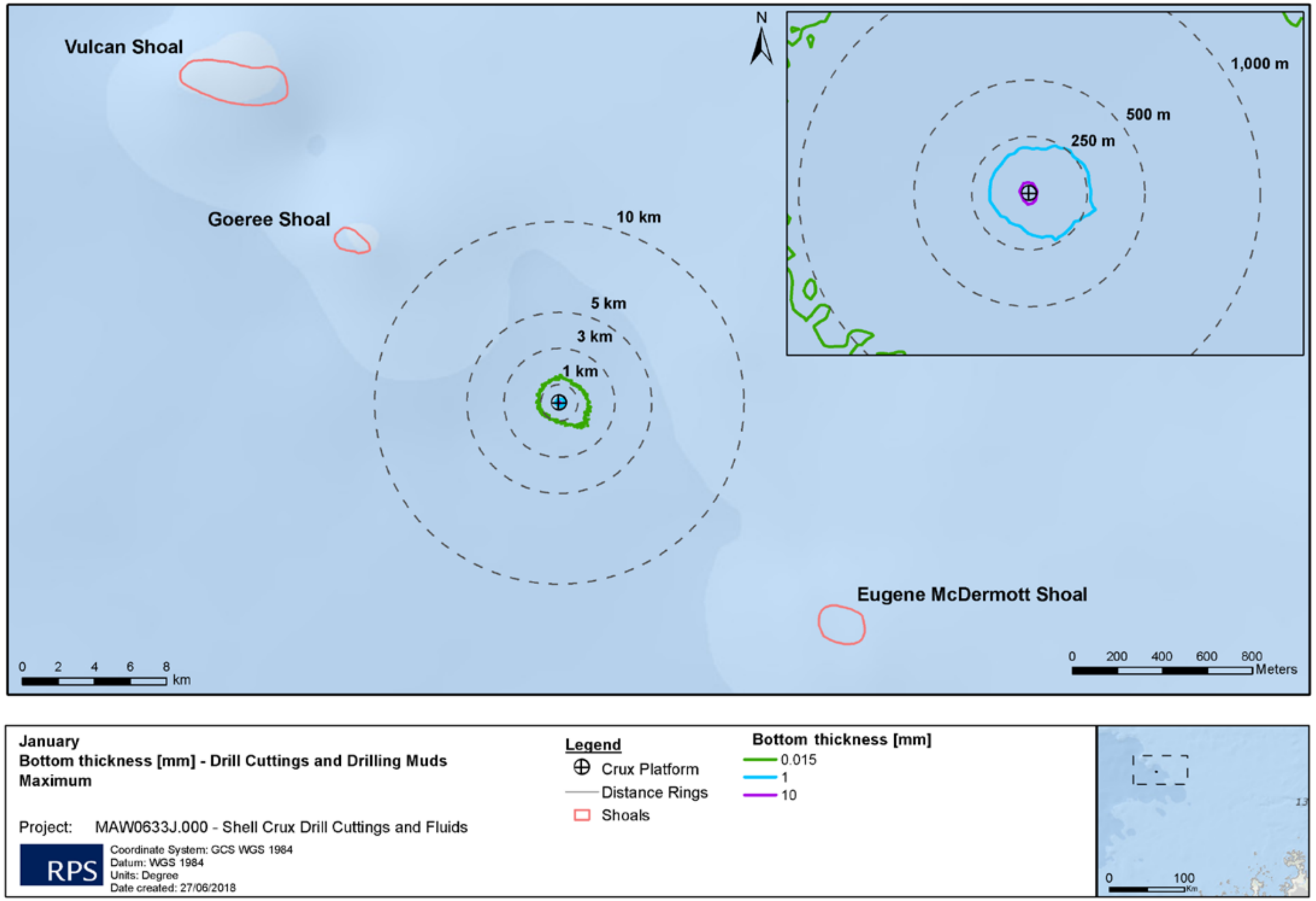


Figure 5.1 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st January during the period 2008-2017.**

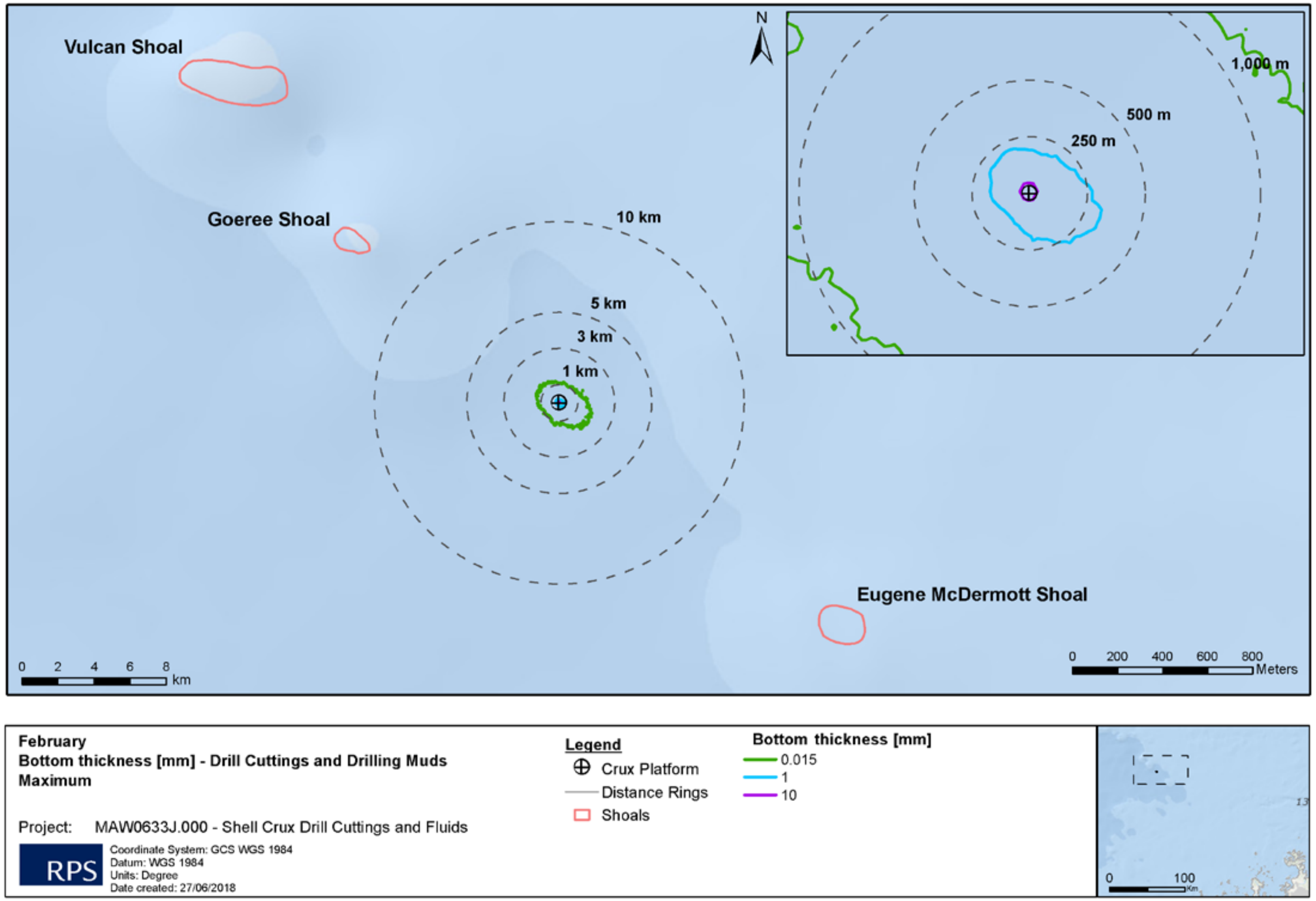


Figure 5.2 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st February during the period 2008-2017.**

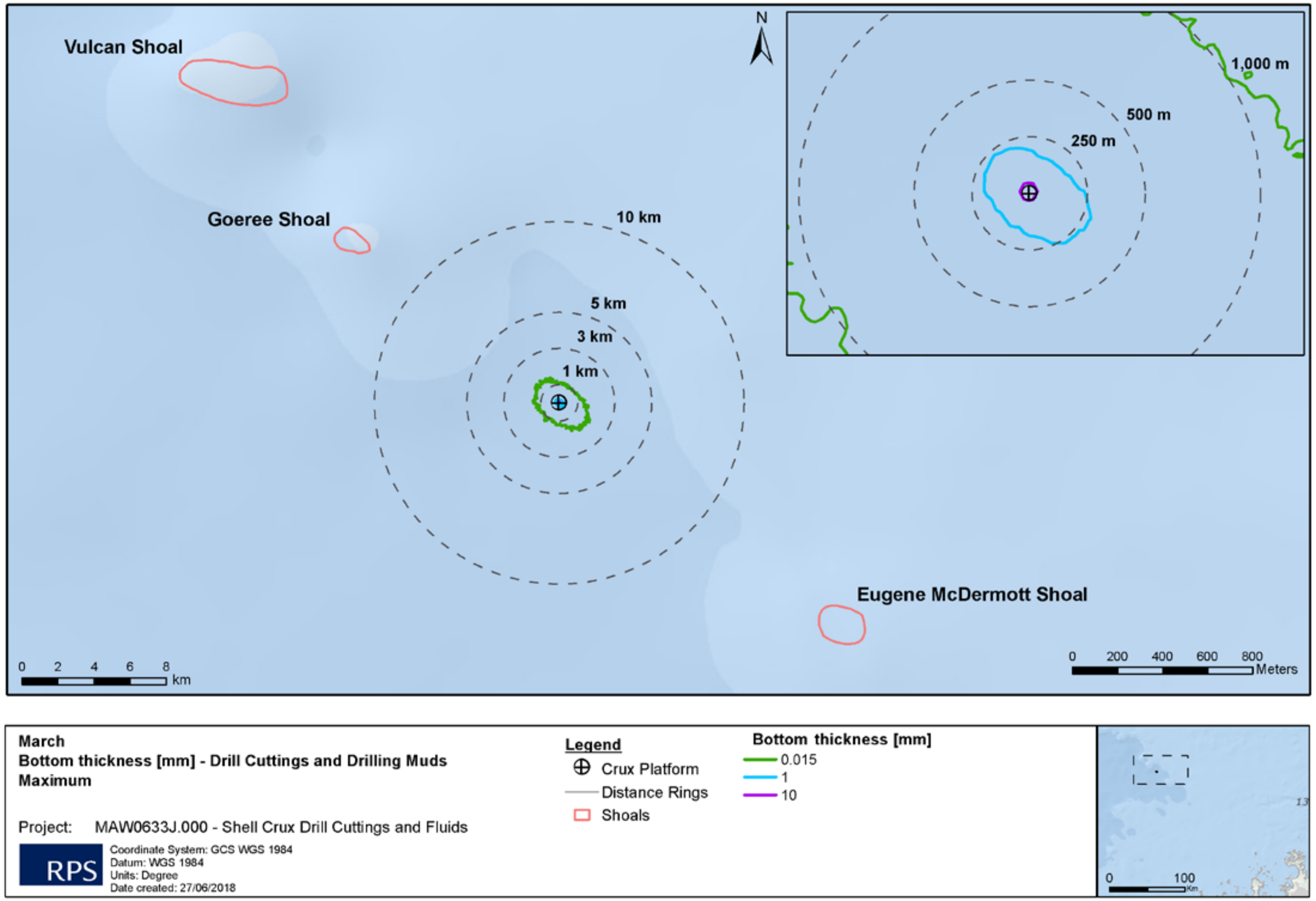


Figure 5.3 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st March during the period 2008-2017.**

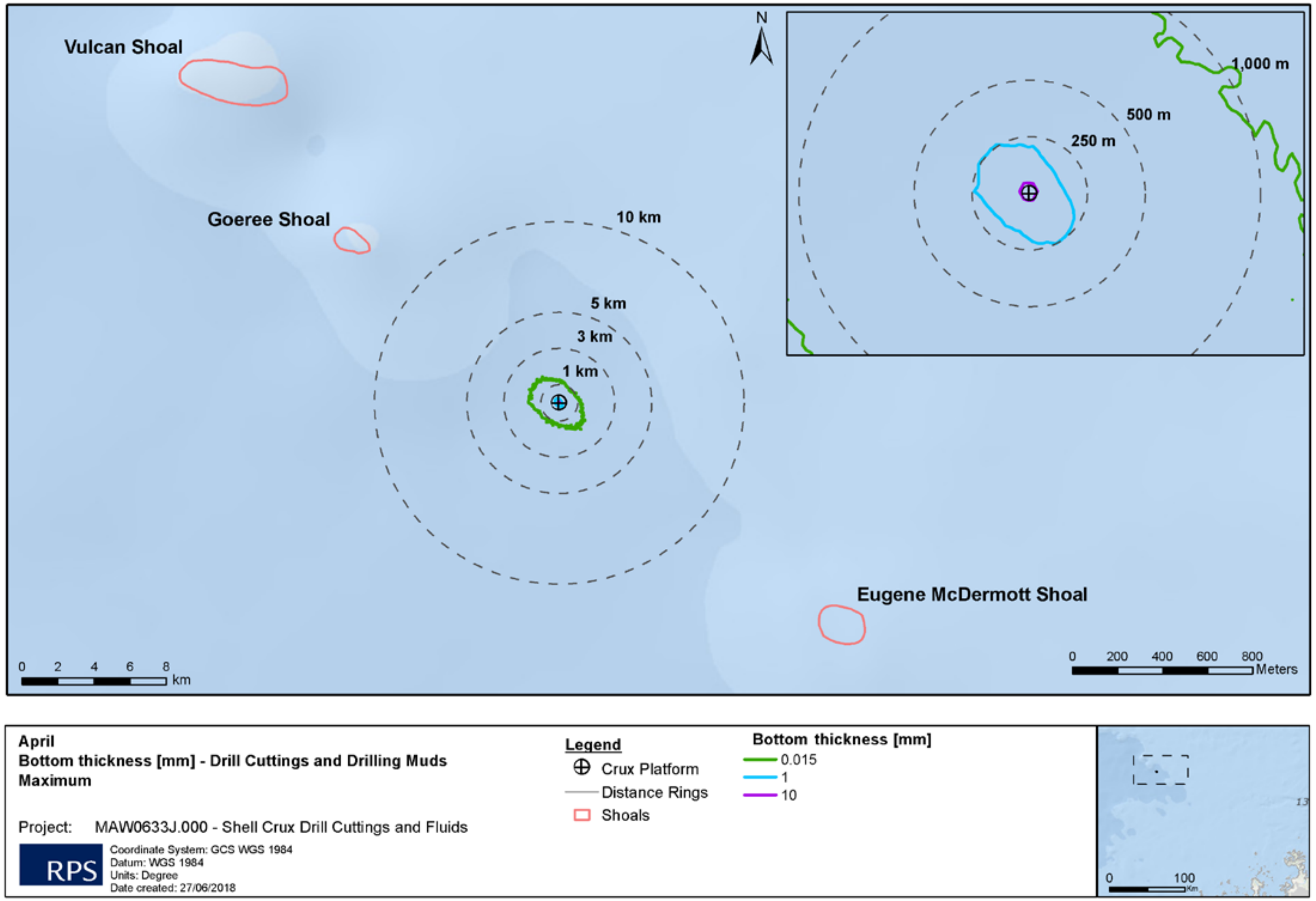


Figure 5.4 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st April during the period 2008-2017.**

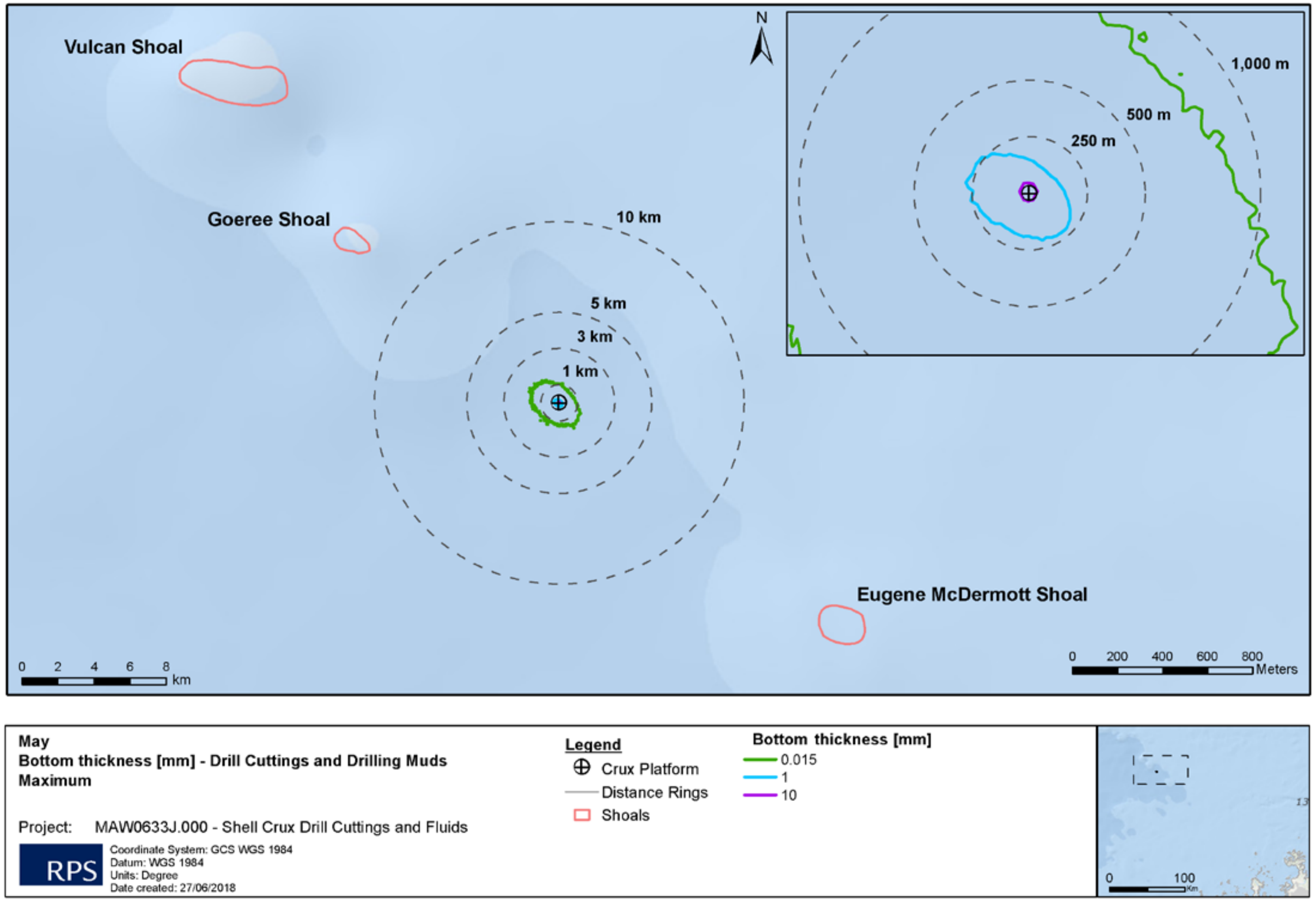


Figure 5.5 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st May during the period 2008-2017.**

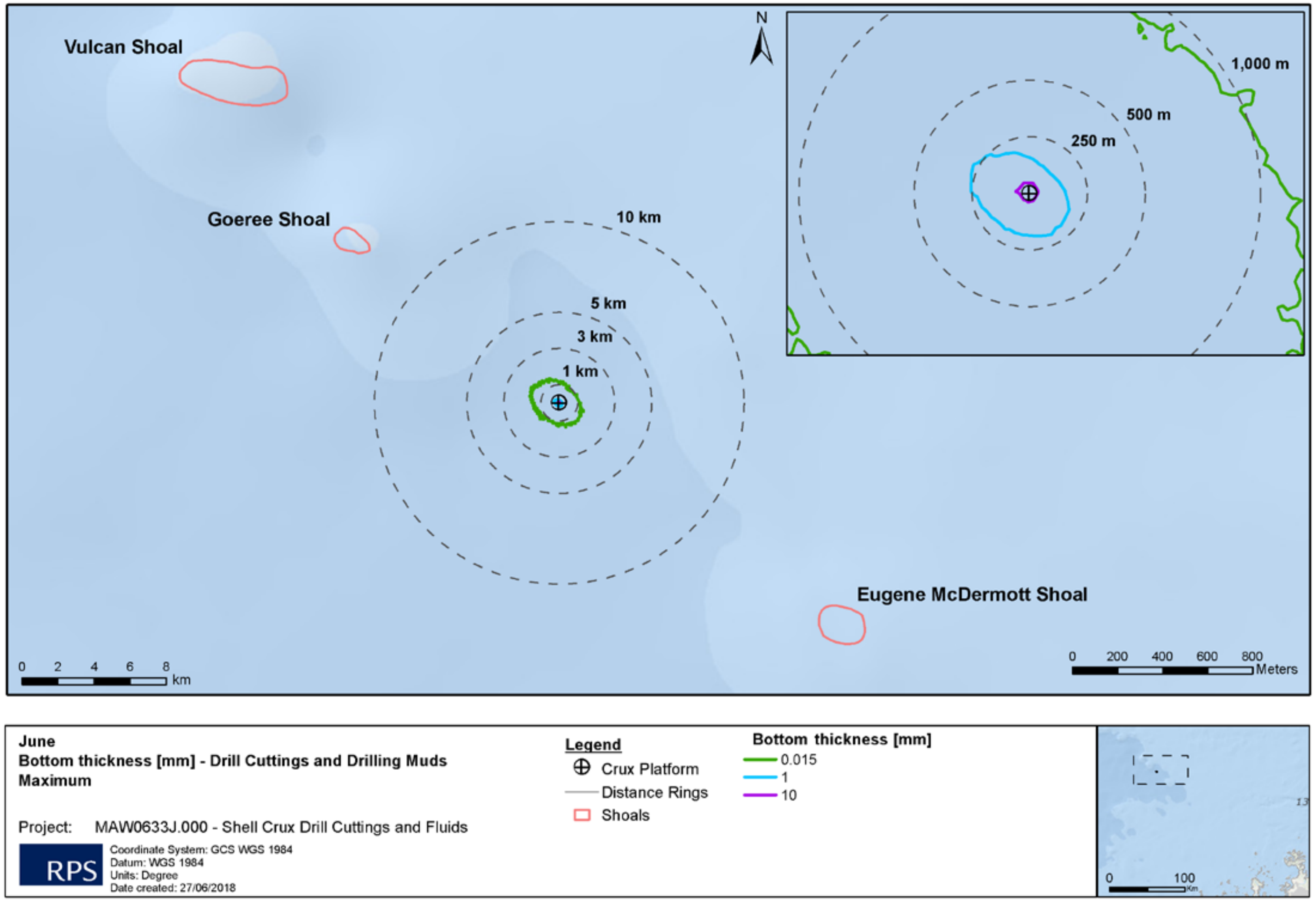


Figure 5.6 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st June during the period 2008-2017.**

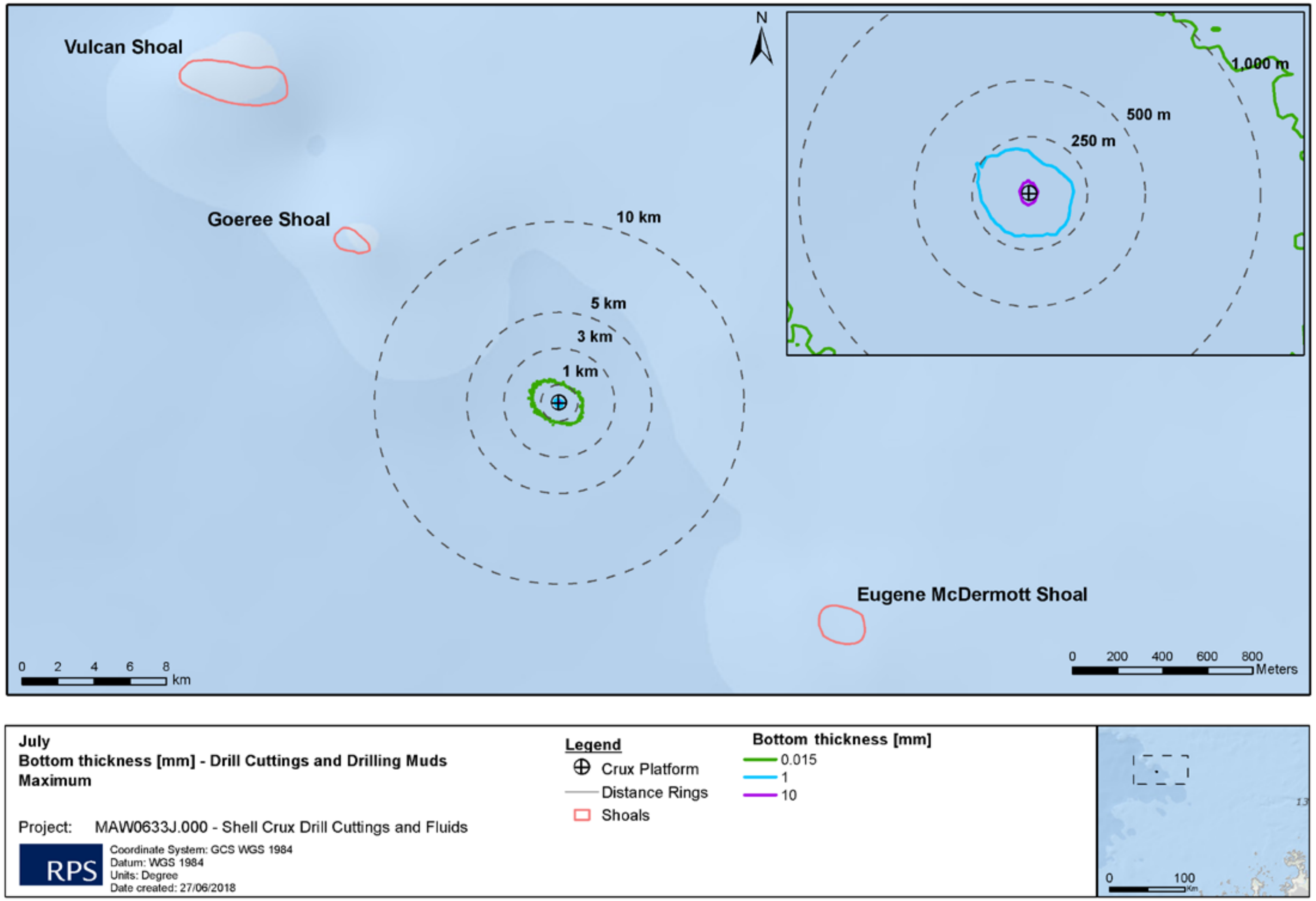


Figure 5.7 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st July during the period 2008-2017.**

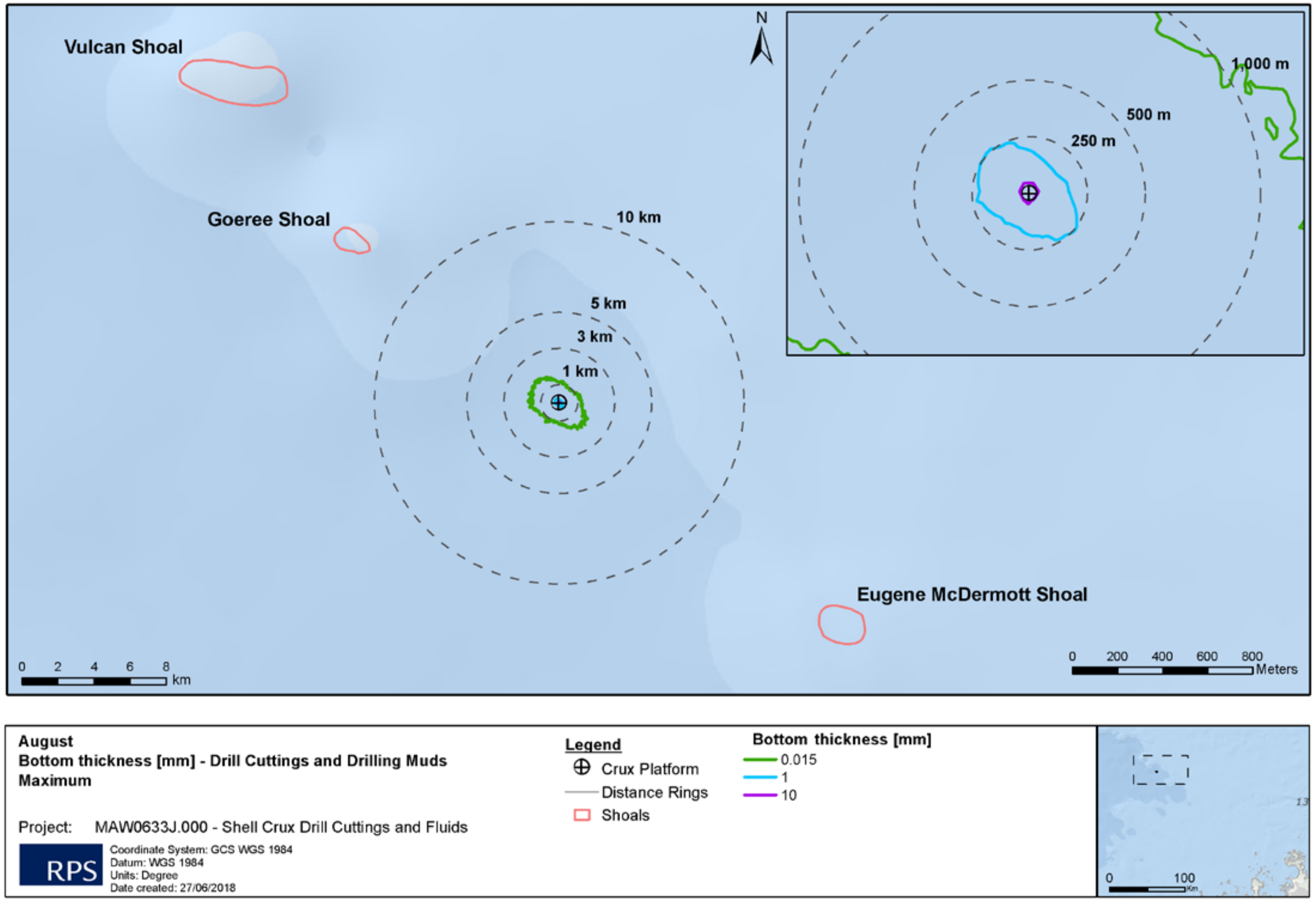


Figure 5.8 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st August during the period 2008-2017.**

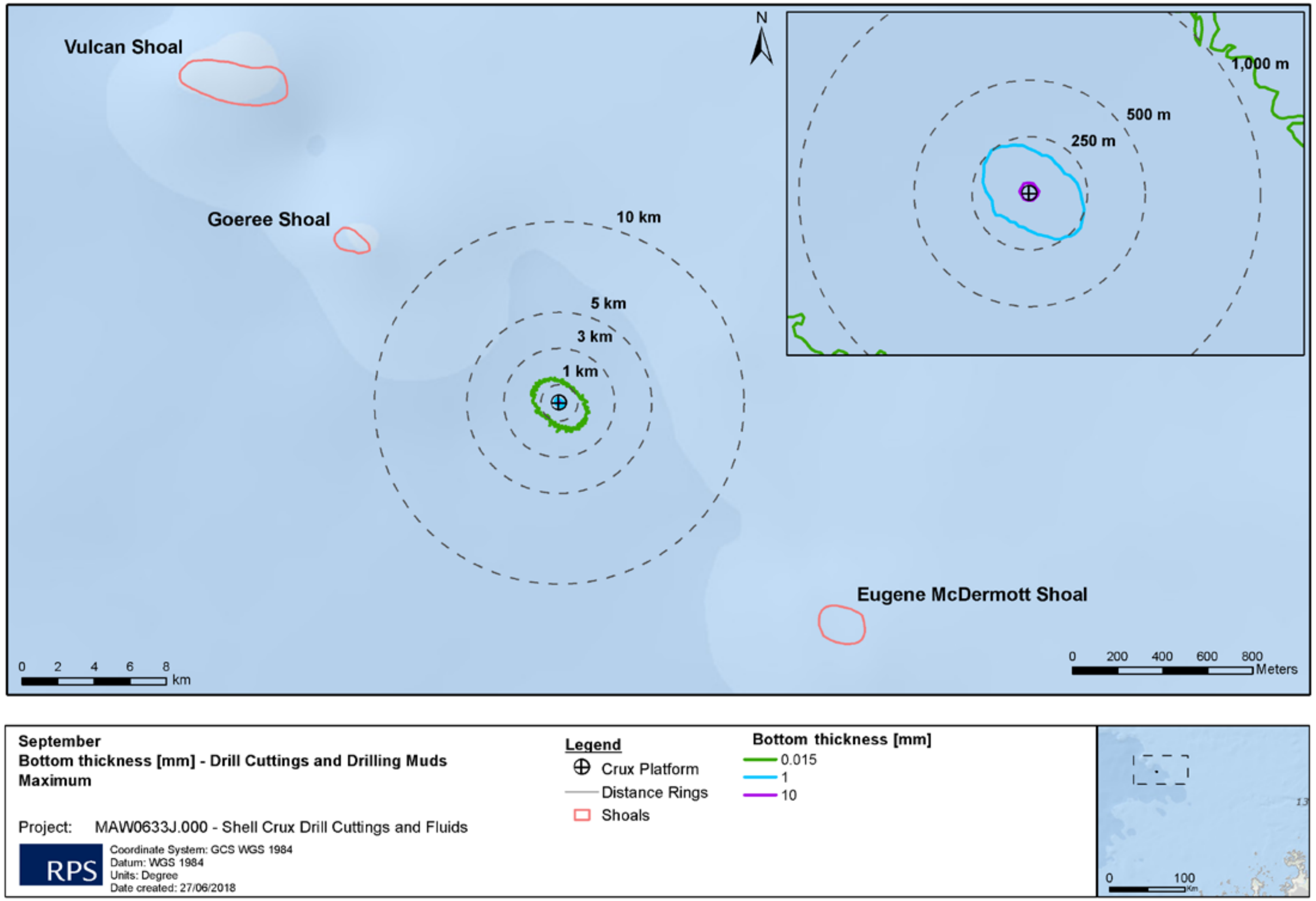


Figure 5.9 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st September during the period 2008-2017.**

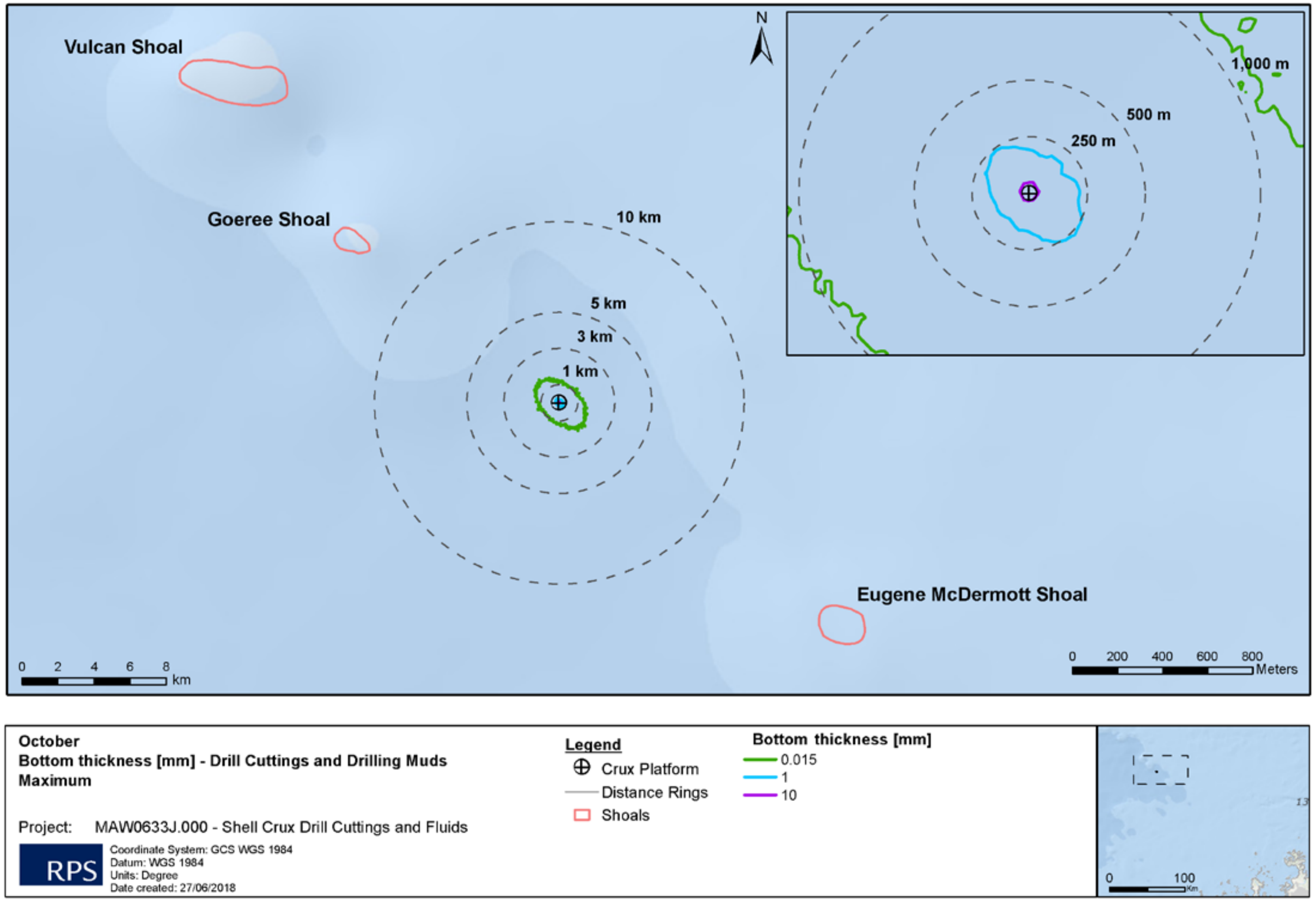


Figure 5.10 Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st October during the period 2008-2017.

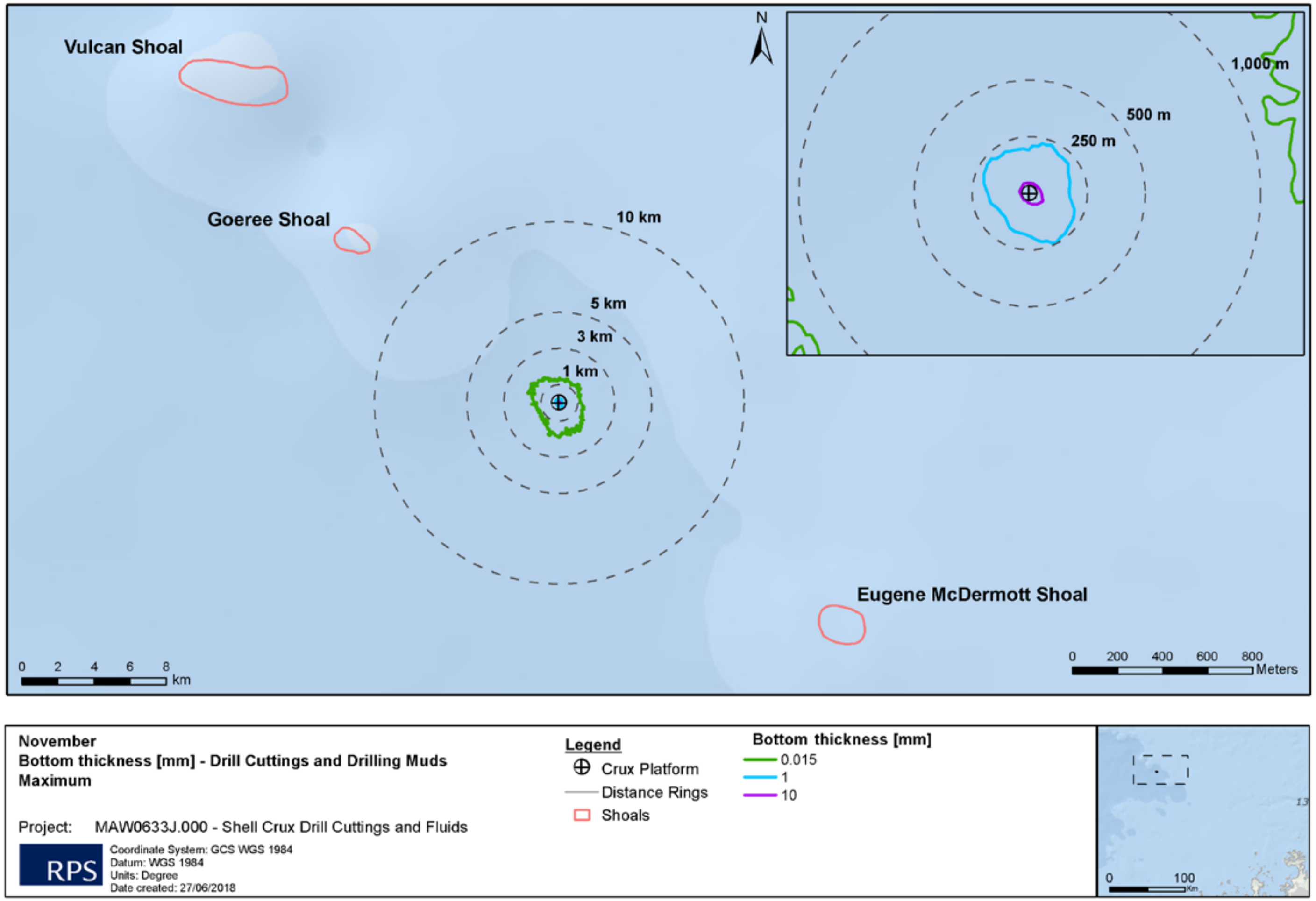


Figure 5.11 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st November during the period 2008-2017.**

RPS

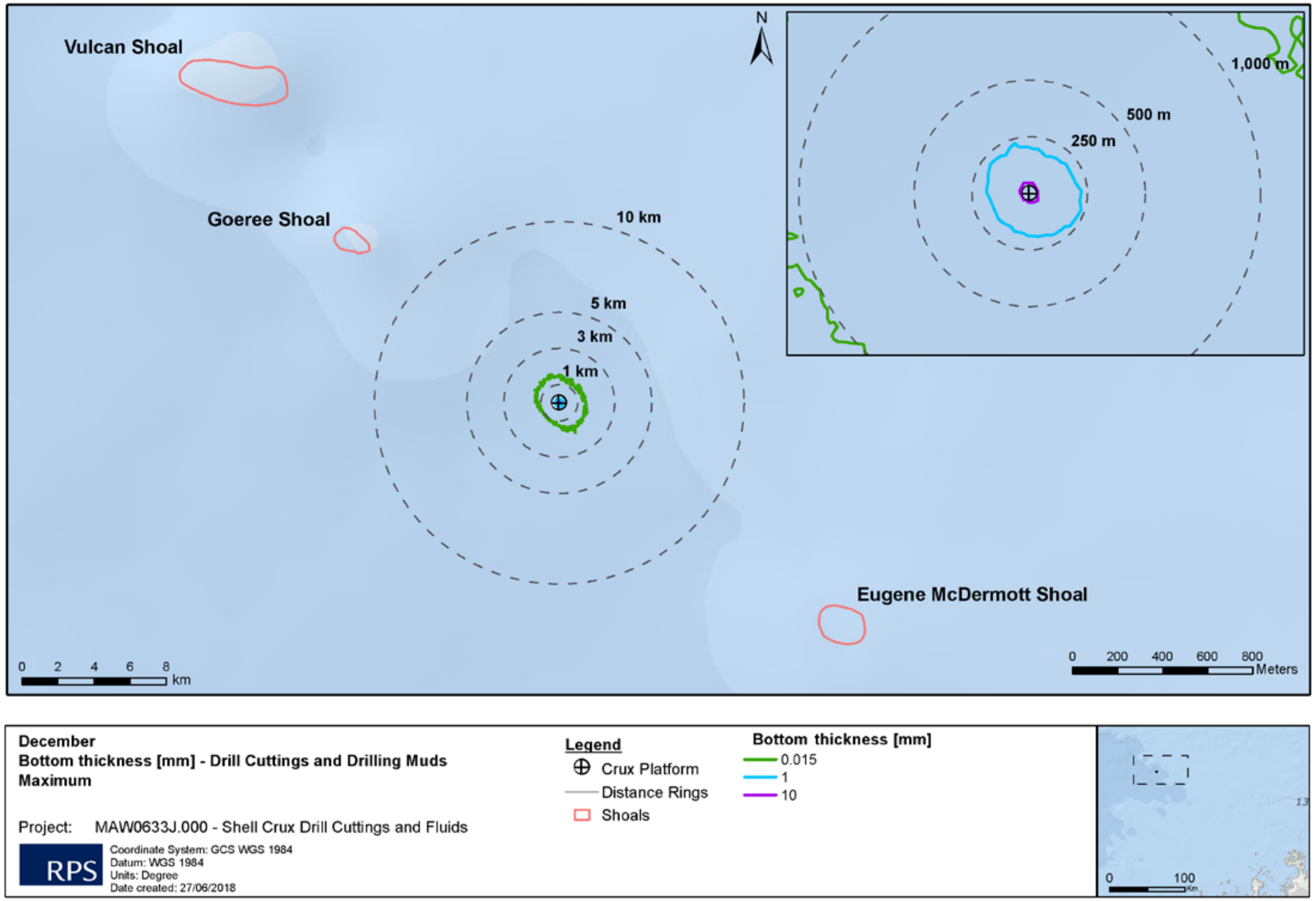


Figure 5.12 Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st December during the period 2008-2017.

RPS

Drill Cuttings Only (Single Well)

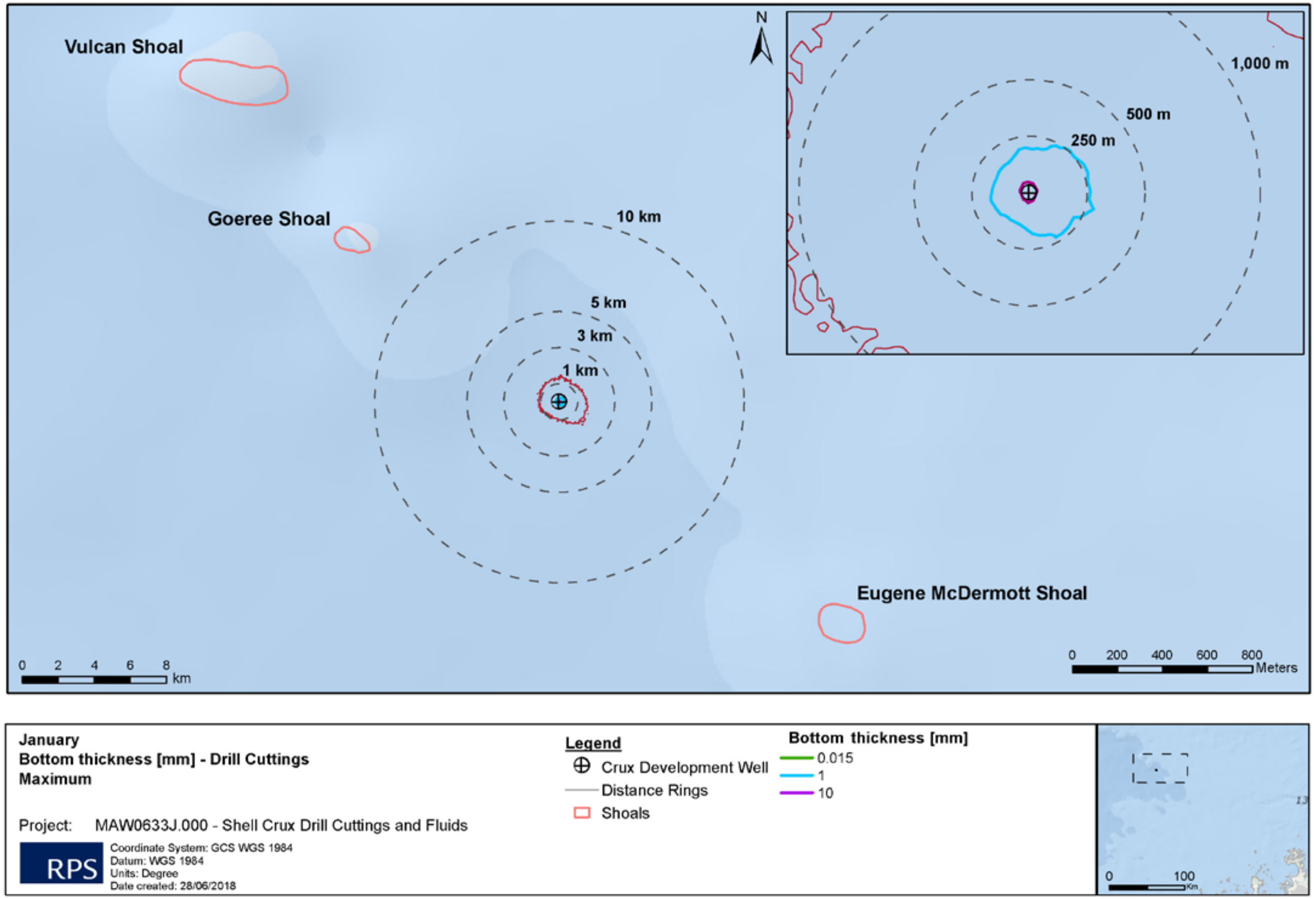


Figure 5.13 **Predicted maximum bottom thickness resulting from only the drill cuttings volumes of the discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st January during the period 2008-2017.**

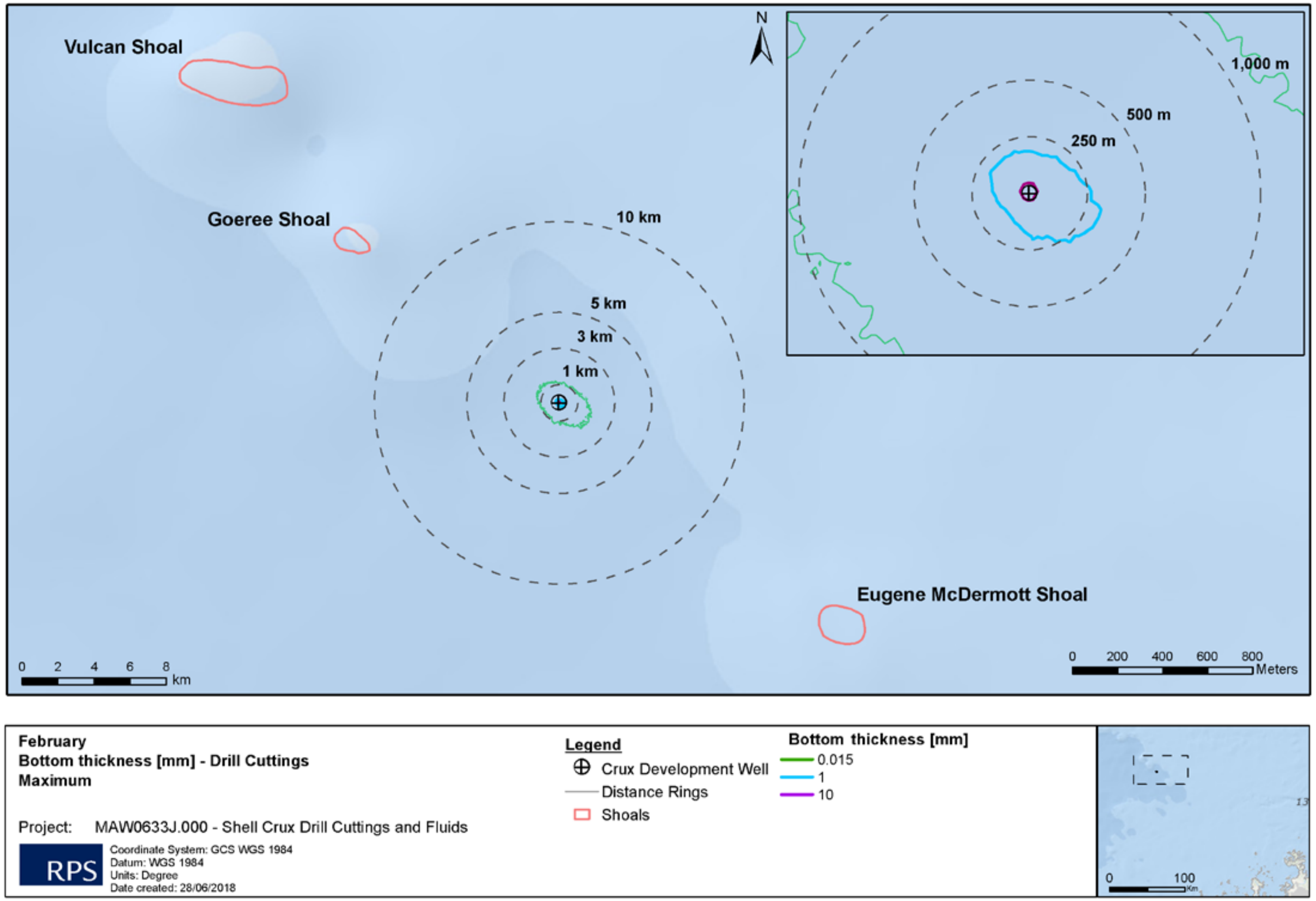
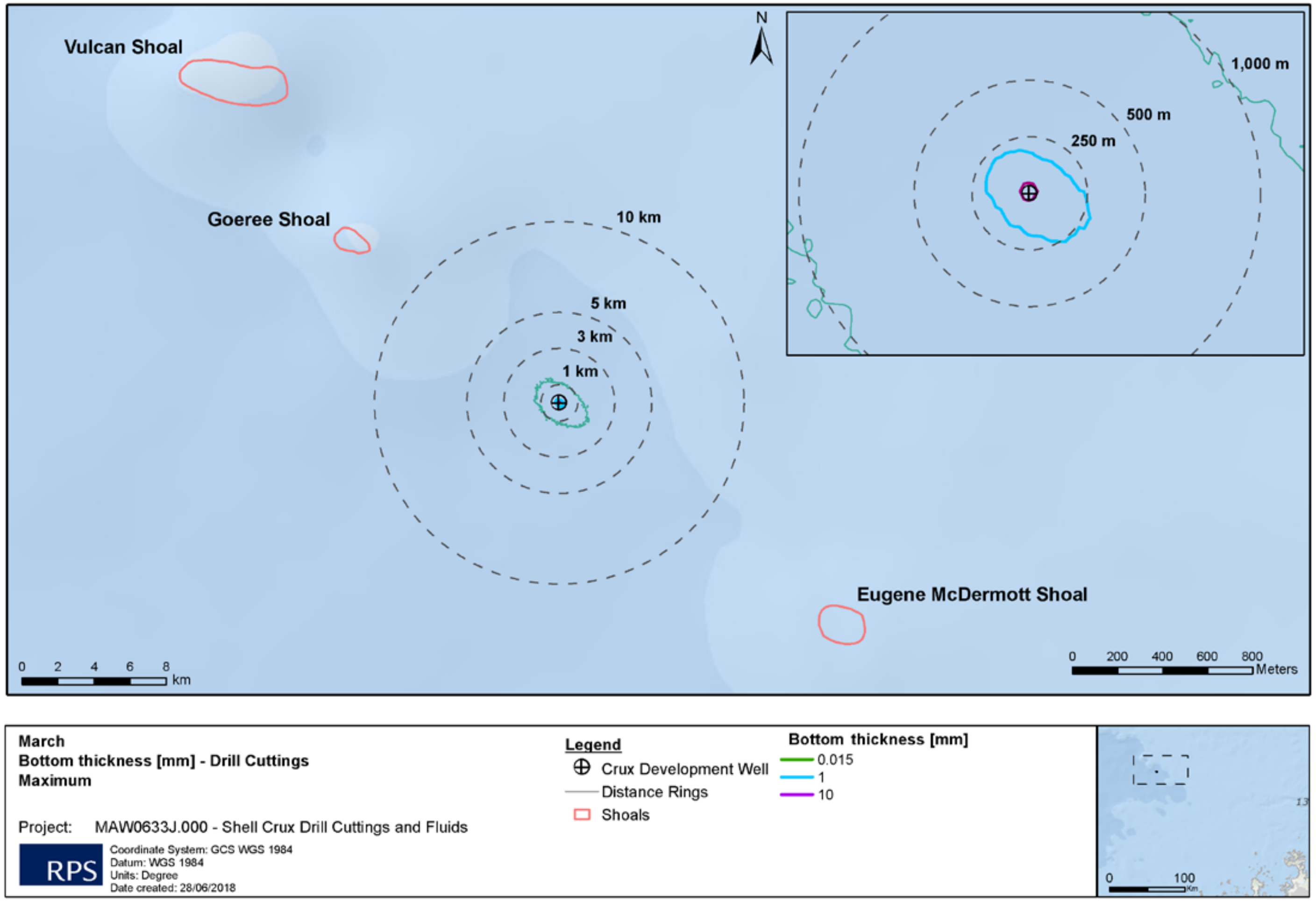


Figure 5.14 **Predicted maximum bottom thickness resulting from only the drill cuttings volumes of the discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st February during the period 2008-2017.**



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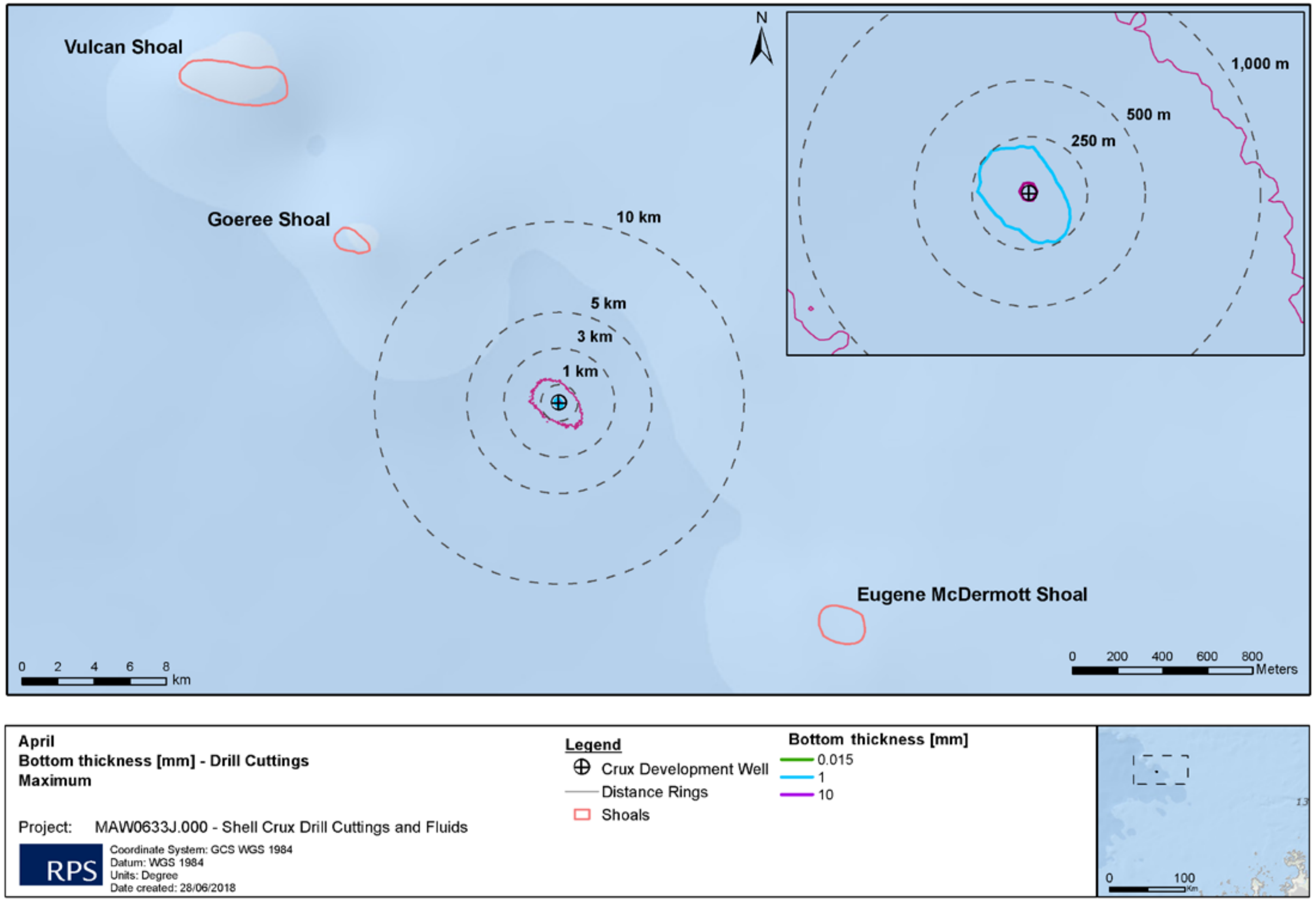
RPS



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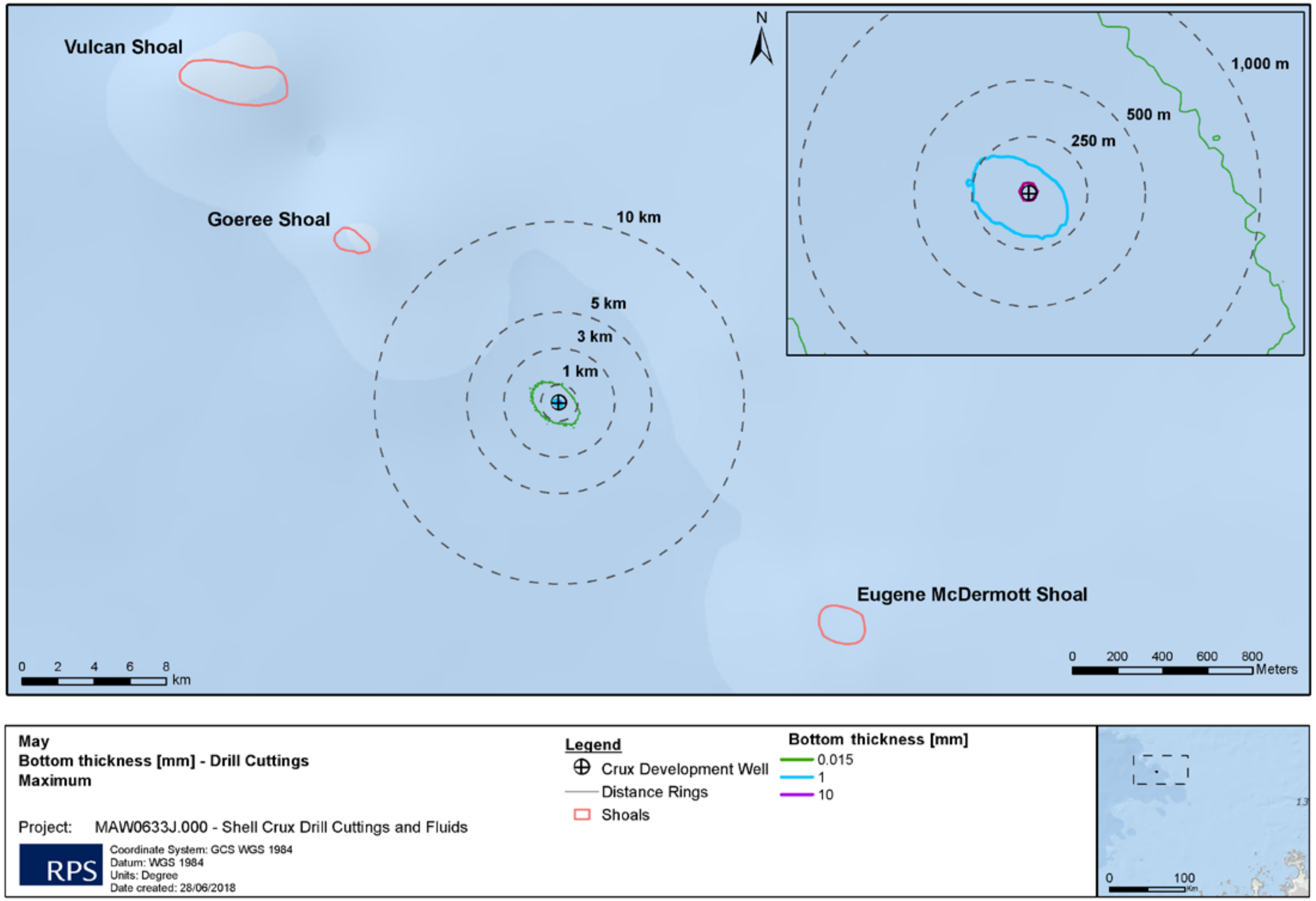

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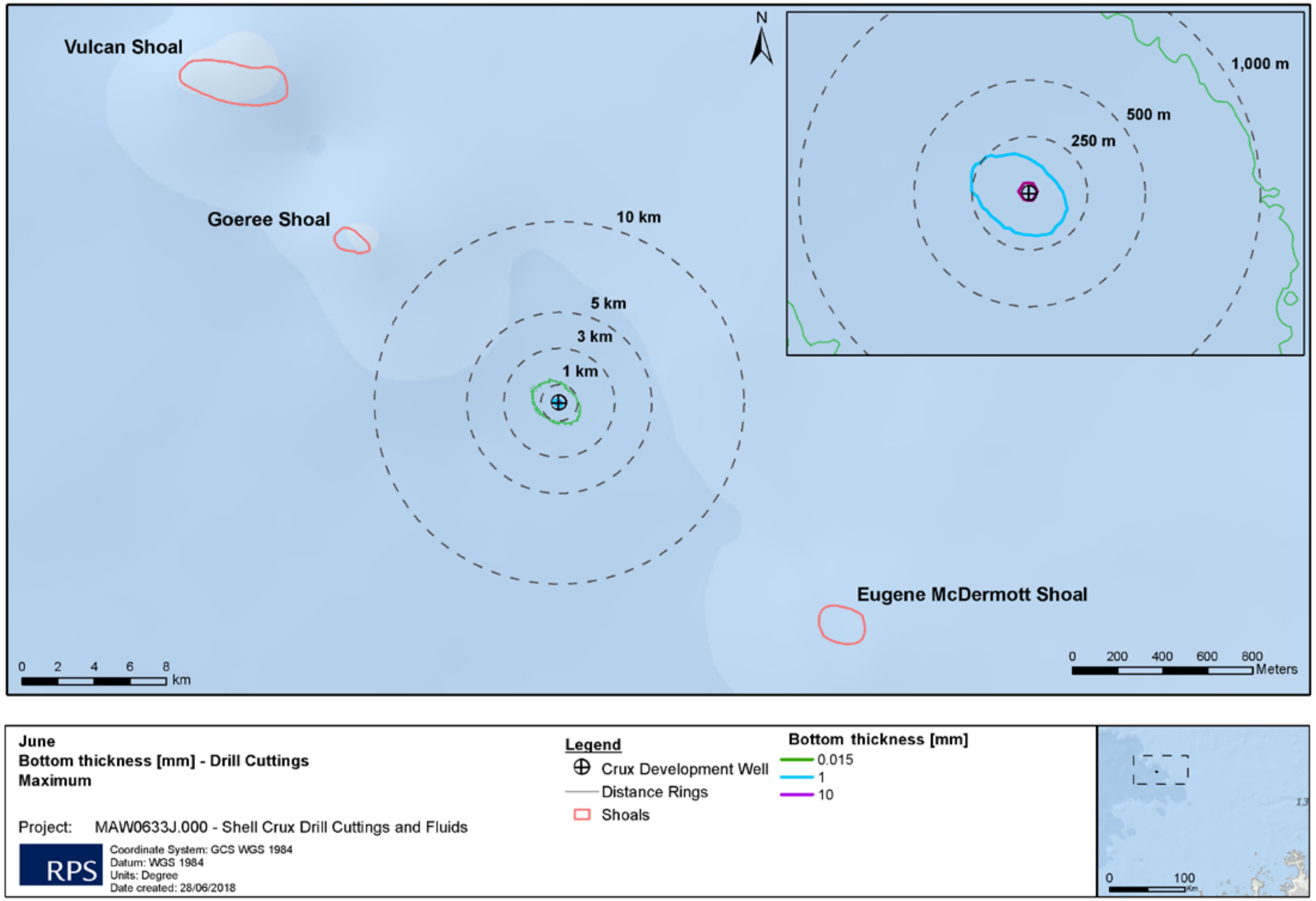

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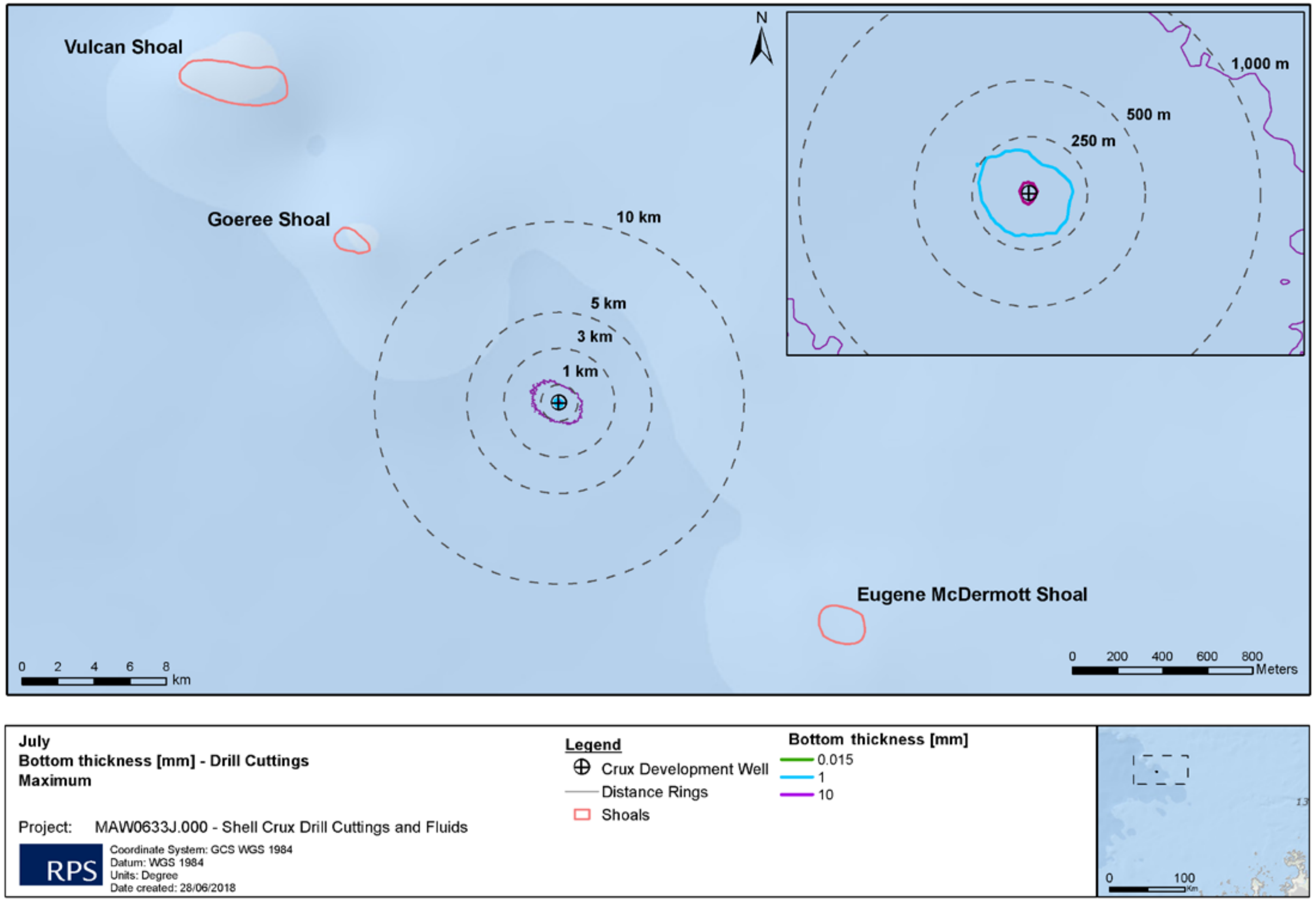

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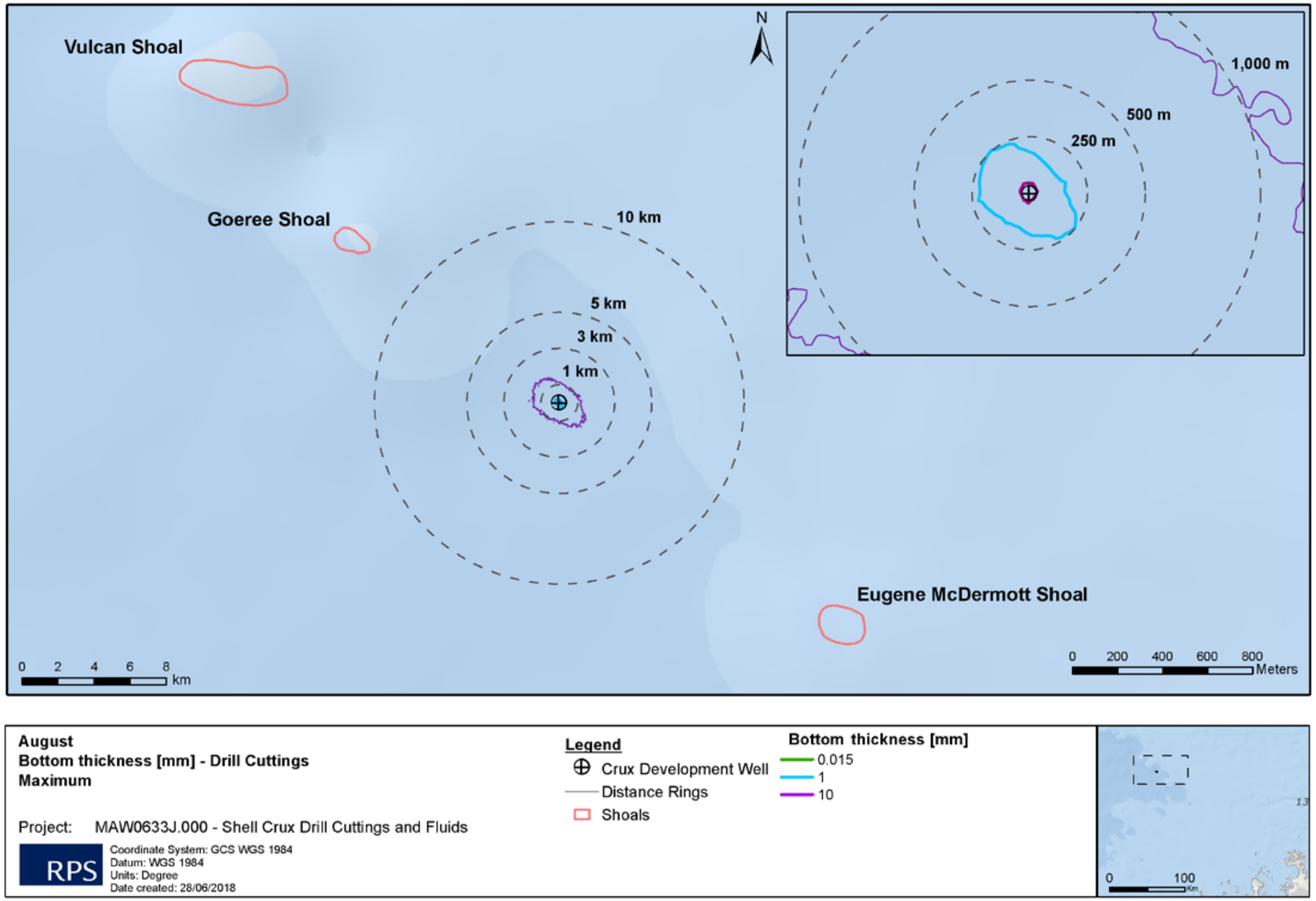

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RPS

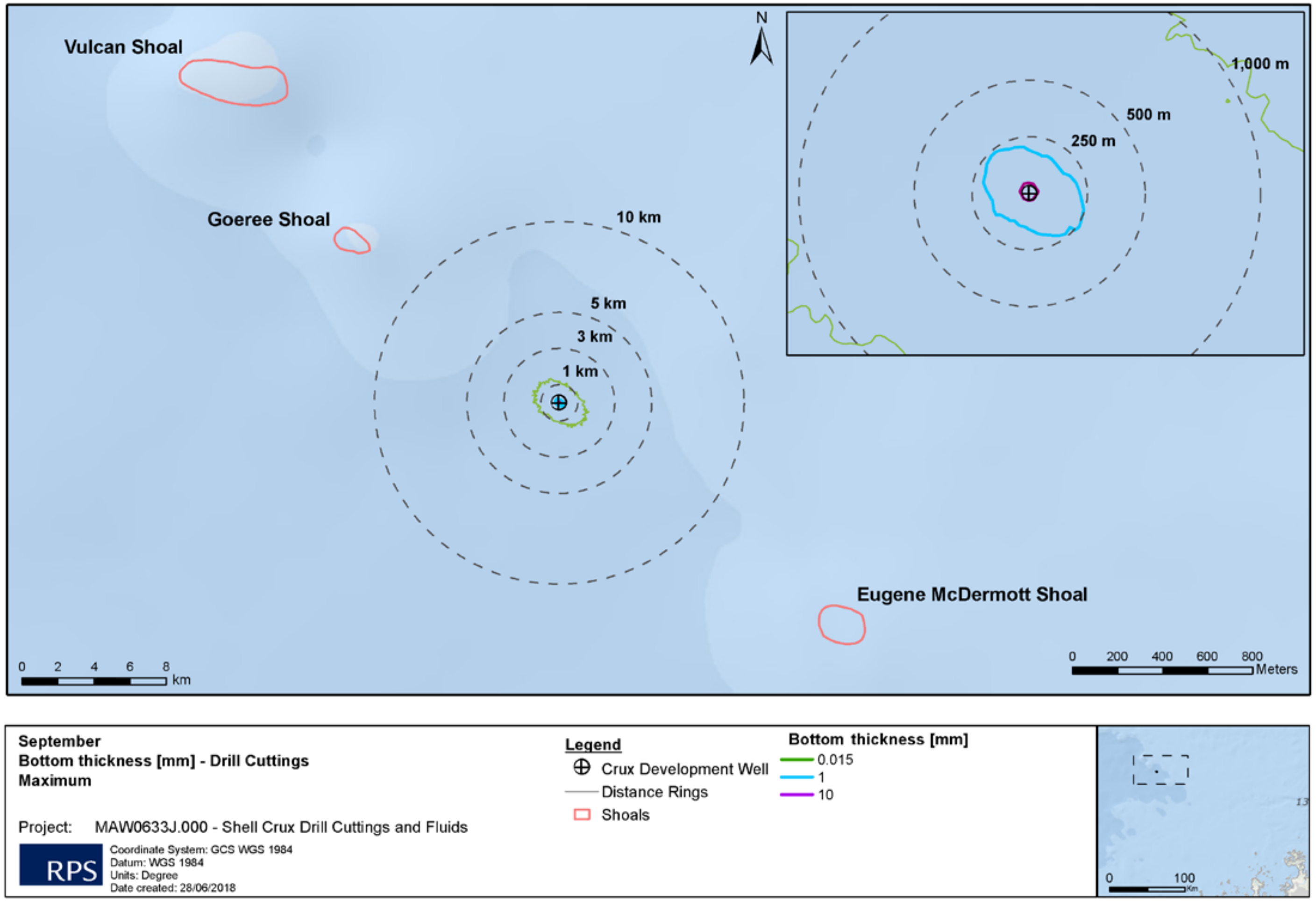


Figure 5.21 **Predicted maximum bottom thickness resulting from only the drill cuttings volumes of the discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st September during the period 2008-2017.**

RPS

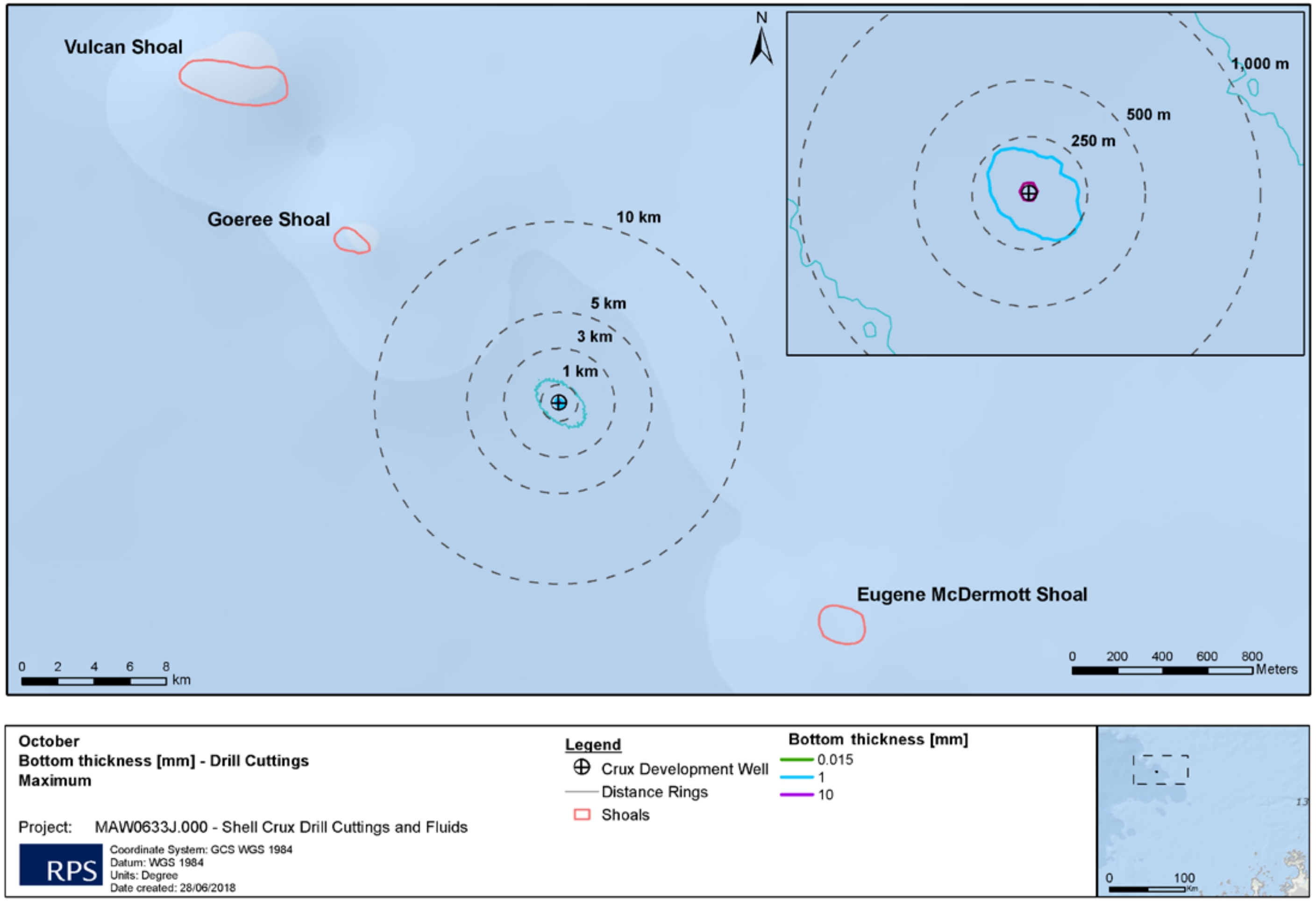


Figure 5.22 **Predicted maximum bottom thickness resulting from only the drill cuttings volumes of the discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st October during the period 2008-2017.**

RPS

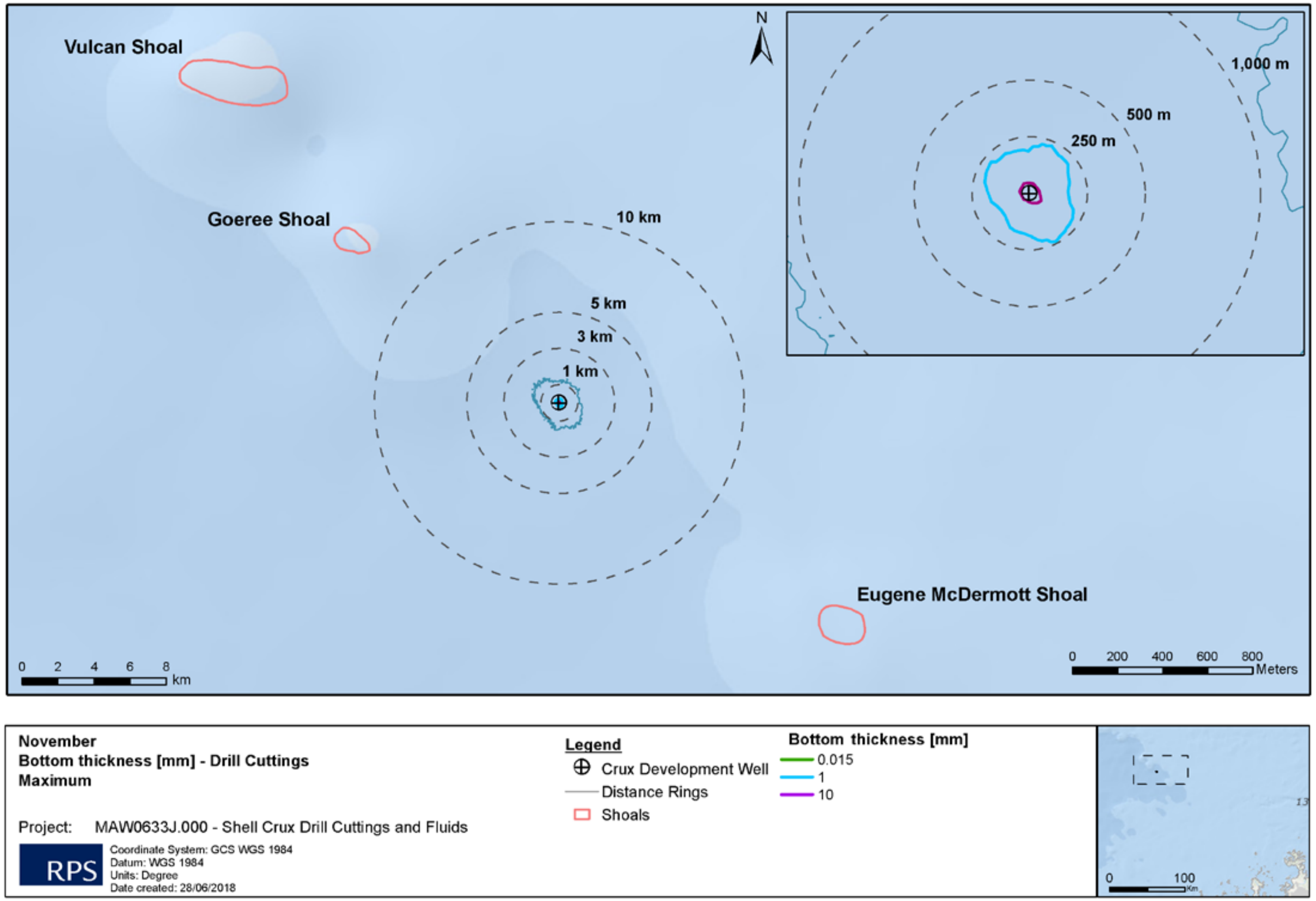
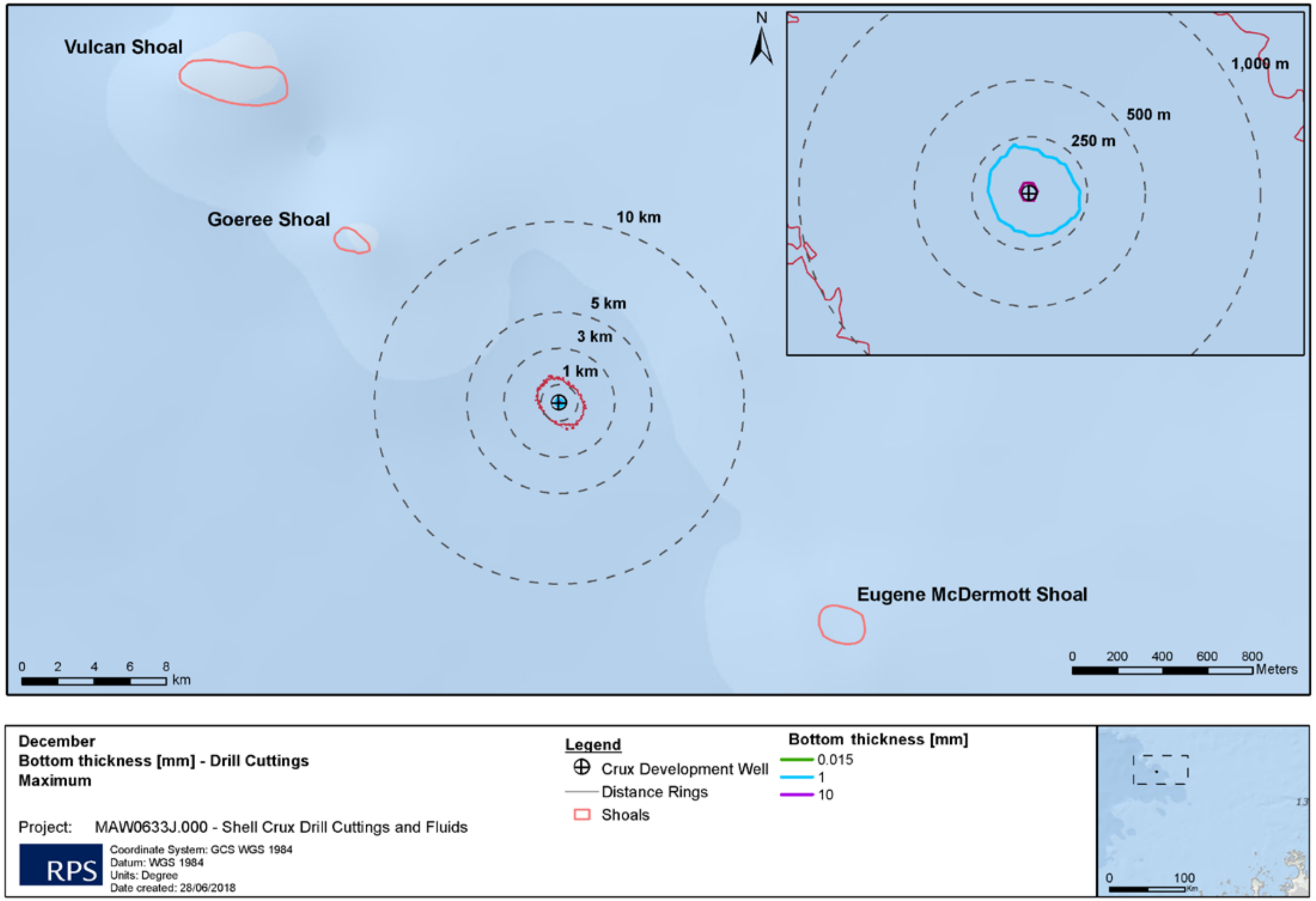


Figure 5.23 **Predicted maximum bottom thickness resulting from only the drill cuttings volumes of the discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st November during the period 2008-2017.**

RPS



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Drill Cuttings & Drilling Muds (Five Wells)

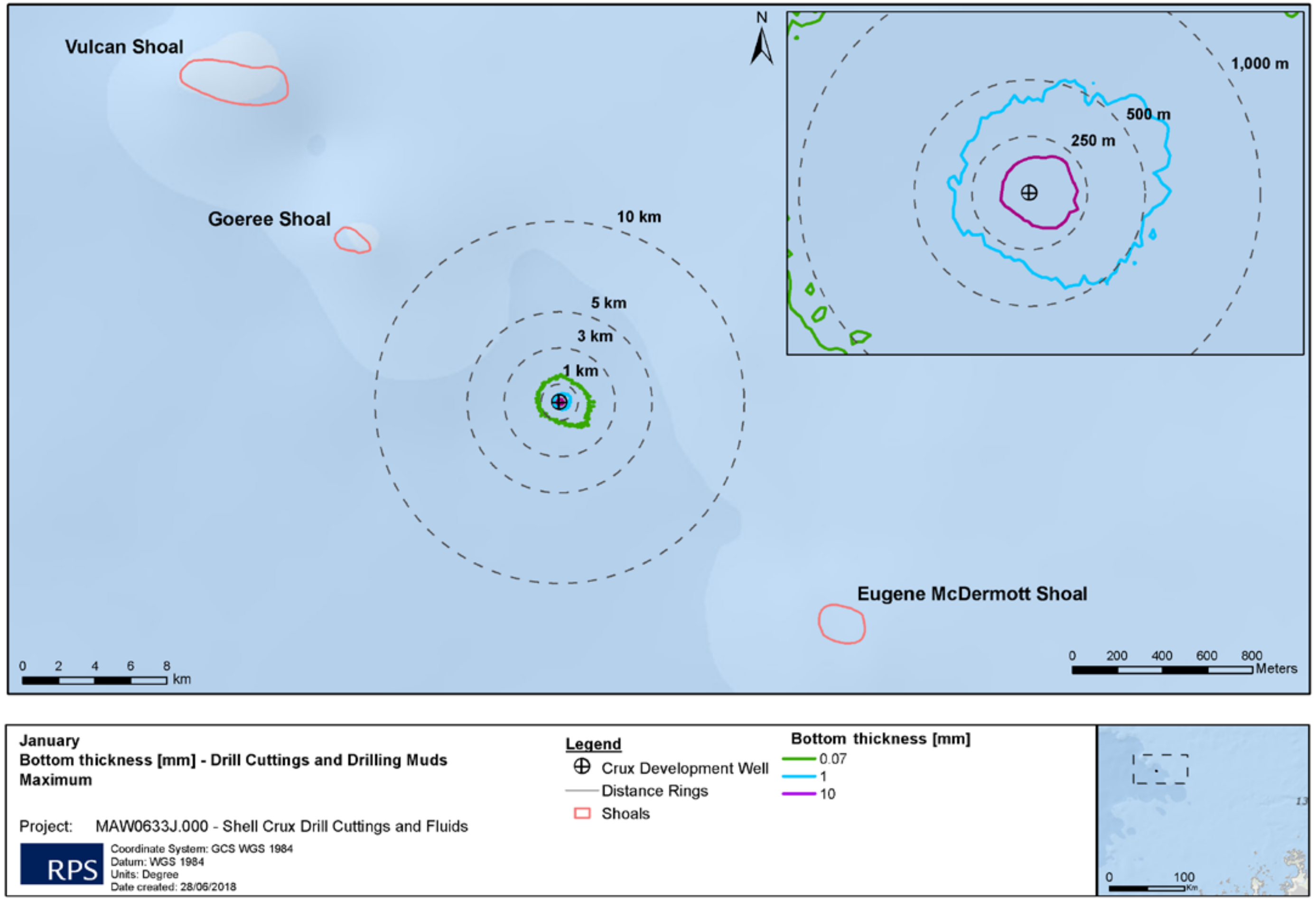


Figure 5.25 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st January during the period 2008-2017.**

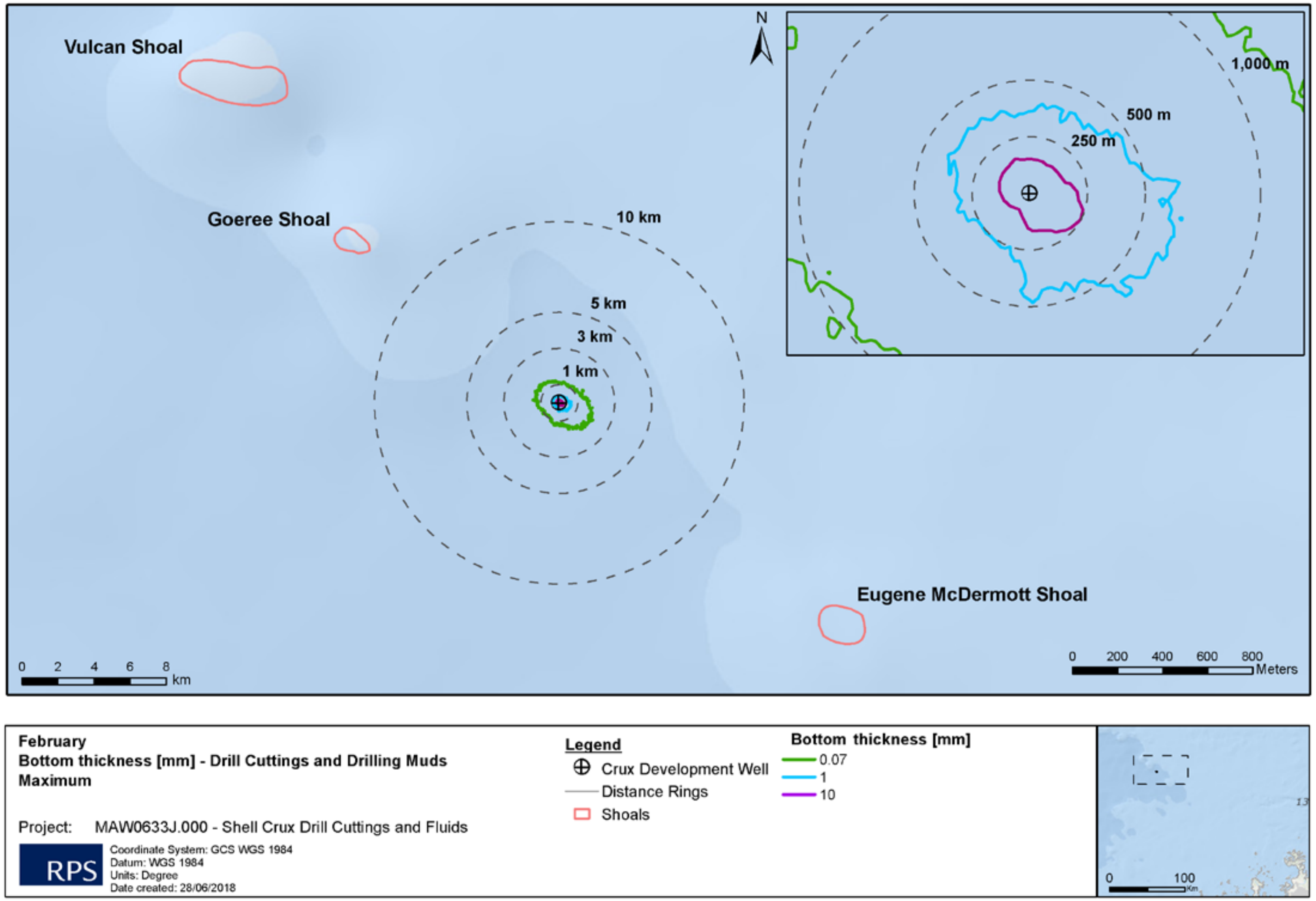
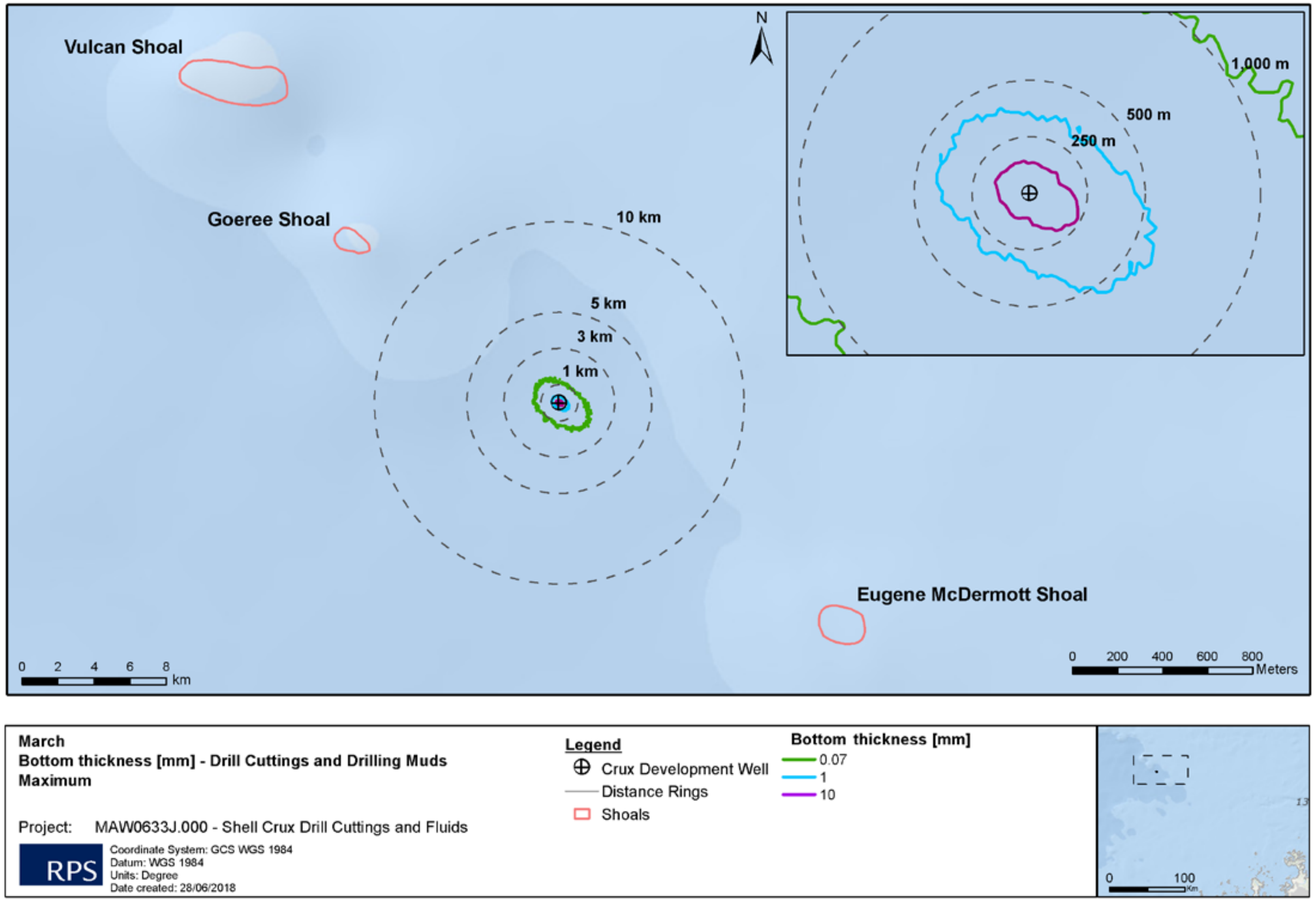


Figure 5.26 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st February during the period 2008-2017.**



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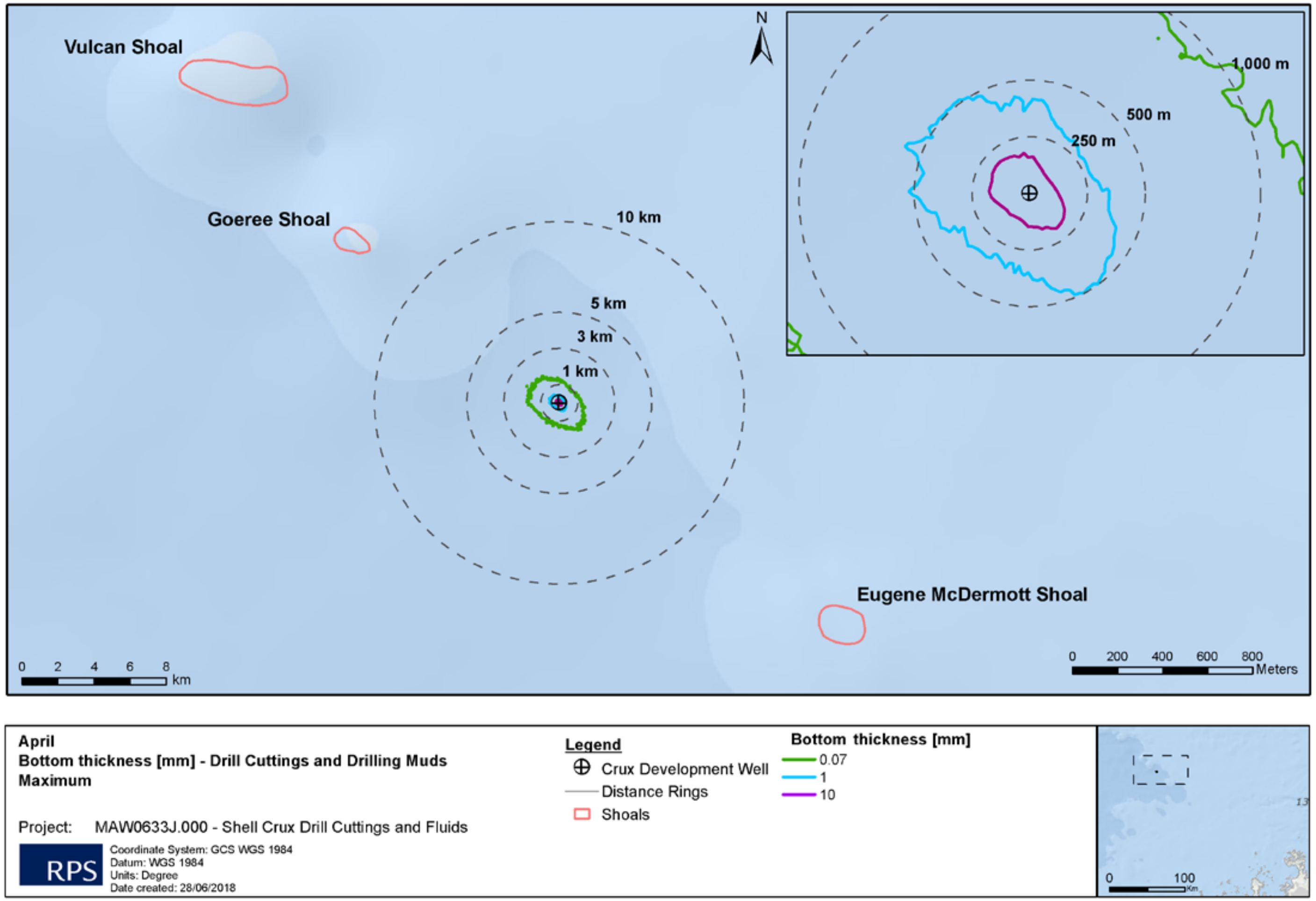
RPS



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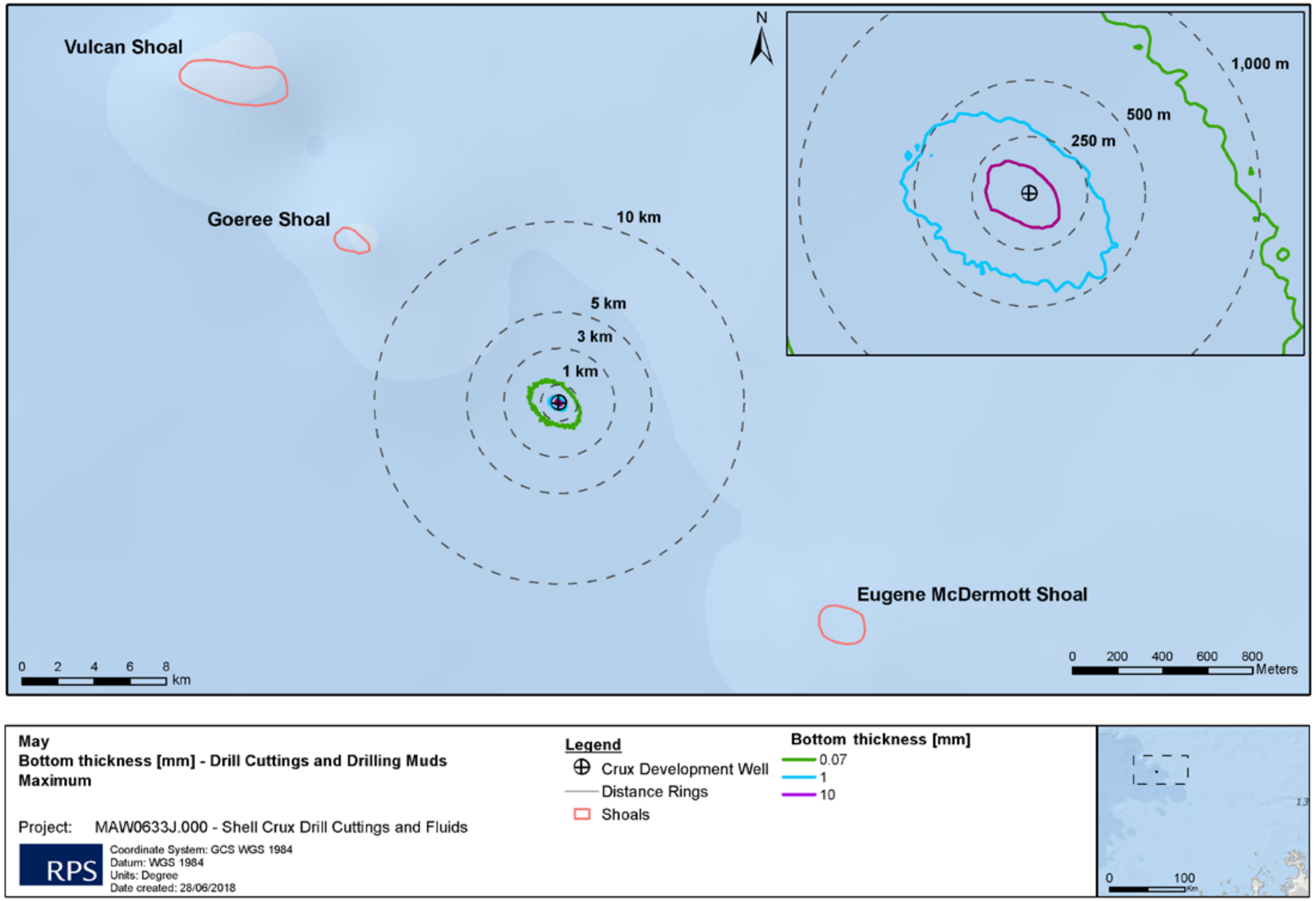

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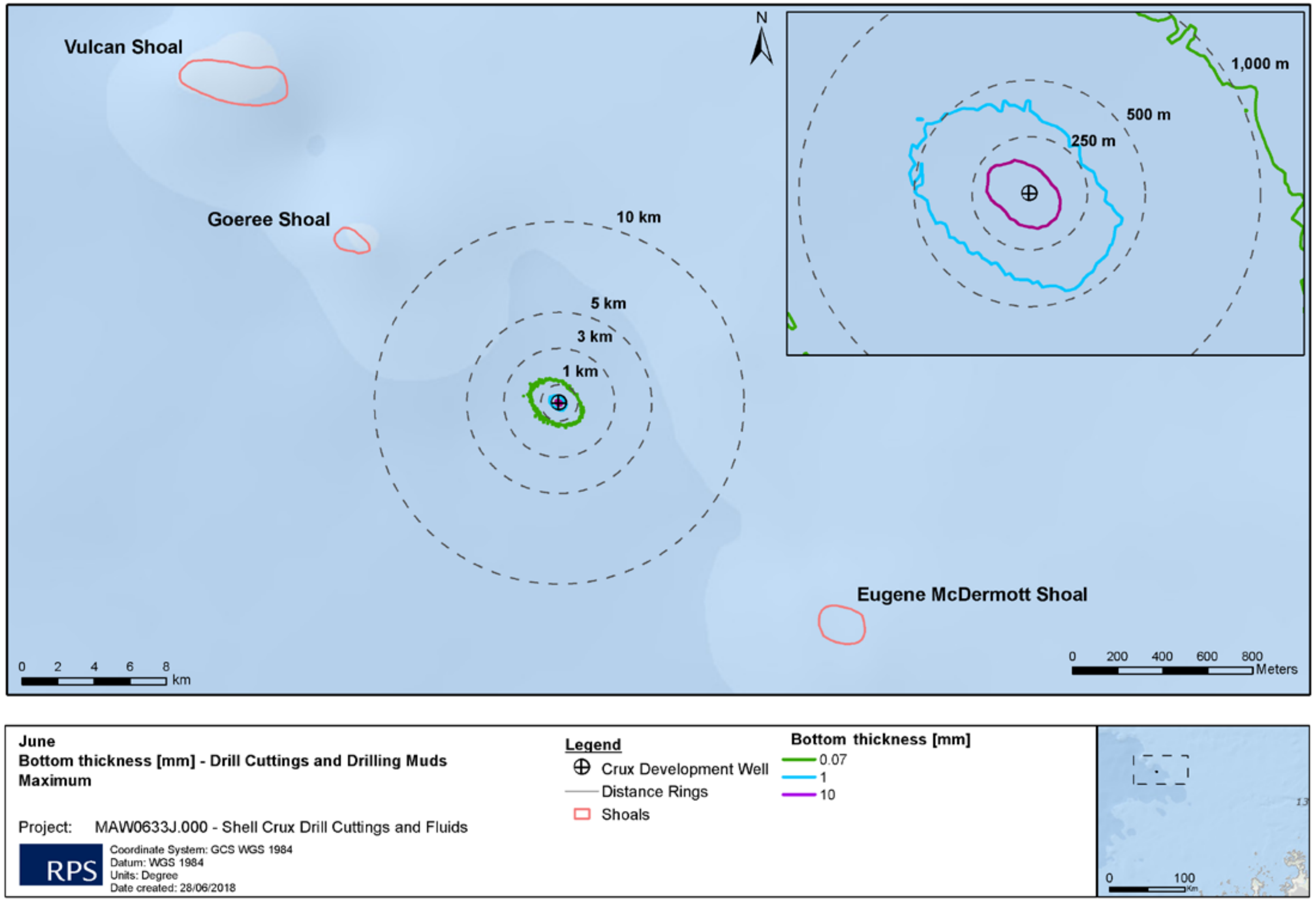

Figure 5.30 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st June during the period 2008-2017.**

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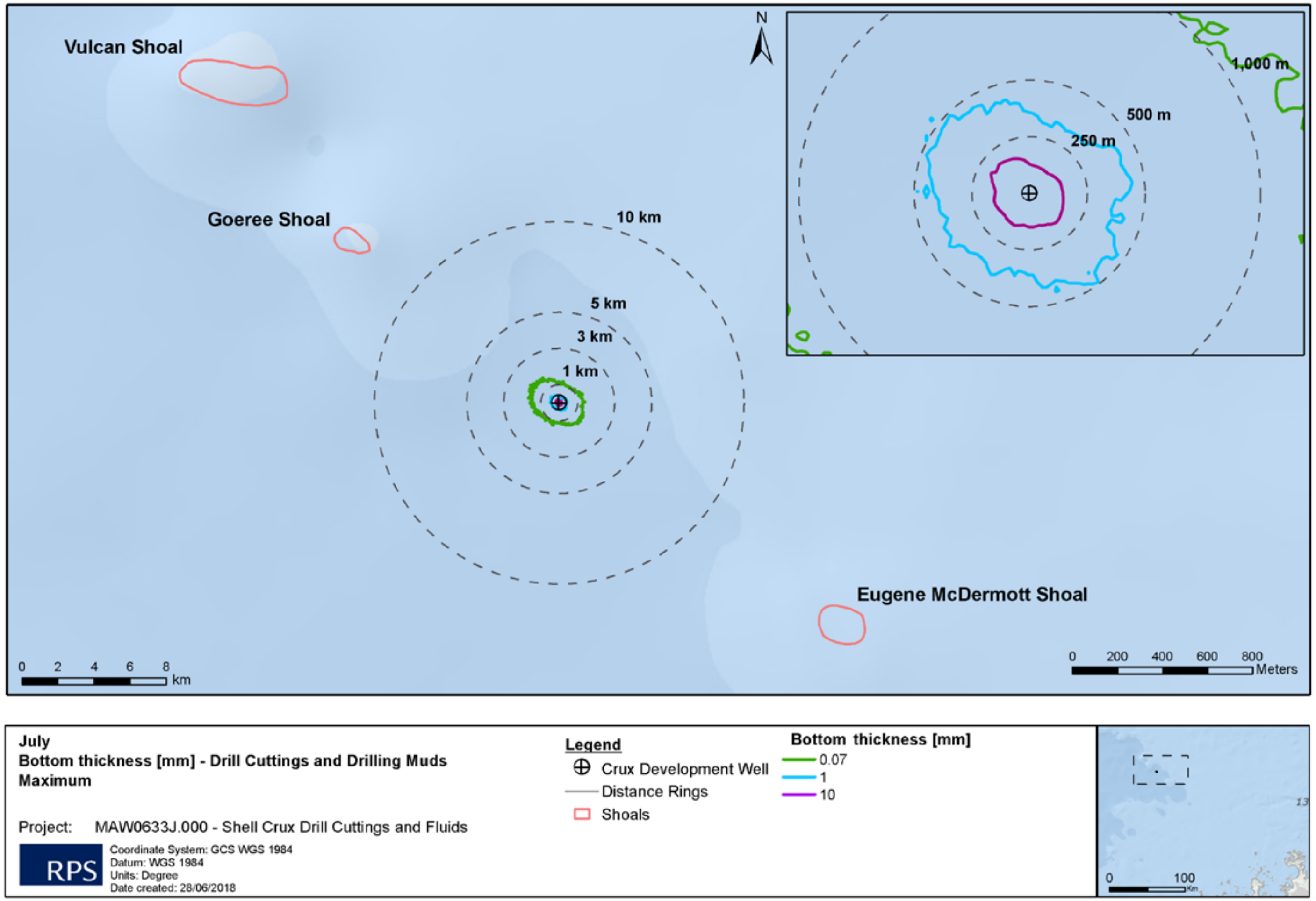
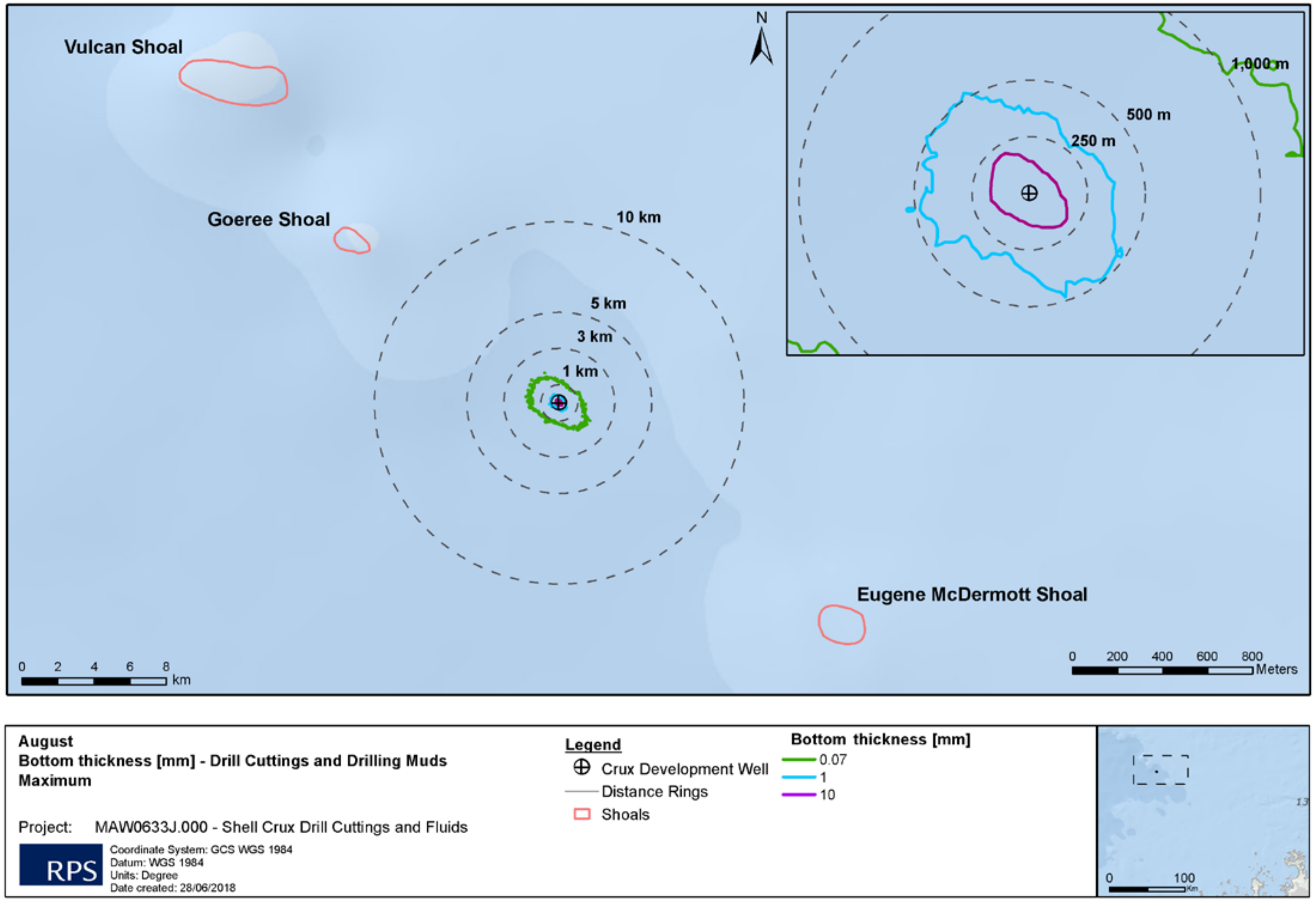


Figure 5.31 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st July during the period 2008-2017.**



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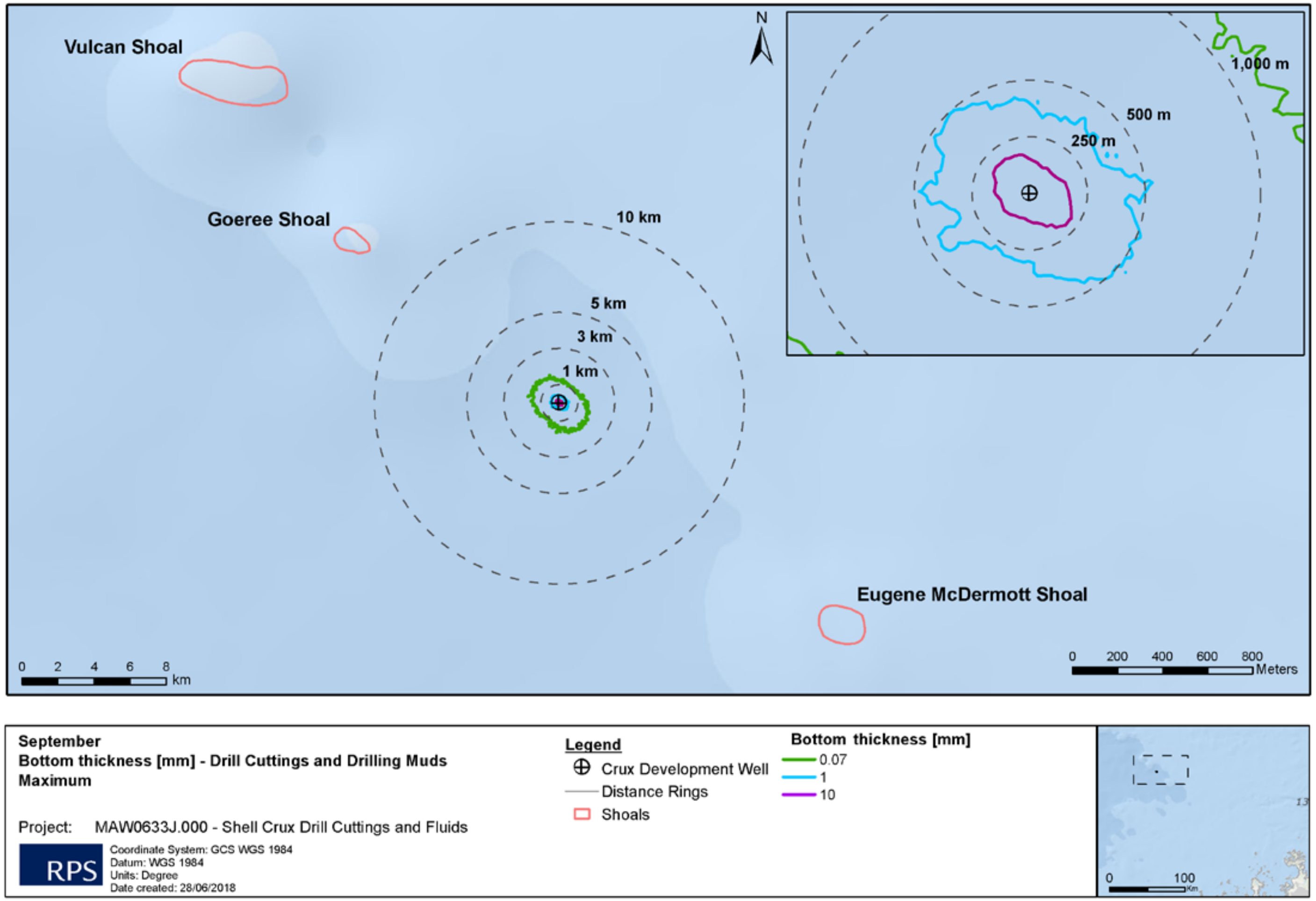

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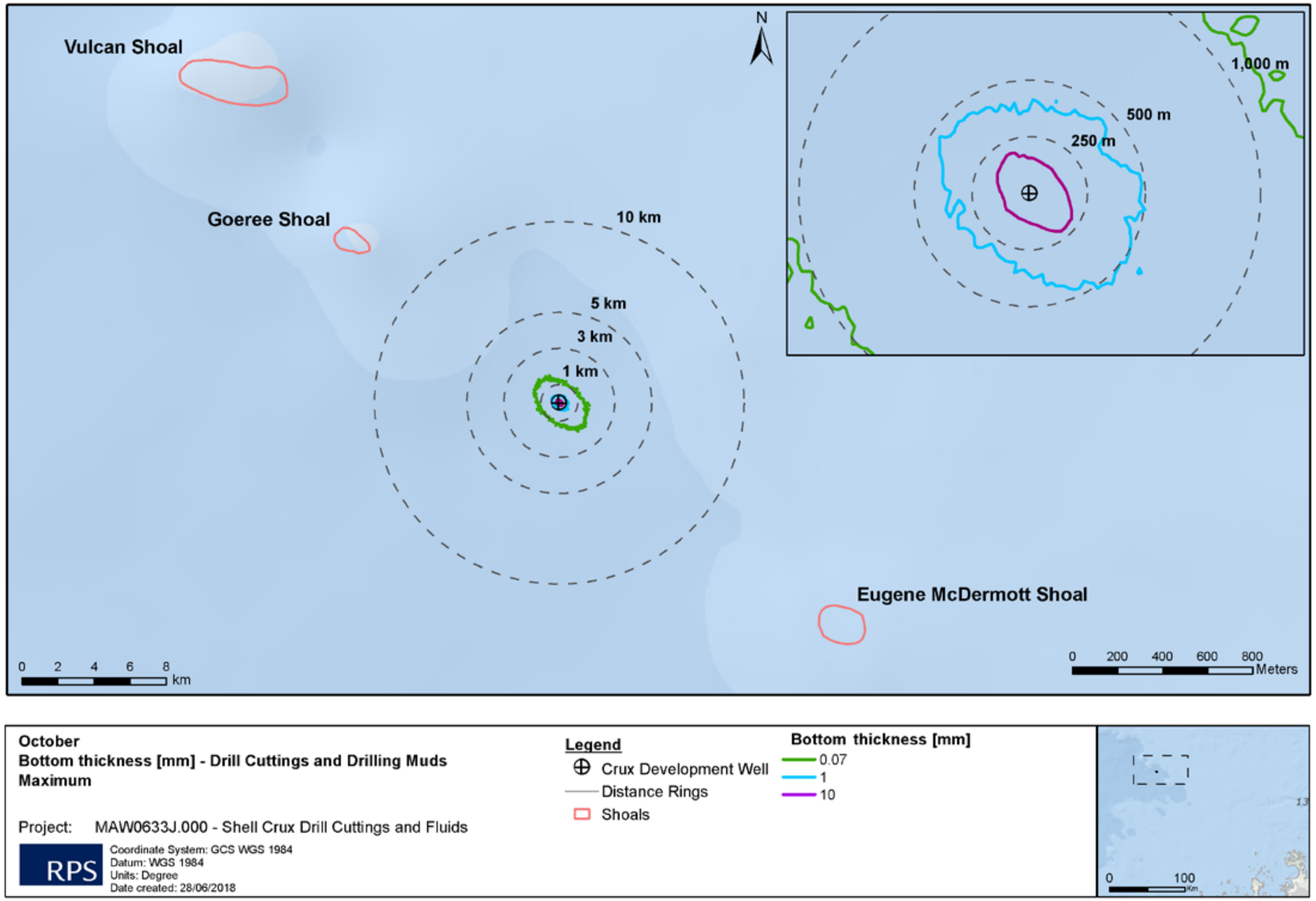

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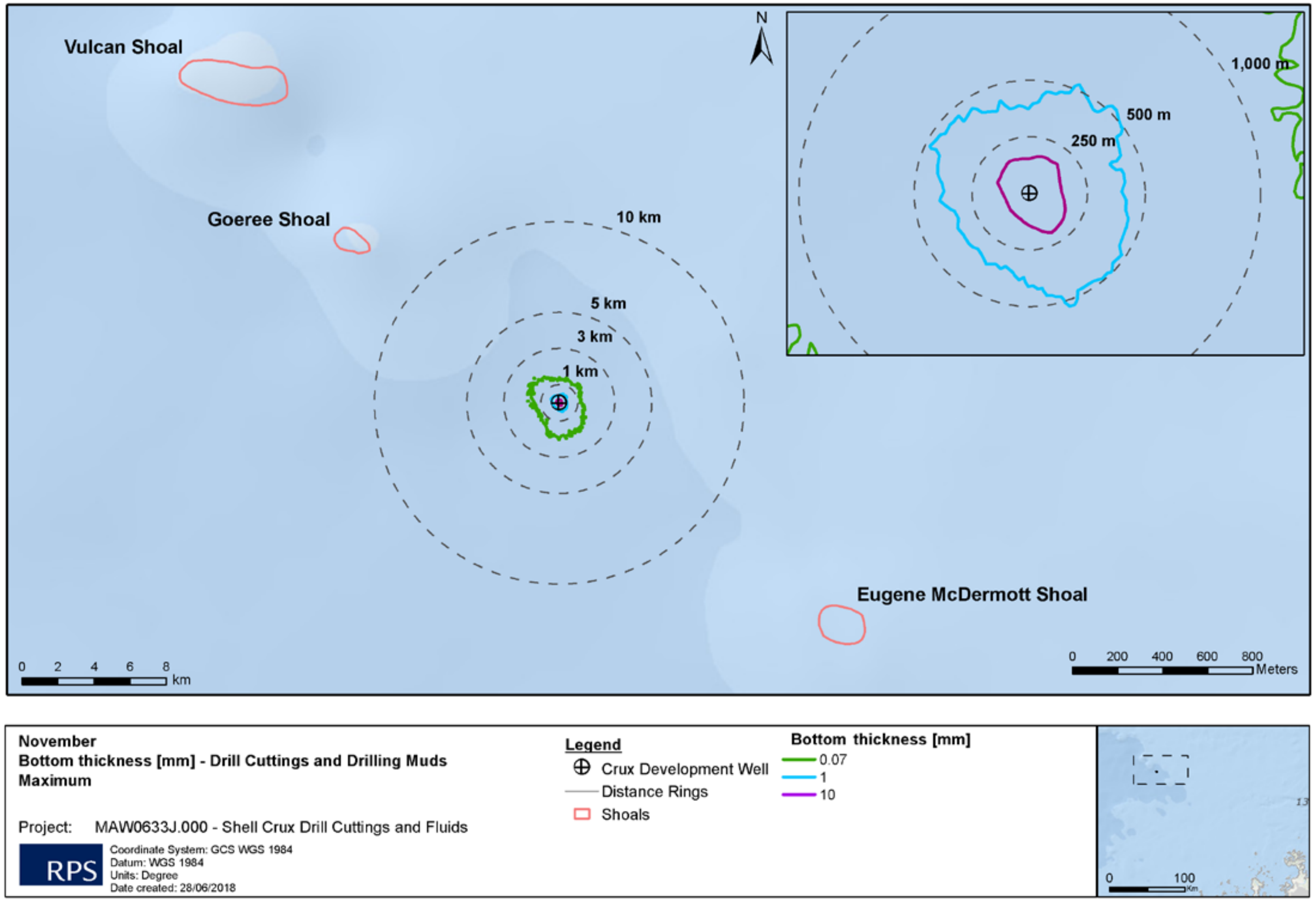

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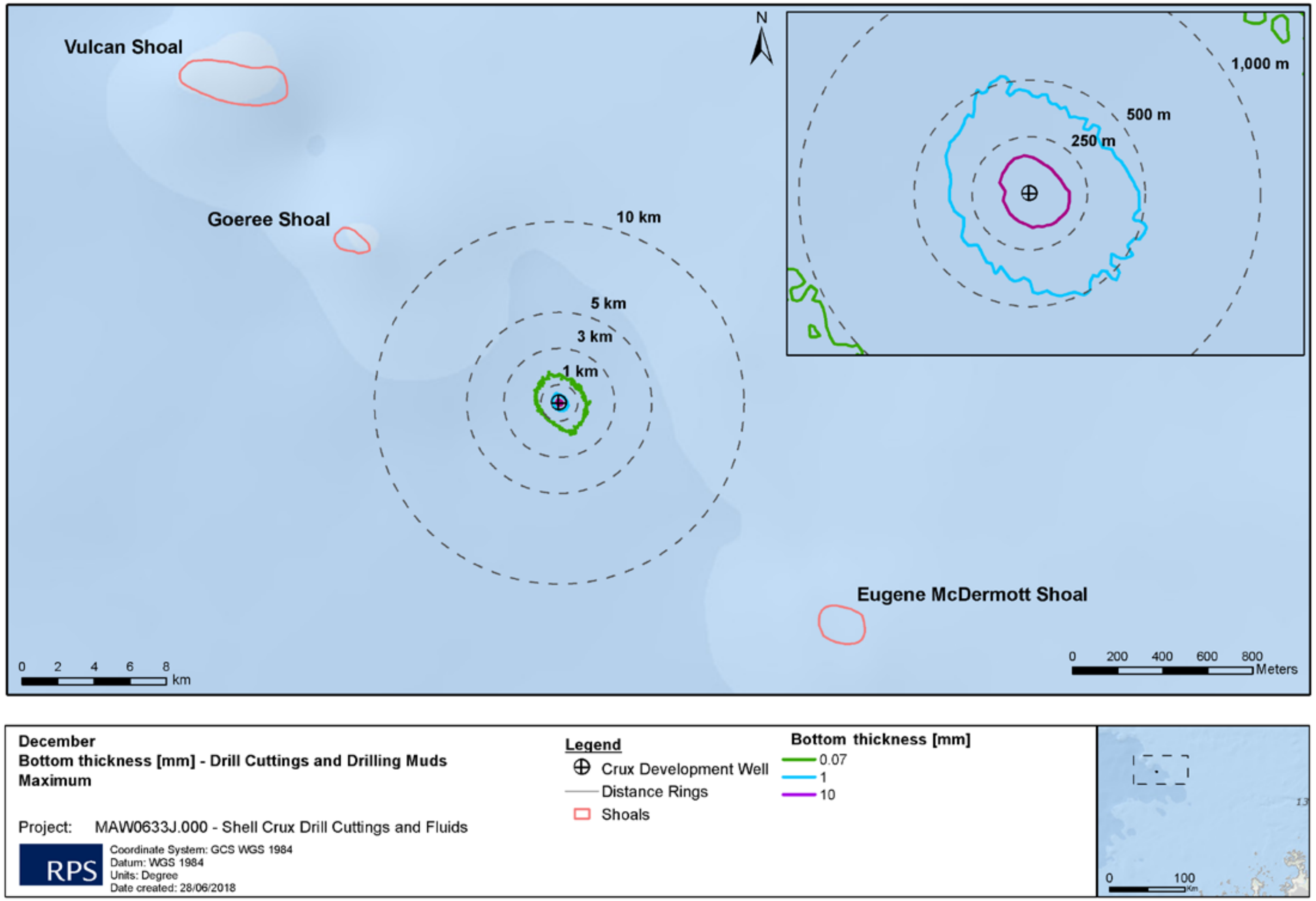

Figure 5.36 **Predicted maximum bottom thickness resulting from the drill cuttings and drilling muds discharge programme. The maximum concentrations are calculated across all simulations commencing on 1st December during the period 2008-2017.**

Appendix E: PFW Modelling Study (RPS 2018b)

REPORT

Shell Crux Project

Marine Dispersion Modelling of PFW Discharges

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No.:	MAW0633J		
Version:	3-Fig		
Date:	19 September 2018		

Document Status

Version	Purpose of Document	Prepared by	Reviewed by	Review Date
A	Issued for internal review	M. Zapata	D. Wright	29/03/2018
0	Issued for Client review	M. Zapata	D. Wright	29/03/2018
1	Issued for Client review	M. Zapata	D. Wright	02/07/2018
2	Issued for Client review	M. Zapata	D. Wright	12/07/2018
3	Issued for Client review	N. Page	D. Wright	19/09/2018

Approval for Issue

Name	Signature	Date
Sasha Zigic	S. Zigic	19/09/2018

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1 Introduction

1.1 Background

RPS has been commissioned by CDM Smith Australia Pty Ltd (CDM Smith), on behalf of Shell Australia Pty Ltd (Shell), to undertake a marine dispersion modelling study of proposed water discharges from the Crux platform (Table 1.1). The Crux platform is located in the northern Browse Basin in offshore Commonwealth marine waters, approximately 190 km offshore north-west Australia and 620 km north-north-east of Broome.

Produced formation water (PFW) occurs naturally within the same rock strata as the hydrocarbons and comprises condensed water and saline formation water.

Operation of the fixed-jacket Crux platform will include discharges of PFW separated from the hydrocarbon production stream. The characteristics of the PFW discharge will transition during the operational life of the Crux platform. Discharges are expected to comprise mostly condensed water with minimal formation water produced during the early operations phase (approximately 8-9 years) (i.e. pre-formation water breakthrough). At around 9 years of operation the water produced will transition to a mixture of condensed water and formation water (i.e. post-formation water breakthrough). The amount of formation water is expected to comprise a greater proportion of the discharge as the field nears end of life, as is typically the case of maturing hydrocarbon fields.

Operational design for the facility has identified that the PFW discharges will vary from ambient seawater in terms of temperature, salinity, and the presence of trace amounts of process chemicals.

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for each of the identified constituents in the PFW discharge. This will indicate whether concentrations of any constituents are likely to be above stated threshold concentrations at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the PFW discharge and the total potential area of influence, the effect of near-field mixing needs to be considered first, followed by an investigation of the far-field mixing. Different modelling approaches are required for calculating near-field and far-field dilutions due to the differing hydrodynamic scales.

To assess the rate of mixing of the process chemicals in the PFW stream from the Crux platform, dispersion modelling was carried out for two flow rates: 287 m^3/d (maximum flow rate during the early operations phase, i.e. first 8-9 years of operation) and 3,179.8 m^3/d (maximum flow rate during the later operations phase, i.e. after year 9 of operations).

The potential area that may be influenced by the PFW discharge stream was assessed for three distinct seasons: (i) summer (December to February); (ii) the transitional periods (March and September to November); and (iii) winter (April to August). This approach assists with understanding the seasonal variability of the PFW discharge stream in the context of nearest environmental values and sensitivities that would be at risk of exposure.

The closest non-transient environmental values and sensitivities to the proposed Crux platform are the submerged shoals of Goeree Shoal (13 km to the north-west), Eugene McDermott Shoal (18 km to the south-east) and Vulcan Shoal (22 km to the north-west) (Figure 1.1).

RPS

Table 1.1 Location of the proposed Crux platform used as the release site for the PFW dispersion modelling assessment.

Release Site	Latitude (°S)	Longitude (°E)	Water Depth (m)
Crux Platform	12° 57’ 52.46”	124° 26’ 33.21”	170

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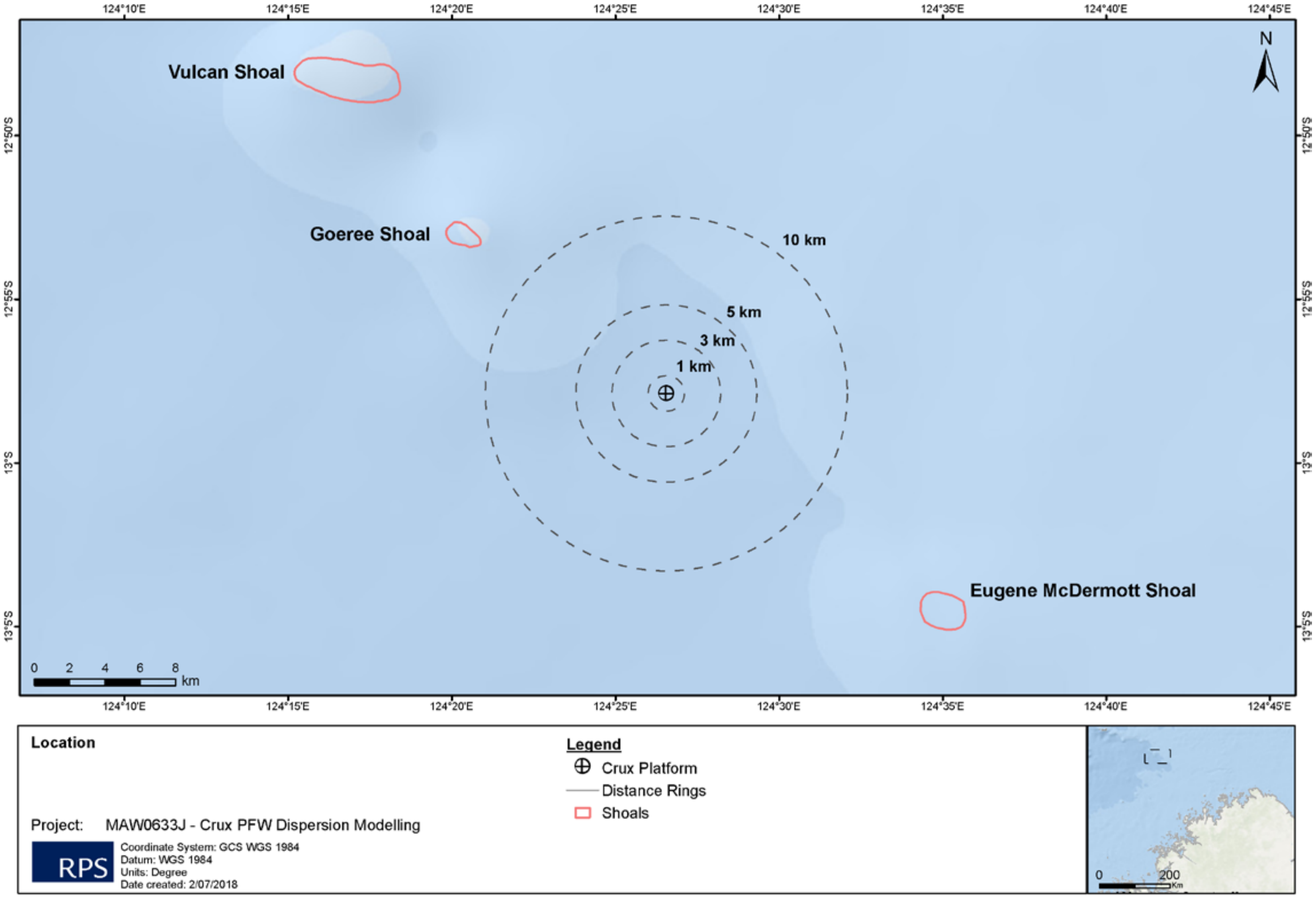


Figure 1.1 Location of the proposed Crux platform relative to the nearest submerged shoals.

1.2 Modelling Scope

The physical mixing of the PFW plume was first investigated for the near-field mixing zone. The limits of the near-field mixing zone are defined by the area where the levels of mixing and dilution are controlled by the plume's initial jet momentum and the buoyancy flux, resulting from density differences between the plume and the receiving water. When the plume encounters a boundary such as the water surface, near-field mixing is complete. At this point, the plume is considered to enter the far-field mixing zone.

The scope of the modelling included the following components:

1. Collation of a suitable three-dimensional, spatially-varying current data set surrounding the proposed Crux platform location for a ten-year (2008-2017) hindcast period. The current data set included the combined influence of drift and tidal currents and was suitably long as to be indicative of interannual variability in ocean currents. The current data set was validated against the metocean data collected in the Crux development area.
2. Derivation of statistical distributions for the current speed and directions for use in the near-field modelling. Analyses included percentile distributions and development of current roses. This analysis was important to ensure that current data samples applied in the dispersion model were statistically representative.
3. Collation of seasonally-varying vertical water density profiles at the Crux development area for use as input to the dispersion models.
4. Near-field modelling conducted for each unique discharge to assess the initial mixing of the discharge due to turbulence and subsequent entrainment of ambient water. This modelling was conducted at high spatial and temporal resolution (scales of metres and seconds, respectively).
5. Outcomes from the near-field modelling included estimates of the width, shape and orientation of the plumes, and resulting contaminant concentrations and dilutions, for each discharge at a range of incident current speeds.
6. Establishment of a far-field dispersion model to repeatedly assess discharge scenarios under different sample conditions, with each sample represented by a unique time-sequence of current flow, chosen at random from the time series of current data.
7. Analysis of the results of all simulations to quantify, by return frequency, the potential extent and shape of the mixing zone.

2 Modelling Methods

2.1 Near-Field Modelling

2.1.1 Overview

Numerical modelling was applied to quantify the area of influence of PFW water discharges, in terms of the distribution of the maximum contaminant concentrations that might occur with distance from the source given defined discharge configurations, source concentrations, and the distribution of the metocean conditions affecting the discharge location.

The dispersion of the PFW discharge will depend, initially, on the geometry and hydrodynamics of the discharges themselves, where the induced momentum and buoyancy effects dominate over background processes. This region is generally referred to as the near-field zone and is characterised by variations over short time and space scales. As the discharges mix with the ambient waters, the momentum and buoyancy signatures are eroded, and the background – or ambient – processes become dominant.

The shape and orientation of the discharged water plumes, and hence the distribution and dilution rate of the plume, will vary significantly with natural variation in prevailing water currents. Therefore, to best calculate the likely outcomes of the discharges, it is necessary to simulate discharge under a statistically representative range of current speeds representative of the Crux development area.

2.1.2 Description of Near-Field Model: Updated Merge

The near-field mixing and dispersion of the water discharge was simulated using the Updated Merge (UM3) flow model. The UM3 model is a three-dimensional Lagrangian steady-state plume trajectory model designed for simulating single and multiple-port submerged discharges in a range of configurations, available within the Visual Plumes modelling package provided by the United States Environmental Protection Agency (Frick *et al.*, 2003). The UM3 model was selected because it has been extensively tested for various discharges and found to predict observed dilutions more accurately (Roberts & Tian, 2004) than other near-field models (i.e. RSB and CORMIX).

In the UM3 model, the equations for conservation of mass, momentum, and energy are solved at each time step, giving the dilution along the plume trajectory. To determine the change of each term, UM3 follows the shear (or Taylor) entrainment hypothesis and the projected-area-entrainment (PAE) hypothesis, which quantifies forced entrainment in the presence of a background ocean current. The flows begin as round buoyant jets and can merge to a plane buoyant jet (Carvalho *et al.*, 2002). Model output consists of plume characteristics including centreline dilution, rise-rate, width, centreline height and plume diameter. Dilution is reported as the “effective dilution”, the ratio of the initial concentration to the concentration of the plume at a given point, following Baumgartner *et al.* (1994).

The near-field zone ends where the discharged plume reaches a physical boundary or assumes the same density as the ambient water.

Figure 2.1 shows a conceptual diagram of the dispersion and fates of a negatively buoyant discharge and the idealised representation of the discharge phases.

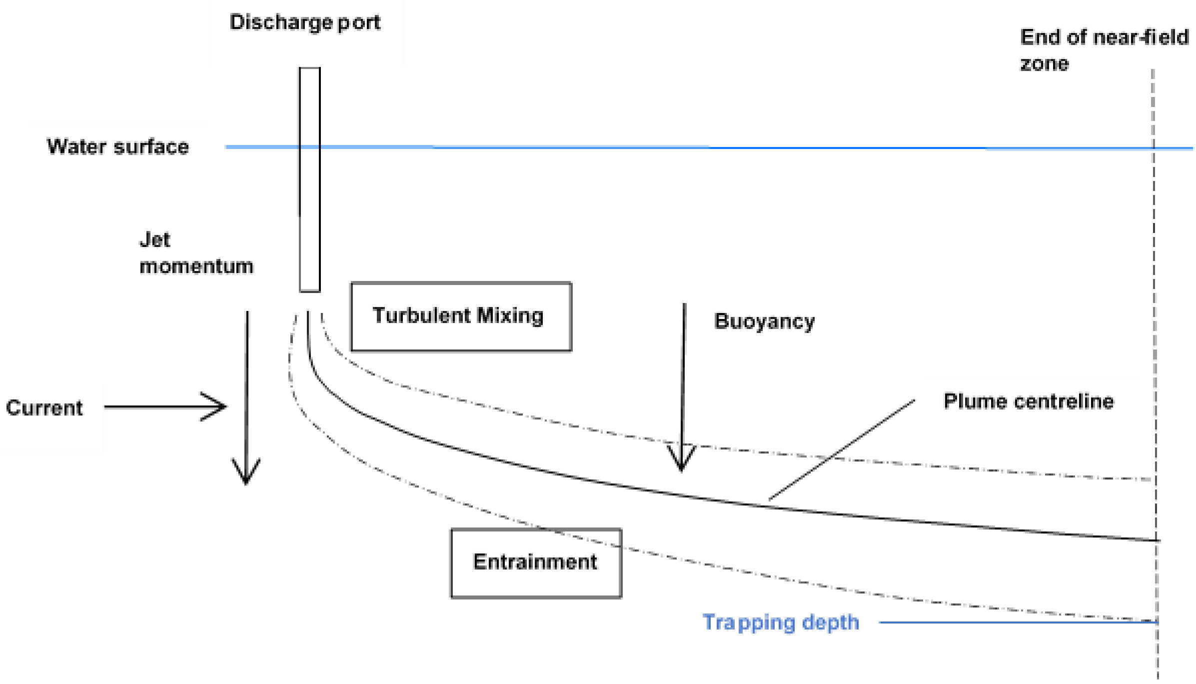


Figure 2.1 Conceptual diagram showing the general behaviour of a negatively buoyant discharge.

2.1.3 Setup of Near-Field Model

2.1.3.1 Discharge Characteristics

The PFW discharge characteristics are summarised in Table 2.1. The discharge was assumed to occur 10 m below the water surface through a single outlet, and was anticipated to have a salinity and temperature of 92.2 parts per thousand (ppt) and 44 °C, respectively.

During the modelling, it was identified that the PFW discharge location would likely be above the sea surface from the Crux platform. To account for this, an additional modelling exercise was undertaken to assess the potential changes in mixing and dilution that may occur if the PFW stream is discharged from the Crux platform above the sea surface rather than below the water surface. This supplemental report is provided in Appendix A and compares the near-field (and far-field) outcomes of one below-surface discharge scenario and one above-surface discharge scenario.

The volumes of PFW generated from the platform will vary over the life of the field. In general, PFW volumes are lowest at the start of production and peak towards the end of each field's lifecycle. Based on the engineering definitions available at the time of undertaking the dispersion modelling study, the maximum flow rates during early operations (i.e. first 8-9 years) and later in the field life (i.e. after year 9) are estimated as 287 m^3/d and 3,179.8 m^3/d, respectively.

Concentrations of constituents within the discharges are described in Table 2.2. These concentrations are conservative estimates for the pre-formation water breakthrough discharge which occurs earlier in the life of the operation. The required dilution factor relates to the number of dilutions required to achieve the 99% Species Protection Level threshold concentration, as defined in the Australian and New Zealand Environment and Conservation Council and Agricultural and Resource Management Council of Australia and New Zealand

(ANZECC & ARMCANZ) (2000) guidelines. This is the highest level of protection provided in the ANZECC & ARMCANZ (2000) guidelines for toxicants in marine water.

Table 2.1 Summary of PFW discharge characteristics.

Parameter	Value/Design
Flow rate (m^3/d)	287 (maximum flow rate during early operations) 3,179.8 (maximum flow rate during later operations)
Outlet pipe internal diameter (m) [in]	0.152 [6]
Outlet pipe orientation	Horizontal
Depth of pipe below sea surface (m)	10
Discharge salinity (ppt)	92.2
Discharge temperature (°C)	44

Table 2.2 Constituents contained within the PFW discharges.

Constituent	Source Concentration (mg/L)	99% Species Protection Level Threshold Concentration (as defined by the ANZECC & ARMCANZ (2000) Guidelines) (mg/L)	Required Dilution Factor to Reach 99% Species Protection Level
Benzene	240	0.5	480
Naphthalene, phenanthrene, dibenzothiophene (NPD)	10.7	$5.0*10^{-2}$	214
Phenol	0.757	0.27	2.8
Cadmium (Cd)	$4.6*10^{-3}$	$7.0*10^{-4}$	6.6
Chromium (III/VI) (Cr)	$2.48*10^{-2}$	$1.4*10^{-4}$	177.1
Copper (Cu)	$9.2*10^{-3}$	$3.0*10^{-4}$	30.7
Lead (Pb)	$4.6*10^{-3}$	$2.2*10^{-3}$	2.1
Nickel (Ni)	$1.91*10^{-2}$	$7.0*10^{-3}$	2.7
Zinc (Zn)	$2.94*10^{-2}$	$7.0*10^{-3}$	4.2

2.1.3.2 Ambient Environmental Conditions

Inputs of ambient environmental conditions to the UM3 model included a vertical profile of temperature and salinity, along with constant current speeds and general direction. The temperature and salinity profiles are required to accurately account for the buoyancy of the diluting plume, while the current speeds control the intensity of initial mixing and the deflection of the PFW plume. These inputs are described in the following sections.

2.1.3.2.1 Ambient Temperature and Salinity

Temperature and salinity data based on one year of measurements carried out at the Crux development area by RPS between April 2016 and May 2017 (2017) was supplied for the study.

Temperature and salinity data applied to the near-field modelling was sourced from the World Ocean Atlas 2013 (WOA13) database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration) and its co-located World Data Center for Oceanography (Levitus *et al.*, 2013).

For both data sets, annualised mean temperature profiles were calculated. Figure 2.2 presents a comparison of the WOA13 and RPS-measured annualised temperature profiles. From the profiles, it is evident that the WOA13 temperature structure offer a good match with the measured data and can be considered representative of the conditions in the Crux development area.

Table 2.3 shows the average seasonal water temperature and salinity levels at varying depths from 0 to 170 m. This data can be considered representative of seasonal conditions in the Crux development area.

The seasonal temperature profiles exhibit a reasonably consistent reduction in temperature with increasing depth. Salinity levels are generally more consistent and exhibit a vertically well-mixed water body (34.19 – 34.59 practical salinity unit, PSU), irrespective of season or depth.

RPS

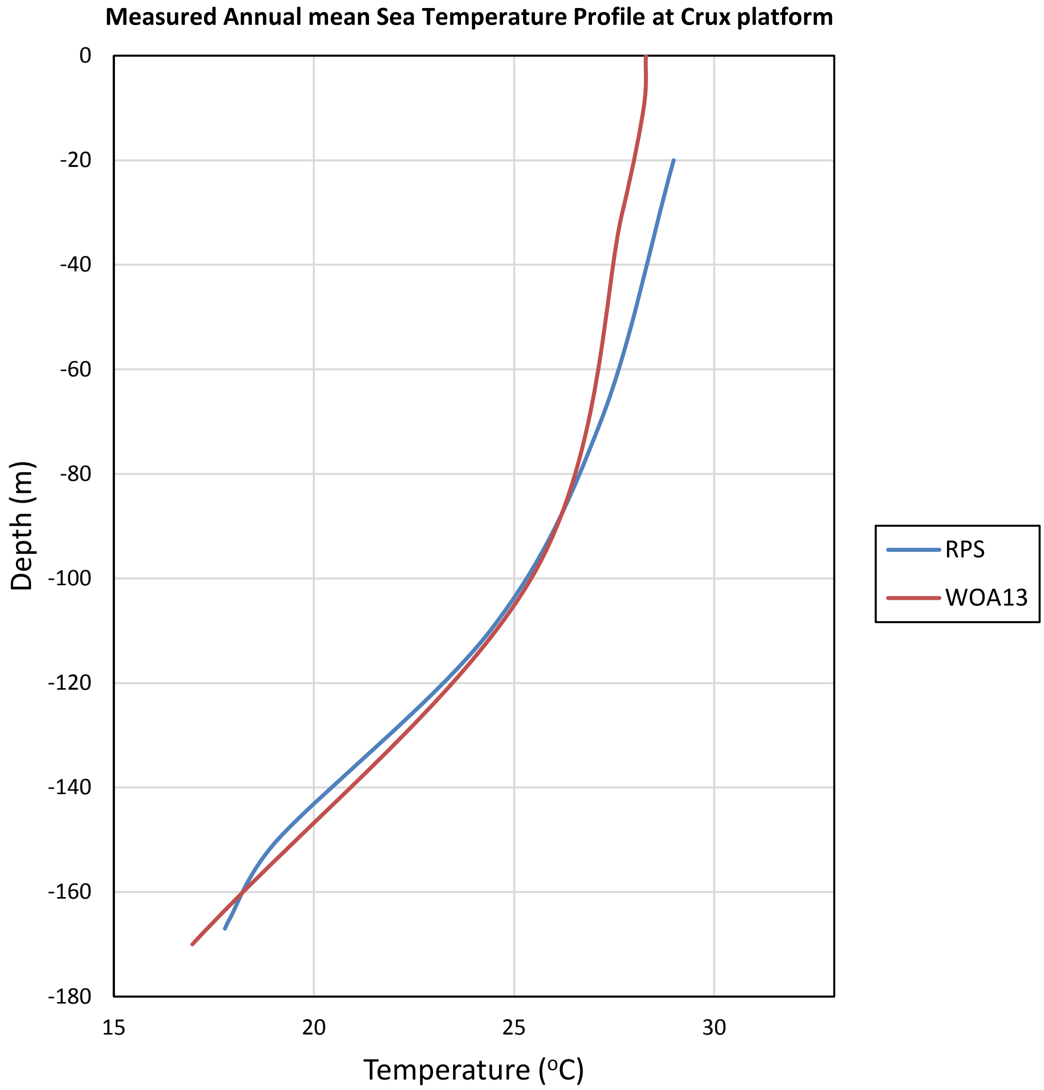


Figure 2.2 **Comparison of World Ocean Atlas 2013 and RPS measured annual temperature profiles at Crux platform location.**

Table 2.3 Average temperature and salinity levels adjacent to the proposed Crux platform.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	29.62	34.58
	10	29.54	34.57
	30	28.89	34.55
	100	25.35	34.54
	170	17.86	34.63
Transitional	0	27.34	34.19
	10	27.33	34.21
	30	27.18	34.23
	100	24.43	34.33
	170	16.25	34.59
Winter	0	28.49	34.34
	10	28.39	34.35
	30	27.48	34.39
	100	24.82	34.39
	170	16.98	34.59

2.1.3.2.2 Ambient Current

Ocean current data was sourced from a 10-year hindcast data set of combined large-scale ocean (HYCOM) and tidal currents. The data was statistically analysed to determine the 5th, 50th and 95th percentile current speeds. These statistical current speeds can be considered representative of seasonal conditions in the Crux development area.

Table 2.4 presents the steady-state, unidirectional current speeds at varying depths used as input to the near-field model as forcing for each discharge case:

- 5th percentile current speed: weak currents, low dilution and slow advection.
- 50th percentile (median) current speed: average currents, moderate dilution and advection.
- 95th percentile current speed: strong currents, high dilution and rapid advection to nearby areas.

The 5th, 50th and 95th percentile values are referenced as weak, medium and strong current speeds, respectively.

RPS

Table 2.4 Adopted ambient current conditions adjacent to the proposed Crux platform.

Season	Depth (m)	5th Percentile (Weak) Current Speed (m/s)	50th Percentile (Medium) Current Speed (m/s)	95th Percentile (Strong) Current Speed (m/s)
Summer	0	0.068	0.248	0.495
	10	0.060	0.218	0.415
	30	0.059	0.207	0.392
	100	0.055	0.193	0.378
	170	0.051	0.187	0.355
Transitional	0	0.063	0.223	0.434
	10	0.060	0.212	0.411
	30	0.057	0.206	0.400
	100	0.054	0.200	0.378
	170	0.050	0.191	0.357
Winter	0	0.058	0.216	0.455
	10	0.055	0.197	0.399
	30	0.054	0.194	0.386
	100	0.054	0.192	0.387
	170	0.051	0.187	0.347

2.2 Far-Field Modelling

2.2.1 Overview

The far-field modelling expands on the near-field work by allowing the time-varying nature of currents to be included, and the potential for recirculation of the plume back to the discharge location to be assessed. In this case, concentrations near the discharge point can be increased due to the discharge plume mixing with the remnant plume from an earlier time. This may be a potential source of episodic increases in pollutant concentrations in the receiving waters.

2.2.2 Description of Far-Field Model: MUDMAP

The mixing and dispersion of the discharges was predicted using the three-dimensional discharge and plume behaviour model, MUDMAP (Koh & Chang, 1973; Khondaker, 2000).

The far-field calculation (passive dispersion stage) employs a particle-based, random walk procedure. Any chemicals/constituents within the discharge stream are represented by a sample of Lagrangian particles. These particles are moved in three dimensions over each subsequent time step according to the prevailing local current data as well as horizontal and vertical mixing coefficients.

MUDMAP treats the Lagrangian particles as conservative tracers (i.e. they are not removed over time to account for chemical interactions, decay or precipitation). Predicted concentrations will therefore be conservative overestimates where these processes actually do occur. Each particle represents a proportion of the discharge, by mass, and particles are released at a given rate to represent the rate of the discharge (mass per unit time). Concentrations of constituents are predicted over time by counting the number of particles that occur within a given depth level and grid square and converting this value to mass per unit volume.

The system has been extensively validated and applied for discharge operations in Australian waters (e.g. Burns *et al.*, 1999; King & McAllister, 1997, 1998).

2.2.3 Stochastic Modelling

A stochastic modelling procedure was applied in the far-field modelling to sample a representative set of conditions that could affect the distribution of constituents. This approach involves multiple (100) simulations of a given discharge scenario and season, with each simulation being carried out under a randomly-selected period of currents. This methodology ensures that the calculated movement and fate of each discharge is representative of the range of prevailing currents at the discharge location. Once the stochastic modelling is complete, all simulations are statistically analysed to develop the distribution of outcomes based on time and event.

2.2.4 Setup of Far-Field Model

2.2.4.1 Discharge Characteristics

The MUDMAP model simulated the discharge into a time-varying current field with the initial dilution set by the near-field results described in Section 2.1.

Both PFW discharge flow rates were modelled as a continuous discharge using 100 simulations for each season. Once the simulations were complete, they were reported on a seasonal basis: (i) summer (December to February); (ii) transitional (March and September to November) and (iii) winter (April to August).

Table 2.5 Summary of far-field PFW discharge modelling assumptions.

Parameter	Value/Design
Hindcast modelling period	2008 to 2017
Seasons	Summer (December to February) Transitional (March and September to November) Winter (April to August)
Flow rate (m^3/d)	287 (maximum flow rate during early operations phase) 3,179.8 (maximum flow rate during later operations phase)
Discharge salinity (ppt)	92.2
Discharge temperature (ºC)	44
Number of simulations	300 (100 per season)
Simulated discharge type	Continuous
Simulated discharge period (days)	5

2.2.4.2 Mixing Parameters

The horizontal and vertical dispersion coefficients represent the mixing and diffusion caused by turbulence, both of which are sub-grid-scale processes. Both coefficients are expressed in units of rate of area change per second (m^2/s). Increasing the horizontal dispersion coefficient will increase the horizontal spread of the discharge plume and decrease the centreline concentrations faster. Increasing the vertical dispersion coefficient spreads the discharge across the vertical layers (or depths) faster.

Spatially constant, conservative dispersion coefficients of 0.15 m^2/s and 0.00005 m^2/s were used to control the spreading of the PFW plume in the horizontal and vertical directions, respectively. Each of the mixing parameters was selected following extensive sensitivity testing to recreate the plume characteristics predicted by the near-field modelling. It would be expected that the in-situ mixing dynamics would be greater under average and high energy conditions by a factor of 10 (King & McAllister, 1997, 1998) and thus the far-field model results are designed to produce a worst-case result for concentration extents.

2.2.4.3 Grid Configuration

MUDMAP uses a three-dimensional grid to represent the geographic region under study (water depth and bathymetric profiles). Due to the rapid mixing and small-scale effect of the effluent discharge, it was necessary to use a fine grid with a resolution of 20 m x 20 m to track the movement and fate of the discharge plume. The extent of the grid region measured approximately 20 km (longitude or x-axis) by 20 km (latitude or y-axis), which was subdivided horizontally into 1,000 x 1,000 cells. The vertical resolution was set to 1 m.

2.2.5 Regional Ocean Currents

2.2.5.1 Overview

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region of the Kimberley Coast. However, the offshore regions with water depths exceeding 100-200 m experience significant large-scale drift 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 contaminant plumes over time scales exceeding a few hours.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (hours to days) and result in long trajectories. Hence, the current-induced transport of plumes can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is important to consider all these potential advective mechanisms to rigorously understand patterns of potential transport from a given discharge location.

To appropriately allow for temporal and spatial variation in the current field, dispersion modelling requires the current speed and direction over a spatial grid covering the potential migration zone of plumes. Estimates of the net currents were derived by combining predictions of the drift currents, available from a mesoscale ocean model, with estimates of the tidal currents generated by an RPS model set up for the study area. These estimates are considered representative of the oceanographic currents that influence the Crux development area. Shell has also collected 12 months of metocean data in the Crux development area, with this data being used to validate the hydrodynamic model used in this modelling study. Refer to Section 2.2.5.4 for further discussion of the tidal and current model validation.

A composite modelled ocean current data product was derived by combining predictions of mesoscale circulation currents, available at daily resolution from global ocean models, with predictions of the hourly tidal currents generated by the RPS HYDROMAP model. By combining a drift current model with a tidal model, the influences of inter-annual and seasonal drift patterns, and the more regular variations in tide, were included.

2.2.5.2 Mesoscale Circulation

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 2.3. They are characterised as follows:

- **Buoyancy driven circulation**. The main buoyancy-driven feature in the region is the Indonesian Throughflow (ITF) 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.

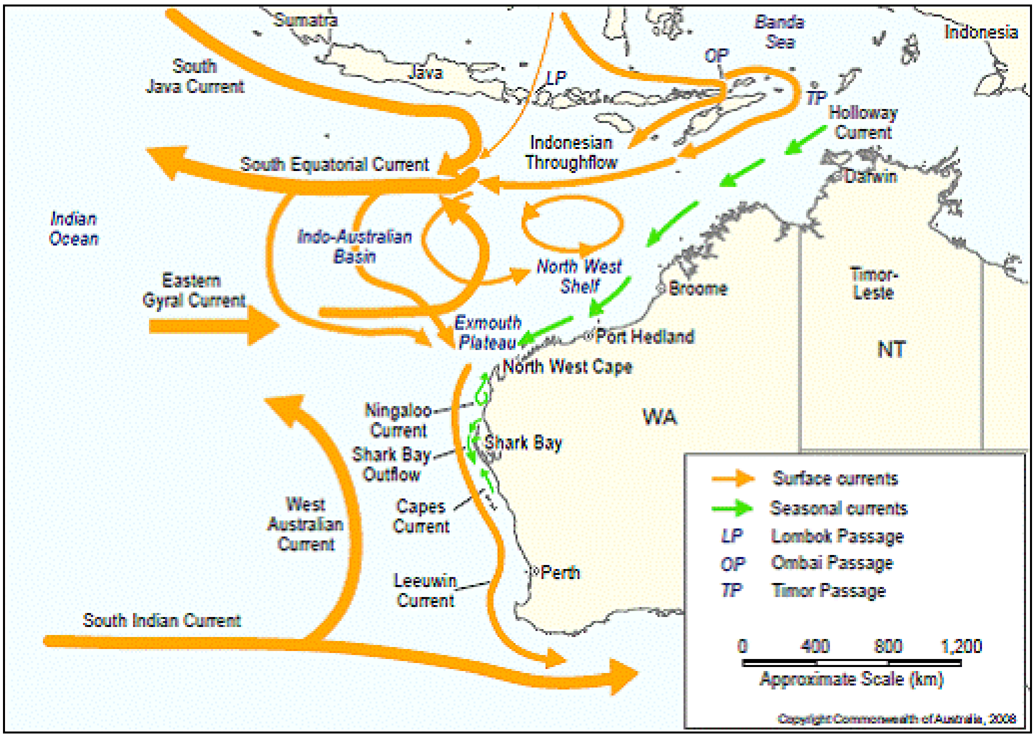


Figure 2.3 A map of the major currents off the West Australian coast (DEWHA, 2008).

RPS

2.2.5.2.1 Description of 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 2008 to 2017 (inclusive).

Figure 2.4 shows the seasonal surface current roses near the proposed Crux platform. The data shows that the surface current speeds and directions vary between seasons. In general, during summer (December to February) currents have the strongest average speed (0.25 m/s with a maximum of 0.65 m/s) and tend to flow west-southwest. During winter (April to August), current flow conditions are more variable and flow mostly toward the west-southwest and east-northeast. During transitional conditions (March and September to November), the current flow is less variable and predominantly toward the west.

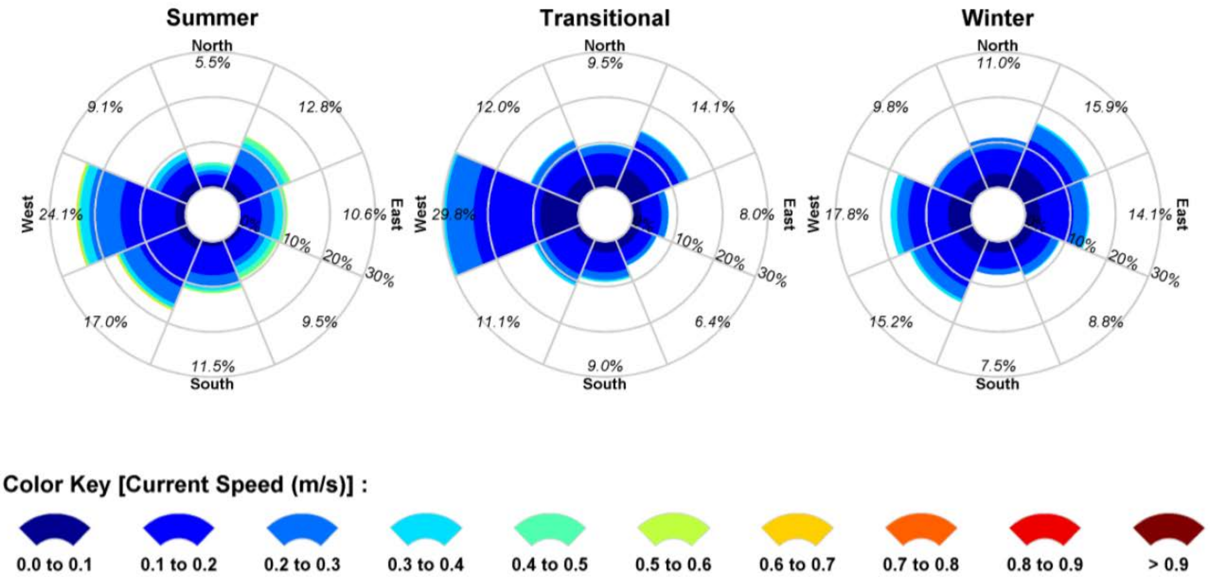


Figure 2.4 Seasonal current distribution (2008-2017, inclusive) derived from the HYCOM database near to the proposed Crux platform. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.2.5.3 Tidal Currents

2.2.5.3.1 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) (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 particular 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).

2.2.5.3.2 Tidal Grid Setup

A HYDROMAP model was established over a domain that extended approximately 3,300 km east-west by 3,100 km north-south over the eastern Indian Ocean. The grid extends beyond Eucla in the south and beyond Bathurst Island in the north (Figure 2.5).

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 98,600 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.

2.2.5.3.3 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.

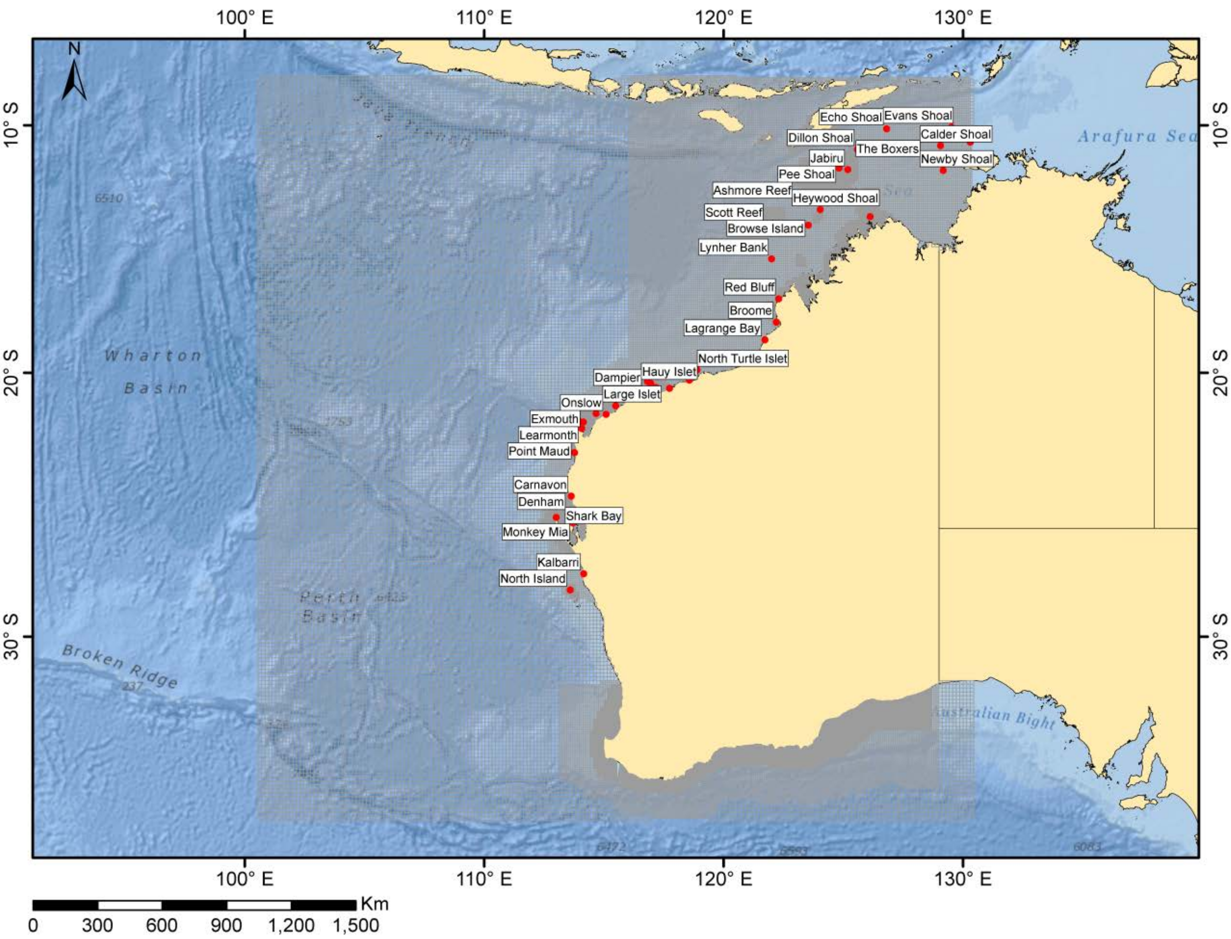


Figure 2.5 Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing the full domain in context with the continental land mass and the locations available for tidal comparisons (red labelled dots). Higher-resolution areas are indicated by the denser mesh zones.

2.2.5.4 Tidal and Current Model Validation

The suitability of the modelled tidal and drift current data products was evaluated by comparing the predicted currents to those measured at the Crux development area. The following sections describe the sources of both the modelled and measured data, the comparison methodology, and the outcomes of the comparisons for both the tidal and drift current components.

2.2.5.4.1 Data Sources

A tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP. HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. This model is described in Section 2.2.5.3.

A mesoscale ocean current data sets was selected for the study: HYCOM (Hybrid Coordinate Ocean Model) Consortium's global ocean model, HYCOM. This model is described in Section 2.2.5.2.

A data set of measured currents was collected by RPS at the Crux development area between April 2016 and May 2017 (RPS, 2017). This data set includes a series of point current measurements made at six depths through the water column using CM04 current meters mounted on a floating mooring. The measurement depths are approximately 20 m, 70 m, 110 m, 150 m, 165 m and 167 m below the water surface. The temporal resolution of the data is 1 minute. The raw data was quality-controlled by RPS and only data identified as high-quality was used for comparison to model data. For the measurements at a 20 m water depth, there is approximately a 7-week gap in the data between early September and late October 2016.

2.2.5.4.2 Model Validation Skills

Overview

The mesoscale and tidal current models were validated through quantitative and visual comparisons of measured and modelled data.

Statistics

A quantitative analysis of a model's skill at replicating the environmental conditions was conducted using the Index of Agreement (IOA), presented in Willmott (1981), and the Mean Absolute Error (MAE), discussed in Willmott (1982) and Willmott & Matsuura (2005). Other traditional error estimates, such as the correlation coefficient and the root mean square error (RMSE) are problematic and prone to ambiguities and bias (Willmott & Matsuura, 2005; Willmott, 1982). Consequently, they are not reported in isolation here.

The MAE is simply the average of the absolute values of the differences between the observed and modelled values. MAE is a more natural measure of average error (Willmott & Matsuura, 2005) and more readily understood. The IOA is determined using the following formula:

$$\mathrm{IOA} = 1 - \frac{\sum |X_{\mathrm{model}} - X_{\mathrm{obs}}|^2}{\sum \left(|X_{\mathrm{model}} - \overline{X_{\mathrm{obs}}}| + |X_{\mathrm{obs}} - \overline{X_{\mathrm{obs}}}| \right)^2}$$

In this equation, X represents the variable being compared and $\bar{X}$ represents the mean of that variable over time.

A perfect agreement can be said to exist between the model and field observations if the IOA gives a measure of one, and complete disagreement will produce an IOA measure of zero (Wilmott, 1981). Although it is difficult to find guidelines for what values of the IOA might represent a good agreement, Willmott *et al.* (1985) suggests that values meaningfully larger than 0.5 represent good model performance. Clearly, the higher the IOA and the lower the MAE, the better the model performance.

An important point to note regarding both, and in fact most, measures of model performance, is that slight phase differences in the series can result in a seemingly poor statistical comparison, particularly in rapidly changing series such as tidal direction or water elevation where the tidal range is large. It is therefore always important to consider both the statistics and the visual representation of the comparison (Willmott *et al.*, 1985). Statistical comparison of current direction can be misleading; skill measures of direction can become biased where the directional fluctuations are near 0-360°. Therefore, we have based the quantitative assessment on the U and V current components and not magnitude and direction.

RPS

Time Series

In addition to bulk statistical measures, model performance for the measurement period was assessed visually with the aid of scatterplots and rose plots. The scatterplots show the correlation between the x- and y-components of the measured and modelled data. The rose plots show the frequency of current direction by sector, and magnitude by colour, to allow comparison of current direction between modelled and measured data.

The model performance was also evaluated against time series plots of water level, U (east-west) velocity component, V (north/south) velocity component, current speed and current direction data. This approach is valuable because statistical measures of model skill can heavily penalise errors in phase (i.e. time lags) even when the dynamics of flow are broadly reproduced.

2.2.5.4.3 Tidal Elevation Validation

For verification of the tidal elevation 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 Crux development area were used for comparison.

Time series comparisons were completed for a six-month period from January to June 2010. The statistics are summarised in Table 2.6, and indicate excellent model performance in this region. Water level time series for these locations are shown in Figure 2.6, Figure 2.7 and Figure 2.8 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.

For the purposes of understanding the limitations in accuracy of the tidal predictions, the RMSE and MAE in Table 2.6 should be noted. On average, the model predictions are within 0.1-0.3 m of XTide predictions based on known constituent data at any point in time. Often the error is mostly attributable to errors of phase in the tidal signal, with the magnitude of the tidal rise and fall over each tide well represented. However, in the application of the data predictions to operational circumstances, the potential errors should be considered.

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 2.9. 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.

RPS

Table 2.6 Statistical comparison of predicted surface elevation data from HYDROMAP and XTide at 18 locations in the tidal model domain (January to July 2010).

Tide Station	Longitude (°E)	Latitude (°S)	IOA	CC	MAE (m)	RMSE (m)
Ashmore Reef	123.02	12.22	0.99	0.99	0.14	0.18
Browse Island	123.55	14.10	0.97	0.97	0.36	0.45
Calder Shoal	129.07	10.85	0.97	0.97	0.17	0.21
Cape Legendre	116.83	20.35	0.99	0.99	0.12	0.14
Dillon Shoal	125.60	11.00	0.97	0.95	0.18	0.22
Echo Shoal	126.82	10.15	0.97	0.94	0.17	0.21
Evans Shoal	129.53	10.08	0.98	0.98	0.11	0.14
Goodrich Bank	130.32	10.70	0.99	0.97	0.13	0.16
Heywood Shoal	124.05	13.47	0.98	0.96	0.27	0.33
Jabiru	125.20	11.83	097	0.95	0.22	0.27
Loxton Shoal	128.72	09.60	0.99	0.98	0.10	0.13
Lynedoch Bank	130.82	10.03	0.98	0.98	0.12	0.15
Lynher Bank	122.02	15.47	0.98	0.97	0.26	0.31
Newby Shoal	129.18	11.87	0.98	0.96	0.23	0.27
Pee Shoal	124.83	11.77	0.97	0.94	0.23	0.27
Scott Reef	121.80	14.05	0.99	0.98	0.16	0.19
The Boxers	128.35	11.45	0.97	0.96	0.16	0.20
Troughton Island	126.13	13.75	0.97	0.95	0.27	0.33

Notes:
IOA — *Index of Agreement – values close to 1 represent a high level of agreement.*
CC — *Correlation Coefficient – values close to 1 represent very good correlation.*
MAE — *Mean Absolute Error – the lower the value, the smaller the error.*
RMSE — *Root Mean Square Error – the lower the value, the smaller the error.*

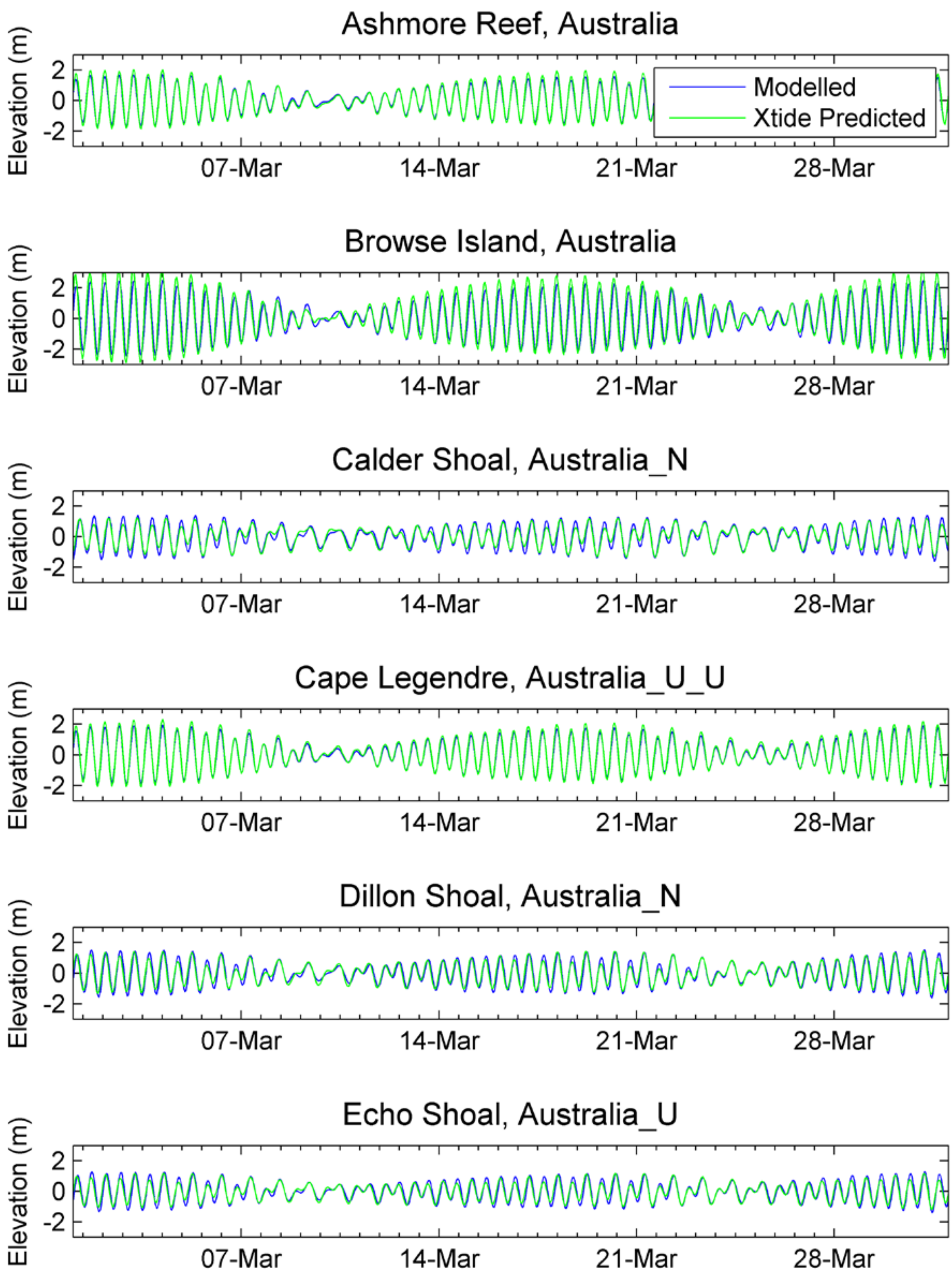


Figure 2.6 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

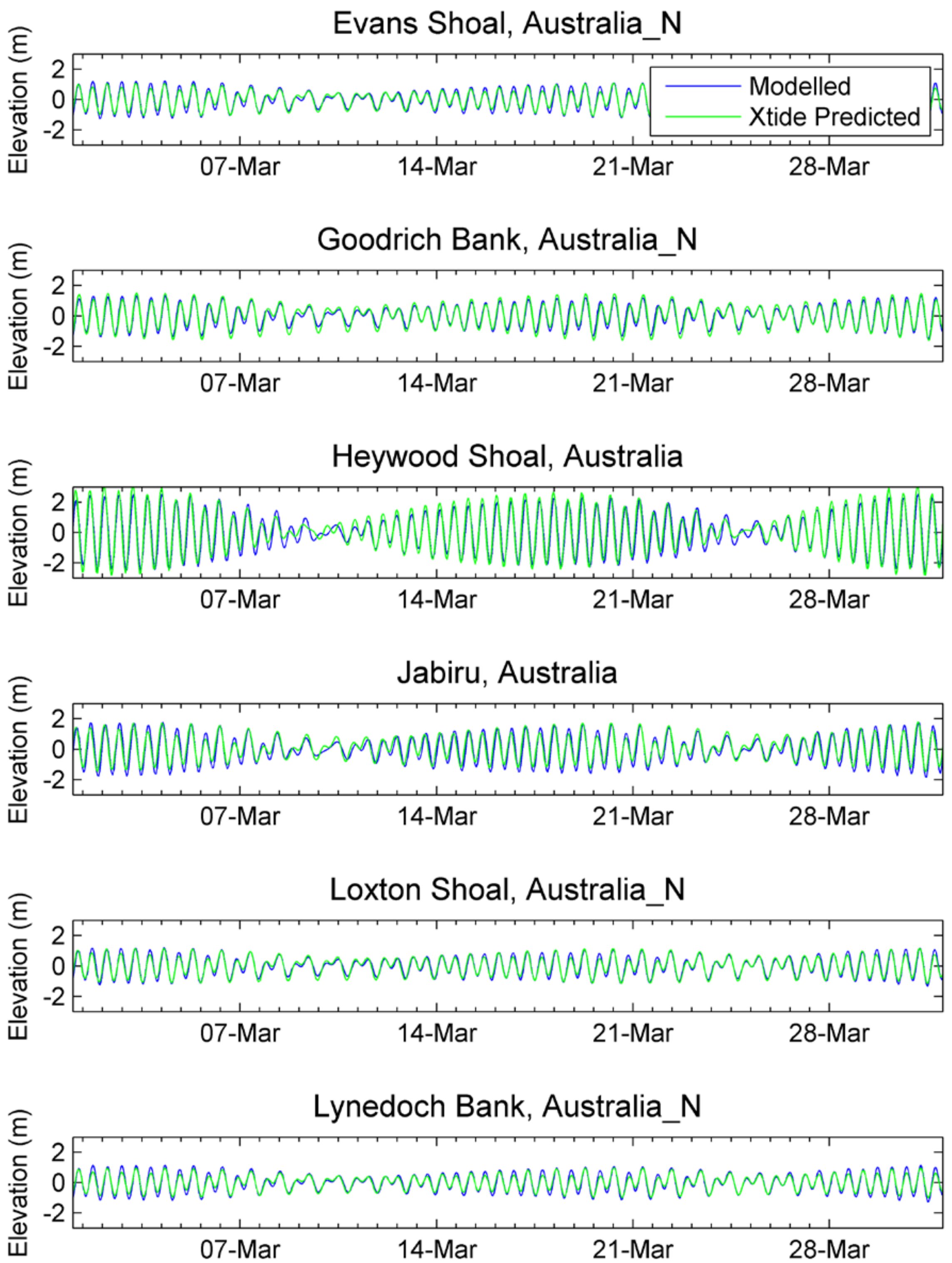


Figure 2.7 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

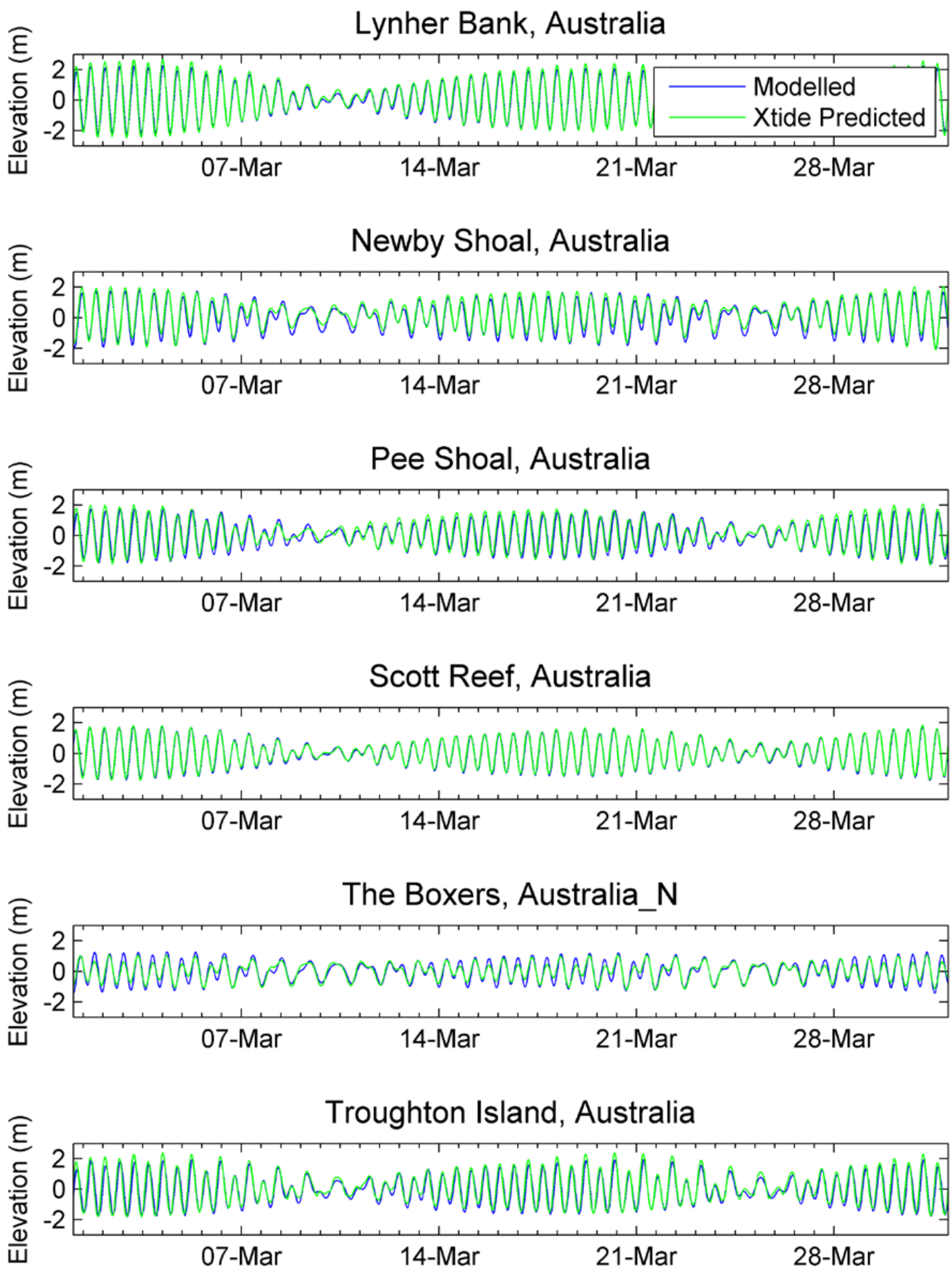
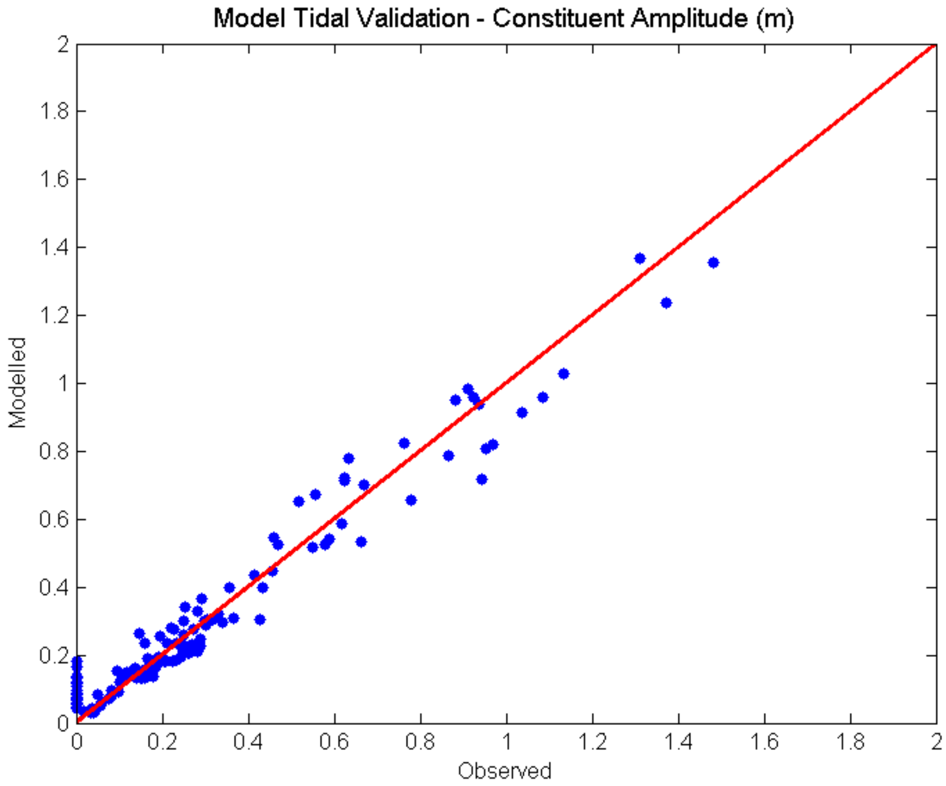


Figure 2.8 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).



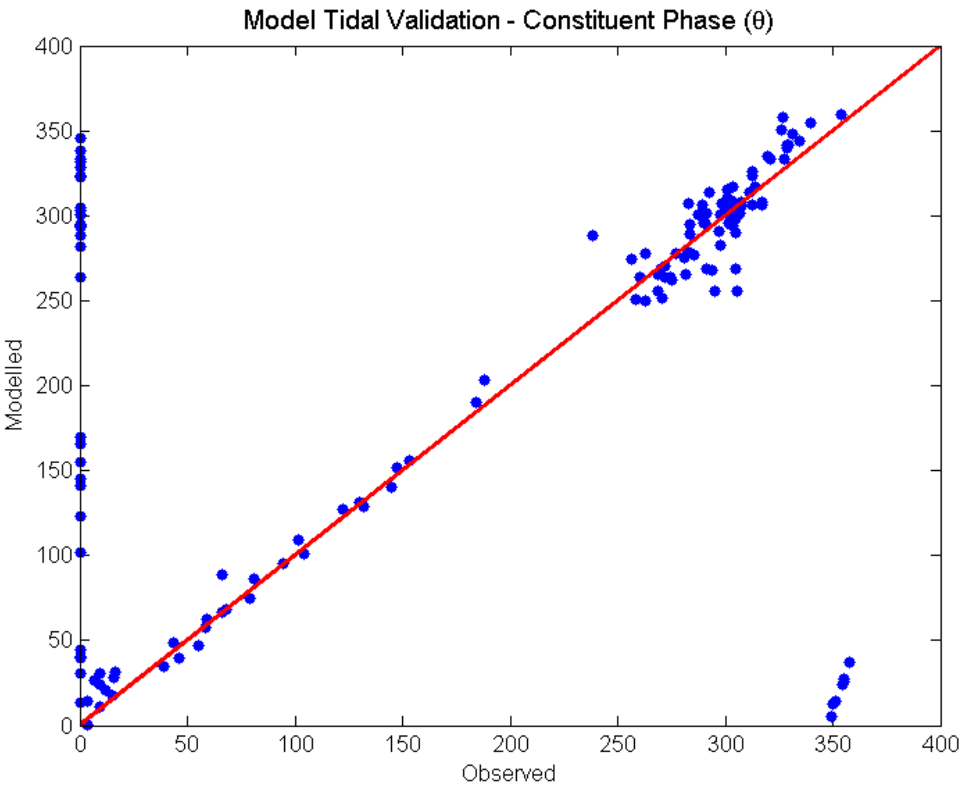


Figure 2.9 Comparisons between predicted tidal constituent amplitudes (top) and phases (bottom) from HYDROMAP and XTide at all stations in the tidal model domain. The red line indicates a 1:1 correlation between the respective data sets.

RPS

2.2.5.4.4 Composite Current Data Set Validation: HYDROMAP + HYCOM

A composite modelled ocean current data product was derived by combining predictions of mesoscale circulation currents, available at daily resolution from the HYCOM ocean model, with predictions of the hourly tidal currents generated by the RPS HYDROMAP model.

To verify the modelled current predictions, the composite model outputs at the Crux development area were compared against the unfiltered site-specific current measurements. The model results were validated through both quantitative and visual comparisons between measured and modelled data at each depth where both data sets were available.

Time series comparison of composite model outputs and measured current magnitude, direction, and U/V velocity components at water depths of 20 m, 70 m and 110 m are presented in Figure 2.10, Figure 2.11 and Figure 2.12, respectively, for one month during winter (June 2016) and summer (December 2016). The time series comparisons reveal that the composite model offers a good match with the measured U/V velocity components at all water depths in both winter and summer, with the magnitudes and timings of the peaks and troughs matching well.

The IOA and MAE values derived from comparisons of the U/V velocity components at water depths of 20 m, 70 m and 110 m over the full measurement period are presented in Table 2.7. The IOA for each velocity component is high at all water depths, reflecting the good match in the magnitudes and timings of the peaks and troughs in the composite model data and measured data. The MAE for the U/V velocity components is relatively low at approximately 0.1 m/s for all water depths, indicating that the magnitude and range of the velocity components match well; however, a slight overprediction of the current magnitude is evident at times.

To compare directionality, roses for the composite model outputs and measured currents at 20 m, 70 m and 110 m water depths over the full measurement period are shown in Figure 2.12. The roses show that the composite model current direction is a good match with the measured direction. A shift in the dominant current direction from a north/south alignment in the measured data set to a northwest/southeast alignment in the composite model data set is evident at the 20 m water depth, and to a lesser extent also at the 70 m water depth. However, the range and variability in the measured current direction is captured by the composite model data, which matches best with the measured data at the water depth of 110 m.

Based on the validation performance, the composite model data set is a good model of standard conditions at the Crux development area and will adequately resolve local and regional circulation patterns. As such, the model is considered suitable for use in the numerical modelling studies conducted as part of the Crux project.

Table 2.7 Statistical comparison of predicted (HYDROMAP+HYCOM) and observed current speeds along orthogonal component axes at the Crux development area (2016-2017).

Skill Measure	Index of Agreement (IOA)			Mean Absolute Error (MAE) (m/s)		
Depth (m)	20	70	110	20	70	110
U Component	0.72	0.75	0.76	0.11	0.11	0.11
V Component	0.82	0.80	0.78	0.11	0.10	0.10

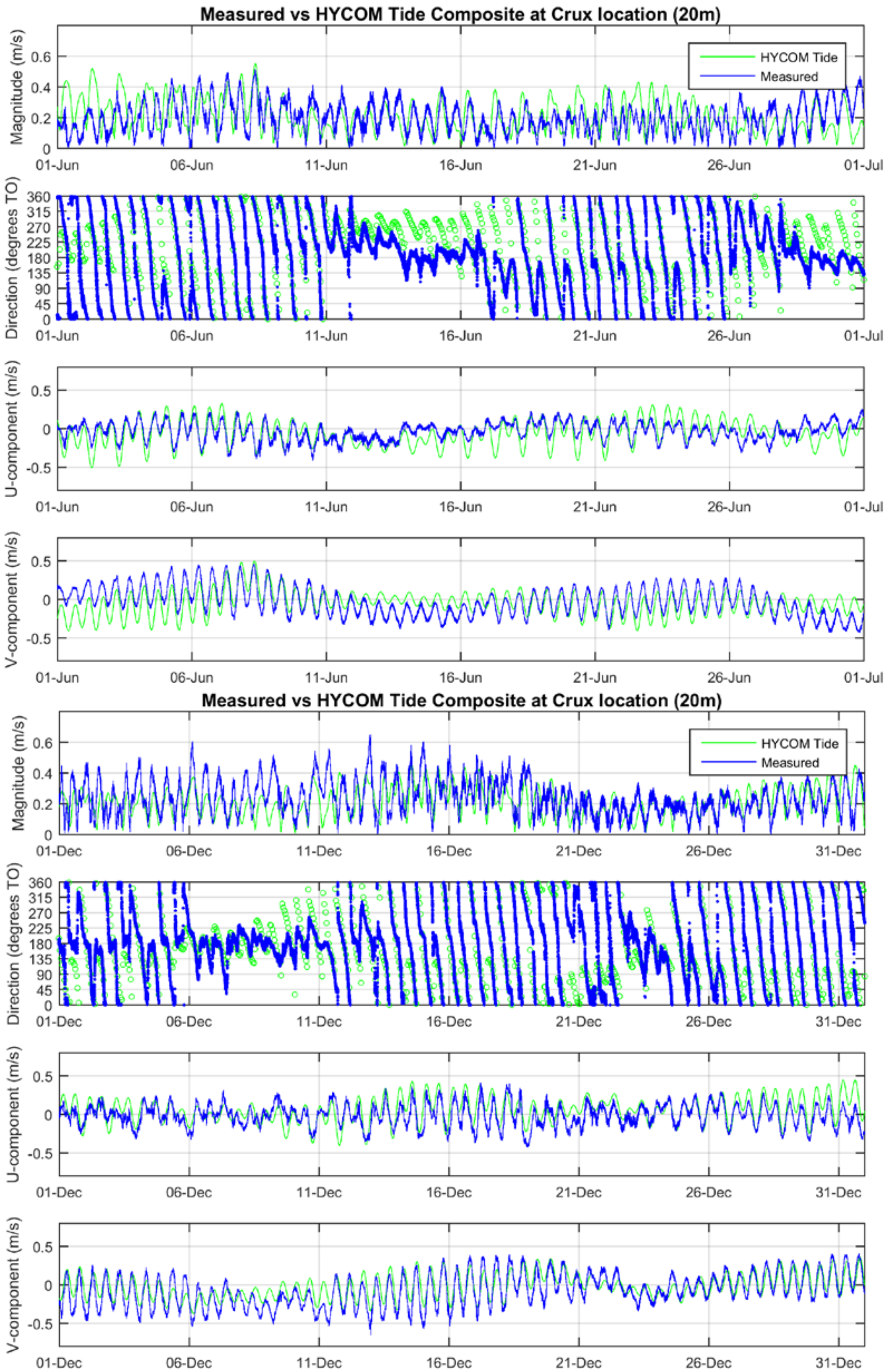


Figure 2.10 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 20 m for June 2016 (top panel) and December 2016 (bottom panel).

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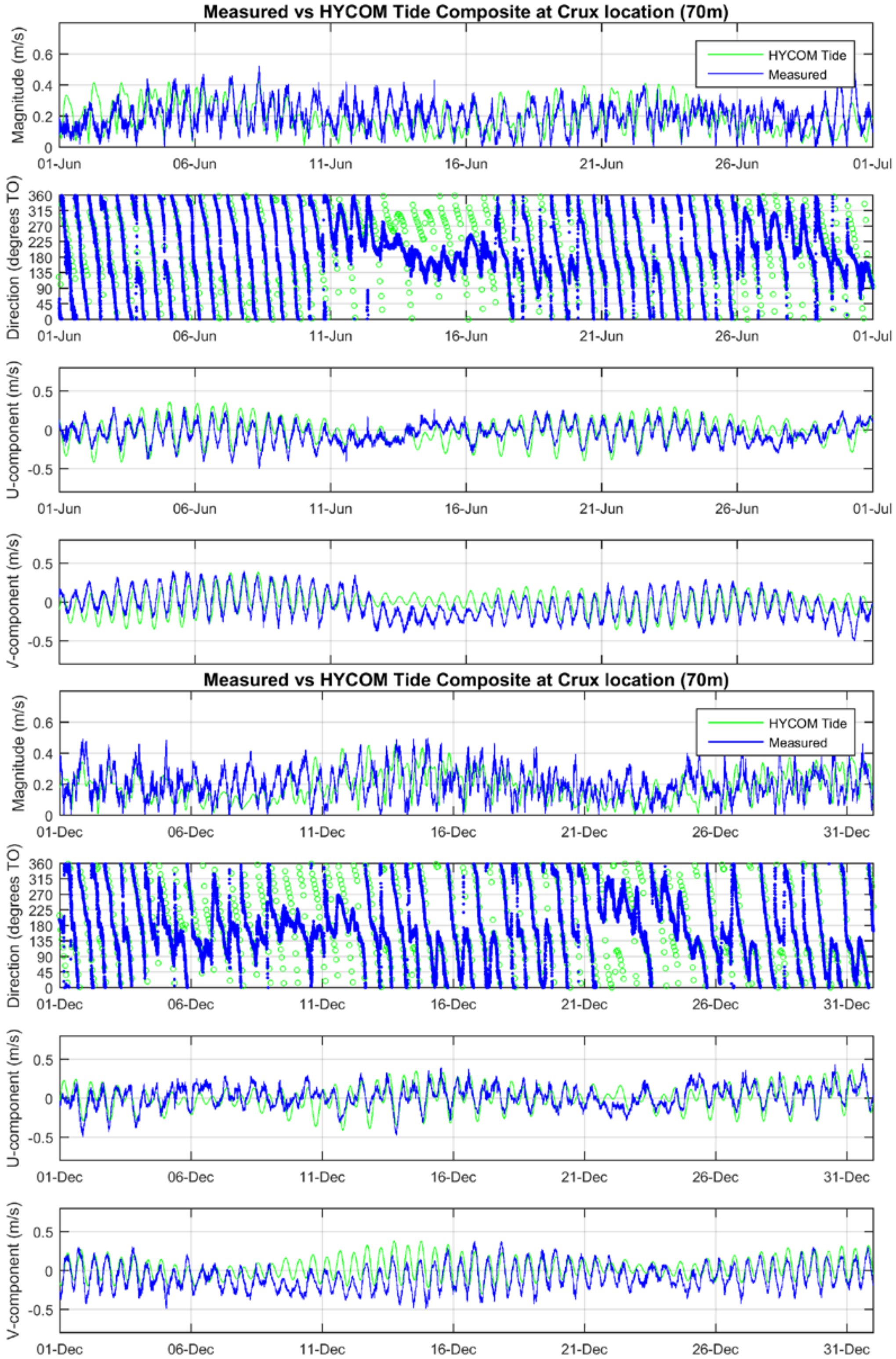

Figure 2.11 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 70 m for June 2016 (top panel) and December 2016 (bottom panel).

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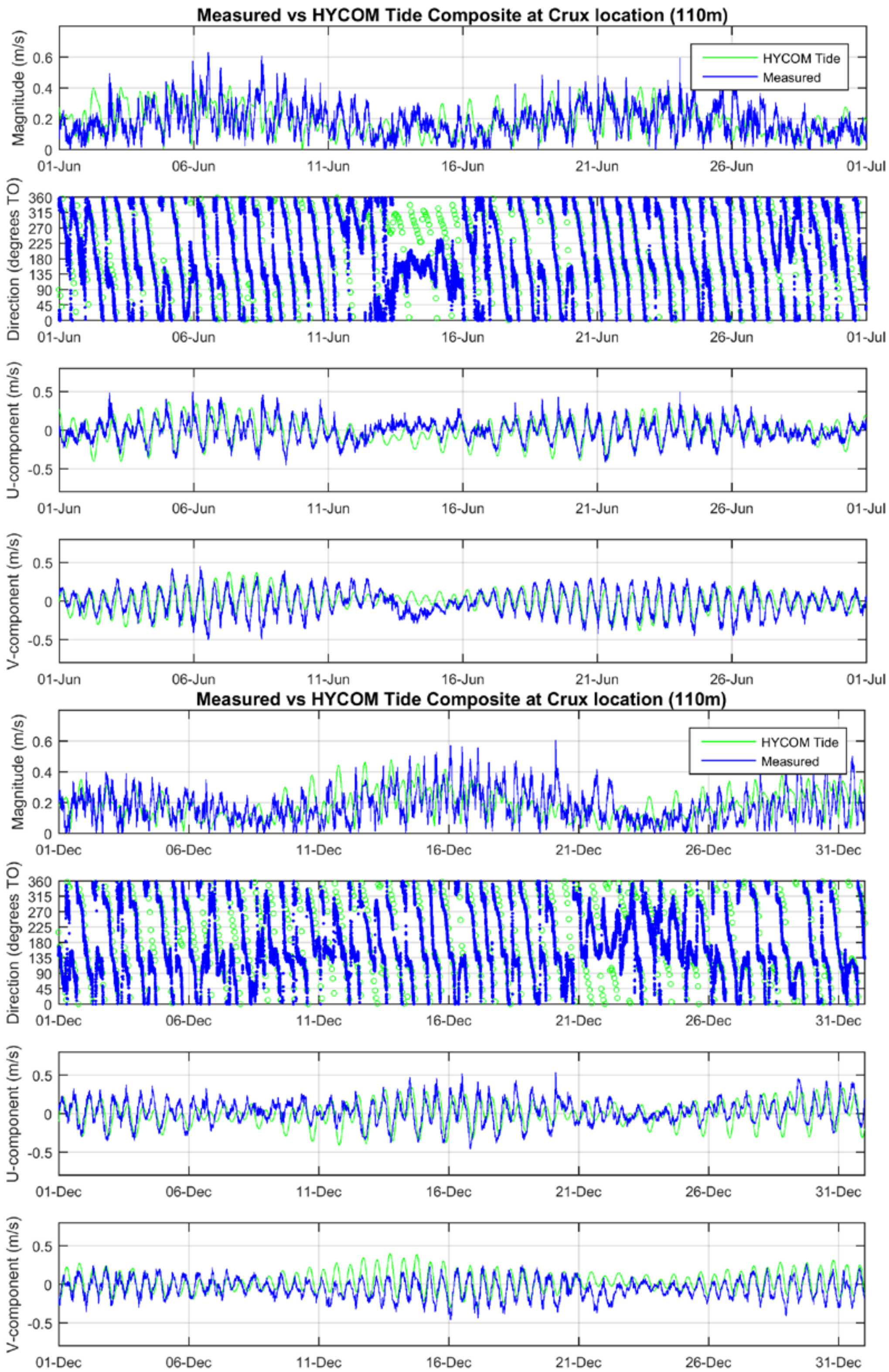

Figure 2.12 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 110 m for June 2016 (top panel) and December 2016 (bottom panel).

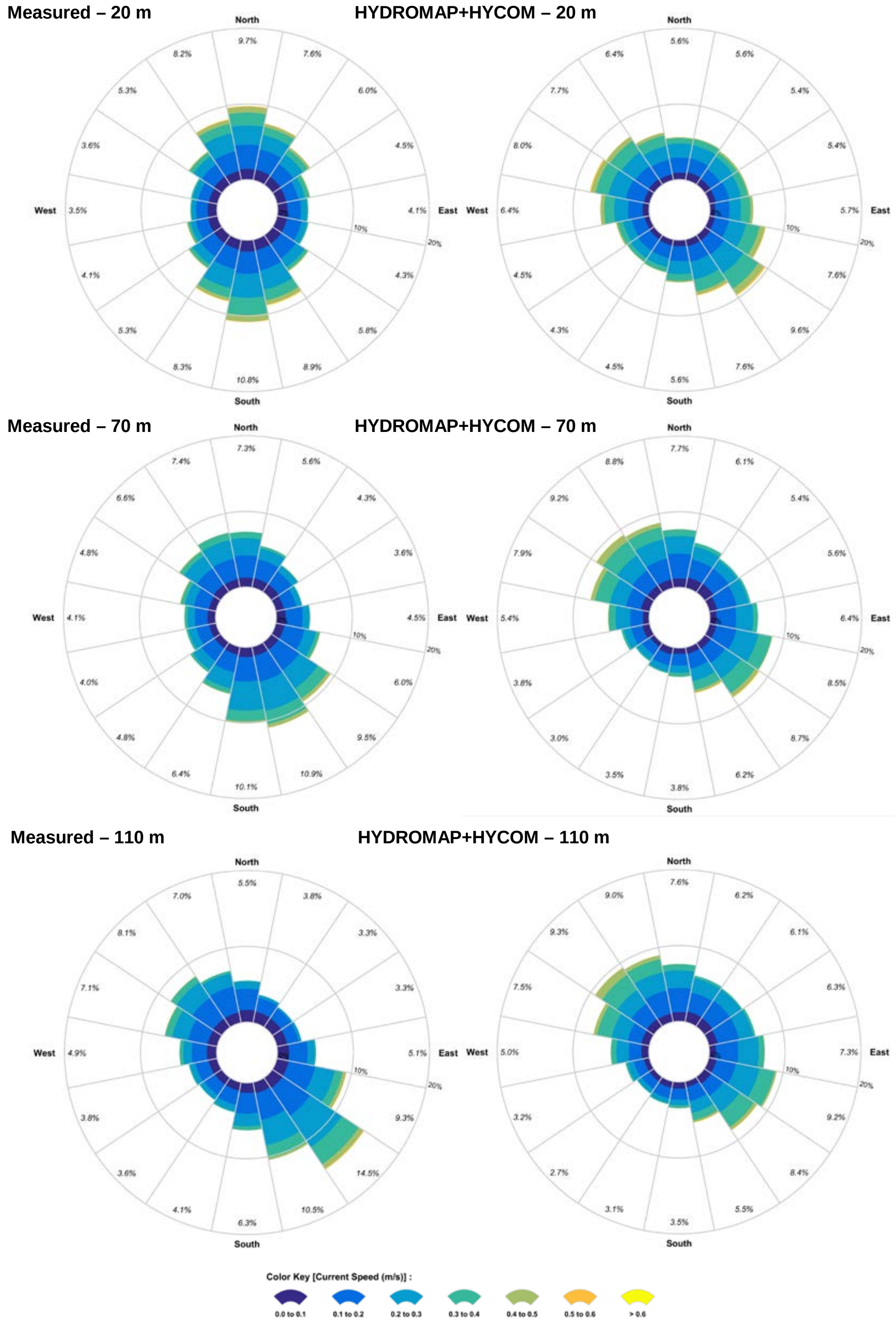

Figure 2.13 Comparative distributions for measured (left column) and predicted (HYDROMAP+HYCOM, right column) current data at the Crux development area (2016-2017) at depths of approximately 20 m (top row), 70 m (middle row) and 110 m (bottom row). The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

3 Modelling Results

3.1 Near-Field Modelling

3.1.1 Overview

In the following sections, two tables are presented for each of the modelled flow rates. The first table summarises the predicted plume characteristics in the near-field mixing zone under varying current speeds. The second table summarises the concentrations of all constituents at the end of the near-field mixing zone, the concentration threshold, and the amount of dilution. Any dilution rates indicated in red show that suitable dilution is not achieved during the near-field stage for at least one current-speed case.

Figure 3.1 to Figure 3.6 (note the differing x-axis and y-axis aspect ratios) show the change in average temperature and dilution of the plume under varying flow rates (287 m^3/d and 3,179.8 m^3/d), seasonal conditions (summer, transitional and winter) and current speeds (weak, medium and strong). The figures show the predicted horizontal distances travelled by the plume before the trapping depth is reached (i.e. before the plume becomes neutrally buoyant).

The results show that due to the momentum of the discharge a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 10 m below the water surface. An increased flow rate is shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the negatively buoyant plumes are predicted to plunge in the water column. The plume is predicted to plunge between 14 m and 55 m below the sea surface depending on flow rate and season. Increased ambient current strengths are shown to reduce the plunge depth and increase the horizontal distance travelled by the plume from the discharge point.

Table 3.1 and Table 3.5 show the predicted plume characteristics for the varying flow rates, seasonal conditions and current speeds. The high currents in the winter season pushed the plume to maximum horizontal distances of 252.3 m and 235.7 m for the 287 m^3/d and 3.179.8 m^3/d flow rate discharges, respectively. The diameter of the plume at the end of the near-field zone ranged from 6 m to 19.5 m for a flow rate of 287 m^3/d, and 13.4 m to 30.2 m for a flow rate of 3.179.8 m^3/d. Increases in current speed serve to restrict the diameter of the plume.

For all seasons and flow rates, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution (Table 3.1 and Table 3.5). The average dilution levels of the plume upon reaching the trapping depth under medium and strong currents are predicted to be 1:2,760 and 1:3,471 for the 287 m^3/d flow rate, and 1:1,219 and 1:1,568 for the 3.179.8 m^3/d flow rate, respectively. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under medium and strong currents are predicted to be 1:792 and 1:894 for the 287 m^3/d flow rate, and 1:318 and 1:406 for the 3.179.8 m^3/d flow rate, respectively. Note that these predictions rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

The results for the 287 m^3/d flow rate (Section 3.1.2; Table 3.2 to Table 3.4) and 3.179.8 m^3/d flow rate (Section 3.1.3; Table 3.6 to Table 3.8) indicate that all constituents of the PFW discharge are expected to reach the required levels of dilution in the near field mixing zone.

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3.1.2 Early Operations Phase: Flow Rate of 287 m^3/d

Table 3.1 Predicted plume characteristics at the end of the near-field mixing zone for the early operations phase flow rate (287 m^3/d) for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth Below Sea Level (BSL) [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.06)	12.8 [23.8]	29.21	0.12	592	2,293	19.5
	Medium (0.22)	8.7 [16.5]	29.40	0.07	999	3,864	72.1
	Strong (0.42)	7.0 [15.1]	29.44	0.06	1,238	4,789	133.0
Transitional	Weak (0.06)	10.8 [30.8]	27.99	0.15	423	1,631	15.1
	Medium (0.21)	7.4 [20.1]	28.22	0.09	712	2,760	54.1
	Strong (0.41)	6.0 [17.7]	28.26	0.05	894	3,471	108.5
Winter	Weak (0.05)	19.5 [22.0]	27.21	0.04	1,265	4,895	31.1
	Medium (0.20)	13.4 [15.6]	27.28	0.03	2,129	8,259	118.4
	Strong (0.40)	10.7 [14.4]	27.29	0.02	2,746	10,635	252.3

Table 3.2 Concentrations of all constituents at the end of the near-field stage, and the threshold concentrations and number of dilutions for the summer season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 2,293, 3,864 and 4,789, respectively.

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			ANZECC & ARMCANZ Threshold Concentration (mg/L)	Required Dilution Factor to Reach 99% Species Protection Level (1:x)
		5th %ile (weak currents)	50th %ile (medium currents)	95th %ile (strong currents)		
		2,293x dilution	3,864x dilution	4,789x dilution		
Benzene	240	$1.0*10^{-2}$	$6.2*10^{-3}$	$5.0*10^{-3}$	0.5	480.0
NPD	10.7	$4.7*10^{-3}$	$2.8*10^{-3}$	$2.2*10^{-3}$	$5.0*10^{-2}$	214.0
Phenol	0.757	$3.3*10^{-4}$	$2.0*10^{-4}$	$1.6*10^{-4}$	0.27	2.8
Cadmium (Cd)	$1.0*10^{-4}$	$4.4*10^{-8}$	$2.6*10^{-8}$	$2.1*10^{-8}$	$7.0*10^{-4}$	6.6
Chromium (III/VI) (Cr)	$7.0*10^{-4}$	$3.1*10^{-7}$	$1.8*10^{-7}$	$1.5*10^{-7}$	$1.4*10^{-4}$	177.1
Copper (Cu)	$3.0*10^{-4}$	$1.3*10^{-7}$	$7.8*10^{-8}$	$6.3*10^{-8}$	$3.0*10^{-4}$	30.7
Lead (Pb)	$1.0*10^{-4}$	$4.4*10^{-8}$	$2.6*10^{-8}$	$2.1*10^{-8}$	$2.2*10^{-3}$	2.1
Nickel (Ni)	$3.0*10^{-4}$	$1.3*10^{-7}$	$7.8*10^{-8}$	$6.3*10^{-8}$	$7.0*10^{-3}$	2.7
Zinc (Zn)	$8.0*10^{-4}$	$3.5*10^{-7}$	$2.1*10^{-7}$	$1.7*10^{-7}$	$7.0*10^{-3}$	4.2

RPS

Table 3.3 Concentrations of all constituents at the end of the near-field stage, and the threshold concentrations and number of dilutions for the transitional season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 1,631, 2,760 and 3,471, respectively.

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			ANZECC & ARMCANZ Threshold Concentration (mg/L)	Required Dilution Factor to Reach 99% Species Protection Level (1:x)
		5th %ile (weak currents)	50th %ile (medium currents)	95th %ile (strong currents)		
		1,631x dilution	2,760x dilution	3,471x dilution		
Benzene	240	$1.5*10^{-2}$	$8.7*10^{-3}$	$6.9*10^{-3}$	0.5	480.0
NPD	10.7	$6.6*10^{-3}$	$3.9*10^{-3}$	$3.1*10^{-3}$	$5.0*10^{-2}$	214.0
Phenol	0.757	$4.6*10^{-4}$	$2.7*10^{-4}$	$2.2*10^{-4}$	0.27	2.8
Cadmium (Cd)	$1.0*10^{-4}$	$6.1*10^{-8}$	$3.6*10^{-8}$	$2.9*10^{-8}$	$7.0*10^{-4}$	6.6
Chromium (III/VI) (Cr)	$7.0*10^{-4}$	$4.3*10^{-7}$	$2.5*10^{-7}$	$2.0*10^{-7}$	$1.4*10^{-4}$	177.1
Copper (Cu)	$3.0*10^{-4}$	$1.8*10^{-7}$	$1.1*10^{-7}$	$8.6*10^{-8}$	$3.0*10^{-4}$	30.7
Lead (Pb)	$1.0*10^{-4}$	$6.1*10^{-8}$	$3.6*10^{-8}$	$2.9*10^{-8}$	$2.2*10^{-3}$	2.1
Nickel (Ni)	$3.0*10^{-4}$	$1.8*10^{-7}$	$1.1*10^{-7}$	$8.6*10^{-8}$	$7.0*10^{-3}$	2.7
Zinc (Zn)	$8.0*10^{-4}$	$4.9*10^{-7}$	$2.9*10^{-7}$	$2.3*10^{-7}$	$7.0*10^{-3}$	4.2

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Table 3.4 Concentrations of all constituents at the end of the near-field stage, and the threshold concentrations and number of dilutions for the winter season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 4,895, 8,259 and 10,635, respectively.

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			ANZECC & ARMCANZ Threshold Concentration (mg/L)	Required Dilution Factor to Reach 99% Species Protection Level (1:x)
		5th %ile (weak currents)	50th %ile (medium currents)	95th %ile (strong currents)		
		4,895x dilution	8,259x dilution	10,635x dilution		
Benzene	240	$4.9*10^{-3}$	$2.9*10^{-3}$	$2.3*10^{-3}$	0.5	480.0
NPD	10.7	$2.2*10^{-3}$	$1.3*10^{-3}$	$1.0*10^{-3}$	$5.0*10^{-2}$	214.0
Phenol	0.757	$1.5*10^{-4}$	$9.2*10^{-5}$	$7.1*10^{-5}$	0.27	2.8
Cadmium (Cd)	$1.0*10^{-4}$	$2.0*10^{-8}$	$1.2*10^{-8}$	$9.4*10^{-9}$	$7.0*10^{-4}$	6.6
Chromium (III/VI) (Cr)	$7.0*10^{-4}$	$1.4*10^{-7}$	$8.5*10^{-8}$	$6.6*10^{-8}$	$1.4*10^{-4}$	177.1
Copper (Cu)	$3.0*10^{-4}$	$6.1*10^{-8}$	$3.6*10^{-8}$	$2.8*10^{-8}$	$3.0*10^{-4}$	30.7
Lead (Pb)	$1.0*10^{-4}$	$2.0*10^{-8}$	$1.2*10^{-8}$	$9.4*10^{-9}$	$2.2*10^{-3}$	2.1
Nickel (Ni)	$3.0*10^{-4}$	$6.1*10^{-8}$	$3.6*10^{-8}$	$2.8*10^{-8}$	$7.0*10^{-3}$	2.7
Zinc (Zn)	$8.0*10^{-4}$	$1.6*10^{-7}$	$9.7*10^{-8}$	$7.5*10^{-8}$	$7.0*10^{-3}$	4.2

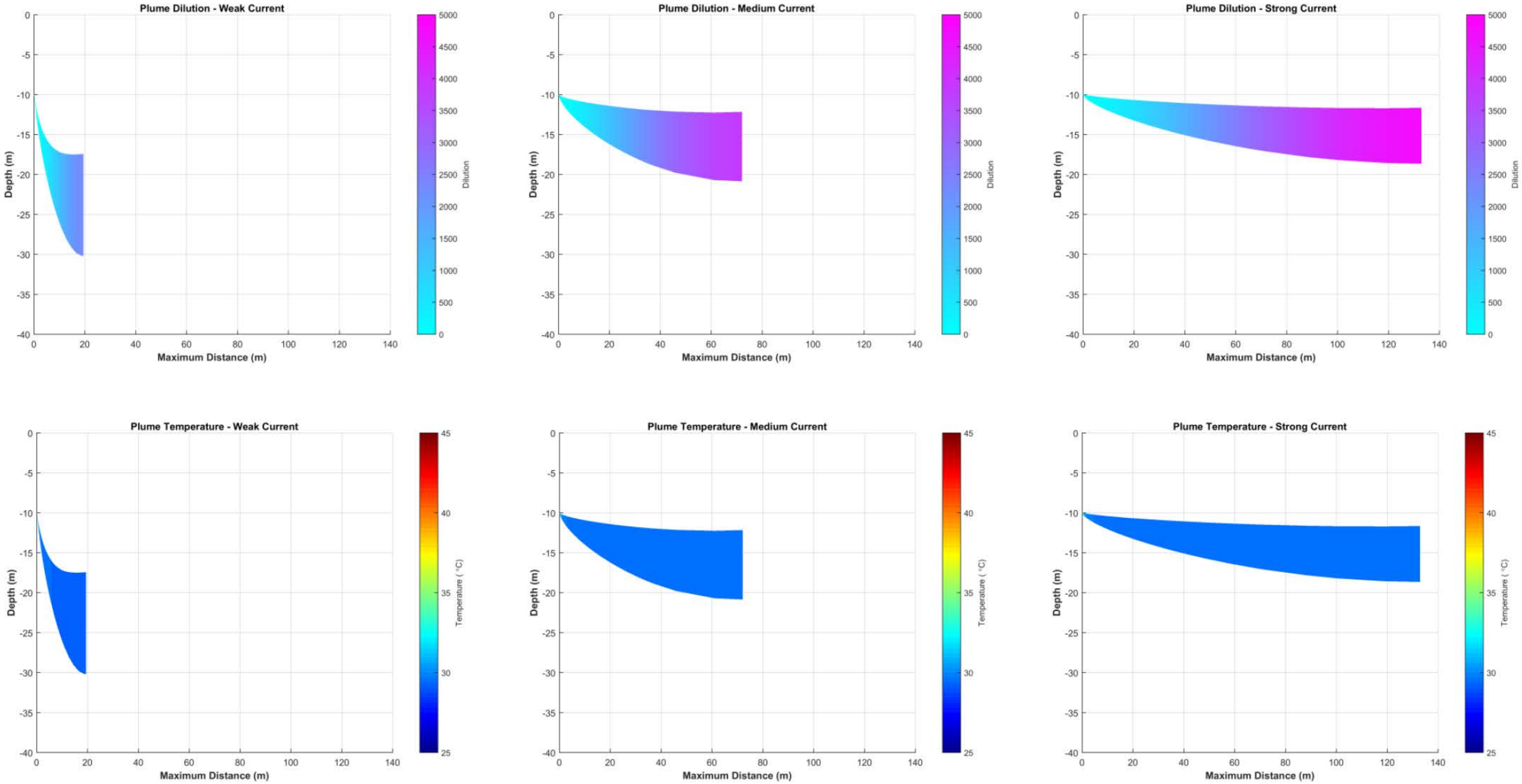

Figure 3.1 **Near-field average temperature and dilution results for weak, medium and strong summer currents (287 m^3/d flow rate).**

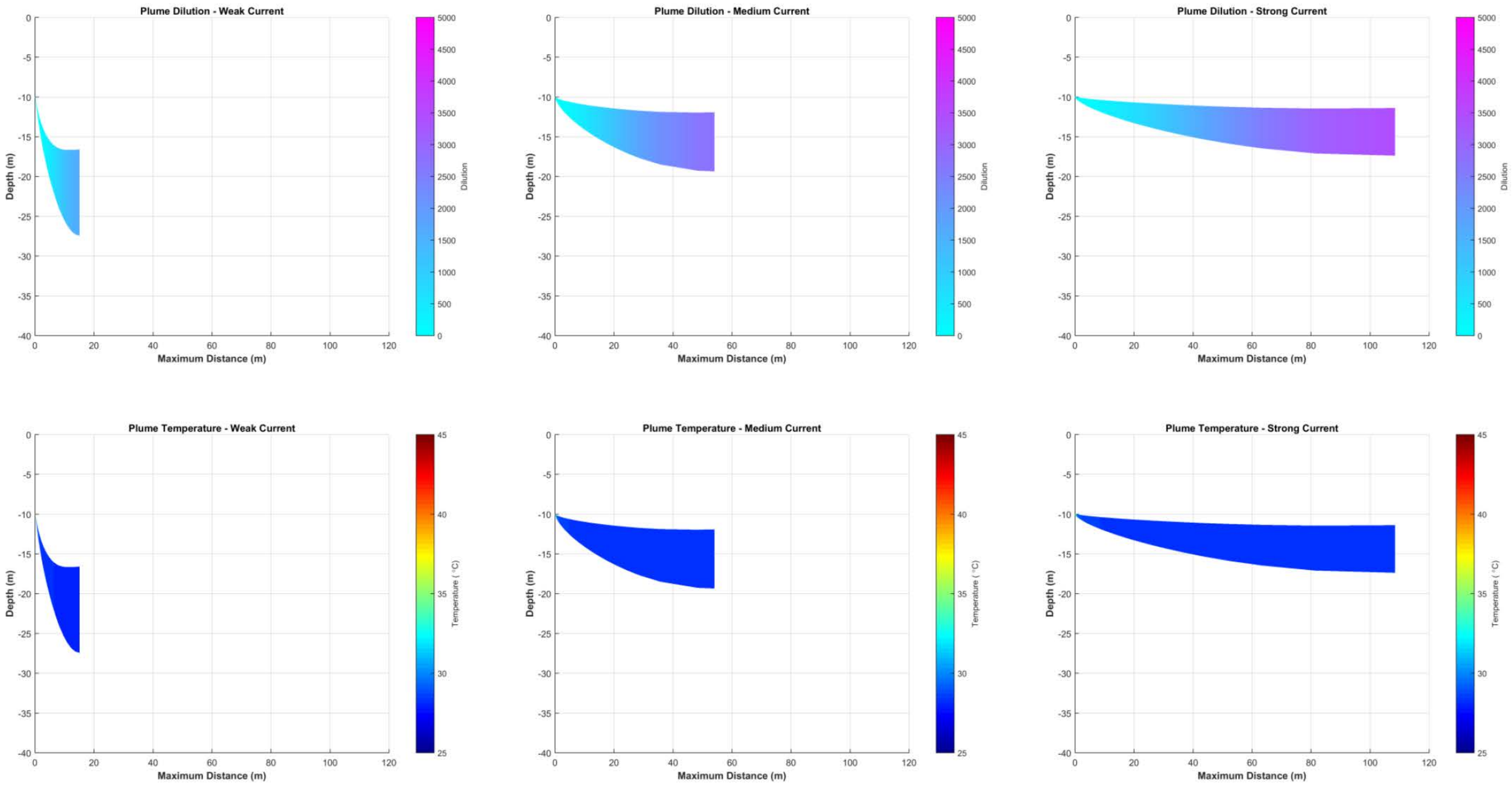

Figure 3.2 Near-field average temperature and dilution results for weak, medium and strong transitional currents (287 m^3/d flow rate).

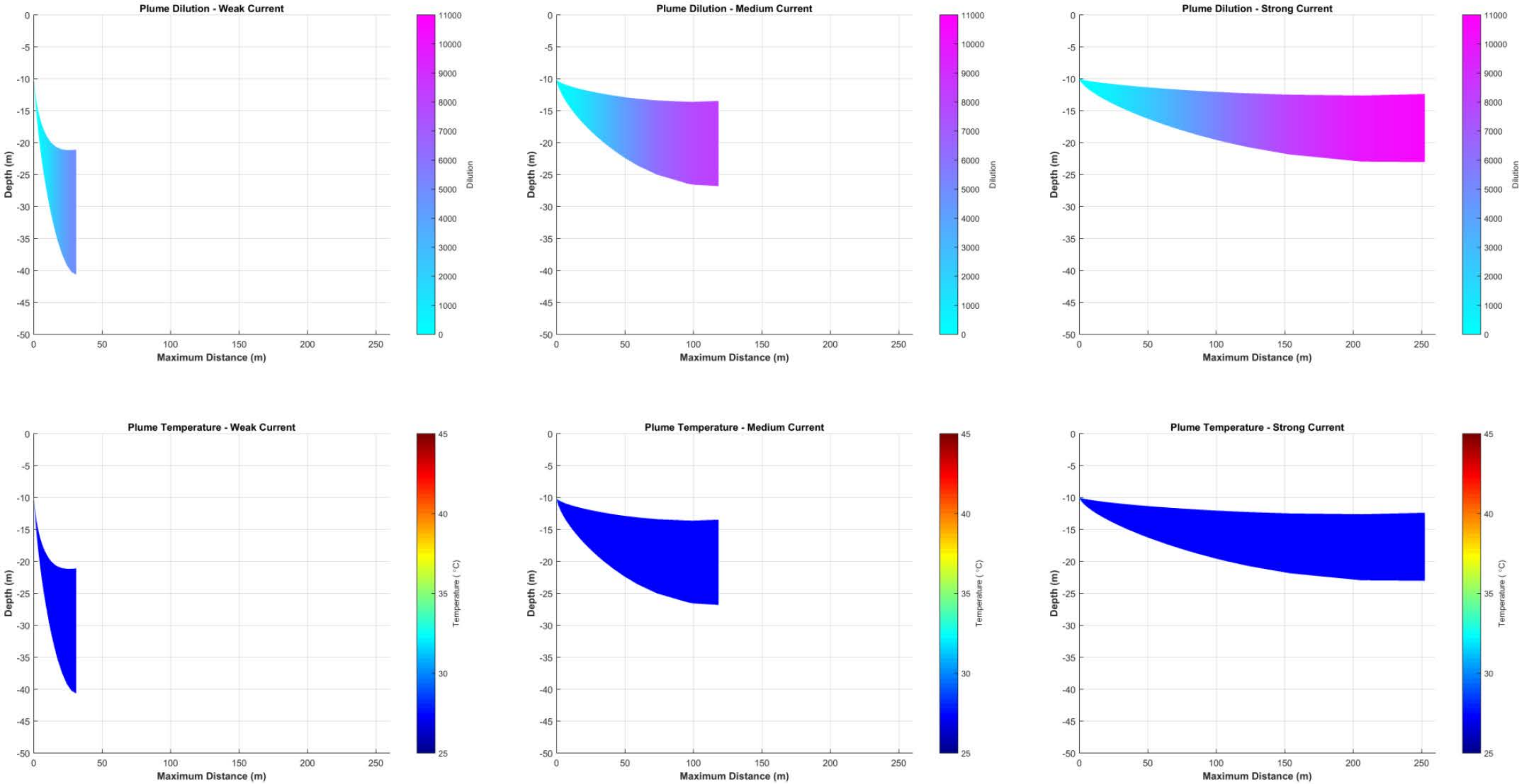

Figure 3.3 Near-field average temperature and dilution results for weak, medium and strong winter currents (287 m^3/d flow rate).

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3.1.3 Later Operations Phase: Flow Rate of 3,179.8 m^3/d

Table 3.5 Predicted plume characteristics at the end of the near-field mixing zone for the later operations phase flow rate (3,179.8 m^3/d) for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth Below Sea Level (BSL) [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.06)	20.9 [40.5]	28.86	0.50	198	581	22.2
	Medium (0.22)	19.3 [24.9]	29.22	0.16	445	1,699	73.4
	Strong (0.42)	15.8 [21.2]	29.31	0.13	565	2,169	139.6
Transitional	Weak (0.06)	20.3 [54.5]	27.57	0.48	177	537	22.3
	Medium (0.21)	16.5 [32.7]	28.01	0.20	318	1,219	57.4
	Strong (0.41)	13.4 [27.2]	28.11	0.15	406	1,568	112.8
Winter	Weak (0.05)	30.2 [38.9]	27.06	0.20	356	1,091	30.6
	Medium (0.20)	28.7 [22.8]	27.21	0.07	891	3,442	108.0
	Strong (0.40)	23.7 [20.5]	27.25	0.03	1,220	4,696	235.7

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Table 3.6 Concentrations of all constituents at the end of the near-field stage, and the threshold concentrations and number of dilutions for the summer season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 581, 1,699 and 2,169, respectively.

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			ANZECC & ARMCANZ Threshold Concentration (mg/L)	Required Dilution Factor to Reach 99% Species Protection Level (1:x)
		5th %ile (weak currents)	50th %ile (medium currents)	95th %ile (strong currents)		
		581x dilution	1,699x dilution	2,169x dilution		
Benzene	240	$4.1*10^{-2}$	$1.4*10^{-2}$	$1.1*10^{-2}$	0.5	480.0
NPD	10.7	$1.8*10^{-2}$	$6.3*10^{-3}$	$4.9*10^{-3}$	$5.0*10^{-2}$	214.0
Phenol	0.757	$1.3*10^{-3}$	$4.5*10^{-4}$	$3.5*10^{-4}$	0.27	2.8
Cadmium (Cd)	$1.0*10^{-4}$	$1.7*10^{-7}$	$5.9*10^{-8}$	$4.6*10^{-8}$	$7.0*10^{-4}$	6.6
Chromium (III/VI) (Cr)	$7.0*10^{-4}$	$1.2*10^{-6}$	$4.1*10^{-7}$	$3.2*10^{-7}$	$1.4*10^{-4}$	177.1
Copper (Cu)	$3.0*10^{-4}$	$5.2*10^{-7}$	$1.8*10^{-7}$	$1.4*10^{-7}$	$3.0*10^{-4}$	30.7
Lead (Pb)	$1.0*10^{-4}$	$1.7*10^{-7}$	$5.9*10^{-8}$	$4.6*10^{-8}$	$2.2*10^{-3}$	2.1
Nickel (Ni)	$3.0*10^{-4}$	$5.2*10^{-7}$	$1.8*10^{-7}$	$1.4*10^{-7}$	$7.0*10^{-3}$	2.7
Zinc (Zn)	$8.0*10^{-4}$	$1.4*10^{-6}$	$4.7*10^{-7}$	$3.7*10^{-7}$	$7.0*10^{-3}$	4.2

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Table 3.7 Concentrations of all constituents at the end of the near-field stage, and the threshold concentrations and number of dilutions for the transitional season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 537, 1,219 and 1,568, respectively.

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			ANZECC & ARMCANZ Threshold Concentration (mg/L)	Required Dilution Factor to Reach 99% Species Protection Level (1:x)
		5th %ile (weak currents)	50th %ile (medium currents)	95th %ile (strong currents)		
		537x dilution	1,219x dilution	1,568x dilution		
Benzene	240	$4.5*10^{-2}$	$2.0*10^{-2}$	$1.5*10^{-2}$	0.5	480.0
NPD	10.7	$2.0*10^{-2}$	$8.8*10^{-3}$	$6.8*10^{-3}$	$5.0*10^{-2}$	214.0
Phenol	0.757	$1.4*10^{-3}$	$6.2*10^{-4}$	$4.8*10^{-4}$	0.27	2.8
Cadmium (Cd)	$1.0*10^{-4}$	$1.9*10^{-7}$	$8.2*10^{-8}$	$6.4*10^{-8}$	$7.0*10^{-4}$	6.6
Chromium (III/VI) (Cr)	$7.0*10^{-4}$	$1.3*10^{-6}$	$5.7*10^{-7}$	$4.5*10^{-7}$	$1.4*10^{-4}$	177.1
Copper (Cu)	$3.0*10^{-4}$	$5.6*10^{-7}$	$2.5*10^{-7}$	$1.9*10^{-7}$	$3.0*10^{-4}$	30.7
Lead (Pb)	$1.0*10^{-4}$	$1.9*10^{-7}$	$8.2*10^{-8}$	$6.4*10^{-8}$	$2.2*10^{-3}$	2.1
Nickel (Ni)	$3.0*10^{-4}$	$5.6*10^{-7}$	$2.5*10^{-7}$	$1.9*10^{-7}$	$7.0*10^{-3}$	2.7
Zinc (Zn)	$8.0*10^{-4}$	$1.5*10^{-6}$	$6.6*10^{-7}$	$5.1*10^{-7}$	$7.0*10^{-3}$	4.2

Table 3.8 Concentrations of all constituents at the end of the near-field stage, and the threshold concentrations and number of dilutions for the winter season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 1,091, 3,442 and 4,696, respectively.

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			ANZECC & ARMCANZ Threshold Concentration (mg/L)	Required Dilution Factor to Reach 99% Species Protection Level (1:x)
		5th %ile (weak currents)	50th %ile (medium currents)	95th %ile (strong currents)		
		1,091x dilution	3,442x dilution	4,696x dilution		
Benzene	240	$2.2*10^{-2}$	$7.0*10^{-3}$	$5.1*10^{-3}$	0.5	480.0
NPD	10.7	$9.8*10^{-3}$	$3.1*10^{-3}$	$2.3*10^{-3}$	$5.0*10^{-2}$	214.0
Phenol	0.757	$6.9*10^{-4}$	$2.2*10^{-4}$	$1.6*10^{-4}$	0.27	2.8
Cadmium (Cd)	$1.0*10^{-4}$	$9.2*10^{-8}$	$2.9*10^{-8}$	$2.1*10^{-8}$	$7.0*10^{-4}$	6.6
Chromium (III/VI) (Cr)	$7.0*10^{-4}$	$6.4*10^{-7}$	$2.0*10^{-7}$	$1.5*10^{-7}$	$1.4*10^{-4}$	177.1
Copper (Cu)	$3.0*10^{-4}$	$2.7*10^{-7}$	$8.7*10^{-8}$	$6.4*10^{-8}$	$3.0*10^{-4}$	30.7
Lead (Pb)	$1.0*10^{-4}$	$9.2*10^{-8}$	$2.9*10^{-8}$	$2.1*10^{-8}$	$2.2*10^{-3}$	2.1
Nickel (Ni)	$3.0*10^{-4}$	$2.7*10^{-7}$	$8.7*10^{-8}$	$6.4*10^{-8}$	$7.0*10^{-3}$	2.7
Zinc (Zn)	$8.0*10^{-4}$	$7.3*10^{-7}$	$2.3*10^{-7}$	$1.7*10^{-7}$	$7.0*10^{-3}$	4.2

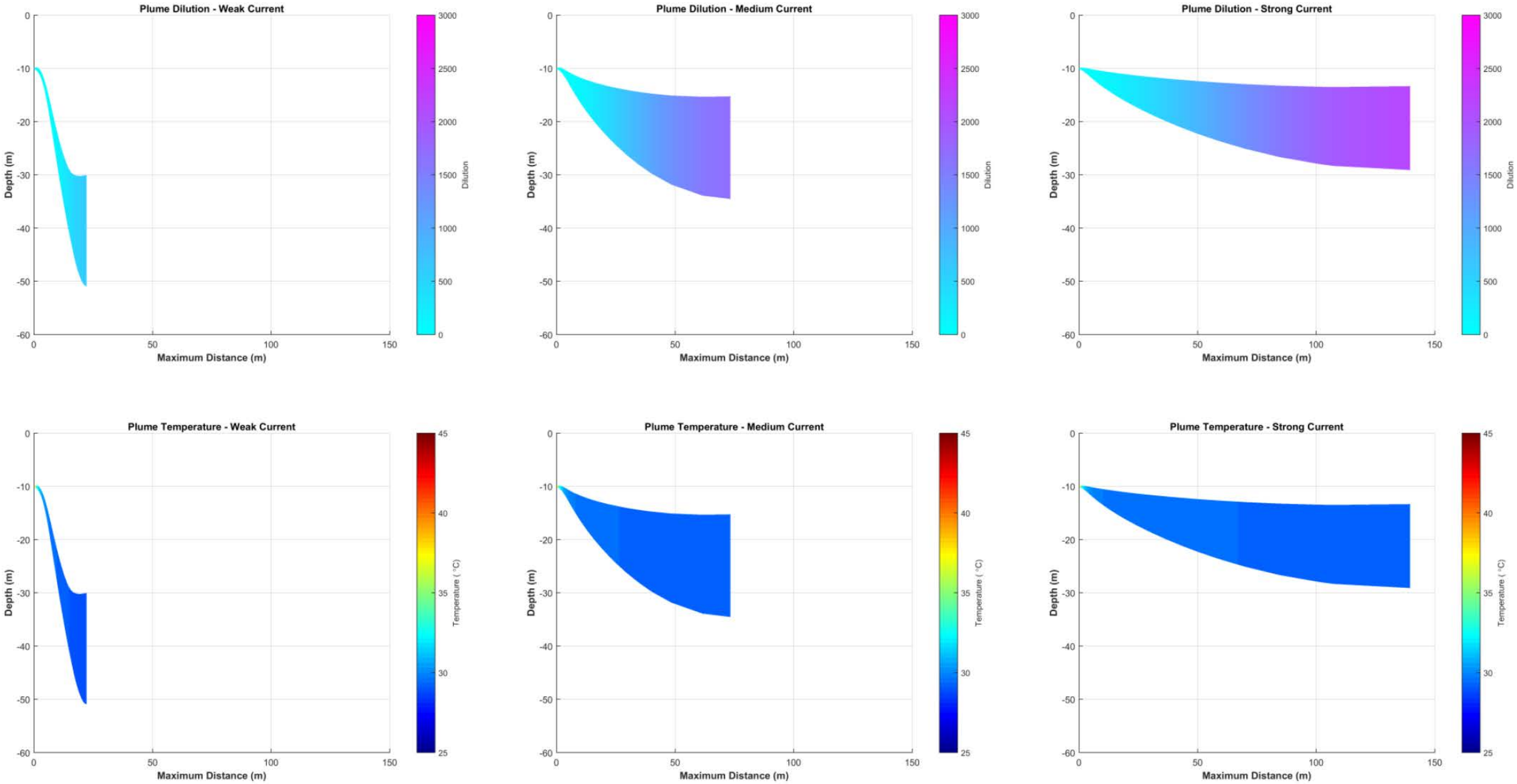

Figure 3.4 **Near-field average temperature and dilution results for weak, medium and strong summer currents (3,179.8 m^3/d flow rate).**

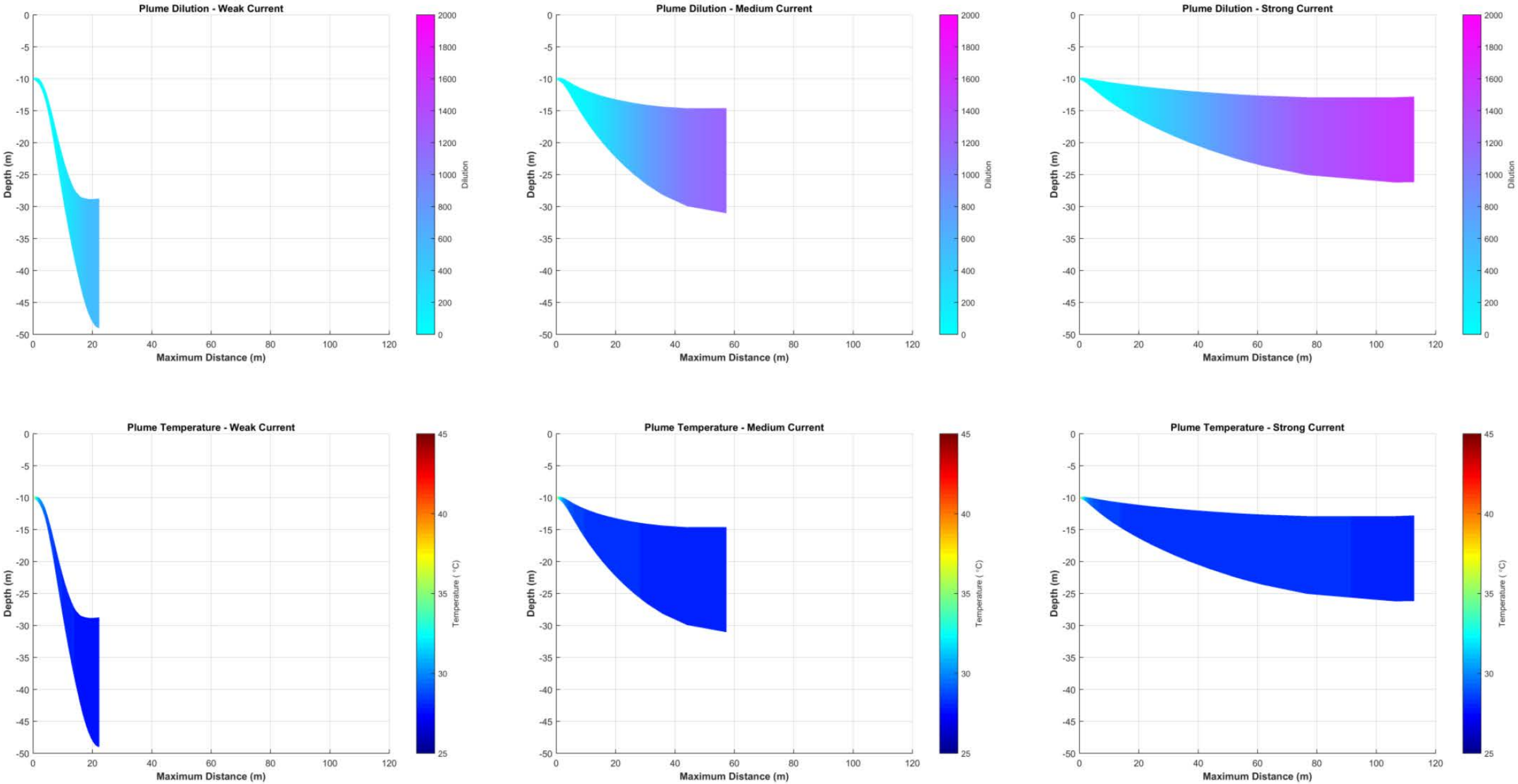

Figure 3.5 **Near-field average temperature and dilution results for weak, medium and strong transitional currents (3,179.8 m^3/d flow rate).**

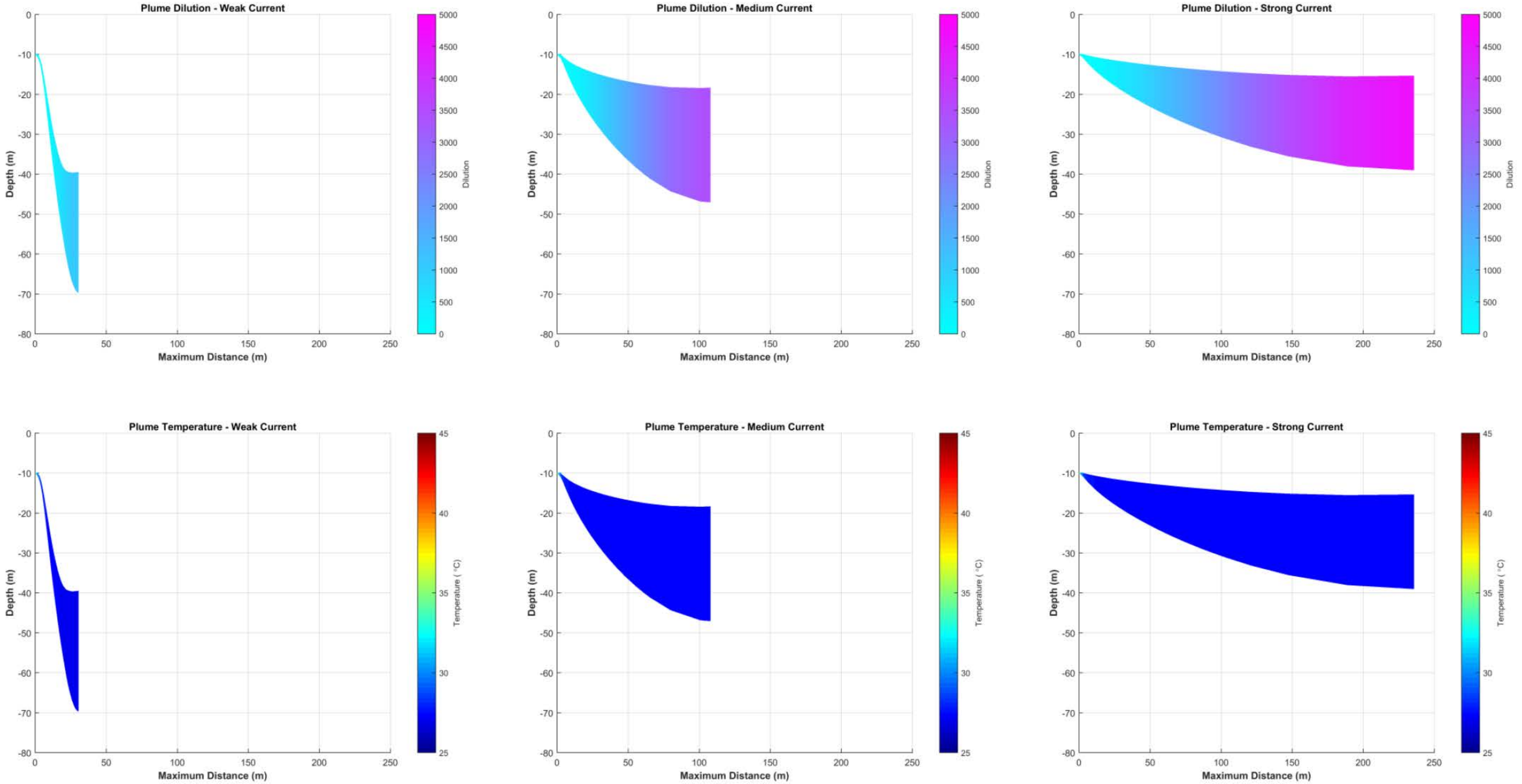

Figure 3.6 **Near-field average temperature and dilution results for weak, medium and strong winter currents (3,179.8 m^3/d flow rate).**

3.2 Far-Field Modelling

3.2.1 Overview

It is important to note that near-field and far-field modelling are used to describe different processes and scales of effect, and therefore the far-field modelling results will not necessarily correspond to the outcomes at the end of the near-field mixing zone for any given discharge scenario. The far-field results included episodes of pooling of the discharge plume under weak currents, which caused lower dilutions (higher concentrations) further from the discharge location when the pooled plume was advected away. Episodes of recirculation – where the plume moved back under the discharge at some later time due to the oscillatory nature of the tide – were also observed, compounding the pooling effect and further lowering the dilution values.

3.2.2 General Observations

Figure 3.7 shows example time series snapshots of predicted dilutions during a single simulation at 3-hour intervals from 00:00 to 15:00 on 2nd December 2016. This simulation – selected merely to be representative of typical conditions – considers the later operations flow rate of 3,179.8 m^3/d. The spatially-varying orientation of the plume with the currents and the rapidly-varying nature of the concentrations around the source can be observed. The snapshots also show the combined effect of the tide and the drift currents, with a clear tidal oscillation.

These snapshots illustrate that the dilutions (and in turn concentrations) become more variable over time because of changes in current speed and direction. Higher dilutions (lower concentrations) are predicted during periods of increased current speed, whereas patches of lower dilutions (higher concentrations) tend to accumulate during the turning of the tide or during periods of weak drift currents. During prolonged periods of lowered current speed, the plume has a more continuous appearance, with higher-concentration patches moving as a unified group. These findings agree with the research of King & McAllister (1997, 1998) who noted that concentrations within effluent plumes generated by an offshore platform were patchy and likely to peak around the reversal of the tides.

Maximum concentrations (lowest dilution) are predicted to occur near where the plume reaches the trapping depth, which ranges from 14-55 m. Concentrations are then expected to reduce as the plume mixes vertically as it moves away from the source.

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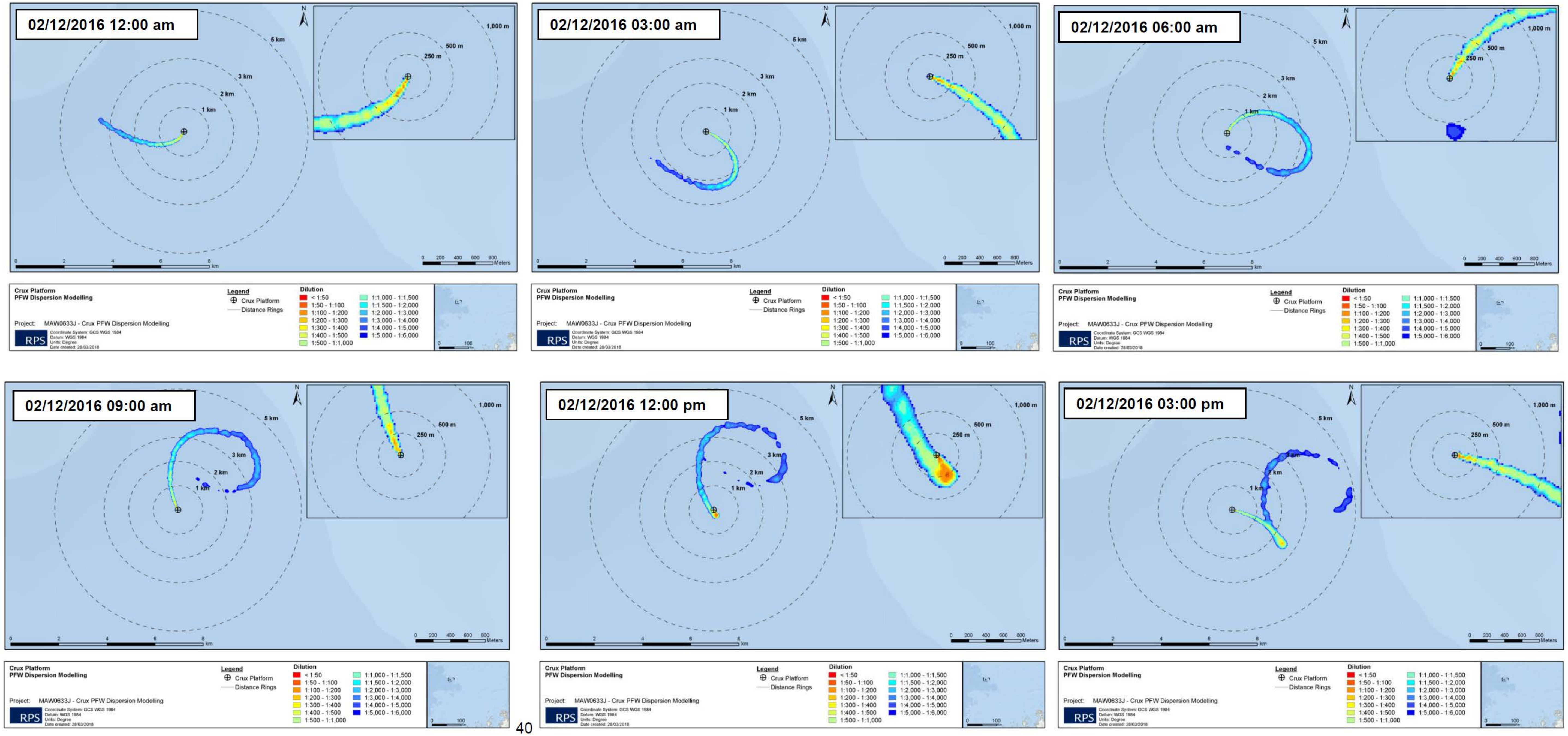

Figure 3.7 Snapshots of predicted dilution levels, at 3-hour intervals from 00:00 to 15:00 on 2nd December 2016, for the later operations phase flow rate (3,179.8 m^3/d).

3.2.3 Seasonal Analysis

The model outputs over the ten-year hindcast period (2008-2017) were combined and analysed on a seasonal basis (summer, transitional and winter). This approach assists with identifying the potential exposure to the shoals nearest to the proposed Crux platform (Goeree Shoal, Eugene McDermott Shoal and Vulcan Shoal) on a seasonal basis whilst considering inter-annual variability in ocean current conditions.

Table 3.9 summarises the minimum dilution achieved at specific radial distances from the discharge location for each flow rate and season.

Table 3.10 provides a summary of the maximum distances from the discharge location to achieve a given dilution for each flow rate and season. The results indicate that the release of effluent under all seasonal conditions results in rapid dispersion of analytes within the ambient environment. Dilution to reach 99% Species Protection Level concentrations is achieved for all analytes within an area of influence ranging from 982 m to 999 m from the Crux platform location, this being the maximum spatial extents of the 1:500 dilution contour in summer and winter, respectively.

Table 3.11 provides a summary of the total area of coverage for a given dilution for each flow rate and season. For all analytes, the area of exposure defined by the 1:500 dilution contour is predicted to reach a maximum of between 1.7 km^2 and 1.8 km^2, the coverage areas predicted in the summer/transitional and winter seasons, respectively.

Figure 3.8 to Figure 3.13 show the aggregated spatial extents of the minimum dilutions for each flow rate and season. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time-step through the water column and do not consider frequency or duration.

The results presented assume that no processes other than dilution would reduce the source concentrations over time.

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Table 3.9 Minimum dilution achieved at specific radial distances from the PFW discharge location for each flow rate and season.

Flow rate (m^3/d)	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location						
		0.1 km	0.5 km	1 km	2 km	3 km	5 km	>5 km
287	Summer	1:639	1:2,686	1:4,881	>1:6,000	>1:6,000	>1:6,000	>1:6,000
	Transitional	1:671	1:2,599	1:4,656	>1:6,000	>1:6,000	>1:6,000	>1:6,000
	Winter	1:628	1:2,551	1:4,517	>1:6,000	>1:6,000	>1:6,000	>1:6,000
3,179.8	Summer	1:73	1:298	1:508	1:971	1:1,302	1:2,503	1:2,503
	Transitional	1:79	1:297	1:501	1:898	1:1,321	1:2,521	1:2,521
	Winter	1:73	1:266	1:497	1:849	1:1,151	1:2,137	1:2,137

Table 3.10 Maximum distance from the PFW discharge location to achieve a given dilution for each flow rate and season.

Flow rate (m^3/d)	Season	Maximum distance (m) from discharge location to achieve given dilution											
		1:50 dilution	1:100 dilution	1:200 dilution	1:300 dilution	1:400 dilution	1:500 dilution	1:1,000 dilution	1:2,000 dilution	1:3,000 dilution	1:4,000 dilution	1:5,000 dilution	1:>6,000 dilution
287	Summer	N/A	N/A	N/A	37	55	63	135	337	595	873	1,004	1,200
	Transitional	N/A	N/A	N/A	37	51	67	125	356	576	823	1,115	1,359
	Winter	N/A	N/A	N/A	37	51	67	146	355	606	846	1,111	1,473
3,179.8	Summer	62	128	314	515	737	982	2,174	4,283	5,637	6,689	7,600	9,172
	Transitional	54	128	303	499	759	995	2,221	4,696	5,642	6,389	7,014	8,668
	Winter	71	135	332	601	807	999	2,263	4,625	6,495	7,814	8,906	9,519

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Table 3.11 Total area of coverage for a given dilution for each flow rate and season.

Flow rate (m^3/d)	Season	Total area (km^2) of coverage for given dilution											
		1:50 dilution	1:100 dilution	1:200 dilution	1:300 dilution	1:400 dilution	1:500 dilution	1:1,000 dilution	1:2,000 dilution	1:3,000 dilution	1:4,000 dilution	1:5,000 dilution	1:>6,000 dilution
287	Summer	N/A	N/A	N/A	<0.001	0.003	0.004	0.035	0.23	0.58	1.1	1.8	2.6
	Transitional	N/A	N/A	N/A	<0.001	0.002	0.004	0.036	0.25	0.62	1.2	1.9	2.8
	Winter	N/A	N/A	N/A	<0.001	0.002	0.004	0.039	0.25	0.64	1.2	2.0	2.8
3,179.8	Summer	0.004	0.027	0.18	0.52	1.0	1.7	7.0	25.6	48.1	72.8	94.5	113.5
	Transitional	0.003	0.026	0.18	0.51	1.0	1.7	7.4	25.7	51.3	72.4	90.1	106.6
	Winter	0.004	0.030	0.20	0.56	1.1	1.8	7.8	27.3	50.0	77.2	98.8	117.2

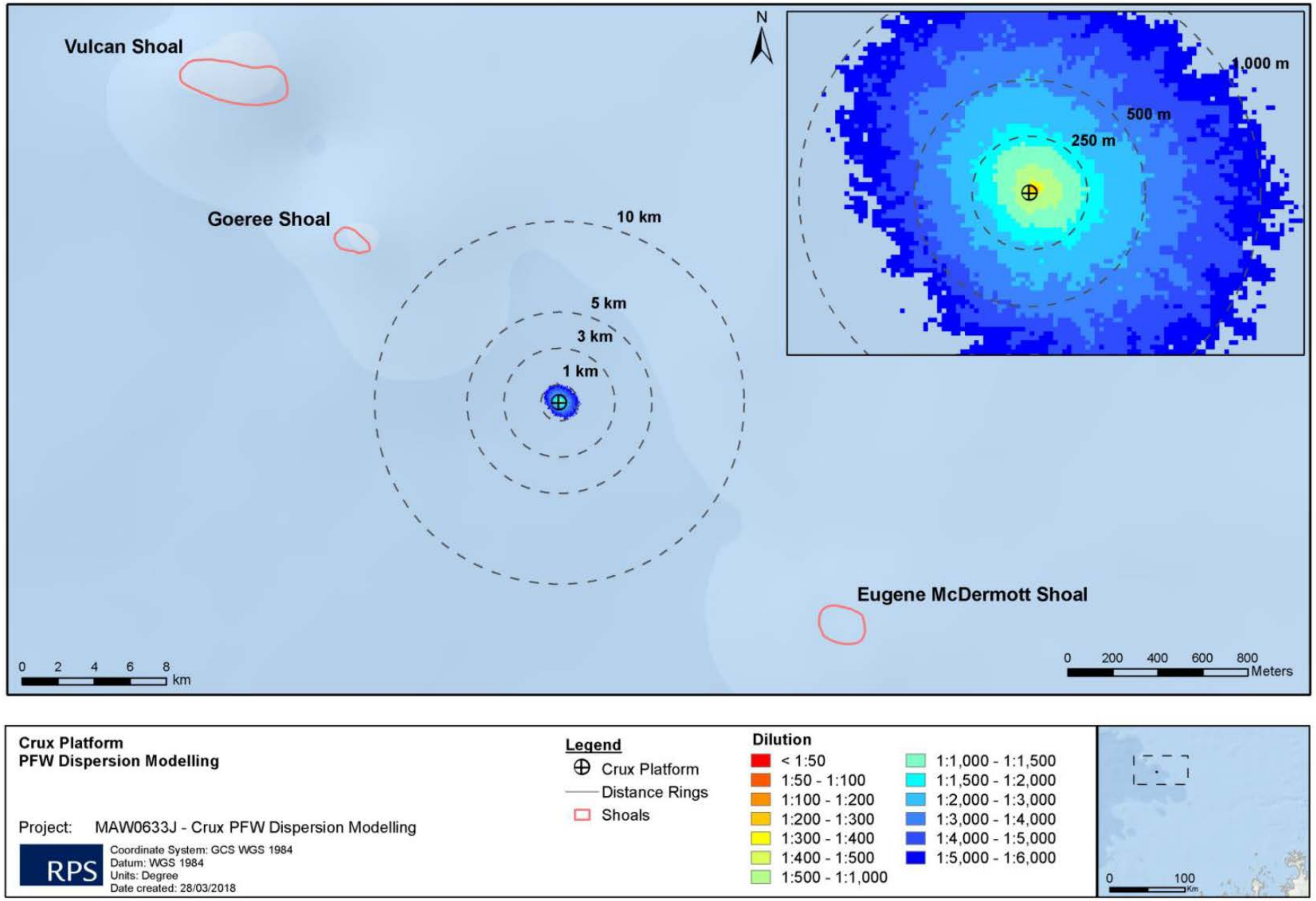

Figure 3.8 Predicted minimum dilutions under summer conditions for the early operations phase flow rate (287 m^3/d).

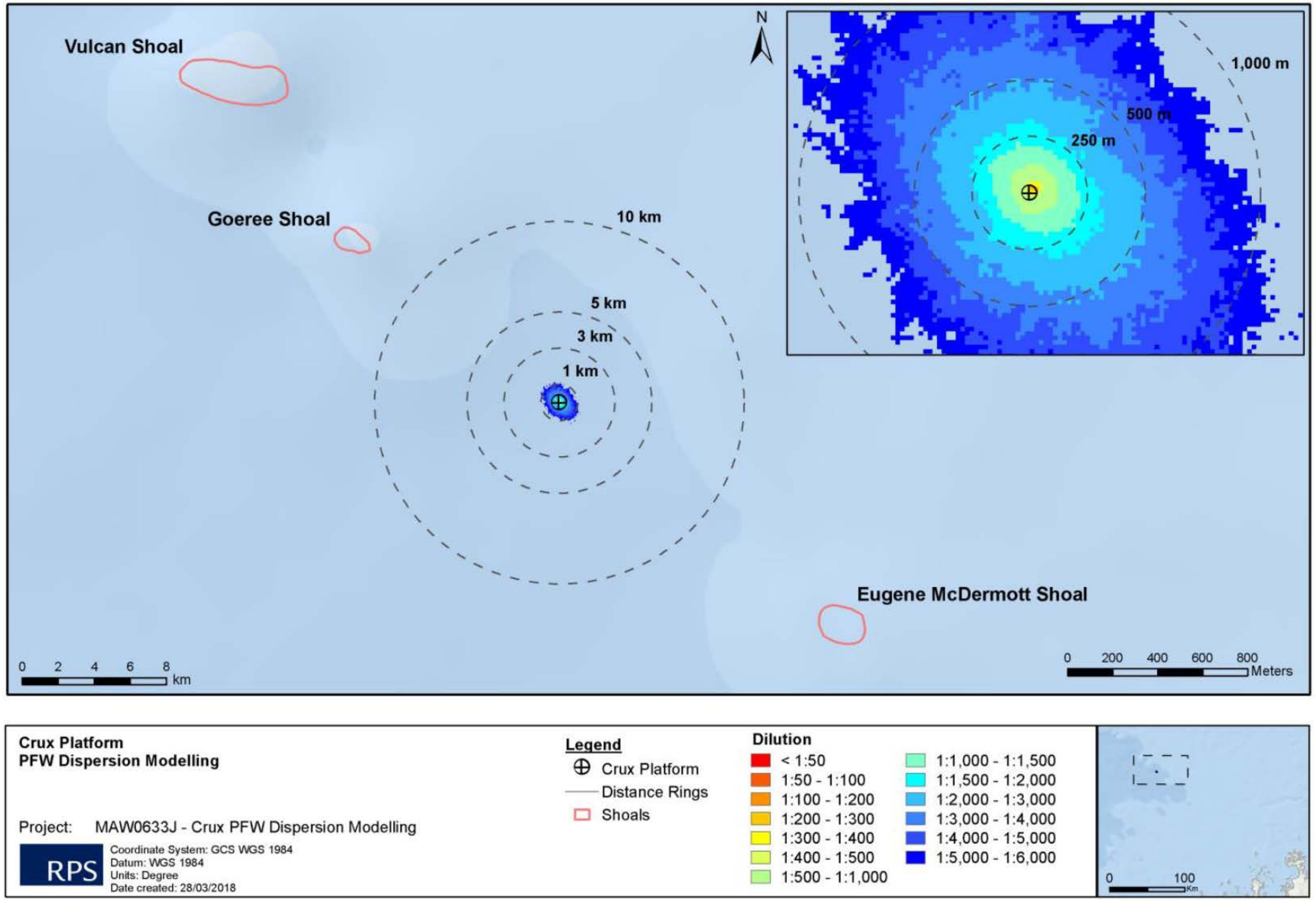

Figure 3.9 **Predicted minimum dilutions under transitional conditions for the early operations phase flow rate (287 m^3/d).**

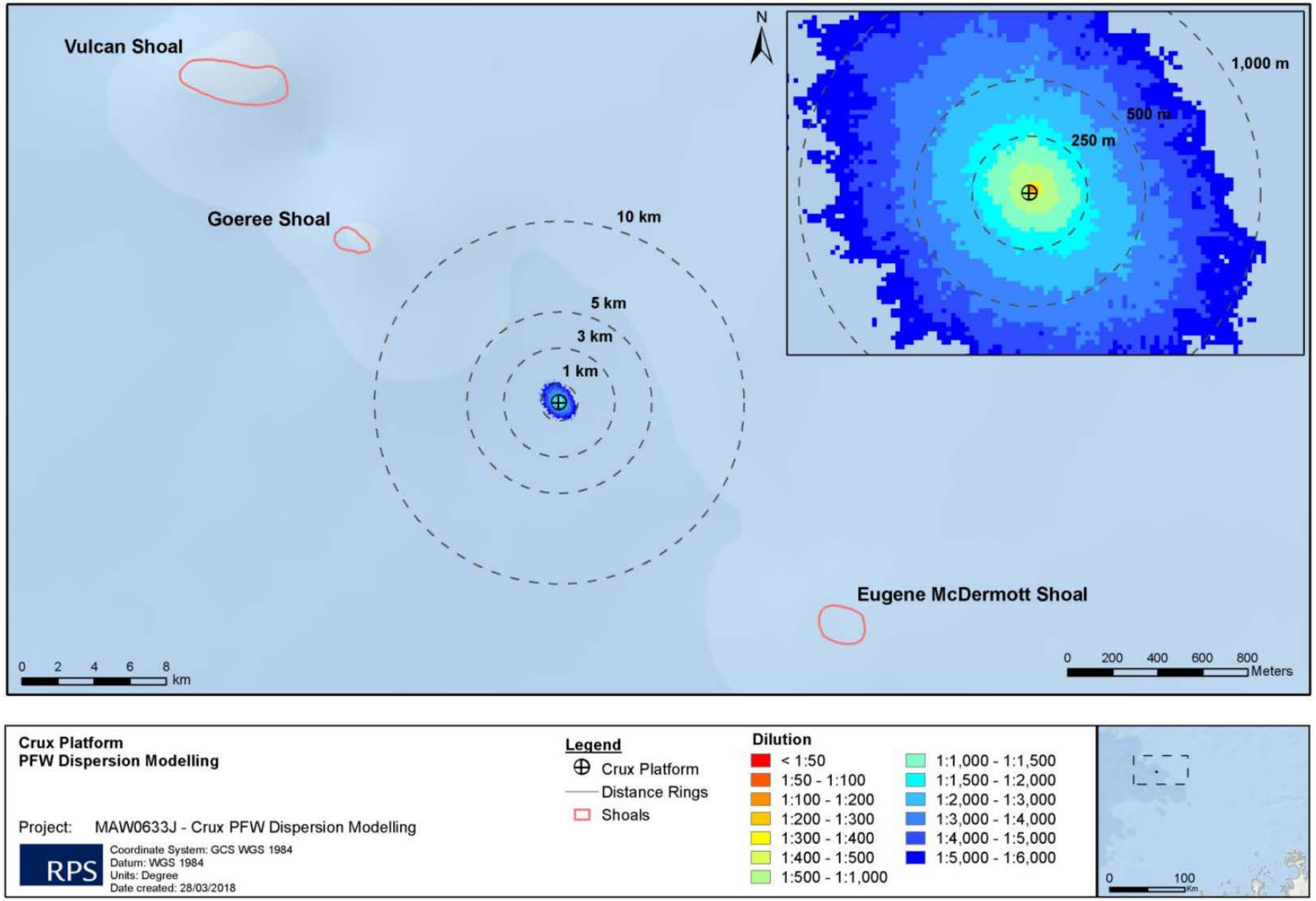

Figure 3.10 Predicted minimum dilutions under winter conditions for the early operations phase flow rate (287 m^3/d).

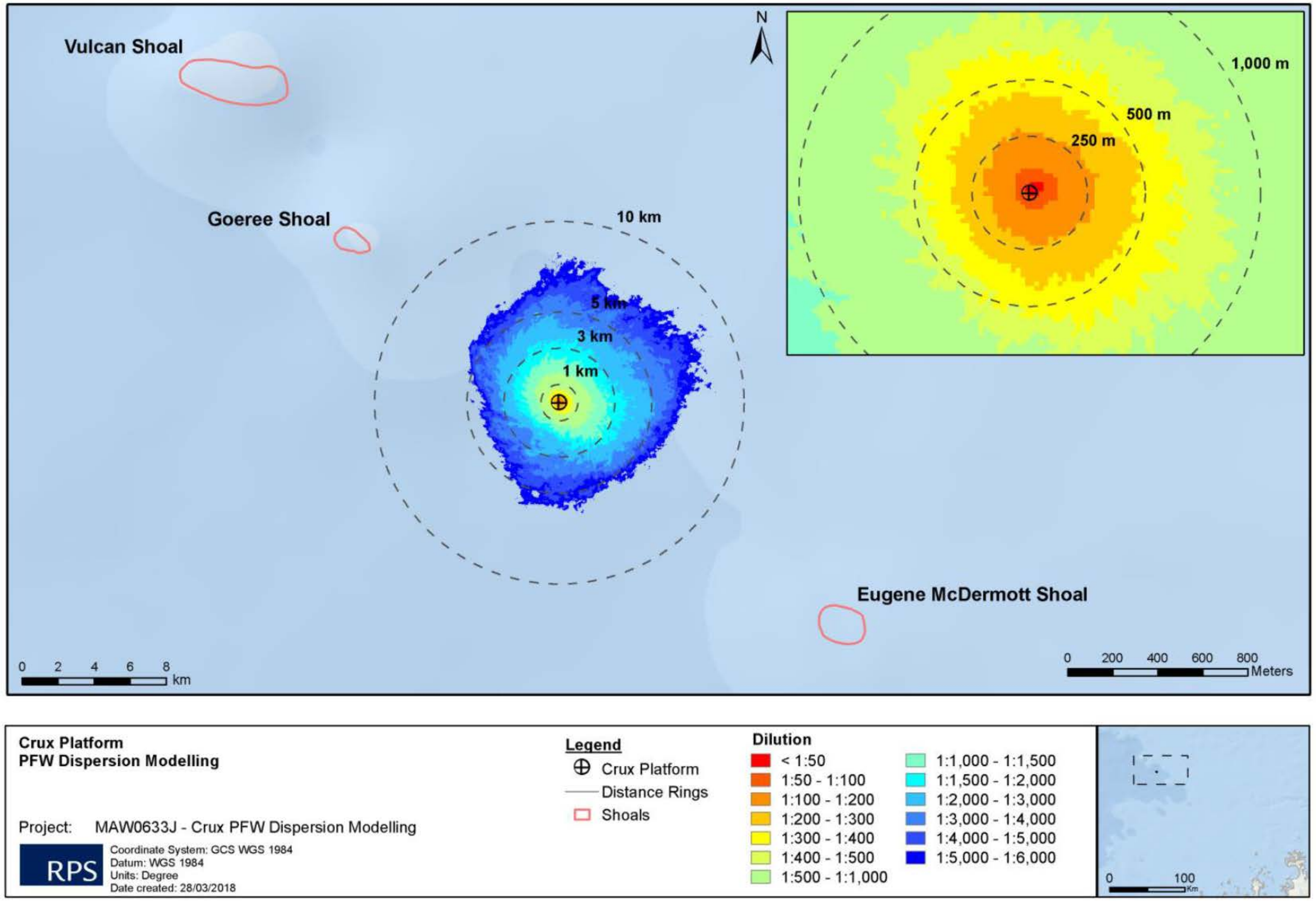

Figure 3.11 **Predicted minimum dilutions under summer conditions for the later operations phase flow rate (3,179.8 m^3/d).**

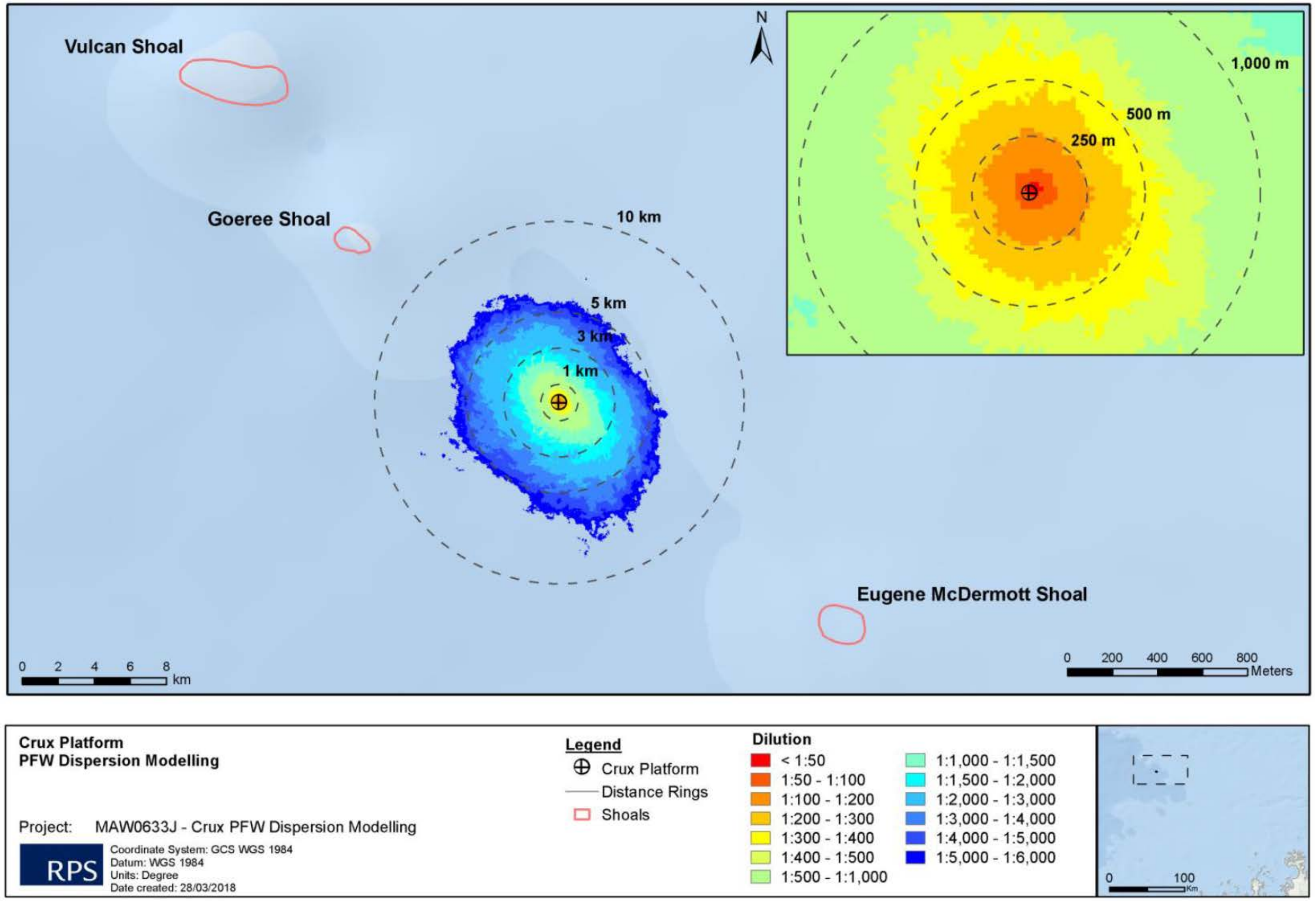

Figure 3.12 Predicted minimum dilutions under transitional conditions for the later operations phase flow rate (3,179.8 m³/d).

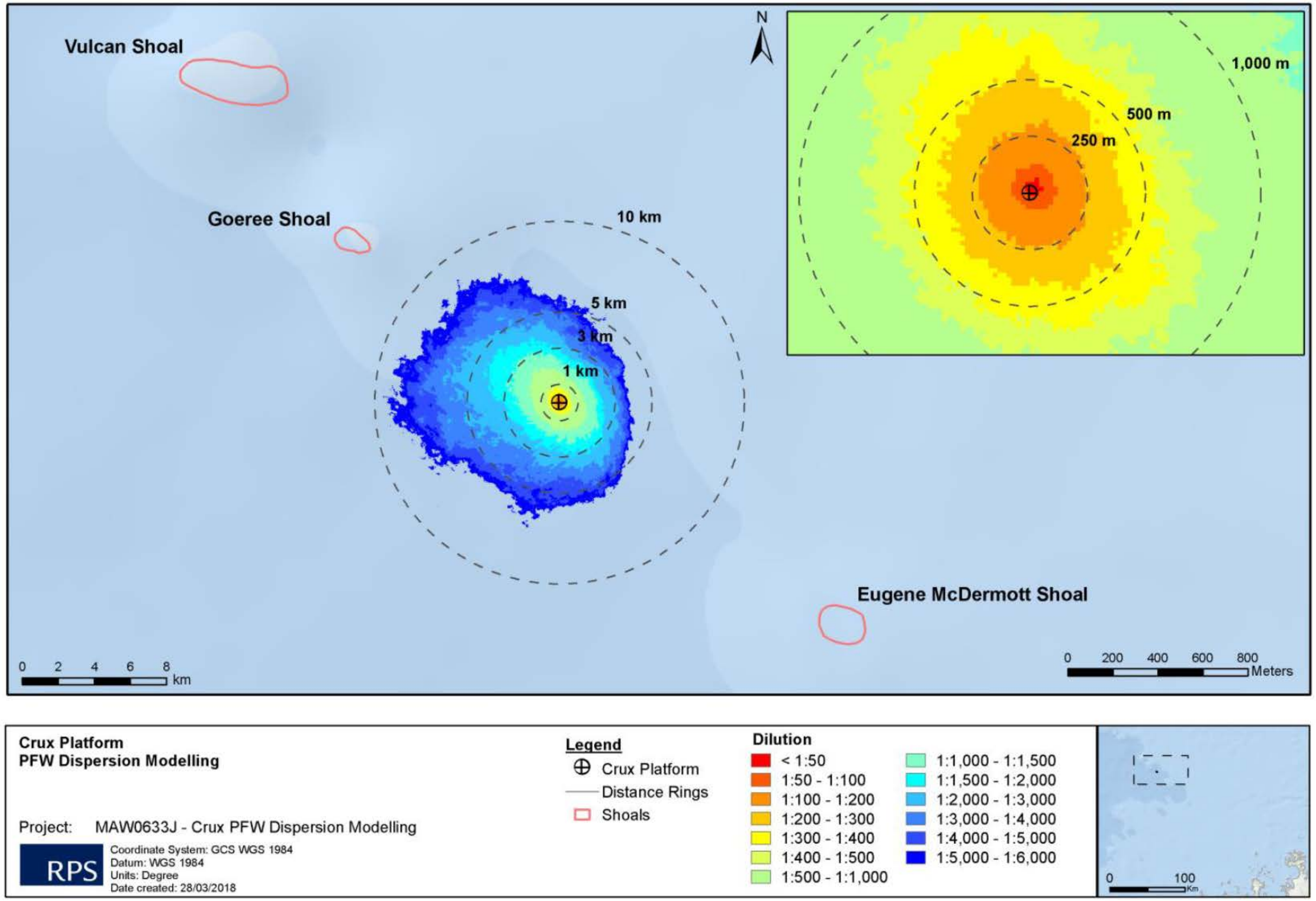

Figure 3.13 Predicted minimum dilutions under winter conditions for the later operations phase flow rate (3,179.8 m^3/d).

3.2.4 Annualised Analysis

The model outputs for each season (summer, transitional and winter) over the ten-year hindcast period (2008-2017) were combined and analysed on an annualised basis.

Table 3.12 shows the maximum distances from the discharge location to achieve a given dilution for each flow rate. The results indicate that the release of effluent under all seasonal conditions results in rapid dispersion of analytes within the ambient environment. Dilution to reach 99% Species Protection Level concentrations is achieved for all analytes within a maximum area of influence of 67 m (at the early operations flow rate of 287 m^3/d) and 999 m (at the later operations flow rate of 3,179.8 m^3/d) from the Crux platform location, this being the maximum spatial extent of the 1:500 dilution contour in any season. At the conservative outer extents of the plume defined by the 1:500 dilution contour, the plume will remain around 11 km from the nearest shoal (Goeree Shoal), and no exposure to harmful contaminant levels is expected for non-transient species.

Table 3.13 shows the total area of coverage for a given dilution for each flow rate. For all analytes, the area of exposure defined by the 1:500 dilution contour is predicted to reach a maximum of 2 km^2 in any season at the maximum later operations flow rate.

Figure 3.14 and Figure 3.15 show the aggregated spatial extents of the minimum dilutions for each flow rate. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time-step through the water column and do not take into account frequency or duration.

The results presented assume that no processes other than dilution would reduce the source concentrations over time.

Table 3.12 Maximum distance from the PFW discharge location to achieve a given dilution for each flow rate.

Flow rate (m^3/d)	Season	Maximum distance (m) from discharge location to achieve given dilution											
		1:50 dilution	1:100 dilution	1:200 dilution	1:300 dilution	1:400 dilution	1:500 dilution	1:1,000 dilution	1:2,000 dilution	1:3,000 dilution	1:4,000 dilution	1:5,000 dilution	1:>6,000 dilution
287	Annualised	N/A	N/A	N/A	37	55	67	146	356	606	873	1,115	1,473
3,179.8	Annualised	71	135	332	601	807	999	2,263	4,696	6,495	7,814	8,906	9,519

Table 3.13 Total area of coverage for a given dilution for each flow rate.

Flow rate (m^3/d)	Season	Total area (km^2) of coverage for given dilution											
		1:50 dilution	1:100 dilution	1:200 dilution	1:300 dilution	1:400 dilution	1:500 dilution	1:1,000 dilution	1:2,000 dilution	1:3,000 dilution	1:4,000 dilution	1:5,000 dilution	1:>6,000 dilution
287	Annualised	N/A	N/A	N/A	<0.001	0.003	0.005	0.042	0.28	0.71	1.4	2.2	3.3
3,179.8	Annualised	0.004	0.032	0.21	0.61	1.2	2.0	9.1	35.5	67.9	104.6	131.9	156.5

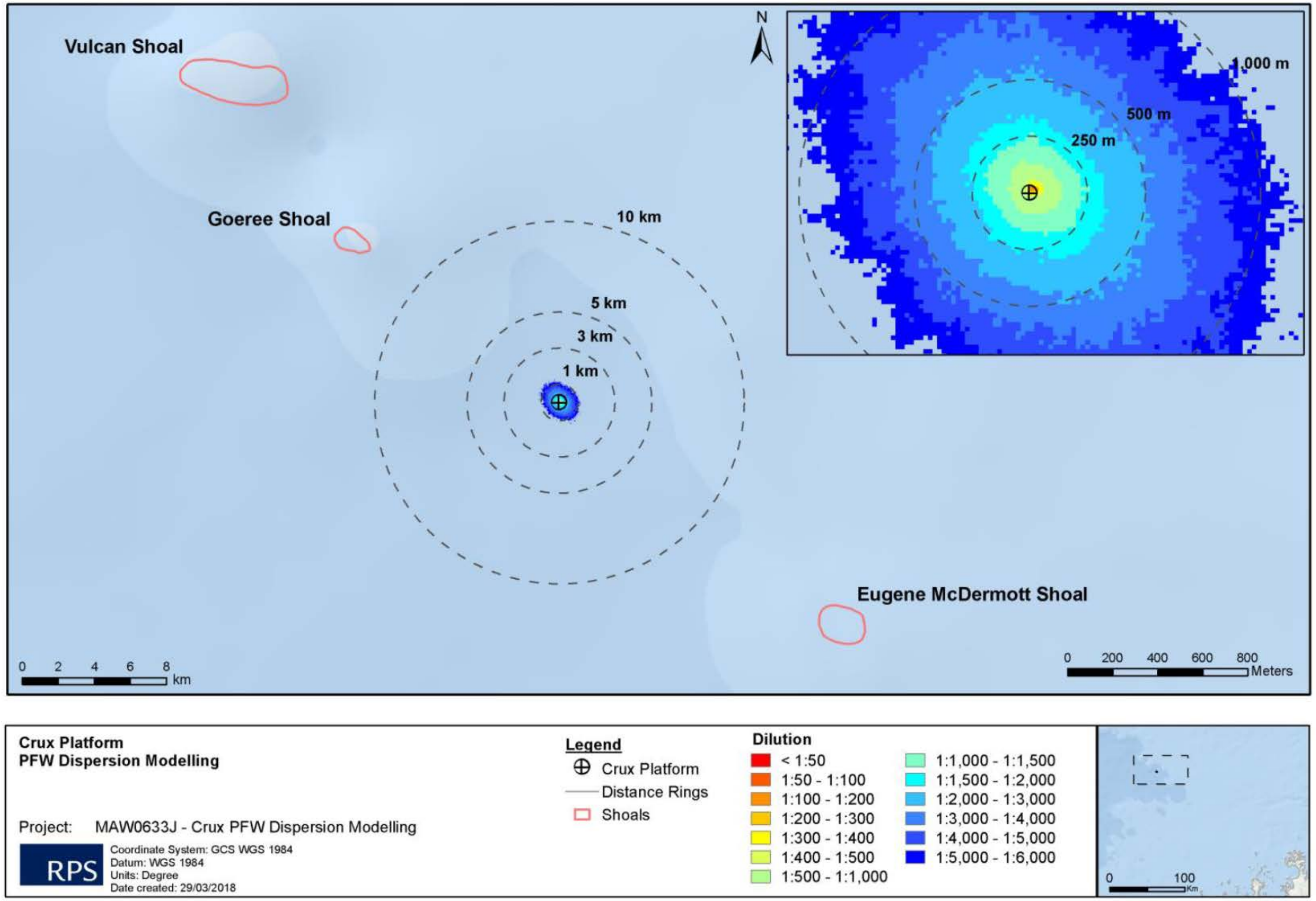

Figure 3.14 Predicted annualised minimum dilutions for the early operations phase flow rate (287 m^3/d).

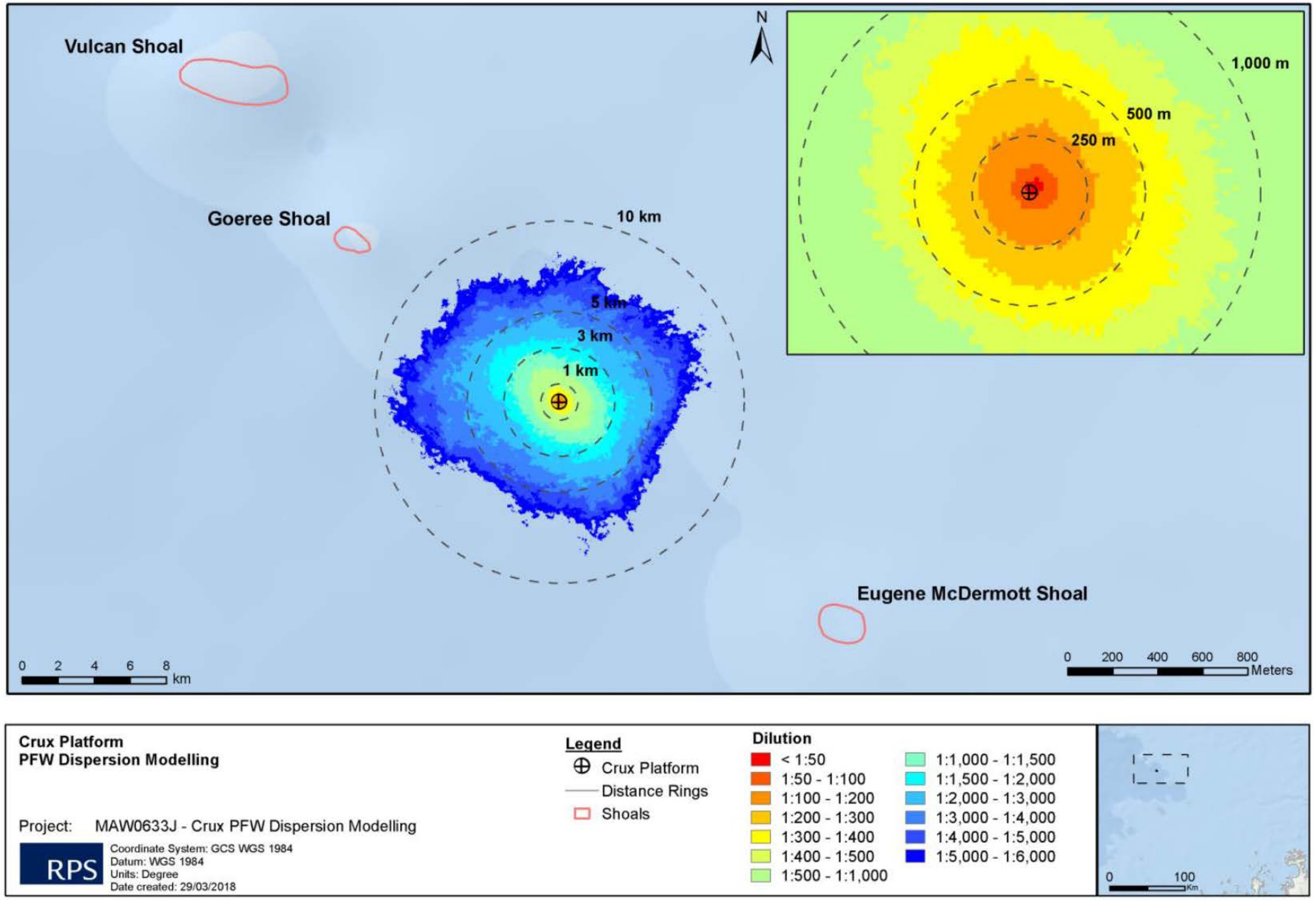

Figure 3.15 Predicted annualised minimum dilutions for the later operations phase flow rate (3,179.8 m^3/d).

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Appendix A

Marine Dispersion Modelling of PFW Discharges – Above Surface Discharge

Contents – Appendix A

Tables – Appendix A

Figures – Appendix A

A1 Introduction

A1.1 Background

RPS has been commissioned by CDM Smith Australia Pty Ltd (CDM Smith), on behalf of Shell Australia Pty Ltd (Shell), to undertake a marine dispersion modelling study of proposed water discharges from the Crux platform (Table A 1). The Crux platform is located in the northern Browse Basin in offshore Commonwealth marine waters, approximately 190 km offshore north-west Australia and 620 km north-north-east of Broome.

Produced formation water (PFW) occurs naturally within the same rock strata as the hydrocarbons and comprises condensed water and saline formation water.

Operation of the fixed-jacket Crux platform will include discharges of PFW separated from the hydrocarbon production stream. The characteristics of the PFW discharge will transition during the operational life of the Crux platform. Discharges are expected to comprise mostly condensed water with minimal formation water produced during the early operations phase (approximately 8-9 years) (i.e. pre-formation water breakthrough). At around 9 years of operation the water produced will transition to a mixture of condensed water and formation water (i.e. post-formation water breakthrough). The amount of formation water is expected to comprise a greater proportion of the discharge as the field nears end of life, as is typically the case of maturing hydrocarbon fields.

Operational design for the facility has identified that the PFW discharges will vary from ambient seawater in terms of temperature, salinity, and the presence of trace amounts of process chemicals.

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for each of the identified constituents in the PFW discharge. This will indicate whether concentrations of any constituents are likely to be above stated threshold concentrations at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold). The outcomes of this study have been provided in Section 3 of the main report.

An additional modelling exercise was undertaken to assess the potential changes in mixing and dilution that may occur if the PFW stream is discharged from the Crux platform above the sea surface rather than below it. This supplemental report compares the near-field and far-field outcomes of one below-surface discharge scenario and one above-surface discharge scenario:

- Case 1: A discharge at a flow rate of 3,179.8 m^3/day occurring 10 m <u>below</u> the water surface through a single horizontal outlet 6 inches in diameter with an anticipated salinity and temperature of 92.2 ppt and 44 °C, respectively.
- Case 2: A discharge at a flow rate of 3,179.8 m^3/day occurring 10 m <u>above</u> the water surface through a single vertical outlet 8 inches in diameter with an anticipated salinity and temperature of 92.2 ppt and 44 °C, respectively.

The potential area that may be influenced by these PFW discharge streams was assessed only for the summer season (December to February).

Table A 1 Location of the proposed Crux platform used as the release site for the PFW dispersion modelling assessment.

Release Site	Latitude (°S)	Longitude (°E)	Water Depth (m)
Crux Platform	12° 57' 52.46"	124° 26' 33.21"	170

A2 Discharge Characteristics

A2.1 Overview

The PFW discharge characteristics are summarised in Table A 2.

Table A 2 Summary of PFW discharge characteristics.

Parameter	Value/Design (Case 1)	Value/Design (Case 2)
Flow rate (m^3/d)	3,179.8 (maximum flow rate during later operations)	
Outlet pipe internal diameter (m) [in]	0.152 [6]	0.203 [8]
Outlet pipe orientation	Horizontal	Vertical
Depth of pipe below/above sea surface (m)	10 (below sea surface)	10 (above sea surface)
Discharge salinity (ppt)	92.2	
Discharge temperature (°C)	44	

A2.2 Case 1: Discharge 10 m Below Sea Surface

The PFW plume will be warmer and considerably more saline than the receiving waters, resulting in negative buoyancy relative to the surrounding water. Following initial turbulent mixing in the immediate vicinity of the discharge, the plume will plunge downwards. The path of the plume during this sinking phase will be deflected by the local current, depending upon the prevailing current speed and the rate of plume sinking. Ambient water will be entrained and mixed as the plume sinks, increasing the buoyancy and slowing the rate of fall, while lowering the concentration of chemical constituents.

Figure A 1 shows a conceptual diagram of the dispersion and fates of a negatively buoyant discharge and the idealised representation of the discharge phases.

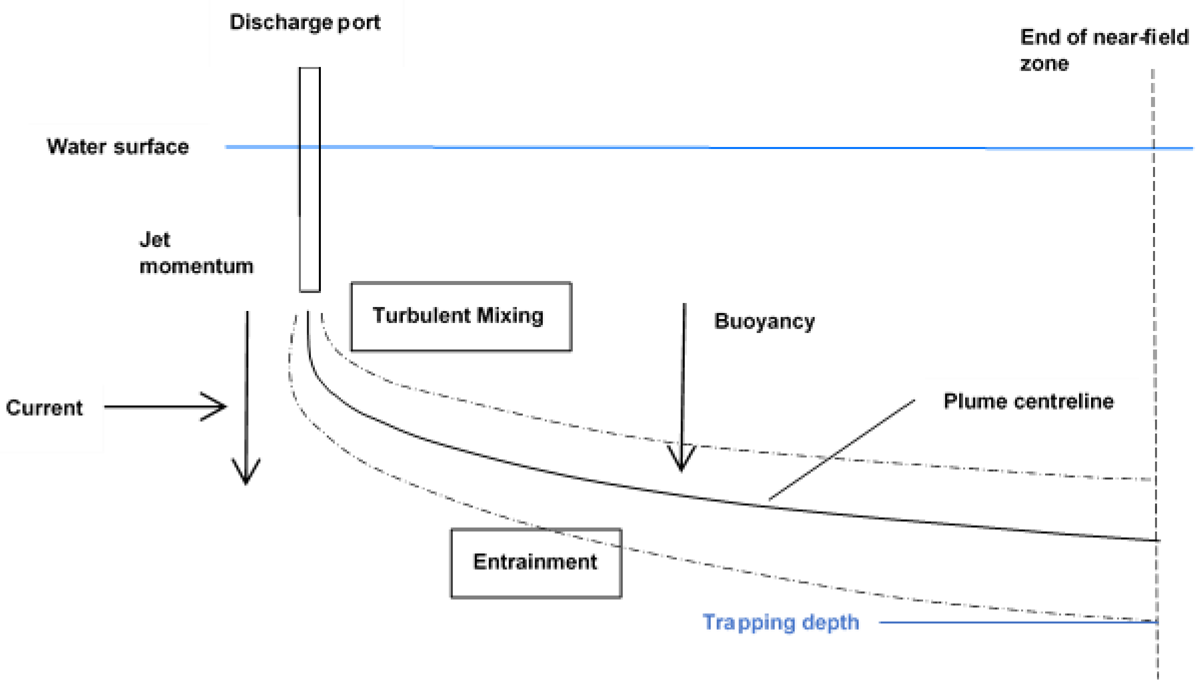

Figure A 1 Conceptual diagram showing the general behaviour of a negatively buoyant discharge.

A2.3 Case 2: Discharge 10 m Above Sea Surface

Large-scale plunging jets impacting a free surface of water, such as the discharge of a PFW stream at a height above the sea surface through a downward-pointing pipe, is a complex problem. The physical phenomena concerning the behaviour of large-scale plunging jets are still not well understood. For jet diameters of more than around 10 cm, studies include those of Guyot *et al.* (2016).

Jet dynamics probes a wide range of physical properties, such as liquid surface tension, viscosity, air entrainment caused by transition between confined and unconfined flows, and density contrast with its environment (Eggers & Villermaux, 2008). On very large scales, gravitational interactions are important. The basic flow state can be both laminar or turbulent. Flow in a pipe is laminar if the Reynolds number (based on the diameter of the pipe) is less than 2,100 and is turbulent if it is greater than 4,000. Between these limits, transitional flow conditions occur. The Reynolds number is calculated as follows:

$$Re = \frac{\rho_l V_0 D_0}{\mu}$$

Where: R_e is the Reynolds number, ρ_l is the volumetric mass density of the liquid, V_0 is the average velocity at the outlet, D_0 is the outlet diameter and μ is the dynamic viscosity of the liquid.

For the purposes of modelling, the above-surface PFW discharge is considered uniform (homogeneous) with no breaking of the jet before it reaches the water surface. For the proposed discharge, a relatively high Reynolds number of ~400,000 indicates that the flow is fully turbulent at the outlet.

Figure A 2 shows a conceptual diagram of the continuous turbulent and laminar flow cases of a large-scale plunging jet, and a resulting negatively buoyant plume.

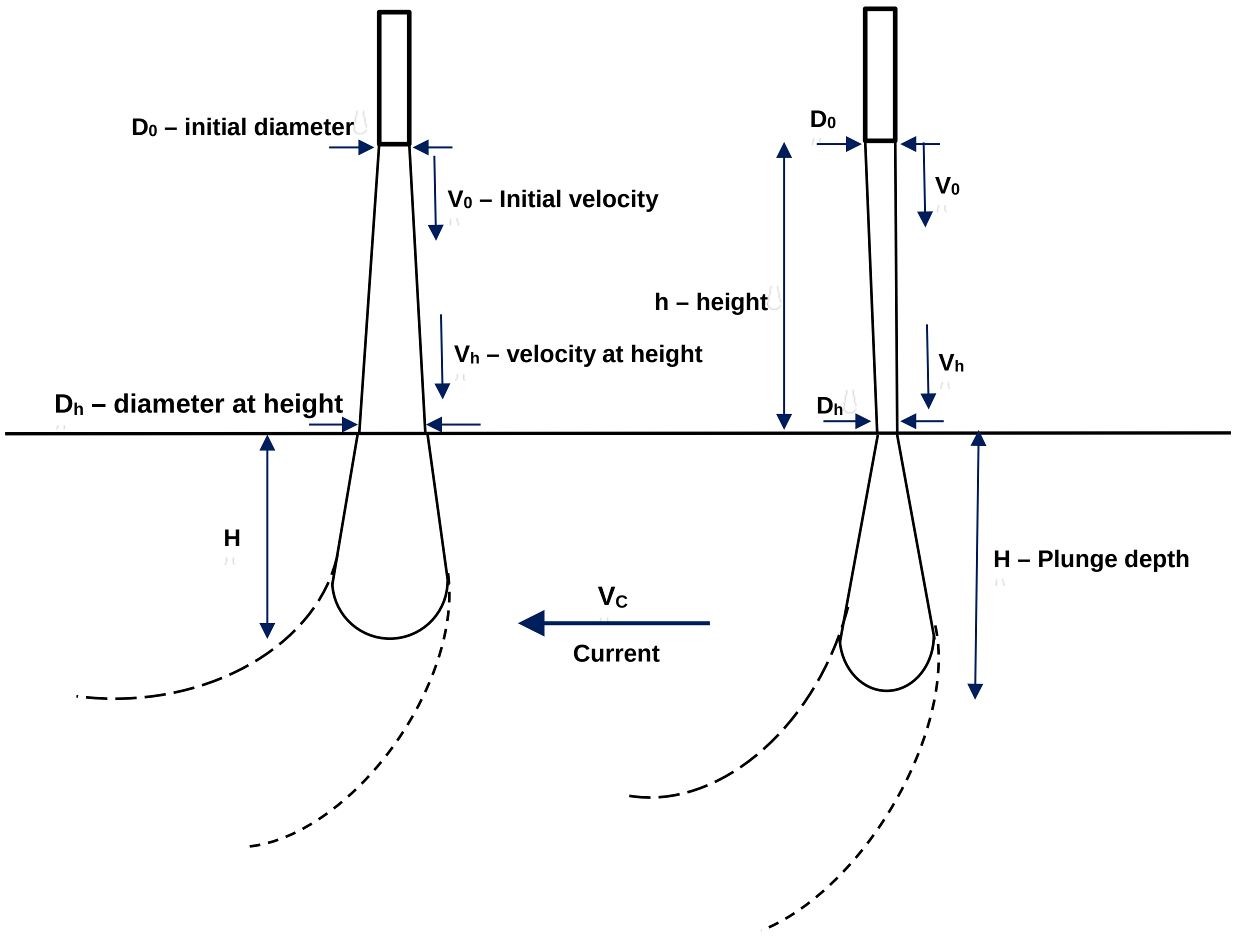

Figure A 2 Conceptual diagram of the continuous turbulent (left) and laminar (right) flow cases of a large-scale plunging jet.

Air entrainment of a plunging jet often occurs when the confined flow of a jet breaks the free-surface of the water causing air-disturbed flows (Guyot *et al.*, 2016). This produces air bubbles under the free surface with an ascent velocity which can impact on the penetration depth of the plume. The following empirical formula proposed by Nakasone (1987), found to be in good agreement with the experimental results detailed in Guyot *et al.* (2016), was used to calculate the penetration depth in this study:

$$H = \frac{2}{3} * H_C$$

Where: H is the penetration depth and H_c is the height of the discharge. The penetration depth was calculated to be 6.7 m below the sea surface.

A3 Modelling Methods

A3.1 Near-Field Modelling

A3.1.1 Overview

An overview of near-field modelling processes is provided in Section 2.1.1 of the main report.

A3.1.2 Description of Near-Field Model: Updated Merge

A description of the UM3 near-field model is provided in Section 2.1.2 of the main report.

A3.1.3 Setup of Near-Field Model

The setup of the near-field model is as described in Section 2.1.3 of the main report, with only summer season conditions being considered.

A3.2 Far-Field Modelling

A3.2.1 Overview

An overview of far-field modelling processes is provided in Section 2.2.1 of the main report.

A3.2.2 Description of Far-Field Model: MUDMAP

A description of the MUDMAP far-field model is provided in Section 2.2.2 of the main report.

A3.2.3 Setup of Far-Field Model

The setup of the far-field model is as described in Sections 2.2.4 and 2.2.5 of the main report, with only summer season conditions being considered and only one simulation run for this period (rather than a stochastic approach).

A4 Modelling Results

A4.1 Near-Field Modelling

A4.1.1 Overview

Forecast plume dimensions and dilutions at the end of the near-field mixing zone for Case 1 (horizontal discharge 10 m below sea level) and Case 2 (vertical discharge 10 m above sea level) under varying current speeds in summer are summarised in Table A 3.

Figure A 3 and Figure A 4 (note the differing x-axis and y-axis aspect ratios) show the change in average temperature and dilution of the plume under varying current speeds (weak, medium and strong) in summer for Case 1 and Case 2, respectively. The figures show the predicted horizontal distances travelled by the plume before the trapping depth is reached (i.e. before the plume becomes neutrally buoyant).

The initial behaviour of the discharge plume is dependent on the discharge conditions (below/above sea surface) and the orientation of the discharge port. For Case 1, the plume moves straight out from the port horizontally and there is no downward momentum. After a period of turbulent mixing due to the momentum of the discharge, the negative buoyancy of the plume causes it to plunge in the water column before it reaches the trapping depth (i.e. the plume becomes neutrally buoyant). For Case 2, the plume plunges downwards after breaking the sea surface, initially due to momentum and then due to its negative buoyancy, before reaching the trapping depth. In both cases, increased ambient current strengths are shown to reduce the plunge depth and increase the horizontal distance travelled by the plume from the discharge point. After the initial behavior of the jet phase of the discharges, the plumes are expected to behave in a similar manner.

The Case 1 plume is forecast to reach neutral density at centreline depths of 21-41 m below the sea surface. This range is forecast to reduce to 14-34 m below the sea surface for the Case 2 plume. In contrast, the minimum and average dilution ranges for Case 2 were predicted to increase in comparison to Case 1, with average dilution ranging between 1:581 and 1:2,169 for Case 1 and between 1:714 and 1:3,290 for Case 2. This is perhaps due to the increased momentum during the initial jet phase of the vertical discharge as it enters the water.

It should be noted that the effects of plunging jet breakup, air entrainment and other non-linear effects were not considered in the modelling process.

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A4.1.2 Results Tables and Figures

Table A 3 Predicted plume characteristics at the end of the near-field mixing zone for the later operations phase flow rate (3,179.8 m^3/d) for each discharge case and current speed.

Discharge Case	Surface Current Speed (m/s)	Plume Diameter (m) at Depth Below Sea Level (BSL) [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Case 1	Weak (0.06)	20.9 [40.5]	28.86	0.50	198	581	22.2
	Medium (0.22)	19.3 [24.9]	29.22	0.16	445	1,699	73.4
	Strong (0.42)	15.8 [21.2]	29.31	0.13	565	2,169	139.6
Case 2	Weak (0.06)	23.7 [33.9]	29.15	0.46	244	714	16.0
	Medium (0.22)	20.8 [17.9]	29.45	0.16	531	2,020	66.5
	Strong (0.42)	19.0 [14.3]	29.52	0.12	875	3,290	149.2

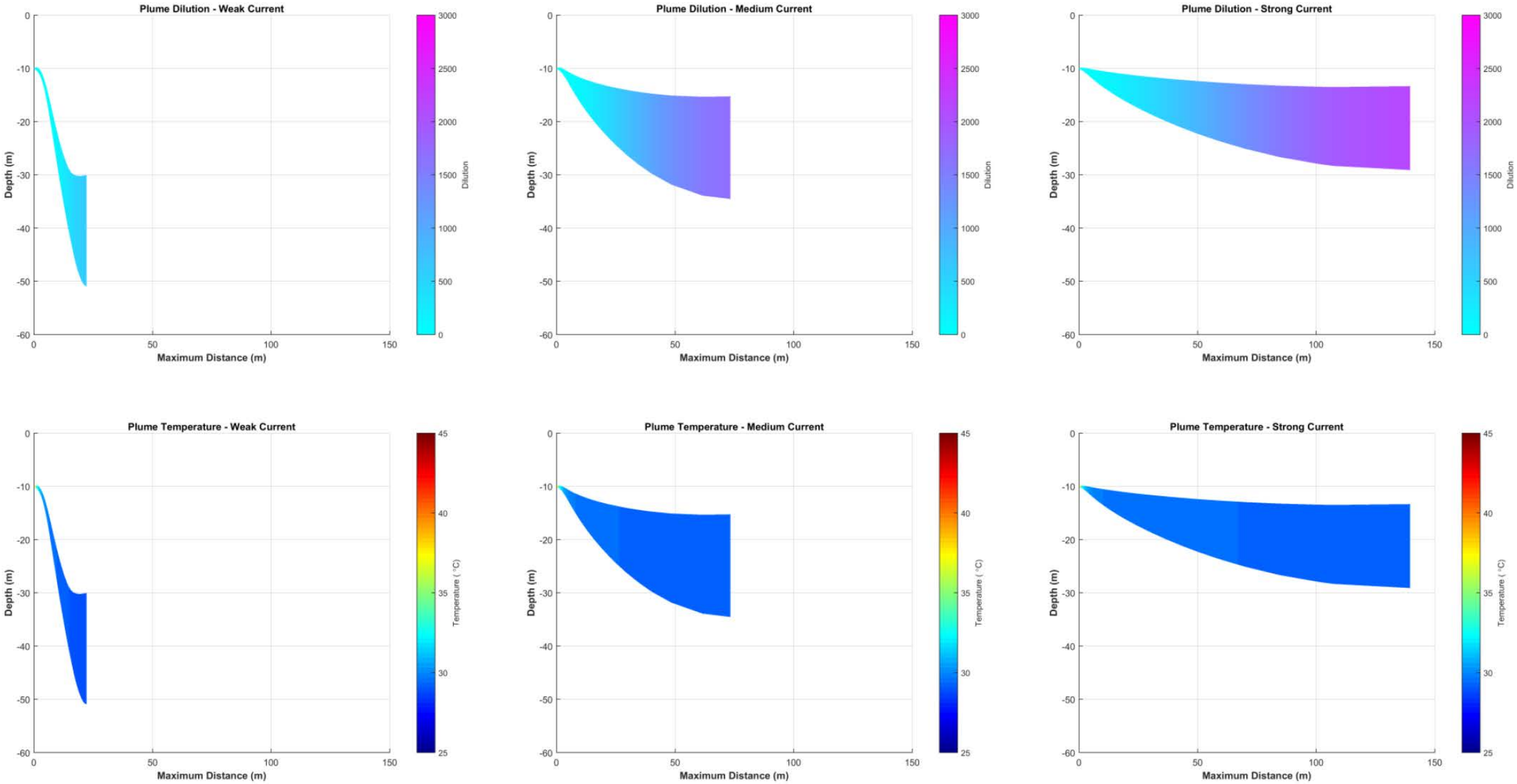

Figure A 3 Near-field Case 1 average temperature and dilution results for weak, medium and strong summer currents (3,179.8 m^3/d flow rate).

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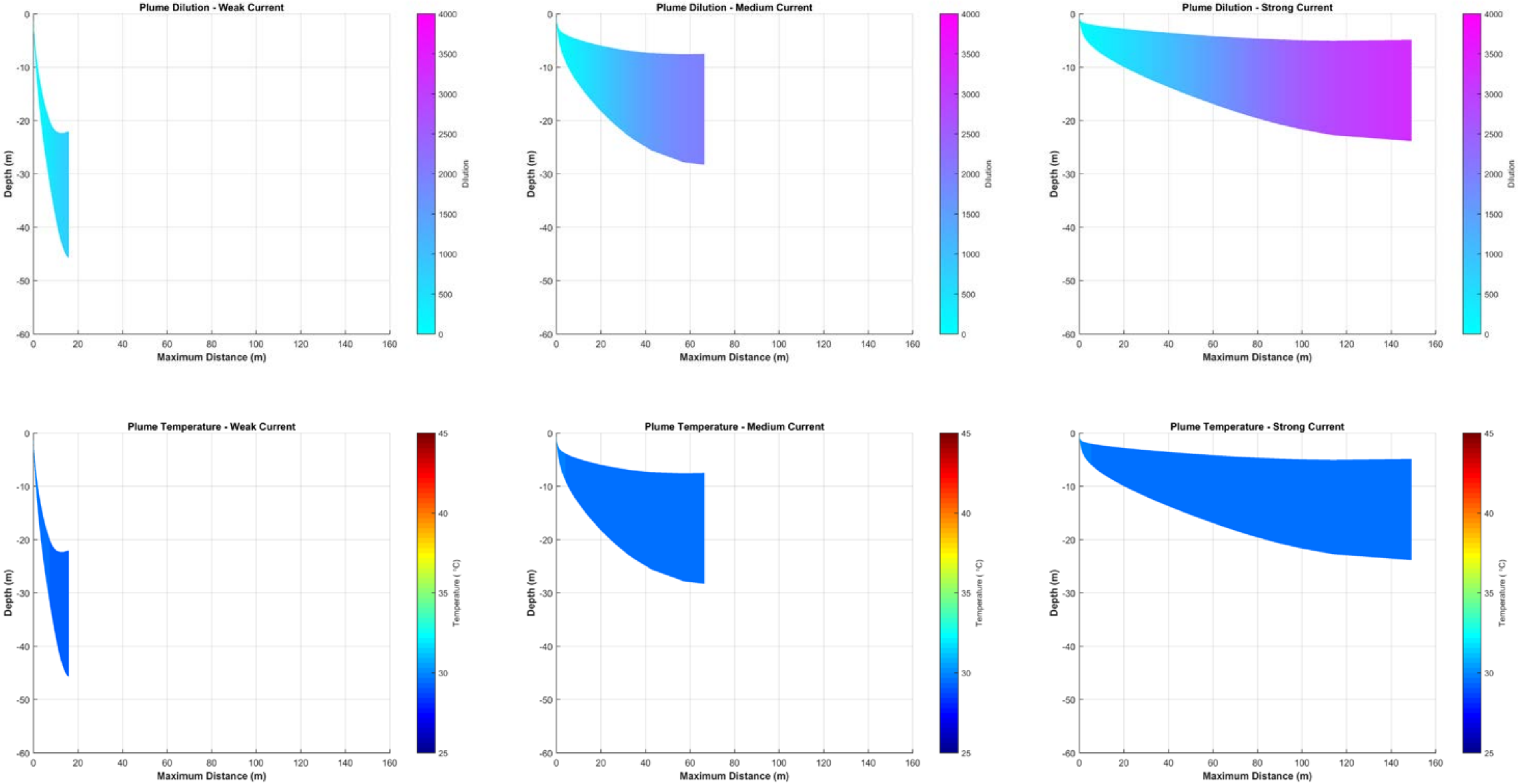

Figure A 4 Near-field Case 2 average temperature and dilution results for weak, medium and strong summer currents (3,179.8 m^3/d flow rate).

A4.2 Far-Field Modelling

A4.2.1 Overview

It is important to note that near-field and far-field modelling are used to describe different processes and scales of effect, and therefore the far-field modelling results will not necessarily correspond to the outcomes at the end of the near-field mixing zone for any given discharge scenario. The far-field results included episodes of pooling of the discharge plume under weak currents, which caused lower dilutions (higher concentrations) further from the discharge location when the pooled plume was advected away. Episodes of recirculation – where the plume moved back under the discharge at some later time due to the oscillatory nature of the tide – were also observed, compounding the pooling effect and further lowering the dilution values.

A single model simulation for Case 1 (horizontal discharge 10 m below sea level) and Case 2 (vertical discharge 10 m above sea level) was run to compare forecast dilutions and plume dimensions in the far-field during summer conditions within the ten-year hindcast period (2008-2017).

Table A 4 summarises the minimum dilution achieved at specific radial distances from the discharge location for each discharge case.

Table A 5 provides a summary of the maximum distances from the discharge location to achieve a given dilution for each discharge case. The results indicate that, for a release of effluent under typical summer conditions, Case 1 exhibited lower dilution (higher concentrations) within 2 km of the discharge location when compared to Case 2. This effect was reversed for distances beyond 2 km, with Case 2 exhibiting lower dilution (higher concentrations).

Figure A 5 and Figure A 6 show the spatial extents of the minimum dilutions for each discharge case during typical summer conditions. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time-step through the water column and do not consider frequency or duration.

From the near-field modelling (Section A4.1), the above-surface discharge plume (Case 2) is predicted to have a reduced plunge depth due to the nature of the discharge, so the plume in the far-field is subjected to a current regime closer to the water surface than the Case 1 plume. This is highlighted when comparing the spatial extent and distribution of the dilution contours for Case 1 (Figure A 5) and Case 2 (Figure A 6). The Case 2 results show a reduced footprint and higher dilution (lower concentrations) near the discharge location, indicating increased mixing due to the influence of a stronger current regime. The influence of stronger currents may also result in plume remnants travelling further from the discharge location in Case 2.

A4.2.2 Results Tables and Figures

Table A 4 Minimum dilution achieved at specific radial distances from the PFW discharge location for each discharge case.

Discharge Case	Minimum dilution (1:x) achieved at specific radial distances from discharge location						
	0.1 km	0.5 km	1 km	2 km	3 km	5 km	>5 km
Case 1	1:114	1:355	1:596	1:1,015	1:1,647	1:2,834	1:2,834
Case 2	1:133	1:386	1:698	1:1,219	1:1,673	1:2,583	1:2,583

Table A 5 Maximum distance from the PFW discharge location to achieve a given dilution for each discharge case.

Discharge Case	Maximum distance (m) from discharge location to achieve given dilution							
	1:50 dilution	1:100 dilution	1:300 dilution	1:500 dilution	1:1,000 dilution	1:3,000 dilution	1:5,000 dilution	1:>6,000 dilution
Case 1	35	78	392	783	1,909	5,280	7,225	7,750
Case 2	N/A	44	380	660	1,518	5,917	8,698	9,041

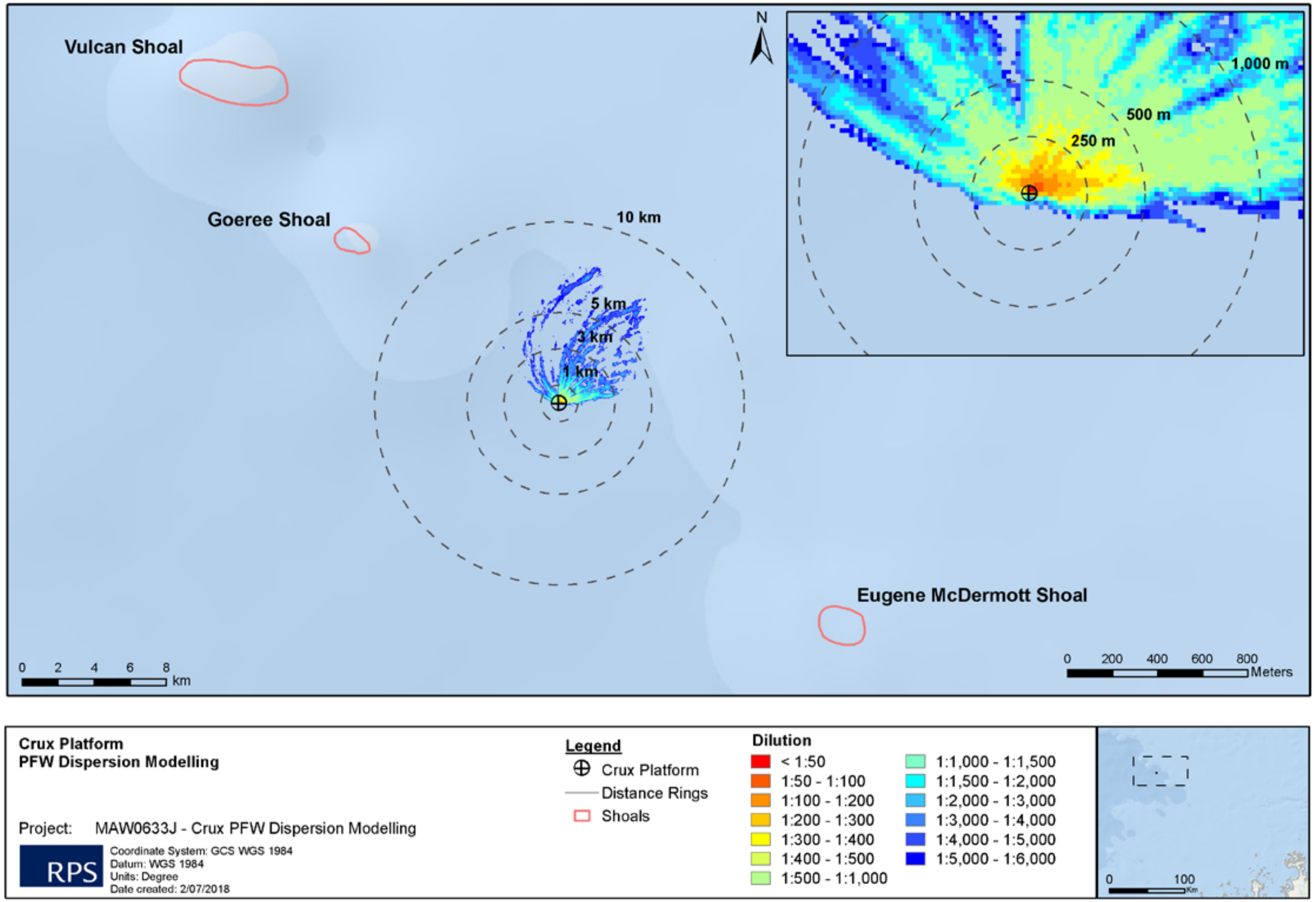

Figure A 5 Predicted Case 1 minimum dilutions under summer conditions for the later operations phase flow rate (3,179.8 m^3/d).

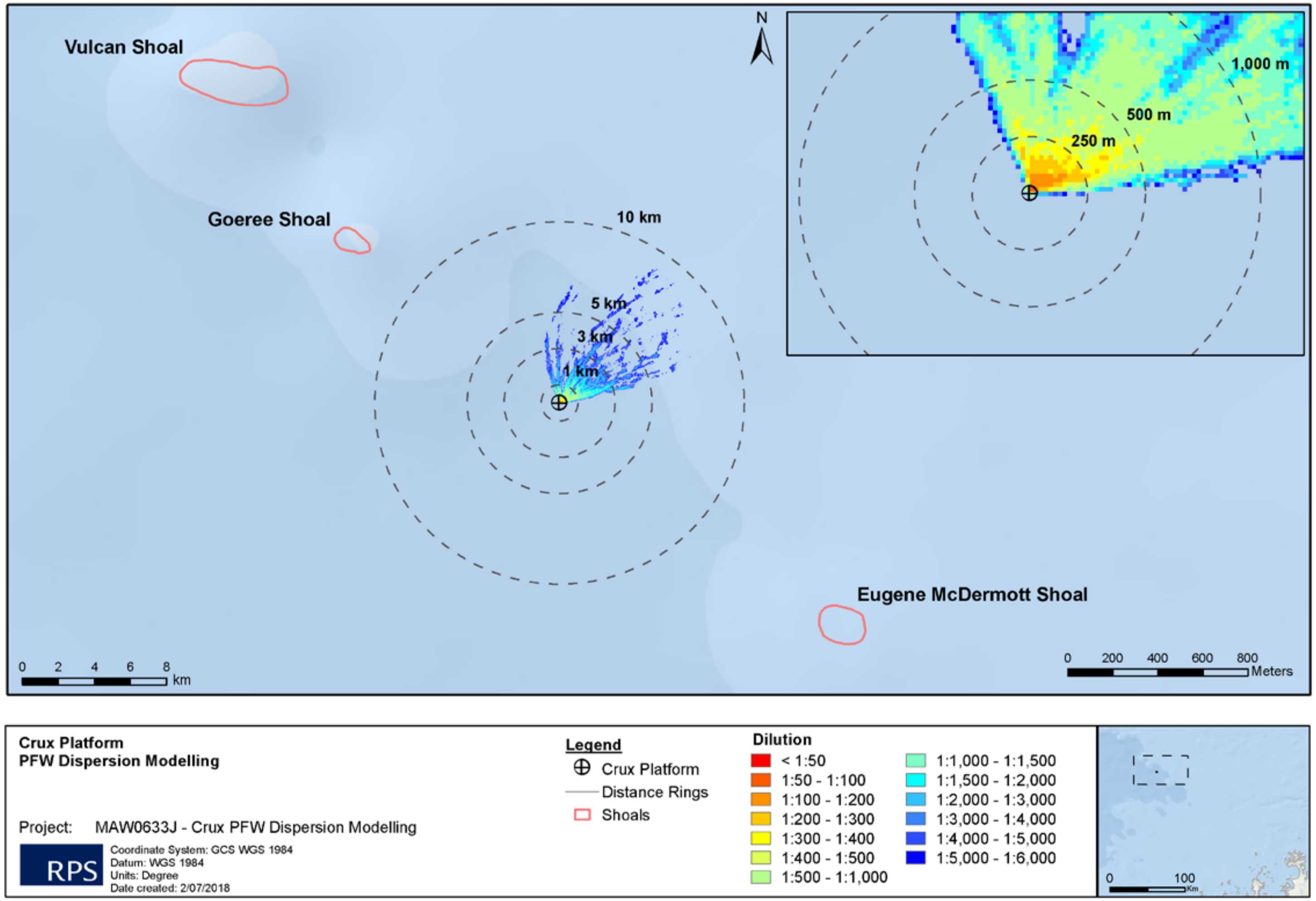

Figure A 6 Predicted Case 2 minimum dilutions under summer conditions for the later operations phase flow rate (3,179.8 m^3/d).

A5 References

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Appendix F: Pipeline and Hydrotest Discharge Modelling Study (RPS 2018c)

REPORT

Shell Crux Project

Marine Dispersion Modelling of Pipeline Hydrotest Discharges

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No.: MAW0633J
Version: 3
Date: 12 July 2018

Document Status

Version	Purpose of Document	Prepared by	Reviewed by	Review Date
A	Issued for internal review	M. Zapata	D. Wright	09/05/2018
0	Issued for Client review	M. Zapata	D. Wright	16/05/2018
1	Issued for Client review	M. Zapata	D. Wright	22/06/2018
2	Issued for Client review	M. Zapata	D. Wright	25/06/2018
3	Issued for Client review	M. Zapata	D. Wright	12/07/2018

Approval for Issue

Name	Signature	Date
Sasha Zigic	S. Zigic	12/07/2018

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1 Introduction

1.1 Background

RPS has been commissioned by CDM Smith Australia Pty Ltd (CDM Smith), on behalf of Shell Australia Pty Ltd (Shell), to undertake a marine dispersion modelling study of proposed water discharges from pipeline hydrotest operations at the Crux end of the export pipeline (i.e. at the proposed Crux Not Normally Manned (NNM) platform location) (Table 1.1). The Crux NNM platform (herein referred to as the 'Crux platform') is located in the northern Browse Basin in offshore Commonwealth marine waters, approximately 190 km offshore north-west Australia and 620 km north-north-east of Broome.

During pre-commissioning activities for the Crux project, Shell will undertake system leak testing, dewatering and preservation of the infield subsea facilities. Chemically-treated seawater will be used for hydrostatic pipeline testing (or hydrotesting) of the infield subsea facilities. The water will be chemically treated with biocide, a hydrate inhibitor and an oxygen scavenger to ensure that corrosion attributable to oxygen, bacterial and microbial action does not occur. While the actual location of hydrotest discharge (potentially at either the Prelude or Crux end of the export pipeline) is unknown at this early stage of engineering definition, this study has conservatively assumed discharge at the Crux end.

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for each of the identified constituents (i.e. biocide) in the hydrotest discharge from the export pipeline, as this is representative of the largest volume of hydrotest water that will be discharged from Crux project activities. This will indicate whether concentrations of any contaminants are still likely to be above defined threshold levels at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the hydrotest discharge and the total potential area of influence, the effect of near-field mixing needs to be considered first, followed by an investigation of the far-field mixing performance. Different modelling approaches are required for calculating near-field and far-field dilutions due to the differing hydrodynamic scales.

To assess the rate of mixing of the biocide in the hydrotest plume from the Crux export pipeline, dispersion modelling was carried out for a flow rate of 0.3 m^3/s (based on 0.3 m^3 volume per metre of pipe and 1 m/s pig speed) over a discharge duration of 44 hours, yielding a total discharge volume of 47,520 m^3.

The potential area that may be influenced by the hydrotest discharge plume was assessed for three distinct seasons: (i) summer (December to February); (ii) the transitional periods (March and September to November); and (iii) winter (April to August).

Table 1.1 Location of the proposed Crux platform used as the release site for the export pipeline hydrotest dispersion modelling assessment.

Release Site	Latitude (°S)	Longitude (°E)	Water Depth (m)
Crux platform (i.e. Crux end of the export pipeline)	12° 57' 52.46"	124° 26' 33.21"	170

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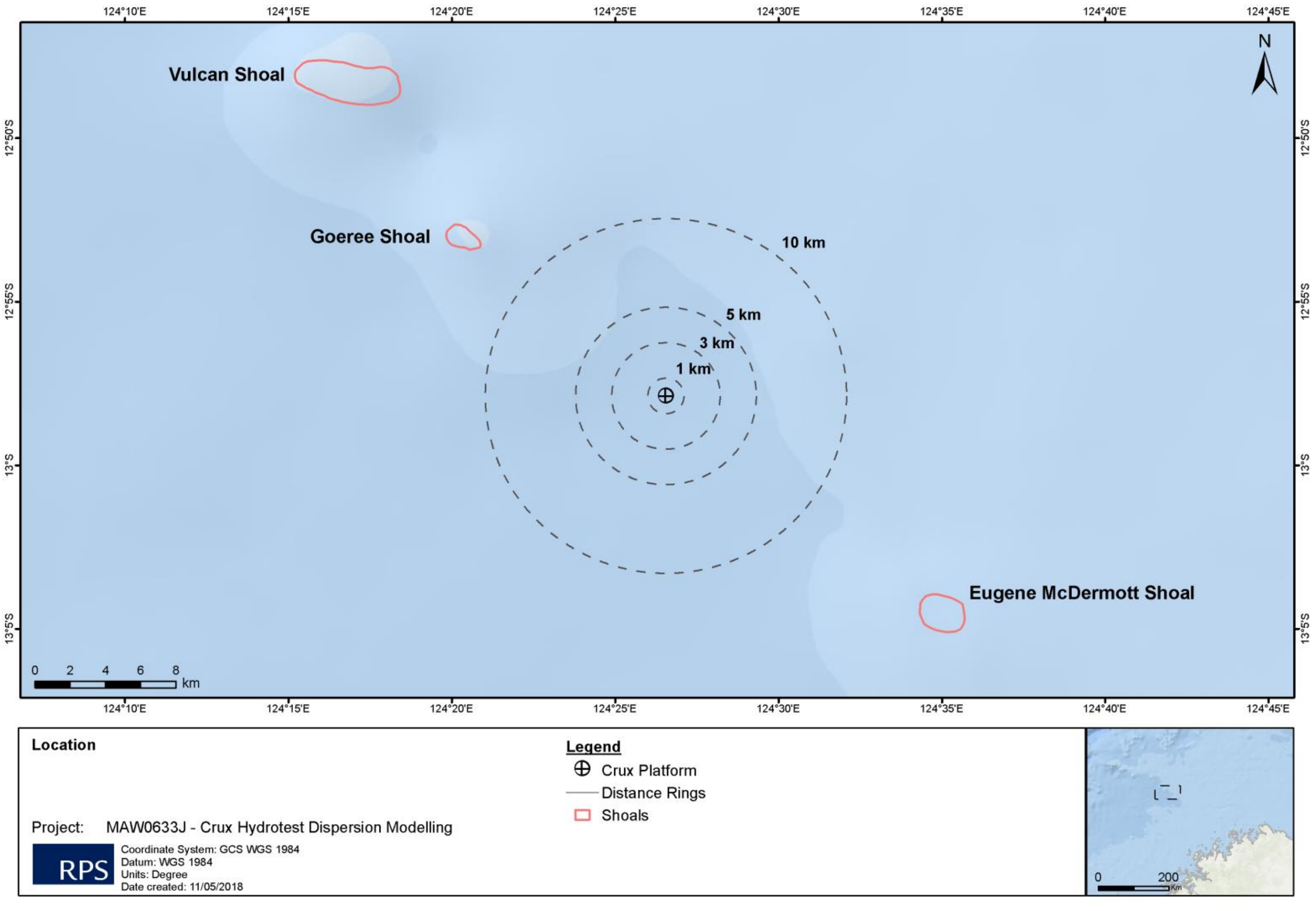

Figure 1.1 Location of the proposed Crux platform relative to the nearest submerged shoals.

1.2 Modelling Scope

The physical mixing of the hydrotest plume was first investigated for the near-field mixing zone. The limits of the near-field mixing zone are defined by the area where the levels of mixing and dilution are controlled by the plume's initial jet momentum and the buoyancy flux, resulting from density differences between the plume and the receiving water. When the plume encounters a boundary such as the seabed, near-field mixing is complete. At this point, the plume is considered to enter the far-field mixing zone.

The scope of the modelling included the following components:

1. Collation of a suitable three-dimensional, spatially-varying current data set surrounding the proposed Crux platform location for a ten-year (2008-2017) hindcast period. The current data set included the combined influence of drift and tidal currents and was suitably long as to be indicative of interannual variability in ocean currents. The current data set was validated against the metocean data collected in the Crux development area.
2. Derivation of statistical distributions for the current speed and directions for use in the near-field modelling. Analyses included percentile distributions and development of current roses. This analysis was important to ensure that current data samples applied in the dispersion model were statistically representative.
3. Collation of seasonally-varying vertical water density profiles at the Crux development area for use as input to the dispersion models.
4. Near-field modelling conducted for each unique discharge to assess the initial mixing of the discharge due to turbulence and subsequent entrainment of ambient water. This modelling was conducted at high spatial and temporal resolution (scales of metres and seconds, respectively).
5. Outcomes from the near-field modelling included estimates of the width, shape and orientation of the plumes, and resulting contaminant concentrations and dilutions, for each discharge at a range of incident current speeds.
6. Establishment of a far-field dispersion model to repeatedly assess discharge scenarios under different sample conditions, with each sample represented by a unique time-sequence of current flow, chosen at random from the time series of current data.
7. Analysis of the results of all simulations to quantify, by return frequency, the potential extent and shape of the mixing zone.

2 Modelling Methods

2.1 Near-Field Modelling

2.1.1 Overview

Numerical modelling was applied to quantify the area of influence of the hydrotest water discharges, in terms of the distribution of the maximum contaminant concentrations that might occur with distance from the source given defined discharge configurations, source concentrations, and the distribution of the metocean conditions affecting the discharge location.

The dispersion of the hydrotest water discharge will depend, initially, on the geometry and hydrodynamics of the discharges themselves, where the induced momentum and buoyancy effects dominate over background processes. This region is generally referred to as the near-field zone and is characterised by variations over short time and space scales. As the discharges mix with the ambient waters, the momentum and buoyancy signatures are eroded, and the background – or ambient – processes become dominant.

The shape and orientation of the discharged water plumes, and hence the distribution and dilution rate of the plume, will vary significantly with natural variation in prevailing water currents. Therefore, to best calculate the likely outcomes of the discharges, it is necessary to simulate discharge under a statistically representative range of current speeds representative of the Crux development area.

2.1.2 Description of Near-Field Model: Updated Merge

The near-field mixing and dispersion of the water discharge was simulated using the Updated Merge (UM3) flow model. The UM3 model is a three-dimensional Lagrangian steady-state plume trajectory model designed for simulating single and multiple-port submerged discharges in a range of configurations, available within the Visual Plumes modelling package provided by the United States Environmental Protection Agency (Frick *et al.*, 2003). The UM3 model was selected because it has been extensively tested for various discharges and found to predict observed dilutions more accurately (Roberts & Tian, 2004) than other near-field models (i.e. RSB and CORMIX).

In the UM3 model, the equations for conservation of mass, momentum, and energy are solved at each time step, giving the dilution along the plume trajectory. To determine the change of each term, UM3 follows the shear (or Taylor) entrainment hypothesis and the projected-area-entrainment (PAE) hypothesis, which quantifies forced entrainment in the presence of a background ocean current. The flows begin as round buoyant jets and can merge to a plane buoyant jet (Carvalho *et al.*, 2002). Model output consists of plume characteristics including centreline dilution, rise-rate, width, centreline height and plume diameter. Dilution is reported as the "effective dilution", the ratio of the initial concentration to the concentration of the plume at a given point, following Baumgartner *et al.* (1994).

The near-field zone ends where the discharged plume reaches a physical boundary or assumes the same density as the ambient water.

Figure 2.1 shows a conceptual diagram of the dispersion and fates of negatively buoyant discharge and the idealised representation of the discharge phases.

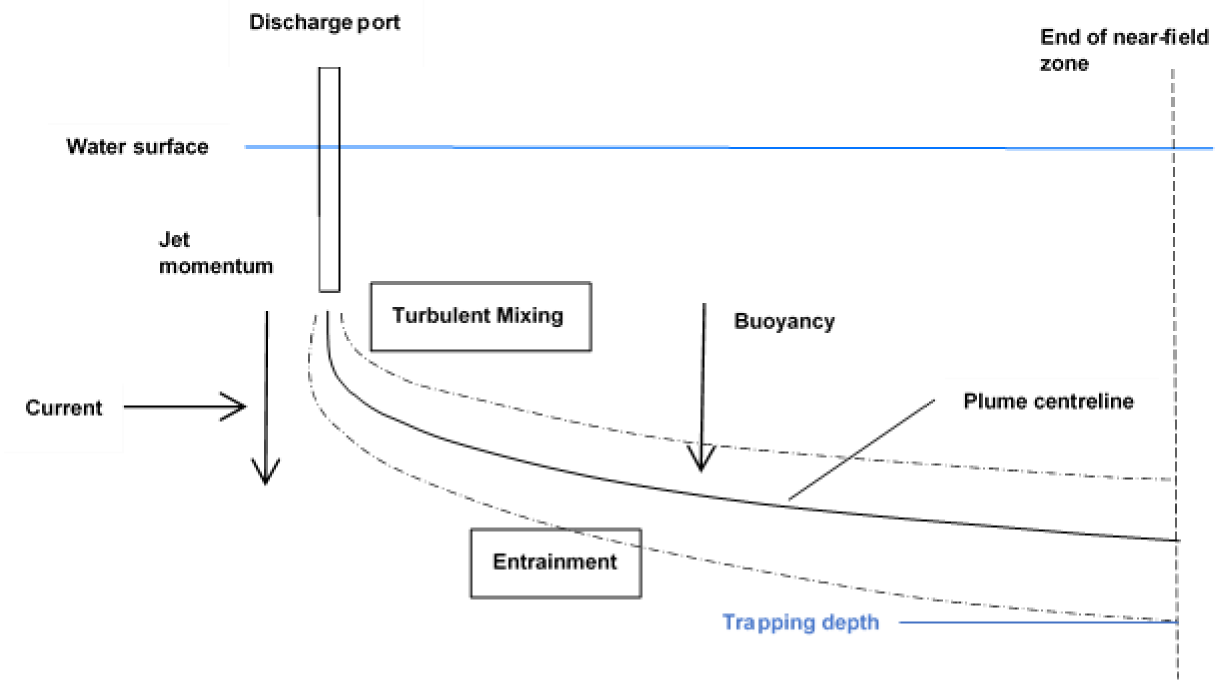

Figure 2.1 Conceptual diagram showing the general behaviour of a negatively buoyant discharge.

2.1.3 Setup of Near-Field Model

2.1.3.1 Discharge Characteristics

The hydrotest discharge characteristics are summarised in Table 2.1. The discharge was assumed to occur 166.5 m below the water surface (2 m above the seabed) through a single outlet and was anticipated to have a salinity and temperature of 34.5 parts per thousand (ppt) and 16.9 °C (average near-seabed water temperature), respectively.

The volume of hydrotest water is 47,520 m^3 and represents the full capacity of the pipeline. Based on the engineering definitions available at the time of undertaking the dispersion modelling study, it is anticipated that the dewatering of the export pipeline will take approximately 44 hours at an average flow rate of 0.3 m^3/s (0.3 m^3 volume per metre of pipe and 1 m/s pig speed).

The concentration of the constituents (biocide) within the discharge is described in Table 2.2. The concentration of biocide was conservatively set at 500 ppm. Although it is anticipated that the residual biocide concentration at the time of discharge will be significantly lower than the initial concentration (i.e. the biocide is expected to be fully used up at the time of commissioning of the export pipeline), the residual discharge concentration was assumed to be the same as the initial dosing concentration.

The biocide threshold concentration/trigger value used as part of this study was 1 ppm (equivalent to 1 mg/L) and is based on the published acute toxicity test data, including that presented in the Wheatstone Project Offshore Facilities and Produced Formation Water Discharge Management Plan: Stage 1 (Chevron, 2015). Note that ecotoxological studies are typically undertaken using constant doses of toxicants for periods of 48 to 96 hours. Results obtained using this approach are difficult to apply directly to the natural environment, where the concentrations and exposure durations for toxicants can vary rapidly. Based on the initial

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concentration of biocide in the hydrotest water, a dilution of 1:500 is required to reduce the concentration of biocide to the impact threshold.

Table 2.1 Summary of hydrotest discharge characteristics.

Parameter	Value/Design
Discharge volume (m^3)	47,520
Discharge duration (hours)	44
Flow rate (m^3/s)	0.3
Outlet pipe internal diameter (m)	0.62
Outlet pipe orientation	Horizontal
Depth of pipe below sea surface (m)	166.5
Discharge salinity (ppt)	34.5
Discharge temperature (°C)	16.9

Table 2.2 Constituents contained within the hydrotest discharge.

Contaminant	Source Concentration (ppm)	Threshold Concentration (ppm)	Required Dilution Factor
Biocide	500	1	500

2.1.3.2 Ambient Environmental Conditions

Inputs of ambient environmental conditions to the UM3 model included a vertical profile of temperature and salinity, along with constant current speeds and general direction. The temperature and salinity profile are required to accurately account for the buoyancy of the diluting plume, while the current speeds control the intensity of initial mixing and the deflection of the hydrotest plume. These inputs are described in the following sections.

2.1.3.2.1 Ambient Temperature and Salinity

Temperature and salinity data based on one year of measurements carried out at the Crux development area by RPS between April 2016 and May 2017 (2017) was supplied for the study.

Temperature and salinity data applied to the near-field modelling was sourced from the World Ocean Atlas 2013 (WOA13) database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration) and its co-located World Data Center for Oceanography (Levitus *et al.*, 2013).

For both data sets, annualised mean temperature profiles were calculated. Figure 2.2 presents a comparison of the WOA13 and RPS-measured annualised temperature profiles. From the profiles, it is evident that the WOA13 temperature structure offer a good match with the measured data and can be considered representative of the conditions in the Crux development area.

Table 2.3 shows the average seasonal water temperature and salinity levels at varying depths from 0 to 170 m. This data can be considered representative of seasonal conditions in the Crux development area.

The seasonal temperature profiles exhibit a reasonably consistent reduction in temperature with increasing depth. Salinity levels are generally more consistent and exhibit a vertically well-mixed water body (34.19 – 34.59 practical salinity unit, PSU), irrespective of season or depth.

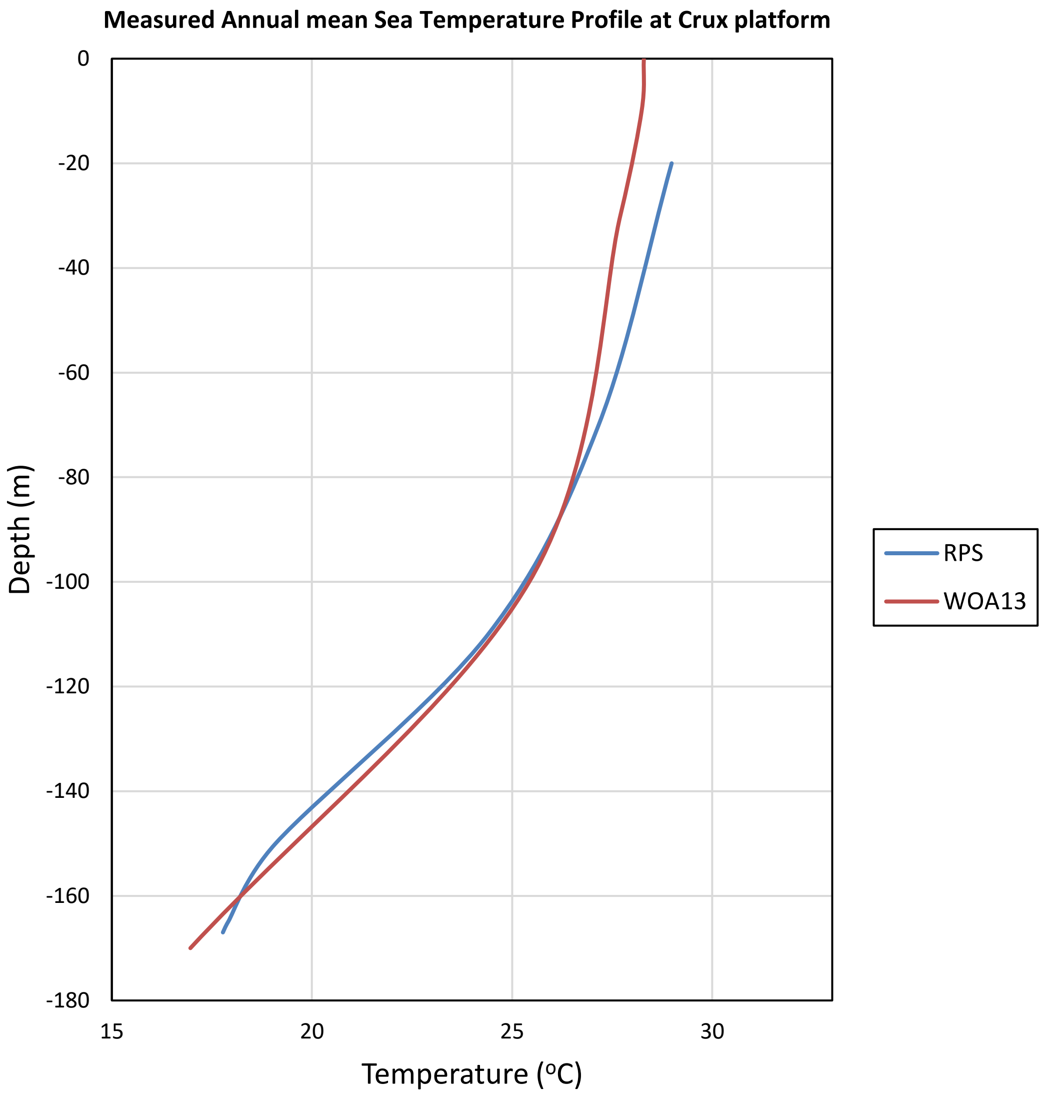

Figure 2.2 Comparison of World Ocean Atlas 2013 and RPS measured annual temperature profiles at Crux platform location.

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Table 2.3 Average temperature and salinity levels adjacent to the proposed Crux platform.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	29.62	34.58
	10	29.54	34.57
	30	28.89	34.55
	100	25.35	34.54
	170	17.86	34.63
Transitional	0	27.34	34.19
	10	27.33	34.21
	30	27.18	34.23
	100	24.43	34.33
	170	16.25	34.59
Winter	0	28.49	34.34
	10	28.39	34.35
	30	27.48	34.39
	100	24.82	34.39
	170	16.98	34.59

2.1.3.2.2 Ambient Current

Ocean current data was sourced from a 10-year hindcast data set of combined large-scale ocean (HYCOM) and tidal currents. The data was statistically analysed to determine the 5th, 50th and 95th percentile current speeds. These statistical current speeds can be considered representative of seasonal conditions in the Crux development area.

Table 2.4 presents the steady-state, unidirectional current speeds at varying depths used as input to the near-field model as forcing for each discharge case:

- 5th percentile current speed: weak currents, low dilution and slow advection.
- 50th percentile (median) current speed: average currents, moderate dilution and advection.
- 95th percentile current speed: strong currents, high dilution and rapid advection to nearby areas.

The 5th, 50th and 95th percentile values are referenced as weak, medium and strong current speeds, respectively.

Table 2.4 Adopted ambient current conditions adjacent to the proposed Crux platform.

Season	Depth (m)	5th Percentile (Weak) Current Speed (m/s)	50th Percentile (Medium) Current Speed (m/s)	95th Percentile (Strong) Current Speed (m/s)
Summer	0	0.068	0.248	0.495
	10	0.060	0.218	0.415
	30	0.059	0.207	0.392
	100	0.055	0.193	0.378
	170	0.051	0.187	0.355
Transitional	0	0.063	0.223	0.434
	10	0.060	0.212	0.411
	30	0.057	0.206	0.400
	100	0.054	0.200	0.378
	170	0.050	0.191	0.357
Winter	0	0.058	0.216	0.455
	10	0.055	0.197	0.399
	30	0.054	0.194	0.386
	100	0.054	0.192	0.387
	170	0.051	0.187	0.347

2.2 Far-Field Modelling

2.2.1 Overview

The far-field modelling expands on the near-field work by allowing the time-varying nature of currents to be included, and the potential for recirculation of the plume back to the discharge location to be assessed. In this case, concentrations near the discharge point can be increased due to the discharge plume mixing with the remnant plume from an earlier time. This may be a potential source of episodic increases in pollutant concentrations in the receiving waters.

2.2.2 Description of Far-Field Model: MUDMAP

The mixing and dispersion of the discharges was predicted using the three-dimensional discharge and plume behaviour model, MUDMAP (Koh & Chang, 1973; Khondaker, 2000).

The far-field calculation (passive dispersion stage) employs a particle-based, random walk procedure. Any chemicals/constituents within the discharge stream are represented by a sample of Lagrangian particles. These particles are moved in three dimensions over each subsequent time step according to the prevailing local current data as well as horizontal and vertical mixing coefficients.

MUDMAP treats the Lagrangian particles as conservative tracers (i.e. they are not removed over time to account for chemical interactions, decay or precipitation). Predicted concentrations will therefore be

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conservative overestimates where these processes actually do occur. Each particle represents a proportion of the discharge, by mass, and particles are released at a given rate to represent the rate of the discharge (mass per unit time). Concentrations of constituents are predicted over time by counting the number of particles that occur within a given depth level and grid square and converting this value to mass per unit volume.

The system has been extensively validated and applied for discharge operations in Australian waters (e.g. Burns *et al.*, 1999; King & McAllister, 1997, 1998).

2.2.3 Stochastic Modelling

A stochastic modelling procedure was applied in the far-field modelling to sample a representative set of conditions that could affect the distribution of constituents. This approach involves multiple (100) simulations of a given discharge scenario and season, with each simulation being carried out under a randomly-selected period of currents. This methodology ensures that the calculated movement and fate of each discharge is representative of the range of prevailing currents at the discharge location. Once the stochastic modelling is complete, all simulations are statistically analysed to develop the distribution of outcomes based on time and event.

2.2.4 Setup of Far-Field Model

2.2.4.1 Discharge Characteristics

The MUDMAP model simulated the discharge into a time-varying current field with the initial dilution set by the near-field results described in Section 2.1.

The hydrotest discharge over 44 hours was modelled using 100 simulations for each season. Once the simulations were complete, they were reported on a seasonal basis: (i) summer (December to February); (ii) transitional (March and September to November) and (iii) winter (April to August).

Table 2.5 Summary of far-field hydrotest discharge modelling assumptions.

Parameter	Value/Design
Hindcast modelling period	2008 to 2017
Seasons	Summer (December to February) Transitional (March and September to November) Winter (April to August)
Discharge volume (m^3)	47,520
Discharge duration (hours)	44
Flow rate (m^3/s)	0.3
Discharge salinity (ppt)	34.5
Discharge temperature (^oC)	16.9
Number of simulations	300 (100 per season)
Discharge duration (hours)	44
Simulated period (days)	5

2.2.4.2 Mixing Parameters

The horizontal and vertical dispersion coefficients represent the mixing and diffusion caused by turbulence, both of which are sub-grid-scale processes. Both coefficients are expressed in units of rate of area change per second (m^2/s). Increasing the horizontal dispersion coefficient will increase the horizontal spread of the discharge plume and decrease the centreline concentrations faster. Increasing the vertical dispersion coefficient spreads the discharge across the vertical layers (or depths) faster.

Spatially constant, conservative dispersion coefficients of 0.15 m^2/s and 0.00005 m^2/s were used to control the spreading of the hydrotest plume in the horizontal and vertical directions, respectively. Each of the mixing parameters was selected following extensive sensitivity testing to recreate the plume characteristics predicted by the near-field modelling. It would be expected that the in-situ mixing dynamics would be greater under average and high energy conditions by a factor of 10 (King & McAllister, 1997, 1998) and thus the far-field model results are designed to produce a worst-case result for concentration extents.

2.2.4.3 Grid Configuration

MUDMAP uses a three-dimensional grid to represent the geographic region under study (water depth and bathymetric profiles). Due to the rapid mixing and small-scale effect of the effluent discharge, it was necessary to use a fine grid with a resolution of 20 m x 20 m to track the movement and fate of the discharge plume. The extent of the grid region measured approximately 20 km (longitude or x-axis) by 20 km (latitude or y-axis), which was subdivided horizontally into 1,000 x 1,000 cells. The vertical resolution was set to 1 m.

2.2.5 Regional Ocean Currents

2.2.5.1 Overview

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region of the Kimberley Coast. However, the offshore regions with water depths exceeding 100-200 m experience significant large-scale drift 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 contaminant plumes over time scales exceeding a few hours.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (hours to days) and result in long trajectories. Hence, the current-induced transport of plumes can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is important to consider all these potential advective mechanisms to rigorously understand patterns of potential transport from a given discharge location.

To appropriately allow for temporal and spatial variation in the current field, dispersion modelling requires the current speed and direction over a spatial grid covering the potential migration zone of plumes. Estimates of the net currents were derived by combining predictions of the drift currents, available from a mesoscale ocean model, with estimates of the tidal currents generated by an RPS model set up for the study area. These estimates are considered representative of the oceanographic currents that influence the Crux development area. Shell has also collected 12 months of metocean data in the Crux development area, with this data being used to validate the hydrodynamic model used in this modelling study. Refer to Section 2.2.5.4 for further discussion of the tidal and current model validation.

A composite modelled ocean current data product was derived by combining predictions of mesoscale circulation currents, available at daily resolution from global ocean models, with predictions of the hourly tidal currents generated by the RPS HYDROMAP model. By combining a drift current model with a tidal model, the influences of inter-annual and seasonal drift patterns, and the more regular variations in tide, were included.

2.2.5.2 Mesoscale Circulation

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 2.3. They are characterised as follows:

- **Buoyancy driven circulation**. The main buoyancy-driven feature in the region is the Indonesian Throughflow (ITF) 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.

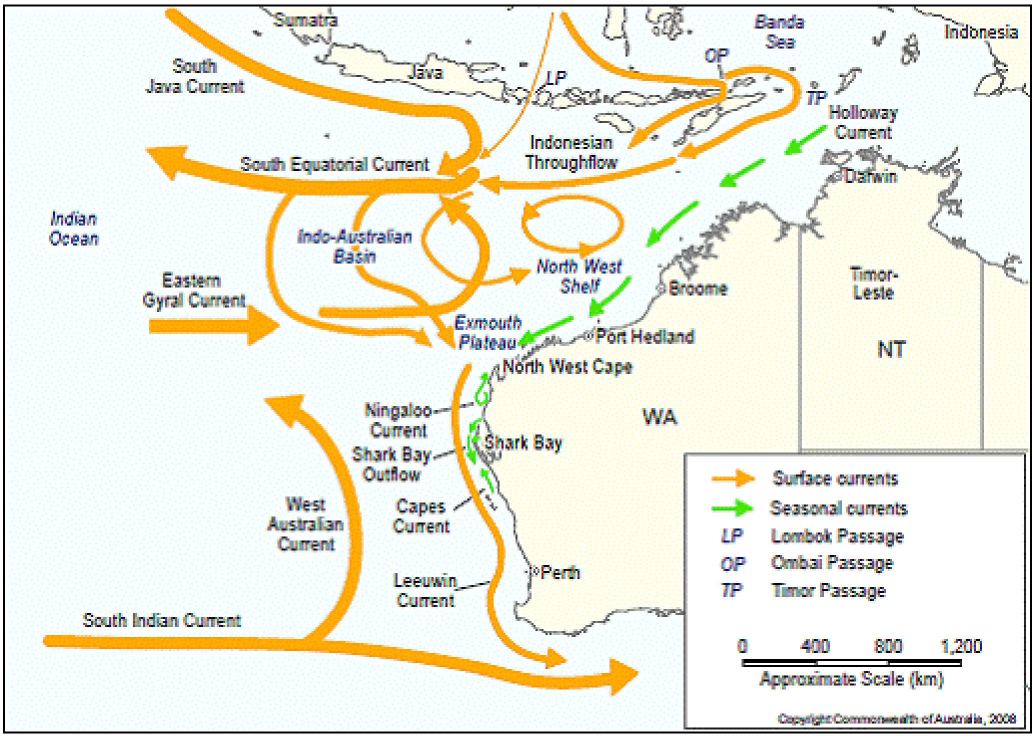

Figure 2.3 A map of the major currents off the West Australian coast (DEWHA, 2008).

RPS

2.2.5.2.1 Description of 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 2008 to 2017 (inclusive).

Figure 2.4 shows the seasonal near-seabed current roses near the proposed Crux platform. The data shows that the near-seabed current speeds and directions vary between seasons. In general, during summer (December to February) currents have the strongest average speed (<0.1 m/s with a maximum of 0.32 m/s) and tend to flow east-southeast. During winter (April to August), currents flow mostly toward the west-southwest. During transitional conditions (March and September to November), currents flow mostly towards the south-southeast.

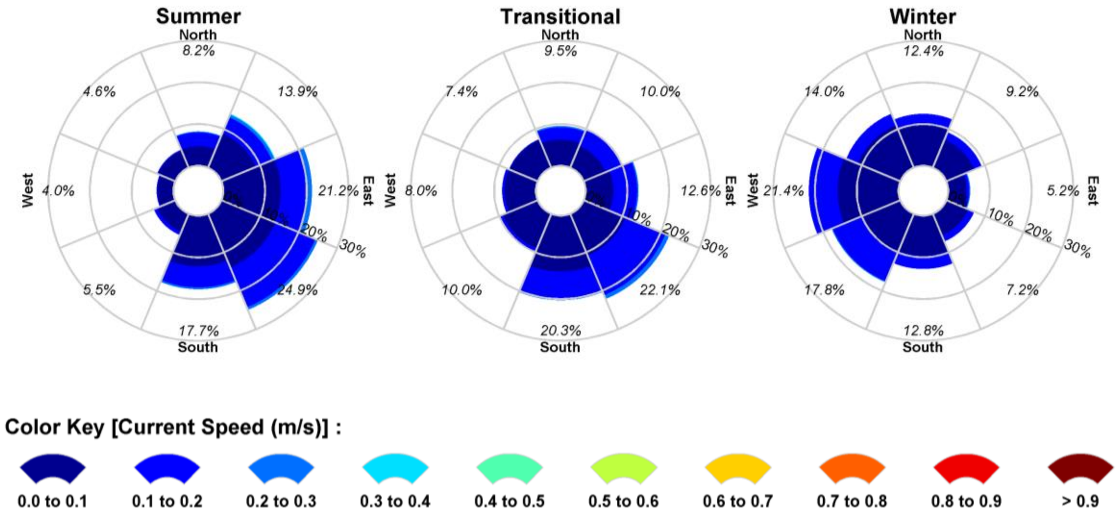

Figure 2.4 Seasonal current distribution (2008-2017, inclusive) derived from the HYCOM database near to the proposed Crux platform. The colour key shows the current magnitude, the compass

direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.2.5.3 Tidal Currents

2.2.5.3.1 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) (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 particular 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).

2.2.5.3.2 Tidal Grid Setup

A HYDROMAP model was established over a domain that extended approximately 3,300 km east-west by 3,100 km north-south over the eastern Indian Ocean. The grid extends beyond Eucla in the south and beyond Bathurst Island in the north (Figure 2.5).

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 98,600 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.

2.2.5.3.3 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.

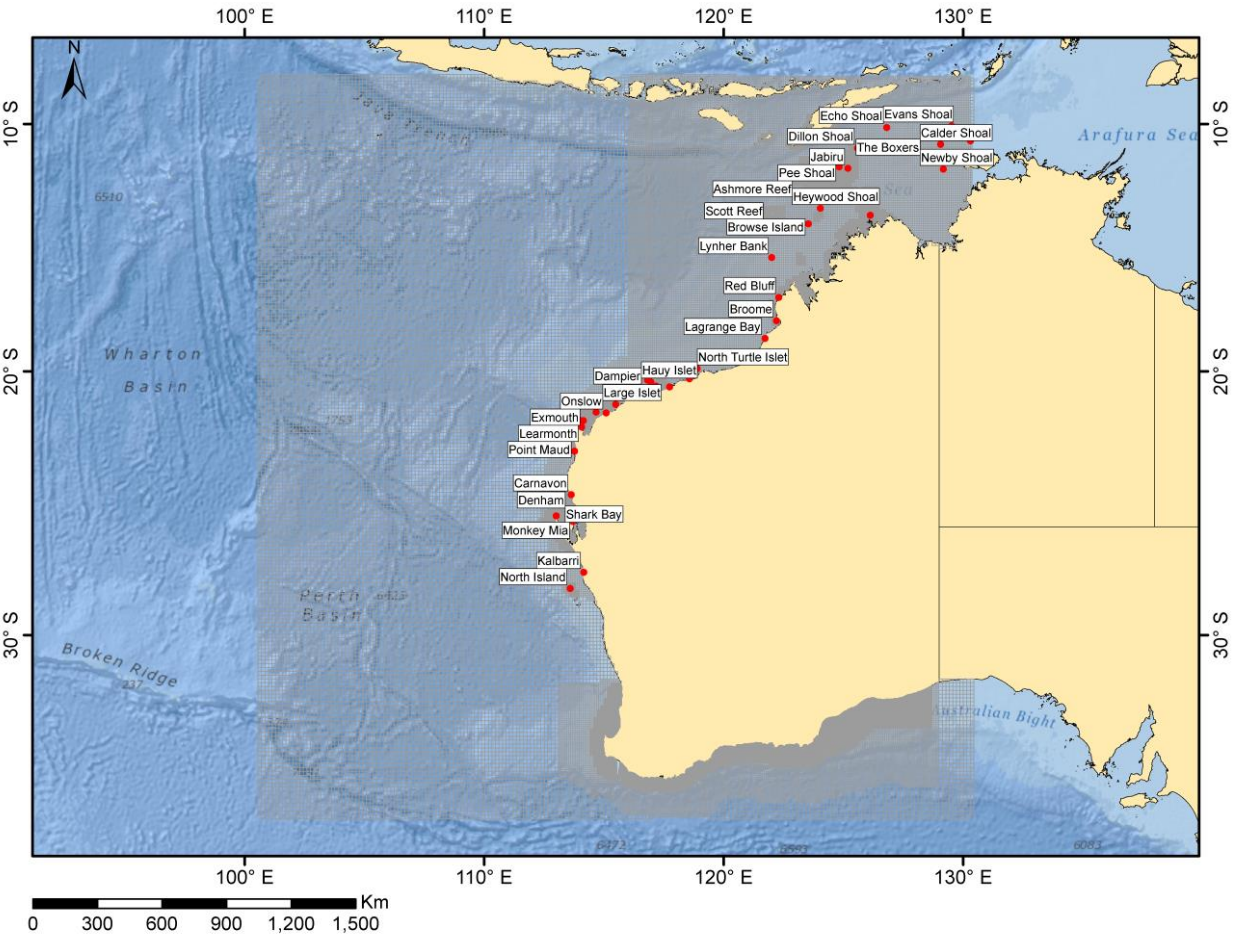

Figure 2.5 Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing the full domain in context with the continental land mass and the locations available for tidal comparisons (red labelled dots). Higher-resolution areas are indicated by the denser mesh zones.

2.2.5.4 Tidal and Current Model Validation

The suitability of the modelled tidal and drift current data products was evaluated by comparing the predicted currents to those measured at the Crux development area. The following sections describe the sources of both the modelled and measured data, the comparison methodology, and the outcomes of the comparisons for both the tidal and drift current components.

2.2.5.4.1 Data Sources

A tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP. HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. This model is described in Section 2.2.5.3.

A mesoscale ocean current data sets was selected for the study: HYCOM (Hybrid Coordinate Ocean Model) Consortium's global ocean model, HYCOM. This model is described in Section 2.2.5.2.

A data set of measured currents was collected by RPS at the Crux development area between April 2016 and May 2017 (RPS, 2017). This data set includes a series of point current measurements made at six depths through the water column using CM04 current meters mounted on a floating mooring. The measurement depths are approximately 20 m, 70 m, 110 m, 150 m, 165 m and 167 m below the water surface. The temporal resolution of the data is 1 minute. The raw data was quality-controlled by RPS and only data identified as high-quality was used for comparison to model data. For the measurements at a 20 m water depth, there is approximately a 7-week gap in the data between early September and late October 2016.

2.2.5.4.2 Model Validation Skills

Overview

The mesoscale and tidal current models were validated through quantitative and visual comparisons of measured and modelled data.

Statistics

A quantitative analysis of a model's skill at replicating the environmental conditions was conducted using the Index of Agreement (IOA), presented in Willmott (1981), and the Mean Absolute Error (MAE), discussed in Willmott (1982) and Willmott & Matsuura (2005). Other traditional error estimates, such as the correlation coefficient and the root mean square error (RMSE) are problematic and prone to ambiguities and bias (Willmott & Matsuura, 2005; Willmott, 1982). Consequently, they are not reported in isolation here.

The MAE is simply the average of the absolute values of the differences between the observed and modelled values. MAE is a more natural measure of average error (Willmott & Matsuura, 2005) and more readily understood. The IOA is determined using the following formula:

$$\mathrm{IOA} = 1 - \frac{\sum |X_{\mathrm{model}} - X_{\mathrm{obs}}|^2}{\sum \left(|X_{\mathrm{model}} - \overline{X_{\mathrm{obs}}}| + |X_{\mathrm{obs}} - \overline{X_{\mathrm{obs}}}| \right)^2}$$

In this equation, X represents the variable being compared and $\bar{X}$ represents the mean of that variable over time.

A perfect agreement can be said to exist between the model and field observations if the IOA gives a measure of one, and complete disagreement will produce an IOA measure of zero (Wilmott, 1981). Although it is difficult to find guidelines for what values of the IOA might represent a good agreement, Willmott *et al.* (1985) suggests that values meaningfully larger than 0.5 represent good model performance. Clearly, the higher the IOA and the lower the MAE, the better the model performance.

An important point to note regarding both, and in fact most, measures of model performance, is that slight phase differences in the series can result in a seemingly poor statistical comparison, particularly in rapidly changing series such as tidal direction or water elevation where the tidal range is large. It is therefore always important to consider both the statistics <u>and</u> the visual representation of the comparison (Willmott *et al.*, 1985). Statistical comparison of current direction can be misleading; skill measures of direction can become biased where the directional fluctuations are near 0-360°. Therefore, we have based the quantitative assessment on the U and V current components and not magnitude and direction.

Time Series

In addition to bulk statistical measures, model performance for the measurement period was assessed visually with the aid of scatterplots and rose plots. The scatterplots show the correlation between the x- and y-components of the measured and modelled data. The rose plots show the frequency of current direction by sector, and magnitude by colour, to allow comparison of current direction between modelled and measured data.

The model performance was also evaluated against time series plots of water level, U (east-west) velocity component, V (north/south) velocity component, current speed and current direction data. This approach is valuable because statistical measures of model skill can heavily penalise errors in phase (i.e. time lags) even when the dynamics of flow are broadly reproduced.

2.2.5.4.3 Tidal Elevation Validation

For verification of the tidal elevation 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 Crux development area were used for comparison.

Time series comparisons were completed for a six-month period from January to June 2010. The statistics are summarised in Table 2.6, and indicate excellent model performance in this region. Water level time series for these locations are shown in Figure 2.6, Figure 2.7 and Figure 2.8 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.

For the purposes of understanding the limitations in accuracy of the tidal predictions, the RMSE and MAE in Table 2.6 should be noted. On average, the model predictions are within 0.1-0.3 m of XTide predictions based on known constituent data at any point in time. Often the error is mostly attributable to errors of phase in the tidal signal, with the magnitude of the tidal rise and fall over each tide well represented. However, in the application of the data predictions to operational circumstances, the potential errors should be considered.

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 2.9. 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.

RPS

Table 2.6 Statistical comparison of predicted surface elevation data from HYDROMAP and XTide at 18 locations in the tidal model domain (January to July 2010).

Tide Station	Longitude (°E)	Latitude (°S)	IOA	CC	MAE (m)	RMSE (m)
Ashmore Reef	123.02	12.22	0.99	0.99	0.14	0.18
Browse Island	123.55	14.10	0.97	0.97	0.36	0.45
Calder Shoal	129.07	10.85	0.97	0.97	0.17	0.21
Cape Legendre	116.83	20.35	0.99	0.99	0.12	0.14
Dillon Shoal	125.60	11.00	0.97	0.95	0.18	0.22
Echo Shoal	126.82	10.15	0.97	0.94	0.17	0.21
Evans Shoal	129.53	10.08	0.98	0.98	0.11	0.14
Goodrich Bank	130.32	10.70	0.99	0.97	0.13	0.16
Heywood Shoal	124.05	13.47	0.98	0.96	0.27	0.33
Jabiru	125.20	11.83	097	0.95	0.22	0.27
Loxton Shoal	128.72	09.60	0.99	0.98	0.10	0.13
Lynedoch Bank	130.82	10.03	0.98	0.98	0.12	0.15
Lynher Bank	122.02	15.47	0.98	0.97	0.26	0.31
Newby Shoal	129.18	11.87	0.98	0.96	0.23	0.27
Pee Shoal	124.83	11.77	0.97	0.94	0.23	0.27
Scott Reef	121.80	14.05	0.99	0.98	0.16	0.19
The Boxers	128.35	11.45	0.97	0.96	0.16	0.20
Troughton Island	126.13	13.75	0.97	0.95	0.27	0.33

Notes: *IOA* *Index of Agreement – values close to 1 represent a high level of agreement.*
CC *Correlation Coefficient – values close to 1 represent very good correlation.*
MAE *Mean Absolute Error – the lower the value, the smaller the error.*
RMSE *Root Mean Square Error – the lower the value, the smaller the error.*

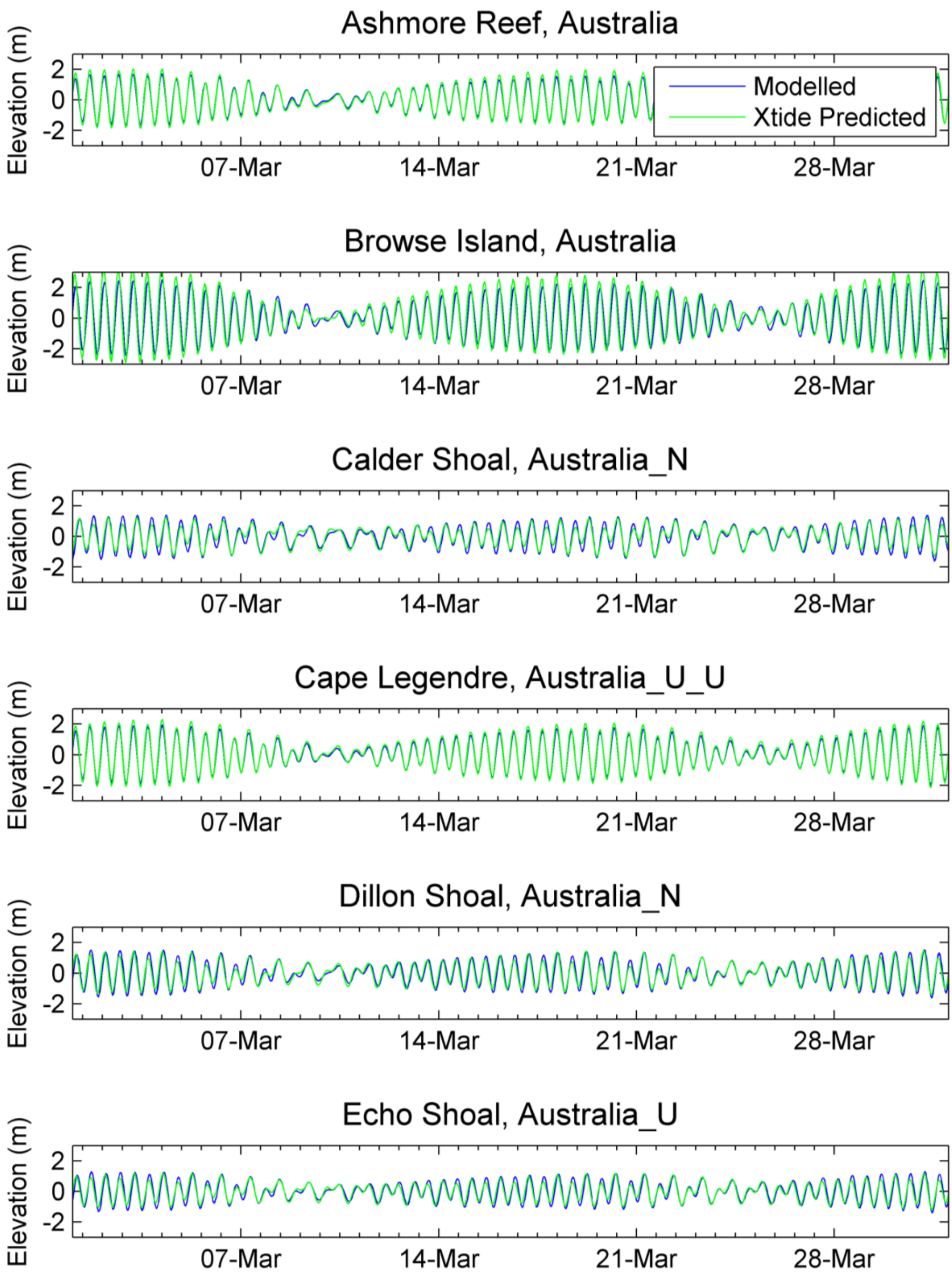

Figure 2.6 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

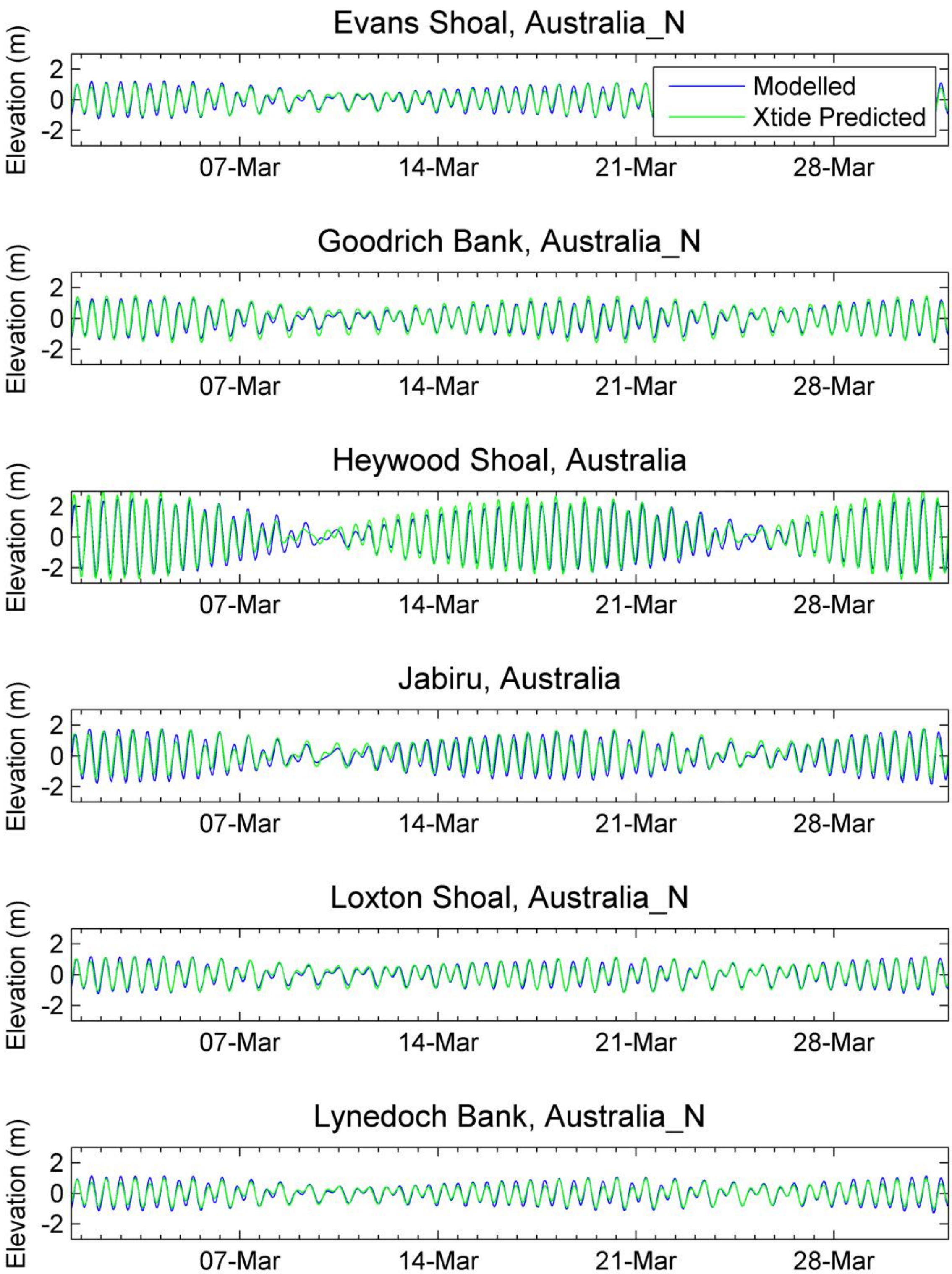

Figure 2.7 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

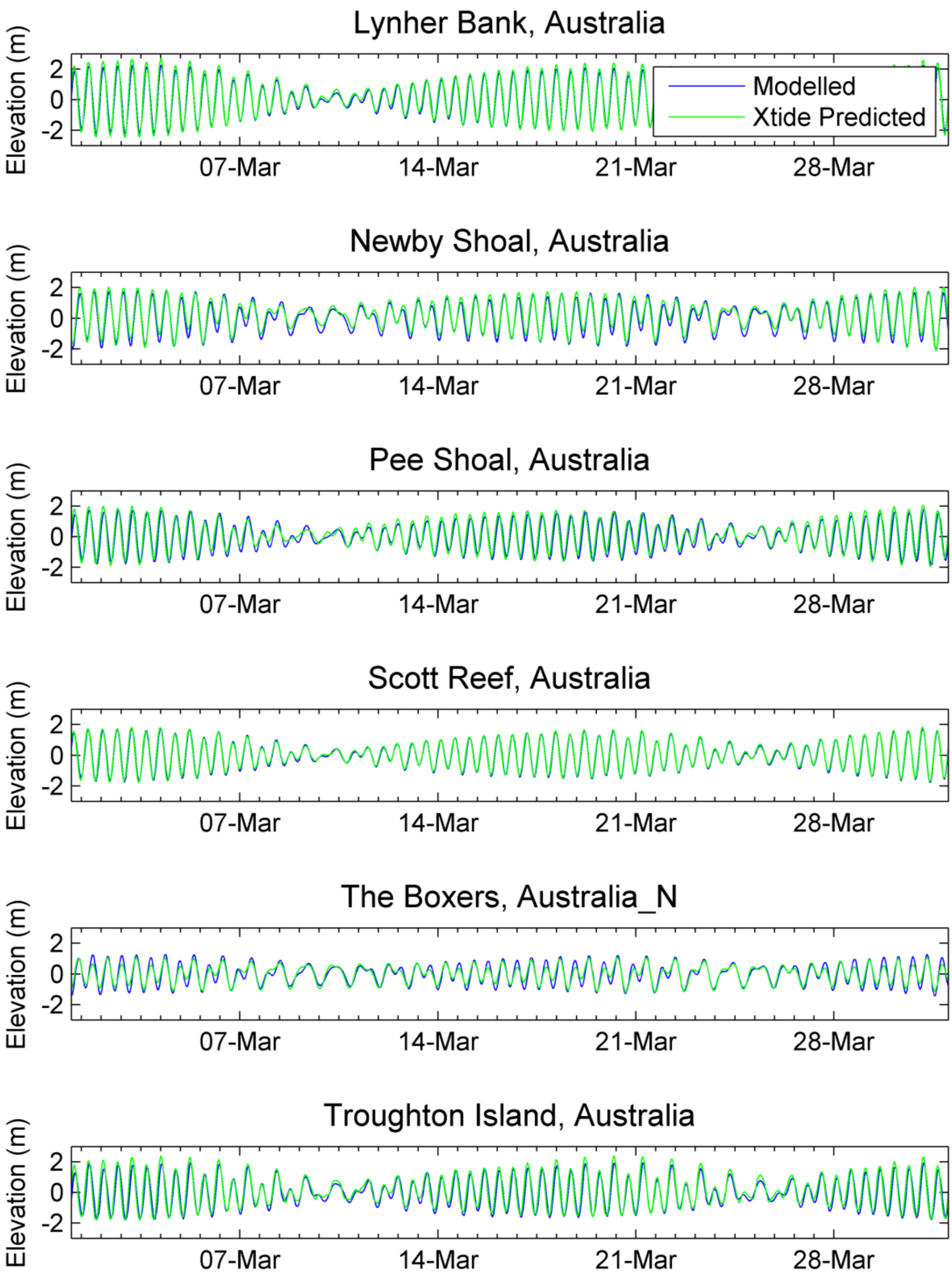

Figure 2.8 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

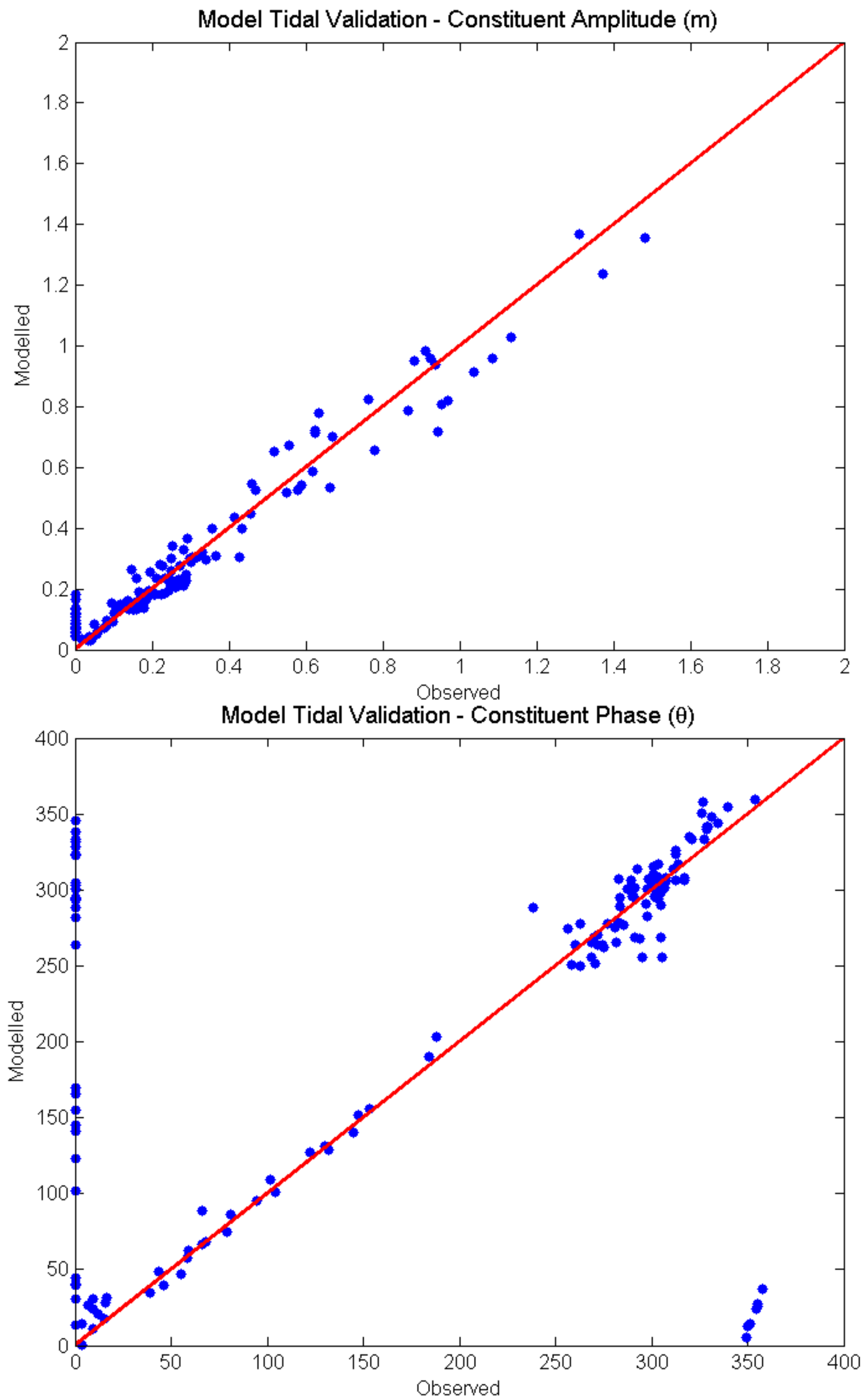

Figure 2.9 Comparisons between predicted tidal constituent amplitudes (top) and phases (bottom) from HYDROMAP and XTide at all stations in the tidal model domain. The red line indicates a 1:1 correlation between the respective data sets.

2.2.5.4.4 Composite Current Data Set Validation: HYDROMAP + HYCOM

A composite modelled ocean current data product was derived by combining predictions of mesoscale circulation currents, available at daily resolution from the HYCOM ocean model, with predictions of the hourly tidal currents generated by the RPS HYDROMAP model.

To verify the modelled current predictions, the composite model outputs at the Crux development area were compared against the unfiltered site-specific current measurements. The model results were validated through both quantitative and visual comparisons between measured and modelled data at each depth where both data sets were available.

Time series comparison of composite model outputs and measured current magnitude, direction, and U/V velocity components at water depths of 20 m, 70 m and 110 m are presented in Figure 2.10, Figure 2.11 and Figure 2.12, respectively, for one month during winter (June 2016) and summer (December 2016). The time series comparisons reveal that the composite model offers a good match with the measured U/V velocity components at all water depths in both winter and summer, with the magnitudes and timings of the peaks and troughs matching well.

The IOA and MAE values derived from comparisons of the U/V velocity components at water depths of 20 m, 70 m and 110 m over the full measurement period are presented in Table 2.7. The IOA for each velocity component is high at all water depths, reflecting the good match in the magnitudes and timings of the peaks and troughs in the composite model data and measured data. The MAE for the U/V velocity components is relatively low at approximately 0.1 m/s for all water depths, indicating that the magnitude and range of the velocity components match well; however, a slight overprediction of the current magnitude is evident at times.

To compare directionality, roses for the composite model outputs and measured currents at 20 m, 70 m and 110 m water depths over the full measurement period are shown in Figure 2.12. The roses show that the composite model current direction is a good match with the measured direction. A shift in the dominant current direction from a north/south alignment in the measured data set to a northwest/southeast alignment in the composite model data set is evident at the 20 m water depth, and to a lesser extent also at the 70 m water depth. However, the range and variability in the measured current direction is captured by the composite model data, which matches best with the measured data at the water depth of 110 m.

Based on the validation performance, the composite model data set is a good model of standard conditions at the Crux development area and will adequately resolve local and regional circulation patterns. As such, the model is considered suitable for use in the numerical modelling studies conducted as part of the Crux project.

Table 2.7 Statistical comparison of predicted (HYDROMAP+HYCOM) and observed current speeds along orthogonal component axes at the Crux development area (2016-2017).

Skill Measure	Index of Agreement (IOA)			Mean Absolute Error (MAE) (m/s)		
Depth (m)	20	70	110	20	70	110
U Component	0.72	0.75	0.76	0.11	0.11	0.11
V Component	0.82	0.80	0.78	0.11	0.10	0.10

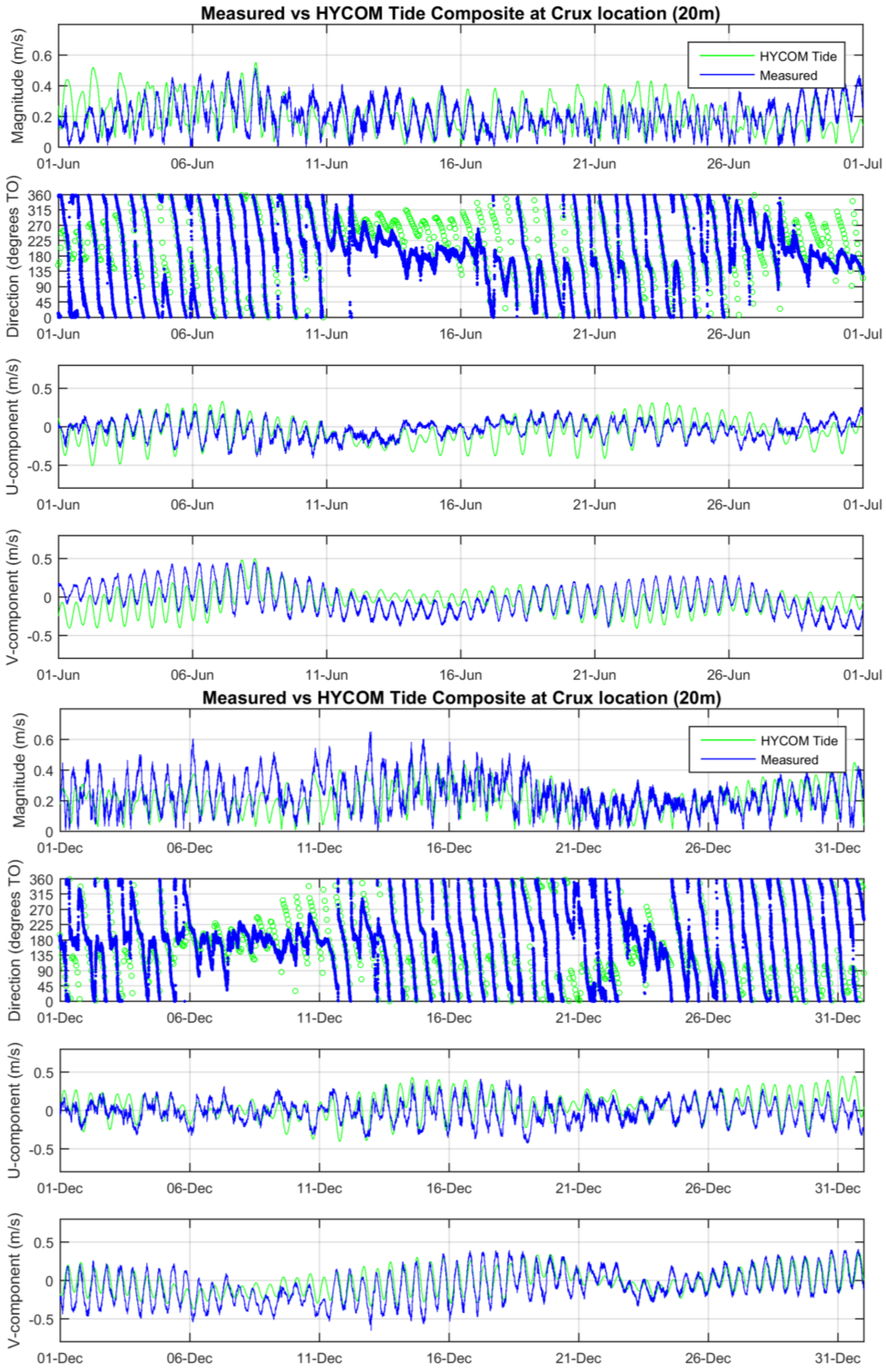

Figure 2.10 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 20 m for June 2016 (top panel) and December 2016 (bottom panel).

RPS

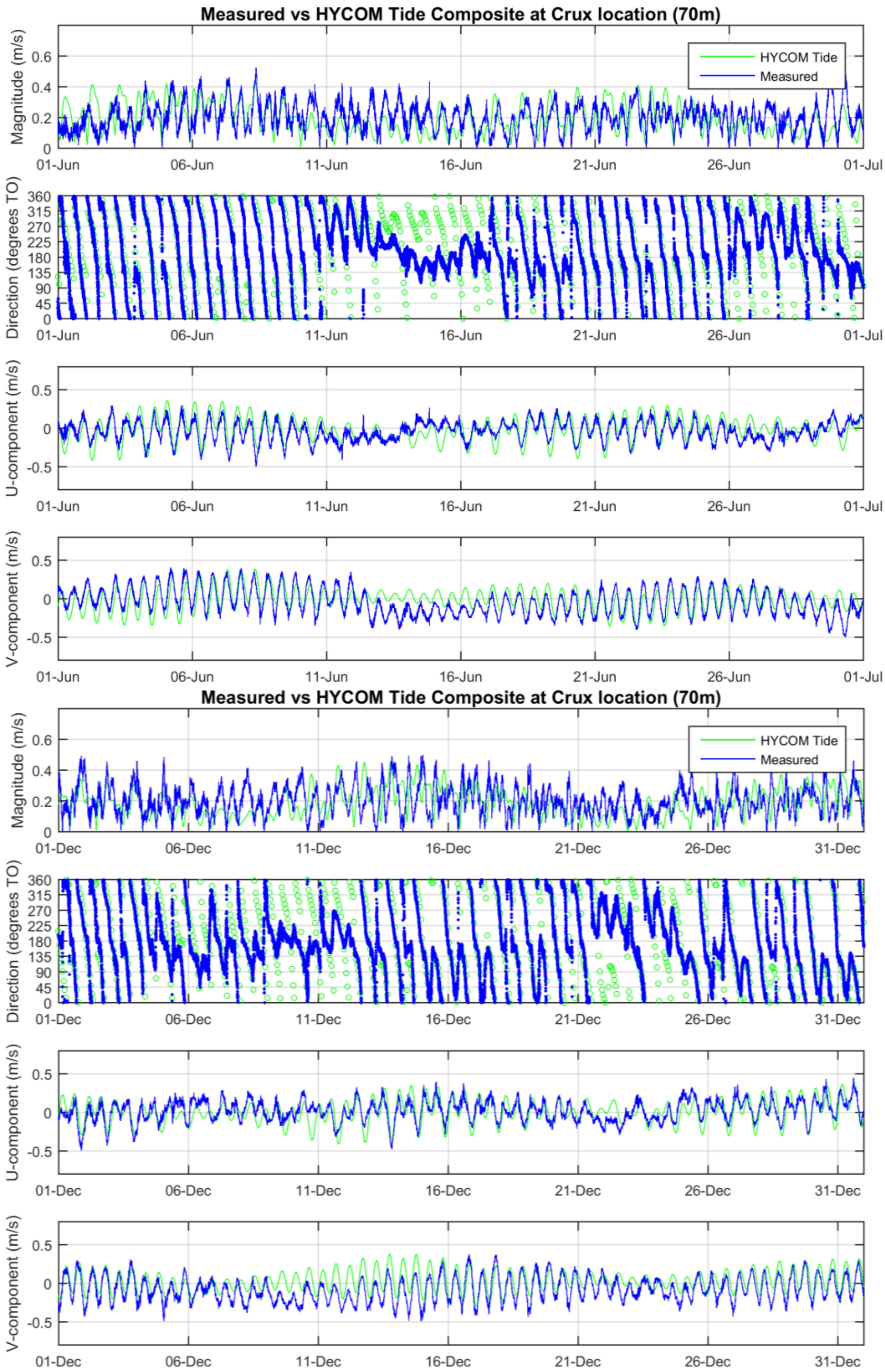

Figure 2.11 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 70 m for June 2016 (top panel) and December 2016 (bottom panel).

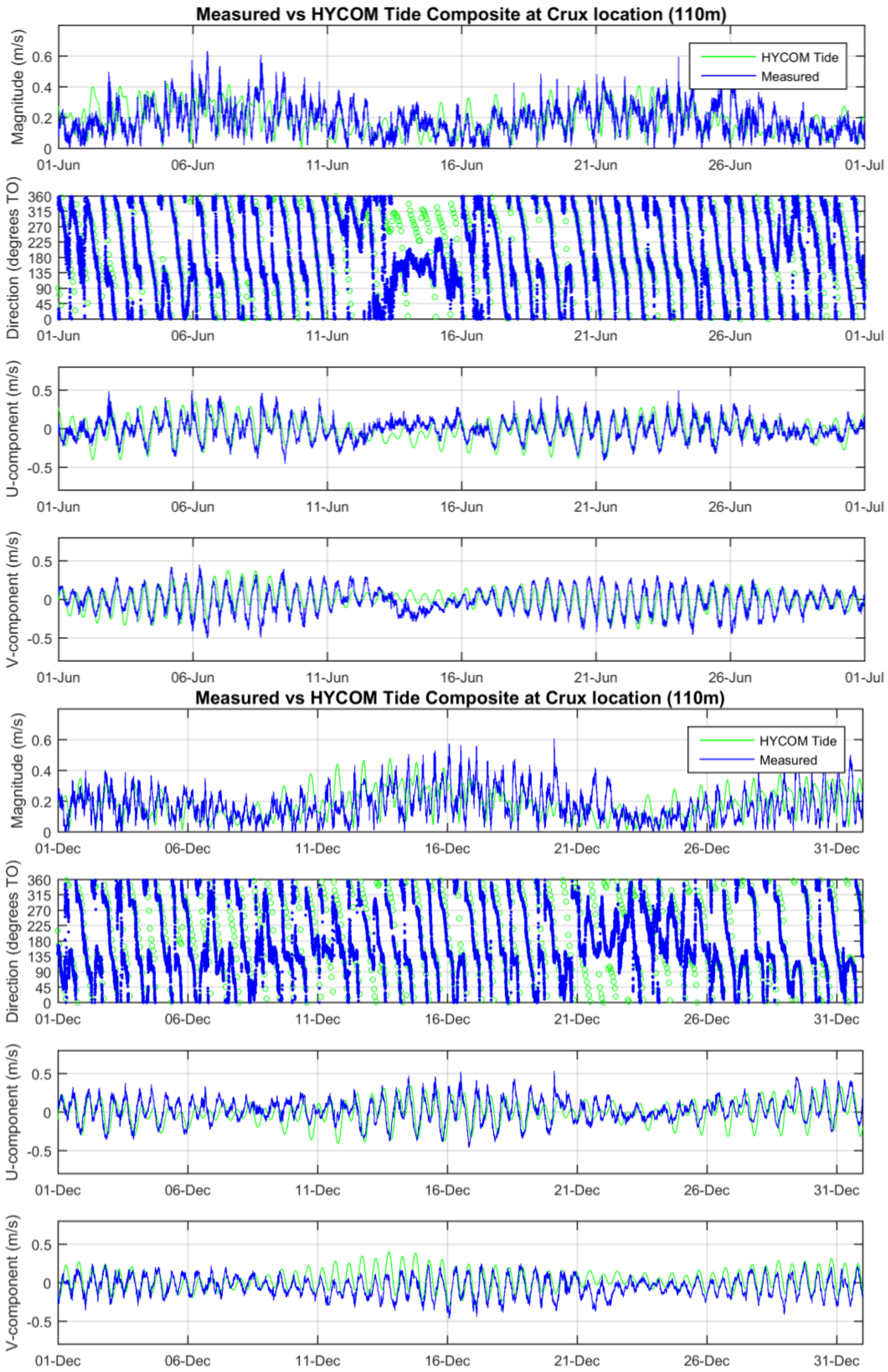

Figure 2.12 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 110 m for June 2016 (top panel) and December 2016 (bottom panel).

RPS

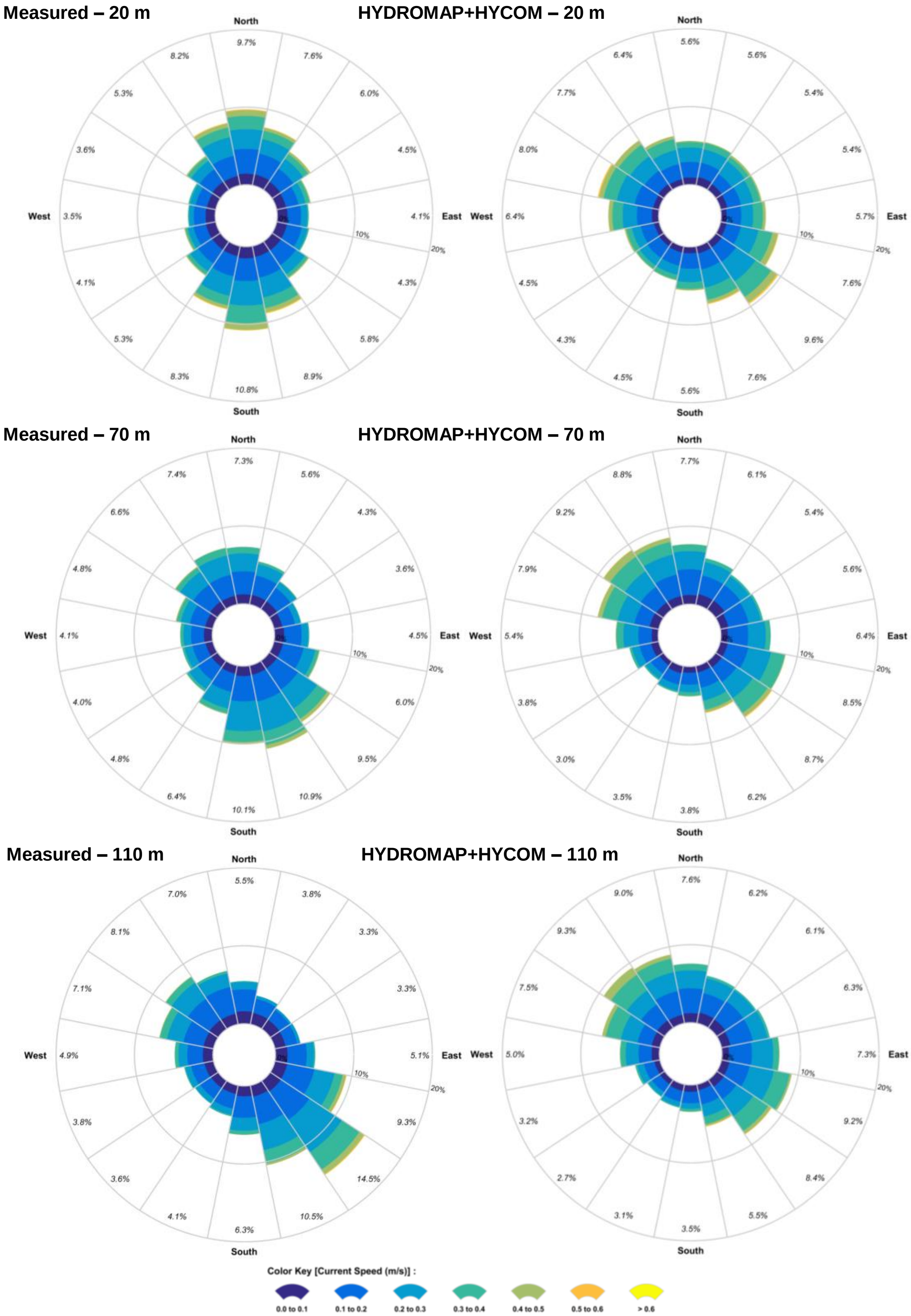

Figure 2.13 Comparative distributions for measured (left column) and predicted (HYDROMAP+HYCOM, right column) current data at the Crux development area (2016-2017) at depths of approximately 20 m (top row), 70 m (middle row) and 110 m (bottom row). The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

3 Modelling Results

3.1 Near-Field Modelling

3.1.1 Overview

In the following sections, two sets of tables are presented. The first table summarises the predicted plume characteristics in the near-field mixing zone under varying current speeds. The second set of tables summarises the concentration of biocide at the end of the near-field mixing zone and the amount of dilution.

Figure 3.1 to Figure 3.3 (note the differing x-axis and y-axis aspect ratios) show the change in average temperature and dilution of the plume under varying seasonal conditions (summer, transitional and winter) and current speeds (weak, medium and strong). The figures show the predicted horizontal distances travelled by the plume before it contacts the seabed.

The results show that due to the momentum of the discharge a turbulent mixing zone is created in the immediate vicinity of the discharge point (1-2 m). Following this initial mixing, the marginally-negatively buoyant plume is predicted to sink slightly in the water column before reaching the seabed. Increases in ambient current speed are shown to increase the horizontal distance travelled by the plume from the discharge point.

Table 3.1 shows the predicted plume characteristics for the varying seasonal conditions and current speeds. A maximum horizontal distance of 19.1 m from the discharge point is achieved in the transitional season. The diameter of the plume at the end of the near-field mixing zone ranges from 2.9 m to 3.4 m. Increases in current speed serve to restrict the diameter of the plume.

In all cases, the temperature is predicted to be within 0.6 °C of the ambient temperature within 20 m of the discharge location.

For all seasons, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to reach the seabed closer to the discharge point, which slows the rate of dilution (Table 3.1). The worst-case average dilution levels of the plume upon reaching the seabed under weak, medium and strong currents are predicted to be 1:5.9, 1:7.5 and 1:9.6, respectively, under summer and winter conditions. Additionally, the worst-case minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon reaching the seabed under weak, medium and strong currents are predicted to be 1:2.7, 1:2.7 and 1:2.8, respectively, under summer and winter conditions. Note that these predictions rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to weak currents or current reversals.

The results indicate that the biocide constituent of the hydrotest discharge is not expected to reach a 1:500 dilution in the near-field mixing zone. This occurs under all current conditions (Table 3.2 to Table 3.4).

Table 3.1 Predicted plume characteristics at the end of the near-field mixing zone for the specified flow rate (0.3 m^3/s) for each season and current speed.

Season	Near-Seabed Current Speed (m/s)	Plume Diameter (m)	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Summer	Weak (0.06)	3.2	19.9	0.58	2.7	5.9	7.2
	Medium (0.19)	3.1	20.0	0.46	2.7	7.5	9.9
	Strong (0.38)	2.9	20.1	0.35	2.8	9.6	15.7
Transitional	Weak (0.05)	3.4	18.8	0.33	2.8	6.3	7.8
	Medium (0.20)	3.3	18.9	0.24	3.0	8.8	12.1
	Strong (0.38)	3.0	18.9	0.19	3.1	10.6	19.1
Winter	Weak (0.05)	3.2	19.7	0.54	2.7	5.9	7.2
	Medium (0.19)	3.1	19.8	0.42	2.7	7.5	9.9
	Strong (0.39)	2.9	19.9	0.32	2.8	9.6	15.7

Table 3.2 Concentrations of biocide at the end of the near-field stage, and the required concentration thresholds and number of dilutions for the summer season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 5.9, 7.5 and 9.6, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		5.9x dilution	7.5x dilution	9.6x dilution
Biocide	500	84.7	66.7	52.1

Table 3.3 Concentrations of biocide at the end of the near-field stage, and the required concentration thresholds and number of dilutions for the transitional season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.3, 8.8 and 10.6, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		6.3x dilution	8.8x dilution	10.6x dilution
Biocide	500	79.4	56.8	47.2

Table 3.4 Concentrations of biocide at the end of the near-field stage, and the required concentration thresholds and number of dilutions for the winter season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 5.9, 7.5 and 9.6, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		5.9x dilution	7.5x dilution	9.6x dilution
Biocide	500	84.7	66.7	52.1

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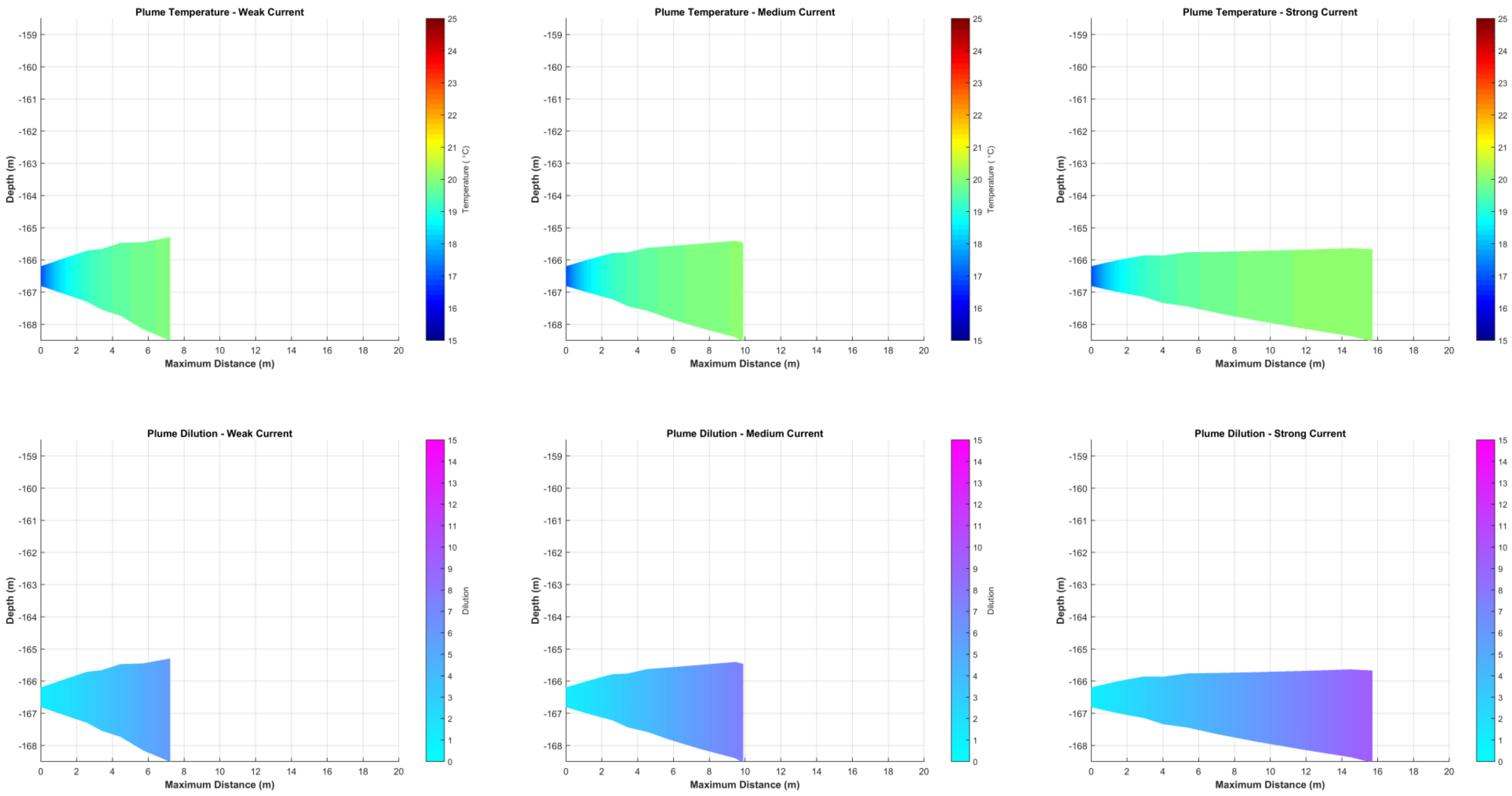

Figure 3.1 **Near-field average temperature and dilution results for constant weak, medium and strong summer currents (0.3 m^3/s flow rate).**

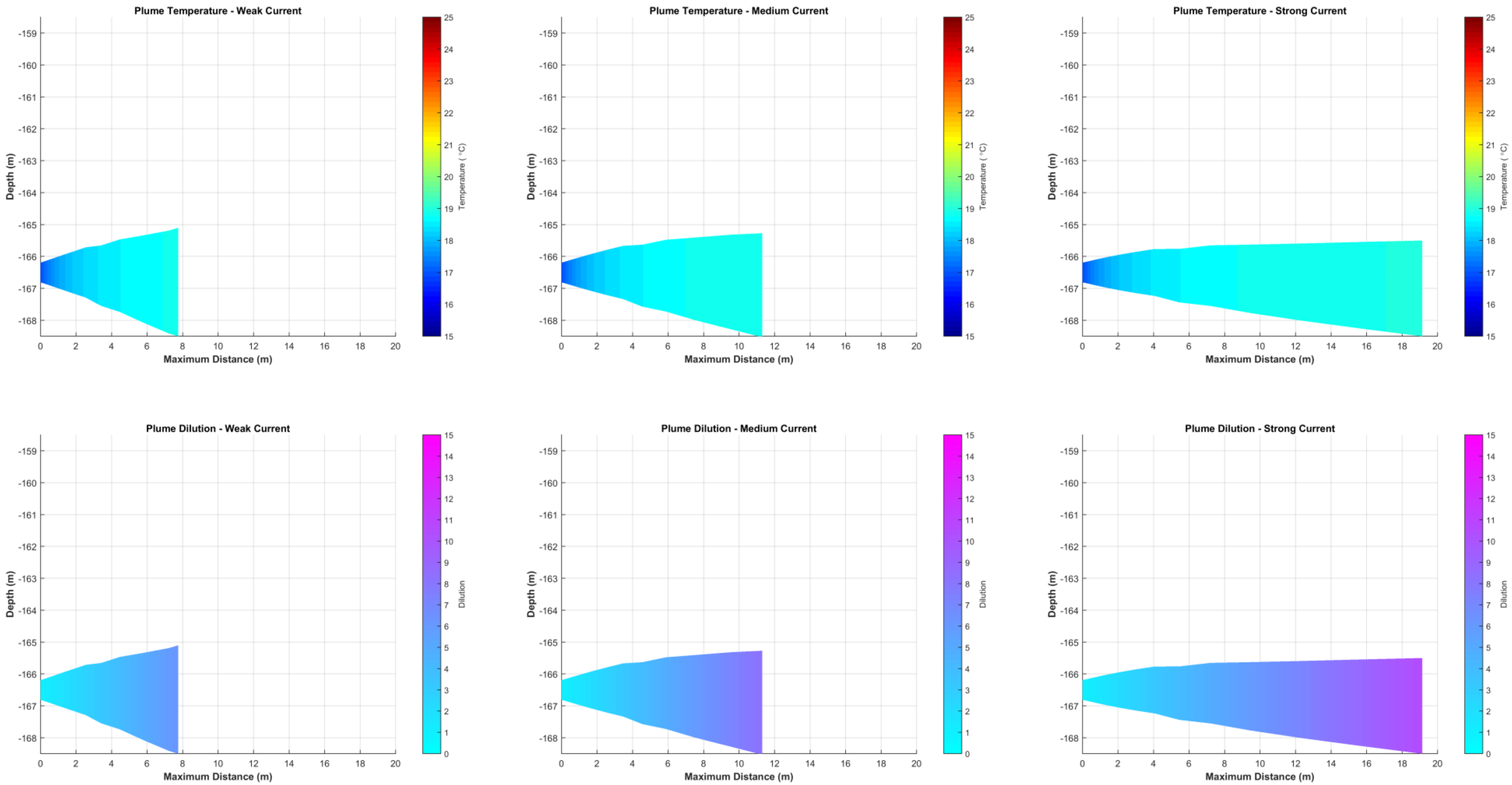

Figure 3.2 **Near-field average temperature and dilution results for constant weak, medium and strong transitional currents (0.3 m^3/s flow rate).**

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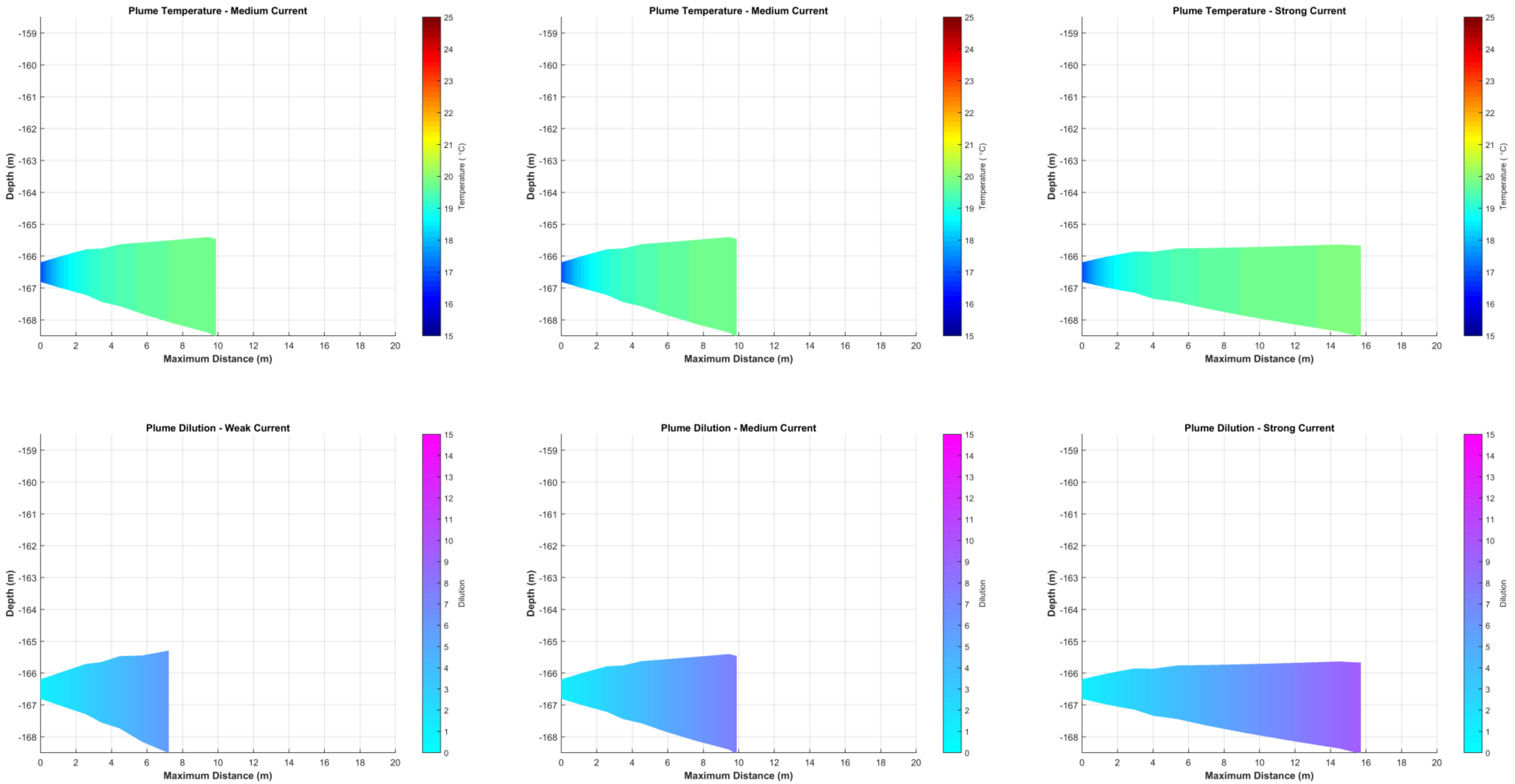

Figure 3.3 **Near-field average temperature and dilution results for constant weak, medium and strong winter currents (0.3 m^3/s flow rate).**

3.2 Far-Field Modelling

3.2.1 Overview

It is important to note that near-field and far-field modelling are used to describe different processes and scales of effect, and therefore the far-field modelling results will not necessarily correspond to the outcomes at the end of the near-field mixing zone for any given discharge scenario. The far-field results included episodes of pooling of the discharge plume under weak currents, which caused lower dilutions (higher concentrations) further from the discharge location when the pooled plume was advected away. Episodes of recirculation – where the plume moved back under the discharge at some later time due to the oscillatory nature of the tide – were also observed, compounding the pooling effect and further lowering the dilution values.

The results of the far-field modelling were statistically analysed to develop the distribution of outcomes based on time and event. These are presented as contours of minimum dilution. Note that the aggregated dilution contours presented in Section 3.2.2 do not represent the location of the plume at any point in time but are a statistical summary of the range of outcomes across all replicate simulations and time steps.

3.2.2 Seasonal Analysis

The model outputs over the ten-year hindcast period (2008-2017) were combined and analysed on a seasonal basis (summer, transitional and winter). This approach assists with identifying the potential exposure to the shoals nearest to the proposed Crux platform (Vulcan Shoal, Goeree Shoal and Eugene McDermott Shoal) on a seasonal basis whilst considering interannual variability in ocean current conditions.

Table 3.5 provides a summary of the minimum and maximum distances for the discharge location to achieve a given dilution for each season. Dilutions of 1:500 – equivalent to 1 ppm, which represents the impact threshold defined in Section 2.1.3.1 – are predicted to occur between 5,209 m and 5,727 m from the discharge point. The 1:500 dilution contour is predicted to remain at a minimum distance of more than 8 km from the nearest shoal (Goeree Shoal) in any season, therefore no exposure to harmful contaminant levels is expected for non-transient species.

Table 3.6 provides a summary of the total area of coverage for a given dilution for each season. The area of exposure for the 1:500 dilution level is predicted to be largest during summer conditions (52.9 km^2) and smallest during transitional conditions (48.3 km^2).

Figure 3.4 to Figure 3.6 show the aggregated spatial extents of the minimum dilutions for each season. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time-step through the water column and do not consider frequency or duration.

The results presented are conservative and assume that no processes other than dilution (i.e. no biodegradation over the relatively short duration of the dispersion process) would reduce the source concentrations over time.

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Table 3.5 Minimum, average and maximum distance from the hydrotest discharge location to achieve a given dilution for each season.

Flow rate (m^3/s)	Season	Minimum/average/maximum distance (m) from discharge location to achieve given dilution								
		1:50 dilution			1:100 dilution			1:500 dilution		
		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
0.3	Summer	825	960	1,063	3,622	3,811	3,980	5,332	5,589	5,727
	Transitional	911	1,112	1,242	2,863	2,925	2,985	4,875	5,077	5,209
	Winter	872	1,095	1,201	2,968	3,152	3,254	4,641	5,125	5,343

Table 3.6 Total area of coverage for a given dilution for each season.

Flow rate (m^3/s)	Season	Total area (km^2) of coverage for given dilution		
		1:50 dilution	1:100 dilution	1:500 dilution
0.3	Summer	1.2	7.8	52.9
	Transitional	1.3	7.6	48.3
	Winter	1.3	8.3	51.3

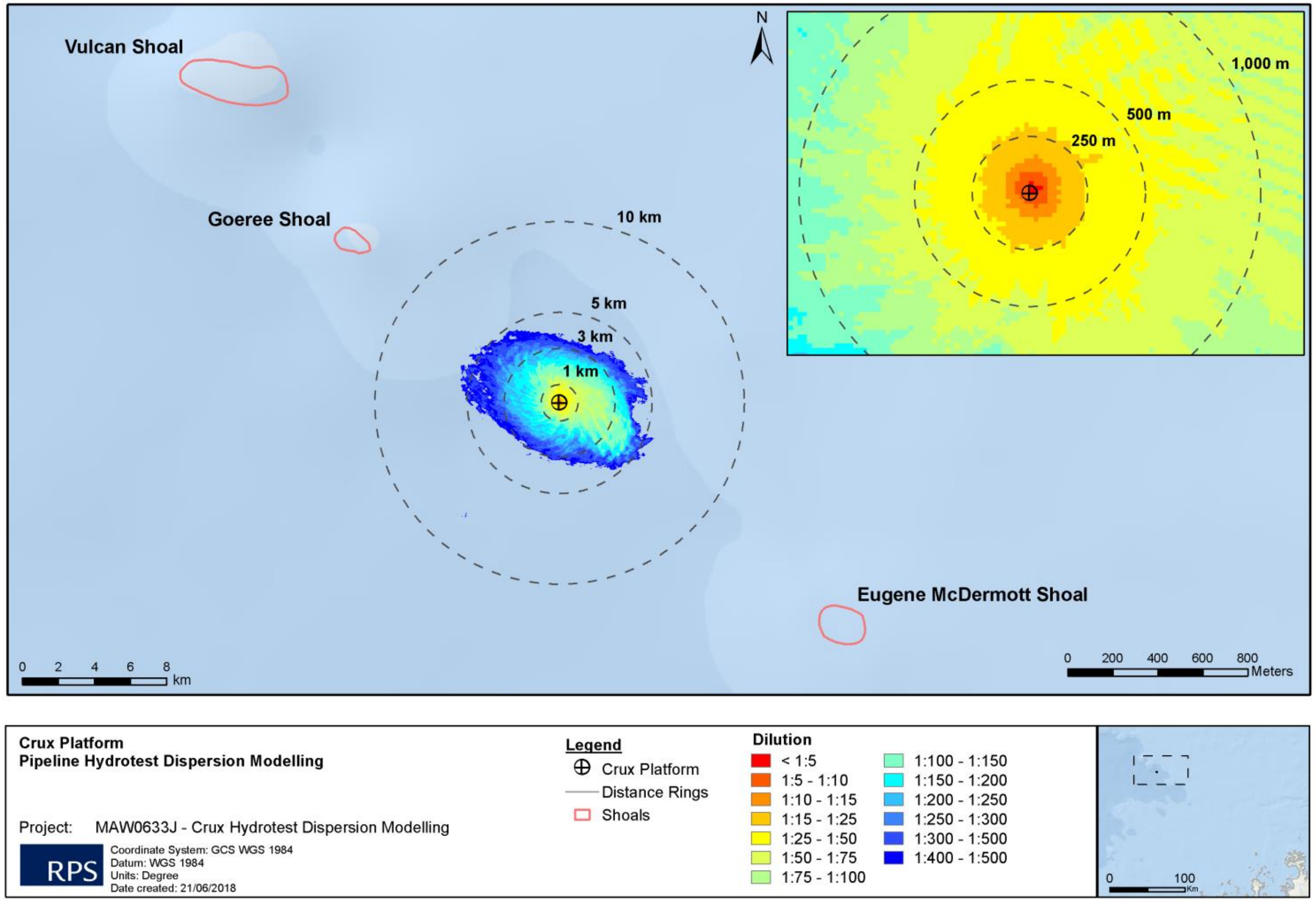

Figure 3.4 Predicted dilutions under summer conditions for the specified flow rate (0.3 m^3/s).

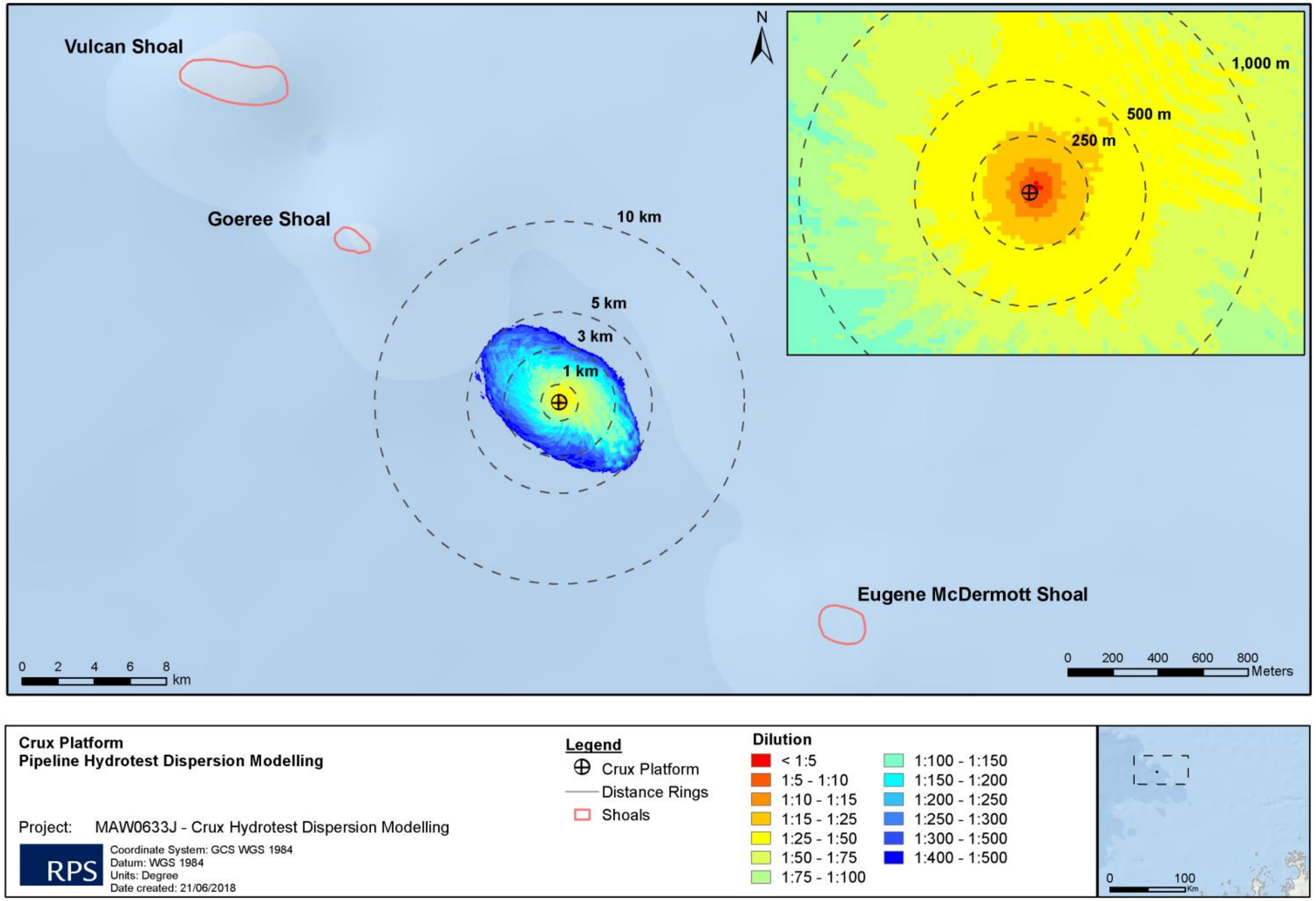

Figure 3.5 Predicted dilutions under transitional conditions for the specified flow rate (0.3 m^3/s).

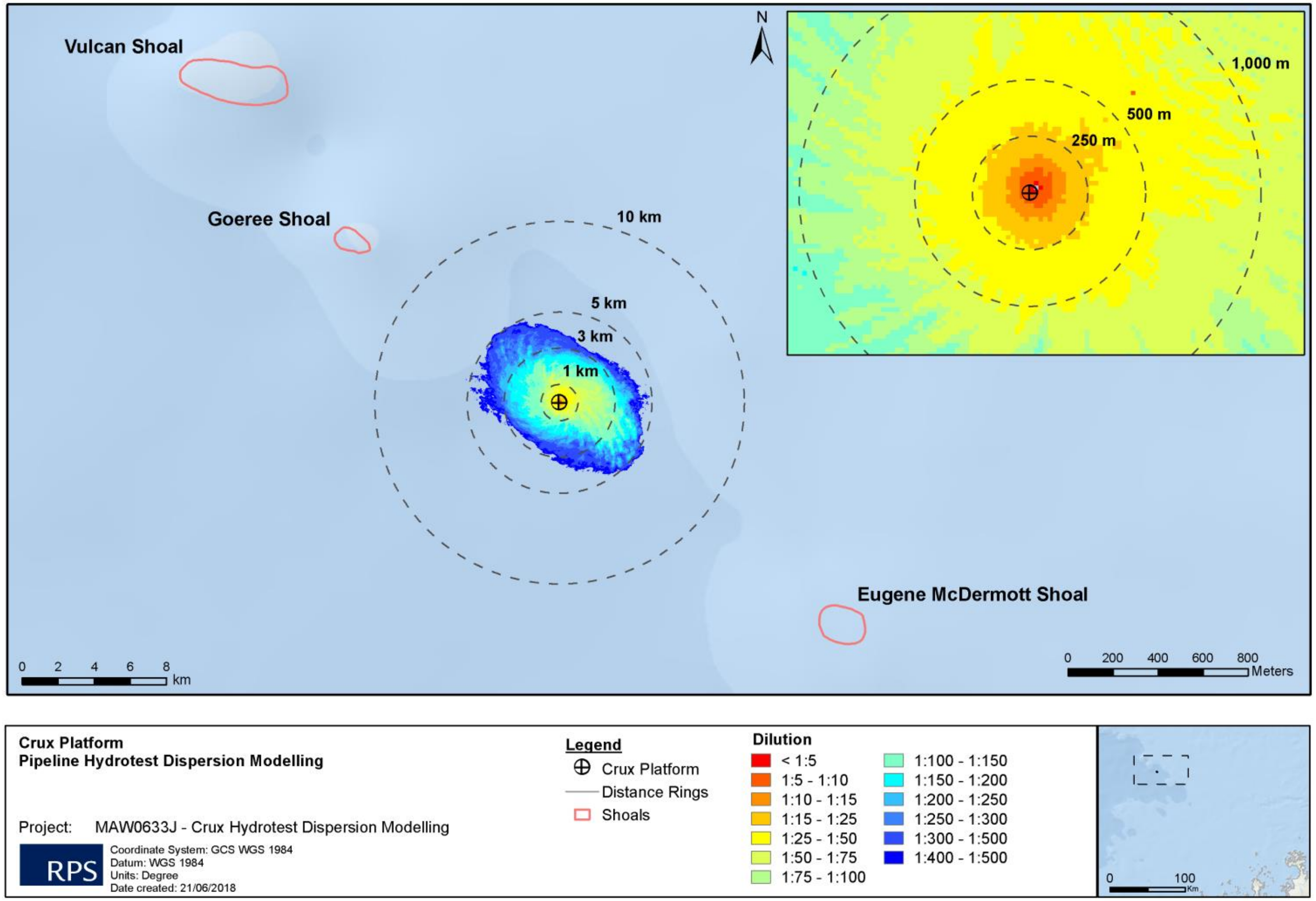

Figure 3.6 **Predicted dilutions under winter conditions for the specified flow rate (0.3 m^3/s).**

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3.2.3 Combined Analysis

The model outputs for each season (summer, transitional and winter) over the ten-year hindcast period (2008-2017) were combined and analysed on an annualised basis.

Table 3.7 provides a summary of the minimum and maximum distances for the discharge location to achieve a given dilution for each season. Dilutions of 1:500 – equivalent to 1 ppm, which represents the impact threshold defined in Section 2.1.3.1 – are predicted to occur between 5,209 m and 5,727 m from the discharge point.

Table 3.8 provides a summary of the total area of coverage for a given dilution. The area of exposure for the 1:500 dilution level is predicted to be 57.0 km^2 for a flow rate of 0.3 m^2/s.

Figure 3.7 show the aggregated spatial extents of the minimum dilutions.

Note that the contours represent the lowest predicted dilution (highest concentration) at any given time-step through the water column and do not consider frequency or duration.

The results presented are conservative and assume that no processes other than dilution (i.e. no biodegradation over the relatively short duration of the dispersion process) would reduce the source concentrations over time.

Table 3.7 Minimum, average and maximum distance from the hydrotest discharge location to achieve a given dilution for each season.

Flow rate (m^3/s)	Season	Minimum/average/maximum distance (m) from discharge location to achieve given dilution								
		1:50 dilution			1:100 dilution			1:500 dilution		
0.3		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
	Annualised	825	1,055	1,242	2,863	3,296	3,980	4,641	5,263	5,727

Table 3.8 Total area of coverage for a given dilution.

Flow rate (m^3/s)	Season	Total area (km^2) of coverage for given dilution		
		1:50 dilution	1:100 dilution	1:500 dilution
0.3	Annualised	1.5	9.5	57.0

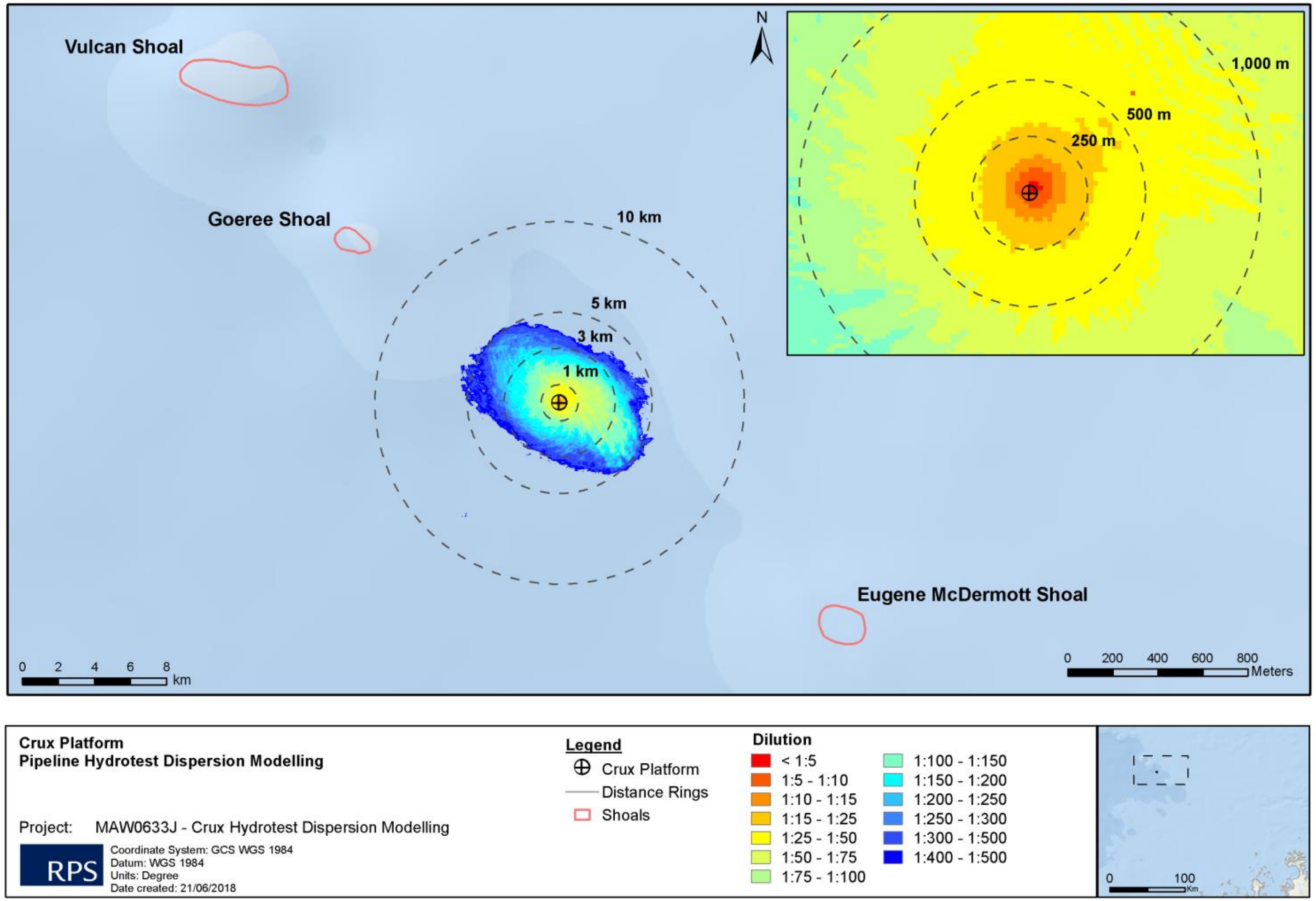

Figure 3.7 Predicted annualised minimum dilutions for the specified flow rate (0.3 m^3/s).

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Appendix G: Oil Spill Modelling Study (RPS 2018d)

REPORT

RPS

Crux Project

Oil Spill Modelling

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No.: MAW0633J
Version: 5-Fig
Date: 18 September 2018

RPS

Document Status

Version	Purpose of Document	Prepared by	Reviewed by	Review Date
A	Issued for internal review	N. Page	D. Wright	10/04/2018
B	Issued for internal review	N. Page B. Gómez	D. Wright	13/04/2018
0	Issued for Client review	N. Page B. Gómez M. Zapata	D. Wright	16/04/2018
1	Issued for Client review	B. Gómez M. Zapata	D. Wright	05/07/2018
2	Issued for Client review	B. Gómez	M. Zapata	16/07/2018
3	Issued for Client review	B. Gómez	M. Zapata	20/07/2018
4	Issued for Client review	B. Gómez	D. Wright	12/09/2018
5	Issued for Client review	N. Page	D. Wright	18/09/2018

Approval for Issue

Name	Signature	Date
S. Zigic	S. Zigic	18/09/2018

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Appendices

1 Introduction

1.1 Background

RPS has been commissioned by CDM Smith Australia Pty Ltd (CDM Smith), on behalf of Shell Australia Pty Ltd (Shell), to undertake a quantitative spill risk assessment of hypothetical hydrocarbon spill scenarios at the proposed Crux platform (Crux platform) and related components of the project (Table 1.1). The Crux platform is located in the northern Browse Basin in offshore Commonwealth marine waters, approximately 190 km offshore north-west Australia and 620 km north-north-east of Broome.

The main objectives of the study were to provide an assessment, through stochastic spill modelling, of the probabilities of hydrocarbon contact (at greater than defined concentrations), and quantify the effects on both the surface waters and within the water column (i.e. entrained and dissolved aromatic hydrocarbons) at key environmental values and sensitivities (e.g. shoals/banks, offshore reefs and islands, Australian Marine Parks etc.).

Shell identified four maximum credible hydrocarbon spill scenarios that may be associated with the Crux project, including a subsea well blowout, a loss of condensate inventory at the platform, a subsea pipeline rupture, and a loss of fuel from a support vessel. Each scenario was modelled and assessed over defined seasonal periods: summer (December to February), winter (April to August) and transitional (March and September to November).

The details of the scenarios assessed in this study are as follows:

- <u>Scenario 1:</u> A long-term (80-day) uncontrolled subsurface blowout of 206,225 m^3 (2,578 m^3/day) of Crux condensate at a development well location;
- <u>Scenario 2:</u> A short-term (instantaneous) surface release of 88 m^3 of Crux condensate at the platform location following an inventory integrity failure;
- <u>Scenario 3:</u> A short-term (5.6-hour) subsurface release of 2,037 m^3 of Crux condensate from the export pipeline at the closest point to Heywood Shoal following a rupture; and
- <u>Scenario 4:</u> A short-term (1-hour) surface release of 1,000 m^3 of Intermediate Fuel Oil (IFO-180) at the Crux end of the export pipeline following a pipelay vessel collision.

The release locations modelled are shown in Table 1.1 and Figure 1.1.

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 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.

The modelling outcomes provide a conservative understanding of where a large-scale hydrocarbon release could travel in any condition, plotted all in one figure. The modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill. Therefore, the modelling results represent the maximum extent that may be influenced by the released hydrocarbons.

The hydrocarbon spill model, and the methodology and analysis applied herein, uses modelling algorithms which have been anonymously peer-reviewed and published in international journals. Further, RPS warrants that this work meets and exceeds the American Society for Testing and Materials (ASTM) Standard F2067-13 "*Standard Practice for Development and Use of Oil Spill Models*".

Table 1.1 Locations of the proposed Crux platform and the pipeline rupture point used as the release sites for the hydrocarbon spill modelling assessment.

Release Site	Latitude (°S)	Longitude (°E)	Water Depth (m)
Crux Development Well/Not Normally Manned platform	12° 57' 52.46"	124° 26' 33.21"	168.5
Pipeline route location closest to Heywood Shoal	13° 15' 29.00"	123° 54' 39.00"	199.0

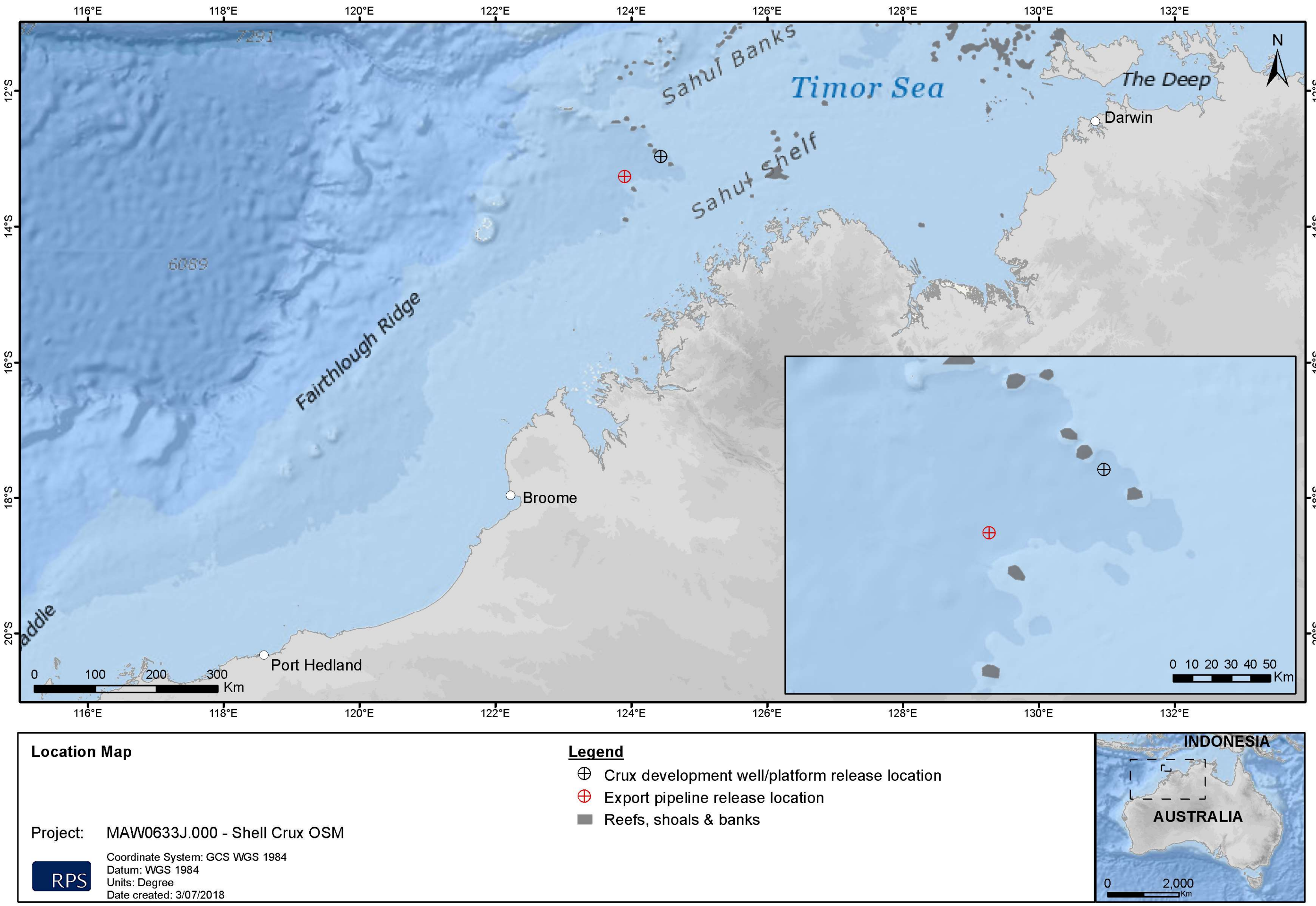

Figure 1.1 Location of the modelled hydrocarbon spill scenario release sites.

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.

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.

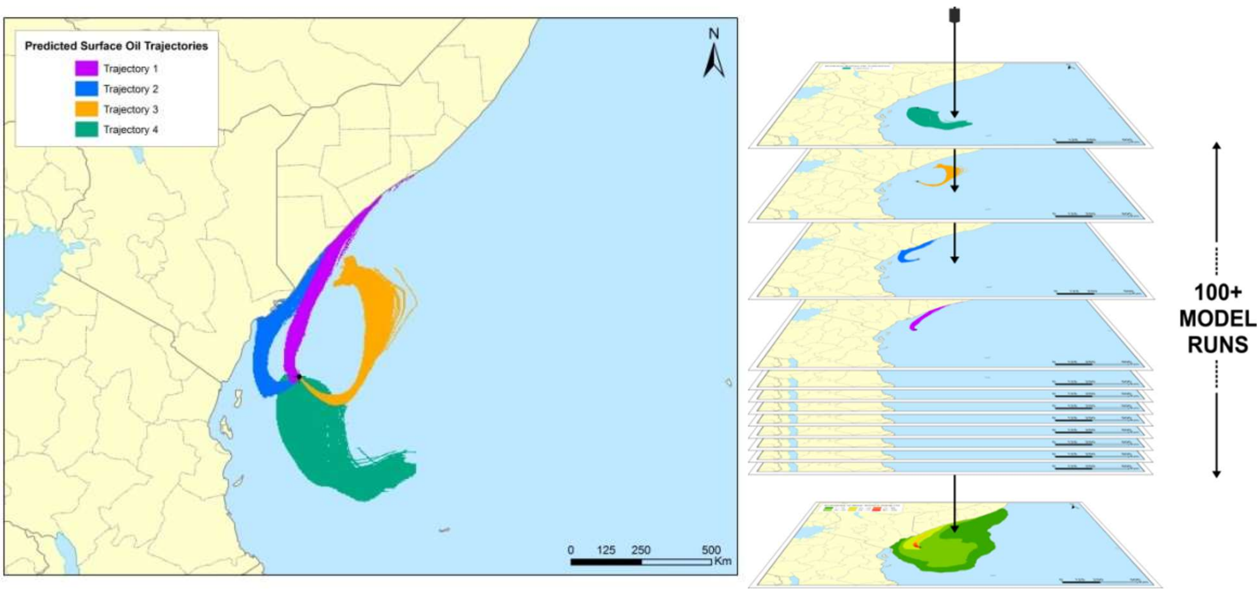

Figure 1.2 Examples of four individual spill trajectories (four replicate simulations) predicted by SIMAP for a spill scenario. The frequency of contact with given locations is used to calculate the probability of impacts during a spill. Essentially, all model runs are overlain (shown as the stacked 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.

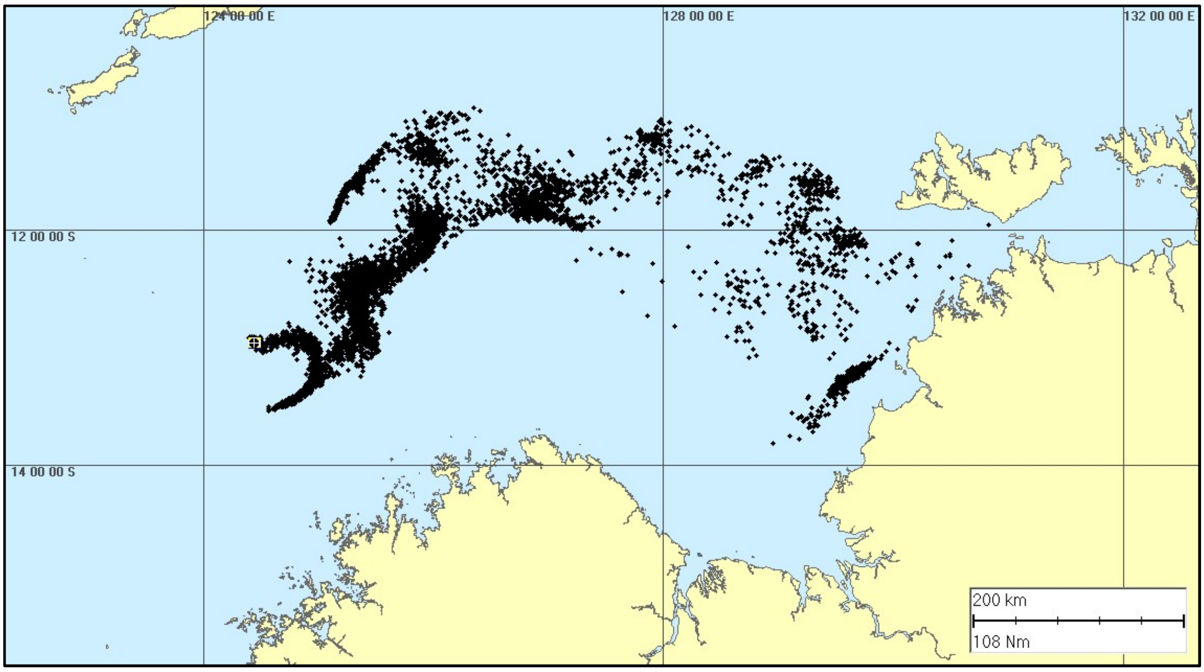

Figure 1.3 Example of an individual spill trajectory predicted by SIMAP for a spill scenario.

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 and 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 hydrocarbons), 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 hydrocarbons on the sea surface and within the water column. The fates algorithms calculate all of the weathering processes known to be important for oil spilled to marine waters. These include droplet and slick formation, entrainment by wave action, emulsification, dissolution of soluble components, sedimentation, evaporation, bacterial and photo-chemical decay and shoreline interactions. These algorithms account for the specific oil type being considered.

Entrainment is the physical process where globules of oil are transported from the sea surface into the water column by breaking waves. It has been observed that entrained oil is broken into droplets of varying sizes. Small droplets spread and diffuse in the water column, while larger ones rise rapidly back to the surface (Delvigne & Sweeney, 1988; Delvigne, 1991).

Dissolution is the process by which soluble hydrocarbons enter the water from a surface slick or from entrained droplets. The lower molecular weight hydrocarbons tend to be both more volatile and more soluble than those of higher molecular weight.

The formation of water-in-oil emulsions, or mousse, which is termed ‘emulsification’, depends on oil composition and sea state. Emulsified oil can contain as much as 80% water in the form of micrometre-sized droplets dispersed within a continuous phase of oil (Wheeler, 1978; Daling & Brandvik, 1991; Bobra, 1991; Daling *et al.*, 1997; Fingas, 1995; Fingas, 1997).

Evaporation can result in the transfer of large proportions of spilled oil from the sea surface to the atmosphere, depending on the type of oil (Gundlach & Boehm, 1981).

Evaporation rates vary over space and time, and are dependent on the prevailing sea temperatures, wind and current speeds, the surface area of the droplets (sea surface and entrained) 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. Dissolution rates are

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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 hydrocarbons on the sea surface 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; and
- 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 subsea 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.

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 (approximately 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), which is representative of the depth profiles in the Crux development area, 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.

OILMAP is an oil spill trajectory and fates model extended for the prediction of oil from subsurface oil/gas blowouts, (Spaulding *et al.*, 2000). The blowout model 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 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 droplet size distribution and the plume dimensions to the SIMAP model, for the long-term discharge simulations.

The current, wind and water column profile data used as input to the modelling are discussed in Sections 2.2, 2.3 and 2.4, respectively.

2.2 Regional Ocean Currents

2.2.1 Overview

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region of the Kimberley Coast. However, the offshore regions with water depths exceeding 100-200 m experience significant large-scale drift 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 hydrocarbon plumes over time scales exceeding a few hours.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (hours to days) and result in long trajectories. Hence, the current-induced transport of plumes can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is important to consider all these potential advective mechanisms to rigorously understand patterns of potential transport from a given discharge location.

To appropriately allow for temporal and spatial variation in the current field, dispersion modelling requires the current speed and direction over a spatial grid covering the potential migration zone of plumes. As long-term measured current data is not available at the Crux development area, 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, available from a mesoscale ocean model, with estimates of the tidal currents generated by an RPS model set up for the study area. These estimates are considered representative of the oceanographic currents that influence the Crux development area.

A composite modelled ocean current data product was derived by combining predictions of mesoscale circulation currents, available at daily resolution from global ocean models, with predictions of the hourly tidal currents generated by the RPS HYDROMAP model. By combining a drift current model with a tidal model, the influences of inter-annual and seasonal drift patterns, and the more regular variations in tide, were included.

2.2.2 Mesoscale Circulation

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 2.1. They are characterised as follows:

- **Buoyancy driven circulation**. The main buoyancy-driven feature in the region is the Indonesian Throughflow (ITF) 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.

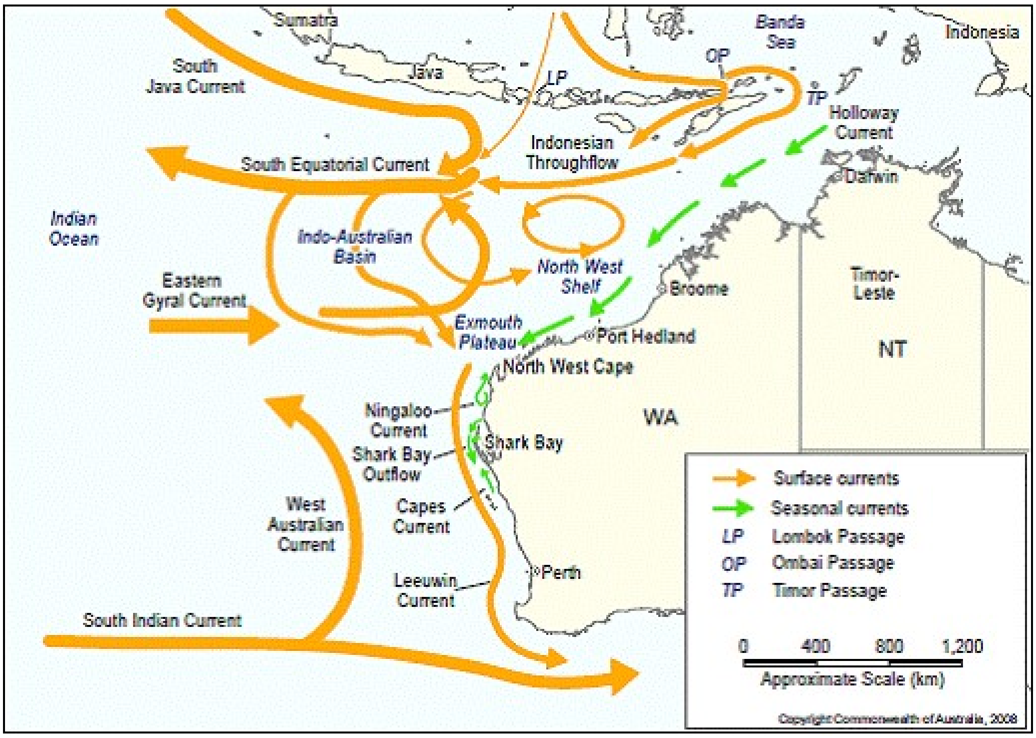

Figure 2.1 A map of the major currents off the West Australian coast (DEWHA, 2008).

2.2.2.1 Description of 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 2008 to 2017 (inclusive).

Figure 2.2 shows the seasonal surface current roses near the Crux platform. The data shows that the surface current speeds and directions vary between seasons. In general, during summer (December to February) currents have the strongest average speed (0.25 m/s with a maximum of 0.65 m/s) and tend to flow west-southwest. During winter (April to August), current flow conditions are more variable and flow mostly toward the west-southwest and east-northeast. During transitional conditions (March and September to November), the current flow is less variable and predominantly toward the west.

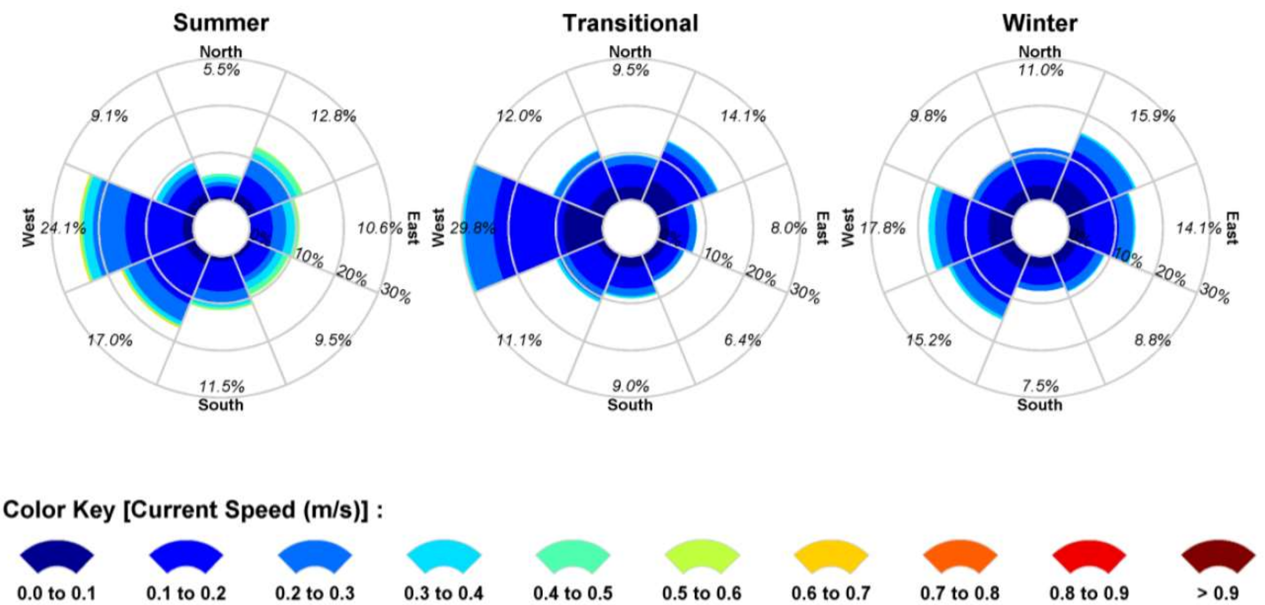

Figure 2.2 Seasonal current distribution (2008-2017, inclusive) derived from the HYCOM database near to the proposed Crux platform. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

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2.2.3 Tidal Currents

2.2.3.1 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) (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 particular 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).

2.2.3.2 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 2.3).

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.

2.2.3.3 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.

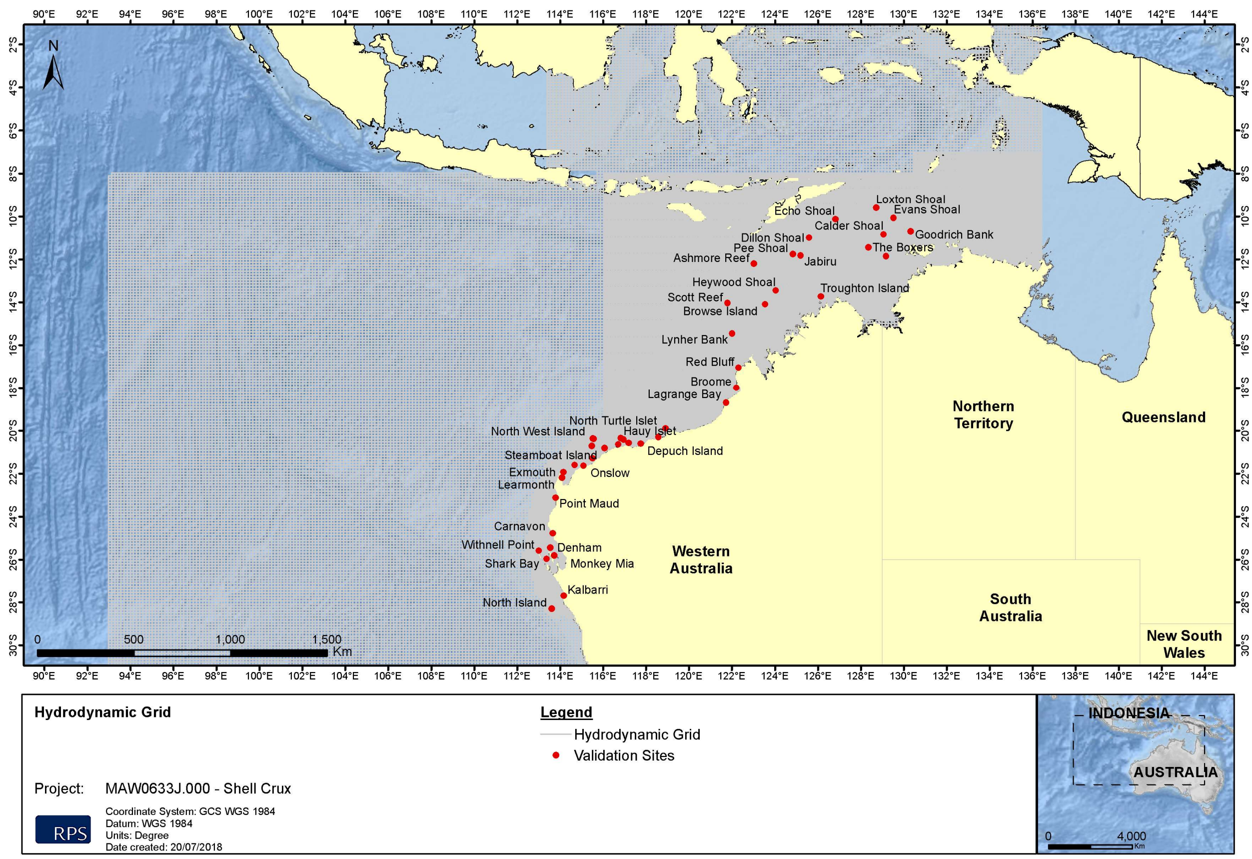

Figure 2.3 Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing the full domain in context with the continental land mass and the locations available for tidal comparisons (red labelled dots). Higher-resolution areas are indicated by the denser mesh zones.

2.2.4 Tidal and Current Model Validation

The suitability of the modelled tidal and drift current data products was evaluated by comparing the predicted currents to those measured at the Crux development area. The following sections describe the sources of both the modelled and measured data, the comparison methodology, and the outcomes of the comparisons for both the tidal and drift current components.

2.2.4.1 Data Sources

A tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP. HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. This model is described in Section 2.2.3.

A mesoscale ocean current data sets was selected for the study: HYCOM (Hybrid Coordinate Ocean Model) Consortium's global ocean model, HYCOM. This model is described in Section 2.2.2.

A data set of measured currents was collected by RPS at the Crux development area between April 2016 and May 2017 (RPS, 2017). This data set includes a series of point current measurements made at six depths through the water column using CM04 current meters mounted on a floating mooring. The measurement depths are approximately 20 m, 70 m, 110 m, 150 m, 165 m and 167 m below the water surface. The temporal resolution of the data is 1 minute. The raw data was quality-controlled by RPS and only data identified as high-quality was used for comparison to model data. For the measurements at a 20 m water depth, there is approximately a 7-week gap in the data between early September and late October 2016.

2.2.4.2 Model Validation Skills

2.2.4.2.1 Overview

The mesoscale and tidal current models were validated through quantitative and visual comparisons of measured and modelled data.

2.2.4.2.2 Statistics

A quantitative analysis of a model's skill at replicating the environmental conditions was conducted using the Index of Agreement (IOA), presented in Willmott (1981), and the Mean Absolute Error (MAE), discussed in Willmott (1982) and Willmott & Matsuura (2005). Other traditional error estimates, such as the correlation coefficient and the root mean square error (RMSE) are problematic and prone to ambiguities and bias (Willmott & Matsuura, 2005; Willmott, 1982). Consequently, they are not reported in isolation here.

The MAE is simply the average of the absolute values of the differences between the observed and modelled values. MAE is a more natural measure of average error (Willmott & Matsuura, 2005) and more readily understood. The IOA is determined using the following formula:

$$\mathrm{IOA} = 1 - \frac{\sum |X_{\mathrm{model}} - X_{\mathrm{obs}}|^2}{\sum \left(|X_{\mathrm{model}} - \overline{X_{\mathrm{obs}}}| + |X_{\mathrm{obs}} - \overline{X_{\mathrm{obs}}}| \right)^2}$$

In this equation, X represents the variable being compared and $\bar{X}$ represents the mean of that variable over time.

A perfect agreement can be said to exist between the model and field observations if the IOA gives a measure of one, and complete disagreement will produce an IOA measure of zero (Wilmott, 1981). Although it is difficult to find guidelines for what values of the IOA might represent a good agreement, Willmott *et al.* (1985) suggests that values meaningfully larger than 0.5 represent good model performance. Clearly, the higher the IOA and the lower the MAE, the better the model performance.

An important point to note regarding both, and in fact most, measures of model performance, is that slight phase differences in the series can result in a seemingly poor statistical comparison, particularly in rapidly changing series such as tidal direction or water elevation where the tidal range is large. It is therefore always important to consider both the statistics <u>and</u> the visual representation of the comparison (Willmott *et al.*, 1985). Statistical comparison of current direction can be misleading; skill measures of direction can become biased where the directional fluctuations are near 0-360°. Therefore, we have based the quantitative assessment on the U and V current components and not magnitude and direction.

2.2.4.2.3 Time Series

In addition to bulk statistical measures, model performance for the measurement period was assessed visually with the aid of scatterplots and rose plots. The scatterplots show the correlation between the x- and y-components of the measured and modelled data. The rose plots show the frequency of current direction by sector, and magnitude by colour, to allow comparison of current direction between modelled and measured data.

The model performance was also evaluated against time series plots of water level, U (east-west) velocity component, V (north/south) velocity component, current speed and current direction data. This approach is valuable because statistical measures of model skill can heavily penalise errors in phase (i.e. time lags) even when the dynamics of flow are broadly reproduced.

2.2.4.3 Tidal Elevation Validation

For verification of the tidal elevation 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 Crux development area were used for comparison.

Time series comparisons were completed for a six-month period from January to June 2010. The statistics are summarised in Table 2.1, and indicate excellent model performance in this region. Water level time series for these locations are shown in Figure 2.4, Figure 2.5 and Figure 2.6 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.

For the purposes of understanding the limitations in accuracy of the tidal predictions, the RMSE and MAE in Table 2.1 should be noted. On average, the model predictions are within 0.1-0.3 m of XTide predictions based on known constituent data at any point in time. Often the error is mostly attributable to errors of phase in the tidal signal, with the magnitude of the tidal rise and fall over each tide well represented. However, in the application of the data predictions to operational circumstances, the potential errors should be considered.

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 2.7. 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.

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Table 2.1 Statistical comparison of predicted surface elevation data from HYDROMAP and XTide at 18 locations in the tidal model domain (January to July 2010).

Tide Station	Longitude (°E)	Latitude (°S)	IOA	CC	MAE (m)	RMSE (m)
Ashmore Reef	123.02	12.22	0.99	0.99	0.14	0.18
Browse Island	123.55	14.10	0.97	0.97	0.36	0.45
Calder Shoal	129.07	10.85	0.97	0.97	0.17	0.21
Cape Legendre	116.83	20.35	0.99	0.99	0.12	0.14
Dillon Shoal	125.60	11.00	0.97	0.95	0.18	0.22
Echo Shoal	126.82	10.15	0.97	0.94	0.17	0.21
Evans Shoal	129.53	10.08	0.98	0.98	0.11	0.14
Goodrich Bank	130.32	10.70	0.99	0.97	0.13	0.16
Heywood Shoal	124.05	13.47	0.98	0.96	0.27	0.33
Jabiru	125.20	11.83	097	0.95	0.22	0.27
Loxton Shoal	128.72	09.60	0.99	0.98	0.10	0.13
Lynedoch Bank	130.82	10.03	0.98	0.98	0.12	0.15
Lynher Bank	122.02	15.47	0.98	0.97	0.26	0.31
Newby Shoal	129.18	11.87	0.98	0.96	0.23	0.27
Pee Shoal	124.83	11.77	0.97	0.94	0.23	0.27
Scott Reef	121.80	14.05	0.99	0.98	0.16	0.19
The Boxers	128.35	11.45	0.97	0.96	0.16	0.20
Troughton Island	126.13	13.75	0.97	0.95	0.27	0.33

Notes: *IOA* *Index of Agreement – values close to 1 represent a high level of agreement.*
CC *Correlation Coefficient – values close to 1 represent very good correlation.*
MAE *Mean Absolute Error – the lower the value, the smaller the error.*
RMSE *Root Mean Square Error – the lower the value, the smaller the error.*

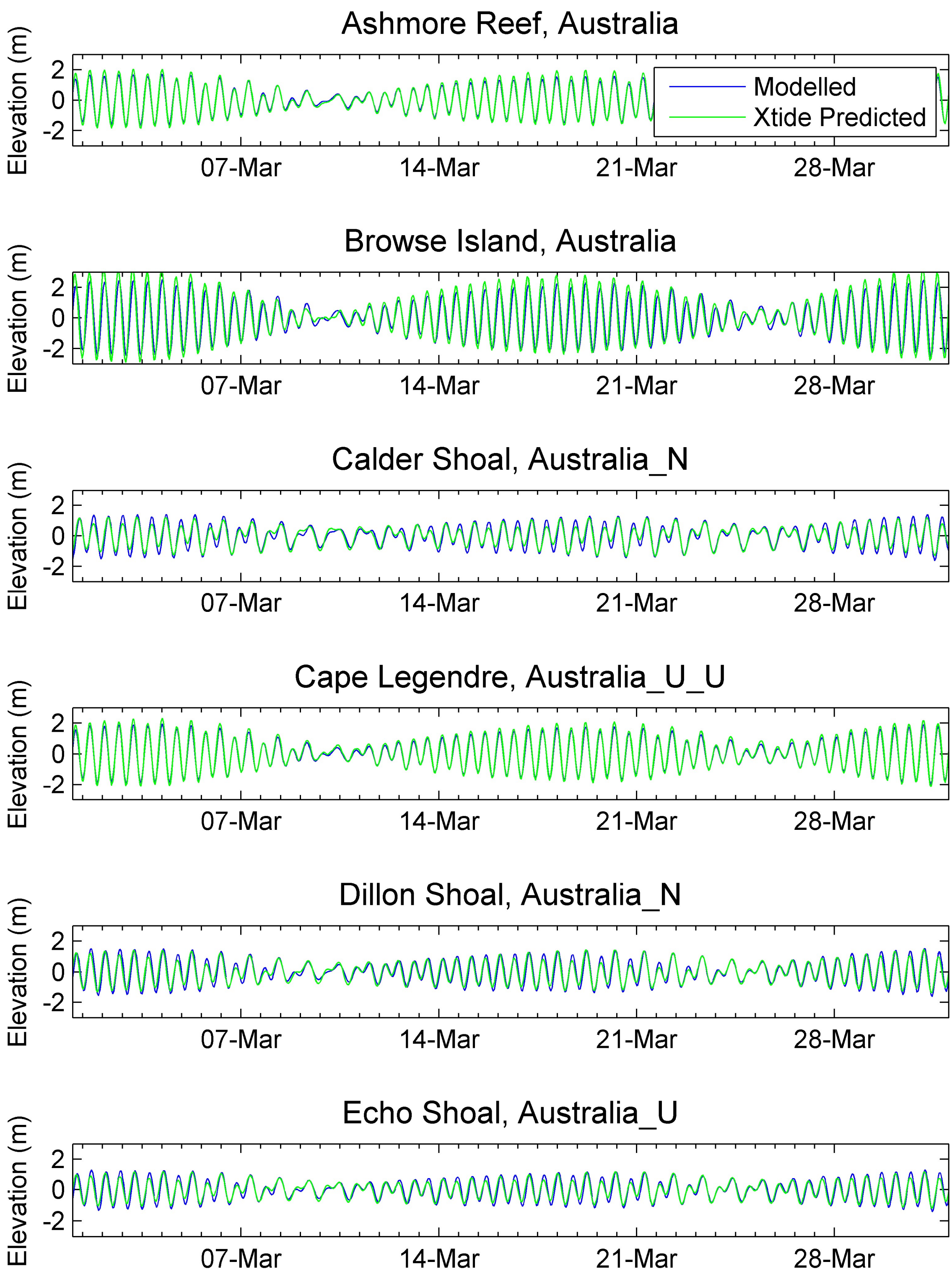

Figure 2.4 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

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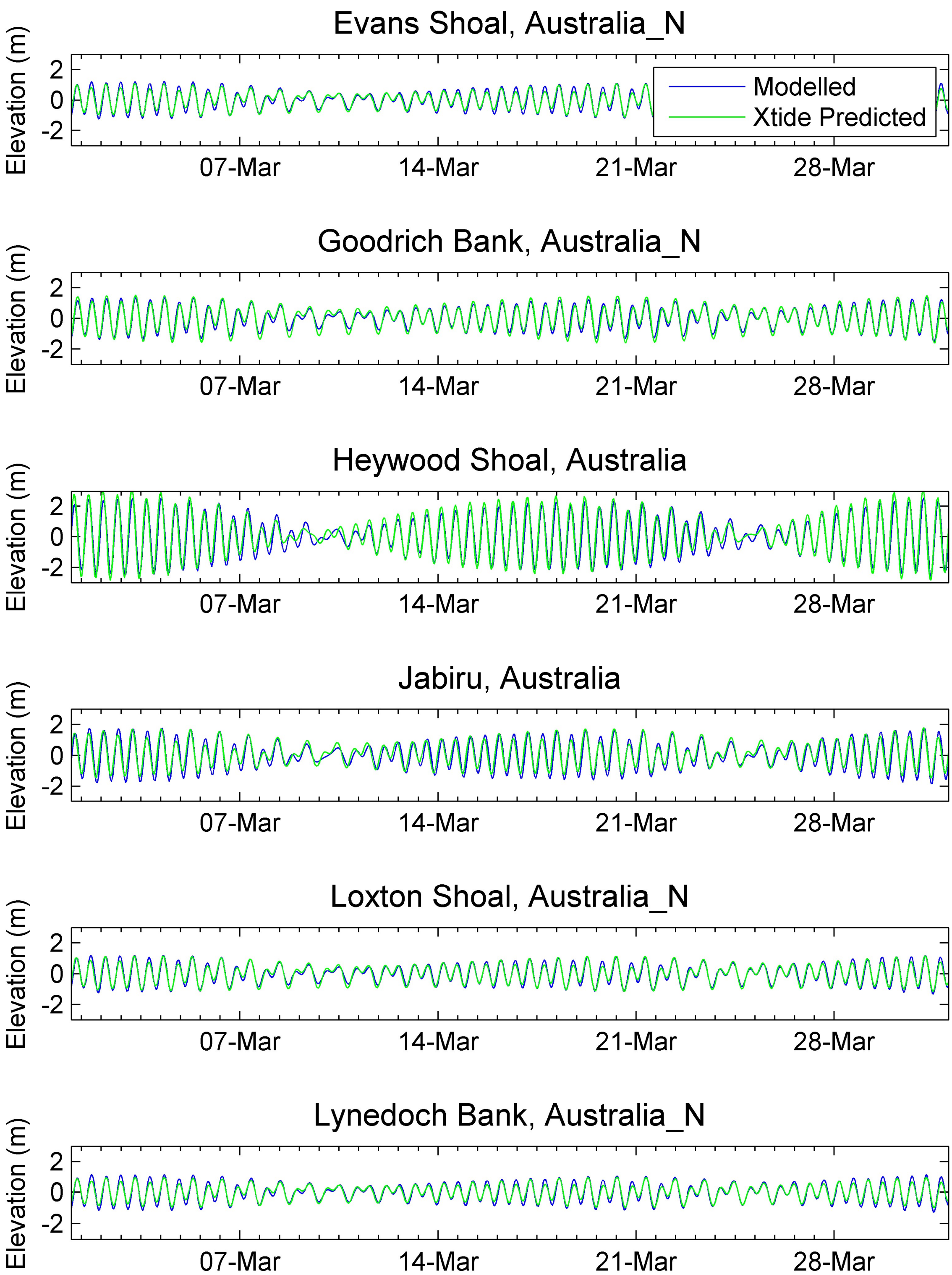

Figure 2.5 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

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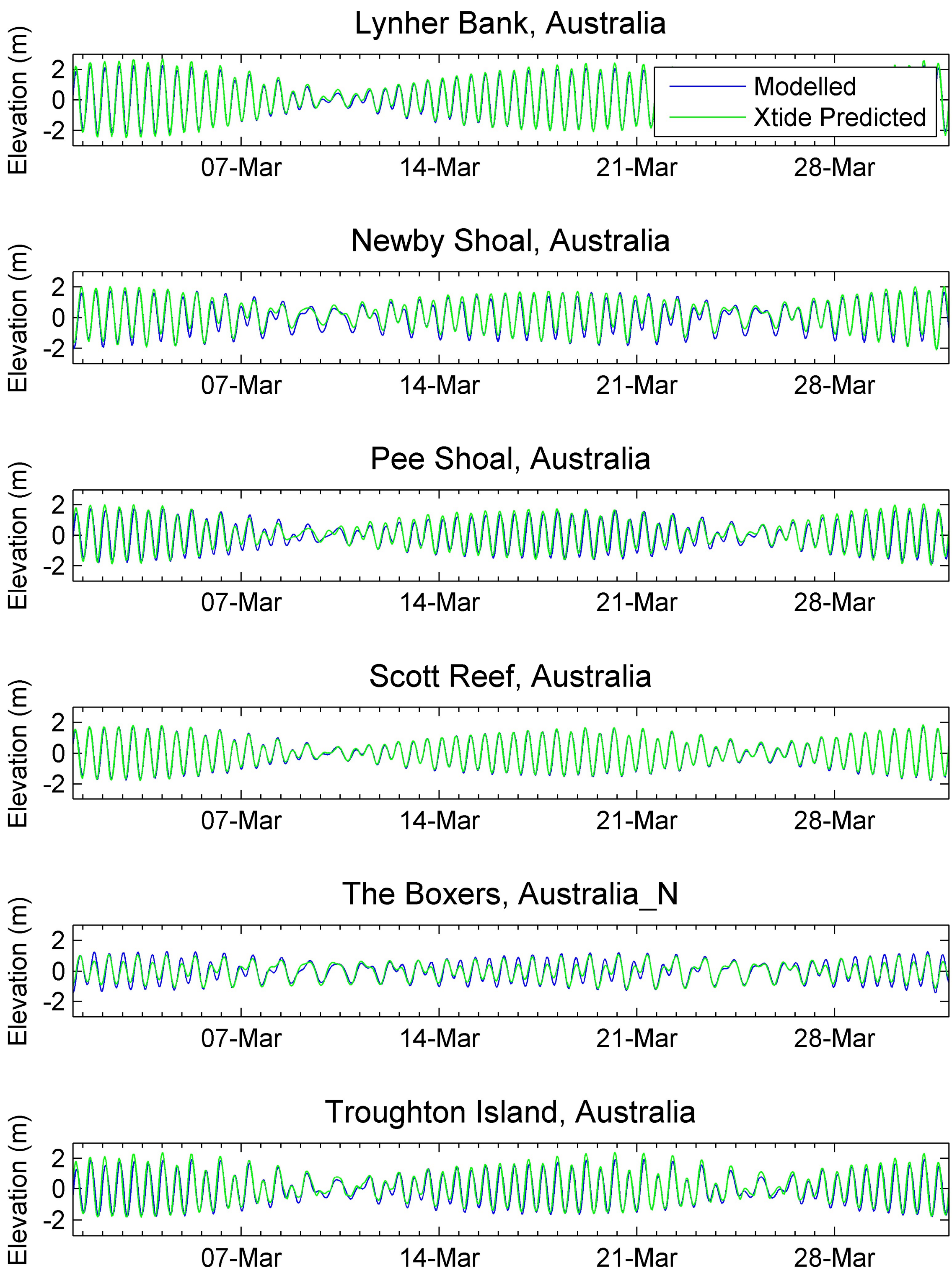

Figure 2.6 Time series comparisons between predicted surface elevation data from HYDROMAP (blue line) and XTide (green line) at six locations in the tidal model domain (March 2010).

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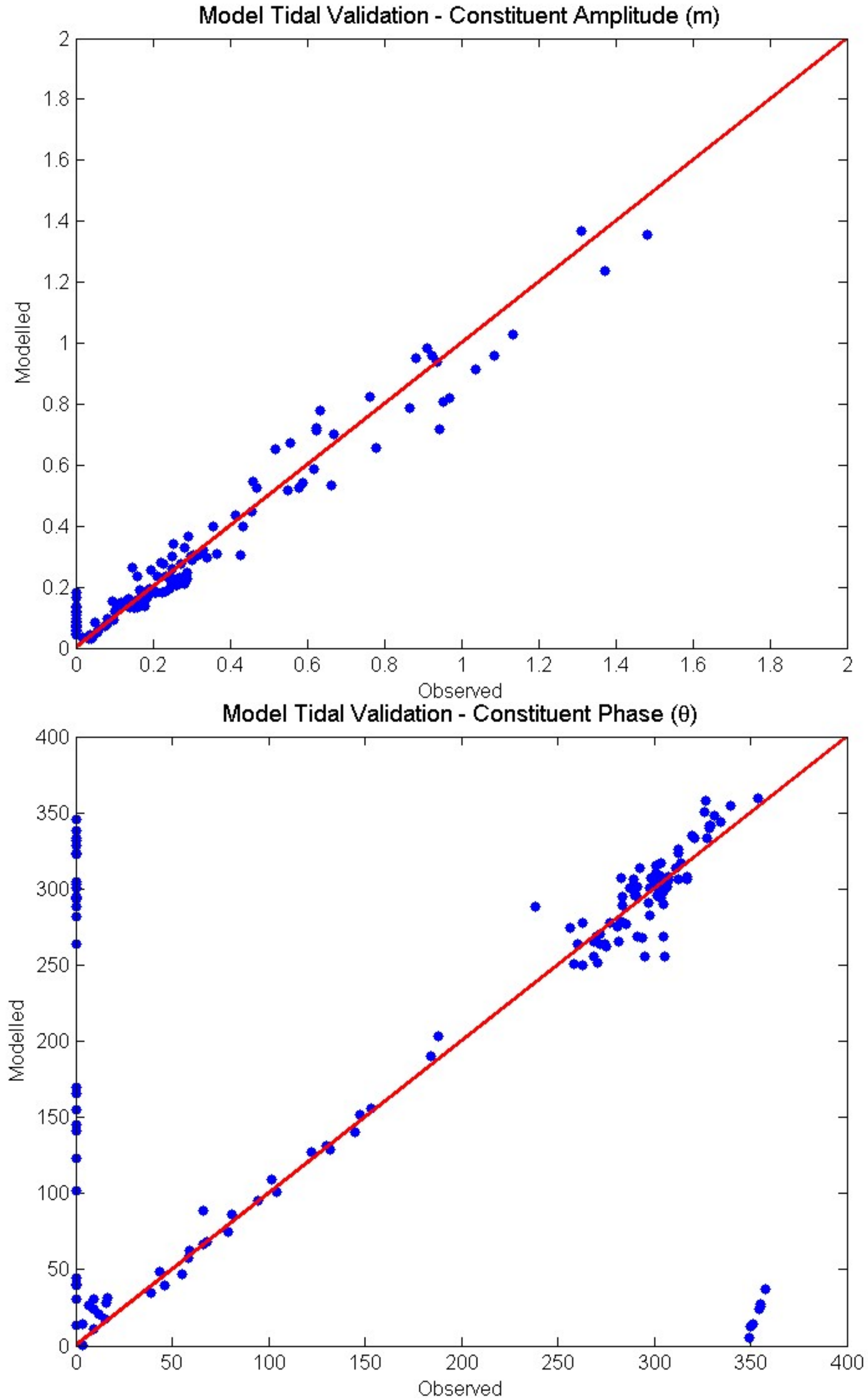

Figure 2.7 Comparisons between predicted tidal constituent amplitudes (top) and phases (bottom) from HYDROMAP and XTide at all stations in the tidal model domain. The red line indicates a 1:1 correlation between the respective data sets.

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2.2.4.4 Composite Current Data Set Validation: HYDROMAP + HYCOM

A composite modelled ocean current data product was derived by combining predictions of mesoscale circulation currents, available at daily resolution from the HYCOM ocean model, with predictions of the hourly tidal currents generated by the RPS HYDROMAP model.

To verify the modelled current predictions, the composite model outputs at the Crux development area were compared against the unfiltered site-specific current measurements. The model results were validated through both quantitative and visual comparisons between measured and modelled data at each depth where both data sets were available.

Time series comparison of composite model outputs and measured current magnitude, direction, and U/V velocity components at water depths of 20 m, 70 m and 110 m are presented in Figure 2.8, Figure 2.9 and Figure 2.10, respectively, for one month during winter (June 2016) and summer (December 2016). The time series comparisons reveal that the composite model offers a good match with the measured U/V velocity components at all water depths in both winter and summer, with the magnitudes and timings of the peaks and troughs matching well.

The IOA and MAE values derived from comparisons of the U/V velocity components at water depths of 20 m, 70 m and 110 m over the full measurement period are presented in Table 2.2. The IOA for each velocity component is high at all water depths, reflecting the good match in the magnitudes and timings of the peaks and troughs in the composite model data and measured data. The MAE for the U/V velocity components is relatively low at approximately 0.1 m/s for all water depths, indicating that the magnitude and range of the velocity components match well; however, a slight overprediction of the current magnitude is evident at times.

To compare directionality, roses for the composite model outputs and measured currents at 20 m, 70 m and 110 m water depths over the full measurement period are shown in Figure 2.10. The roses show that the composite model current direction is a good match with the measured direction. A shift in the dominant current direction from a north/south alignment in the measured data set to a northwest/southeast alignment in the composite model data set is evident at the 20 m water depth, and to a lesser extent also at the 70 m water depth. However, the range and variability in the measured current direction is captured by the composite model data, which matches best with the measured data at the water depth of 110 m.

Based on the validation performance, the composite model data set is a good model of standard conditions at the Crux development area and will adequately resolve local and regional circulation patterns. As such, the model is considered suitable for use in the numerical modelling studies conducted as part of the Crux project.

Table 2.2 Statistical comparison of predicted (HYDROMAP+HYCOM) and observed current speeds along orthogonal component axes at the Crux development area (2016-2017).

Skill Measure	Index of Agreement (IOA)			Mean Absolute Error (MAE) (m/s)		
Depth (m)	20	70	110	20	70	110
U Component	0.72	0.75	0.76	0.11	0.11	0.11
V Component	0.82	0.80	0.78	0.11	0.10	0.10

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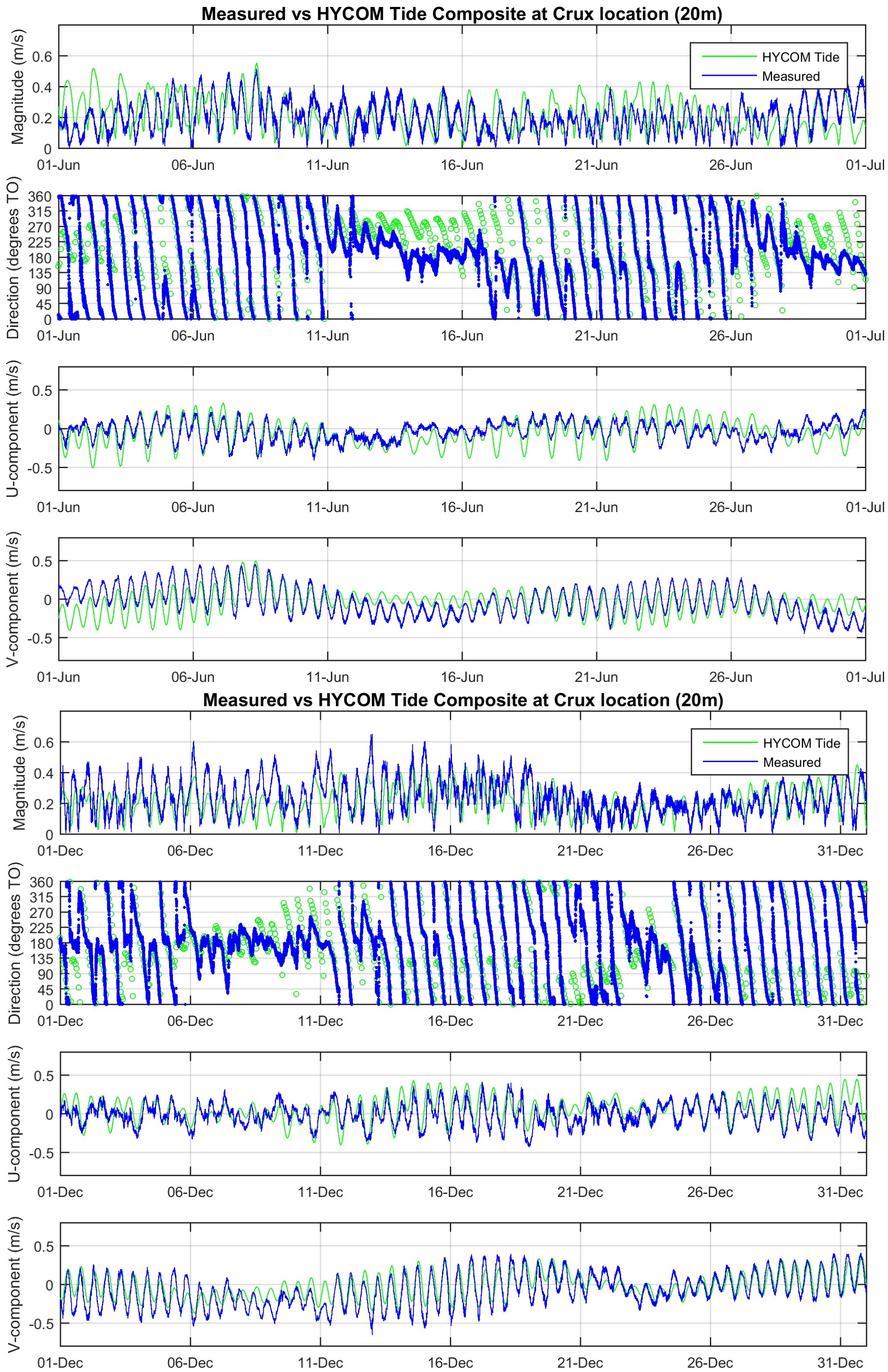

Figure 2.8 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 20 m for June 2016 (top panel) and December 2016 (bottom panel).

RPS

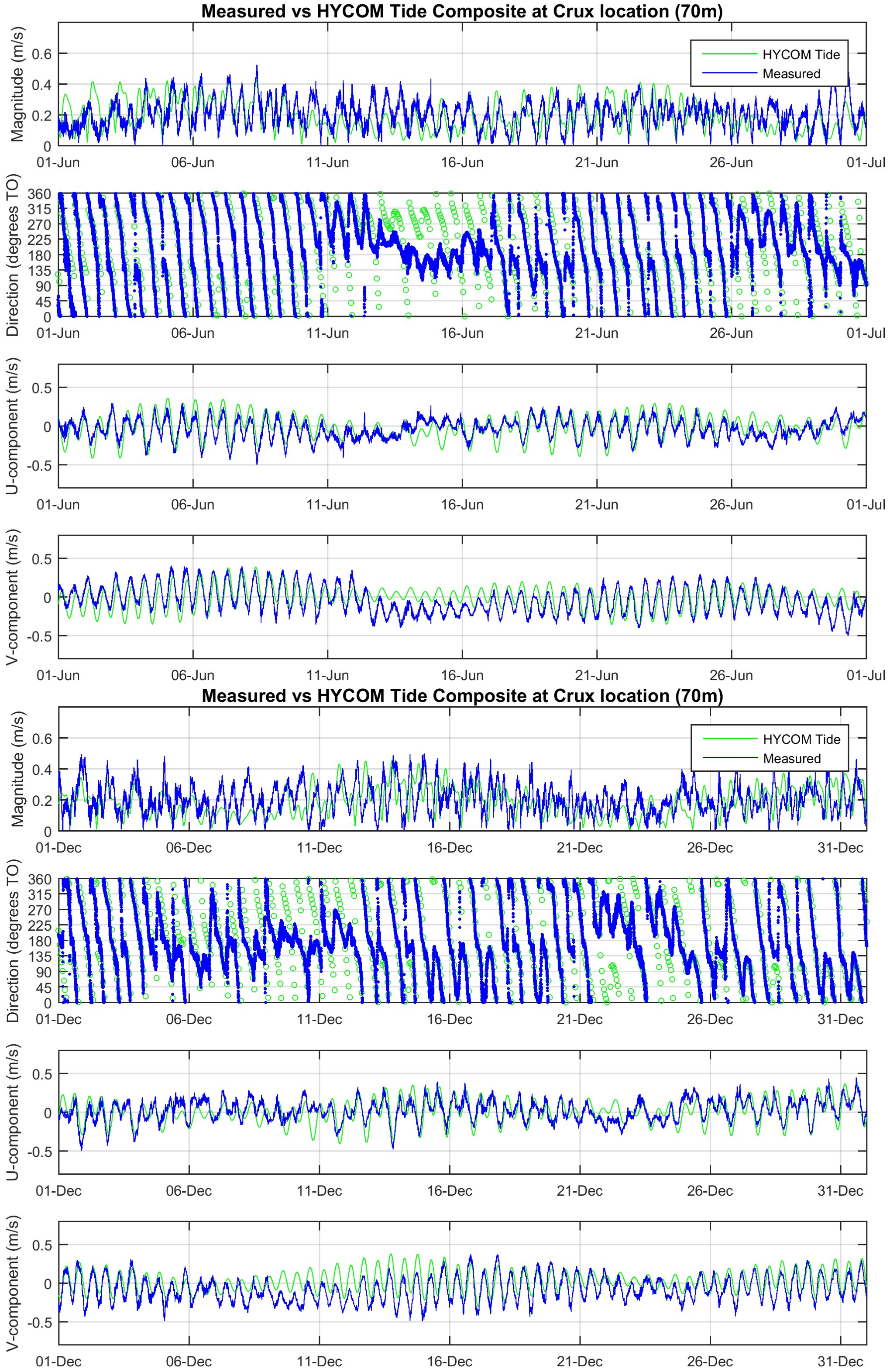

Figure 2.9 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 70 m for June 2016 (top panel) and December 2016 (bottom panel).

RPS

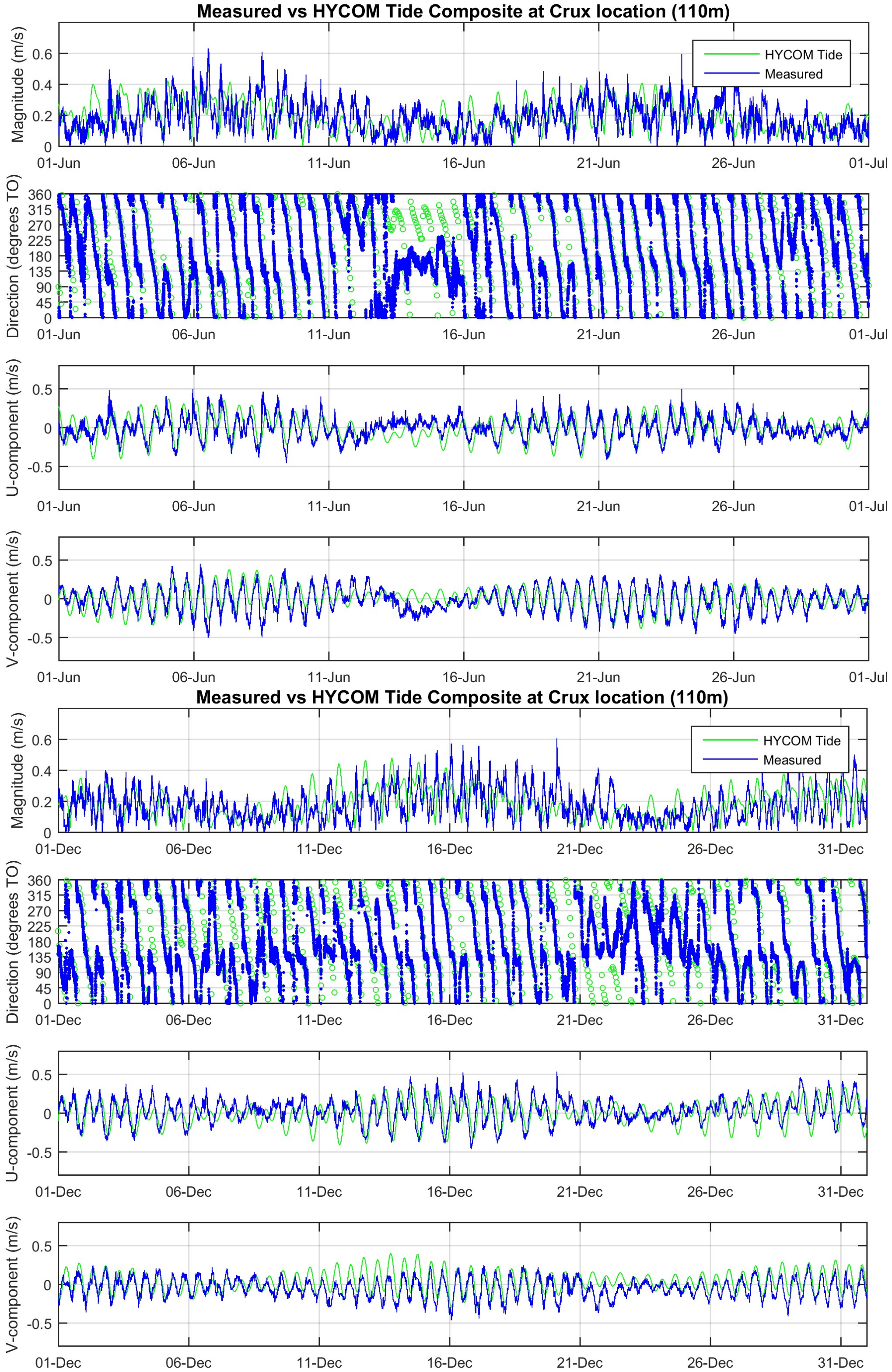

Figure 2.10 Time series comparisons between predicted (HYDROMAP+HYCOM, green line) and measured (blue line) current data at the Crux development area at a depth of approximately 110 m for June 2016 (top panel) and December 2016 (bottom panel).

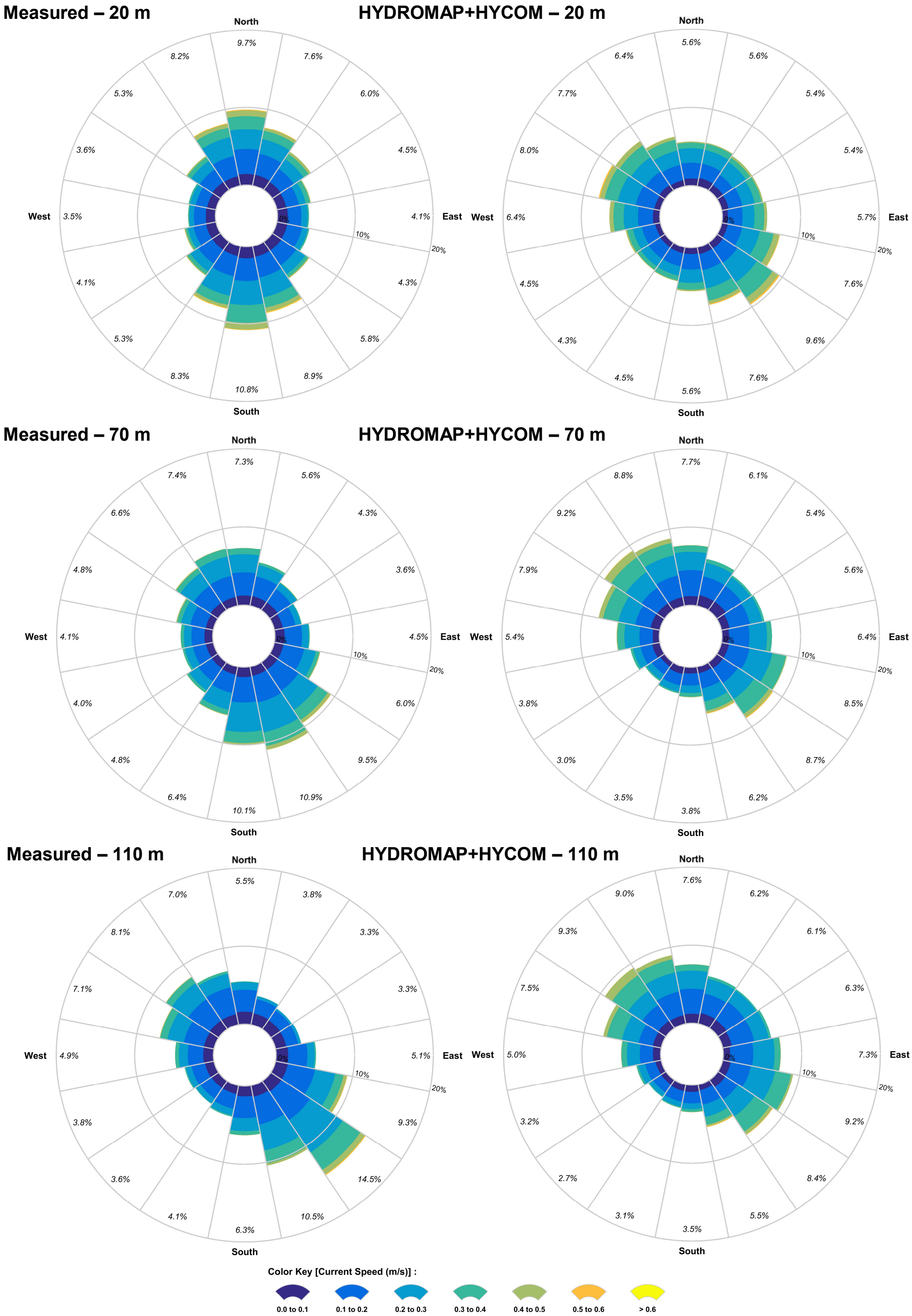

Figure 2.11 Comparative distributions for measured (left column) and predicted (HYDROMAP+HYCOM, right column) current data at the Crux development area (2016-2017) at depths of approximately 20 m (top row), 70 m (middle row) and 110 m (bottom row). The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.3 Wind Data

To account for the influence of the wind on surface-bound hydrocarbons, representation of the wind conditions was provided by spatial wind fields sourced from the National Center for Environmental Prediction (NCEP), National Oceanic and Atmospheric Administration (NOAA) Cooperative Institute for Research in Environmental Sciences (CIRES) Climate Diagnostics Center in Boulder, Colorado, United States of America (USA). 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 (2008-2017, inclusive). The data was assumed to be a suitably representative sample of the wind conditions over the study area for future years.

Figure 2.12 shows the seasonal wind roses near the Crux platform. The data shows that the wind speeds and directions vary between seasons. During summer (December to February), the winds blow predominantly from the west, and in winter (April to August) the winds blow predominantly from the east. During transitional conditions, wind directionality is more variable and wind speeds are generally lower than in the other seasons. Peak wind speeds of around 20 m/s are most commonly observed in summer and winter.

The extracted wind data near the release location suggests that, in the absence of any current effects, the wind acting on hydrocarbons on the sea surface will tend to result in initial trajectories that will most frequently be towards the east during summer period and towards the west during winter period. Note that the actual trajectories of the hydrocarbons on the sea surface will be the net result of a combination of the prevailing wind and current vectors acting at a given time and location. For long duration spills which may span multiple "periods" of the year, the net outcomes may be a blend between the major seasonal outcomes.

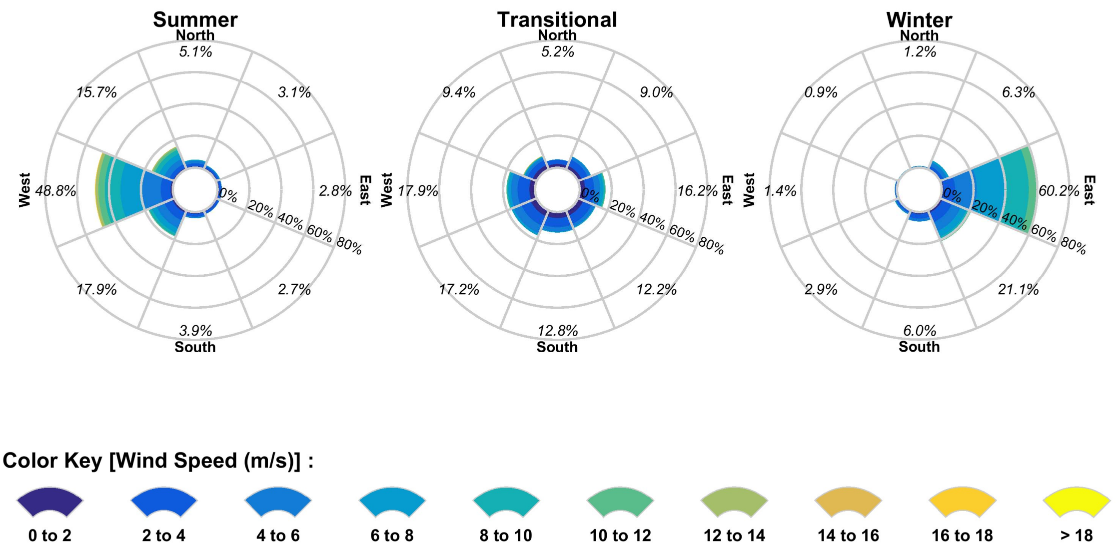

Figure 2.12 Seasonal wind distribution (2008-2017, inclusive) derived from the CFSR database near to the proposed Crux platform. The colour key shows the wind magnitude, the compass direction provides the direction from which the wind is blowing, and the size of the wedge gives the percentage of the record.

2.4 Temperature and Salinity Data

Temperature and salinity data based on one year of measurements carried out at the Crux development area by RPS between April 2016 and May 2017 (RPS, 2017) was supplied for the study.

Temperature and salinity data applied to the near-field modelling was sourced from the World Ocean Atlas 2013 (WOA13) database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration) and its co-located World Data Center for Oceanography (Levitus *et al.*, 2013).

For both data sets, annualised mean temperature profiles were calculated. Figure 2.13 presents a comparison of the WOA13 and RPS-measured annualised temperature profiles. From the profiles, it is evident that the WOA13 temperature structure offer a good match with the measured data and can be considered representative of the conditions in the Crux development area.

Table 2.3 shows the average seasonal water temperature and salinity levels at varying depths from 0 to 170 m. This data can be considered representative of seasonal conditions in the Crux development area.

The seasonal temperature profiles exhibit a reasonably consistent reduction in temperature with increasing depth. Salinity levels are generally more consistent and exhibit a vertically well-mixed water body (34.19 – 34.59 practical salinity unit, PSU), irrespective of season or depth.

Table 2.3 Average temperature and salinity levels adjacent to the proposed Crux platform.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	29.62	34.58
	10	29.54	34.57
	30	28.89	34.55
Transitional	0	27.34	34.19
	10	27.33	34.21
	30	27.18	34.23
Winter	0	28.49	34.34
	10	28.39	34.35
	30	27.48	34.39

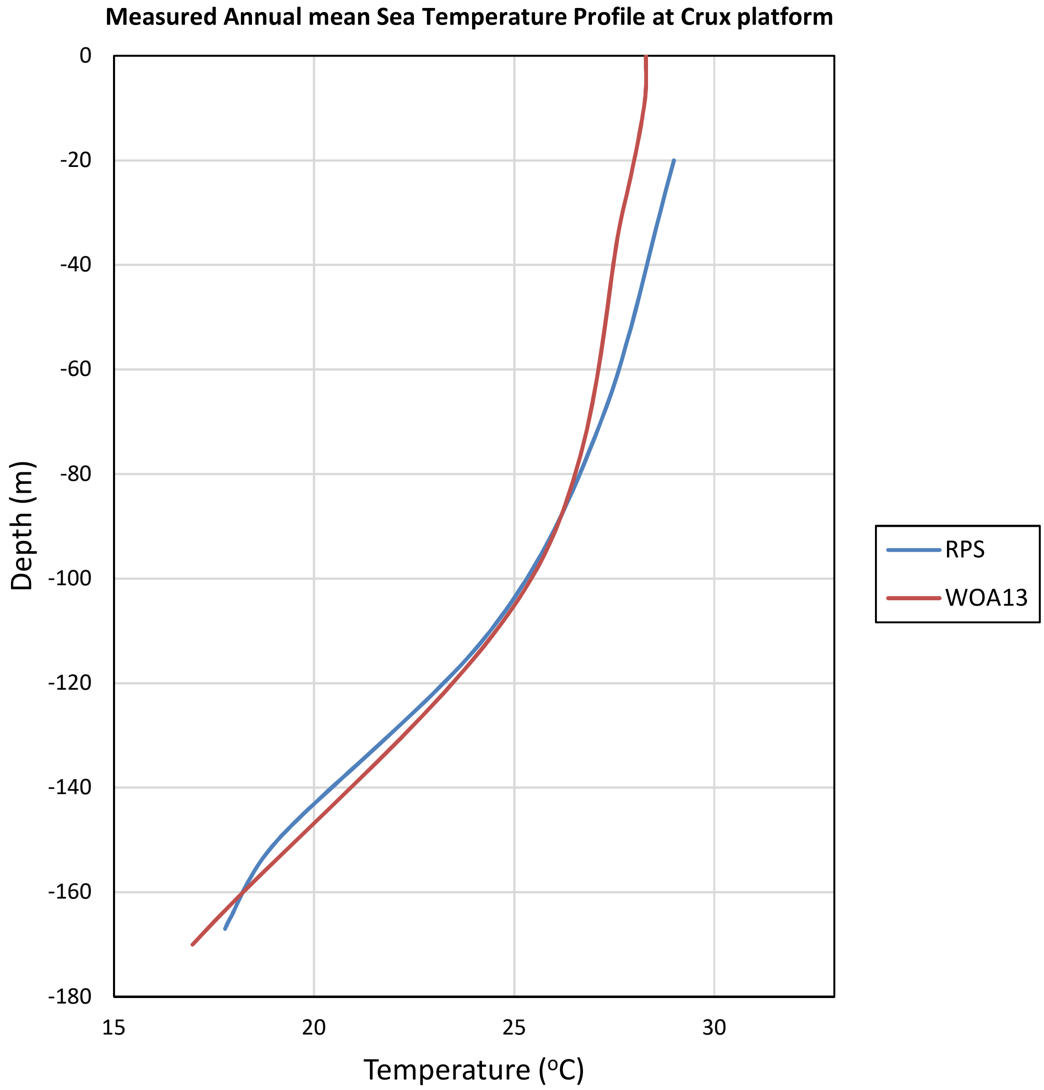

Figure 2.13 Comparison of World Ocean Atlas 2013 and RPS measured annual temperature profiles at Crux platform location.

2.5 Stochastic Modelling

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 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.

The SIMAP model simulates both surface and subsurface releases and uses the unique physical and chemical properties of an oil type to calculate rates of evaporation and viscosity change, including the tendency to form oil-in-water emulsions. Moreover, the unique transport and dispersion of surface hydrocarbons and in-water components (entrained and dissolved) are modelled separately. Thus, the model can be used to understand the wider potential consequences of a spill, including direct contact to oil on the sea surface for surface features and exposure to entrained and dissolved oil for organisms in the water column.

To define trends and variations in the potential outcomes of a given scenario, a stochastic modelling scheme was followed in this study, whereby SIMAP was applied to repeatedly simulate the defined spill scenarios using different samples of current and wind data selected randomly from an historic time series of wind and current data representative of the study area. To ensure seasonal representation, a fixed number of replicate simulations were performed using start times from each seasonal period. Results of the replicate simulations were then statistically analysed and mapped to define contours of risk around the release point.

For this purpose, a long-term archive of spatially-variable wind and current data covering northern Australia and spanning 10 years (2008-2017, inclusive) was assembled. Current patterns accounted for temporal and spatial variations in large-scale drift currents over the outer shelf waters (typically >200 m depth) together with tidal and wind-driven currents. Modelling was carried out using current and wind data sampled from the data archive for periods corresponding to the nominated seasons to quantify seasonal risks of contact at surrounding locations.

Note that the duration of the simulations requires that they may extend beyond the period in which the simulated spill occurred. Each simulation was run for the duration of the specified spill, plus a further period after the cessation of discharge to allow for oil concentrations to decrease below the low threshold concentrations applied in the analysis. It is expected that remnant floating oil, which may be present at low thresholds at the end of each simulation, would represent highly weathered and degraded products. This assumption of an extended duration period beyond the simulated spill event provides for a conservative modelling outcome and contributes to a worst-case outer extent of influence.

It is important to note that the modelling results presented in this report relate to the predicted outcomes once defined spill events have occurred. The probability of the spill scenarios occurring is not considered. Furthermore, the results are presented in terms of statistical probability maps, based on many simulations under different conditions. Different locations within the potential zone of influence would be affected under each different time series of environmental forces. Consequently, these contours for the potential zone of influence will cover a larger area than the area that could be affected during any one single spill event (see Figure 1.2). The contours should therefore be judged as contours of probability and not representations of the area swept by individual releases.

In performing stochastic analyses, it is important to understand the significance of the stochastic footprints relative to the footprint of one individual spill. Readers unfamiliar with modelling methodologies may misinterpret the model outcomes. To prevent misinterpretation, the stochastic results are often paired with a single deterministic trajectory for comparison.

2.6 Deterministic Modelling

From the stochastic set of replicate simulations for each scenario, deterministic model runs of interest were selected according to the following criteria:

- Maximum oil volume accumulated across all shoreline receptors;
- Minimum time to commencement of oil accumulation at any shoreline receptor (at a threshold of 10 g/m^2);
- Maximum length of oiled shoreline (at a threshold of 10 g/m^2).

2.7 Hydrocarbon Properties

2.7.1 Overview

Two different hydrocarbons were modelled as part of the study: Crux condensate and Intermediate Fuel Oil (IFO) 180. The different hydrocarbons have varying physical and chemical properties which determine the way they will behave in the marine environment.

Table 2.4 and Table 2.5 show the physical characteristics and boiling point ranges for each hydrocarbon, respectively. The hydrocarbon property category and hydrocarbon persistence classification were derived from AMSA (AMSA, 2015a) guidelines. The classification is based on a hydrocarbon's specific gravity in combination with relevant boiling point ranges.

Table 2.4 Physical properties of the hydrocarbons used in the modelling.

Physical Properties	Crux Condensate	IFO-180
Density (kg/m^3)	783.6 (at 15 °C)	967.0 (at 25 °C)
API	49.0	14.8
Dynamic viscosity (cP)	1.052 (at 20 °C)	2,324 (at 15 °C)
Pour point (°C)	9.0	-10.0
Hydrocarbon property category	Group I	Group IV
Hydrocarbon persistence classification	Non-persistent	Persistent (heavy)

Table 2.5 Boiling-point breakdown of the hydrocarbons used in the modelling.

Oil Type	Volatiles (%)	Semi-Volatiles (%)	Low Volatiles (%)	Residual (%)	Aromatics (%)
Boiling point (°C)	**<180 C4 to C10**	**180 - 265 C11 to C15**	**265 - 380 C16 to C20**	**>380 >C20**	**Of whole oil <380 BP**
		Non-persistent		**Persistent**	-
Crux condensate	54.8	22.8	14.6	7.8	12.3
IFO-180	1.0	14.4	20.8	63.8	5.9

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.

In the above, the 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, which will resist evaporation, persist in the marine environment for longer periods, and be subject to relatively slow degradation.

The actual fate of the released hydrocarbon in the marine environment will depend greatly on the amount of the hydrocarbon that reaches the surface, either through the initial release or by rising after discharge in the water column.

2.7.2 Crux Condensate

Crux condensate (API 49.0) contains a low proportion (approximately 7.8% by mass) of hydrocarbon compounds (mostly non-toxic inert waxes) that will not evaporate at atmospheric temperatures. These compounds will persist in the marine environment.

The unweathered hydrocarbon has a dynamic viscosity of 1.052 cP. The pour point of the whole condensate (9 °C) ensures that the unweathered hydrocarbon will remain in a liquid state over the annual temperature range observed in northern Australian waters.

The condensate is composed of hydrocarbons that have a wide range of boiling points and volatilities at atmospheric temperatures, and which will begin to evaporate at different rates on exposure to the atmosphere. Evaporation rates will increase with temperature, but in general about 54.8% of the hydrocarbon mass should evaporate within the first 12 hours (BP < 180 °C); a further 22.8% should evaporate within the first 24 hours (180 °C < BP < 265 °C); and a further 14.6% should evaporate over several days (265 °C < BP < 380 °C).

Selective evaporation of the lower boiling-point components will lead to a shift in the physical properties of the remaining Crux condensate, including an increase in the viscosity and pour point. Although removal of the most volatile compounds through evaporation and dissolution will result in an increase in density of the remaining Crux condensate, the mixture will not solidify or sink as it weathers.

The whole condensate has low asphaltene content (<0.05%), indicating a low tendency for the hydrocarbon to take up water to form water-in-oil emulsion over the weathering cycle.

Soluble aromatic hydrocarbons contribute approximately 12.3% by mass of the whole condensate, with a large proportion (9.8%) in the C4-C10 range of hydrocarbons. These compounds will evaporate rapidly, reducing the potential for dissolution of a proportion of them into the water.

A series of model weather tests were conducted to illustrate the potential behaviour of Crux condensate when exposed to idealised environmental conditions. The predicted weathering of hydrocarbons when simulations are conducted under constant wind speeds of 5, 10 and 15 knots is shown in Figure 2.14, Figure 2.15 and Figure 2.16 for Scenarios 1, 2 and 3, respectively.

For Scenarios 2 and 3, the figures show that as wind speed increases a larger volume of hydrocarbons becomes entrained in the water column; consequently, less oil is available on the water surface for evaporation to occur. For Scenario 1, increases in wind speed are observed to have a minimal effect on levels of entrainment because the subsurface discharge characteristics dictate that the vast majority of the oil mass will remain entrained after release, as opposed to being present on the sea surface.

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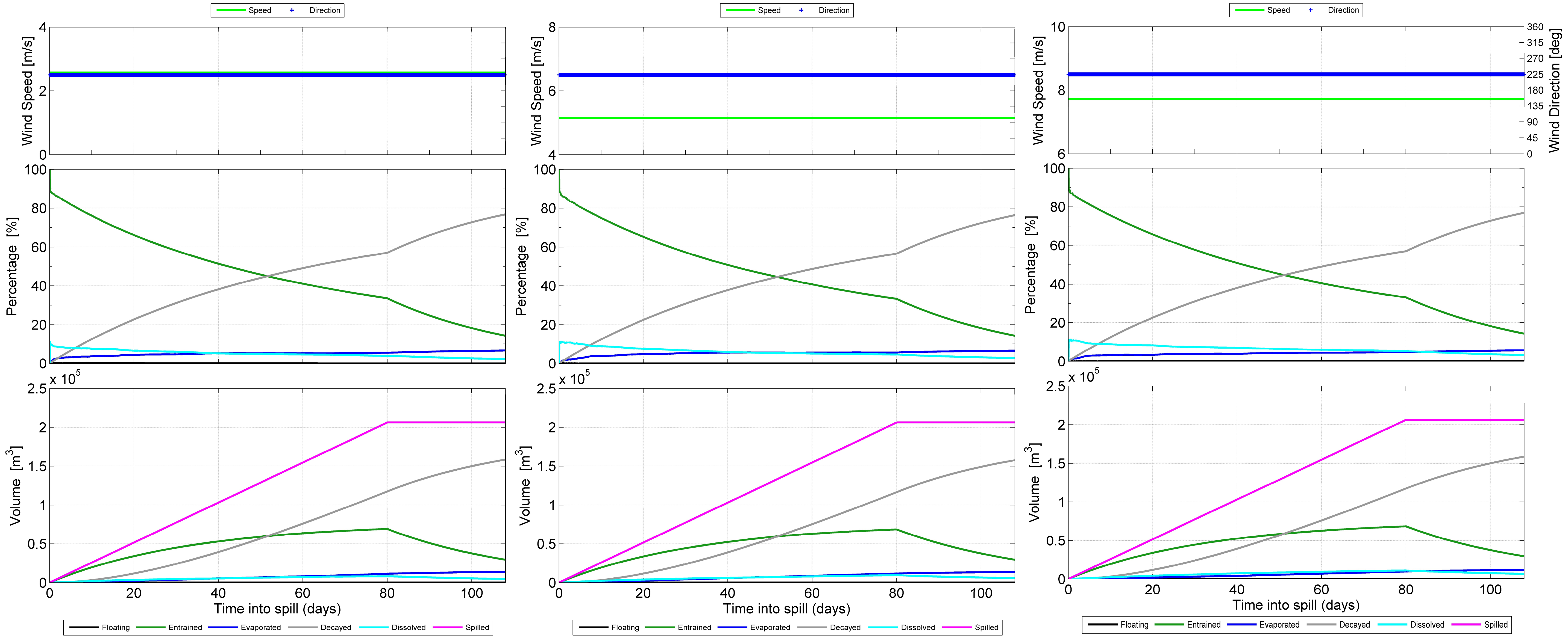

Figure 2.14 Mass balance plot representing, as proportion (middle row) and volume (bottom row), the weathering of an 80-day subsurface release of Crux condensate at a Development Well (Scenario 1) subject to constant wind speeds (top row) of 5 knots (left column), 10 knots (middle column) and 15 knots (right column).

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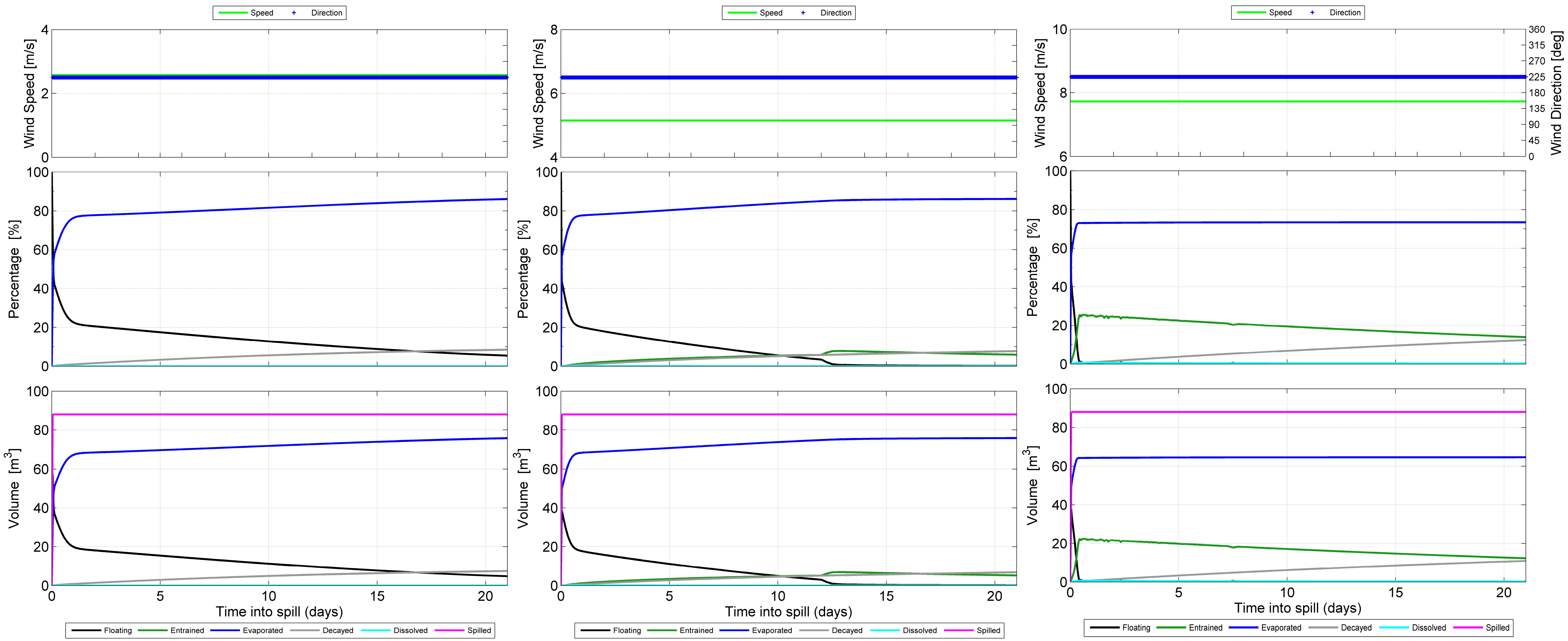

Figure 2.15 Mass balance plot representing, as proportion (middle row) and volume (bottom row), the weathering of an instantaneous surface release of Crux condensate at the Crux platform (Scenario 2) subject to constant wind speeds (top row) of 5 knots (left column), 10 knots (middle column) and 15 knots (right column).

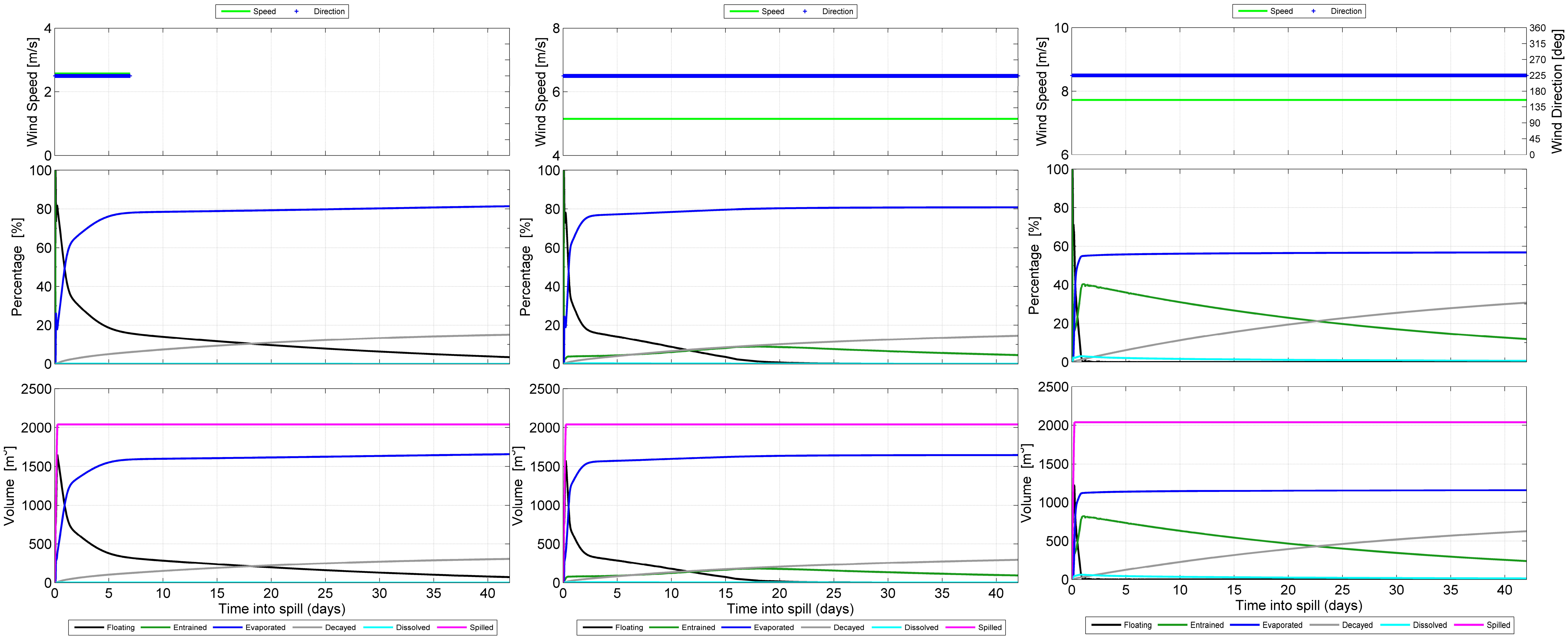

Figure 2.16 **Mass balance plot representing, as proportion (middle row) and volume (bottom row), the weathering of a 5.6-hour subsurface release of Crux condensate from a pipeline (Scenario 3) subject to constant wind speeds (top row) of 5 knots (left column), 10 knots (middle column) and 15 knots (right column).**

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2.7.3 IFO-180

IFO-180 (API 14.8) has a high density (967 kg/m^3) and a high viscosity (2,324 cP). It consists mainly of low volatiles (20.8%) and persistent hydrocarbons (63.8%). If released to the marine environment, the light volatiles (1%) are rapidly lost via evaporation while the residual component is expected to become semi-solid to solid at ambient temperatures. IFO-180 does not tend to entrain in the upper water column based on the hydrocarbon characteristics.

Depending on the environmental conditions and its state of weathering, IFO-180 can form stable or mesostable water-in-oil emulsions (emulsions) in which seawater droplets become suspended into the oil matrix (Fingas & Fieldhouse, 2004). This process requires physical mixing (i.e. wave action) with the stability of the emulsion influenced by the properties of the hydrocarbon product, including viscosities and asphaltene/resin content. Emulsions generally have an average water content of approximately 80% after 24 hours and have been shown to remain stable for up to four weeks under laboratory and test tank conditions (Fingas & Fieldhouse, 2004). Emulsions have an average water content of around 70% after 24 hours which decreases to approximately 30% after one week (Fingas & Fieldhouse, 2004). Emulsions generally become unstable within three days, as shown under laboratory conditions. Emulsification of IFO-180 will affect the spreading and weathering of the oil and increase the volume of oily material. If not within an emulsion state, the decay of IFO-180 is more rapid in comparison to condensates and marine diesel as microbial decay is generally faster for hydrocarbons with higher viscosity.

The toxic potential of IFO-180 is largely dependent on the properties of the blend, but generally contains <10% distillate with the remaining 90% composed of Heavy Fuel Oils (HFOs). The volatile and soluble components include those that are responsible for producing most of the aquatic toxicity due to its bioavailability to marine organisms. Thus, Crux condensate is considered to have a higher aquatic toxicity potential in comparison to IFO-180. However, these volatile, non-persistent components are short-lived and susceptible to evaporation and degradation. The weathered portion of IFO would behave similarly to HFO. The residual components would eventually become insoluble in seawater and end up adhered to sediment or biota, reducing the risk of acute toxicity.

A series of model weather tests were conducted to illustrate the potential behaviour of IFO-180 when exposed to idealised environmental conditions. The predicted weathering of hydrocarbons when simulations are conducted under constant wind speeds of 5, 10 and 15 knots is shown in Figure 2.17 for Scenario 4.

The figure demonstrates the highly persistent and viscous nature of the oil, with a similar evaporative loss rate and negligible levels of entrainment for all wind speeds.

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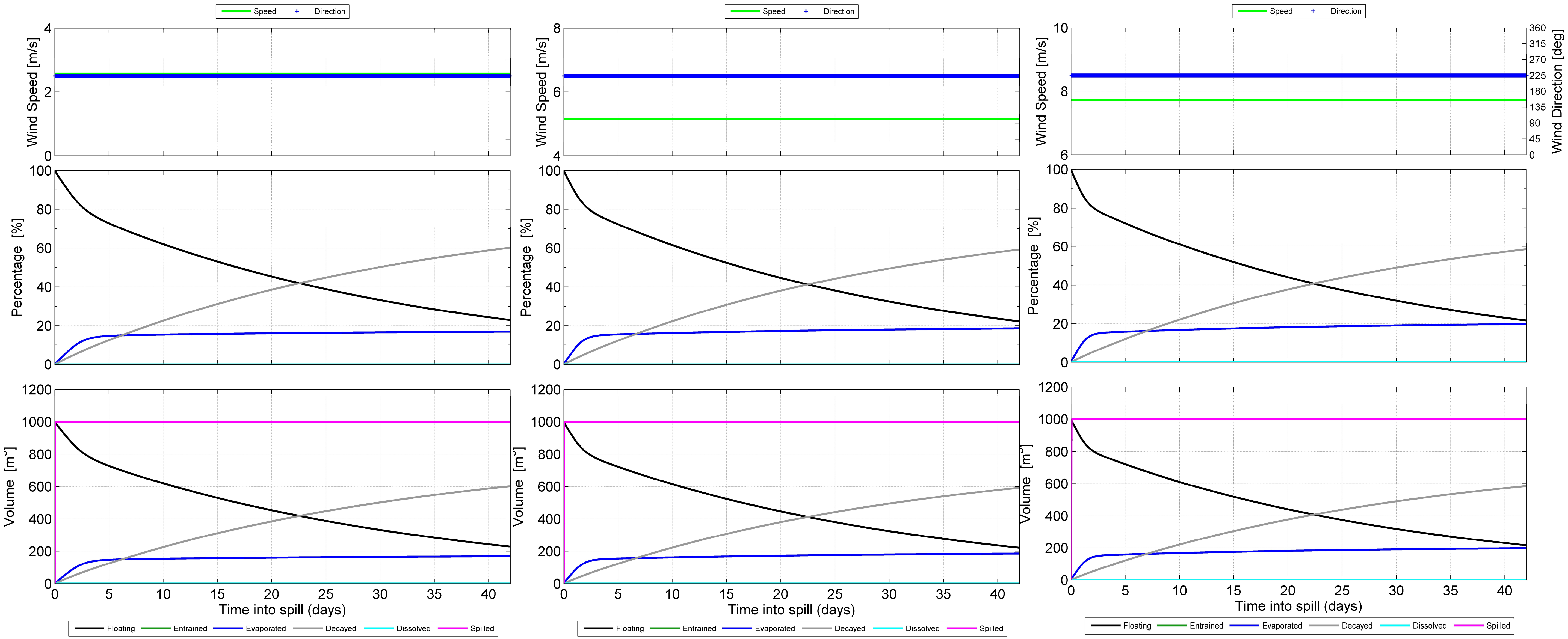

Figure 2.17 Mass balance plot representing, as proportion (middle row) and volume (bottom row), the weathering of a 1-hour surface release of IFO-180 at the Crux end of the export pipeline (Scenario 4) subject to constant wind speeds (top row) of 5 knots (left column), 10 knots (middle column) and 15 knots (right column).

2.8 Subsurface Discharge Characteristics

2.8.1 Overview

High-pressure releases that involve mixed gas and hydrocarbon 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 hydrocarbon to the surface at a substantially faster rate than would occur from the relative buoyancy of the hydrocarbon 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 hydrocarbon will then tend to separate before the hydrocarbon surfaces because the gas either goes into solution or accelerates away from the hydrocarbon droplets. The height at which the gas lift ceases is referred to as the trapping height. The rate at which hydrocarbon rises from the trapping height will be determined by a number of factors, including the relative buoyancy of the hydrocarbon 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.

The OILMAP model was used in this study to predict the behaviour of the rising plume of gas-oil-water and the oil droplet distribution resulting from subsurface discharge scenarios. These comprised one subsea well blowout and one subsea pipeline rupture (Scenarios 1 and 3).

Inputs to the OILMAP model included specification of the discharge rate, hole size, gas-to-oil ratio, and the temperature of the hydrocarbon 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 each of these scenarios are presented in the following sections.

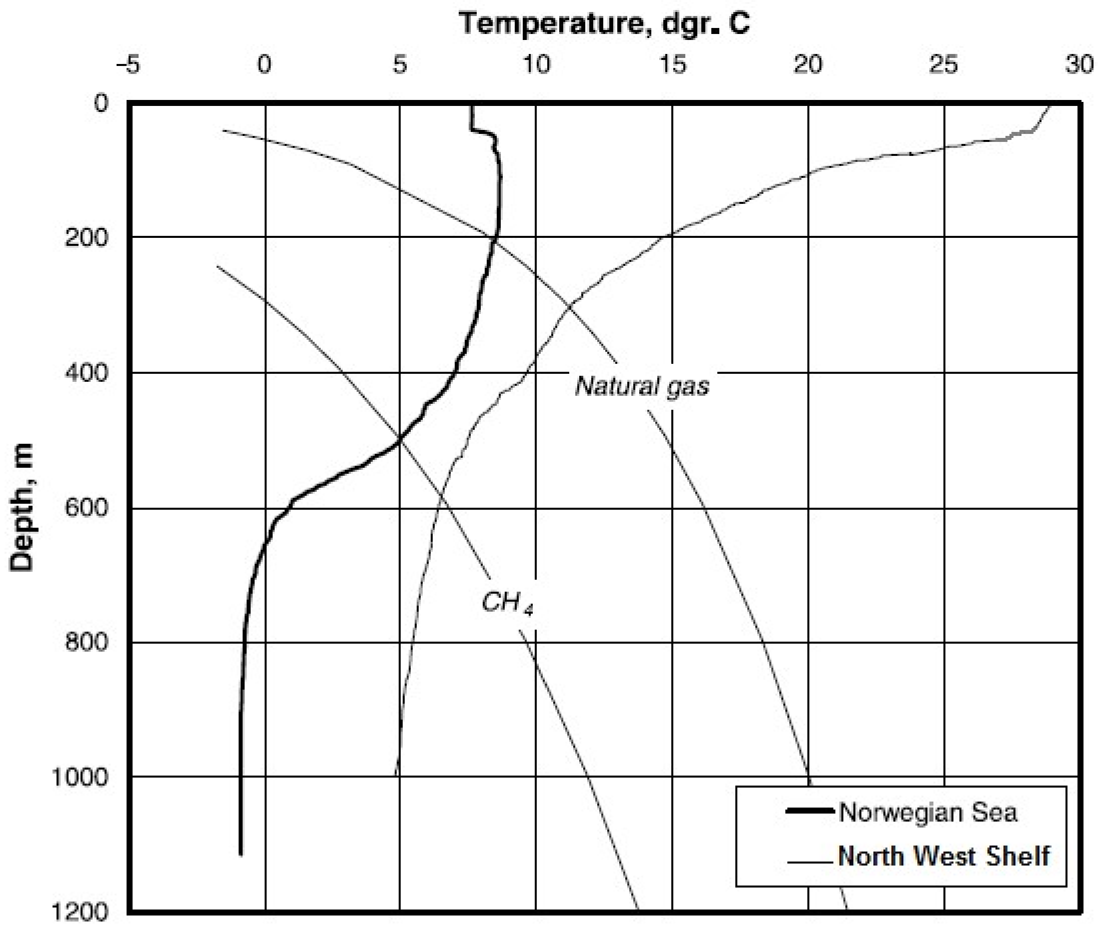

Figure 2.18 Theoretical equilibrium lines for hydrate formation based on the temperature and pressure at the release point. The line for "natural gas" assumes 80% methane, 10% ethane and 10% propane. Typical indicative sea temperature profiles with depth are indicated (Johansen, 2003).

2.8.2 Scenario 1: Subsurface Blowout at a Development Well

For the release of Crux condensate following a subsurface blowout from a development well, the OILMAP input parameters and the resulting output parameters that were used as input into SIMAP are presented in Table 2.6. The model input also included temperature and salinity profiles representative of the location.

The results of the OILMAP simulation predict that the discharge will generate a cone of rising gas that will entrain the hydrocarbon 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 12.2 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 hydrocarbon at the neutral-buoyancy point is predicted to be 21.8 m.

The high discharge velocity and turbulence generated by the expanding gas plume is predicted to generate very small oil droplets (<30 µm) that will have very low rise velocities (<0.005 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, despite reaching the surface due to the lift produced by the rising plume, the droplets will then initially remain within the wave-mixed layer of the water column (3-

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10 m deep, depending on the conditions), where they can resist surfacing due to their weak buoyancy relative to other mixing processes. While most of the oil droplets will tend to remain in the upper water column (where the most elevated concentrations will usually be found as a result), turbulent mixing and dispersion processes will distribute oil throughout the whole water column at lower concentrations.

The ongoing nature of the release combined with the potential for the plume to breach the water surface may present other hazards, including conditions that may lead to high local concentrations of atmospheric volatiles. The results suggest that beyond the immediate vicinity of the blowout the majority of the released hydrocarbons will be present in the upper layers of the ocean (with lower concentrations deeper in the water column), with the potential for hydrocarbons to form localised floating films under sufficiently calm local wind conditions.

2.8.3 Scenario 3: Subsurface Rupture of the Crux Export Pipeline

For the release of Crux condensate following a rupture of the export pipeline, the OILMAP input parameters and the resulting output parameters that were used as input into SIMAP are presented in Table 2.6. The model input also included temperature and salinity profiles representative of the Crux project area.

The results of the OILMAP simulation predict that the discharge will generate a cone of rising gas that will entrain the hydrocarbon 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 4.3 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 neutral-buoyancy point is predicted to be 24.9 m.

The discharge velocity and turbulence generated by the expanding gas plume is predicted to generate relatively large hydrocarbon droplets (approximately 500-2,500 µm) that will have relatively high rise velocities (approximately 1.6-10 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. Floating oil films are likely to be formed under typical wind conditions.

The ongoing nature of the release combined with the potential for the plume to breach the water surface may present other hazards, including conditions that may lead to high local concentrations of atmospheric volatiles. The results suggest that beyond the immediate vicinity of the rupture the majority of the released hydrocarbons will be present in the upper layers of the ocean, with the potential for hydrocarbons to form localised floating films under sufficiently calm conditions. While most of the entrained oil droplets will tend to remain in the upper water column (where the most elevated concentrations will usually be found as a result), turbulent mixing and dispersion processes will distribute oil throughout the whole water column at lower concentrations.

Table 2.6 Near-field subsurface discharge plume dynamics for Scenarios 1 and 3.

Variable	Scenario 1 – Well Blowout	Scenario 3 – Pipeline Rupture
Initial plume rise velocity (m/s)	12.2	4.3
Terminal plume rise velocity (m/s)	9.8	2.9
Plume rise time (s)	28.6	116.5
Maximum plume core diameter (m)	21.8	24.9
Plume trapping depth (m below mean sea level)	0 (surface)	0 (surface)

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2.9 Model Settings and Assumptions

Table 2.7 provides a summary of the hydrocarbon spill model settings and assumptions. The simulation durations were carefully selected for each scenario based on extensive sensitivity testing. During the sensitivity testing process, sample spill simulations are run for longer than the intended durations for each scenario. Upon completion of the spill simulations, the results are carefully assessed to examine the persistence of the hydrocarbon (i.e. whether the maximum evaporative loss has been achieved for the period of time modelled; and whether a substantial volume of hydrocarbons – if any – remain in the water column) in conjunction with the extent of sea surface exposure based on reporting thresholds. The persistence of the hydrocarbons on the sea surface and entrained within the water column is based on several factors, including the nature of release (duration, volume and type), residual properties of the hydrocarbon type, and weathering. Once there is agreement between the two factors (i.e. the final fate of hydrocarbon is accounted for and the full exposure area is identified) the simulation duration is deemed appropriate.

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Table 2.7 Summary of the hydrocarbon spill model settings.

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Scenario description	Subsurface blowout after loss of well control	Surface storage tank rupture after inventory integrity failure	Subsurface pipeline rupture	Surface fuel tank rupture after pipelay vessel collision
Location	Development well	Crux platform	Pipeline route at closest point to Heywood Shoal	Crux end of the export pipeline
Number of randomly-selected spill start times per season	100	100	100	100
Hydrocarbon type	Crux condensate	Crux condensate	Crux condensate	IFO-180
Spill volume (m^3)	206,225 (2,578 m^3/day)	88	2,037	1,000
Release type	Subsurface	Surface	Subsurface	Surface
Release duration	80 days	Instantaneous	5.6 hours	1 hour
Simulation duration	108 days	21 days	42 days	42 days
Seasons assessed	Summer (December to February) Transitional (March and September to November) Winter (April to August)			
Sea surface (floating) hydrocarbon exposure thresholds	1 g/m^2 (low exposure) 10 g/m^2 (moderate exposure) 25 g/m^2 (high exposure)			
Shoreline hydrocarbon exposure thresholds	10 g/m^2 (low exposure) 100 g/m^2 (moderate exposure) 1,000 g/m^2 (high exposure)			
Subsurface: Entrained hydrocarbon exposure thresholds	10 ppb (low exposure) 100 ppb (moderate exposure) 500 ppb (high exposure)			
Subsurface: Dissolved aromatic hydrocarbon exposure thresholds	6 ppb (low exposure) 50 ppb (moderate exposure) 400 ppb (high exposure)			

2.10 Sea Surface, Shoreline and Subsurface Thresholds

The SIMAP model can track hydrocarbon concentrations to levels lower than those biologically significant or visible to the naked eye. Therefore, it is useful to define meaningful threshold concentrations (based on scientific literature) to account for exposure and contact by oil components.

The judgement of meaningful levels is complex and is influenced by the mode of action, sensitivity of the biota contacted, the duration of the contact and the particular toxicity of the compounds that are represented in the hydrocarbon. For the latter factor, further consideration must be given to the change in the composition of a hydrocarbon type over time due to weathering processes which in general terms becomes less toxic as the oil weathers.

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For this study, thresholds for sea surface (i.e. floating) hydrocarbons, shoreline hydrocarbons, entrained oil and dissolved aromatic hydrocarbons were specified for use in defining the potential zone of influence of the spill event. These thresholds are summarised in Table 2.8, along with supporting justification and additional context relating to the area of influence.

Table 2.8 Summary of the zones of exposure and thresholds applied in this study.

Exposure Zone	Threshold	Justification
Floating Hydrocarbon Threshold		
Exposure zone Low exposure (1 g/m^2-10 g/m^2)	1 g/m^2	The 1 g/m^2 threshold represents the practical limit of observing hydrocarbon sheens in the marine environment and therefore has been used to define the outer boundary of the low exposure zone. 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. This exposure zone is not considered to be of significant biological impact but may be visible to the human eye. This exposure zone represents the area contacted by the spill and defines the conservative outer boundary of the area of influence from a hydrocarbon spill. For context, <15 ppm is an allowable discharge limit from ships and 30 ppm is a typical discharge limit from an offshore oil and gas facility. Above 30 ppm, a visible sheen is observable at the sea surface.
Adverse exposure zone Moderate exposure (10 g/m^2-25 g/m^2)	10 g/m^2	Ecological impact has been estimated to occur at 10 g/m^2 as this level of oiling has been observed to mortally impact birds and other wildlife associated with the water surface (French *et al.*, 1996; French-McCay, 2009). The 10 g/m^2 threshold has been selected to define the moderate exposure zone. Contact within this exposure zone may result in impacts to the marine environment.
Adverse exposure zone High exposure (>25 g/m^2)	25 g/m^2	The 25 g/m^2 threshold is above the minimum threshold observed to cause ecological impact. Studies have indicated that a concentration of surface oil 25 g/m^2 or greater would be harmful for the majority of birds that contact the hydrocarbon at this concentration (Scholten *et al.*, 1996; Koops *et al.*, 2004). Exposure above this threshold is used to define the high exposure zone.
Shoreline Hydrocarbon Threshold		
Exposure zone Low exposure (10 g/m^2-100 g/m^2)	10 g/m^2	In previous risk assessment studies by French-McCay *et al.* (2005a, 2005b), a threshold of 1 g/m^2 was used to assess the potential for shoreline contact (by oil stranding on shorelines/beaches). It is a conservative threshold used to define regions of socio-economic impact, such as the triggering of temporary closures of fisheries, or the need for shore clean-up on man-made concrete/stone walls or on amenity beaches. A less conservative threshold of 10 g/m^2 has been defined as 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.
Adverse exposure zone Moderate exposure (100 g/m^2-1,000 g/m^2)	100 g/m^2	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). Thresholds of 100 g/m^2 and 1,000 g/m^2
Adverse exposure zone High exposure (>1,000 g/m^2)	1,000 g/m^2	

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Exposure Zone	Threshold	Justification
		will define the zones of potential 'moderate' and 'high' exposure on shorelines, respectively. Contact within these exposure zones may result in impacts to the marine environment.
Entrained Hydrocarbon Threshold		
Exposure zone Low exposure (10 ppb-100 ppb)	10 ppb	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. This 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.
Adverse exposure zone Moderate exposure (100 ppb-500 ppb)	100 ppb	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 to indicate a potential zone of acute exposure, which is more meaningful over shorter exposure durations. The 100 ppb threshold has been selected to define the moderate exposure zone. Contact within this exposure zone may result in impacts to the marine environment.
Adverse exposure zone High exposure (>500 ppb)	500 ppb	The 500 ppb threshold is considered conservative high exposure level in terms of potential for toxic effects leading to mortality for more tolerant species or habitats. This threshold has been defined to indicate a potential zone of acute exposure, which is more meaningful over shorter exposure durations. The 500 ppb threshold has been selected to define the high exposure zone.
Dissolved Aromatic Hydrocarbon Threshold		
Exposure zone Low exposure (6 ppb-50 ppb)	6 ppb	The threshold value for species toxicity in the water column is based on global data from French *et al.* (1999) and French-McCay (2002, 2003), which showed that species sensitivity (fish and invertebrates) to dissolved aromatics exposure >4 days (96-hour LC_{50}) under different environmental conditions varied from 6 ppb-400 ppb, with an average of 50 ppb. This range covered 95% of aquatic organisms tested, which included species during sensitive life stages (eggs and larvae). Based on scientific literature, a minimum threshold of 6 ppb used to define the low exposure zones (Engelhardt, 1983; Clark, 1984; Geraci & St. Aubin, 1988; Jenssen, 1994; Tsvetnenko, 1998). This 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.
Adverse exposure zone Moderate exposure (50 ppb-400 ppb)	50 ppb	A conservative threshold of 50 ppb was chosen as it is more likely to be indicative of potentially harmful exposure to fixed habitats over short exposure durations (French-McCay 2002). French-McCay (2002) indicates that an average 96-hour LC_{50} of 50 ppb could serve as an acute lethal threshold to 5% of biota.

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Exposure Zone	Threshold	Justification
		The 50 ppb threshold has been selected to define the moderate exposure zone. Contact within this exposure zone may result in impacts to the marine environment.
Adverse exposure zone High exposure (>400 ppb)	400 ppb	A conservative threshold of 400 ppb was chosen as it is more likely to be indicative of potentially harmful exposure to fixed habitats over short exposure durations (French-McCay 2002). French-McCay (2002) indicates that an average 96-hour LC_{50} of 400 ppb could serve as an acute lethal threshold to 50% of biota. The 400 ppb threshold has been selected to define the high exposure zone.

LC_{50}: Median lethal dose required for mortality of 50% of a tested population after a specified test duration.

2.11 Receptors Overview

The key sensitive receptors assessed in this study are shown in Figure 2.19 to Figure 2.28. These include Australian Marine Parks (AMPs), State/Territory Marine Parks, mainland and island coastlines (emergent receptors), Key Ecological Features (KEFs), reefs, shoals and banks (submerged receptors) and biologically important areas (BIAs) for turtles.

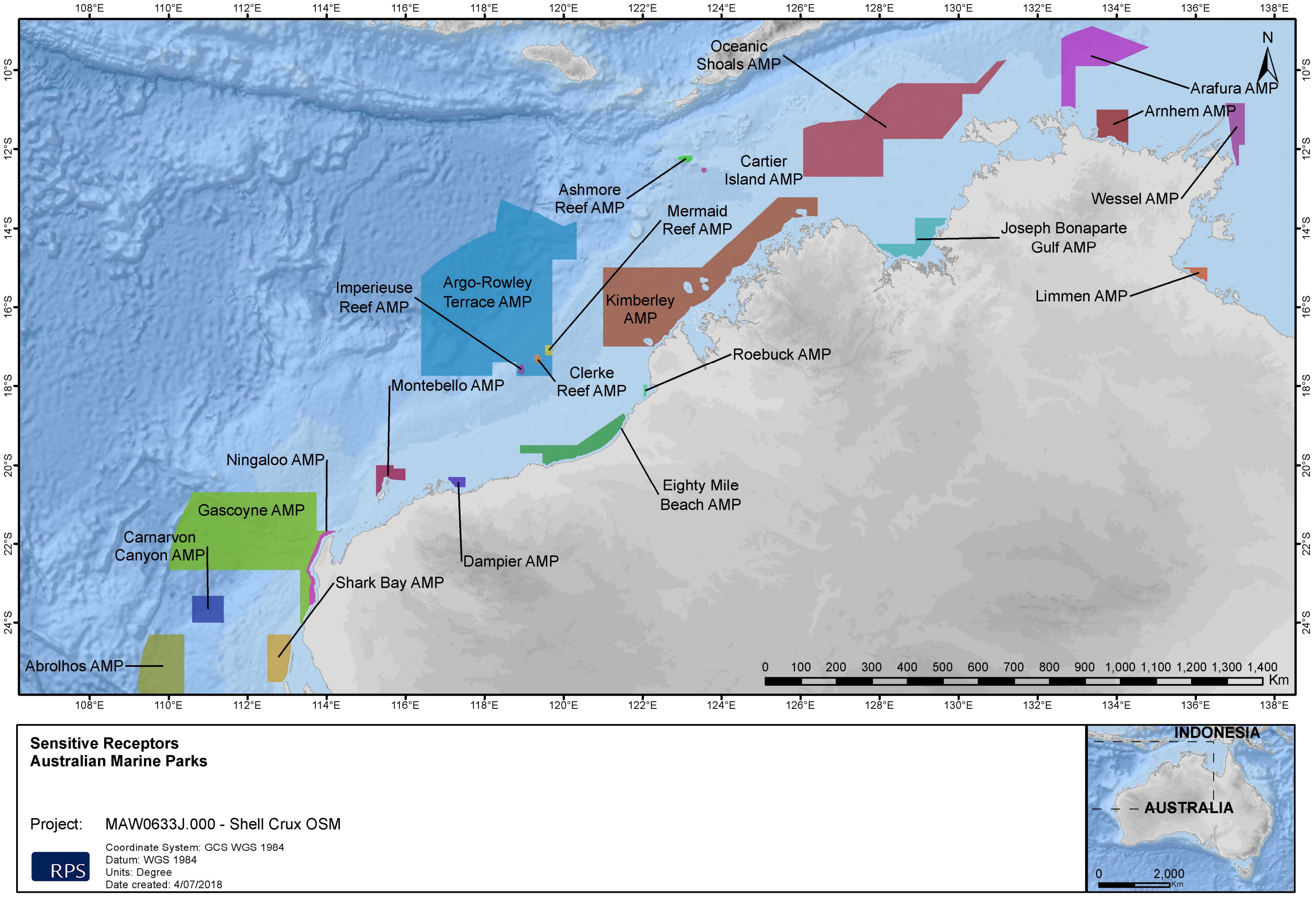

Figure 2.19 Locations of Australian Marine Parks (AMPs) in the study region.

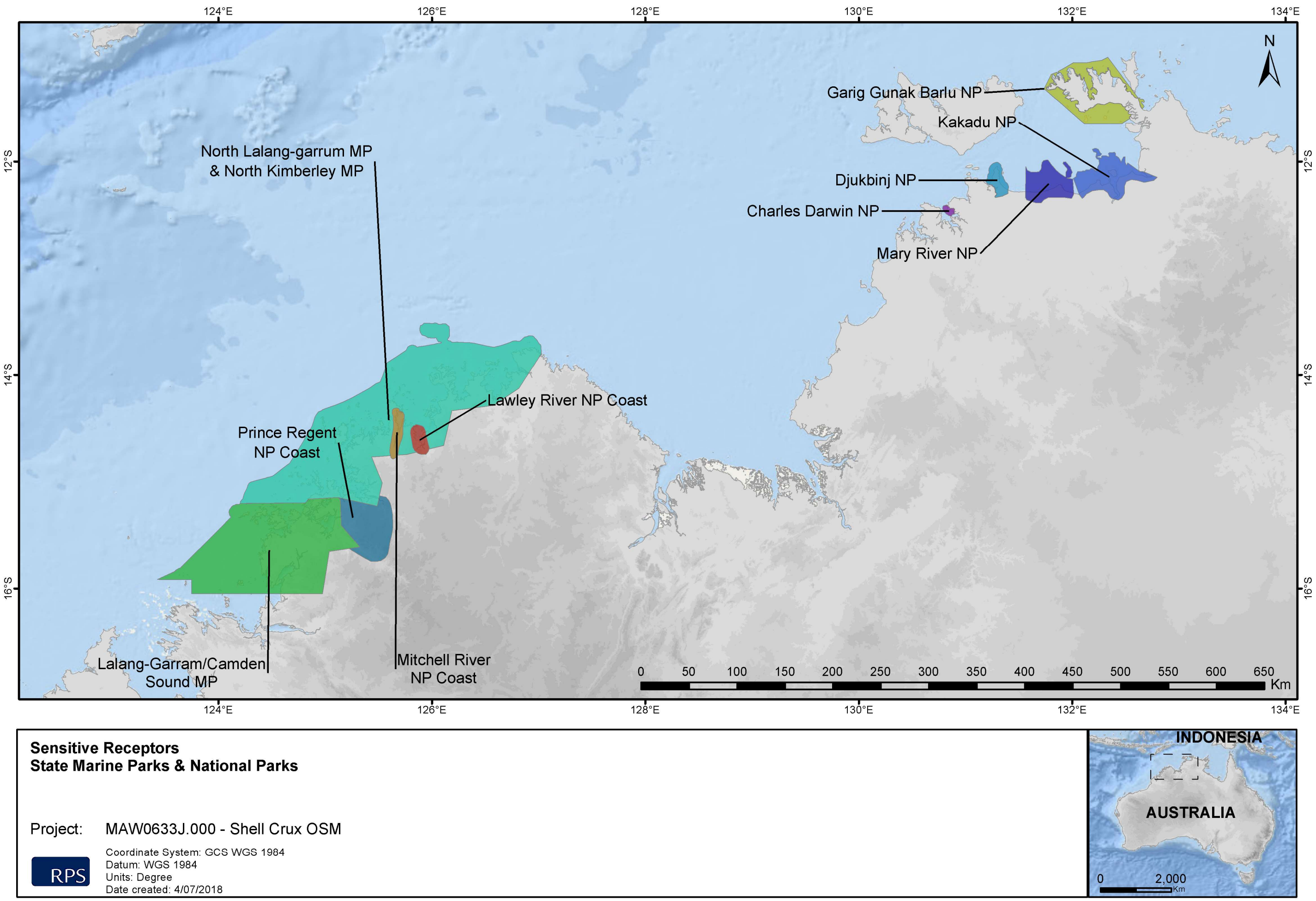

Figure 2.20 Locations of State Marine Parks (MPs) and National Parks (NPs) in the study region.

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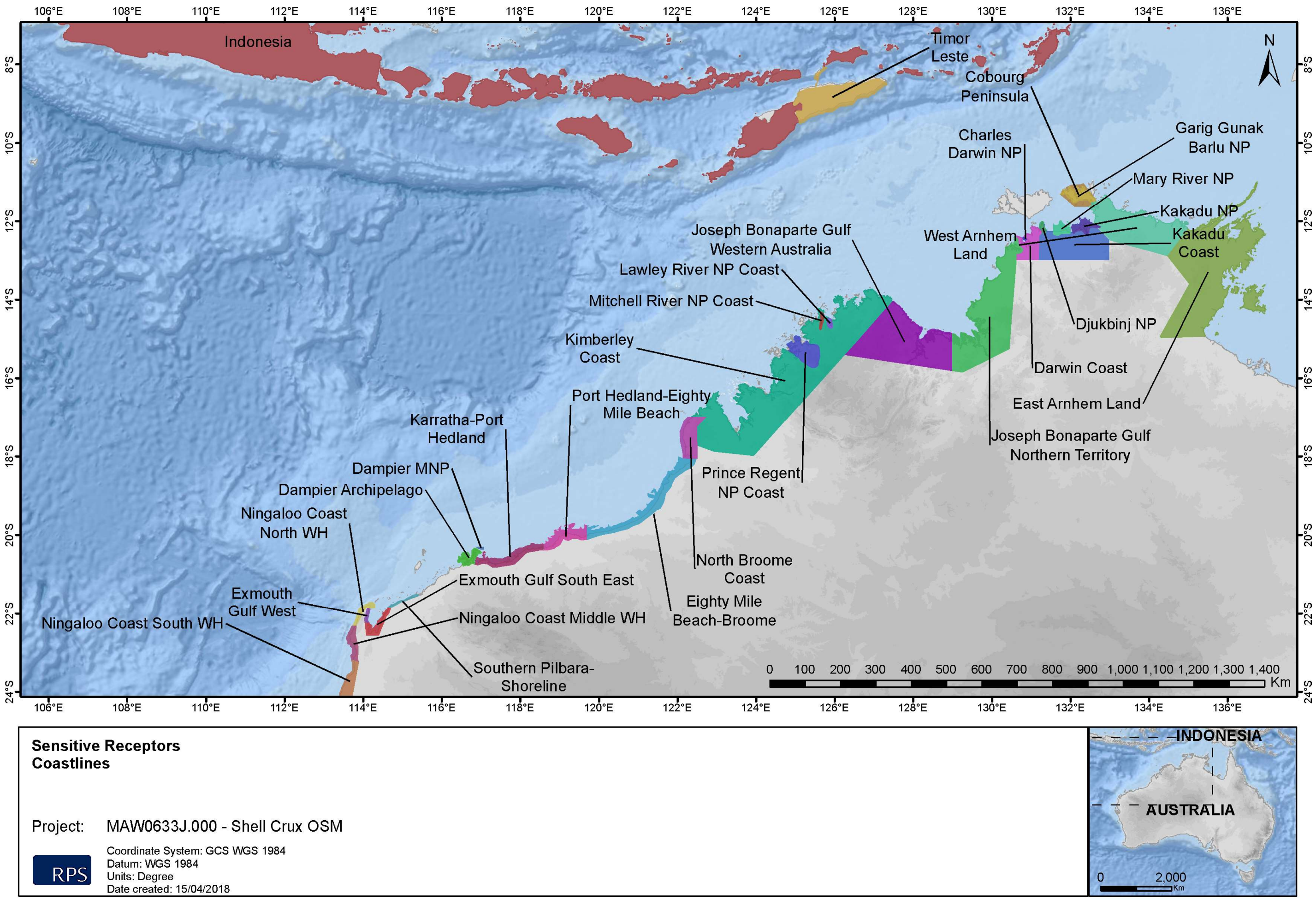

Figure 2.21 Locations of mainland coastlines (emergent receptors) in the study region.

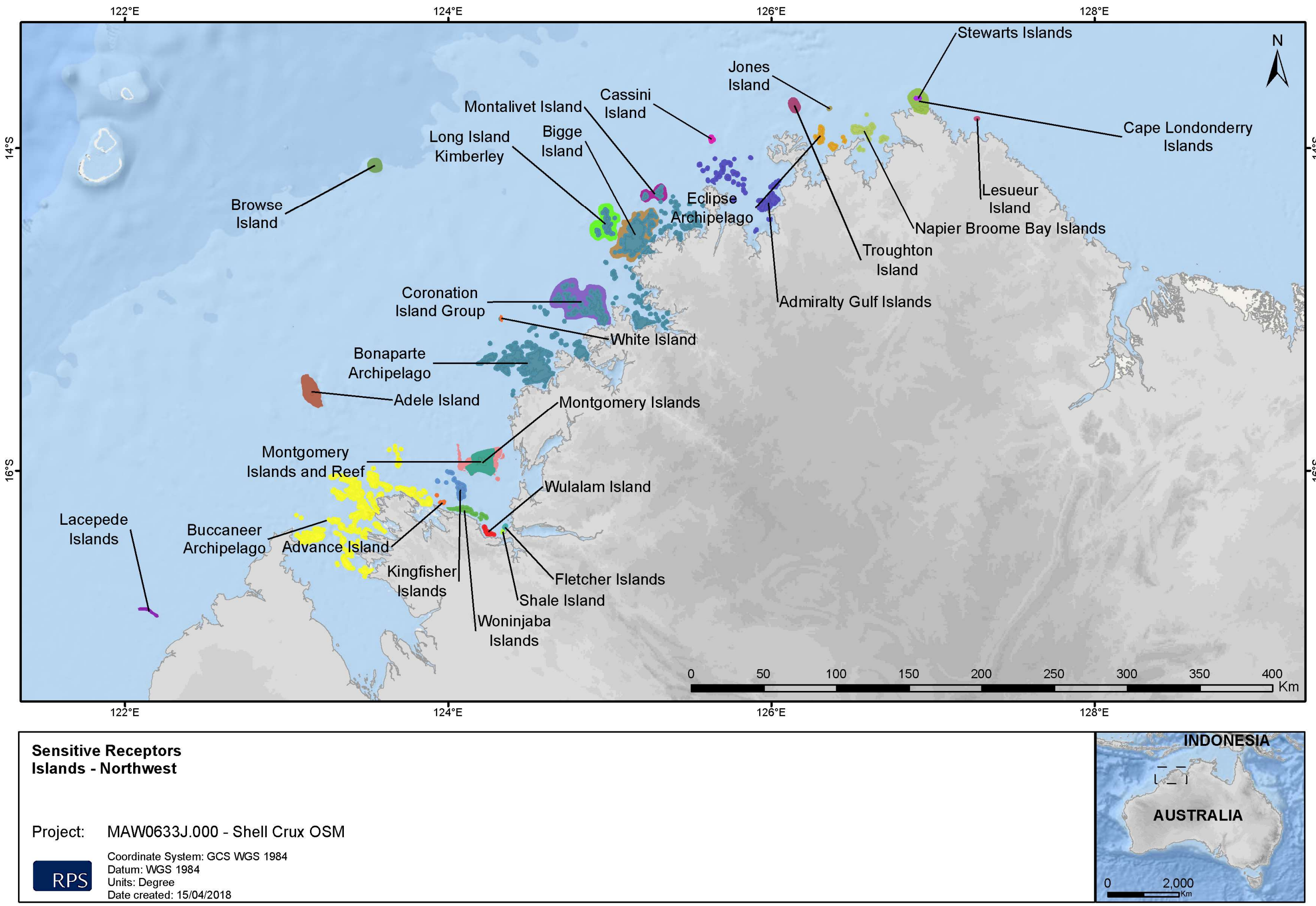

Figure 2.22 Locations of north-western island coastlines (emergent receptors) in the study region.

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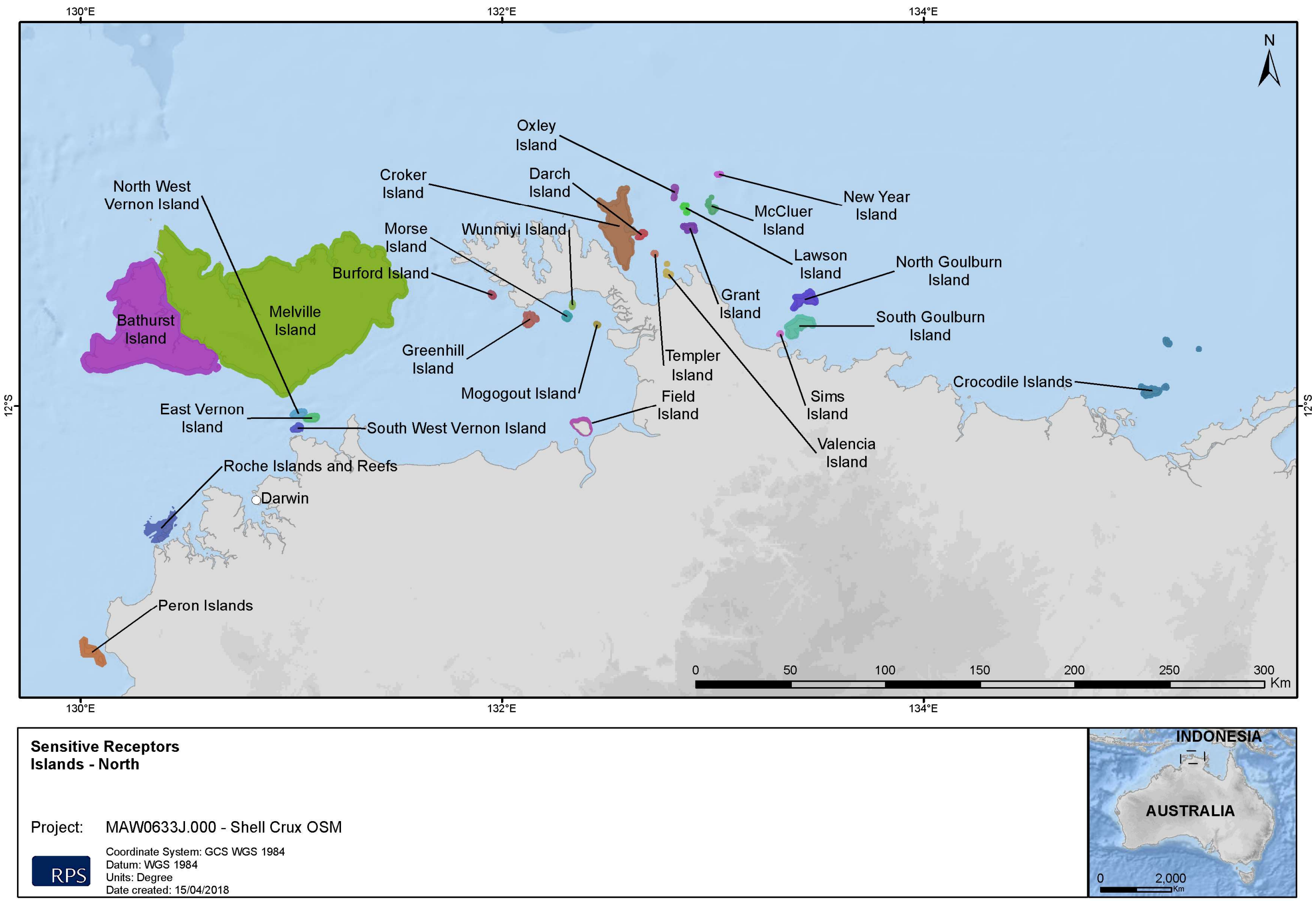

Figure 2.23 Locations of northern island coastlines (emergent receptors) in the study region.

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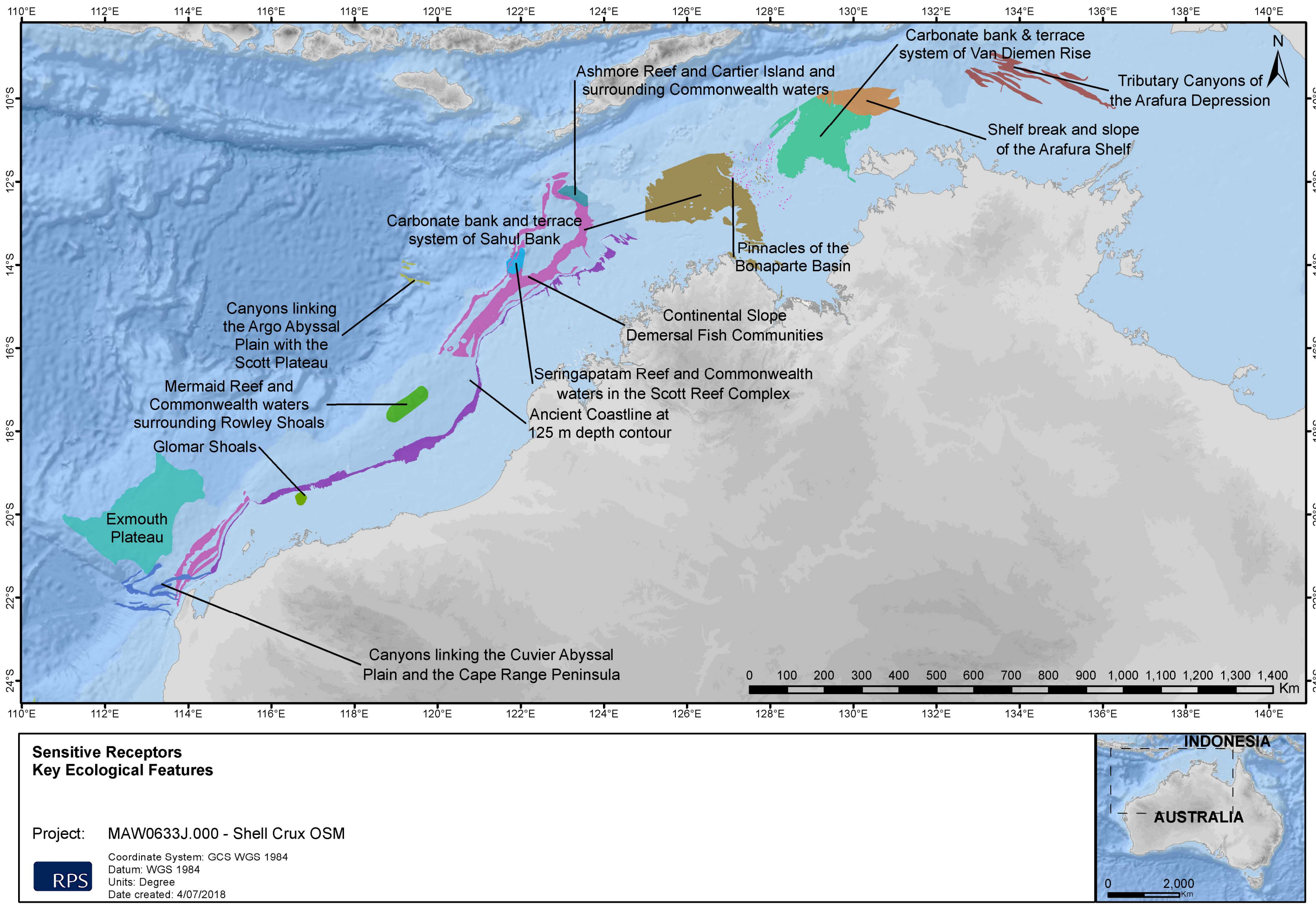

Figure 2.24 Locations of Key Ecological Features (KEFs) in the study region.

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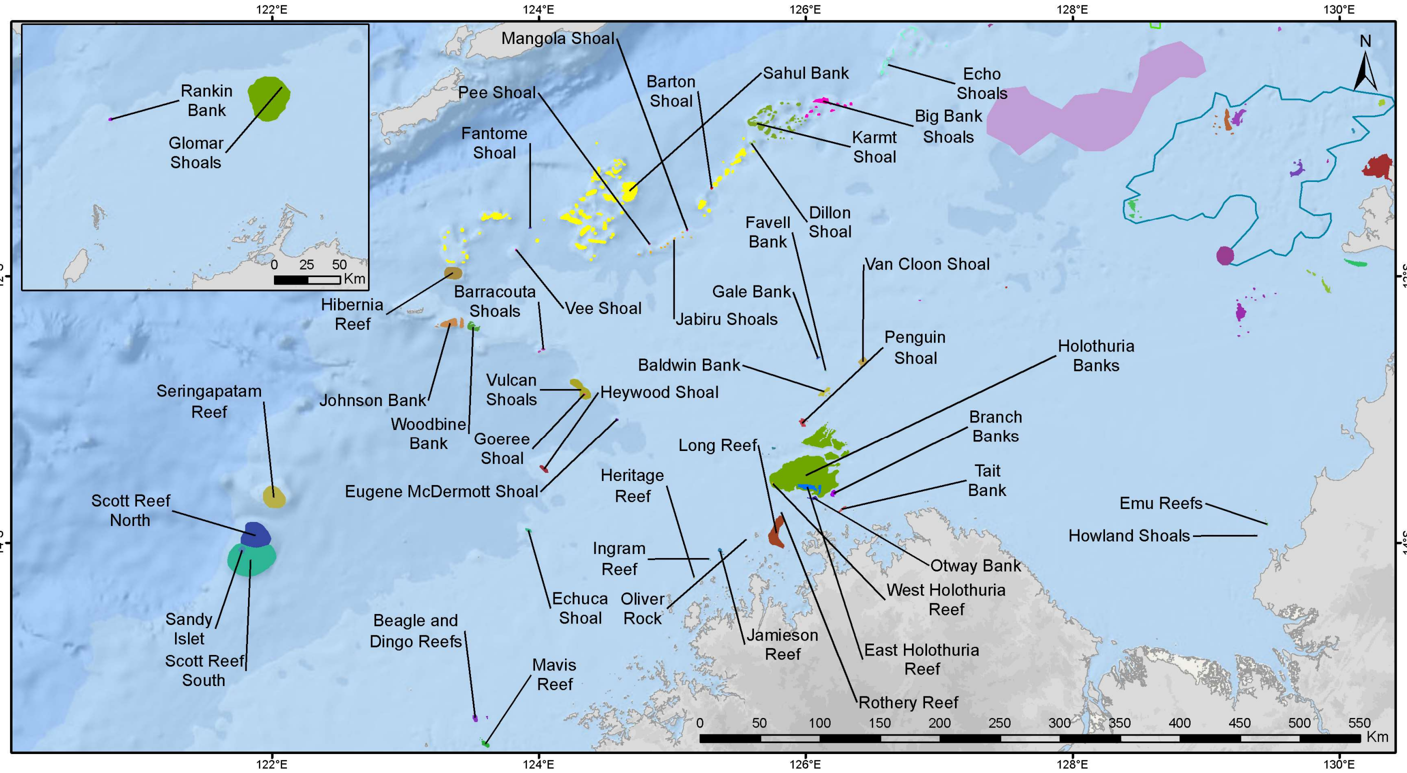

Sensitive Receptors
Reefs, Shoals and Banks - Northwest

Project: MAW0633J.000 - Shell Crux OSM

Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree
Date created: 15/04/2018

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Figure 2.25 Locations of north-western reefs, shoals and banks (submerged receptors) in the study region.

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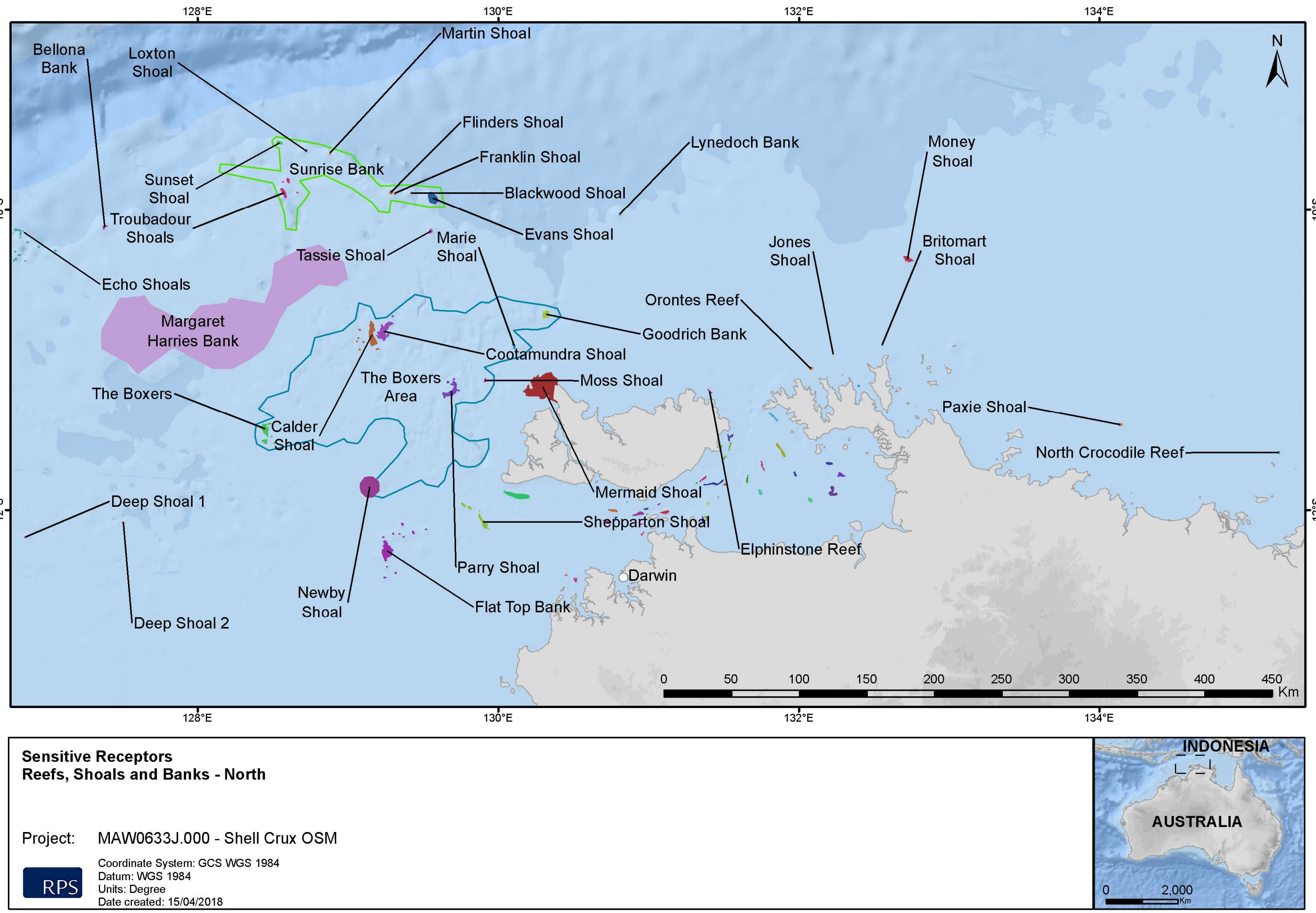

Figure 2.26 Locations of northern reefs, shoals and banks (submerged receptors) in the study region.

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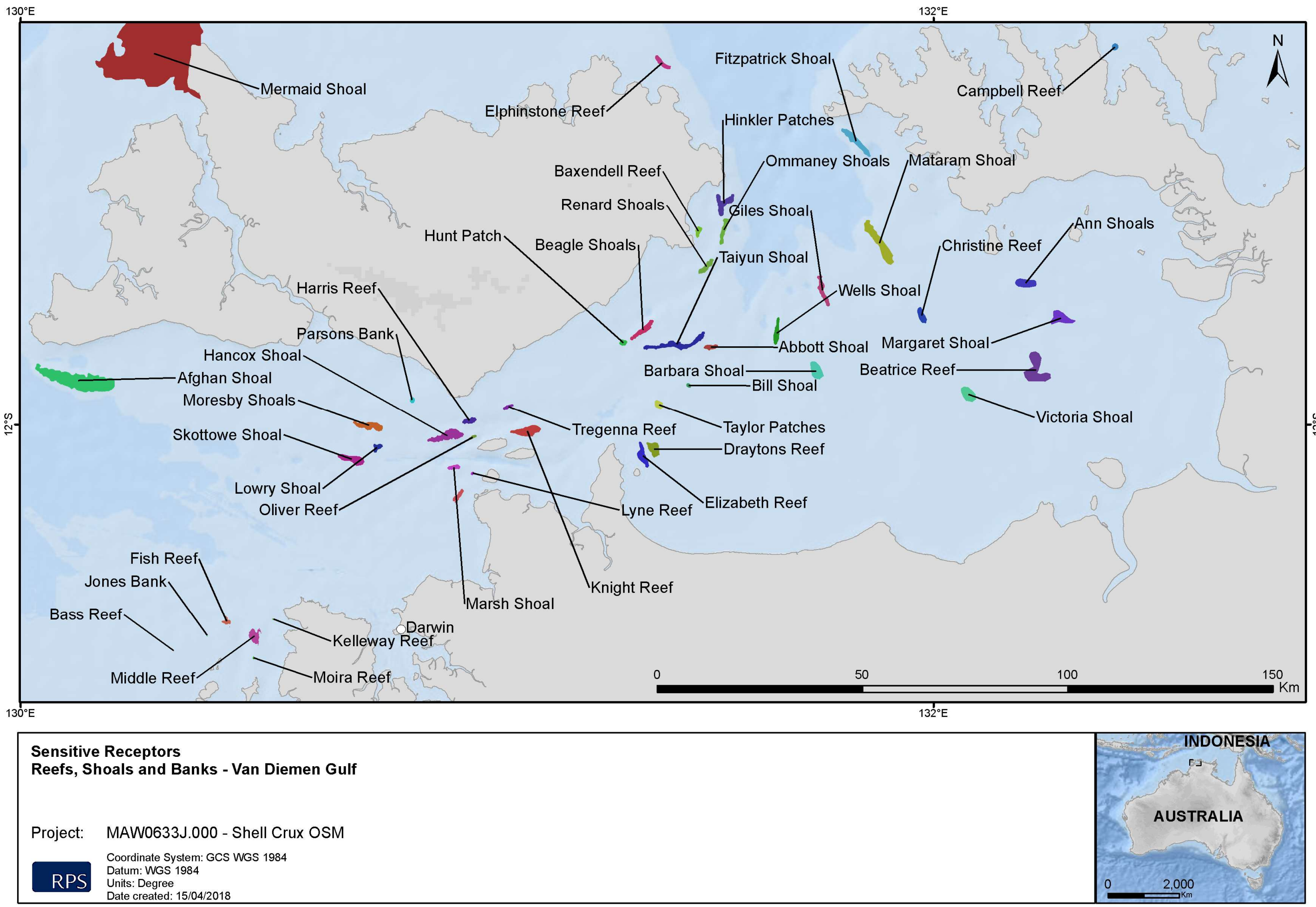

Figure 2.27 Locations of reefs, shoals and banks (submerged receptors) in the Van Diemen Gulf.

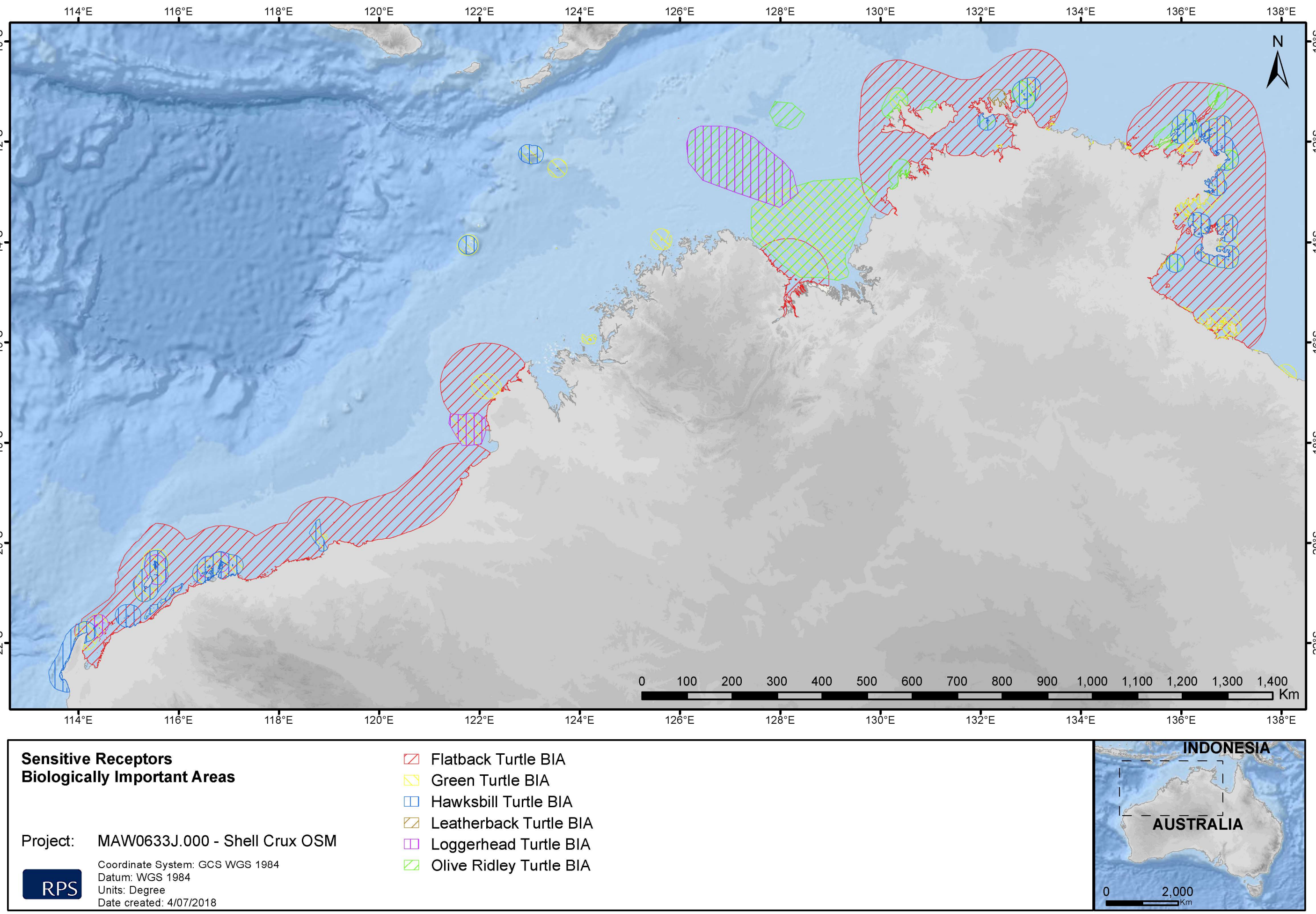

Figure 2.28 Locations of BIAs for turtles in the study region.

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3 Modelling Results

3.1 Overview

If readers are not fully familiar with how to interpret stochastic modelling outputs, please refer to the following NOPSEMA factsheet before reading this report section:

https://www.nopsema.gov.au/assets/Publications/A626200.pdf

Predictions for the probability of contact and time to contact by hydrocarbon concentrations equalling or exceeding defined thresholds for floating and shoreline hydrocarbons, entrained hydrocarbons 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 (≥1 g/m^2, ≥10 g/m^2 and ≥25 g/m^2 for floating hydrocarbons; ≥10 g/m^2, ≥100 g/m^2 and ≥1,000 g/m^2 for shoreline hydrocarbons, ≥10 ppb, ≥100 ppb and ≥500 ppb for entrained hydrocarbons, and ≥6 ppb, ≥50 ppb and ≥400 ppb for dissolved aromatic hydrocarbons) for at least one time step (1 hour). These contours summarise the outcomes for **all replicate simulations** commencing across each seasonal period – 100 replicate simulations for each season giving a **total of 300 replicate simulations for each scenario**.

Readers should note that the contour maps presented in this report (in Appendices) do not represent the predicted coverage of any one hydrocarbon spill or a depiction of a film or plume at any particular instant in time. Rather, the contours are a composite of a large number of theoretical paths, integrated over the full duration of the simulations relevant to each scenario. The 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 predicted to be 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 a hypothetical spill scenario were to occur. 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, probabilities of nil are not attributed to areas beyond the lowest probability contour but are referred to as <0.3%. While noting this, the results are considered to provide an appropriate representation of the potential probability for locations to be contacted given the large number of replicate simulations run (300 per scenario).

Tables are presented to summarise estimates of contact risk for key sensitive receptors (Section 2.11).

The probability estimates for contact by floating hydrocarbons that are presented in the tables summarise the probability that hydrocarbons will arrive at shorelines as floating films at the specified threshold concentration or greater for at least one hour. The tables show the seasonal probabilities determined from the results for each season.

The minimum time estimates shown in the tables present the shortest time for any hydrocarbons to drift from the release location to any part of the sensitive receptor, relative to the commencement of the spill. These times then indicate the minimum weathering time for hydrocarbons that might make contact with the receptor.

The mean and maximum shoreline concentrations indicate the concentrations forecast to potentially accumulate over time on any discrete part of a shoreline (calculated for individual portions of approximately 1 km length). Accumulated concentrations are calculated by summing the mass of hydrocarbons that arrives at any concentration (including < threshold) over time at a model cell and subtracting any mass lost through evaporation and washing off, where relevant.

The maximum local accumulated concentration in the worst replicate spill is the greatest accumulation predicted for any point on the shoreline during any replicate simulation, and thus represents an overly conservative estimate of the potential impact to a shoreline. The maximum local accumulated concentration averaged over all replicate spills is the greatest concentration calculated for any point on the shoreline after averaging over all replicate simulations, and is more appropriate for assessing the potential impact to shorelines.

Note that it is possible that hydrocarbons arriving at concentrations that are less than the threshold may accumulate over the course of a spill event to result in concentrations that may exceed the threshold. Hence, the mean expected, and maximum concentrations of accumulated hydrocarbons can exceed the threshold applied to the probability calculations for the arrival of floating hydrocarbons even where no instantaneous exceedances above threshold are predicted. While noting this, the results are considered to provide an appropriate representation of the potential accumulation of hydrocarbons on shorelines given the large number of replicate simulations run (300 per scenario). 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.

For the entrained and dissolved components, the tabulated results summarise interrogations of cells representing the water surrounding the sensitive receptor shorelines (or submerged features), with individual buffer zones as illustrated in Figure 2.19 to Figure 2.28. Buffer zones were defined with consideration of the bathymetry bordering each receptor, natural boundaries, or sensible legislative boundaries.

The modelling for each scenario assumed no spill response efforts are undertaken to collect or otherwise affect the natural transport and weathering of the hydrocarbons.

The predicted outcomes based on the modelling results are discussed in the following sections in terms of floating and shoreline, entrained and dissolved aromatic hydrocarbons. The discussion is also predominantly focused on the outcomes of stochastic risk contours.

Plots of the annualised Zones of Potential Exposure (ZoPEs) are presented for each scenario.

From the stochastic set of replicate simulations, three replicate simulations were identified as yielding the worst-case or best oil spill response planning outcomes for Scenarios 1, 2, 3 and 4. This section summarises the risk of contact estimates calculated for the replicate simulations selected according to the following criteria:

- Maximum oil volume accumulated across all shoreline receptors;
- Minimum time to commencement of oil accumulation at any shoreline receptor (at a threshold of 10 g/m^2);
- Maximum length of oiled shoreline (at a threshold of 10 g/m^2).

The worst-case replicates identified for each scenario are summarised in Table 3.1 to Table 3.3.

A time series compilation of figures from the replicate deterministic simulation (i.e. a single spill event) yielding the maximum oil volume accumulated across all shoreline receptors for each scenario is presented in Appendix E. Each of the time series figure compilations presented in Appendix E includes areal exposure at discrete time intervals during each deterministic scenario, along with snapshots of the vertical distribution of dissolved aromatic hydrocarbons in the water column at the corresponding time intervals. Where a vertical distribution

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figure is not presented, this means that no plume of hydrocarbons intersected the defined transect line at that particular time interval.

Table 3.1 Identified replicate simulations meeting the maximum accumulated shoreline oil volume criterion.

Scenario	Maximum Volume Ashore Criterion		
	Worst-Affected Receptor	**Volume (m^3)**	**Season**
1	Djukbinj NP	9.3	Summer
2	Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF	2.0	Winter
3	Hawksbill Turtle BIA Green Turtle BIA Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF	116.0	Transitional
4	Bonaparte Archipelago (Bigge Island)	624.3	Summer

Table 3.2 Identified replicate simulations meeting the minimum time to shoreline accumulation criterion.

Scenario	Minimum Time to Shoreline Contact Criterion		
	Worst-Affected Receptor	**Time (d)**	**Season**
1	Hawksbill Turtle BIA Green Turtle BIA Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF	10.3	Winter
2	Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF	11.9	Winter
3	Hawksbill Turtle BIA Green Turtle BIA Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF	6.0	Transitional
4	Hawksbill Turtle BIA Green Turtle BIA Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF	5.1	Winter

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Table 3.3 Identified replicate simulations meeting the maximum length of oiled shoreline criterion.

Scenario	Maximum Length of Shoreline Contact Criterion		
	Worst-Affected Receptor	**Length (km)**	**Season**
1	Darwin Coast	11.0	Transitional
2	Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF	2.0	Winter
3	Green Turtle BIA Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF	10.0	Transitional
4	North Lalang-garram MP & North Kimberley MP	117.0	Transitional

3.2 Scenario 1 – 80-Day Subsurface Blowout of Crux Condensate at a Development Well

3.2.1 Discussion of Results

3.2.1.1 Overview

This scenario investigated the probability of exposure to key sensitive receptors by hydrocarbons resulting from an 80-day uncontrolled subsurface blowout, discharging 206,225 m^3 (2,578 m^3/day) of Crux condensate from a development well at any time of year, with no spill response mitigation measures applied.

Considering the discharge characteristics, the properties of the hydrocarbon and its expected weathering behaviour, the bulk of the condensate, which is predicted to form relatively small oil droplets due to the large gas/oil ratio, will remain entrained in the water column, with a relatively small proportion (the largest oil droplets, i.e. >80 µm) rising to the surface to form floating films under typical to calm wind conditions. Once at the surface given the low viscosity of the condensate, re-entrainment into the water column is highly likely to occur under all but relatively calm wind conditions. On reaching the surface, it is likely that the majority of the hydrocarbon mass will be found in the surface mixed layer (3-10 m deep, depending on the conditions), with a small proportion on the water surface. Evaporation rates will be high, given the large proportion of volatile (55%) and semi-volatile (23%) compounds within the condensate, with the residual fraction (8%) persisting in the environment until degradation processes occur (over periods of weeks to months). Considering the spill volume and the relatively high likelihood of entrainment occurring, there is a high potential for dissolution of soluble aromatic compounds.

Figure 3.1 to Figure 3.3 show a summary of the areal extent for all hydrocarbon phases at the low, moderate and high thresholds, respectively.

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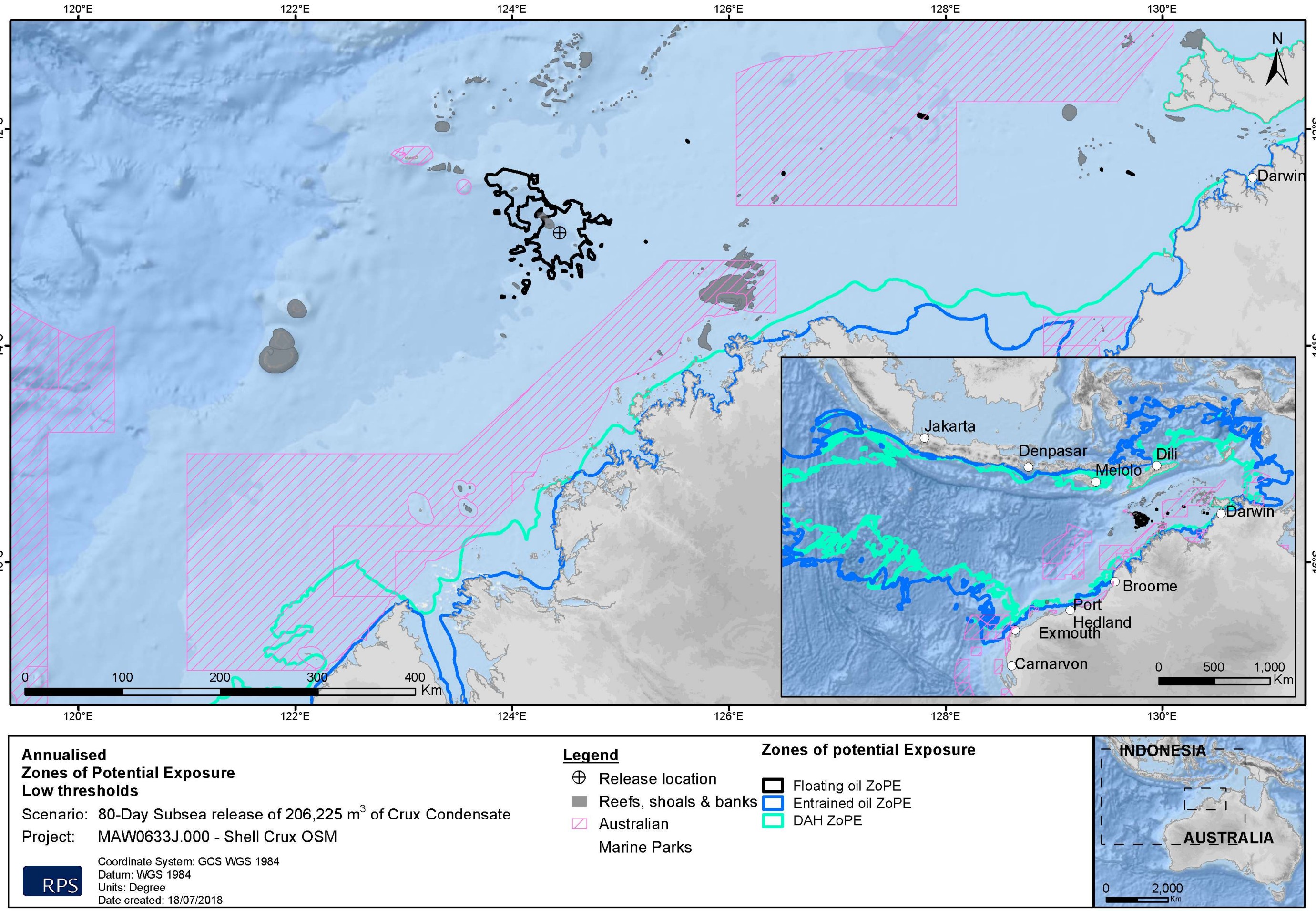

Figure 3.1 Surface and Subsurface Hydrocarbons | Blowout Scenario | Stochastic Outcomes. Areal extent of potential exposure at the low thresholds resulting from an 80-day subsurface release of Crux condensate at a development well.

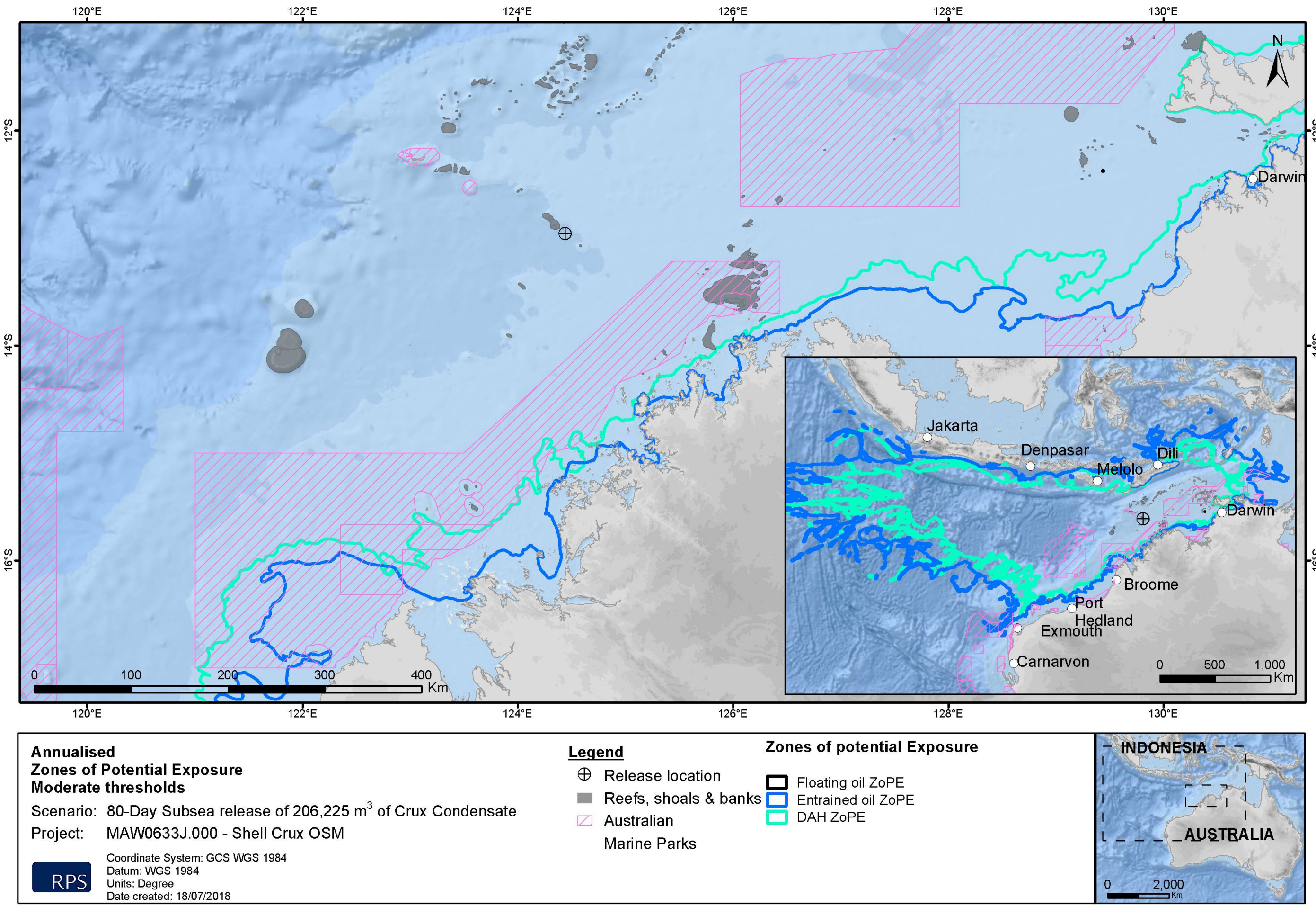

Figure 3.2 Surface and Subsurface Hydrocarbons | Blowout Scenario | Stochastic Outcomes. Areal extent of potential exposure at the moderate thresholds resulting from an 80-day subsurface release of Crux condensate at a development well.

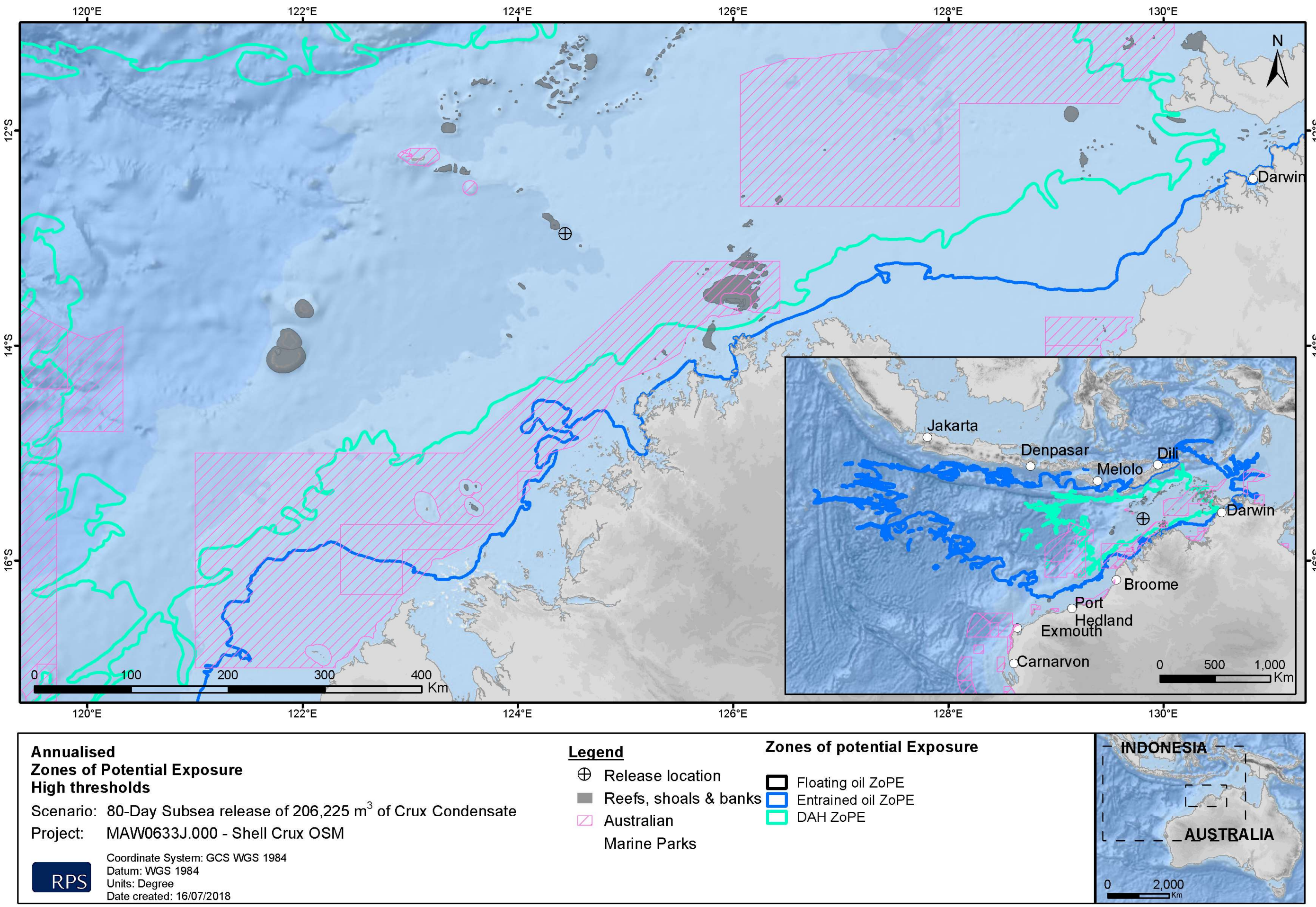

Figure 3.3 Surface and Subsurface Hydrocarbons | Blowout Scenario | Stochastic Outcomes. Areal extent of potential exposure at the high thresholds resulting from an 80-day subsurface release of Crux condensate at a development well.

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3.2.1.2 Floating and Shoreline Hydrocarbons

The annualised probability contour figures (Appendix A) indicate that hydrocarbons on the sea surface at or greater than the threshold concentrations are predicted to remain relatively localised around the release location, with very low probability of contact to the nearest shoreline receptors. The maximum distances to the outer extents of the low and moderate floating oil thresholds (1 g/m^2 and 10 g/m^2, respectively) are predicted to be 577 km and 548 km, respectively (Table 3.4). Floating oil concentrations are not predicted to exceed the high threshold (25 g/m^2).

The Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors have the highest predicted probability of contact at the low threshold being 58% (Table 3.5). Only a small number of Fisheries receptors are predicted to receive floating oil at moderate threshold concentrations with probabilities of approximately 0.6%.

The minimum time to contact with any receptor by floating oil at the low threshold is forecast at approximately 2-3 hours over all seasons at the Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors. The minimum time to contact with these receptors at the moderate threshold is forecast at approximately 103 days.

Potential for accumulation of hydrocarbons on shorelines is predicted to be low (<1% probability at the moderate threshold of 100 g/m^2), with a maximum accumulated volume forecast at Melville Island (9 m^3), Darwin Coast (6 m^3), Kakadu Coast (10 m^3), and Djukbinj NP (NT) (10 m^3), and maximum local accumulated concentration on shorelines of 473 g/m^2 forecast at Melville Island (Table 3.5).

Table 3.4 Maximum distances from the release location to zones of floating oil exposure for Scenario 1 (206,225 m^3 Crux condensate).

	Floating Oil Exposure Threshold		
	Low (1-10 g/m^2)	Moderate (10-25 g/m^2)	High (>25 g/m^2)
Maximum distance travelled (km) by a spill trajectory	577	548	-

3.2.1.3 Subsurface – Entrained Hydrocarbons

The annualised probability contour figures (Figure 3.7 and Appendix A) indicate that entrained oil concentrations at or greater than the threshold concentrations travel up to 3,292 km (10 ppb) from the release location. The maximum extents are forecast to be slightly reduced for the moderate (100 ppb; 3,279 km) and high (500 ppb; 3,239 km) thresholds.

Stochastic modelling shows that the entrained hydrocarbon concentrations greater that the conservative thresholds can potentially occur at most of the environmental sensitivities. Southern Bluefin Tuna Fishery, Western Skipjack Fishery, Western Tuna and Billfish Fishery, North-West Slope Trawl Fishery, Eugene McDermott Shoal, Vulcan Shoals and Goeree Shoal receptors are predicted to be contacted at the high threshold with probabilities >90% (Table 3.6).

Receptors with the highest probability of receiving entrained oil at low threshold concentrations are waters above Key Ecological Features including Ancient Coastline at 125 m Depth Contour (96%), Continental Slope Demersal Fish Communities (95%), and Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF (91%). Biologically Important Areas for Green Turtle and Hawksbill Turtle are forecast to receive entrained oil at the low threshold with probabilities of 95% and 84%, respectively. High probabilities of contact at this threshold are also forecast at the closest AMPs (Cartier Island AMP, 91%; Ashmore Reef AMP, 82%) and at the waters above the nearest shoals and banks (Barracouta Shoals, 89%; Heywood Shoal, 89%; Johnson Bank, 84%; Woodbine Bank, 80%). These sensitive receptors are also contacted at the moderate threshold with lower probabilities.

The minimum time to contact with any receptor by entrained oil at the low, moderate and high thresholds is forecast at Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery, at approximately 1 hour.

3.2.1.4 Subsurface – Dissolved Aromatic Hydrocarbons

The annualised probability contour figures (Figure 3.9 to Figure 3.11) indicate that dissolved aromatic hydrocarbons at or greater than the threshold concentrations travel up to 3,280 km (6 ppb) from the release location. The maximum extents are forecast to be slightly reduced for the moderate (50 ppb; 3,181 km) and high (400 ppb; 2,946 km) thresholds.

A number of receptors are predicted to receive dissolved aromatic hydrocarbons at high threshold concentrations. Southern Bluefin Tuna Fishery, Western Skipjack Fishery, Western Tuna and Billfish Fishery and Vulcan Shoals receptors are predicted to be contacted at the high threshold with probabilities >90% (Table 3.7).

Receptors with the highest probability of receiving dissolved aromatic hydrocarbons at low threshold concentrations include Goeree Shoal (98%), Eugene McDermott Shoal (98%) and Heywood Shoal (85%). Key Ecological Features are forecast to receive dissolved aromatic hydrocarbons at the low threshold with highest probabilities forecast at Ancient Coastline at 125 m Depth Contour (95%), Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex KEF (91%), Continental Slope Demersal Fish Communities (89%), and Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters (82%). High annualised probabilities of contact at the low threshold are also forecast at North-West Slope Trawl Fishery (98%) and Green Turtle BIAs (86%). These sensitive receptors are also contacted at the moderate threshold with lower probabilities.

3.2.1.5 Deterministic Cases

A replicate simulation during the summer season (spill starting at 10:00 18th December 2013) has been identified as the worst-case replicate according to the maximum oil volume accumulated across all shoreline receptors criteria for Scenario 1 (9.3 m^3 at Djukbinj NP). Figures showing the evolution of this spill simulation are contained in Appendix E. Hydrocarbons on the sea surface mainly drifted southwest of the release location. The potential floating oil exposure zones (low threshold) was limited to within 15 km of the release location, with the moderate and high thresholds not exceeded. The entrained oil and dissolved aromatic hydrocarbons were shown to move east and northeast of the release location. Low, moderate and high entrained hydrocarbons were observed up to 1,155 km, 1,048 km and 890 km, respectively, from the release location. Low, moderate and high dissolved aromatic hydrocarbons were observed up to 1,071 km, 597 km and 364 km, respectively, from the release location.

A replicate simulation during the winter season (spill starting at 09:00 21st July 2016) has been identified as the worst-case replicate according to the minimum time to commencement of oil accumulation at any shoreline receptor criteria for Scenario 1 (10.3 days at Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF). Hydrocarbons on the sea surface mainly drifted northwest of the release location. The potential floating oil exposure zones (low threshold) was limited to within 30 km of the release location, with the moderate and high thresholds not exceeded. The entrained oil and dissolved aromatic hydrocarbons were shown to move west of the release location. Low, moderate and high entrained hydrocarbons were recorded up to 3,211 km, 3,211 km and 3,207 km, respectively, from the release location.

Low, moderate and high dissolved aromatic hydrocarbons were observed up to 3,209 km, 3,190 km and 2,946 km, respectively, from the release location.

A replicate simulation during the transitional season (spill starting at 19:00 30th November 2010) has been identified as the worst-case replicate according to the maximum length of oiled shoreline criteria for Scenario 1 (11 km at Darwin Coast). Hydrocarbons on the sea surface mainly drifted northeast of the release location. The potential floating oil exposure zones (low threshold) was limited to within 17 km of the release location, with the moderate and high thresholds not exceeded. The entrained oil and dissolved aromatic hydrocarbons were shown to move east and northeast of the release location. Low, moderate and high entrained hydrocarbons were recorded up to 1,206 km, 1,199 km and 972 km, respectively, from the release location. Low, moderate and high dissolved aromatic hydrocarbons were observed up to 960 km, 917 km and 700 km, respectively, from the release location.

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3.2.2 Floating and Shoreline Hydrocarbons

Table 3.5 Expected annualised floating and shoreline oil outcomes at sensitive receptors resulting from an 80-day subsurface release of Crux condensate at a development well.

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
Coastlines	Cobourg Peninsula	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.4	<1	<1	NC	NC
	Darwin Coast	<0.3	<0.3	<0.3	NC	NC	NC	0.6	<0.3	<0.3	2,251	NC	NC	0.3	93	<1	6	<1	11
	Indonesia	<0.3	<0.3	<0.3	NC	NC	NC	1.2	0.6	<0.3	945	1,022	NC	1.3	357	<1	3	<1	3
	Joseph Bonaparte Gulf Northern Territory	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	3.4	<1	<1	NC	NC
	Kakadu Coast	<0.3	<0.3	<0.3	NC	NC	NC	0.9	0.6	<0.3	2,222	2,356	NC	1.1	243	<1	10	<1	4
	Kakadu National Park	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Kimberley Coast	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	2.1	<1	<1	NC	NC
	North Broome Coast	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Port Hedland-Eighty Mile Beach	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Timor Leste	<0.3	<0.3	<0.3	NC	NC	NC	0.6	<0.3	<0.3	953	NC	NC	0.1	31	<1	<1	<1	1
	West Arnhem Land	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
Islands	Adele Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Admiralty Gulf Islands	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	1.3	<1	<1	NC	NC
	Advance Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Bathurst Island	<0.3	<0.3	<0.3	NC	NC	NC	0.6	0.6	<0.3	1,719	2,373	NC	0.6	190	<1	3	<1	1
	Bigge Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.4	<1	<1	NC	NC
	Bonaparte Archipelago	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.6	<1	<1	NC	NC
	Browse Island	<0.3	<0.3	<0.3	NC	NC	NC	6.6	0.9	<0.3	337	1,677	NC	3.7	167	<1	3	<1	1
	Buccaneer Archipelago	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Burford Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Cape Londonderry Islands	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Cassini Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.8	<1	<1	NC	NC
	Coronation Island Group	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Crocodile Islands	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Croker Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC
	Darch Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	East Vernon Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.1	<1	<1	NC	NC
	Eclipse Archipelago	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Field Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Grant Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Greenhill Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.1	<1	<1	NC	NC
	Jones Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	2.5	<1	<1	NC	NC
	Kingfisher Islands	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Lacepede Islands	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Lawson Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Lesueur Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Long Island Kimberley	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.6	<1	<1	NC	NC
	McCluer Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Melville Island	<0.3	<0.3	<0.3	NC	NC	NC	0.6	0.6	<0.3	2,096	2,109	NC	1.6	473	<1	9	<1	5
	Montalivet Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Montgomery Islands	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Montgomery Islands and Reef	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Napier Broome Bay Islands	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	New Year Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	North Goulburn Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	North West Vernon Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	1.5	<1	<1	NC	NC
	Oxley Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC
	Peron Islands	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.1	<1	<1	NC	NC
	Roche Islands and Reefs	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC
	South West Vernon Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Stewarts Islands	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Templer Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Troughton Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	2.5	<1	<1	NC	NC
	Valencia Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	White Island*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Reefs	Baxendell Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Beagle and Dingo Reefs*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Beatrice Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Campbell Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

RPS

Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
Christine Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Draytons Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
East Holothuria Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Elizabeth Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Elphinstone Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Emu Reefs*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fish Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Harris Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heritage Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hibernia Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hinkler Patches*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hunt Patch*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ingram Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Jamieson Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Knight Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Long Reef	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	1.2	<1	<1	NC	NC
Lyne Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mavis Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Middle Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
North Crocodile Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Oliver Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Oliver Rock*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Orontes Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Rothery Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sandy Islet	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	0.2	9.2	<1	<1	NC	NC
Scott Reef North*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scott Reef South	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	0.2	9.2	<1	<1	NC	NC
Seringapatam Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Taylor Patches*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
The Boxers*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
The Boxers Area*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Tregenna Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	West Holothuria Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Abbott Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Afghan Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ann Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Barbara Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Barracouta Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Barton Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Bassett-Smith Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Beagle Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Big Bank Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Bill Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Britomart Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Calder Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Cootamundra Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Deep Shoal 1*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Deep Shoal 2*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dillon Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Echo Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Echuca Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Eugene McDermott Shoal*	0.9	<0.3	<0.3	1,033	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Evans Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fantome Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fitzpatrick Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Flinders Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Franklin Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Giles Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Goeree Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Hancox Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Heywood Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jabiru Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

RPS

Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
Jones Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Karmt Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lowry Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Loxton Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mangola Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Margaret Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Marie Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Marsh Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Martin Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mataram Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mermaid Shoal	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
Money Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Moresby Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Moss Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Newby Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ommaney Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Parry Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Paxie Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pee Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Penguin Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Penguin Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Renard Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shepparton Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Skottowe Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sunset Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Taiyun Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tassie Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Troubadour Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Van Cloon Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vee Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Victoria Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Vulcan Shoals*	1.8	<0.3	<0.3	103	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wells Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Baldwin Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Bellona Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Branch Banks*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Favell Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Flat Top Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Foelsche Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Gale Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Goodrich Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Holothuria Banks*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Johnson Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Lynedoch Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Margaret Harries Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Otway Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Parsons Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Rankin Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sahul Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sunrise Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Tait Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Woodbine Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Marine Parks	Arafura AMP*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Arnhem AMP*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ashmore Reef AMP	<0.3	<0.3	<0.3	NC	NC	NC	3	<0.3	<0.3	246	NC	NC	1.3	38	<1	2	<1	5
	Lalang-garram/Camden Sound MP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Carnarvon Canyon AMP*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Cartier Island AMP	<0.3	<0.3	<0.3	NC	NC	NC	12.3	0.6	<0.3	272	418	NC	5	104	<1	2	<1	3
	Charles Darwin NP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC
	Djukbinj NP	<0.3	<0.3	<0.3	NC	NC	NC	0.9	0.6	<0.3	2,222	2,356	NC	1.1	243	<1	10	<1	4
	Eighty Mile Beach AMP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Garig Gunak Barlu NP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.1	<1	<1	NC	NC

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Gascoyne AMP*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Kakadu NP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Kimberley AMP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	North Lalang-garram MP & North Kimberley MP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	2.5	<1	<1	NC	NC
	Lawley River NP Coast	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Mary River NP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.1	<1	<1	NC	NC
	Mermaid Reef AMP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.1	<1	<1	NC	NC
	Mitchell River NP Coast	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Montebello AMP*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ningaloo AMP*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Oceanic Shoals AMP*	0.6	<0.3	<0.3	991	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Prince Regent NP Coast	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
Key Ecological Features	Ancient Coastline at 125 m depth contour*	0.9	<0.3	<0.3	497	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	<0.3	<0.3	<0.3	NC	NC	NC	12.3	0.6	<0.3	246	418	NC	5	104	<1	3	<1	7
	Canyons linking the Argo Abyssal Plain with the Scott Plateau*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carbonate bank & terrace system of Van Diemen Rise*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carbonate bank and terrace system of Sahul Shelf	0.6	<0.3	<0.3	392	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Continental Slope Demersal Fish Communities*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Exmouth Plateau*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Glomar Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.4	<1	<1	NC	NC
	Pinnacles of the Bonaparte Basin*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	0.2	9.2	<1	<1	NC	NC

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Shelf break and slope of the Arafura Shelf*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Tributary Canyons of the Arafura Depression*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	Northern Prawn Fishery	0.6	0.6	<0.3	1,991	2,474	NC	0.6	0.6	<0.3	1,719	2,109	NC	1.6	473	NC	NC	NC	NC
	North-West Slope Trawl Fishery*	0.9	<0.3	<0.3	237	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Southern Bluefin Tuna Fishery	58.2	0.6	<0.3	2	2,474	NC	12.3	0.6	<0.3	246	418	NC	5	473	NC	NC	NC	NC
	Timor Reef Fishery (NT Managed)*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Skipjack Fishery	58.2	0.6	<0.3	2	2,474	NC	12.3	0.6	<0.3	246	418	NC	5	473	NC	NC	NC	NC
	Western Tuna and Billfish Fishery	58.2	0.6	<0.3	2	2,474	NC	12.3	0.6	<0.3	246	418	NC	5	473	NC	NC	NC	NC
Biologically Important Areas	Flatback Turtle BIA	0.6	<0.3	<0.3	991	NC	NC	0.6	0.6	<0.3	1,719	2,109	NC	1.6	473	<1	9	NC	NC
	Green Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC	12.3	0.6	<0.3	246	418	NC	5	104	<1	3	<1	7
	Hawksbill Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC	3	<0.3	<0.3	246	NC	NC	1.3	38	<1	2	<1	5
	Leatherback Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Loggerhead Turtle BIA	0.6	<0.3	<0.3	991	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Olive Ridley Turtle BIA	0.6	<0.3	<0.3	991	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.7	<1	<1	NC	NC

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.*

RPS

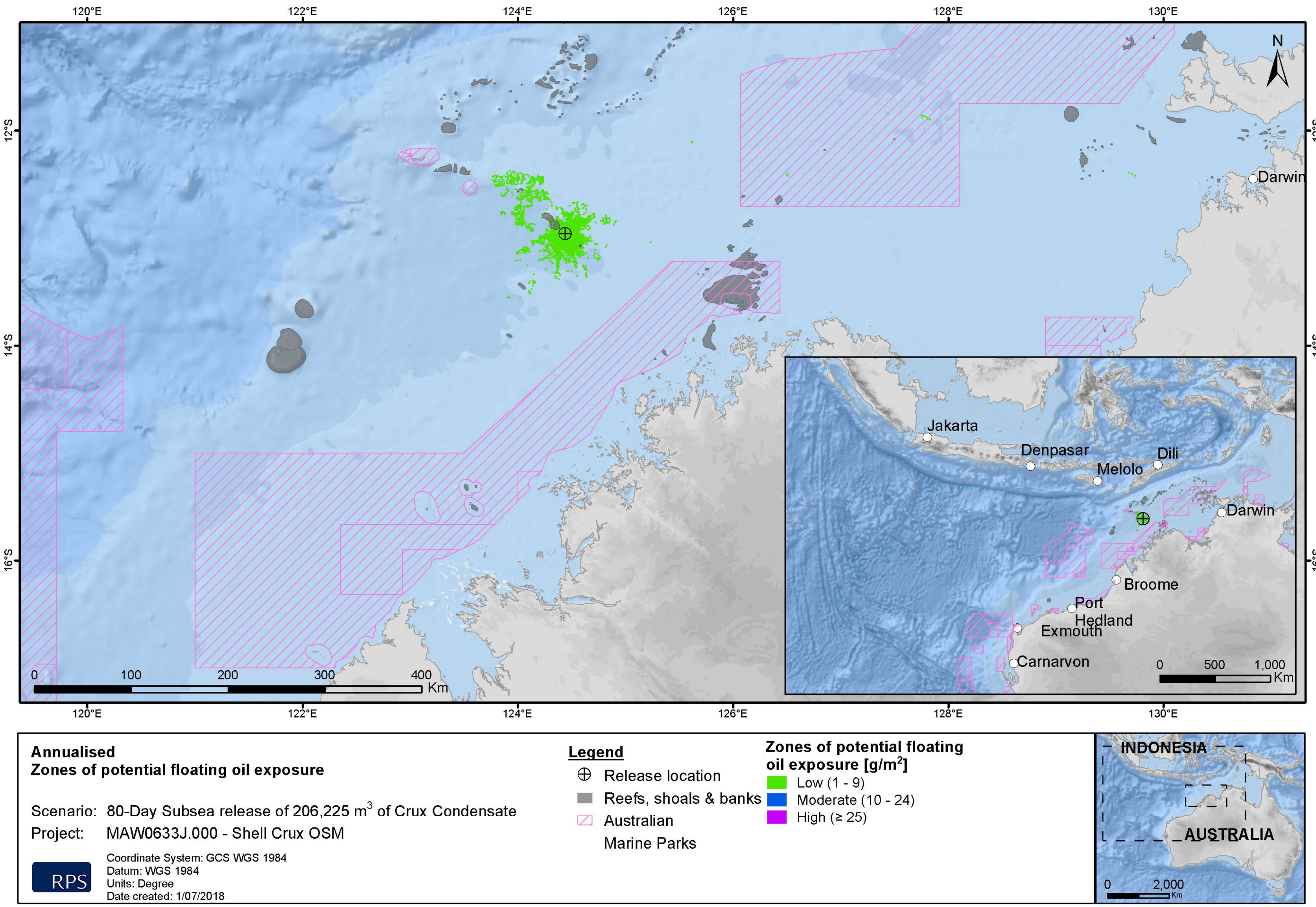


Figure 3.4 Surface Hydrocarbons | Blowout Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined floating oil threshold concentrations resulting from an 80-day subsurface release of Crux condensate at a development well.

RPS

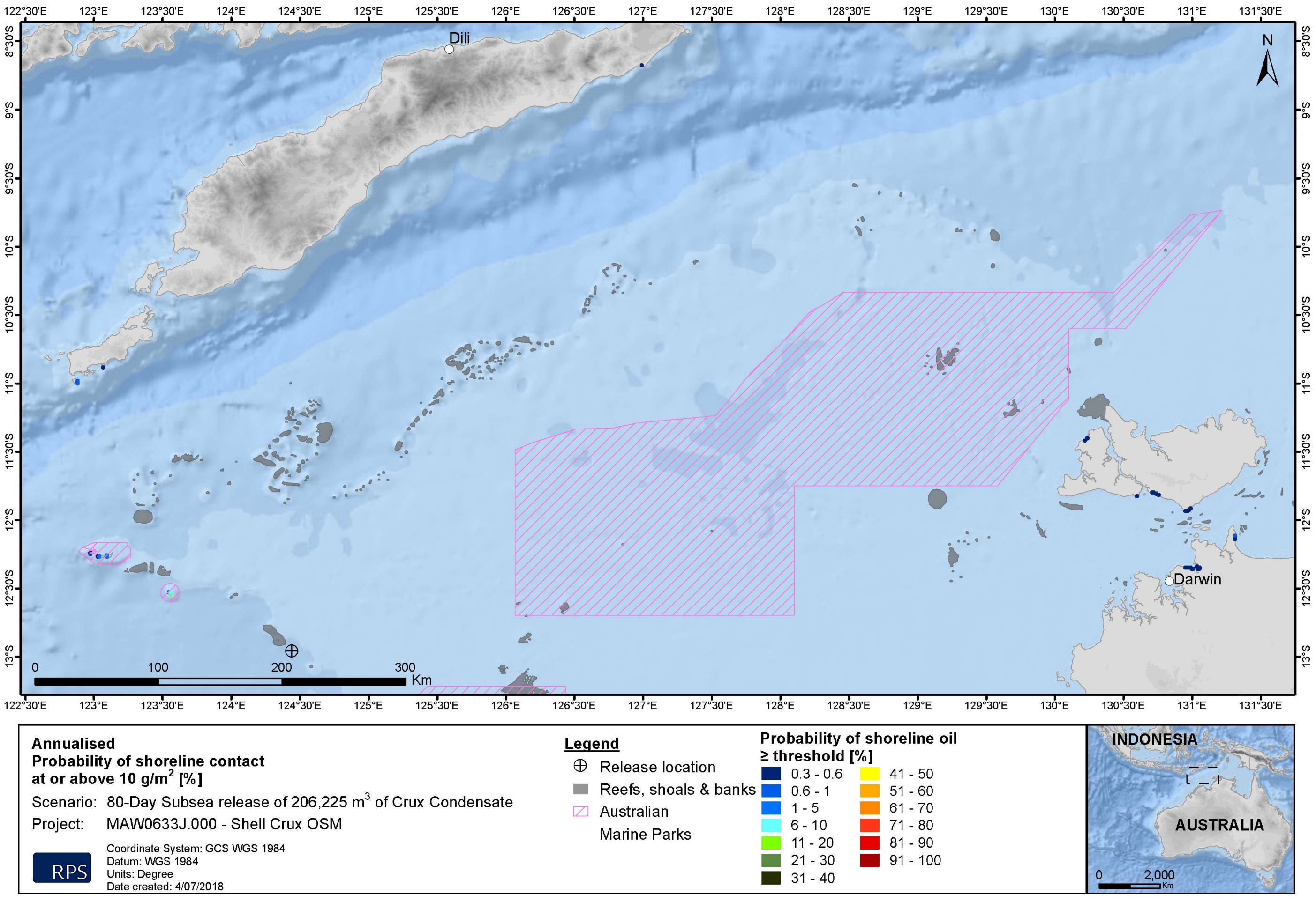


Figure 3.5 Shoreline Hydrocarbons | Blowout Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 10 g/m^2 resulting from an 80-day subsurface release of Crux condensate at a development well.

RPS

3.2.3 Entrained Hydrocarbons

Table 3.6 Expected annualised entrained oil outcomes at sensitive receptors resulting from an 80-day subsurface release of Crux condensate at a development well.

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
Coastlines	Cobourg Peninsula	6	4.2	1.5	1,177	1,187	1,220
	Darwin Coast	7.2	5.1	2.4	1,078	1,109	1,129
	Indonesia	30.6	17.1	5.4	672	677	738
	Joseph Bonaparte Gulf Northern Territory	7.2	4.5	2.1	1,075	1,129	1,138
	Kakadu Coast	9.6	7.5	4.8	1,313	1,351	1,370
	Kakadu National Park	1.8	0.9	<0.3	1,798	2,072	NC
	Kimberley Coast	4.5	3.9	3	589	592	817
	North Broome Coast	2.1	<0.3	<0.3	2,051	NC	NC
	Port Hedland-Eighty Mile Beach	0.6	<0.3	<0.3	2,175	NC	NC
	Timor Leste	20.4	14.7	5.4	706	739	1,028
	West Arnhem Land	1.2	0.6	<0.3	1,482	1,611	NC
Islands	Adele Island	8.1	5.7	2.4	1,032	1,496	1,509
	Admiralty Gulf Islands	4.5	3.6	2.4	576	697	722
	Advance Island	<0.3	<0.3	<0.3	NC	NC	NC
	Bathurst Island	17.4	15.6	10.8	971	1,009	1,016
	Bigge Island	4.8	3.9	3	673	675	687
	Bonaparte Archipelago	5.7	4.2	3	647	649	662
	Browse Island	79.8	74.7	54.6	278	290	338
	Buccaneer Archipelago	4.8	3	1.8	1,618	1,656	2,261
	Burford Island	4.2	0.9	<0.3	2,139	2,345	NC
	Cape Londonderry Islands	1.2	0.6	<0.3	930	2,556	NC
	Cassini Island	6.6	3.9	3.6	528	564	699
	Coronation Island Group	5.4	2.1	0.9	1,320	1,352	1,628
	Crocodile Islands	0.9	0.6	0.6	2,101	2,104	2,113
	Croker Island	4.5	2.7	1.8	1,266	1,297	1,328
	Darch Island	2.4	1.2	0.6	1,445	1,458	2,078
	East Vernon Island	9.9	7.5	5.4	1,123	1,151	1,348
	Eclipse Archipelago	3.9	2.7	<0.3	764	990	NC

RPS

Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
	≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
Field Island	1.8	0.9	<0.3	1,858	2,072	NC
Grant Island	2.4	1.5	0.6	1,472	1,672	1,782
Greenhill Island	1.2	<0.3	<0.3	2,193	NC	NC
Jones Island	4.2	3.6	3	579	670	728
Kingfisher Islands	1.5	<0.3	<0.3	2,275	NC	NC
Lacepede Islands	2.7	1.2	<0.3	2,040	2,256	NC
Lawson Island	2.4	2.1	0.9	1,383	1,497	1,775
Lesueur Island	0.9	<0.3	<0.3	2,266	NC	NC
Long Island Kimberley	6	4.2	3	637	648	650
McCluer Island	2.4	2.4	0.6	1,416	1,425	1,860
Melville Island	13.2	10.5	7.5	980	985	1,131
Montalivet Island	5.4	3.6	2.7	650	660	663
Montgomery Islands	2.4	1.2	0.6	2,279	2,280	2,368
Montgomery Islands and Reef	2.4	1.2	0.6	2,268	2,280	2,368
Napier Broome Bay Islands	1.2	0.6	<0.3	2,118	2,556	NC
New Year Island	3.9	2.1	0.9	1,420	1,606	1,891
North Goulburn Island	1.2	0.6	<0.3	1,687	1,860	NC
North West Vernon Island	9.9	8.4	6	1,111	1,120	1,285
Oxley Island	3.9	2.4	1.2	1,368	1,391	1,852
Peron Islands	3.9	1.8	0.6	1,468	2,023	2,543
Roche Islands and Reefs	5.7	4.2	1.8	1,144	1,275	1,280
South West Vernon Island	9	6.6	4.5	1,193	1,255	1,349
Stewarts Islands	0.9	<0.3	<0.3	2,396	NC	NC
Templer Island	0.9	<0.3	<0.3	1,472	NC	NC
Troughton Island	8.1	3.9	3.6	252	263	263
Valencia Island	0.6	<0.3	<0.3	1,593	NC	NC
White Island	5.1	2.1	0.6	1,465	1,802	2,461
Reefs						
Baxendell Reef	5.4	4.2	1.5	1,753	1,774	1,901
Beagle and Dingo Reefs	6.9	2.7	1.5	1,118	1,743	1,953
Beatrice Reef	2.1	1.8	1.2	1,742	1,758	1,799
Campbell Reef	2.1	<0.3	<0.3	1,364	NC	NC
Christine Reef	4.2	1.8	<0.3	1,570	1,576	NC

RPS

Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
	≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
Draytons Reef	9	6	4.2	1,339	1,369	1,440
East Holothuria Reef	15.6	9.6	6.9	228	228	238
Elizabeth Reef	9	6	4.2	1,335	1,379	1,435
Elphinstone Reef	10.5	7.8	2.1	1,144	1,190	1,273
Emu Reefs	0.9	<0.3	<0.3	2,216	NC	NC
Fish Reef	7.5	5.1	2.1	1,131	1,194	1,297
Harris Reef	9.6	8.7	7.2	1,091	1,112	1,303
Heritage Reef	5.1	3	2.7	649	651	669
Hibernia Reef	67.2	49.5	27.9	296	304	328
Hinkler Patches	5.4	3.6	1.5	1,760	1,802	1,879
Hunt Patch	7.8	6.6	4.2	1,427	1,480	1,536
Ingram Reef	8.4	4.8	3.6	648	649	971
Jamieson Reef	8.1	5.7	3.9	527	651	652
Knight Reef	9.9	8.4	5.4	1,128	1,144	1,318
Long Reef	7.5	4.2	3.9	527	527	528
Lyne Reef	8.1	6.6	3.9	1,205	1,322	1,484
Mavis Reef	4.8	1.8	0.9	1,127	1,581	2,243
Middle Reef	6.6	3.9	1.8	1,246	1,260	1,299
North Crocodile Reef	0.9	0.6	<0.3	2,086	2,114	NC
Oliver Reef	9.6	8.4	5.1	1,103	1,115	1,320
Oliver Rock	5.7	3.6	3	551	684	958
Orontes Reef	5.7	2.7	1.2	1,195	1,211	1,357
Rothery Reef	7.8	4.8	3.6	236	527	528
Sandy Islet	78.6	64.8	44.4	437	445	472
Scott Reef North	79.5	66.6	48.9	422	427	461
Scott Reef South	79.8	66.3	45.6	435	438	456
Seringapatam Reef	80.7	68.4	52.2	397	400	401
Taylor Patches	8.1	7.5	5.4	1,350	1,375	1,385
The Boxers	35.4	30.3	19.2	503	527	529
The Boxers Area	35.7	30.3	20.4	498	517	519
Tregenna Reef	8.7	8.1	5.4	1,112	1,125	1,326
West Holothuria Reef	19.5	13.8	8.4	198	226	228

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
Shoals	Abbott Shoal	7.5	6.6	3.9	1,399	1,404	1,670
	Afghan Shoal	16.2	14.4	12.3	958	985	1,021
	Ann Shoals	1.2	<0.3	<0.3	2,206	NC	NC
	Barbara Shoal	6.9	6	2.4	1,459	1,462	1,472
	Barracouta Shoals	89.1	84.9	66.6	89	90	104
	Barton Shoal	50.1	44.1	28.8	349	353	451
	Bassett-Smith Shoal	38.1	32.7	24.9	152	162	241
	Beagle Shoals	7.5	6.6	3.9	1,446	1,472	1,555
	Big Bank Shoals	41.1	35.7	23.1	399	399	403
	Bill Shoal	7.8	6.6	4.2	1,391	1,397	1,413
	Britomart Shoal	5.7	2.4	0.9	1,324	1,550	1,569
	Calder Shoal	25.2	18.9	9.6	698	701	811
	Cootamundra Shoal	23.4	17.1	7.8	721	722	907
	Deep Shoal 1	54.6	53.1	43.8	160	164	175
	Deep Shoal 2	46.2	43.5	32.7	252	253	277
	Dillon Shoal	45.9	39.3	29.1	344	348	475
	Echo Shoals	35.1	29.1	16.5	455	464	479
	Echuca Shoal	71.7	64.5	51.9	261	263	353
	Eugene McDermott Shoal	98.7	98.7	97.5	16	17	17
	Evans Shoal	13.8	10.5	5.1	1,026	1,029	1,172
	Fantome Shoal	53.4	39.3	19.8	376	390	399
	Fitzpatrick Shoal	4.8	2.7	0.6	1,246	1,364	1,387
	Flinders Shoal	14.7	8.4	2.7	1,018	1,026	1,334
	Franklin Shoal	14.1	8.7	3	1,019	1,022	1,269
	Giles Shoal	7.2	4.8	2.1	1,521	1,524	1,776
	Goeree Shoal	100	99.6	97.5	18	18	19
	Hancox Shoal	9.9	8.7	6	1,090	1,101	1,291
	Heywood Shoal	88.8	84.9	76.8	91	118	126
	Jabiru Shoals	56.4	49.8	39.9	146	155	208
	Jones Shoal	7.2	4.2	0.6	1,240	1,306	1,936
	Karmt Shoal	46.5	38.1	28.5	328	333	367
	Lowry Shoal	10.5	8.7	5.4	1,040	1,075	1,153

RPS

Receptor		Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Loxton Shoal	15.6	8.4	4.2	1,037	1,040	1,063
	Mangola Shoal	54.3	48.6	37.2	268	268	290
	Margaret Shoal	1.5	1.2	0.6	1,932	1,941	2,439
	Marie Shoal	16.2	13.8	7.8	965	989	1,020
	Marsh Shoal	9.6	6.6	5.4	1,200	1,283	1,435
	Martin Shoal	14.1	8.1	3.6	1,058	1,085	1,110
	Mataram Shoal	6	4.2	1.2	1,657	1,685	2,262
	Mermaid Shoal	17.1	13.8	9	962	966	970
	Money Shoal	5.4	1.8	0.6	1,344	1,346	2,155
	Moresby Shoals	10.2	8.4	7.5	1,034	1,061	1,107
	Moss Shoal	18.6	16.5	9	951	958	1,006
	Newby Shoal	27.6	23.7	17.4	576	721	767
	Ommaney Shoals	5.4	4.2	1.8	1,698	1,746	1,855
	Parry Shoal	21.3	17.4	12.6	931	934	976
	Paxie Shoal	0.6	<0.3	<0.3	1,914	NC	NC
	Pee Shoal	52.8	44.7	30.9	207	215	244
	Penguin Shoal	42.6	37.2	26.7	166	166	232
	Penguin Shoal	42.6	37.2	26.7	166	166	232
	Renard Shoals	5.4	4.5	2.1	1,559	1,726	1,758
	Shepparton Shoal	19.2	15.9	12.6	664	695	703
	Skottowe Shoal	11.1	9.6	5.7	1,027	1,044	1,079
	Sunset Shoal	16.5	13.5	4.2	1,023	1,027	1,031
	Taiyun Shoal	7.8	6.9	4.2	1,405	1,430	1,548
	Tassie Shoal	13.5	10.8	5.7	973	1,008	1,107
	Troubadour Shoals	13.5	10.8	3.9	967	1,149	1,311
	Van Cloon Shoal	53.1	47.1	34.5	174	175	176
	Vee Shoal	59.1	44.7	21.3	234	243	245
	Victoria Shoal	2.7	1.8	1.2	1,688	1,695	1,712
	Vulcan Shoals	100	100	100	7	7	8
	Wells Shoal	7.2	6	2.4	1,438	1,446	1,591
Banks	Baldwin Bank	49.5	42.3	35.1	219	226	232
	Bellona Bank	32.4	26.1	13.2	680	770	779

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Branch Banks	8.7	4.5	3.6	264	264	264
	Favell Bank	53.4	47.7	42.3	167	170	171
	Flat Top Bank	22.8	19.8	16.2	450	451	452
	Foelsche Bank	7.2	6	3.6	1,195	1,207	1,429
	Gale Bank	57.6	54.3	46.5	92	93	96
	Goodrich Bank	13.2	9.9	3.9	1,033	1,062	1,067
	Holothuria Banks	34.2	30.9	24.6	186	187	197
	Johnson Bank	83.7	73.8	44.1	168	169	192
	Lynedoch Bank	10.2	6.9	1.2	1,068	1,184	1,580
	Margaret Harries Bank	37.2	32.7	21.3	532	536	540
	Otway Bank	10.5	6.9	4.2	240	240	250
	Parsons Bank	8.7	7.8	7.5	1,078	1,090	1,182
	Rankin Bank	1.8	0.6	<0.3	2,203	2,209	NC
	Sahul Bank	61.8	49.2	37.8	128	128	129
	Sunrise Bank	17.1	13.5	6.6	906	964	977
	Tait Bank	4.5	3.6	3	558	567	569
	Woodbine Bank	80.4	73.2	48.3	145	146	158
Marine Parks	Arafura AMP	7.2	3.9	1.5	1,282	1,283	1,493
	Arnhem AMP	2.4	2.4	0.9	1,474	1,476	1,868
	Ashmore Reef AMP	81.9	72.3	47.4	177	188	193
	Lalang-garram/Camden Sound MP	4.5	2.4	1.8	1,336	1,350	2,234
	Carnarvon Canyon AMP	0.6	<0.3	<0.3	2,273	NC	NC
	Cartier Island AMP	90.6	85.2	64.5	89	95	98
	Charles Darwin NP	2.4	1.5	1.5	1,186	1,186	1,298
	Djukbinj NP	9.6	7.8	5.4	1,304	1,320	1,368
	Eighty Mile Beach AMP	1.2	0.6	<0.3	2,161	2,460	NC
	Garig Gunak Barlu NP	6.6	4.2	1.8	1,177	1,185	1,197
	Gascoyne AMP	1.8	0.9	0.6	1,680	2,208	2,230
	Kakadu NP	2.7	2.4	1.5	1,688	1,707	1,772
	Kimberley AMP	75.6	57.3	45.3	81	82	82
	North Lalang-garram MP & North Kimberley MP	16.5	10.8	7.5	226	227	227

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Lawley River NP Coast	0.6	0.6	<0.3	1,743	2,041	NC
	Mary River NP	5.7	3.6	2.4	1,402	1,417	1,493
	Mermaid Reef AMP	41.4	26.4	11.1	892	924	1,082
	Mitchell River NP Coast	1.5	0.9	<0.3	1,601	1,838	NC
	Montebello AMP	2.1	0.6	<0.3	1,981	2,241	NC
	Ningaloo AMP	0.6	<0.3	<0.3	1,735	NC	NC
	Oceanic Shoals AMP	63.3	60.3	53.7	85	86	87
	Prince Regent NP Coast	2.4	2.1	1.2	1,133	1,464	1,831
Key Ecological Features	Ancient Coastline at 125 m depth contour	95.7	94.8	91.8	28	29	30
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	90.6	85.2	64.5	89	95	98
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	47.4	32.4	17.1	578	581	670
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	1.5	0.9	0.6	1,685	2,266	2,304
	Carbonate bank & terrace system of Van Diemen Rise	39.6	36.3	29.1	356	358	367
	Carbonate bank and terrace system of Sahul Shelf	74.7	72.6	68.4	30	30	31
	Continental Slope Demersal Fish Communities	95.4	90.6	75.9	53	55	60
	Exmouth Plateau	6.9	2.4	0.6	1,570	1,575	1,590
	Glomar Shoals	2.4	1.2	0.6	1,656	2,103	2,129
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals	43.2	26.4	11.1	886	924	1,018
	Pinnacles of the Bonaparte Basin	50.4	45.9	34.5	226	227	231
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	80.7	68.1	52.2	396	399	401
	Shelf break and slope of the Arafura Shelf	15.9	11.7	7.2	929	937	944
	Tributary Canyons of the Arafura Depression	4.5	2.4	1.2	1,488	1,531	1,917
Fisheries	Northern Prawn Fishery	54.6	51.9	42.3	180	185	201
	North-West Slope Trawl Fishery	99.9	98.7	97.2	11	11	11

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Southern Bluefin Tuna Fishery	100	100	100	1	1	1
	Timor Reef Fishery (NT Managed)	34.8	32.7	19.5	555	582	601
	Western Skipjack Fishery	100	100	100	1	1	1
	Western Tuna and Billfish Fishery	100	100	100	1	1	1
Biologically Important Areas	Flatback Turtle BIA	61.5	59.4	52.5	101	103	106
	Green Turtle BIA	94.5	90.3	68.4	68	70	71
	Hawksbill Turtle BIA	84.3	75.6	51.3	155	157	163
	Leatherback Turtle BIA	6.6	3.6	1.8	1,214	1,225	1,239
	Loggerhead Turtle BIA	61.5	59.4	52.5	101	103	106
	Olive Ridley Turtle BIA	61.5	59.4	52.5	101	103	106

NC: No contact to receptor predicted for specified threshold.

** Probabilities and maximum concentrations calculated at depth of submerged feature.*

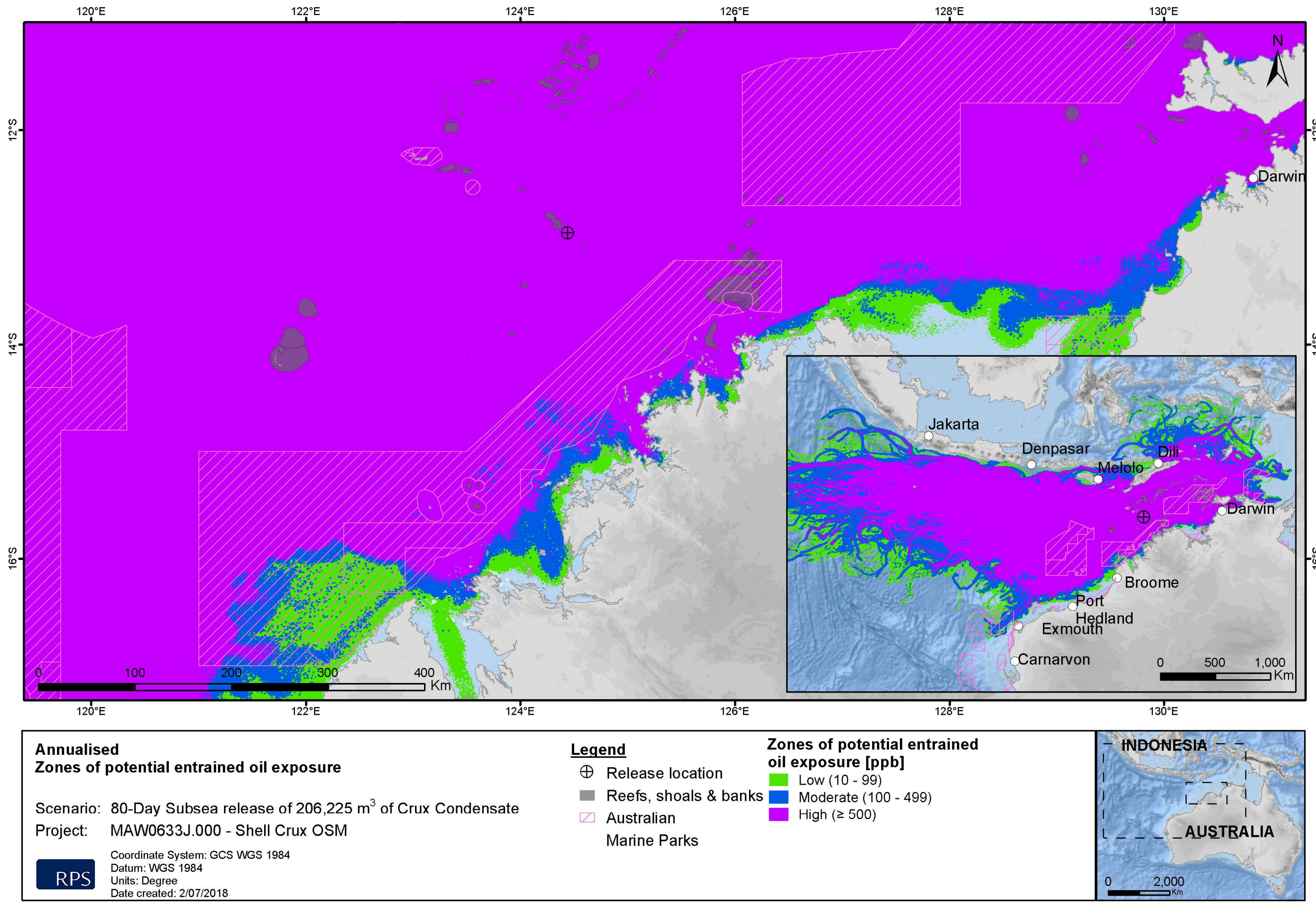


Figure 3.6 Subsurface Hydrocarbons | Entrained | Blowout Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined entrained oil threshold concentrations resulting from an 80-day subsurface release of Crux condensate at a development well.

RPS

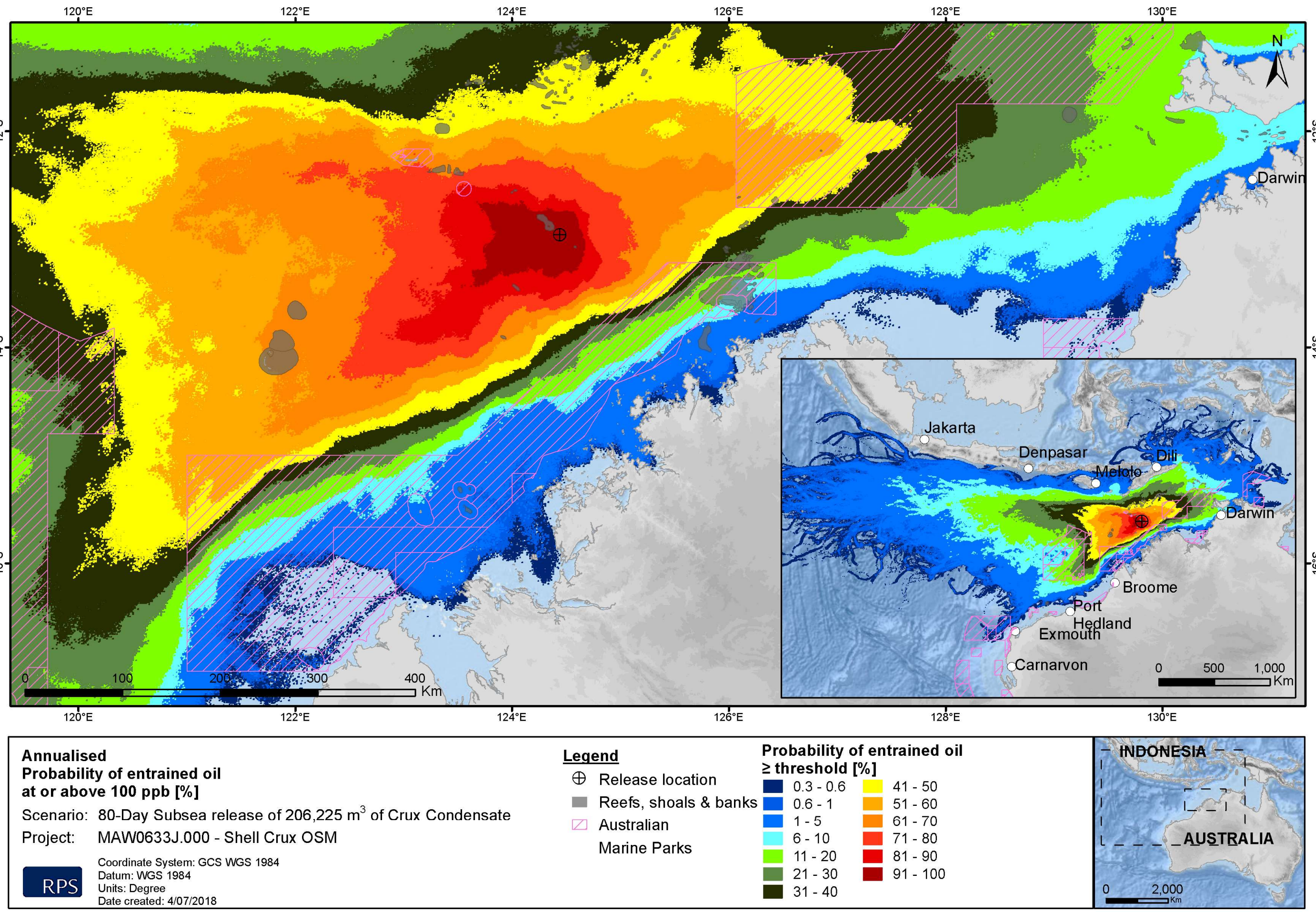


Figure 3.7 Subsurface Hydrocarbons | Entrained | Blowout Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 100 ppb resulting from an 80-day subsurface release of Crux condensate at a development well.

RPS

3.2.4 Dissolved Aromatic Hydrocarbons

Table 3.7 Expected annualised dissolved aromatic hydrocarbon outcomes at sensitive receptors resulting from an 80-day subsurface release of Crux condensate at a development well.

	Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
Coastlines	Cobourg Peninsula	1.8	0.6	<0.3
	Darwin Coast	2.1	1.2	<0.3
	Indonesia	13.2	4.2	0.9
	Joseph Bonaparte Gulf Northern Territory	2.4	1.5	<0.3
	Kakadu Coast	5.1	0.6	<0.3
	Kakadu National Park	<0.3	<0.3	<0.3
	Kimberley Coast	3	0.9	<0.3
	North Broome Coast	0.9	<0.3	<0.3
	Port Hedland-Eighty Mile Beach	<0.3	<0.3	<0.3
	Timor Leste	11.1	2.1	0.6
	West Arnhem Land	<0.3	<0.3	<0.3
Islands	Adele Island	6	1.8	0.6
	Admiralty Gulf Islands	2.7	1.8	<0.3
	Advance Island	<0.3	<0.3	<0.3
	Bathurst Island	14.1	6.6	0.6
	Bigge Island	3	2.7	0.6
	Bonaparte Archipelago	3.6	2.7	0.6
	Browse Island	73.2	48.6	3.9
	Buccaneer Archipelago	2.7	0.6	<0.3
	Burford Island	<0.3	<0.3	<0.3
	Cape Londonderry Islands	<0.3	<0.3	<0.3
	Cassini Island	3.6	1.8	<0.3
	Coronation Island Group	1.8	0.6	0.6
	Crocodile Islands	<0.3	<0.3	<0.3
	Croker Island	1.8	0.9	<0.3
	Darch Island	<0.3	<0.3	<0.3
	East Vernon Island	6	1.2	<0.3
	Eclipse Archipelago	1.2	<0.3	<0.3
	Field Island	<0.3	<0.3	<0.3

RPS

Receptor		Probability (%) of dissolved aromatic hydrocarbon concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
	Grant Island	0.6	<0.3	<0.3
	Greenhill Island	<0.3	<0.3	<0.3
	Jones Island	3	0.6	<0.3
	Kingfisher Islands	<0.3	<0.3	<0.3
	Lacepede Islands	0.9	<0.3	<0.3
	Lawson Island	0.9	0.6	<0.3
	Lesueur Island	<0.3	<0.3	<0.3
	Long Island Kimberley	3.6	2.7	0.6
	McCluer Island	1.5	0.6	<0.3
	Melville Island	6.6	2.4	<0.3
	Montalivet Island	3	2.7	0.6
	Montgomery Islands	<0.3	<0.3	<0.3
	Montgomery Islands and Reef	0.6	<0.3	<0.3
	Napier Broome Bay Islands	<0.3	<0.3	<0.3
	New Year Island	1.2	<0.3	<0.3
	North Goulburn Island	<0.3	<0.3	<0.3
	North West Vernon Island	6.6	2.4	<0.3
	Oxley Island	1.8	0.6	<0.3
	Peron Islands	1.2	<0.3	<0.3
	Roche Islands and Reefs	2.1	<0.3	<0.3
	South West Vernon Island	5.7	<0.3	<0.3
	Stewarts Islands	<0.3	<0.3	<0.3
	Templer Island	<0.3	<0.3	<0.3
	Troughton Island	4.2	3.6	2.7
	Valencia Island	<0.3	<0.3	<0.3
	White Island	2.1	<0.3	<0.3
Reefs	Baxendell Reef	0.9	0.6	<0.3
Reefs	Beagle and Dingo Reefs	4.8	0.9	<0.3
Reefs	Beatrice Reef	<0.3	<0.3	<0.3
Reefs	Campbell Reef	<0.3	<0.3	<0.3
Reefs	Christine Reef	<0.3	<0.3	<0.3
Reefs	Draytons Reef	3.9	<0.3	<0.3
Reefs	East Holothuria Reef	9.6	5.4	2.4

	Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
	Elizabeth Reef	3.9	<0.3	<0.3
	Elphinstone Reef	1.5	<0.3	<0.3
	Emu Reefs	<0.3	<0.3	<0.3
	Fish Reef	2.4	0.9	<0.3
	Harris Reef	7.2	2.7	<0.3
	Heritage Reef	3	2.4	<0.3
	Hibernia Reef	45.3	24.6	2.1
	Hinkler Patches	1.2	<0.3	<0.3
	Hunt Patch	2.1	<0.3	<0.3
	Ingram Reef	3.9	1.8	<0.3
	Jamieson Reef	5.1	1.8	<0.3
	Knight Reef	5.4	2.1	<0.3
	Long Reef	4.2	3.6	2.7
	Lyne Reef	4.5	<0.3	<0.3
	Mavis Reef	1.2	0.9	<0.3
	Middle Reef	1.5	<0.3	<0.3
	North Crocodile Reef	<0.3	<0.3	<0.3
	Oliver Reef	6.6	2.7	<0.3
	Oliver Rock	3	0.9	<0.3
	Orontes Reef	1.8	0.9	<0.3
	Rothery Reef	4.8	3.6	3
	Sandy Islet	61.5	35.7	2.7
	Scott Reef North	65.7	42.9	6.9
	Scott Reef South	63.9	37.8	4.2
	Seringapatam Reef	65.7	46.8	6.6
	Taylor Patches	5.4	0.9	<0.3
	The Boxers	28.5	17.7	2.4
	The Boxers Area	28.5	18.6	2.4
	Tregenna Reef	5.4	2.1	<0.3
	West Holothuria Reef	13.2	6.9	2.4
Shoals	Abbott Shoal	2.7	0.9	<0.3
	Afghan Shoal	14.4	8.7	0.6
	Ann Shoals	<0.3	<0.3	<0.3

RPS

Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration at specific receptor depth		
	≥6 ppb	≥50 ppb	≥400 ppb
Barbara Shoal	1.2	<0.3	<0.3
Barracouta Shoals	82.5	66.6	22.8
Barton Shoal	41.4	27.6	3.6
Bassett-Smith Shoal	33.9	24.3	2.4
Beagle Shoals	2.1	<0.3	<0.3
Big Bank Shoals	33.6	19.8	1.2
Bill Shoal	3.9	<0.3	<0.3
Britomart Shoal	0.6	<0.3	<0.3
Calder Shoal	18.3	6.6	0.6
Cootamundra Shoal	15.6	4.8	<0.3
Deep Shoal 1	52.2	39.3	3.6
Deep Shoal 2	38.7	29.7	5.4
Dillon Shoal	37.5	23.4	1.2
Echo Shoals	26.4	10.2	0.6
Echuca Shoal	63.6	46.5	5.1
Eugene McDermott Shoal	97.5	96.3	86.4
Evans Shoal	8.7	3.6	<0.3
Fantome Shoal	38.1	16.5	1.2
Fitzpatrick Shoal	<0.3	<0.3	<0.3
Flinders Shoal	6.6	1.8	<0.3
Franklin Shoal	7.8	1.8	<0.3
Giles Shoal	0.9	<0.3	<0.3
Goeree Shoal	98.4	96.9	88.8
Hancox Shoal	6.6	3.6	<0.3
Heywood Shoal	84.9	79.2	30.9
Jabiru Shoals	48.9	38.1	9
Jones Shoal	1.2	<0.3	<0.3
Karmt Shoal	37.2	23.4	2.7
Lowry Shoal	7.2	3	<0.3
Loxton Shoal	8.1	1.8	<0.3
Mangola Shoal	47.1	36.6	6.6
Margaret Shoal	<0.3	<0.3	<0.3
Marie Shoal	10.2	2.4	<0.3

	Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
	Marsh Shoal	5.7	0.6	<0.3
	Martin Shoal	6.6	2.1	<0.3
	Mataram Shoal	0.6	<0.3	<0.3
	Mermaid Shoal	10.5	3	<0.3
	Money Shoal	0.9	<0.3	<0.3
	Moresby Shoals	7.2	3.9	<0.3
	Moss Shoal	13.5	4.2	<0.3
	Newby Shoal	23.1	16.8	1.5
	Ommaney Shoals	0.9	0.6	<0.3
	Parry Shoal	16.8	8.4	<0.3
	Paxie Shoal	<0.3	<0.3	<0.3
	Pee Shoal	44.1	28.8	5.1
	Penguin Shoal	38.1	26.1	2.7
	Penguin Shoal	38.1	26.1	2.7
	Renard Shoals	1.2	<0.3	<0.3
	Shepparton Shoal	14.1	9.6	0.6
	Skottowe Shoal	7.5	4.2	<0.3
	Sunset Shoal	10.2	2.1	<0.3
	Taiyun Shoal	2.7	0.9	<0.3
	Tassie Shoal	7.8	3	<0.3
	Troubadour Shoals	7.5	2.4	<0.3
	Van Cloon Shoal	46.5	31.8	6
	Vee Shoal	39.3	19.8	2.7
	Victoria Shoal	<0.3	<0.3	<0.3
	Vulcan Shoals	100	99.9	97.2
	Wells Shoal	1.8	<0.3	<0.3
Banks	Baldwin Bank	42.6	32.7	8.1
	Bellona Bank	21.6	6	0.9
	Branch Banks	4.5	3.9	1.2
	Favell Bank	47.1	40.2	6.6
	Flat Top Bank	18.6	12.9	1.5
	Foelsche Bank	2.7	0.6	<0.3
	Gale Bank	52.8	44.4	6.6

RPS

Receptor		Probability (%) of dissolved aromatic hydrocarbon concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
	Goodrich Bank	6.6	1.2	<0.3
	Holothuria Banks	31.5	23.1	5.7
	Johnson Bank	70.5	46.2	8.1
	Lynedoch Bank	4.5	0.6	<0.3
	Margaret Harries Bank	32.1	16.5	1.5
	Otway Bank	5.1	3.9	2.1
	Parsons Bank	7.2	2.1	<0.3
	Rankin Bank	0.6	<0.3	<0.3
	Sahul Bank	46.8	37.5	7.2
	Sunrise Bank	10.8	4.8	1.2
	Tait Bank	3	3	<0.3
	Woodbine Bank	72.6	50.4	10.8
Marine Parks	Arafura AMP	2.1	0.6	<0.3
	Arnhem AMP	1.5	0.6	<0.3
	Ashmore Reef AMP	68.4	40.8	9.3
	Lalang-garram/Camden Sound MP	2.1	0.6	<0.3
	Carnarvon Canyon AMP	<0.3	<0.3	<0.3
	Cartier Island AMP	82.2	63.9	18.6
	Charles Darwin NP	1.5	<0.3	<0.3
	Djukbinj NP	5.1	0.6	<0.3
	Eighty Mile Beach AMP	0.6	<0.3	<0.3
	Garig Gunak Barlu NP	2.1	1.2	<0.3
	Gascoyne AMP	1.2	<0.3	<0.3
	Kakadu NP	<0.3	<0.3	<0.3
	Kimberley AMP	57.3	46.2	12.6
	North Lalang-garram MP & North Kimberley MP	11.4	6	3
	Lawley River NP Coast	<0.3	<0.3	<0.3
	Mary River NP	1.8	<0.3	<0.3
	Mermaid Reef AMP	27.3	9	0.6
	Mitchell River NP Coast	<0.3	<0.3	<0.3
	Montebello AMP	0.9	0.6	<0.3
	Ningaloo AMP	<0.3	<0.3	<0.3
	Oceanic Shoals AMP	60.6	53.1	12.9

RPS

	Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
	Prince Regent NP Coast	<0.3	<0.3	<0.3
Key Ecological Features	Ancient Coastline at 125 m depth contour	94.8	93.6	67.5
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	82.2	64.2	18.6
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	30.6	9.6	0.9
	Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	0.9	<0.3	<0.3
	Carbonate bank & terrace system of Van Diemen Rise	35.1	24.6	2.4
	Carbonate bank and terrace system of Sahul Shelf	72.6	66.9	42.6
	Continental Slope Demersal Fish Communities	88.8	72.6	28.5
	Exmouth Plateau	2.1	0.6	<0.3
	Glomar Shoals	1.2	<0.3	<0.3
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals	27.3	9	0.9
	Pinnacles of the Bonaparte Basin	43.2	31.2	5.1
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	65.7	46.8	6.9
	Shelf break and slope of the Arafura Shelf	9.9	4.5	0.6
	Tributary Canyons of the Arafura Depression	1.2	<0.3	<0.3
Fisheries	Northern Prawn Fishery	51.6	39.9	7.2
	North-West Slope Trawl Fishery	98.1	97.5	84.9
	Southern Bluefin Tuna Fishery	100	100	100
	Timor Reef Fishery (NT Managed)	30.9	14.7	1.8
	Western Skipjack Fishery	100	100	100
	Western Tuna and Billfish Fishery	100	100	100
Biologically Important Areas	Flatback Turtle BIA	59.7	52.5	12.9
	Green Turtle BIA	85.5	68.1	20.4
	Hawksbill Turtle BIA	71.4	44.7	10.8
	Leatherback Turtle BIA	2.1	1.2	<0.3
	Loggerhead Turtle BIA	59.7	52.5	12.9
	Olive Ridley Turtle BIA	59.7	52.5	12.9

** Probabilities and maximum concentrations calculated at depth of submerged feature.*

RPS

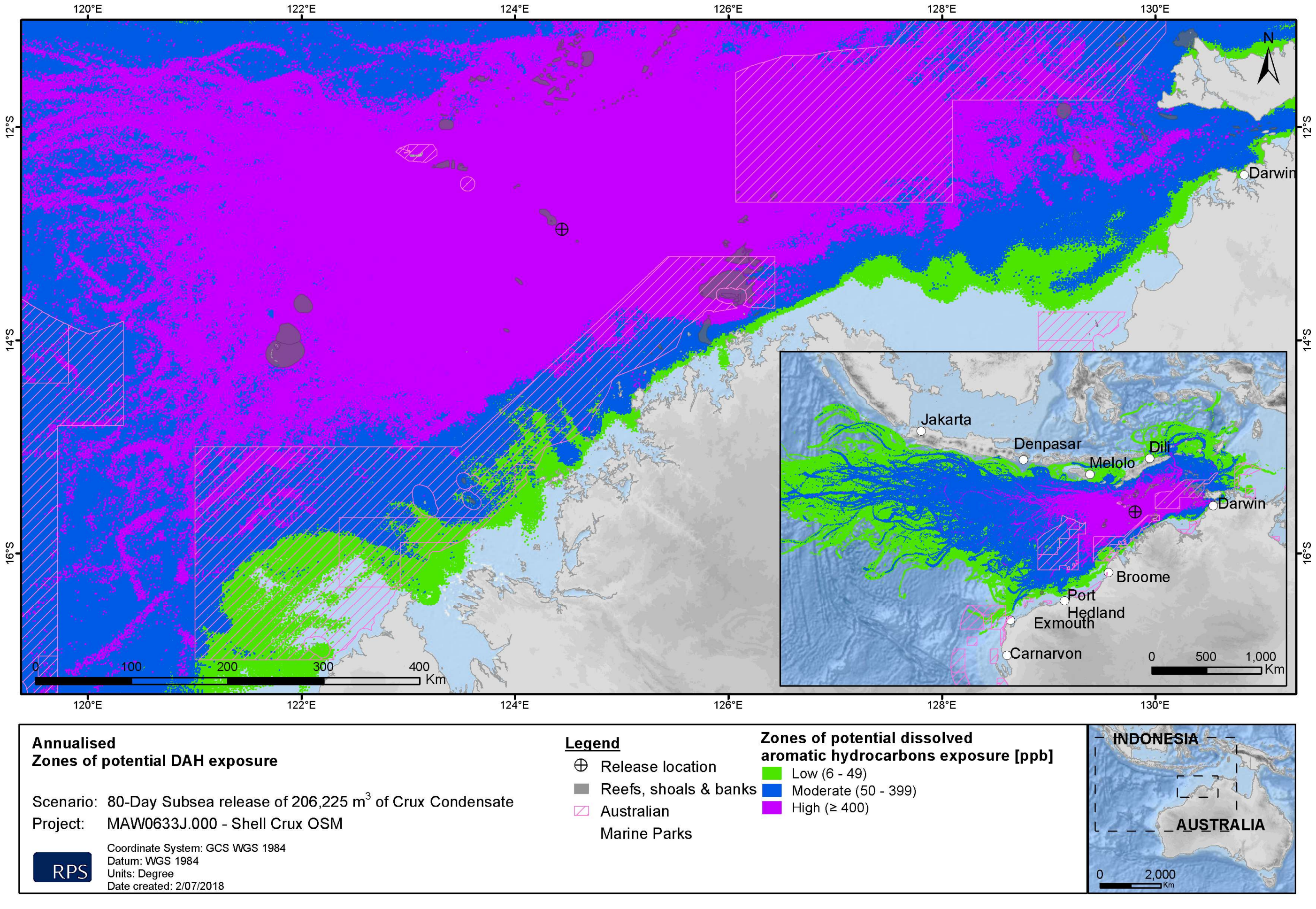


Figure 3.8 Subsurface Hydrocarbons | Dissolved | Blowout Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined dissolved aromatic hydrocarbon threshold concentrations resulting from an 80-day subsurface release of Crux condensate at a development well.

RPS

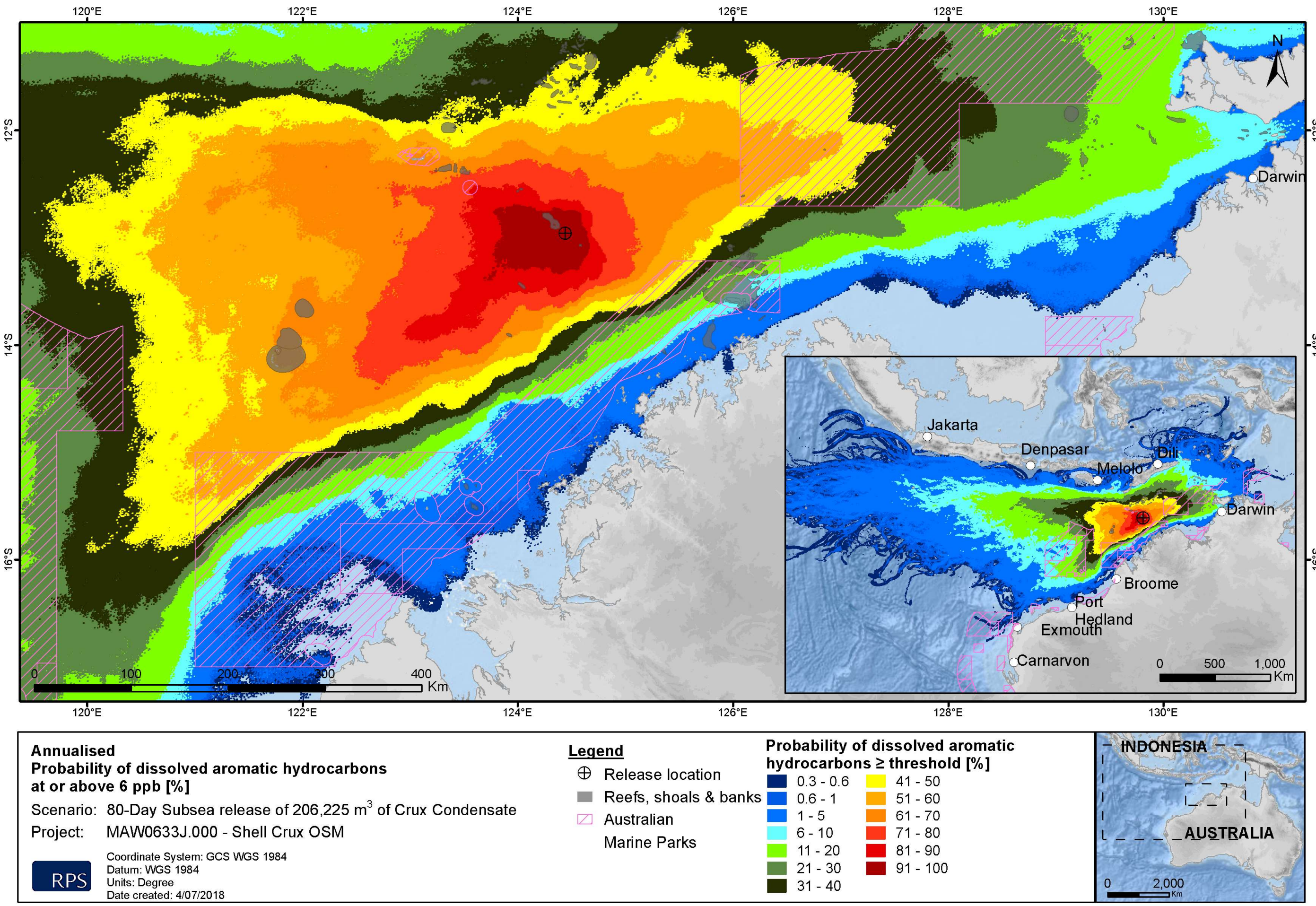


Figure 3.9 Subsurface Hydrocarbons | Dissolved | Blowout Scenario | Stochastic Outcomes. Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 6 ppb resulting from an 80-day subsurface release of Crux condensate at a development well.

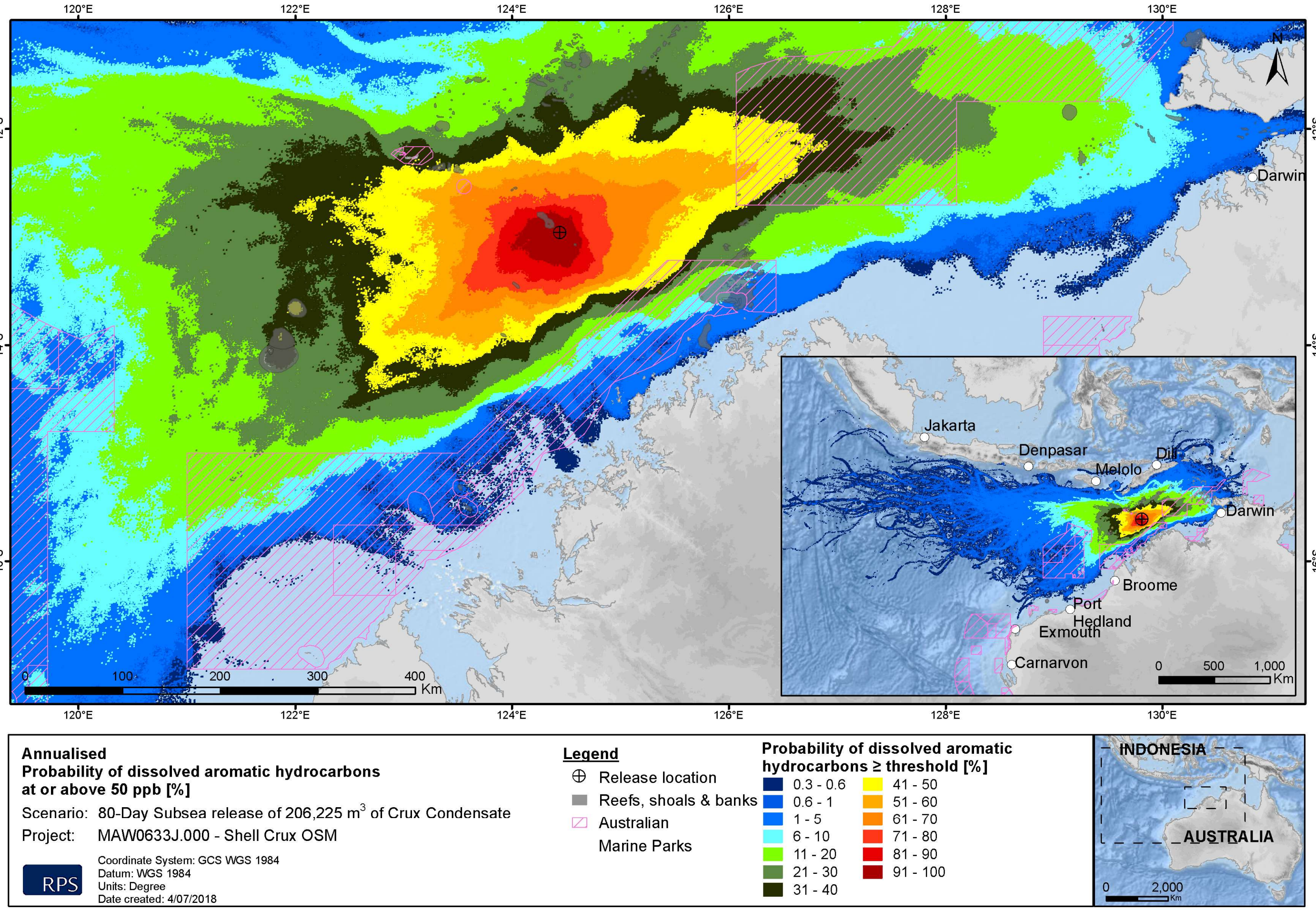


Figure 3.10 Subsurface Hydrocarbons | Dissolved | Blowout Scenario | Stochastic Outcomes. Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from an 80-day subsurface release of Crux condensate at a development well.

RPS

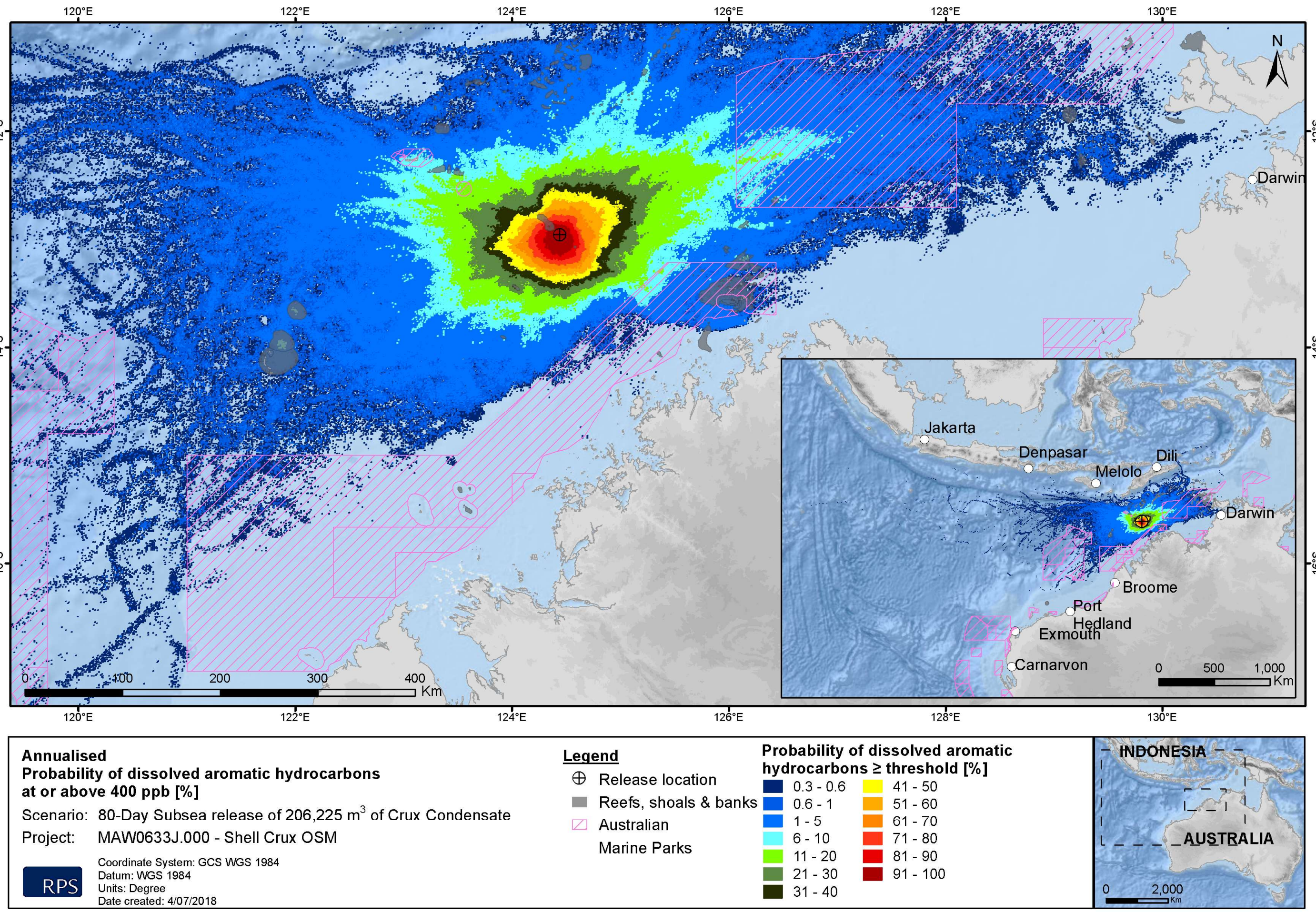


Figure 3.11 Subsurface Hydrocarbons | Dissolved | Blowout Scenario | Stochastic Outcomes. Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 400 ppb resulting from an 80-day subsurface release of Crux condensate at a development well.

RPS

3.3 Scenario 2 – Short-Term Surface Release of Crux Condensate at the Crux Platform

3.3.1 Discussion of Results

3.3.1.1 Overview

This scenario investigated the probability of exposure to key sensitive receptors by hydrocarbons resulting from a short-term (instantaneous) surface release following an inventory integrity failure, discharging 88 m^3 of Crux condensate at the Crux platform location at any time of year, with no spill response mitigation measures applied.

Considering the discharge characteristics, the properties of the condensate and its expected weathering behaviour, floating films are likely to be formed under typical to calm wind conditions. Given the low viscosity of the condensate, entrainment into the water column is highly likely to occur under all but relatively calm wind conditions. It is likely that the bulk of the oil mass at any time will be found in the surface mixed layer and on the water surface. Evaporation rates will be high, given the large proportion of volatile (54%) and semi-volatile (22%) compounds within the condensate, with the residual fraction (8%) persisting in the environment until degradation processes occur (over periods of weeks to months). Considering the relatively high likelihood of entrainment occurring, there is a high potential for dissolution of soluble aromatic compounds.

Figure 3.12 to Figure 3.14 show a summary of the areal extent for all hydrocarbon phases at the low, moderate and high thresholds, respectively.

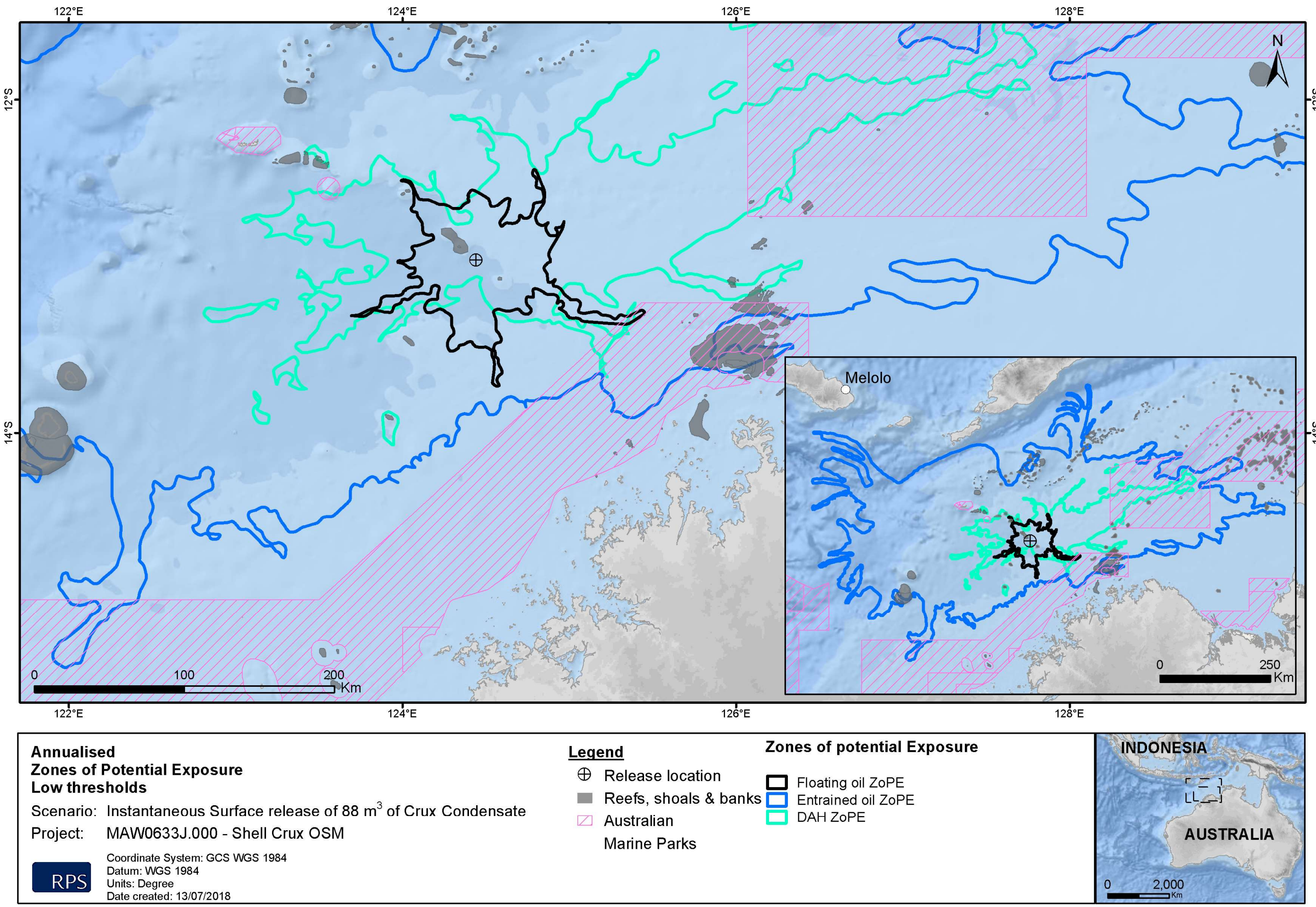


Figure 3.12 Surface and Subsurface Hydrocarbons | Inventory Scenario | Stochastic Outcomes. Areal extent of potential exposure at the low thresholds resulting from an instantaneous surface release of Crux condensate at the Crux platform.

RPS

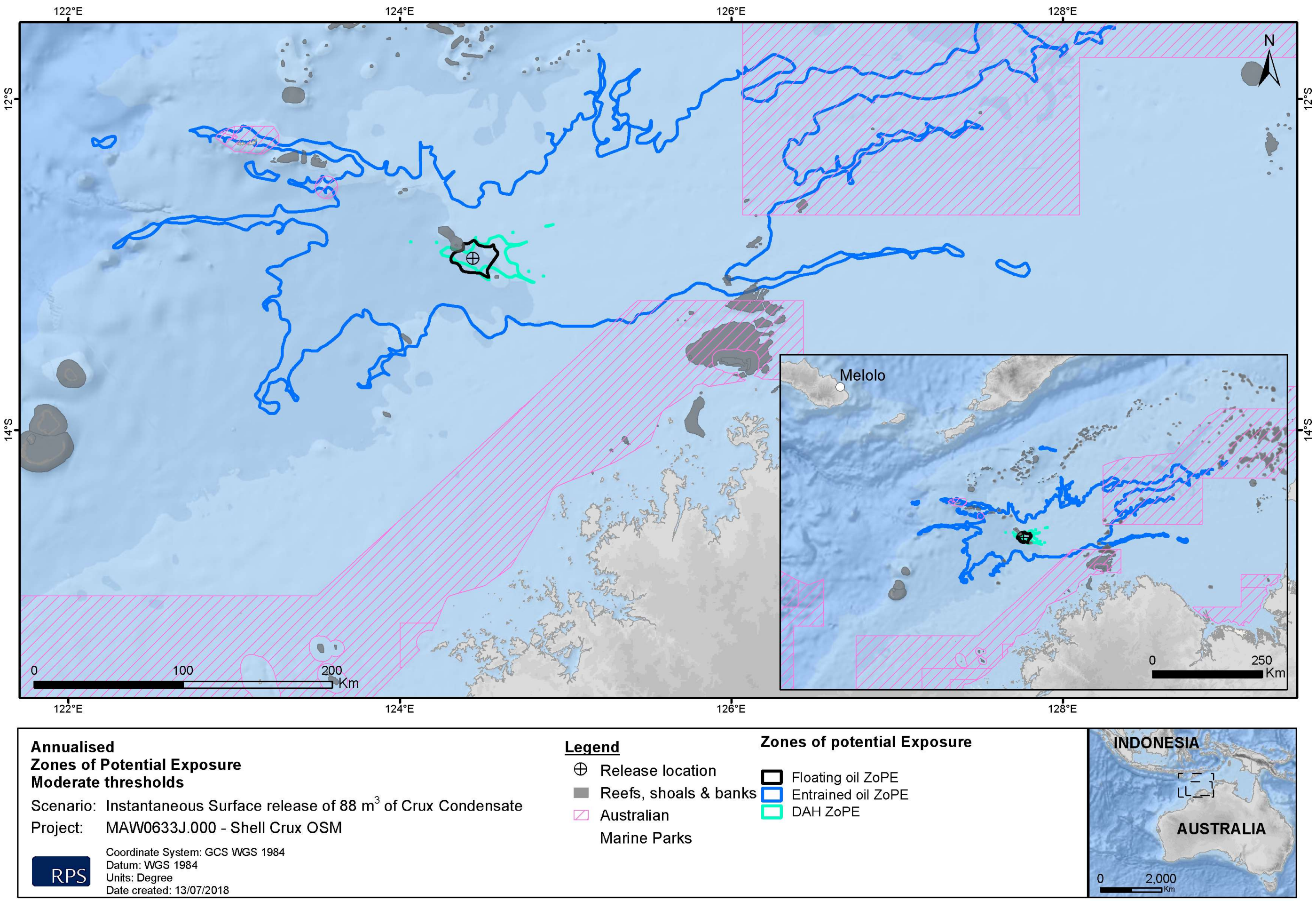


Figure 3.13 Surface and Subsurface Hydrocarbons | Inventory Scenario | Stochastic Outcomes. Areal extent of potential exposure at the moderate thresholds resulting from an instantaneous surface release of Crux condensate at the Crux platform.

RPS

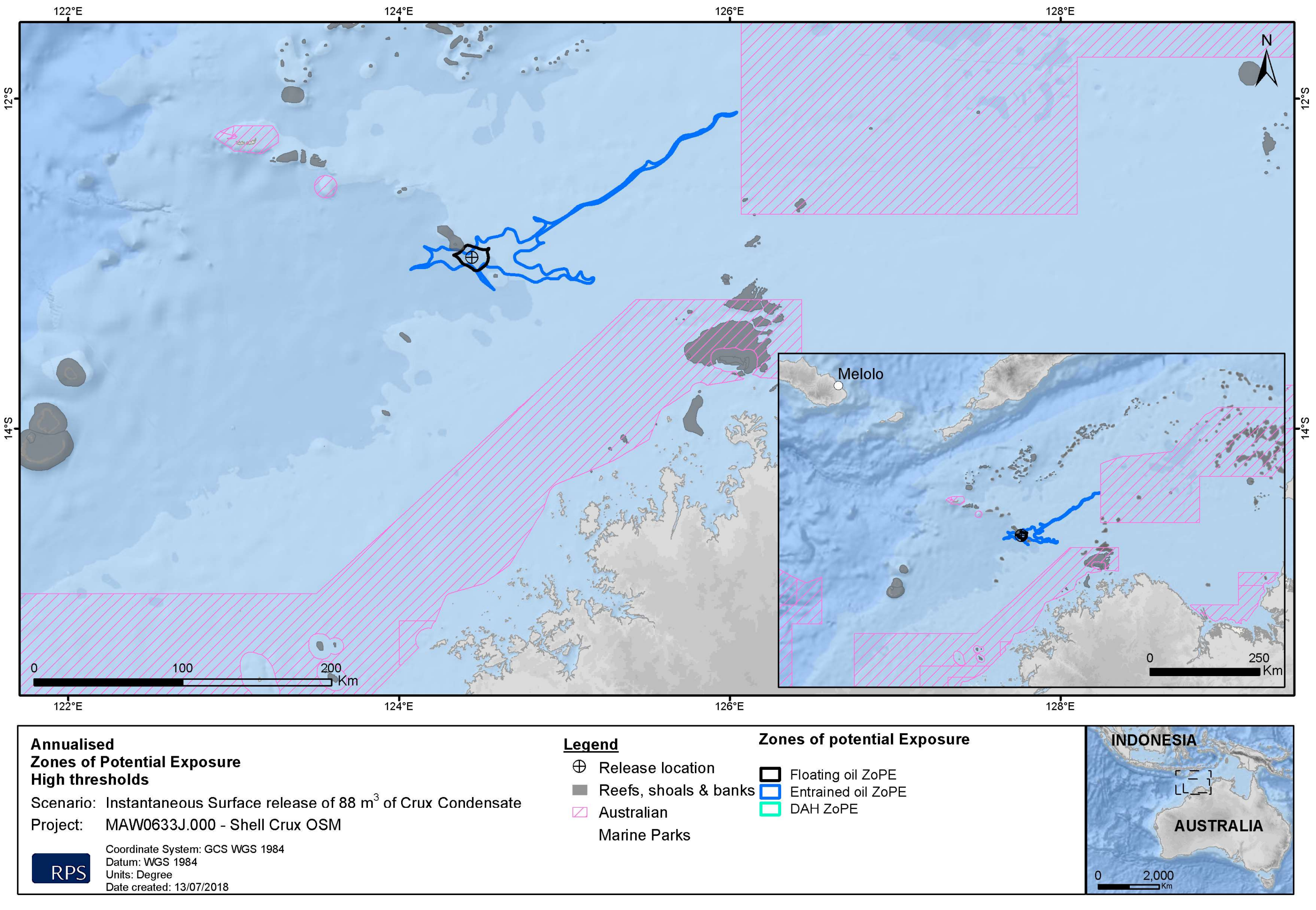


Figure 3.14 Surface and Subsurface Hydrocarbons | Inventory Scenario | Stochastic Outcomes. Areal extent of potential exposure at the high thresholds resulting from an instantaneous surface release of Crux condensate at the Crux platform.

RPS

3.3.1.2 Floating and Shoreline Hydrocarbons

The annualised probability contour figures (Figure 3.16, Figure 3.17 and Appendix B) indicate that hydrocarbons on the sea surface at or greater than the threshold concentrations remain in relatively close proximity to the release location, with limited potential for interaction with the nearest shoreline receptors. The maximum distance to the outer extent of the low floating oil threshold (1 g/m^2) is predicted to be 116 km (Table 3.8). The ZoPE at the moderate and high floating oil threshold is further reduced, with floating oil not predicted to exceed the moderate (10 g/m^2) and high (25 g/m^2) thresholds beyond distances of 17 km and 14 km, respectively.

The Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors have the highest predicted probability of contact, being 100% for all thresholds (Table 3.9). Only a small number of other receptors are predicted to receive floating oil at the low threshold concentration, with the highest probability of contact with the waters above Vulcan Shoals being 7.2%.

The minimum time to contact with any receptor by floating oil at the low threshold is forecast at approximately 1 hour at the Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors.

Potential for accumulation of hydrocarbons on shorelines is predicted to be low (<1% probability at the moderate threshold of 100 g/m^2), with a maximum accumulated volume of 2 m^3 forecast at Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters, and also Green Turtle BIA, and maximum local accumulated concentration on shorelines of 127 g/m^2 forecast at Ashmore Reef and Cartier Island, Green Turtle BIA and Hawksbill Turtle BIA (Table 3.9).

Table 3.8 Maximum distances from the release location to zones of floating oil exposure for Scenario 2 (88 m^3 Crux condensate).

	Floating Oil Exposure Threshold		
	Low (1-10 g/m^2)	**Moderate (10-25 g/m^2)**	**High (>25 g/m^2)**
Maximum distance travelled (km) by a spill trajectory	116	17	14

3.3.1.3 Subsurface – Entrained Hydrocarbons

The annualised probability contour figures (Figure 3.19 and Appendix B) indicate that entrained oil concentrations at or greater than the threshold concentrations travel up to 566 km (10 ppb) from the release location. The maximum extent is forecast to be reduced for the moderate (100 ppb; 494 km) and high (500 ppb; 195 km) thresholds.

A small number of receptors are predicted to receive entrained oil at high threshold concentrations. Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors are predicted to be contacted at the high threshold with probabilities less than 4% (Table 3.10). Higher probabilities of contact at a greater number of receptors are predicted at the low and moderate thresholds.

Receptors with the highest probability of receiving entrained oil concentrations at the low threshold are Southern Bluefin Tuna Fishery (14%), Western Skipjack Fishery (14%), Western Tuna and Billfish Fishery (14%) and North-West Slope Trawl Fishery (13%). Entrained oil concentrations at the low threshold are also forecast at Vulcan Shoals (11%), Continental Slope Demersal Fish Communities KEF (7%), Carbonate Bank and Terrace System of Sahul Shelf KEF (7%), Green Turtle BIA (5%), Goeree Shoal (6%), Ancient Coastline at 125 m Depth Contour KEF (5%), Flatback Turtle BIA (5%), Loggerhead Turtle BIA (5%), Olive Ridley Turtle BIA (5%), Oceanic Shoals AMP (5%), Ashmore Reef AMP (3%) and Cartier Island AMP (4%). The listed sensitive receptors are also contacted at the moderate threshold with lower probabilities.

The minimum time to contact with any receptor by entrained oil at the low and moderate thresholds is forecast at Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery, at approximately 1 hour.

3.3.1.4 Subsurface – Dissolved Aromatic Hydrocarbons

The annualised probability contour figures (Figure 3.21 and Figure 3.22) indicate that dissolved aromatic hydrocarbons at or greater than the threshold concentrations travel up to 465 km (6 ppb) from the release location. The maximum extent is forecast to be reduced for the moderate threshold (50 ppb; 47 km), and the high (400 ppb) threshold is not exceeded for this scenario.

No receptors are predicted to receive dissolved aromatic hydrocarbons at high threshold concentrations. Southern Bluefin Tuna Fishery, Western Skipjack Fishery, Western Tuna and Billfish Fishery receptors are predicted to have the highest probability of contact at the low and moderate thresholds with probabilities of 8% and 1%, respectively (Table 3.11). Lower probabilities of contact are predicted at several receptors at the low threshold, with the highest at Vulcan Shoals (4%).

3.3.1.5 Deterministic Cases

A replicate simulation during the winter season (spill starting at 14:00 12th April 2013) has been identified as the worst-case replicate according to the maximum oil volume accumulated across all shoreline receptors, minimum time to commencement of oil accumulation at any shoreline receptor and maximum length of oiled shoreline criteria for Scenario 2 (2 m^3, 11.9 days and 2 km, respectively, at Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF). Figures showing the evolution of this spill simulation are contained in Appendix E. Hydrocarbons on the sea surface mainly drifted north-west of the release location. The potential floating oil exposure zones were shown up to 57 km, 8 km and 1 km of the release location at the low, moderate and high thresholds, respectively. The entrained oil and dissolved aromatic hydrocarbons were shown to move west of the release location. Low entrained hydrocarbons were recorded up to 304 km from the release location. Low dissolved aromatic hydrocarbons were observed up to 1 km from the release location.

RPS

3.3.2 Floating and Shoreline Hydrocarbons

Table 3.9 Expected annualised floating and shoreline oil outcomes at sensitive receptors resulting from an instantaneous surface release of Crux condensate at the Crux platform.

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
Islands	Browse Island	<0.3	<0.3	<0.3	NC	NC	NC	0.6	<0.3	<0.3	218	NC	NC	<0.1	16	<1	<1	<1	<1
Reefs	East Holothuria Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Hibernia Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sandy Islet	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Scott Reef North*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Scott Reef South	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Seringapatam Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	The Boxers*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	The Boxers Area*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	West Holothuria Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Barracouta Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Barton Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Deep Shoal 1*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Deep Shoal 2*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dillon Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Echuca Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Eugene McDermott Shoal*	1.5	<0.3	<0.3	20	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fantome Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Goeree Shoal*	2.1	<0.3	<0.3	15	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Heywood Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jabiru Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Karmt Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mangola Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Penguin Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Penguin Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Van Cloon Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m^2)		Maximum accumulated volume (m^3) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Vee Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Vulcan Shoals*	7.2	0.9	0.6	5	5	5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Baldwin Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Favell Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Flat Top Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Gale Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Holothuria Banks*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Johnson Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Otway Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sahul Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Woodbine Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Marine Parks	Ashmore Reef AMP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	1.5	<1	<1	NC	NC
	Cartier Island AMP	<0.3	<0.3	<0.3	NC	NC	NC	0.6	0.6	<0.3	285	294	NC	0.4	127	<1	2	<1	2
	Kimberley AMP	0.9	<0.3	<0.3	109	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	North Lalang-garram MP & North Kimberley MP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.3	<1	<1	NC	NC
	Oceanic Shoals AMP*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Ancient Coastline at 125 m depth contour*	0.9	<0.3	<0.3	40	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	<0.3	<0.3	<0.3	NC	NC	NC	0.6	0.6	<0.3	285	294	NC	0.4	127	<1	2	<1	2
	Carbonate bank & terrace system of Van Diemen Rise*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carbonate bank and terrace system of Sahul Shelf	0.6	<0.3	<0.3	174	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Continental Slope Demersal Fish Communities*	0.6	<0.3	<0.3	114	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Pinnacles of the Bonaparte Basin*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
Fisheries	Northern Prawn Fishery	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	North-West Slope Trawl Fishery*	3.6	<0.3	<0.3	15	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Southern Bluefin Tuna Fishery	100	100	100	1	1	1	0.6	0.6	<0.3	285	294	NC	0.4	127	NC	NC	NC	NC
	Western Skipjack Fishery	100	100	100	1	1	1	0.6	0.6	<0.3	285	294	NC	0.4	127	NC	NC	NC	NC
	Western Tuna and Billfish Fishery	100	100	100	1	1	1	0.6	0.6	<0.3	285	294	NC	0.4	127	NC	NC	NC	NC
Biologically Important Areas	Flatback Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Green Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC	0.6	0.6	<0.3	285	294	NC	0.4	127	<1	2	<1	2
	Hawksbill Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC	0.6	0.6	<0.3	285	294	NC	0.4	127	<1	<1	<1	2
	Loggerhead Turtle BIA*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Olive Ridley Turtle BIA*	<0.3	<0.3	<0.3	NC	NC	NC	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.*

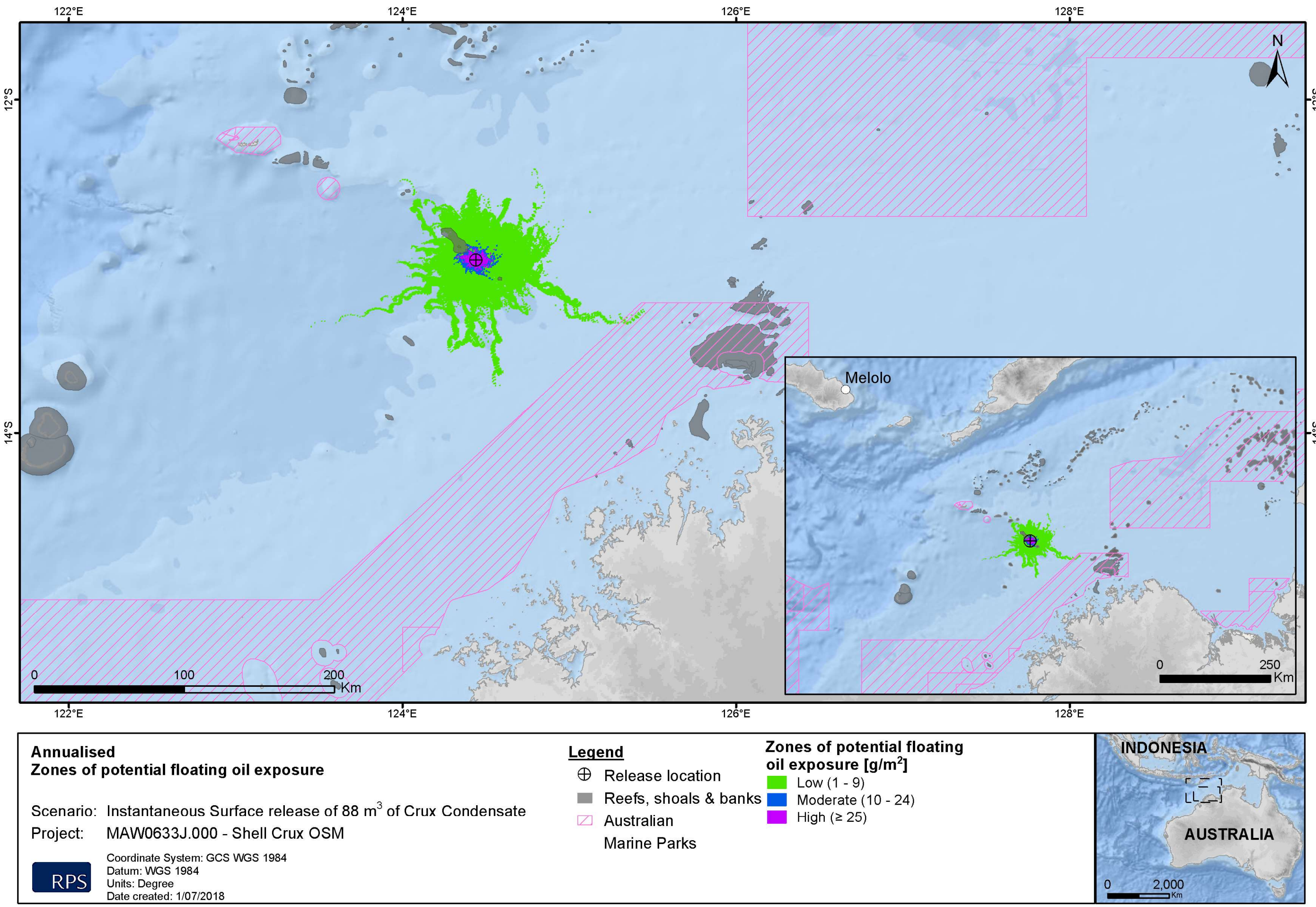


Figure 3.15 Surface Hydrocarbons | Inventory Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined floating oil threshold concentrations resulting from an instantaneous surface release of Crux condensate at the Crux platform.

RPS

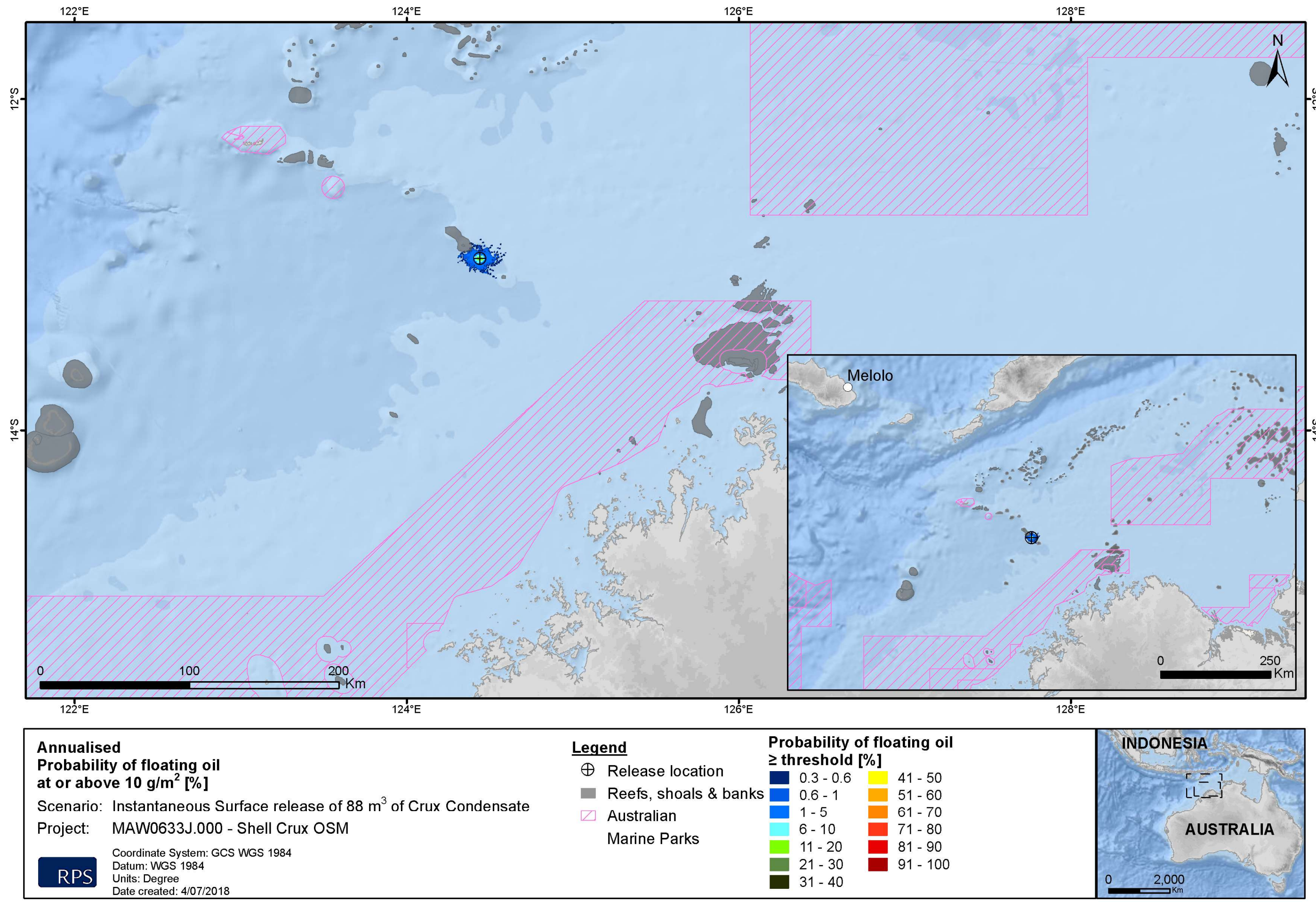


Figure 3.16 Surface Hydrocarbons | Inventory Scenario | Stochastic Outcomes. Predicted annualised probability of floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of Crux condensate at the Crux platform.

RPS

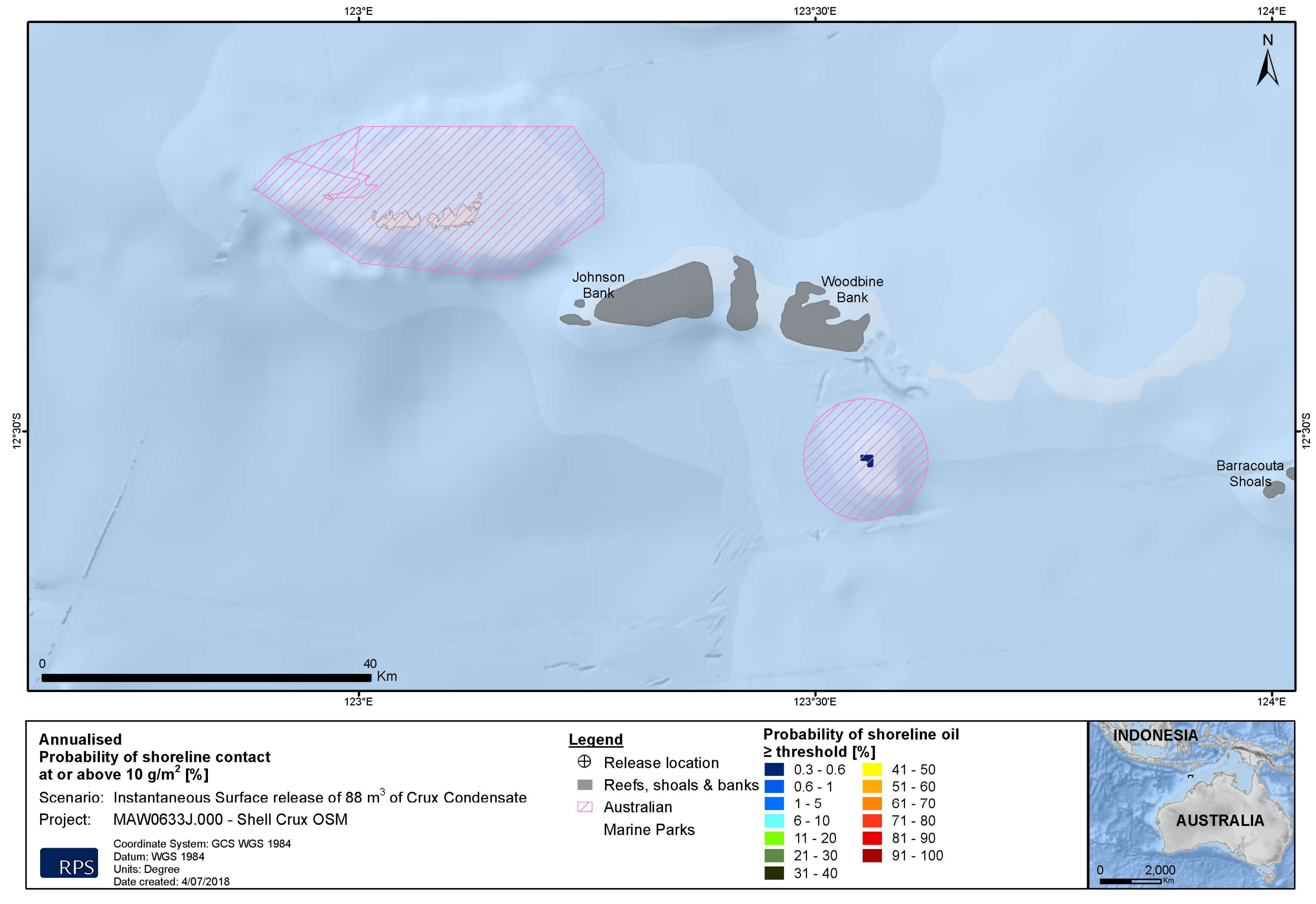


Figure 3.17 Shoreline Hydrocarbons | Inventory Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of Crux condensate at the Crux platform.

RPS

3.3.3 Entrained Hydrocarbons

Table 3.10 Expected annualised entrained oil outcomes at sensitive receptors resulting from an instantaneous surface release of Crux condensate at the Crux platform.

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours) at		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
Islands	Browse Island	1.2	<0.3	<0.3	244	NC	NC
Reefs	East Holothuria Reef	0.6	<0.3	<0.3	232	NC	NC
	Hibernia Reef	1.5	<0.3	<0.3	165	NC	NC
	Sandy Islet	0.6	<0.3	<0.3	444	NC	NC
	Scott Reef North	0.9	<0.3	<0.3	439	NC	NC
	Scott Reef South	0.9	<0.3	<0.3	438	NC	NC
	Seringapatam Reef	0.9	<0.3	<0.3	398	NC	NC
	The Boxers	1.2	<0.3	<0.3	424	NC	NC
	The Boxers Area	1.2	0.6	<0.3	416	425	NC
	West Holothuria Reef	0.6	<0.3	<0.3	213	NC	NC
Shoals	Barracouta Shoals	3.6	0.9	<0.3	68	170	NC
	Barton Shoal	0.6	<0.3	<0.3	399	NC	NC
	Deep Shoal 1	2.1	<0.3	<0.3	169	NC	NC
	Deep Shoal 2	1.2	<0.3	<0.3	374	NC	NC
	Dillon Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Echuca Shoal	2.4	<0.3	<0.3	263	NC	NC
	Eugene McDermott Shoal	3	0.6	<0.3	25	49	NC
	Fantome Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Goeree Shoal	5.7	0.6	<0.3	10	17	NC
	Heywood Shoal	2.4	0.6	<0.3	80	80	NC
	Jabiru Shoals	0.9	<0.3	<0.3	180	NC	NC
	Karmt Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Mangola Shoal	0.6	<0.3	<0.3	371	NC	NC
	Penguin Shoal	1.2	0.6	<0.3	152	154	NC
	Penguin Shoal	1.2	0.6	<0.3	152	154	NC
	Van Cloon Shoal	1.5	<0.3	<0.3	166	NC	NC
	Vee Shoal	0.6	<0.3	<0.3	231	NC	NC

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours) at		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Vulcan Shoals	11.1	3	0.6	6	7	7
Banks	Baldwin Bank	1.8	0.6	<0.3	274	278	NC
	Favell Bank	1.5	0.6	<0.3	87	370	NC
	Flat Top Bank	0.6	<0.3	<0.3	439	NC	NC
	Gale Bank	1.5	<0.3	<0.3	149	NC	NC
	Holothuria Banks	0.9	0.6	<0.3	188	190	NC
	Johnson Bank	2.7	0.6	<0.3	152	162	NC
	Otway Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Sahul Bank	1.2	<0.3	<0.3	130	NC	NC
	Woodbine Bank	1.8	<0.3	<0.3	161	NC	NC
Marine Parks	Ashmore Reef AMP	3	0.9	<0.3	167	176	NC
	Cartier Island AMP	3.6	0.6	<0.3	117	135	NC
	Kimberley AMP	3	0.9	<0.3	76	120	NC
	North Lalang-garram MP & North Kimberley MP	0.6	<0.3	<0.3	225	NC	NC
	Oceanic Shoals AMP	4.5	0.9	0.6	85	86	132
Key Ecological Features	Ancient Coastline at 125 m depth contour	4.8	0.9	<0.3	28	29	NC
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	3.6	0.9	<0.3	112	130	NC
	Carbonate bank & terrace system of Van Diemen Rise	1.5	0.6	<0.3	390	393	NC
	Carbonate bank and terrace system of Sahul Shelf	6.6	1.5	0.6	29	29	30
	Continental Slope Demersal Fish Communities	6.9	0.9	<0.3	48	49	NC
	Pinnacles of the Bonaparte Basin	2.4	0.9	<0.3	237	240	NC
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	1.2	<0.3	<0.3	398	NC	NC
Fisheries	Northern Prawn Fishery	2.7	0.9	0.6	174	176	268
	North-West Slope Trawl Fishery	13.2	5.1	0.6	7	8	9
	Southern Bluefin Tuna Fishery	14.4	7.2	1.5	1	1	1
	Western Skipjack Fishery	14.4	7.2	1.5	1	1	1
	Western Tuna and Billfish Fishery	14.4	7.2	1.5	1	1	1

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours) at		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
Biologically Important Areas	Flatback Turtle BIA	4.5	0.9	0.6	99	101	142
	Green Turtle BIA	5.4	0.9	<0.3	64	66	NC
	Hawksbill Turtle BIA	3.6	0.9	<0.3	142	175	NC
	Loggerhead Turtle BIA	4.5	0.9	0.6	99	101	142
	Olive Ridley Turtle BIA	4.5	0.9	0.6	99	101	142

NC: No contact to receptor predicted for specified threshold.

** Probabilities and maximum concentrations calculated at depth of submerged feature.*

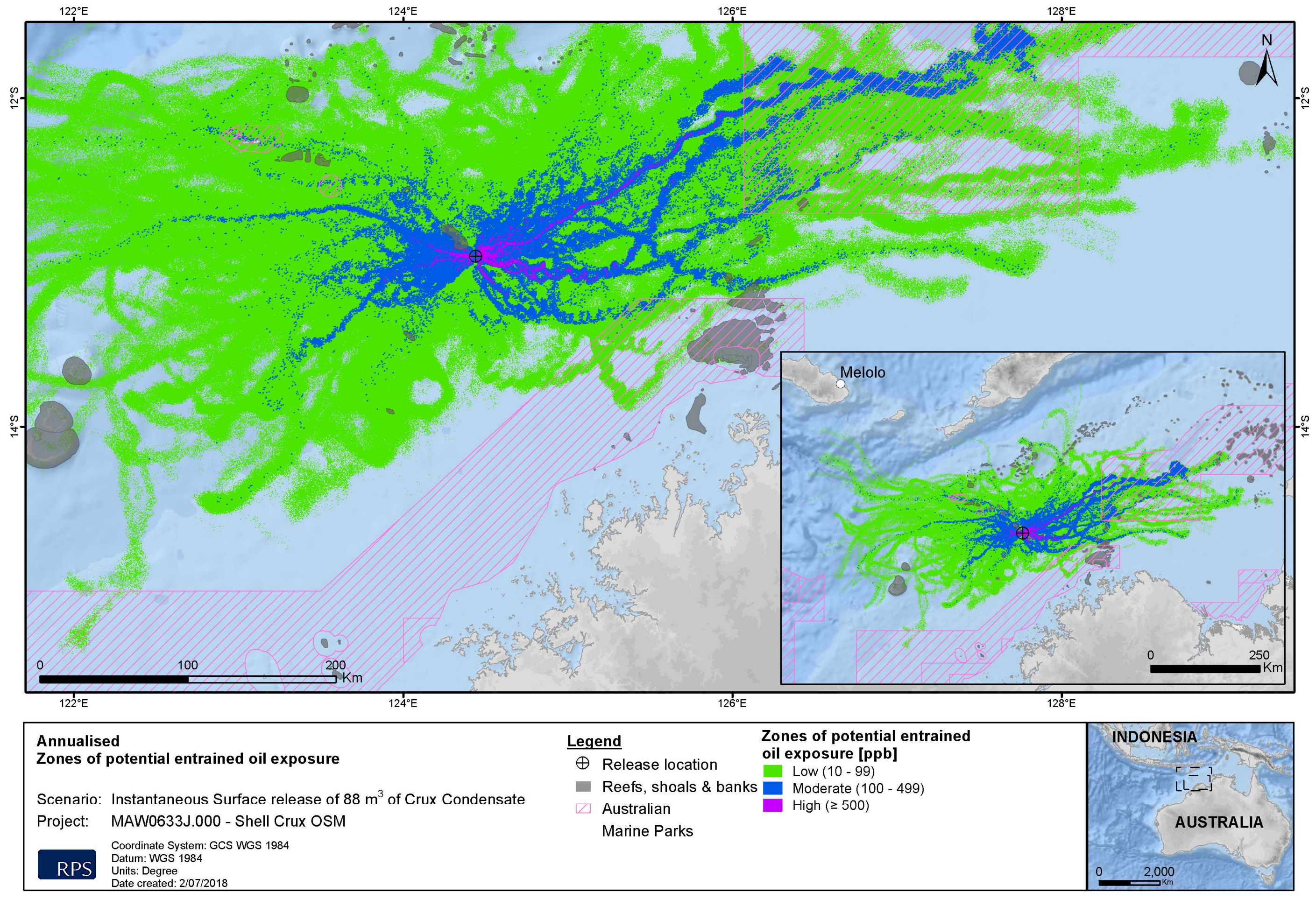


Figure 3.18 Subsurface Hydrocarbons | Entrained | Inventory Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined entrained oil threshold concentrations resulting from an instantaneous surface release of Crux condensate at the Crux platform.

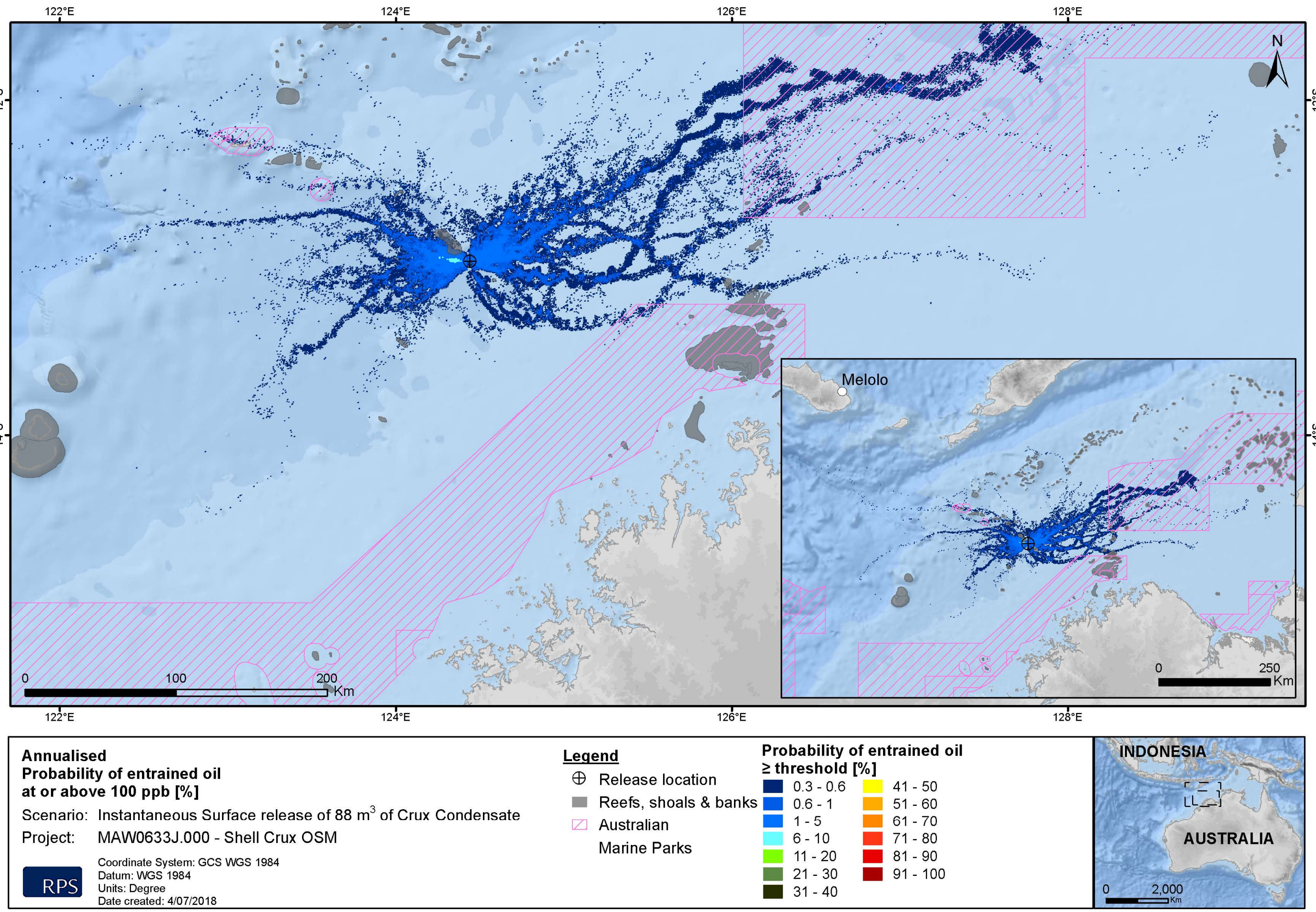


Figure 3.19 Subsurface Hydrocarbons | Entrained | Inventory Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 100 ppb resulting from an instantaneous surface release of Crux condensate at the Crux platform.

RPS

3.3.4 Dissolved Aromatic Hydrocarbons

Table 3.11 Expected annualised dissolved aromatic hydrocarbon outcomes at sensitive receptors resulting from an instantaneous surface release of Crux condensate at the Crux platform.

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
Islands	Browse Island	<0.3	<0.3	<0.3
Reefs	East Holothuria Reef	<0.3	<0.3	<0.3
	Hibernia Reef	<0.3	<0.3	<0.3
	Sandy Islet	<0.3	<0.3	<0.3
	Scott Reef North	<0.3	<0.3	<0.3
	Scott Reef South	<0.3	<0.3	<0.3
	Seringapatam Reef	<0.3	<0.3	<0.3
	The Boxers	<0.3	<0.3	<0.3
	The Boxers Area	<0.3	<0.3	<0.3
	West Holothuria Reef	<0.3	<0.3	<0.3
Shoals	Barracouta Shoals	0.6	<0.3	<0.3
	Barton Shoal	<0.3	<0.3	<0.3
	Deep Shoal 1	<0.3	<0.3	<0.3
	Deep Shoal 2	<0.3	<0.3	<0.3
	Dillon Shoal	<0.3	<0.3	<0.3
	Echuca Shoal	0.6	<0.3	<0.3
	Eugene McDermott Shoal	0.6	<0.3	<0.3
	Fantome Shoal	<0.3	<0.3	<0.3
	Goeree Shoal	0.9	<0.3	<0.3
	Heywood Shoal	<0.3	<0.3	<0.3
	Jabiru Shoals	<0.3	<0.3	<0.3
	Karmt Shoal	<0.3	<0.3	<0.3
	Mangola Shoal	<0.3	<0.3	<0.3
	Penguin Shoal	0.6	<0.3	<0.3
	Penguin Shoal	0.6	<0.3	<0.3
	Van Cloon Shoal	0.6	<0.3	<0.3
	Vee Shoal	<0.3	<0.3	<0.3

RPS

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
	Vulcan Shoals	3.9	0.6	<0.3
Banks	Baldwin Bank	<0.3	<0.3	<0.3
Banks	Favell Bank	<0.3	<0.3	<0.3
Banks	Flat Top Bank	<0.3	<0.3	<0.3
Banks	Gale Bank	0.6	<0.3	<0.3
Banks	Holothuria Banks	0.6	<0.3	<0.3
Banks	Johnson Bank	0.6	<0.3	<0.3
Banks	Otway Bank	<0.3	<0.3	<0.3
Banks	Sahul Bank	<0.3	<0.3	<0.3
Banks	Woodbine Bank	0.6	<0.3	<0.3
Marine Parks	Ashmore Reef AMP	<0.3	<0.3	<0.3
Marine Parks	Cartier Island AMP	0.6	<0.3	<0.3
Marine Parks	Kimberley AMP	0.6	<0.3	<0.3
Marine Parks	North Lalang-garram MP & North Kimberley MP	<0.3	<0.3	<0.3
Marine Parks	Oceanic Shoals AMP	0.9	<0.3	<0.3
Key Ecological Features	Ancient Coastline at 125 m depth contour	0.9	<0.3	<0.3
Key Ecological Features	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	0.6	<0.3	<0.3
Key Ecological Features	Carbonate bank & terrace system of Van Diemen Rise	<0.3	<0.3	<0.3
Key Ecological Features	Carbonate bank and terrace system of Sahul Shelf	1.2	<0.3	<0.3
Key Ecological Features	Continental Slope Demersal Fish Communities	0.9	<0.3	<0.3
Key Ecological Features	Pinnacles of the Bonaparte Basin	0.6	<0.3	<0.3
Key Ecological Features	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	<0.3	<0.3	<0.3

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
Fisheries	Northern Prawn Fishery	0.9	<0.3	<0.3
	North-West Slope Trawl Fishery	2.7	0.6	<0.3
	Southern Bluefin Tuna Fishery	7.8	1.2	<0.3
	Western Skipjack Fishery	7.8	1.2	<0.3
	Western Tuna and Billfish Fishery	7.8	1.2	<0.3
Biologically Important Areas	Flatback Turtle BIA	0.9	<0.3	<0.3
	Green Turtle BIA	0.9	<0.3	<0.3
	Hawksbill Turtle BIA	0.6	<0.3	<0.3
	Loggerhead Turtle BIA	0.9	<0.3	<0.3
	Olive Ridley Turtle BIA	0.9	<0.3	<0.3

NC: No contact to receptor predicted for specified threshold.

** Probabilities and maximum concentrations calculated at depth of submerged feature.*

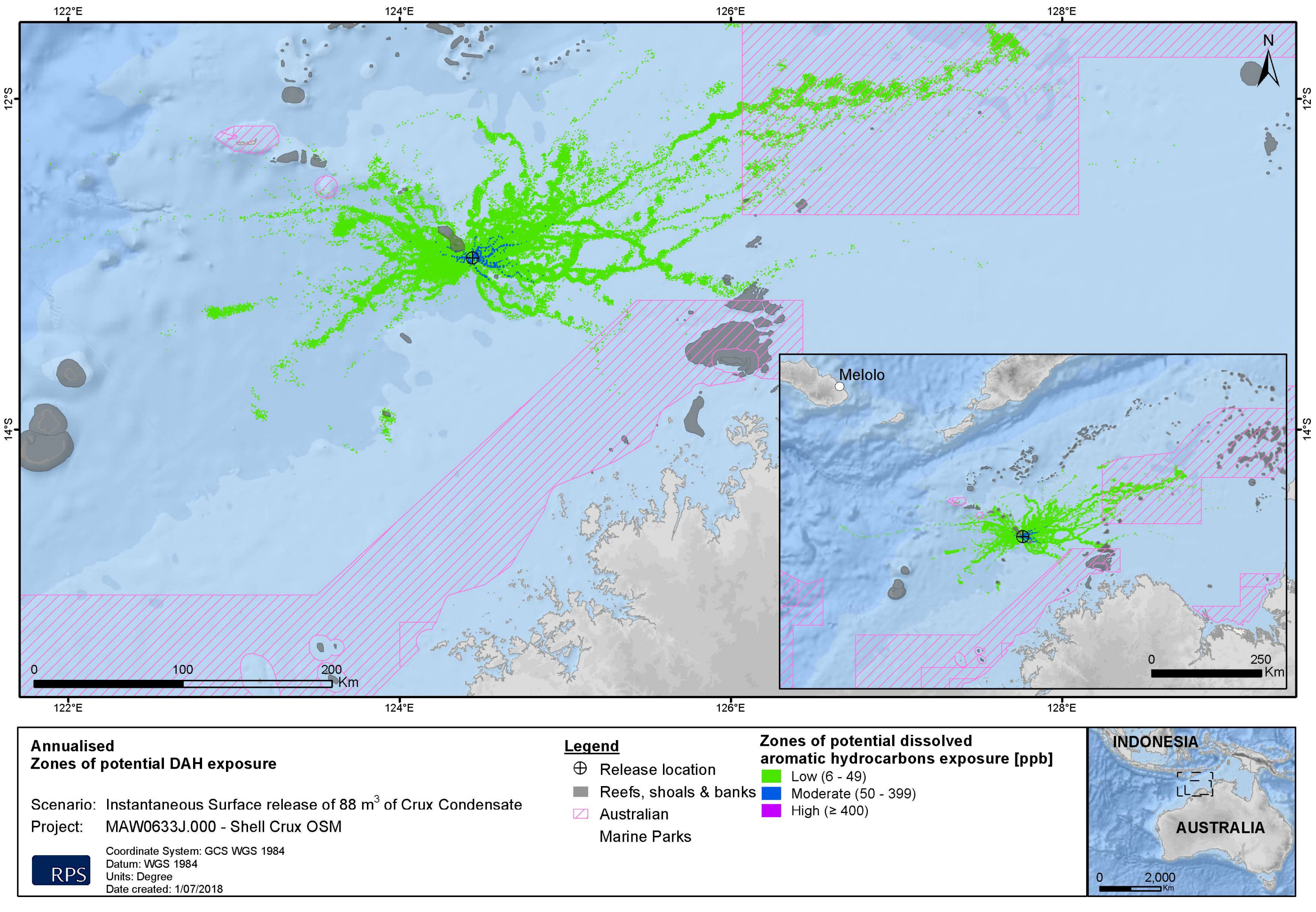


Figure 3.20 Subsurface Hydrocarbons | Dissolved | Inventory Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined dissolved aromatic hydrocarbon threshold concentrations resulting from an instantaneous surface release of Crux condensate at the Crux platform.

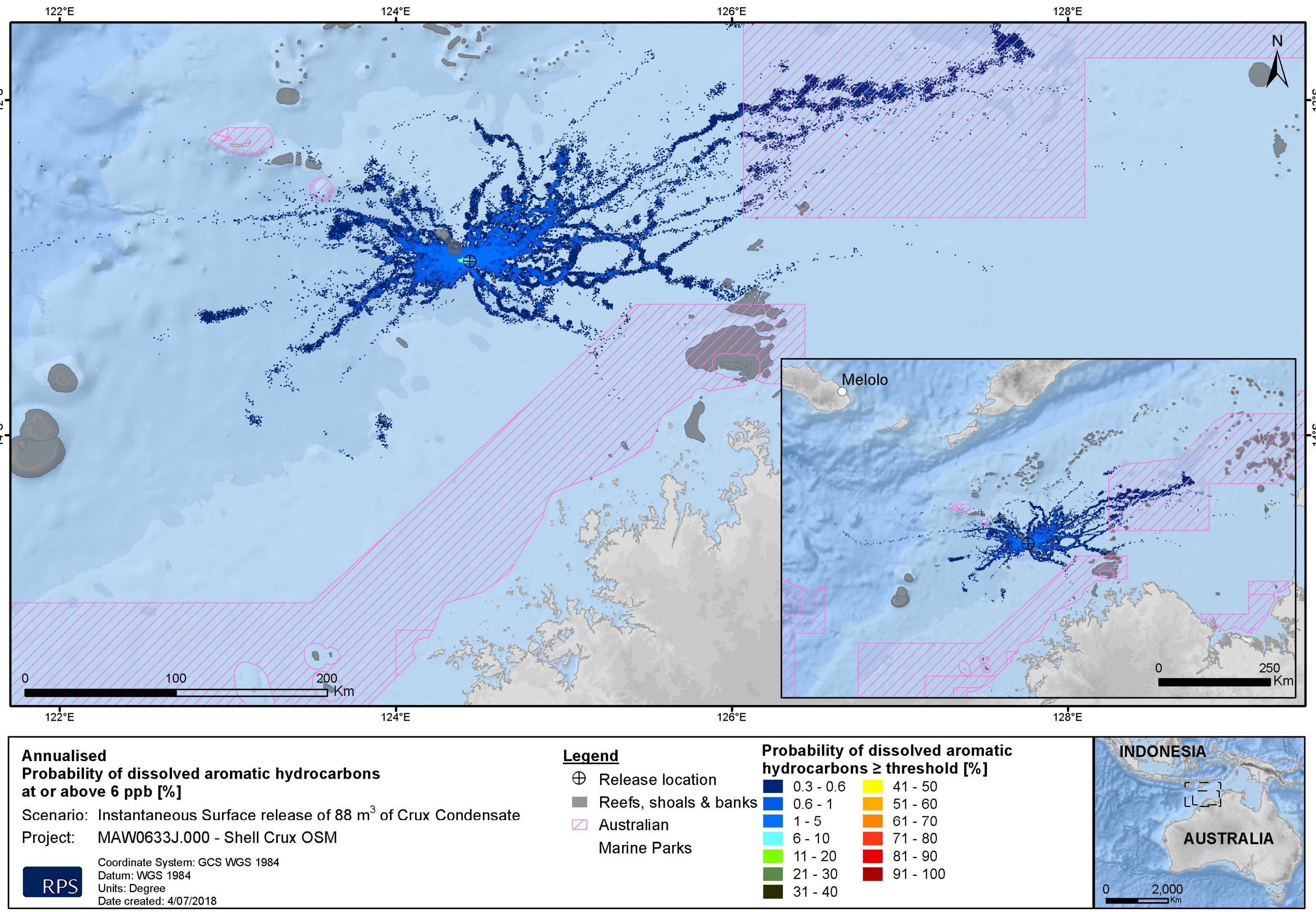
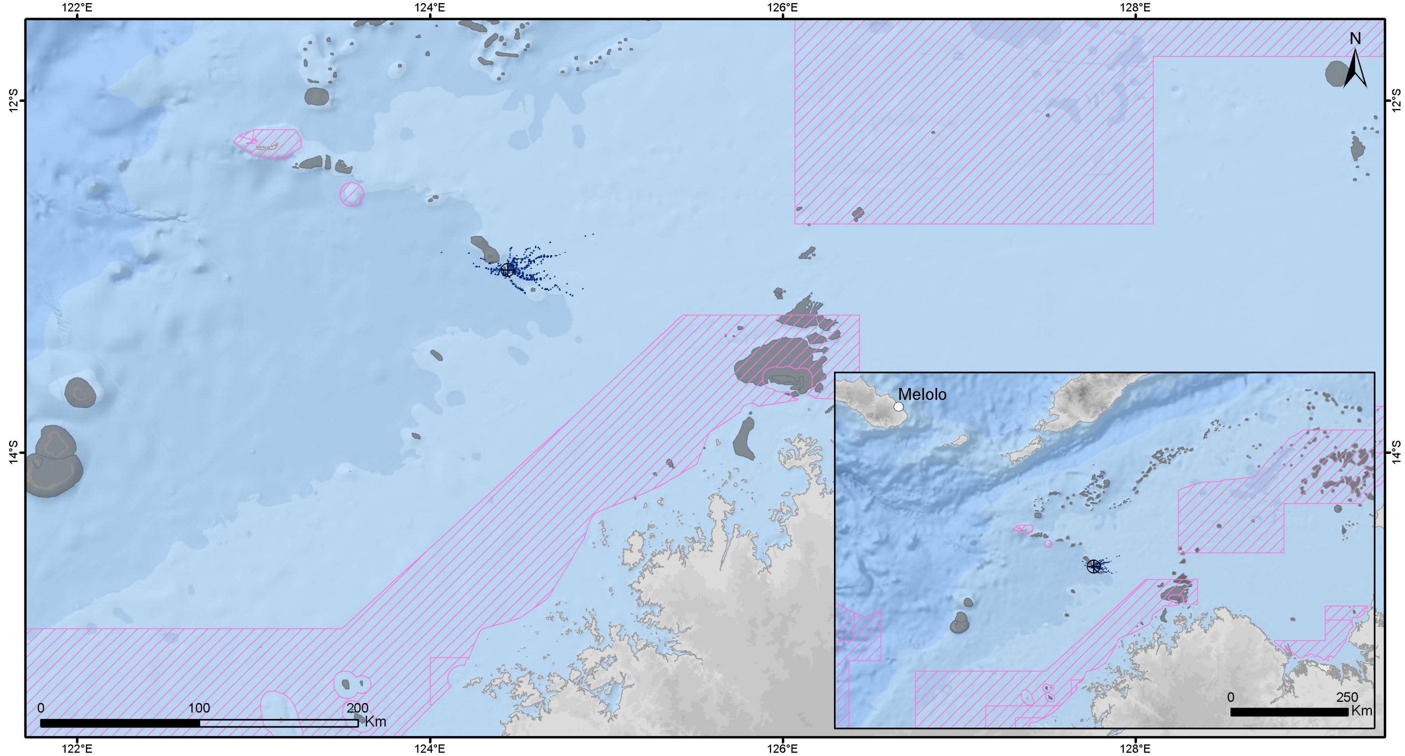


Figure 3.21 Subsurface Hydrocarbons | Dissolved | Inventory Scenario | Stochastic Outcomes. Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 6 ppb resulting from an instantaneous surface release of Crux condensate at the Crux platform.



Annualised
Probability of dissolved aromatic hydrocarbons at or above 50 ppb [%]

Scenario: Instantaneous Surface release of 88 m^3 of Crux Condensate

Project: MAW0633J.000 - Shell Crux OSM

Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree
Date created: 4/07/2018

Legend
- Release location
- Reefs, shoals & banks
- Australian Marine Parks

Probability of dissolved aromatic hydrocarbons ≥ threshold [%]

0.3 - 0.6, 0.6 - 1, 1 - 5, 6 - 10, 11 - 20, 21 - 30, 31 - 40, 41 - 50, 51 - 60, 61 - 70, 71 - 80, 81 - 90, 91 - 100

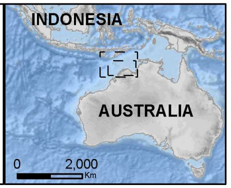


Figure 3.22 Subsurface Hydrocarbons | Dissolved | Inventory Scenario | Stochastic Outcomes. Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from an instantaneous surface release of Crux condensate at the Crux platform.

3.4 Scenario 3 – Short-Term Subsurface Release of Crux Condensate from a Pipeline Rupture Near Heywood Shoal

3.4.1 Discussion of Results

3.4.1.1 Overview

This scenario investigated the probability of exposure to key sensitive receptors by hydrocarbons resulting from a short-term (5.6 hour) subsurface release following from a rupture of the export pipeline, discharging 2,037 m^3 of Crux condensate at the closest point to Heywood Shoal at any time of year, with no spill response mitigation measures applied.

Considering the discharge characteristics, the properties of the hydrocarbon and its expected weathering behaviour, the relatively large hydrocarbon droplets initially entrained in the water column will rise to the surface within a few hours after release. Floating films are likely to be formed under typical wind conditions, and condensate that is re-entrained into the wave-mixed layer under stronger wind conditions will have the potential to rise back to the surface once calmer conditions prevail. It is likely that the bulk of the hydrocarbon mass will initially be found on the water surface or in the wave-mixed layer. Once at the surface evaporation rates will be high, given the large proportion of volatile (55%) and semi-volatile (23%) compounds within the oil, with the residual fraction (8%) persisting in the environment until degradation processes occur (over periods of weeks to months). Considering the spill volume and the relatively high likelihood of entrainment occurring, there is a high potential for dissolution of soluble aromatic compounds.

Figure 3.23 to Figure 3.25 show a summary of the areal extent for all hydrocarbon phases at the low, moderate and high thresholds, respectively.

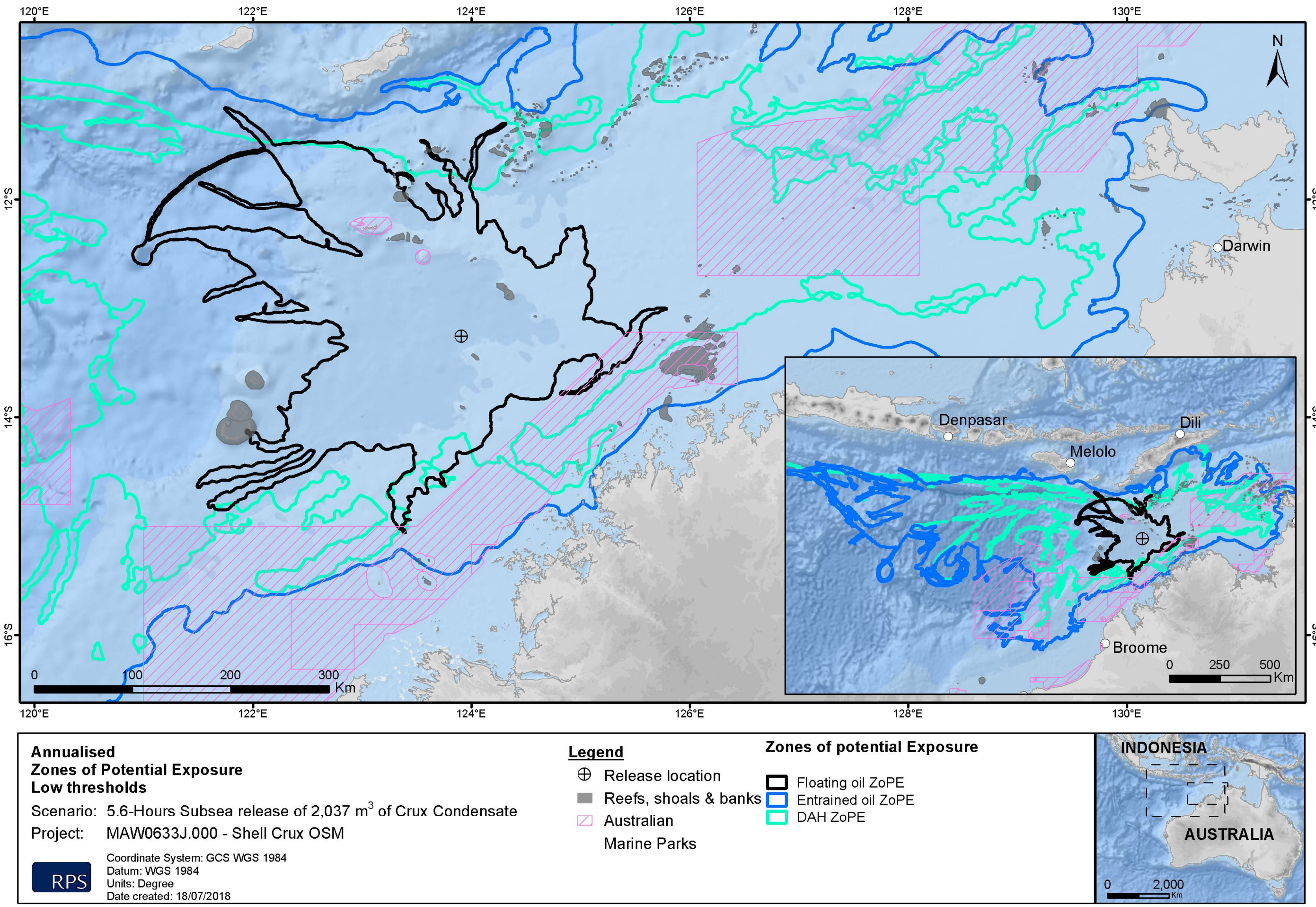


Figure 3.23 Surface and Subsurface Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Areal extent of potential exposure at the low thresholds resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

RPS

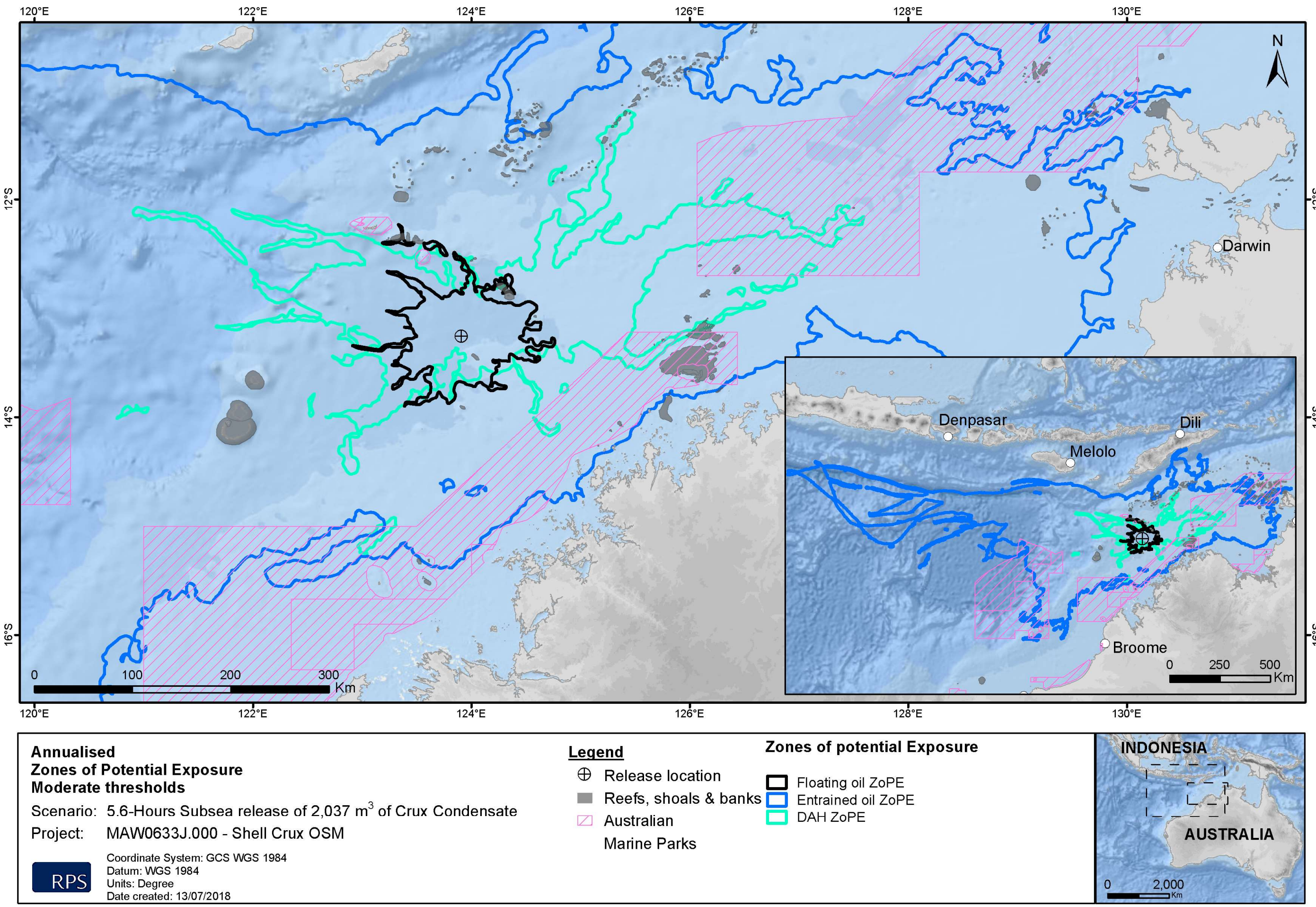


Figure 3.24 Surface and Subsurface Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Areal extent of potential exposure at the moderate thresholds resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

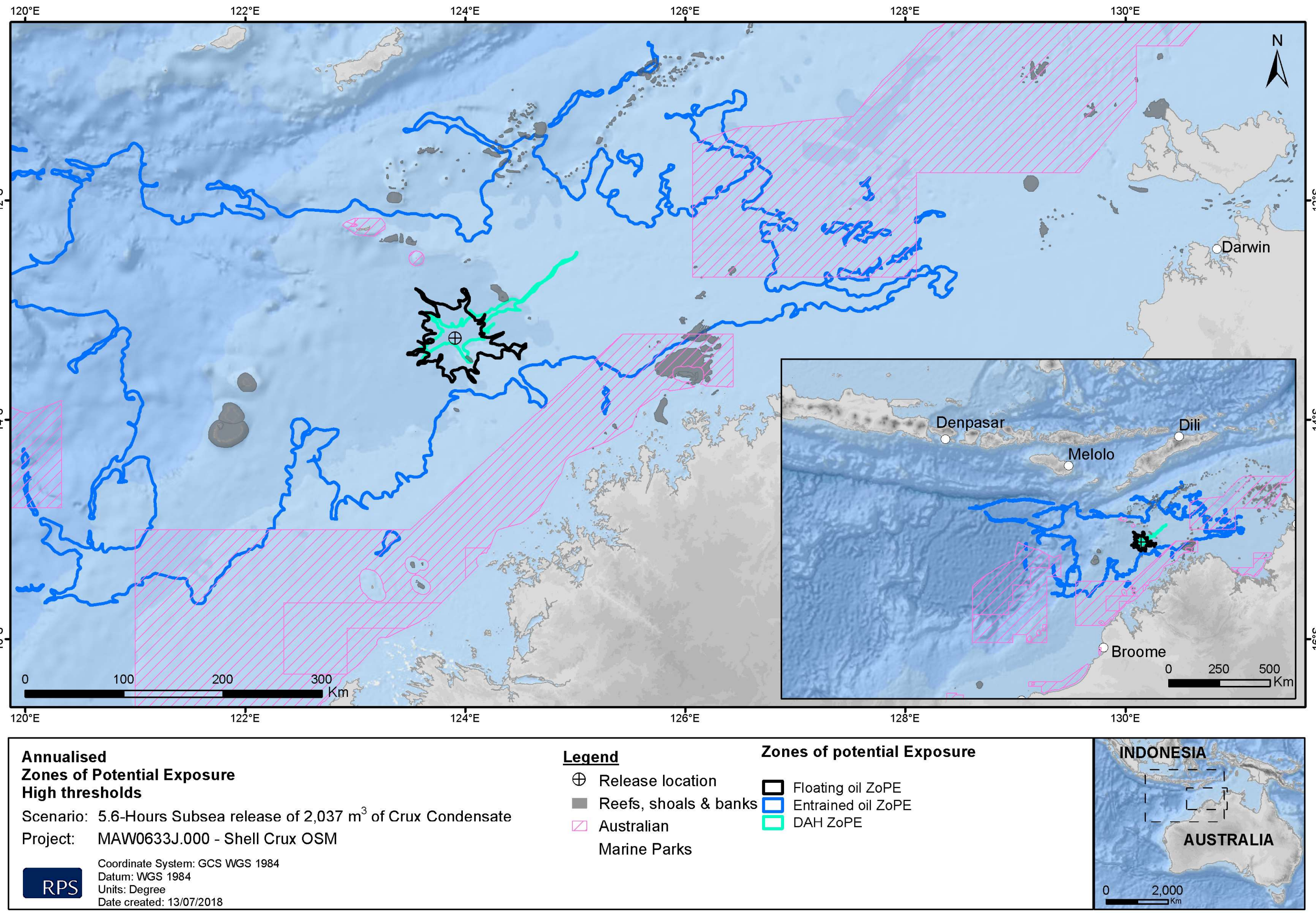


Figure 3.25 Surface and Subsurface Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Areal extent of potential exposure at the high thresholds resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

RPS

3.4.1.2 Floating and Shoreline Hydrocarbons

The annualised probability contour figures (Figure 3.27 and Appendix C) indicate that hydrocarbons on the sea surface at or greater than the threshold concentrations may travel up to 581 km (1 g/m^2) from the release location, with low probability of contact to the nearest shoreline receptors. The ZoPE at the moderate and high floating oil threshold is further reduced, with floating oil not predicted to exceed the moderate (10 g/m^2) and high (25 g/m^2) thresholds beyond distances of 130 km and 118 km, respectively.

Only a small number of receptors are predicted to receive floating oil at high threshold concentrations. The Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors have the highest predicted probability of contact at the high threshold, being 71% (Table 3.13). Probabilities of 75% are predicted at the moderate threshold for these receptors.

The minimum time to contact with any receptor by floating oil at the low and moderate thresholds is forecast at approximately 2 hours at the Southern Bluefin Tuna Fishery, Western Skipjack Fishery, Western Tuna and Billfish Fishery, and North-West Slope Trawl Fishery receptors.

Potential for accumulation of hydrocarbons on shorelines is predicted to be low (<3% probability at the moderate threshold of 100 g/m^2), with a maximum accumulated volume of 116 m^3 forecast at Hawksbill Turtle BIA, Green Turtle BIA and Ashmore Reef AMP. Maximum local accumulated concentration on shorelines of 3,131 g/m^2 is forecast at Hawksbill Turtle BIA, Green Turtle BIA and Ashmore Reef AMP (Table 3.13).

Table 3.12 Maximum distances from the release location to zones of floating oil exposure for Scenario 3 (2,037 m^3 Crux condensate).

	Floating Oil Exposure Threshold		
	Low (1-10 g/m^2)	Moderate (10-25 g/m^2)	High (>25 g/m^2)
Maximum distance travelled (km) by a spill trajectory	581	130	118

3.4.1.3 Subsurface – Entrained Hydrocarbons

The annualised probability contour figures (Figure 3.29 and Appendix C) indicate that entrained oil concentrations at or greater than the threshold concentrations travel up to 1,770 km (10 ppb) from the release location. The maximum extent is forecast to be reduced for the moderate (100 ppb; 1,762 km) and high (500 ppb; 1,478 km) thresholds.

A small number of receptors are predicted to receive entrained oil at high threshold concentrations. Southern Bluefin Tuna Fishery, Western Skipjack Fishery, Western Tuna and Billfish Fishery, and North-West Slope Trawl Fishery receptors are predicted to be contacted at the high threshold with probabilities greater than 45% (Table 3.14). Higher probabilities of contact at a greater number of receptors are predicted at the low and moderate thresholds.

Receptors with the highest probability of receiving entrained oil concentrations at the low threshold are Continental Slope Demersal Fish Communities KEF (23%), Ancient Coastline at 125 m Depth Contour KEF (22%), Carbonate Bank and Terrace System of Sahul Shelf KEF (17%), Eugene McDermott Shoal (23%) and Vulcan Shoals (16%). The listed sensitive receptors are also contacted at the moderate threshold with lower probabilities.

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The minimum time to contact with any receptor by entrained oil at the low threshold is forecast at Southern Bluefin Tuna Fishery, Western Skipjack Fishery, Western Tuna and Billfish Fishery, and North-West Slope Trawl Fishery, at approximately 1 hour.

3.4.1.4 Subsurface – Dissolved Aromatic Hydrocarbons

The annualised probability contour figures (Figure 3.32 to Figure 3.34) indicate that dissolved aromatic hydrocarbons at or greater than the threshold concentrations travel up to 1,770 km (6 ppb) from the release location. The maximum extent is forecast to be reduced for the moderate (50 ppb; 715 km) and high (400 ppb; 251 km) thresholds.

A small number of receptors are predicted to receive dissolved aromatic hydrocarbons at high threshold concentrations. Southern Bluefin Tuna Fishery, Western Skipjack Fishery, Western Tuna and Billfish Fishery, and North-West Slope Trawl Fishery receptors are predicted to be contacted at the high threshold with probabilities of 5 % (Table 3.15). These receptors are predicted to be contacted at the moderate threshold with probabilities of 16%.

Receptors with the highest probability of receiving dissolved aromatic hydrocarbons at low threshold concentrations are Continental Slope Demersal Fish Communities KEF (9%), Ancient Coastline at 125 m Depth Contour KEF (8%), and Eugene McDermott Shoal (7%). These receptors are also contacted at the moderate threshold with lower probabilities.

3.4.1.5 Deterministic Cases

A replicate simulation during the transitional season (spill starting at 21:00 14th September 2011) has been identified as the worst-case replicate according to the maximum oil volume accumulated across all shoreline receptors and minimum time to commencement of oil accumulation at any shoreline receptor criteria for Scenario 3 (116 m^3 and 6 days, respectively, at Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF). Figures showing the evolution of this spill simulation are contained in Appendix E. Hydrocarbons on the sea surface mainly drifted north-west of the release location. The potential floating oil exposure zones were shown up to 312 km, 34 km and 14 km of the release location at the low, moderate and high thresholds, respectively. The entrained oil and dissolved aromatic hydrocarbons were shown to move west and south-west of the release location. Low, moderate and high entrained hydrocarbons were recorded up to 1,419 km, 1,323 km and 12 km, respectively, from the release location. Low and moderate dissolved aromatic hydrocarbons were observed up to 428 km, 276 km, respectively, from the release location.

A replicate simulation during the transitional season (spill starting at 10:00 19th September 2014) has been identified as the worst-case replicate according to the maximum length of oiled shoreline criteria for Scenario 3 (10 km at Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF). Hydrocarbons on the sea surface mainly drifted north-west of the release location. The potential floating oil exposure zones were shown up to 115 km, 12 km and 10 km of the release location at the low, moderate and high thresholds, respectively. The entrained oil and dissolved aromatic hydrocarbons were shown to move west and northwest of the release location. Low, moderate and high entrained hydrocarbons were recorded up to 1,017km, 2 km and 2 km, respectively, from the release location. Low and moderate dissolved aromatic hydrocarbons were observed up to 20 km and 2 km, respectively, from the release location.

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3.4.2 Floating and Shoreline Hydrocarbons

Table 3.13 Expected annualised floating and shoreline oil outcomes at sensitive receptors resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
Coastlines	Cobourg Peninsula	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	4.2	<1	<1	NC	NC
	Indonesia	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	2.1	<1	<1	NC	NC
	Joseph Bonaparte Gulf Northern Territory	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	1.3	<1	<1	NC	NC
	Kimberley Coast	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	5.4	<1	<1	NC	NC
	Timor Leste	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
Islands	Admiralty Gulf Islands	<0.3	<0.3	<0.3	NC	NC	NC	0.6	<0.3	<0.3	959	NC	NC	<0.1	24	<1	<1	<1	<1
	Bathurst Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC
	Bigge Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	2	<1	<1	NC	NC
	Bonaparte Archipelago	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	6.7	<1	<1	NC	NC
	Browse Island	1.5	<0.3	<0.3	142	NC	NC	4.2	2.7	0.9	148	149	151	23	2,009	2	48	<1	3
	Cassini Island	<0.3	<0.3	<0.3	NC	NC	NC	0.6	<0.3	<0.3	874	NC	NC	0.1	32	<1	<1	<1	4
	Coronation Island Group	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.3	<1	<1	NC	NC
	Croker Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.7	<1	<1	NC	NC
	Greenhill Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.9	<1	<1	NC	NC
	Jones Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.8	<1	<1	NC	NC
	Long Island Kimberley	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	6.7	<1	<1	NC	NC
	Melville Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	4.6	<1	<1	NC	NC
	Montalivet Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC
	Montgomery Islands	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	1.4	<1	<1	NC	NC
	Montgomery Islands and Reef	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	1.4	<1	<1	NC	NC
	Peron Islands	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC
	Troughton Island	<0.3	<0.3	<0.3	NC	NC	NC	0.9	<0.3	<0.3	819	NC	NC	0.3	75	<1	<1	<1	<1
	White Island*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Reefs	Beagle and Dingo Reefs*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	East Holothuria Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Heritage Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Hibernia Reef*	0.6	<0.3	<0.3	281	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ingram Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Jamieson Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Long Reef	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	8.9	<1	<1	NC	NC
	Oliver Rock*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Rothery Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sandy Islet	<0.3	<0.3	<0.3	NC	NC	NC	2.1	<0.3	<0.3	244	NC	NC	0.7	54	<1	<1	<1	<1
	Scott Reef North*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Scott Reef South	0.6	<0.3	<0.3	199	NC	NC	2.1	<0.3	<0.3	244	NC	NC	0.7	54	<1	<1	<1	<1
	Seringapatam Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	The Boxers*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	The Boxers Area*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	West Holothuria Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Barracouta Shoals*	1.2	<0.3	<0.3	156	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Barton Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Bassett-Smith Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Big Bank Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Calder Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Cootamundra Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Deep Shoal 1*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Deep Shoal 2*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dillon Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Echo Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Echuca Shoal*	1.8	<0.3	<0.3	142	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Eugene McDermott Shoal*	3.6	<0.3	<0.3	77	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fantome Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Goeree Shoal*	1.8	<0.3	<0.3	65	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Heywood Shoal*	6	2.7	1.2	13	13	14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jabiru Shoals*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Karmt Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mangola Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marie Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Shoal	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	<0.1	<1	<1	NC	NC

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Moss Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Newby Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Parry Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Pee Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Penguin Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Penguin Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Shepparton Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Van Cloon Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Vee Shoal*	0.6	<0.3	<0.3	260	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Vulcan Shoals*	2.7	0.6	<0.3	61	107	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Baldwin Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Bellona Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Branch Banks*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Favell Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Flat Top Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Gale Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Holothuria Banks*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Johnson Bank*	1.8	0.9	<0.3	122	132	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Margaret Harries Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Otway Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Sahul Bank*	0.6	<0.3	<0.3	299	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Sunrise Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Tait Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Woodbine Bank*	2.1	0.9	<0.3	115	121	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Marine Parks	Ashmore Reef AMP	1.2	<0.3	<0.3	145	NC	NC	2.7	1.2	0.9	145	150	155	15	3,131	2	116	<1	7
Marine Parks	Lalang-garram/Camden Sound MP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	1.4	<1	<1	NC	NC
Marine Parks	Cartier Island AMP	1.5	<0.3	<0.3	104	NC	NC	4.2	2.7	0.6	197	215	338	17	3,131	2	62	<1	4
Marine Parks	Garig Gunak Barlu NP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.9	<1	<1	NC	NC
Marine Parks	Kimberley AMP	0.9	<0.3	<0.3	239	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.4	<1	<1	NC	NC
Marine Parks	North Lalang-garram MP & North Kimberley MP	<0.3	<0.3	<0.3	NC	NC	NC	0.9	<0.3	<0.3	819	NC	NC	0.3	75	<1	3	<1	7
Marine Parks	Mermaid Reef AMP	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.5	<1	<1	NC	NC

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Oceanic Shoals AMP*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Prince Regent NP Coast	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.9	<1	<1	NC	NC
Key Ecological Features	Ancient Coastline at 125 m depth contour*	10.2	5.7	3.9	7	8	8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	2.1	0.9	0.9	103	111	122	4.2	2.7	0.9	145	150	155	17	3,131	3	116	<1	10
Key Ecological Features	Canyons linking the Argo Abyssal Plain with the Scott Plateau*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Carbonate bank & terrace system of Van Diemen Rise*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Carbonate bank and terrace system of Sahul Shelf	0.9	<0.3	<0.3	127	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.2	<1	<1	NC	NC
Key Ecological Features	Continental Slope Demersal Fish Communities*	7.2	2.4	0.9	23	30	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.5	<1	<1	NC	NC
Key Ecological Features	Pinnacles of the Bonaparte Basin*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Key Ecological Features	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	0.6	<0.3	<0.3	198	NC	NC	2.1	<0.3	<0.3	244	NC	NC	0.7	54	<1	<1	<1	<1
Key Ecological Features	Shelf break and slope of the Arafura Shelf*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	Northern Prawn Fishery	0.6	<0.3	<0.3	933	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	4.6	NC	NC	NC	NC
Fisheries	North-West Slope Trawl Fishery	78.9	74.7	71.4	2	2	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	Southern Bluefin Tuna Fishery	78.9	74.7	71.4	2	2	2	4.2	2.7	0.9	145	150	155	17	3,131	NC	NC	NC	NC
Fisheries	Timor Reef Fishery (NT Managed)*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	Western Skipjack Fishery	78.9	74.7	71.4	2	2	2	4.2	2.7	0.9	145	150	155	17	3,131	NC	NC	NC	NC
Fisheries	Western Tuna and Billfish Fishery	78.9	74.7	71.4	2	2	2	4.2	2.7	0.9	145	150	155	17	3,131	NC	NC	NC	NC
Biologically Important Areas	Flatback Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	4.6	<1	<1	NC	NC
Biologically Important Areas	Green Turtle BIA	3	0.9	0.9	91	98	122	4.2	2.7	0.9	145	150	155	17	3,131	3	116	<1	10
Biologically Important Areas	Hawksbill Turtle BIA	1.2	0.9	<0.3	136	139	NC	2.7	1.2	0.9	145	150	155	15	3,131	2	116	<1	7
Biologically Important Areas	Leatherback Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	0.9	<1	<1	NC	NC
Biologically Important Areas	Loggerhead Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
Biologically Important Areas	Olive Ridley Turtle BIA	0.6	<0.3	<0.3	933	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	1	<1	<1	NC	NC

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.*

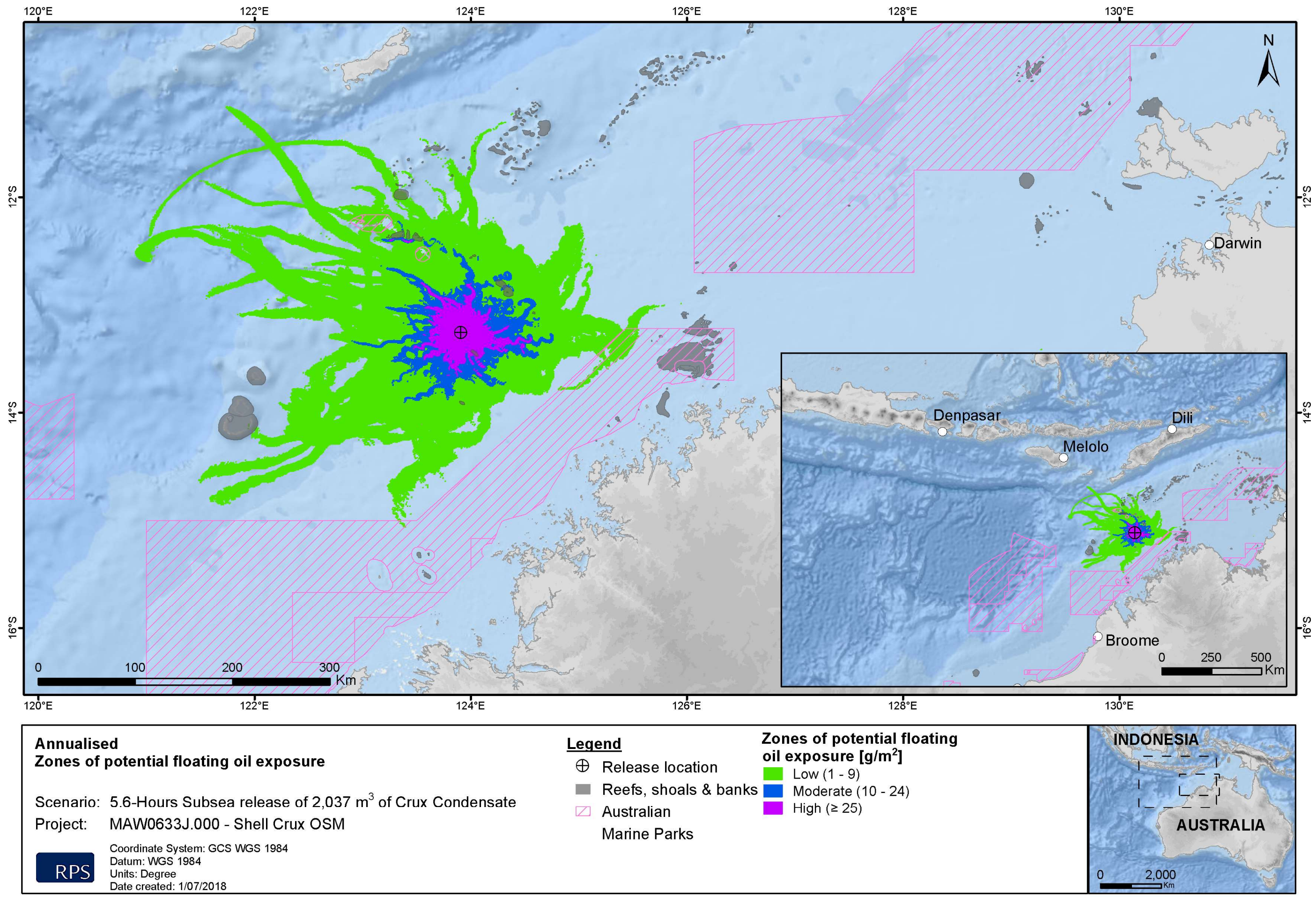


Figure 3.26 Surface Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined floating oil threshold concentrations resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

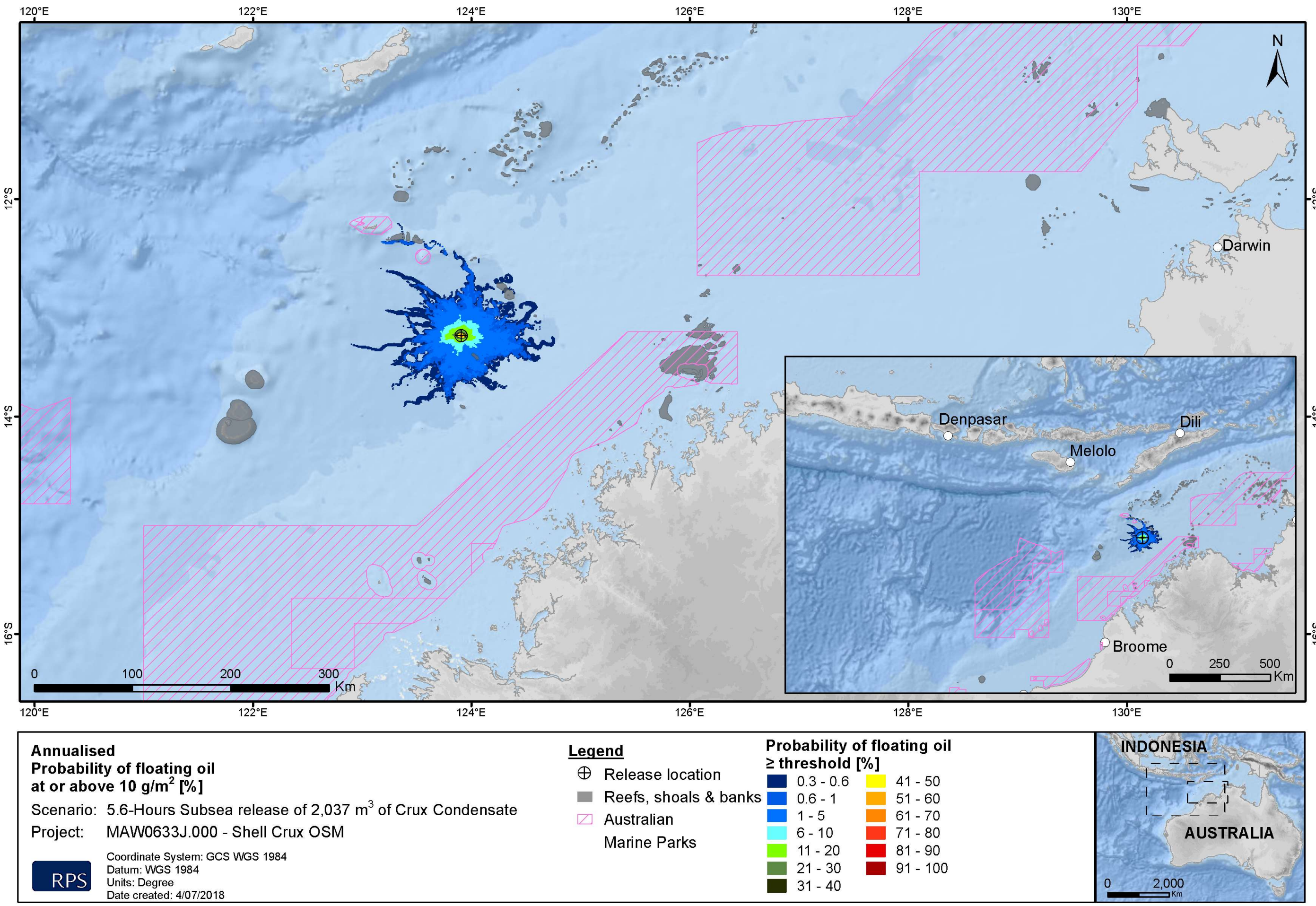


Figure 3.27 Surface Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of floating oil concentrations at or above 10 g/m² resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

RPS

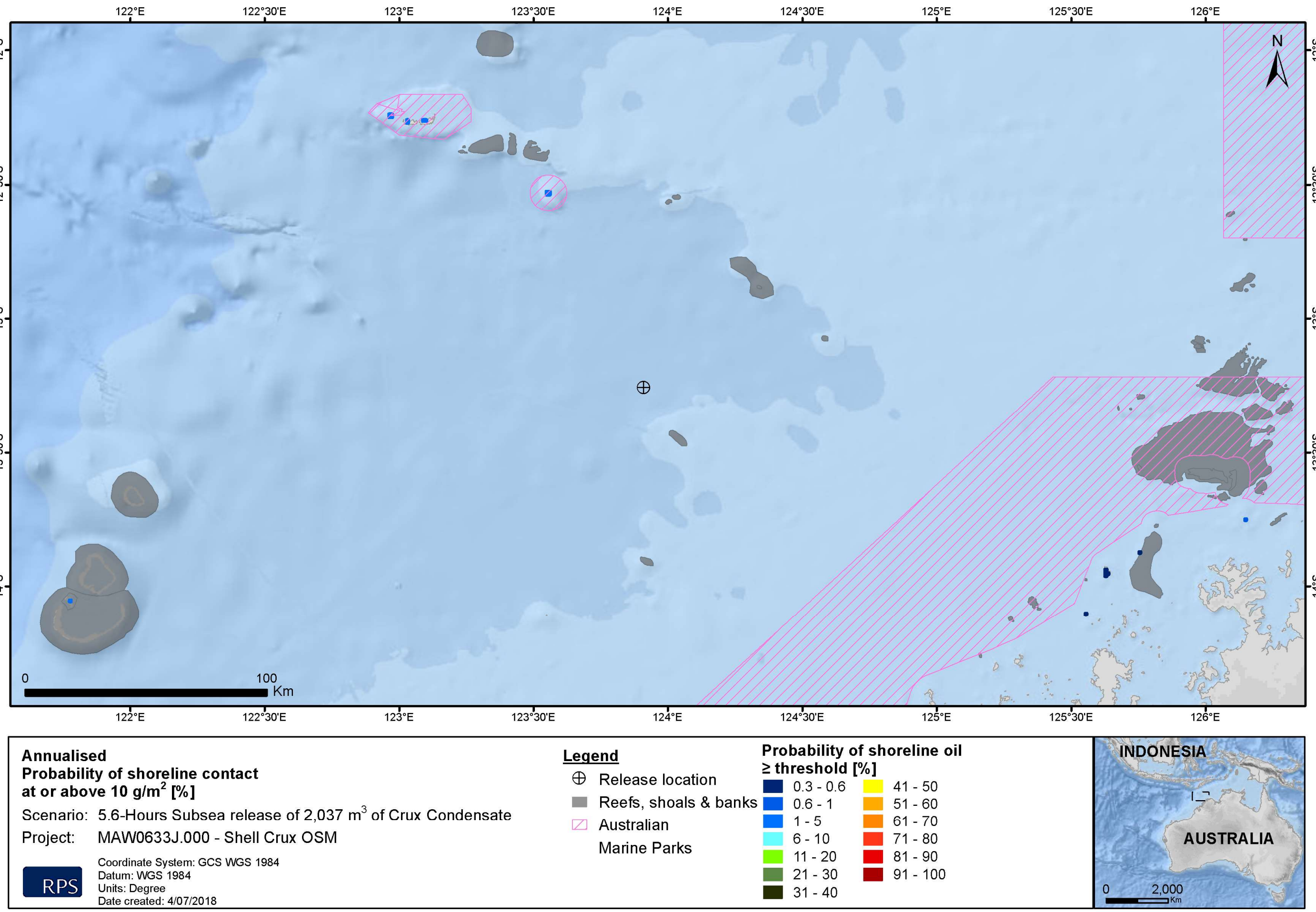


Figure 3.28 Shoreline Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 10 g/m^2 resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

RPS

3.4.3 Entrained Hydrocarbons

Table 3.14 Expected annualised entrained oil outcomes at sensitive receptors resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
Coastlines	Cobourg Peninsula	<0.3	<0.3	<0.3	NC	NC	NC
	Indonesia	0.6	<0.3	<0.3	520	NC	NC
	Joseph Bonaparte Gulf Northern Territory	<0.3	<0.3	<0.3	NC	NC	NC
	Kimberley Coast	0.6	<0.3	<0.3	950	NC	NC
	Timor Leste	0.9	0.6	<0.3	926	987	NC
Islands	Admiralty Gulf Islands	0.6	<0.3	<0.3	444	NC	NC
	Bathurst Island	0.6	<0.3	<0.3	996	NC	NC
	Bigge Island	0.9	0.6	<0.3	347	413	NC
	Bonaparte Archipelago	1.2	0.9	<0.3	283	302	NC
	Browse Island	7.5	1.8	<0.3	97	99	NC
	Cassini Island	0.6	0.6	<0.3	434	439	NC
	Coronation Island Group	0.9	<0.3	<0.3	260	NC	NC
	Croker Island	<0.3	<0.3	<0.3	NC	NC	NC
	Greenhill Island	<0.3	<0.3	<0.3	NC	NC	NC
	Jones Island	<0.3	<0.3	<0.3	NC	NC	NC
	Long Island Kimberley	1.2	0.9	<0.3	261	290	NC
	Melville Island	<0.3	<0.3	<0.3	NC	NC	NC
	Montalivet Island	1.2	0.6	<0.3	362	373	NC
	Montgomery Islands	<0.3	<0.3	<0.3	NC	NC	NC
	Montgomery Islands and Reef	<0.3	<0.3	<0.3	NC	NC	NC
	Peron Islands	0.6	<0.3	<0.3	1,006	NC	NC
	Troughton Island	0.9	0.6	<0.3	544	544	NC
	White Island	0.6	<0.3	<0.3	689	NC	NC
Reefs	Beagle and Dingo Reefs	0.6	0.6	<0.3	390	413	NC
	East Holothuria Reef	1.5	0.6	<0.3	447	470	NC
	Heritage Reef	1.2	0.6	<0.3	360	384	NC
	Hibernia Reef	2.4	0.6	<0.3	291	306	NC
	Ingram Reef	1.2	0.6	<0.3	339	342	NC

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Jamieson Reef	1.8	0.6	<0.3	344	368	NC
	Long Reef	1.2	<0.3	<0.3	445	NC	NC
	Oliver Rock	0.6	0.6	<0.3	418	437	NC
	Rothery Reef	0.9	0.9	<0.3	445	457	NC
	Sandy Islet	7.8	0.9	<0.3	321	522	NC
	Scott Reef North	11.1	3.6	0.9	248	289	343
	Scott Reef South	8.4	1.5	0.6	193	207	556
	Seringapatam Reef	10.5	2.4	0.9	127	135	136
	The Boxers	1.8	0.6	<0.3	698	712	NC
	The Boxers Area	2.4	1.2	<0.3	697	712	NC
	West Holothuria Reef	1.2	<0.3	<0.3	435	NC	NC
Shoals	Barracouta Shoals	6	2.1	0.9	104	122	131
Shoals	Barton Shoal	3.9	1.2	<0.3	448	459	NC
Shoals	Bassett-Smith Shoal	3.6	0.6	<0.3	278	662	NC
Shoals	Big Bank Shoals	1.8	0.6	<0.3	477	596	NC
Shoals	Calder Shoal	1.2	<0.3	<0.3	890	NC	NC
Shoals	Cootamundra Shoal	0.9	<0.3	<0.3	904	NC	NC
Shoals	Deep Shoal 1	5.4	2.7	<0.3	225	225	NC
Shoals	Deep Shoal 2	5.1	0.6	<0.3	443	664	NC
Shoals	Dillon Shoal	3.9	0.9	<0.3	414	730	NC
Shoals	Echo Shoals	1.2	0.6	<0.3	712	723	NC
Shoals	Echuca Shoal	7.2	0.9	<0.3	82	84	NC
Shoals	Eugene McDermott Shoal	22.5	9.3	2.7	49	51	63
Shoals	Fantome Shoal	1.5	<0.3	<0.3	454	NC	NC
Shoals	Goeree Shoal	14.1	5.7	2.1	38	38	38
Shoals	Heywood Shoal	16.2	5.4	1.5	13	14	15
Shoals	Jabiru Shoals	6.6	2.1	0.6	263	265	341
Shoals	Karmt Shoal	4.2	1.2	0.6	432	541	618
Shoals	Mangola Shoal	5.7	1.2	<0.3	299	372	NC
Shoals	Marie Shoal	0.6	<0.3	<0.3	987	NC	NC
Shoals	Mermaid Shoal	0.6	<0.3	<0.3	969	NC	NC
Shoals	Moss Shoal	0.6	<0.3	<0.3	955	NC	NC

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Newby Shoal	2.1	1.2	<0.3	830	893	NC
	Parry Shoal	0.6	0.6	<0.3	938	944	NC
	Pee Shoal	3.6	0.9	<0.3	333	344	NC
	Penguin Shoal	3	0.6	<0.3	204	217	NC
	Penguin Shoal	3	0.6	<0.3	204	217	NC
	Shepparton Shoal	0.9	0.6	<0.3	955	1,006	NC
	Van Cloon Shoal	3.9	1.2	<0.3	402	418	NC
	Vee Shoal	2.1	0.6	<0.3	264	766	NC
	Vulcan Shoals	16.2	7.2	2.7	36	36	36
Banks	Baldwin Bank	4.5	1.8	0.9	186	211	212
	Bellona Bank	1.2	<0.3	<0.3	829	NC	NC
	Branch Banks	0.9	0.6	<0.3	556	557	NC
	Favell Bank	2.7	0.6	<0.3	392	502	NC
	Flat Top Bank	1.2	0.9	<0.3	628	631	NC
	Gale Bank	4.8	1.5	0.9	124	125	127
	Holothuria Banks	3	1.2	0.6	219	226	325
	Johnson Bank	6.9	2.4	0.6	125	140	143
	Margaret Harries Bank	1.8	0.9	0.6	683	709	822
	Otway Bank	1.5	0.9	<0.3	462	462	NC
	Sahul Bank	6	1.8	0.6	273	276	315
	Sunrise Bank	1.2	<0.3	<0.3	976	NC	NC
	Tait Bank	0.9	<0.3	<0.3	567	NC	NC
	Woodbine Bank	8.4	1.8	0.9	117	119	245
Marine Parks	Ashmore Reef AMP	7.5	2.4	0.9	154	157	283
	Lalang-garram/Camden Sound MP	0.6	<0.3	<0.3	475	NC	NC
	Cartier Island AMP	12	3.6	0.6	98	100	111
	Garig Gunak Barlu NP	<0.3	<0.3	<0.3	NC	NC	NC
	Kimberley AMP	8.4	3	1.2	82	95	140
	North Lalang-garram MP & North Kimberley MP	1.5	0.9	0.6	234	246	384
	Mermaid Reef AMP	1.8	0.9	<0.3	796	809	NC
	Oceanic Shoals AMP	11.1	4.2	1.2	123	124	124

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours)		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Prince Regent NP Coast	<0.3	<0.3	<0.3	NC	NC	NC
Key Ecological Features	Ancient Coastline at 125 m depth contour	22.2	11.4	5.1	6	7	8
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	12	3.6	0.9	98	100	111
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	2.7	0.9	<0.3	523	592	NC
	Carbonate bank & terrace system of Van Diemen Rise	3	1.2	0.6	659	662	889
	Carbonate bank and terrace system of Sahul Shelf	17.1	8.1	2.1	74	74	75
	Continental Slope Demersal Fish Communities	23.7	11.7	5.1	24	26	26
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals	1.8	0.9	<0.3	729	809	NC
	Pinnacles of the Bonaparte Basin	6.3	2.1	0.6	287	298	531
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	11.1	3.6	0.9	126	134	136
	Shelf break and slope of the Arafura Shelf	0.6	<0.3	<0.3	996	NC	NC
Fisheries	Northern Prawn Fishery	6.3	2.4	0.9	231	235	239
	North-West Slope Trawl Fishery	79.5	59.7	52.2	1	1	1
	Southern Bluefin Tuna Fishery	79.5	59.7	52.2	1	1	1
	Timor Reef Fishery (NT Managed)	1.8	0.9	0.6	758	780	822
	Western Skipjack Fishery	79.5	59.7	52.2	1	1	1
	Western Tuna and Billfish Fishery	79.5	59.7	52.2	1	1	1
Biologically Important Areas	Flatback Turtle BIA	9.6	3.9	1.2	136	137	140
	Green Turtle BIA	16.8	6	1.5	65	65	66
	Hawksbill Turtle BIA	11.1	4.5	1.2	109	142	143
	Leatherback Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC
	Loggerhead Turtle BIA	9.6	3.9	1.2	136	137	140
	Olive Ridley Turtle BIA	9.6	3.9	1.2	136	137	140

NC: No contact to receptor predicted for specified threshold.

** Probabilities and maximum concentrations calculated at depth of submerged feature.*

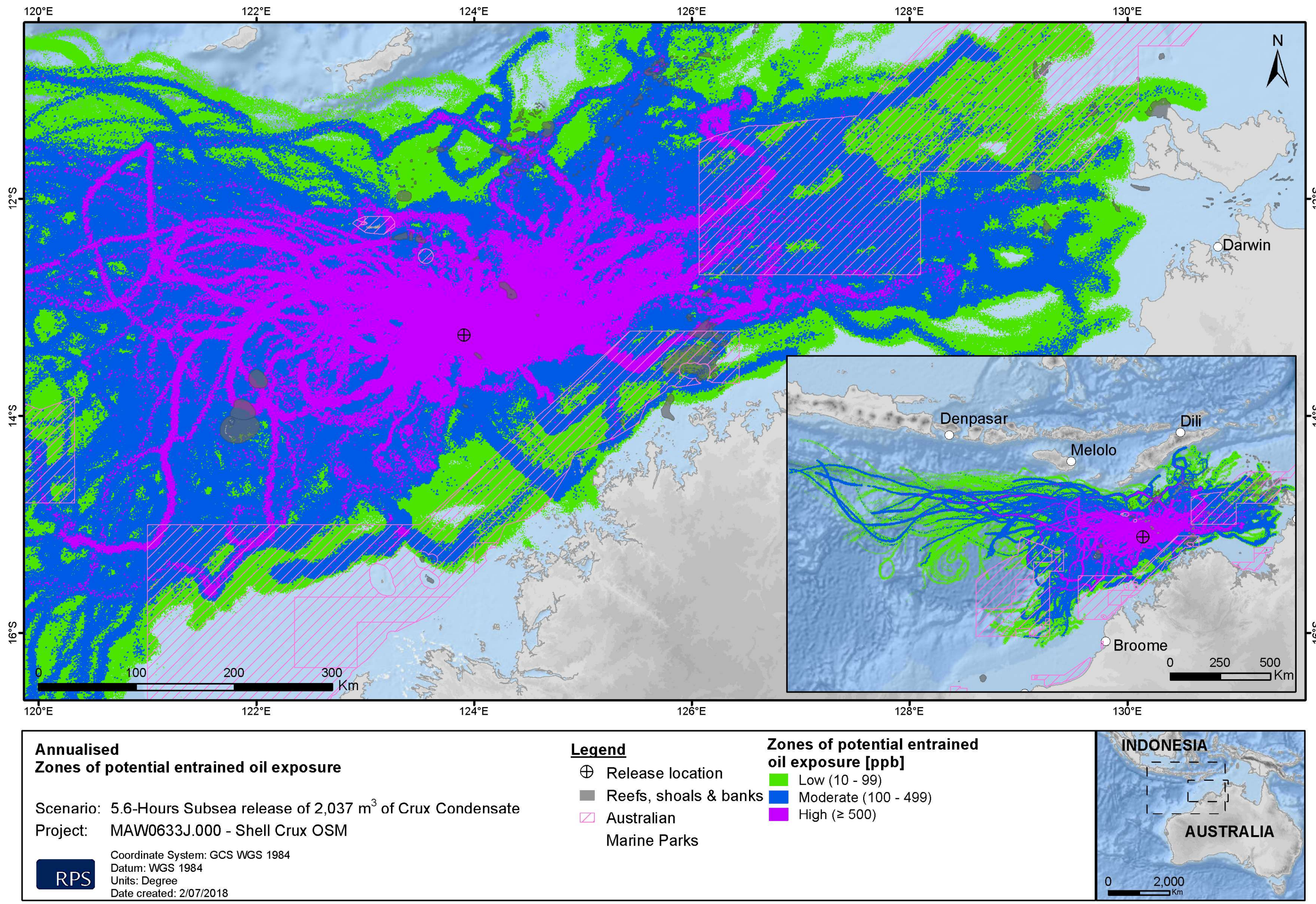


Figure 3.29 Subsurface Hydrocarbons | Entrained | Pipeline Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined entrained oil threshold concentrations resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

RPS

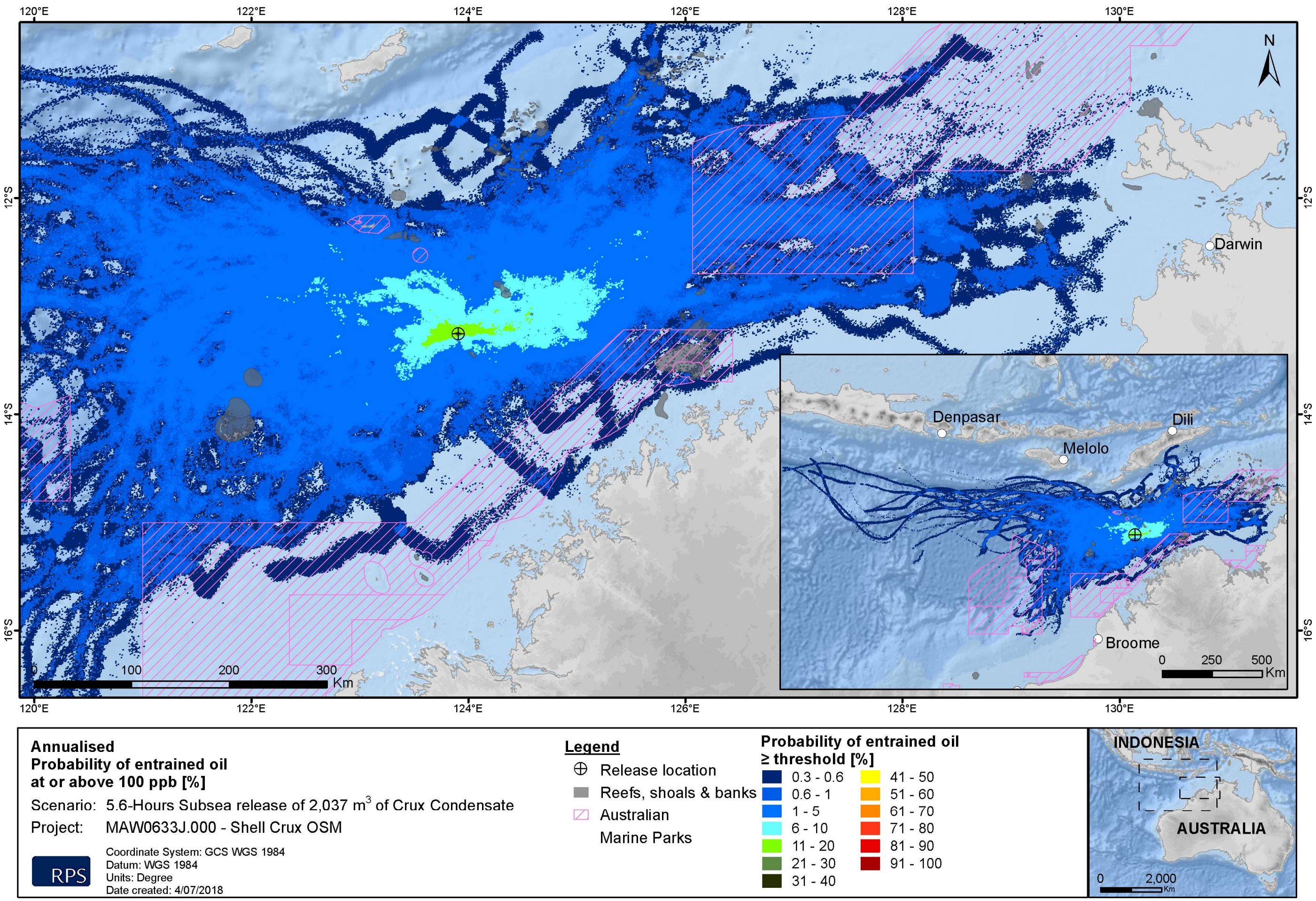


Figure 3.30 Subsurface Hydrocarbons | Entrained | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 100 ppb resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

RPS

3.4.4 Dissolved Aromatic Hydrocarbons

Table 3.15 Expected annualised dissolved aromatic hydrocarbon outcomes at sensitive receptors resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
Coastlines	Cobourg Peninsula	<0.3	<0.3	<0.3
	Indonesia	0.6	<0.3	<0.3
	Joseph Bonaparte Gulf Northern Territory	<0.3	<0.3	<0.3
	Kimberley Coast	<0.3	<0.3	<0.3
	Timor Leste	<0.3	<0.3	<0.3
Islands	Admiralty Gulf Islands	<0.3	<0.3	<0.3
	Bathurst Island	<0.3	<0.3	<0.3
	Bigge Island	0.6	<0.3	<0.3
	Bonaparte Archipelago	0.6	<0.3	<0.3
	Browse Island	2.1	<0.3	<0.3
	Cassini Island	<0.3	<0.3	<0.3
	Coronation Island Group	<0.3	<0.3	<0.3
	Croker Island	<0.3	<0.3	<0.3
	Greenhill Island	<0.3	<0.3	<0.3
	Jones Island	<0.3	<0.3	<0.3
	Long Island Kimberley	0.6	<0.3	<0.3
	Melville Island	<0.3	<0.3	<0.3
	Montalivet Island	<0.3	<0.3	<0.3
	Montgomery Islands	<0.3	<0.3	<0.3
	Montgomery Islands and Reef	<0.3	<0.3	<0.3
	Peron Islands	<0.3	<0.3	<0.3
	Troughton Island	<0.3	<0.3	<0.3
	White Island	<0.3	<0.3	<0.3
Reefs	Beagle and Dingo Reefs	<0.3	<0.3	<0.3
	East Holothuria Reef	<0.3	<0.3	<0.3
	Heritage Reef	0.6	<0.3	<0.3
	Hibernia Reef	0.6	<0.3	<0.3
	Ingram Reef	0.6	<0.3	<0.3
	Jamieson Reef	<0.3	<0.3	<0.3

RPS

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
	Long Reef	<0.3	<0.3	<0.3
	Oliver Rock	<0.3	<0.3	<0.3
	Rothery Reef	<0.3	<0.3	<0.3
	Sandy Islet	0.9	<0.3	<0.3
	Scott Reef North	1.2	0.6	<0.3
	Scott Reef South	0.9	<0.3	<0.3
	Seringapatam Reef	1.5	<0.3	<0.3
	The Boxers	<0.3	<0.3	<0.3
	The Boxers Area	0.6	<0.3	<0.3
	West Holothuria Reef	<0.3	<0.3	<0.3
Shoals	Barracouta Shoals	1.5	<0.3	<0.3
	Barton Shoal	0.6	0.6	<0.3
	Bassett-Smith Shoal	0.9	0.6	<0.3
	Big Bank Shoals	<0.3	<0.3	<0.3
	Calder Shoal	<0.3	<0.3	<0.3
	Cootamundra Shoal	<0.3	<0.3	<0.3
	Deep Shoal 1	1.5	0.6	<0.3
	Deep Shoal 2	0.6	<0.3	<0.3
	Dillon Shoal	0.9	<0.3	<0.3
	Echo Shoals	<0.3	<0.3	<0.3
	Echuca Shoal	0.9	0.6	<0.3
	Eugene McDermott Shoal	7.2	1.2	<0.3
	Fantome Shoal	<0.3	<0.3	<0.3
	Goeree Shoal	3.9	0.6	<0.3
	Heywood Shoal	3.9	1.5	0.6
	Jabiru Shoals	1.8	0.6	<0.3
	Karmt Shoal	0.6	<0.3	<0.3
	Mangola Shoal	<0.3	<0.3	<0.3
	Marie Shoal	<0.3	<0.3	<0.3
	Mermaid Shoal	<0.3	<0.3	<0.3
	Moss Shoal	0.6	<0.3	<0.3
	Newby Shoal	0.6	<0.3	<0.3

RPS

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
	Parry Shoal	0.6	<0.3	<0.3
	Pee Shoal	0.9	<0.3	<0.3
	Penguin Shoal	0.6	<0.3	<0.3
	Penguin Shoal	0.6	<0.3	<0.3
	Shepparton Shoal	<0.3	<0.3	<0.3
	Van Cloon Shoal	0.6	<0.3	<0.3
	Vee Shoal	0.6	<0.3	<0.3
	Vulcan Shoals	4.8	1.8	<0.3
Banks	Baldwin Bank	0.6	<0.3	<0.3
Banks	Bellona Bank	<0.3	<0.3	<0.3
Banks	Branch Banks	<0.3	<0.3	<0.3
Banks	Favell Bank	0.6	<0.3	<0.3
Banks	Flat Top Bank	0.6	<0.3	<0.3
Banks	Gale Bank	1.5	0.6	<0.3
Banks	Holothuria Banks	1.2	0.6	<0.3
Banks	Johnson Bank	1.5	<0.3	<0.3
Banks	Margaret Harries Bank	0.6	<0.3	<0.3
Banks	Otway Bank	<0.3	<0.3	<0.3
Banks	Sahul Bank	2.1	0.6	<0.3
Banks	Sunrise Bank	<0.3	<0.3	<0.3
Banks	Tait Bank	<0.3	<0.3	<0.3
Banks	Woodbine Bank	1.5	<0.3	<0.3
Marine Parks	Ashmore Reef AMP	1.5	<0.3	<0.3
Marine Parks	Lalang-garram/Camden Sound MP	<0.3	<0.3	<0.3
Marine Parks	Cartier Island AMP	2.4	0.6	<0.3
Marine Parks	Garig Gunak Barlu NP	<0.3	<0.3	<0.3
Marine Parks	Kimberley AMP	1.8	0.9	0.6
Marine Parks	North Lalang-garram MP & North Kimberley MP	0.6	<0.3	<0.3
Marine Parks	Mermaid Reef AMP	0.6	<0.3	<0.3
Marine Parks	Oceanic Shoals AMP	2.7	0.9	<0.3
Marine Parks	Prince Regent NP Coast	<0.3	<0.3	<0.3

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
Key Ecological Features	Ancient Coastline at 125 m depth contour	8.4	3.6	0.6
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	2.4	0.6	<0.3
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	0.6	<0.3	<0.3
	Carbonate bank & terrace system of Van Diemen Rise	0.9	<0.3	<0.3
	Carbonate bank and terrace system of Sahul Shelf	4.2	1.2	0.6
	Continental Slope Demersal Fish Communities	8.7	3.6	0.6
	Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals	0.6	<0.3	<0.3
	Pinnacles of the Bonaparte Basin	1.2	<0.3	<0.3
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	1.8	0.6	<0.3
	Shelf break and slope of the Arafura Shelf	<0.3	<0.3	<0.3
Fisheries	Northern Prawn Fishery	1.8	0.9	<0.3
	North-West Slope Trawl Fishery	66.3	15.9	5.4
	Southern Bluefin Tuna Fishery	66.3	15.9	5.4
	Timor Reef Fishery (NT Managed)	0.6	<0.3	<0.3
	Western Skipjack Fishery	66.3	15.9	5.4
	Western Tuna and Billfish Fishery	66.3	15.9	5.4
Ecologically Important Areas	Flatback Turtle BIA	2.7	0.9	<0.3
	Green Turtle BIA	4.8	1.2	<0.3
	Hawksbill Turtle BIA	2.4	0.6	<0.3
	Leatherback Turtle BIA	<0.3	<0.3	<0.3
	Loggerhead Turtle BIA	2.7	0.9	<0.3
	Olive Ridley Turtle BIA	2.7	0.9	<0.3

NC: No contact to receptor predicted for specified threshold.

** Probabilities and maximum concentrations calculated at depth of submerged feature.*

RPS

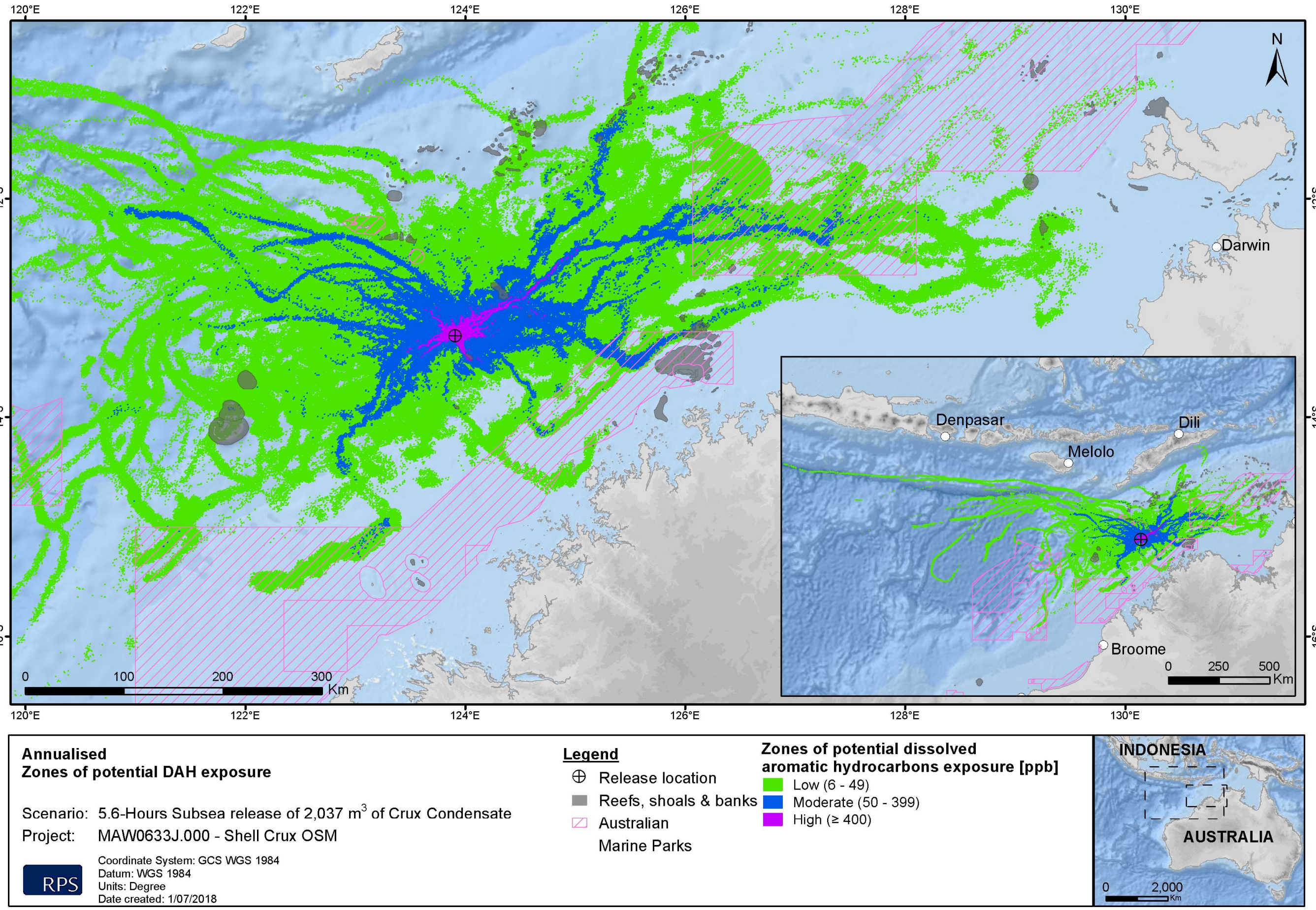


Figure 3.31 Subsurface Hydrocarbons | Dissolved | Pipeline Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined dissolved aromatic hydrocarbon threshold concentrations resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

RPS

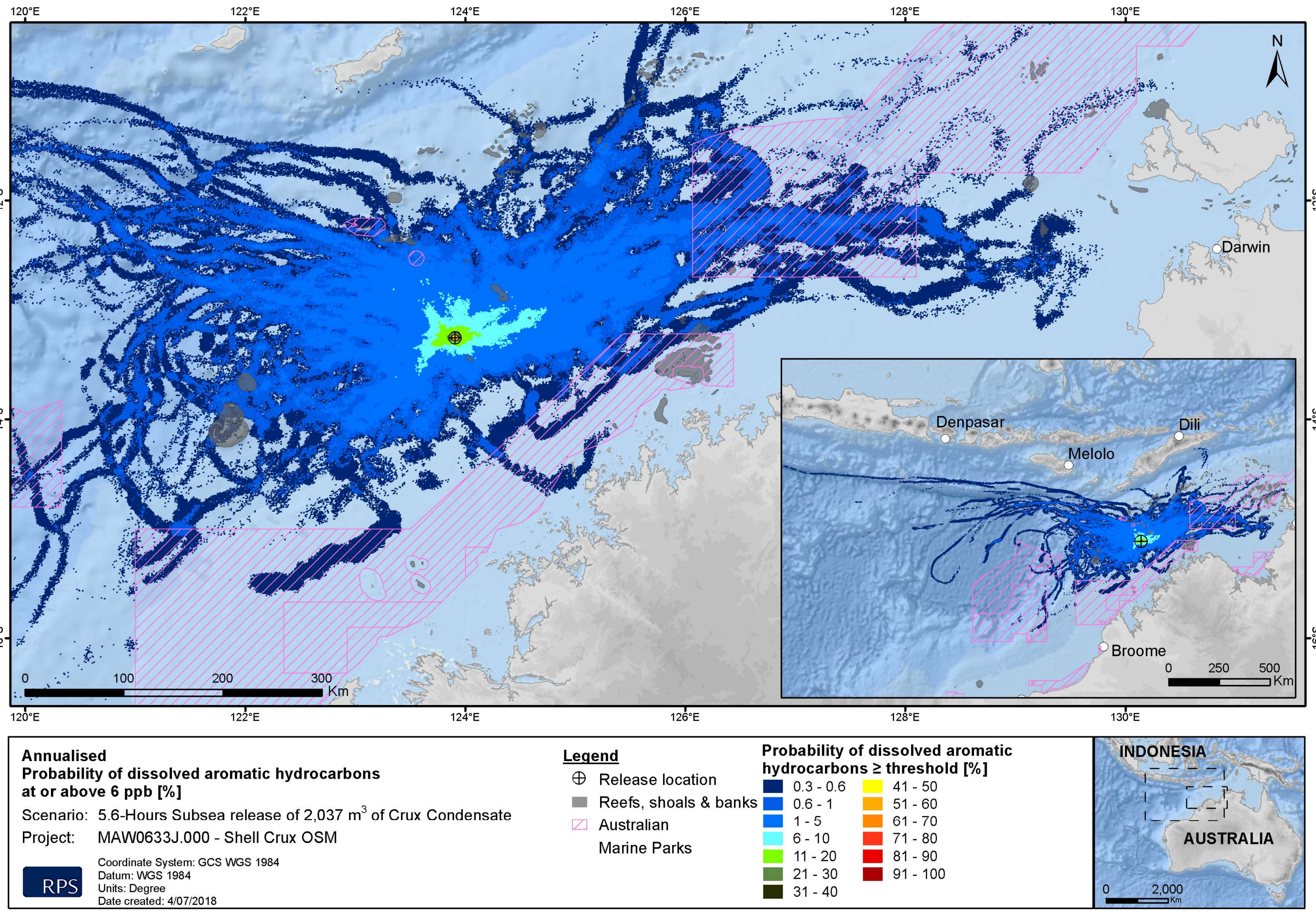


Figure 3.32 Subsurface Hydrocarbons | Dissolved | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 6 ppb resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

RPS

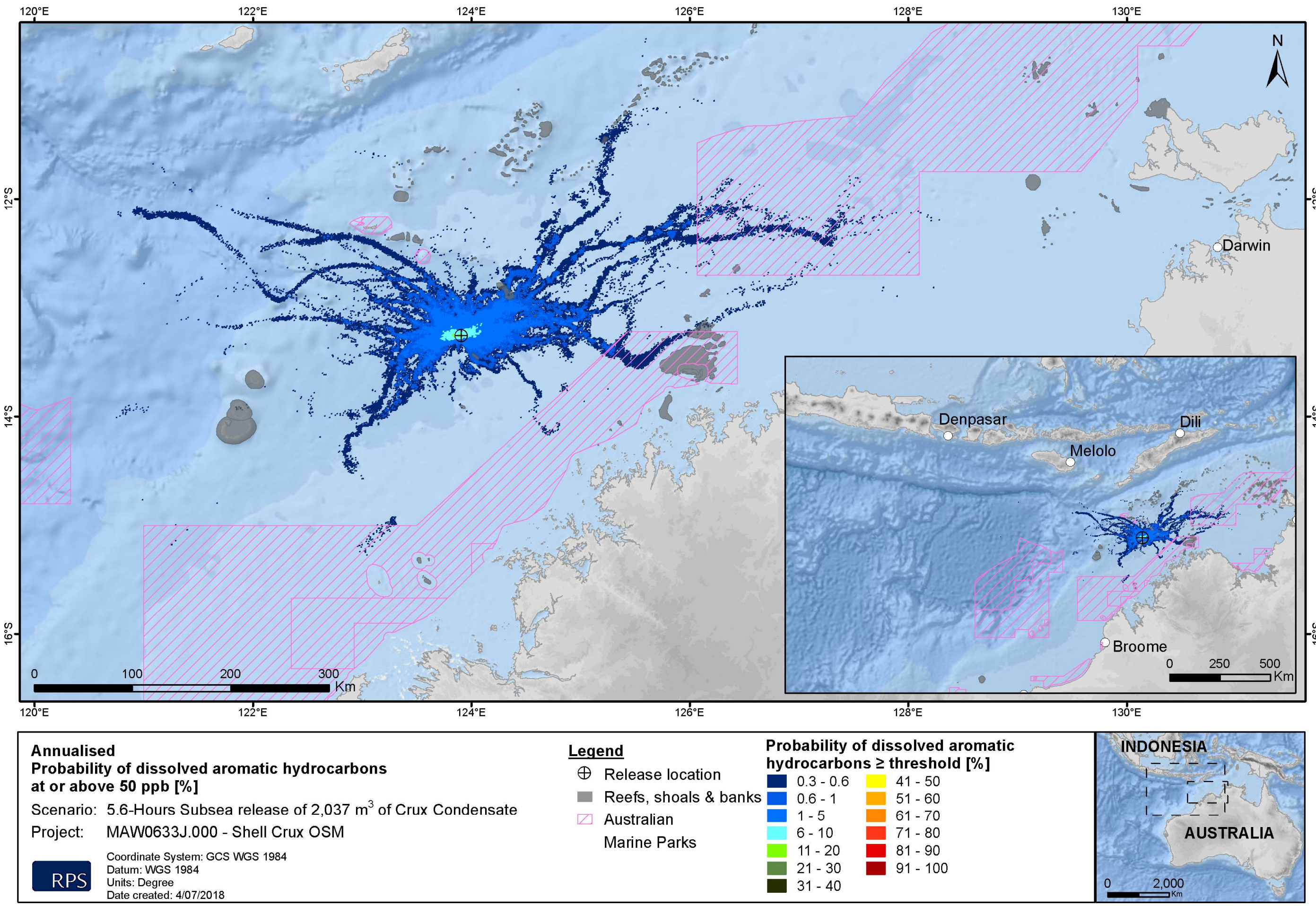


Figure 3.33 Subsurface Hydrocarbons | Dissolved | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

RPS

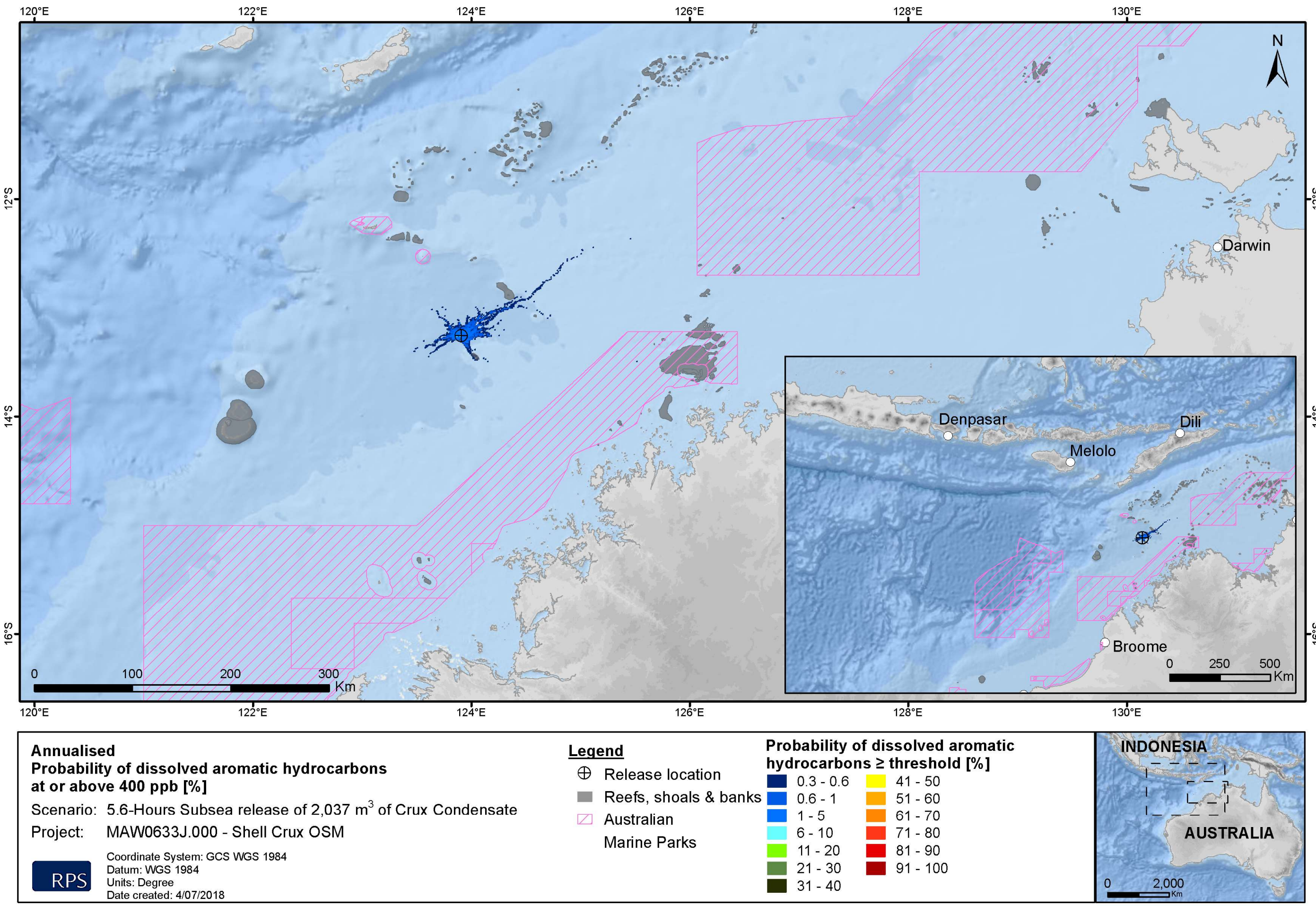


Figure 3.34 Subsurface Hydrocarbons | Dissolved | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 400 ppb resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

3.5 Scenario 4 – Short-Term Surface Release of IFO-180 from a Pipelay Vessel Collision at the Crux End of the Export Pipeline

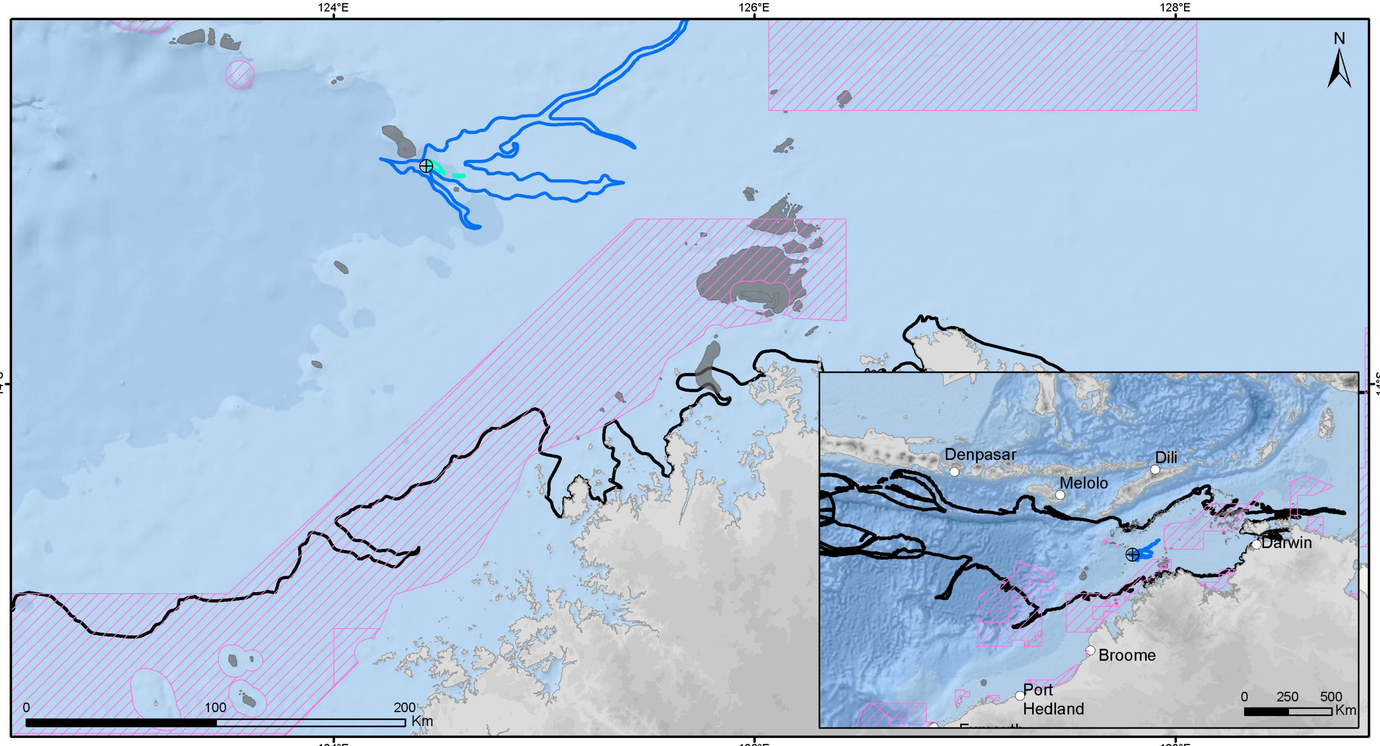
3.5.1 Discussion of Results

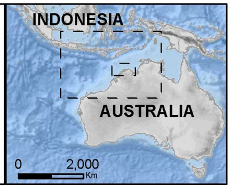
3.5.1.1 Overview

This scenario investigated the probability of exposure to key sensitive receptors by hydrocarbons resulting from a short-term (1-hour) surface release following a pipelay vessel collision, discharging 1,000 m^3 of IFO-180 at the Crux end of the export pipeline at any time of year, with no spill response mitigation measures applied.

Considering the discharge characteristics, the properties of the hydrocarbon and its expected weathering behaviour, floating films are likely to be formed under typical wind conditions. Given the high viscosity of the hydrocarbon, entrainment into the water column is only likely to occur under relatively windy conditions. It is likely that the bulk of the hydrocarbon mass at any time will be found on the water surface. Evaporation rates will be relatively low, given the large proportion (21%) of low-volatility compounds within the hydrocarbon, and the residual fraction (64%) will persist in the environment until degradation processes occur (over periods of weeks to months). Considering the relatively low likelihood of entrainment occurring, the potential for dissolution of soluble aromatic compounds is low.

Figure 3.35 to Figure 3.37 show a summary of the areal extent for all hydrocarbon phases at the low, moderate and high thresholds, respectively.





Annualised Zones of Potential Exposure Low thresholds

Scenario: Instantaneous Surface release of 1,000 m^3 of IFO180

Project: MAW0633J.000 - Shell Crux OSM

Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree
Date created: 13/07/2018

Legend

- Release location
- Reefs, shoals & banks
- Australian Marine Parks

Zones of potential Exposure

- Floating oil ZoPE
- Entrained oil ZoPE
- DAH ZoPE

Figure 3.35 Surface and Subsurface Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Areal extent of potential exposure at the low thresholds resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

RPS

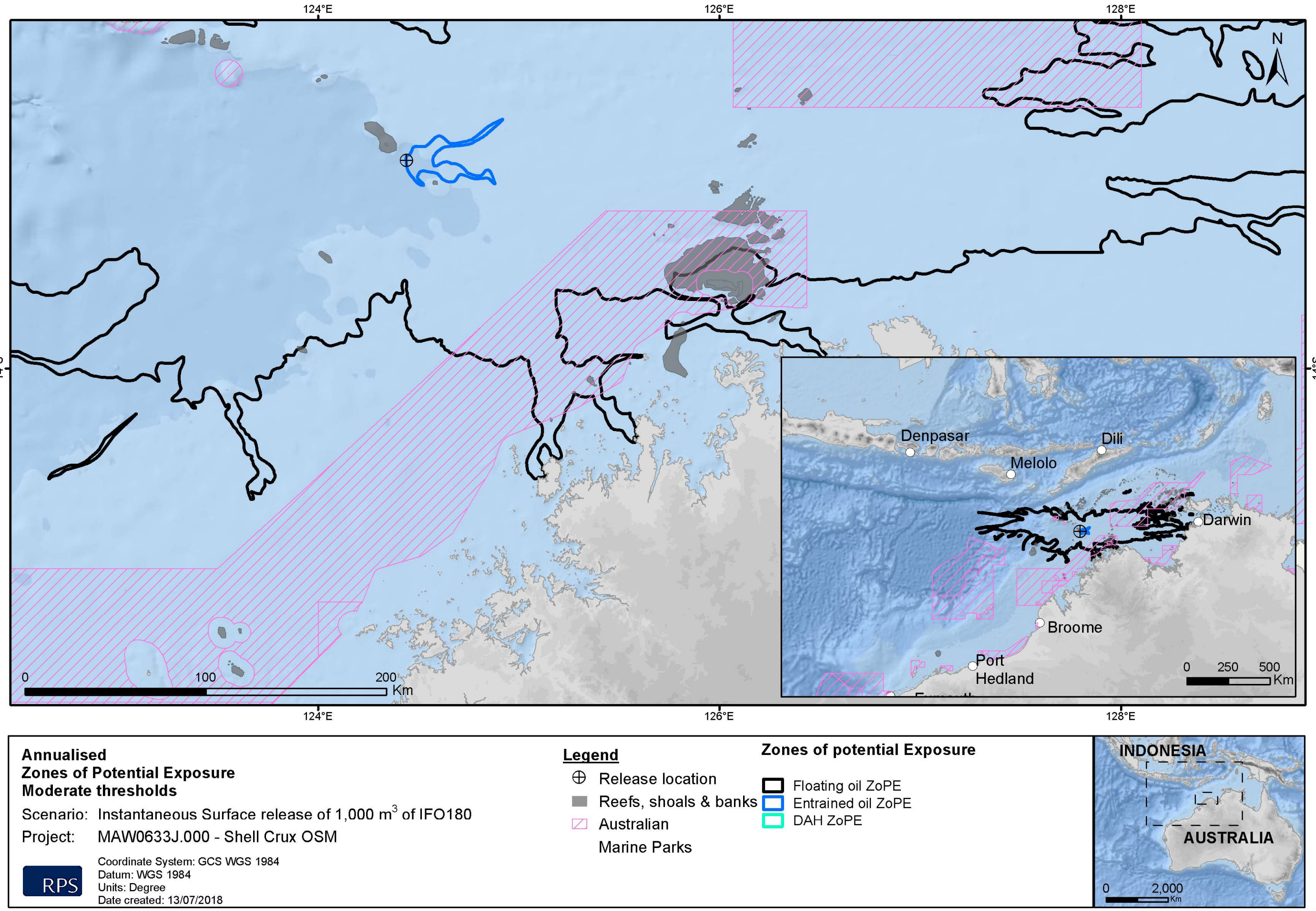


Figure 3.36 Surface and Subsurface Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Areal extent of potential exposure at the moderate thresholds resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

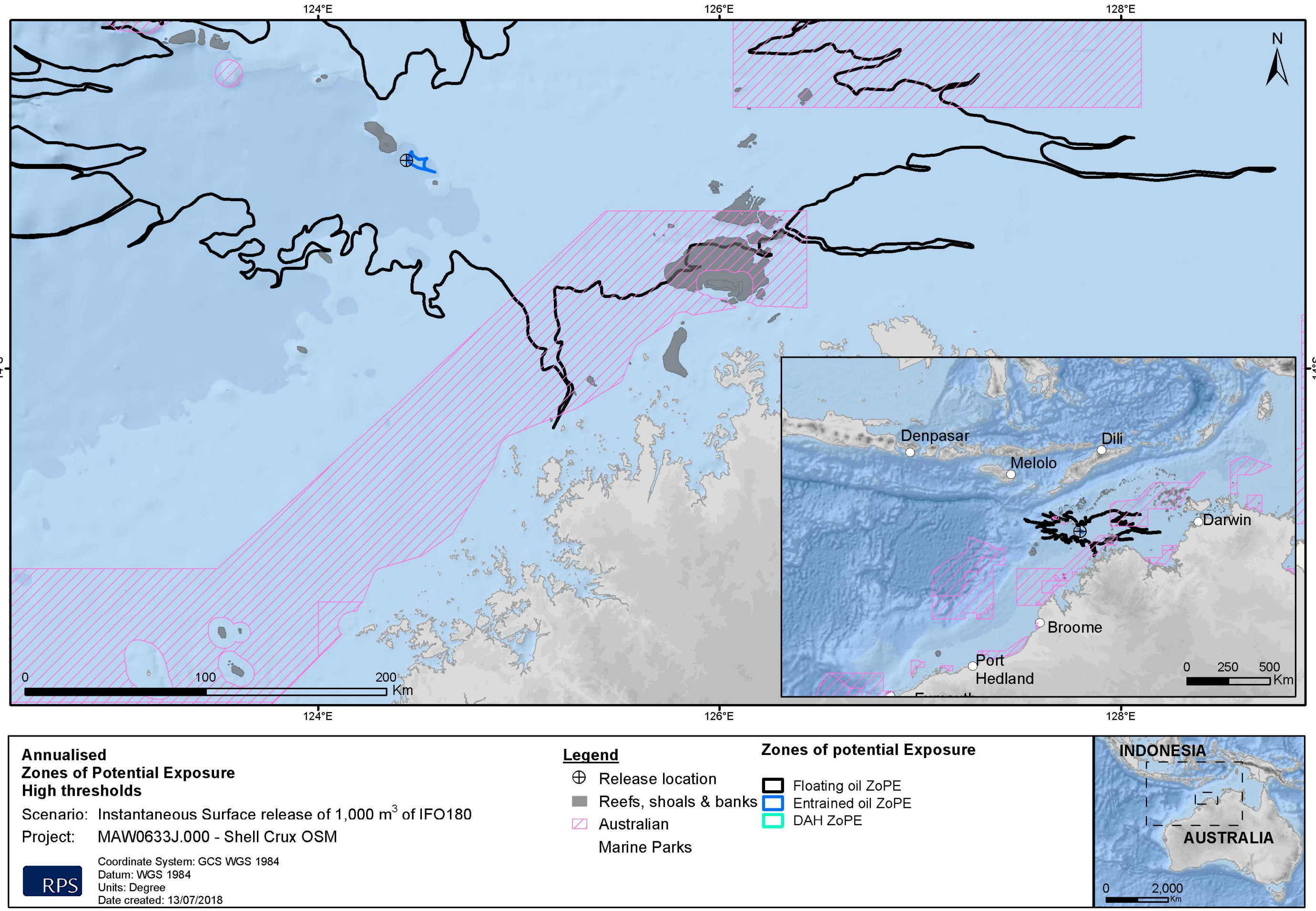


Figure 3.37 Surface and Subsurface Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Areal extent of potential exposure at the low thresholds resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

3.5.1.2 Floating and Shoreline Hydrocarbons

The annualised probability contour figures (Figure 3.39 and Appendix D) indicate that hydrocarbons on the sea surface at or greater than the threshold concentrations travel up to 1,853 km (1 g/m^2) from the release location. The ZoPE at the moderate and high floating oil threshold is further reduced, with floating oil not predicted to exceed the moderate (10 g/m^2) and high (25 g/m^2) thresholds beyond distances of 1,061 km and 484 km, respectively.

The Southern Bluefin Tuna Fishery, Western Skipjack Fishery and Western Tuna and Billfish Fishery receptors have the highest predicted probability of contact, being 100% at all thresholds (Table 3.17). Several other receptors are predicted to receive floating oil at low threshold concentrations, with the highest probabilities of contact occurring at North-West Slope Trawl Fishery (24%), Vulcan Shoals (23%), Ancient Coastline at 125 m Depth Contour KEF (16%), Continental Slope Demersal Fish Communities KEF (27%), Carbonate Bank and Terrace System of Sahul Shelf KEF (24%), Green Turtle BIA (10%), Loggerhead Turtle BIA (8%), Flatback Turtle BIA (8%), Northern Prawn Fishery (8%), Olive Ridley Turtle BIA (8%), Oceanic Shoals AMP (8%), Eugene McDermott Shoal (17%) and Pinnacles of the Bonaparte Basin KEF (7%).

The minimum time to contact with any receptor by floating oil at the low threshold is forecast at approximately 1 hour at the Southern Bluefin Tuna Fishery, Western Skipjack Fishery, and Western Tuna and Billfish Fishery receptors.

Potential for accumulation of oil on shorelines is predicted to be low (≤6% probability at the moderate threshold of 100 g/m^2), with a maximum accumulated volume of 771 m^3 forecast at Bonaparte Archipelago and North Lalang-garram MP & North Kimberley MP, and maximum local accumulated concentration on shorelines of 7,777 g/m^2 forecast at Bonaparte Archipelago, Kimberley Coast and North Lalang-garram MP & North Kimberley MP (Table 3.17).

Table 3.16 Maximum distances from the release location to zones of floating oil exposure for Scenario 4 (1,000 m^3 IFO-180).

	Floating Oil Exposure Threshold		
	Low (1-10 g/m^2)	**Moderate (10-25 g/m^2)**	**High (>25 g/m^2)**
Maximum distance travelled (km) by a spill trajectory	1,853	1,061	484

3.5.1.3 Subsurface – Entrained Hydrocarbons

The annualised probability contour figures (Figure 3.43 and Appendix D) indicate that entrained oil concentrations at or greater than the threshold concentrations do not travel a significant distance from the release location. The maximum distance to the outer extent of the low entrained oil threshold (10 ppb) is predicted to extend up to 170 km. The maximum extent is forecast to be reduced for the moderate (100 ppb; 57 km) and high (500 ppb; 17 km) thresholds for all the seasons.

A small number of receptors are predicted to be contacted by entrained oil at high threshold concentrations. Southern Bluefin Tuna Fishery, Western Skipjack Fishery, and Western Tuna and Billfish Fishery receptors are predicted to be contacted at the high threshold with probabilities of 1% (Entrained Hydrocarbons

Table 3.18). Higher probabilities of contact at a greater number of receptors are predicted at the low and moderate thresholds.

RPS

Receptors with the highest probability of receiving entrained oil at low threshold concentrations were Southern Bluefin Tuna Fishery (5%), Western Skipjack Fishery (5%), Western Tuna and Billfish Fishery (5%), and Carbonate Bank and Terrace System of Sahul Shelf KEF (1%).

The minimum time to contact with any receptor by entrained oil at the low threshold is forecast at Southern Bluefin Tuna Fishery, Western Skipjack Fishery. and Western Tuna and Billfish Fishery, at approximately 1 hour.

3.5.1.4 Subsurface – Dissolved Aromatic Hydrocarbons

The annualised probability contour figures (Figure 3.45) indicate that dissolved aromatic hydrocarbons at or greater than the threshold concentrations travel a small distance from the release location. The maximum distance to the outer extent of the low dissolved aromatic hydrocarbon threshold (6 ppb) is predicted to extend up to 20 km. The moderate (50 ppb) and high (400 ppb) thresholds are not exceeded for this scenario.

No receptors are predicted to receive dissolved aromatic hydrocarbons at moderate or high threshold concentrations. Southern Bluefin Tuna Fishery, Western Skipjack Fishery, and Western Tuna and Billfish Fishery receptors are predicted to have the highest probability of contact at the low threshold with probabilities of 2% (Table 3.19). Low probability of contact (<1%) is predicted at all other receptors at the low threshold.

3.5.1.5 Deterministic Cases

A replicate simulation during the summer season (spill starting at 07:00 6th February 2011) has been identified as the worst-case replicate according to the maximum oil volume accumulated across all shoreline receptors criteria for Scenario 4 (624 m^3 at Bonaparte Archipelago/Bigge Island). Figures showing the evolution of this spill simulation are contained in Appendix E. Hydrocarbons on the sea surface mainly drifted south of the release location. The potential floating oil exposure zones were shown up to 198 km, 190 km and 159 km of the release location at the low, moderate and high thresholds, respectively. There was no entrained oil or dissolved aromatic hydrocarbon exposure predicted at any threshold; consequently, no subsea images are presented for this scenario.

A replicate simulation during the winter season (spill starting at 07:00 20th July 2008) has been identified as the worst-case replicate according to the minimum time to commencement of oil accumulation at any shoreline receptor criteria for Scenario 4 (5.1 days at Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF). Hydrocarbons on the sea surface mainly drifted west and northwest of the release location. The potential floating oil exposure zones were shown up to 1,819 km, 380 km and 251 km of the release location at the low, moderate and high thresholds, respectively. There was no entrained oil or dissolved aromatic hydrocarbon exposure predicted at any threshold; consequently, no subsea images are presented for this scenario.

A replicate simulation during the transitional season (spill starting at 12:00 19th November 2016) has been identified as the worst-case replicate according to the maximum length of oiled shoreline criteria for Scenario 4 (117 km at North Lalang-garram MP & North Kimberley MP). Hydrocarbons on the sea surface mainly drifted southwest of the release location. The potential floating oil exposure zones were shown up to 206 km, 73 km and 66 km of the release location at the low, moderate and high thresholds, respectively. There was no entrained oil or dissolved aromatic hydrocarbon exposure predicted at any threshold; consequently, no subsea images are presented for this scenario.

RPS

3.5.2 Floating and Shoreline Hydrocarbons

Table 3.17 Expected annualised floating and shoreline oil outcomes at sensitive receptors resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
Coastlines	Cobourg Peninsula	<0.3	<0.3	<0.3	NC	NC	NC	1.5	0.6	<0.3	495	588	NC	0.9	231	<1	9	<1	12
Coastlines	Darwin Coast	1.2	<0.3	<0.3	525	NC	NC	2.7	2.4	1.5	489	525	532	36	4,601	10	307	3	68
Coastlines	Indonesia	<0.3	<0.3	<0.3	NC	NC	NC	0.6	0.6	<0.3	527	641	NC	0.8	245	<1	47	<1	84
Coastlines	Joseph Bonaparte Gulf Northern Territory	2.4	1.2	<0.3	300	313	NC	4.2	3	1.5	300	301	314	55	7,777	60	523	12	99
Coastlines	Kakadu Coast	0.6	<0.3	<0.3	735	NC	NC	0.6	0.6	0.6	732	739	763	3.9	1,165	2	107	<1	35
Coastlines	Kakadu National Park	0.6	<0.3	<0.3	735	NC	NC	0.9	0.6	0.6	732	739	763	3.9	1,165	2	84	<1	40
Coastlines	Kimberley Coast	1.8	0.6	<0.3	190	195	NC	2.4	1.8	1.5	189	190	196	44	7,777	12	491	4	69
Coastlines	West Arnhem Land	0.6	<0.3	<0.3	872	NC	NC	1.2	1.2	0.6	864	870	1,002	3.9	1,164	2	68	2	34
Islands	Admiralty Gulf Islands	0.6	<0.3	<0.3	890	NC	NC	1.5	1.5	<0.3	490	772	NC	5.3	894	2	73	<1	32
Islands	Bathurst Island	3.6	0.9	<0.3	409	413	NC	6	4.5	2.4	409	410	412	77	7,773	37	417	11	92
Islands	Bigge Island	0.9	0.6	<0.3	181	188	NC	1.5	0.9	0.6	194	197	200	23	6,657	10	624	<1	48
Islands	Bonaparte Archipelago	0.9	0.6	0.6	163	198	207	1.5	0.9	0.6	189	197	199	27	7,777	12	625	2	82
Islands	Browse Island	2.7	0.6	0.6	164	165	166	9.6	5.7	2.1	166	167	168	72	7,197	4	124	<1	3
Islands	Cape Londonderry Islands	0.6	<0.3	<0.3	353	NC	NC	2.4	1.2	<0.3	354	354	NC	4.6	916	<1	50	<1	15
Islands	Cassini Island	0.9	0.6	<0.3	190	193	NC	2.1	1.5	0.6	189	191	193	22	4,850	2	139	<1	4
Islands	Coronation Island Group	<0.3	<0.3	<0.3	NC	NC	NC	0.6	<0.3	<0.3	900	NC	NC	0.1	42	<1	<1	<1	4
Islands	Croker Island	1.5	<0.3	<0.3	511	NC	NC	1.5	1.5	1.5	506	510	519	52	4,991	12	347	2	30
Islands	East Vernon Island	0.9	<0.3	<0.3	626	NC	NC	1.8	1.2	0.6	624	626	629	12	2,462	<1	39	<1	6
Islands	Eclipse Archipelago	1.8	0.6	<0.3	382	395	NC	2.4	1.8	1.8	382	384	394	61	6,680	4	128	<1	14
Islands	Field Island	<0.3	<0.3	<0.3	NC	NC	NC	0.9	0.6	<0.3	841	850	NC	0.7	210	<1	11	NC	NC
Islands	Greenhill Island	<0.3	<0.3	<0.3	NC	NC	NC	0.6	<0.3	<0.3	967	NC	NC	<0.1	12	<1	<1	NC	NC
Islands	Jones Island	1.2	<0.3	<0.3	501	NC	NC	2.7	2.1	<0.3	382	501	NC	8.4	833	<1	7	<1	<1
Islands	Lawson Island	0.9	<0.3	<0.3	551	NC	NC	1.5	1.2	<0.3	545	549	NC	7.2	774	<1	11	<1	4
Islands	Lesueur Island	0.6	<0.3	<0.3	371	NC	NC	1.5	0.6	<0.3	370	373	NC	2.8	704	<1	12	<1	4
Islands	Long Island Kimberley	0.9	0.6	<0.3	180	183	NC	1.5	0.6	<0.3	189	936	NC	3	883	<1	78	<1	26
Islands	McCluer Island	1.2	<0.3	<0.3	558	NC	NC	1.5	1.2	0.6	555	560	571	9.4	1,087	<1	25	<1	6
Islands	Melville Island	1.2	<0.3	<0.3	631	NC	NC	2.4	1.5	0.9	474	490	652	15	2,200	11	287	4	69
Islands	Mogogout Island	<0.3	<0.3	<0.3	NC	NC	NC	<0.3	<0.3	<0.3	NC	NC	NC	<0.1	5.3	<1	<1	NC	NC

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Montalivet Island	0.9	0.6	<0.3	160	164	NC	2.1	0.9	0.6	164	165	173	5.4	1,320	<1	18	<1	8
	Morse Island	<0.3	<0.3	<0.3	NC	NC	NC	0.6	<0.3	<0.3	985	NC	NC	<0.1	22	<1	<1	<1	<1
	Napier Broome Bay Islands	1.8	0.9	<0.3	393	410	NC	2.1	1.8	1.8	394	394	407	64	6,236	9	188	2	31
	New Year Island	<0.3	<0.3	<0.3	NC	NC	NC	0.6	<0.3	<0.3	702	NC	NC	<0.1	16	<1	<1	<1	<1
	North Goulburn Island	<0.3	<0.3	<0.3	NC	NC	NC	1.2	<0.3	<0.3	756	NC	NC	0.4	51	<1	2	<1	7
	North West Vernon Island	0.9	0.6	<0.3	626	629	NC	2.4	1.2	0.6	623	625	627	22	5,318	2	155	<1	8
	Oxley Island	1.2	<0.3	<0.3	536	NC	NC	1.5	1.5	1.2	535	541	550	18	1,961	2	48	<1	5
	Peron Islands	1.8	0.6	<0.3	380	427	NC	2.4	1.5	0.9	380	381	428	21	3,061	4	166	<1	17
	Roche Islands and Reefs	2.1	0.9	<0.3	444	444	NC	4.5	2.7	2.1	403	446	447	51	4,560	12	298	2	22
	South Goulburn Island	<0.3	<0.3	<0.3	NC	NC	NC	0.6	<0.3	<0.3	861	NC	NC	0.1	19	<1	<1	<1	2
	South West Vernon Island	0.9	<0.3	<0.3	621	NC	NC	1.8	0.9	<0.3	621	622	NC	3.2	710	<1	20	<1	5
	Stewarts Islands	0.6	<0.3	<0.3	354	NC	NC	2.4	1.2	<0.3	354	354	NC	4.6	916	<1	27	<1	5
	Troughton Island	2.4	0.6	<0.3	219	489	NC	3.9	2.7	1.8	286	373	489	35	2,782	<1	23	<1	<1
Reefs	Beatrice Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Christine Reef*	0.6	<0.3	<0.3	915	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Draytons Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	East Holothuria Reef*	1.5	<0.3	<0.3	226	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Elphinstone Reef*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fish Reef*	1.5	<0.3	<0.3	530	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Harris Reef*	0.6	<0.3	<0.3	822	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Heritage Reef*	0.6	<0.3	<0.3	454	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Hibernia Reef*	1.5	0.6	0.6	148	156	158	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Hunt Patch*	0.6	<0.3	<0.3	845	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ingram Reef*	0.9	0.6	<0.3	146	149	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jamieson Reef*	0.9	<0.3	<0.3	162	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Knight Reef*	0.6	<0.3	<0.3	631	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Long Reef	1.2	0.6	<0.3	194	204	NC	3	2.1	<0.3	195	203	NC	8	655	<1	9	<1	3
	Lyne Reef*	0.6	<0.3	<0.3	620	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Middle Reef*	1.8	<0.3	<0.3	473	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Oliver Reef*	0.9	<0.3	<0.3	629	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Oliver Rock*	0.6	<0.3	<0.3	188	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Orontes Reef*	0.9	<0.3	<0.3	492	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Rothery Reef*	1.5	<0.3	<0.3	197	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sandy Islet	1.2	<0.3	<0.3	414	NC	NC	7.2	3	0.9	308	415	667	20	1,279	<1	11	<1	<1
	Scott Reef North*	1.5	<0.3	<0.3	285	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Scott Reef South	1.2	<0.3	<0.3	363	NC	NC	7.2	3	0.9	308	415	667	20	1,279	<1	11	<1	<1
	Seringapatam Reef*	2.4	0.6	<0.3	229	235	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Taylor Patches*	0.6	<0.3	<0.3	644	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	The Boxers*	1.8	<0.3	<0.3	411	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	The Boxers Area*	4.5	1.2	<0.3	322	329	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Tregenna Reef*	0.9	<0.3	<0.3	748	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	West Holothuria Reef*	1.2	0.6	<0.3	134	144	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Abbott Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Afghan Shoal*	1.5	<0.3	<0.3	527	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Ann Shoals*	0.6	<0.3	<0.3	963	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Barbara Shoal*	0.6	<0.3	<0.3	900	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Barracouta Shoals*	6.9	0.9	<0.3	61	74	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Barton Shoal*	0.6	<0.3	<0.3	717	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Bassett-Smith Shoal*	2.4	0.6	<0.3	273	324	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Beagle Shoals*	0.6	<0.3	<0.3	855	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Big Bank Shoals*	0.6	<0.3	<0.3	468	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Bill Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Britomart Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Calder Shoal*	0.6	<0.3	<0.3	642	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Cootamundra Shoal*	0.6	<0.3	<0.3	645	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Deep Shoal 1*	5.4	0.6	<0.3	195	241	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Deep Shoal 2*	1.8	<0.3	<0.3	296	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Dillon Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Echo Shoals*	0.9	<0.3	<0.3	506	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Echuca Shoal*	2.4	0.6	<0.3	173	220	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Eugene McDermott Shoal*	17.1	5.7	3	10	11	11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoals	Fantome Shoal*	0.6	<0.3	<0.3	900	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Fitzpatrick Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Giles Shoal*	0.6	<0.3	<0.3	885	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Goeree Shoal*	16.2	7.8	4.5	9	9	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Hancox Shoal*	1.2	<0.3	<0.3	635	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Heywood Shoal*	6	1.5	<0.3	109	112	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jabiru Shoals*	2.4	<0.3	<0.3	362	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jones Shoal*	1.2	<0.3	<0.3	498	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Karmt Shoal*	0.9	<0.3	<0.3	295	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Lowry Shoal*	0.9	<0.3	<0.3	482	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mangola Shoal*	1.8	<0.3	<0.3	423	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marie Shoal*	1.5	<0.3	<0.3	382	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Marsh Shoal*	0.9	<0.3	<0.3	621	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mermaid Shoal	1.5	<0.3	<0.3	590	NC	NC	2.4	1.5	0.9	588	598	653	13	2,012	<1	21	<1	2
	Moresby Shoals*	1.8	<0.3	<0.3	473	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Moss Shoal*	2.1	<0.3	<0.3	374	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Newby Shoal*	4.2	<0.3	<0.3	362	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Parry Shoal*	2.4	0.6	<0.3	354	370	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Pee Shoal*	1.8	<0.3	<0.3	396	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Penguin Shoal*	3.9	1.5	0.9	68	68	68	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Penguin Shoal*	3.9	1.5	0.9	68	68	68	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Shepparton Shoal*	1.2	<0.3	<0.3	420	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Skottowe Shoal*	1.2	<0.3	<0.3	478	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Taiyun Shoal*	0.6	<0.3	<0.3	844	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Van Cloon Shoal*	3.6	1.2	0.6	123	125	130	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Vee Shoal*	0.9	<0.3	<0.3	680	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Victoria Shoal*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Vulcan Shoals*	23.1	13.5	10.8	4	4	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wells Shoal*	0.6	<0.3	<0.3	867	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Baldwin Bank*	2.4	0.9	0.6	101	102	103	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Bellona Bank*	0.6	<0.3	<0.3	673	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Banks	Branch Banks*	1.8	<0.3	<0.3	221	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Favell Bank*	4.2	1.2	0.6	116	124	124	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Flat Top Bank*	2.1	0.6	<0.3	267	268	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Foelsche Bank*	<0.3	<0.3	<0.3	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Gale Bank*	4.8	1.8	0.6	109	109	134	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Goodrich Bank*	0.6	<0.3	<0.3	965	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Holothuria Banks*	3.6	1.5	0.9	69	71	71	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Johnson Bank*	4.2	1.8	0.9	97	98	98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Jones Bank*	1.5	<0.3	<0.3	475	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Margaret Harries Bank*	1.8	<0.3	<0.3	504	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Otway Bank*	1.8	0.9	<0.3	215	472	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Parsons Bank*	0.9	<0.3	<0.3	729	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sahul Bank*	1.2	0.6	<0.3	166	167	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sunrise Bank*	0.6	<0.3	<0.3	666	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Tait Bank*	1.8	<0.3	<0.3	372	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Woodbine Bank*	4.5	1.2	0.9	90	91	91	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Marine Parks	Arafura AMP*	0.6	<0.3	<0.3	666	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Arnhem AMP*	0.6	<0.3	<0.3	623	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ashmore Reef AMP	4.5	2.4	1.5	110	113	114	8.7	5.7	3	122	123	124	130	7,781	12	302	<1	7
	Cartier Island AMP	6.6	1.5	0.9	74	76	77	9.6	6	3	134	139	144	136	7,781	6	149	<1	4
	Charles Darwin NP	1.2	<0.3	<0.3	544	NC	NC	1.8	1.2	0.6	504	553	626	7.5	1,903	2	77	<1	13
	Djukbinj NP	0.6	<0.3	<0.3	635	NC	NC	0.6	<0.3	<0.3	980	NC	NC	<0.1	27	<1	<1	<1	4
	Garig Gunak Barlu NP	1.5	<0.3	<0.3	494	NC	NC	1.5	0.9	<0.3	500	501	NC	2	306	<1	4	<1	2
	Kakadu NP	0.6	<0.3	<0.3	707	NC	NC	0.9	0.6	0.6	732	739	763	3.9	1,165	2	84	<1	55
	Kimberley AMP	6.9	2.1	1.5	42	43	43	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	North Lalang-garram MP & North Kimberley MP	2.4	0.9	0.6	155	159	164	3.9	2.7	1.8	189	190	193	64	7,777	38	625	8	122
	Mary River NP	0.6	<0.3	<0.3	653	NC	NC	0.6	0.6	<0.3	763	781	NC	0.7	224	<1	8	<1	8
	Oceanic Shoals AMP*	7.5	2.4	1.8	60	60	61	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Prince Regent NP Coast	<0.3	<0.3	<0.3	NC	NC	NC	0.6	<0.3	<0.3	496	NC	NC	<0.1	11	<1	<1	NC	NC
Key Eco	Ancient Coastline at 125 m depth contour*	15.9	3.9	1.8	19	19	20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

RPS

	Receptor	Probability (%) of films arriving at receptors at			Minimum time to receptor (hours) for films at			Probability (%) of shoreline oil on receptors at			Minimum time to receptor (hours) for shoreline oil at			Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline		Maximum length of shoreline (km) with concentrations ≥10.0 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 simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation	averaged over all replicate simulations	worst replicate simulation
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	6.6	2.4	1.5	74	76	77	9.6	6	3	122	123	124	136	7,781	18	302	2	10
	Canyons linking the Argo Abyssal Plain with the Scott Plateau*	0.9	<0.3	<0.3	417	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carbonate bank & terrace system of Van Diemen Rise*	4.5	1.2	<0.3	286	294	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carbonate bank and terrace system of Sahul Shelf	14.4	6	2.7	18	18	18	0.9	0.6	<0.3	373	375	NC	1.7	478	<1	5	<1	2
	Continental Slope Demersal Fish Communities*	11.4	4.8	2.4	29	30	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Pinnacles of the Bonaparte Basin*	6.9	1.2	0.6	135	148	154	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	2.4	<0.3	<0.3	232	NC	NC	7.2	3	0.9	308	415	667	20	1,279	<1	11	<1	<1
	Shelf break and slope of the Arafura Shelf*	0.9	<0.3	<0.3	949	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fisheries	Northern Prawn Fishery	7.2	2.1	0.9	86	86	87	6	4.5	2.4	345	347	412	77	7,773	NC	NC	NC	NC
	North-West Slope Trawl Fishery*	24.3	13.8	9.9	7	7	7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Southern Bluefin Tuna Fishery	100	100	100	1	1	1	9.6	6	3	122	123	124	136	7,781	NC	NC	NC	NC
	Timor Reef Fishery (NT Managed)*	1.5	<0.3	<0.3	528	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Western Skipjack Fishery	100	100	100	1	1	1	9.6	6	3	122	123	124	136	7,781	NC	NC	NC	NC
	Western Tuna and Billfish Fishery	100	100	100	1	1	1	9.6	6	3	122	123	124	136	7,781	NC	NC	NC	NC
Biologically Important Areas	Flatback Turtle BIA	7.5	2.4	1.2	65	65	65	6	4.5	2.4	345	347	412	77	7,773	85	417	3	12
	Green Turtle BIA	9.9	4.5	1.5	63	64	65	9.6	6	3	122	123	124	136	7,781	18	302	2	10
	Hawksbill Turtle BIA	4.5	2.4	1.5	106	107	108	8.7	5.7	3	122	123	124	130	7,781	12	302	<1	7
	Leatherback Turtle BIA	1.5	<0.3	<0.3	494	NC	NC	1.5	1.5	0.9	496	501	519	28	4,796	2	71	<1	5
	Loggerhead Turtle BIA	7.5	2.4	1.2	65	65	65	<0.3	<0.3	<0.3	NC	NC	NC	NC	NC	NC	NC	NC	NC
	Olive Ridley Turtle BIA	7.5	2.4	1.2	65	65	65	4.5	2.7	2.1	345	347	425	51	4,560	16	315	<1	9

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.*

RPS

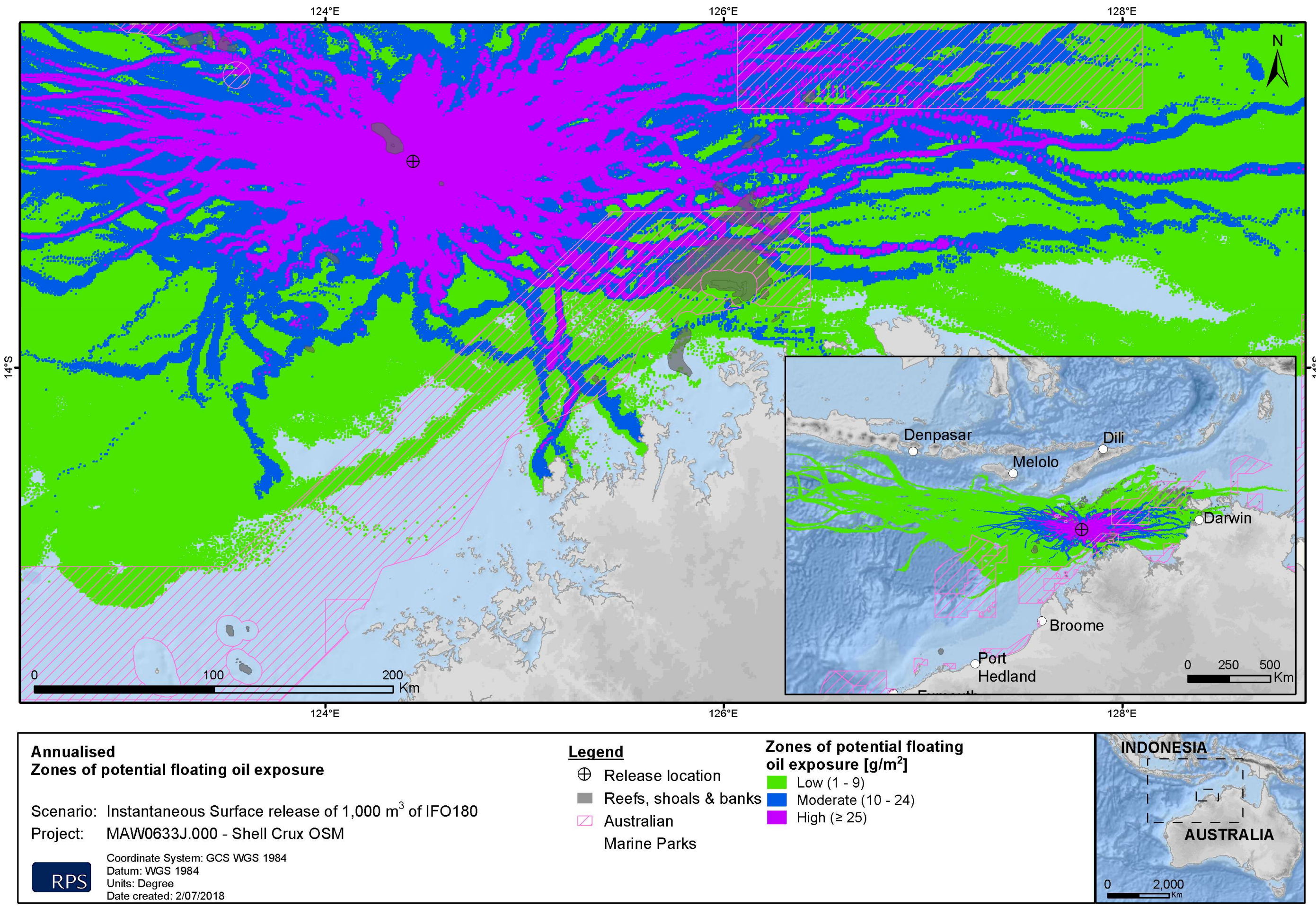


Figure 3.38 Surface Hydrocarbons | Collision Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined floating oil threshold concentrations resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

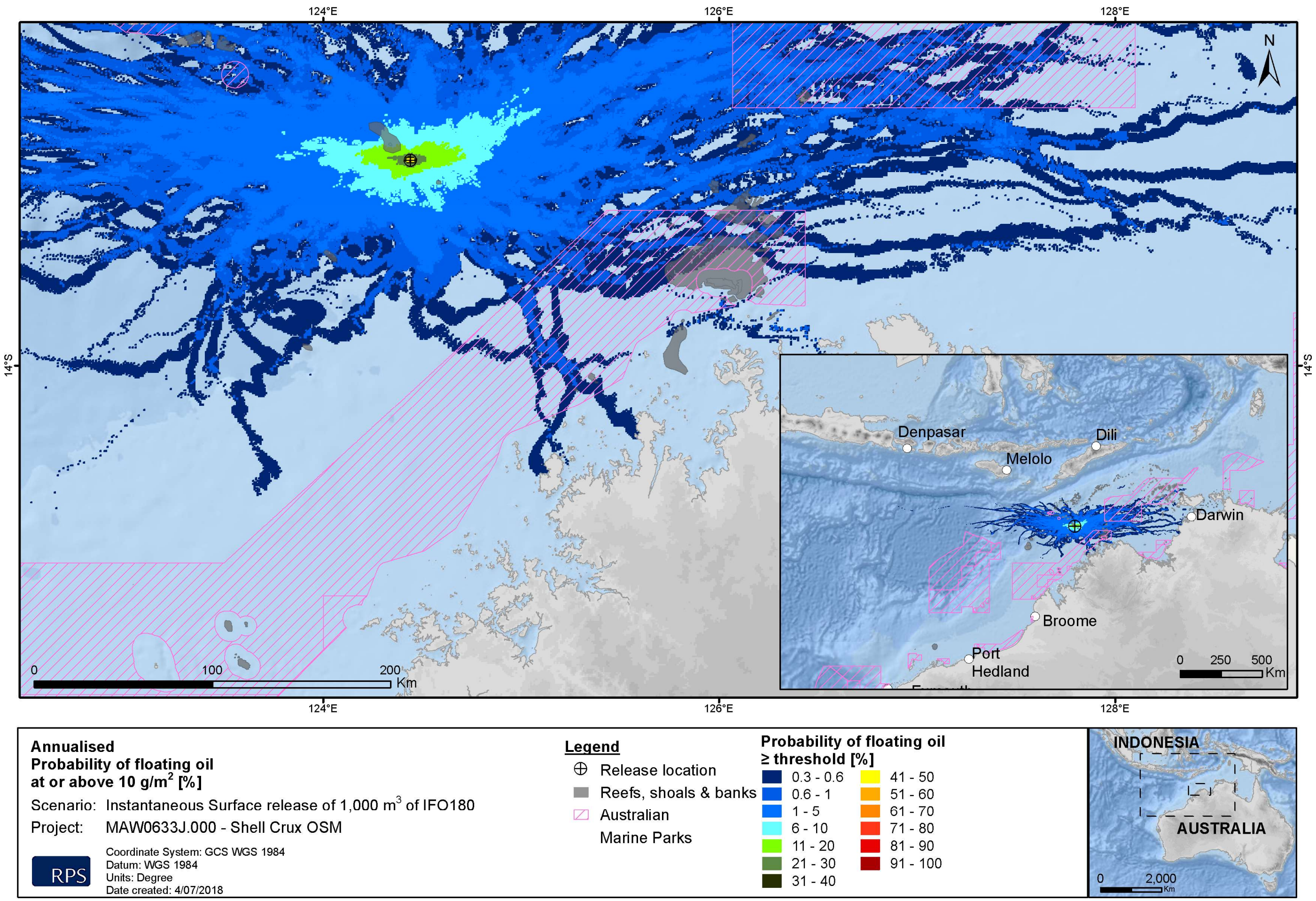


Figure 3.39 Surface Hydrocarbons | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of floating oil concentrations at or above 10 g/m² resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

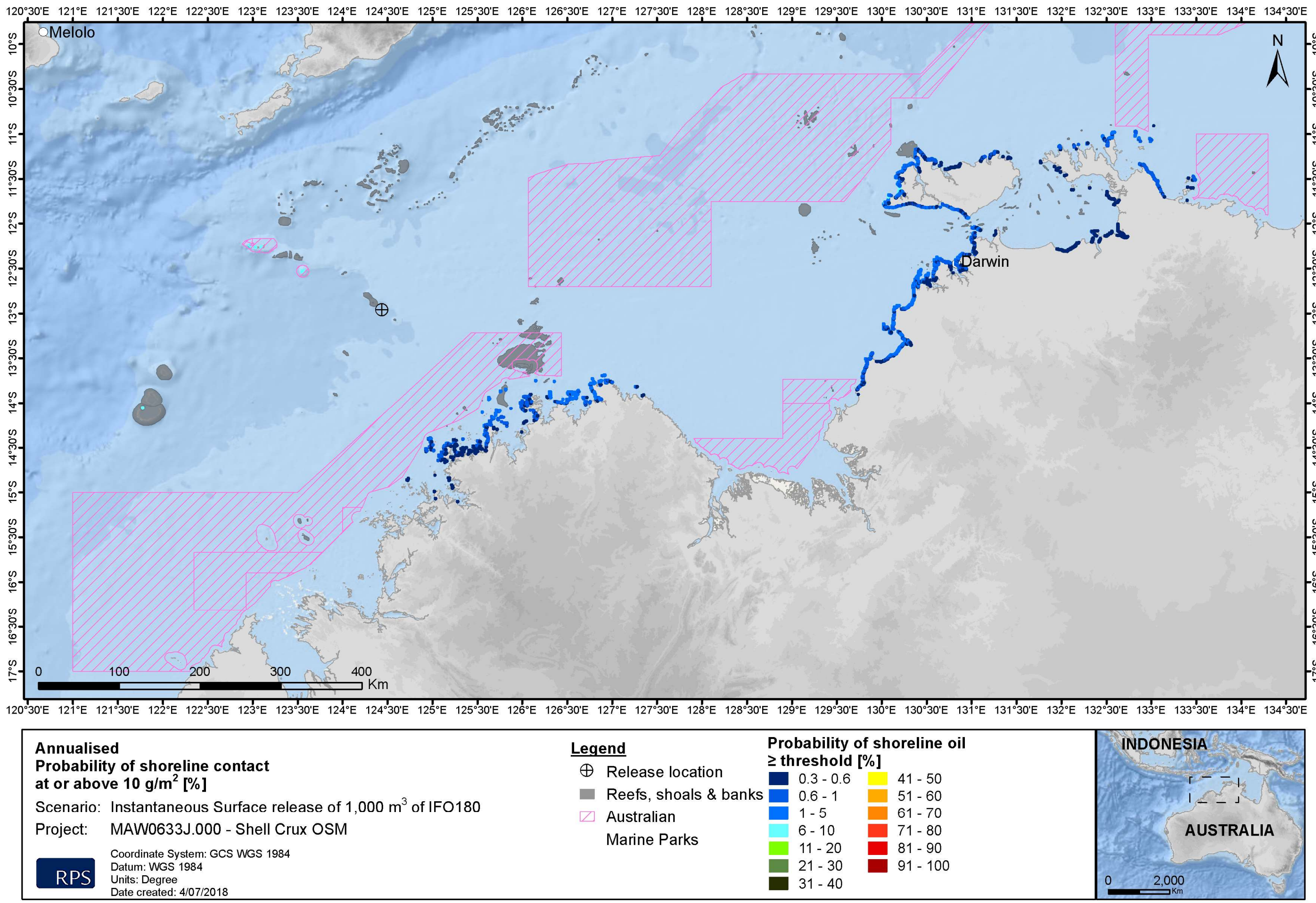


Figure 3.40 Shoreline Hydrocarbons | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 10 g/m^2 resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

RPS

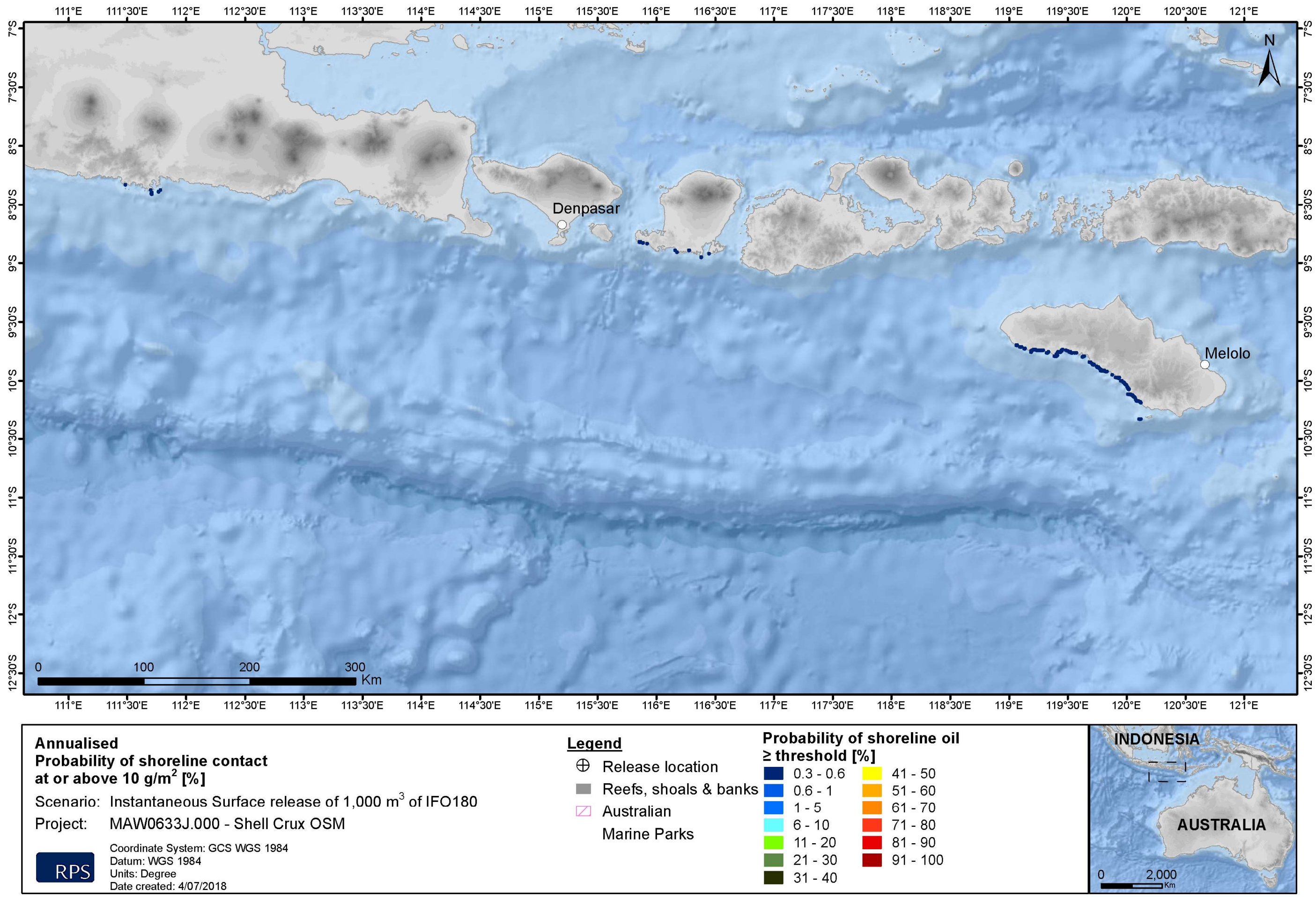


Figure 3.41 Shoreline Hydrocarbons | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 10 g/m^2 resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

RPS

3.5.3 Entrained Hydrocarbons

Table 3.18 Expected annualised entrained oil outcomes at sensitive receptors resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours) at		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
Coastlines	Cobourg Peninsula	<0.3	<0.3	<0.3	NC	NC	NC
	Darwin Coast	<0.3	<0.3	<0.3	NC	NC	NC
	Indonesia	<0.3	<0.3	<0.3	NC	NC	NC
	Joseph Bonaparte Gulf Northern Territory	<0.3	<0.3	<0.3	NC	NC	NC
	Kakadu Coast	<0.3	<0.3	<0.3	NC	NC	NC
	Kakadu National Park	<0.3	<0.3	<0.3	NC	NC	NC
	Kimberley Coast	<0.3	<0.3	<0.3	NC	NC	NC
	West Arnhem Land	<0.3	<0.3	<0.3	NC	NC	NC
Islands	Admiralty Gulf Islands	<0.3	<0.3	<0.3	NC	NC	NC
	Bathurst Island	<0.3	<0.3	<0.3	NC	NC	NC
	Bigge Island	<0.3	<0.3	<0.3	NC	NC	NC
	Bonaparte Archipelago	<0.3	<0.3	<0.3	NC	NC	NC
	Browse Island	<0.3	<0.3	<0.3	NC	NC	NC
	Cape Londonderry Islands	<0.3	<0.3	<0.3	NC	NC	NC
	Cassini Island	<0.3	<0.3	<0.3	NC	NC	NC
	Coronation Island Group	<0.3	<0.3	<0.3	NC	NC	NC
	Croker Island	<0.3	<0.3	<0.3	NC	NC	NC
	East Vernon Island	<0.3	<0.3	<0.3	NC	NC	NC
	Eclipse Archipelago	<0.3	<0.3	<0.3	NC	NC	NC
	Field Island	<0.3	<0.3	<0.3	NC	NC	NC
	Greenhill Island	<0.3	<0.3	<0.3	NC	NC	NC
	Jones Island	<0.3	<0.3	<0.3	NC	NC	NC
	Lawson Island	<0.3	<0.3	<0.3	NC	NC	NC
	Lesueur Island	<0.3	<0.3	<0.3	NC	NC	NC
	Long Island Kimberley	<0.3	<0.3	<0.3	NC	NC	NC
	McCluer Island	<0.3	<0.3	<0.3	NC	NC	NC
	Melville Island	<0.3	<0.3	<0.3	NC	NC	NC
	Mogogout Island	<0.3	<0.3	<0.3	NC	NC	NC

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours) at		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Montalivet Island	<0.3	<0.3	<0.3	NC	NC	NC
	Morse Island	<0.3	<0.3	<0.3	NC	NC	NC
	Napier Broome Bay Islands	<0.3	<0.3	<0.3	NC	NC	NC
	New Year Island	<0.3	<0.3	<0.3	NC	NC	NC
	North Goulburn Island	<0.3	<0.3	<0.3	NC	NC	NC
	North West Vernon Island	<0.3	<0.3	<0.3	NC	NC	NC
	Oxley Island	<0.3	<0.3	<0.3	NC	NC	NC
	Peron Islands	<0.3	<0.3	<0.3	NC	NC	NC
	Roche Islands and Reefs	<0.3	<0.3	<0.3	NC	NC	NC
	South Goulburn Island	<0.3	<0.3	<0.3	NC	NC	NC
	South West Vernon Island	<0.3	<0.3	<0.3	NC	NC	NC
	Stewarts Islands	<0.3	<0.3	<0.3	NC	NC	NC
	Troughton Island	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Beatrice Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Christine Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Draytons Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	East Holothuria Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Elphinstone Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Fish Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Harris Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Heritage Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Hibernia Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Hunt Patch	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Ingram Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Jamieson Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Knight Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Long Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Lyne Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Middle Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Oliver Reef	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Oliver Rock	<0.3	<0.3	<0.3	NC	NC	NC
Reefs	Orontes Reef	<0.3	<0.3	<0.3	NC	NC	NC

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours) at		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Rothery Reef	<0.3	<0.3	<0.3	NC	NC	NC
	Sandy Islet	<0.3	<0.3	<0.3	NC	NC	NC
	Scott Reef North	<0.3	<0.3	<0.3	NC	NC	NC
	Scott Reef South	<0.3	<0.3	<0.3	NC	NC	NC
	Seringapatam Reef	<0.3	<0.3	<0.3	NC	NC	NC
	Taylor Patches	<0.3	<0.3	<0.3	NC	NC	NC
	The Boxers	<0.3	<0.3	<0.3	NC	NC	NC
	The Boxers Area	<0.3	<0.3	<0.3	NC	NC	NC
	Tregenna Reef	<0.3	<0.3	<0.3	NC	NC	NC
	West Holothuria Reef	<0.3	<0.3	<0.3	NC	NC	NC
Shoals	Abbott Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Afghan Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Ann Shoals	<0.3	<0.3	<0.3	NC	NC	NC
	Barbara Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Barracouta Shoals	<0.3	<0.3	<0.3	NC	NC	NC
	Barton Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Bassett-Smith Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Beagle Shoals	<0.3	<0.3	<0.3	NC	NC	NC
	Big Bank Shoals	<0.3	<0.3	<0.3	NC	NC	NC
	Bill Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Britomart Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Calder Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Cootamundra Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Deep Shoal 1	<0.3	<0.3	<0.3	NC	NC	NC
	Deep Shoal 2	<0.3	<0.3	<0.3	NC	NC	NC
	Dillon Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Echo Shoals	<0.3	<0.3	<0.3	NC	NC	NC
	Echuca Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Eugene McDermott Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Fantome Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Fitzpatrick Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Giles Shoal	<0.3	<0.3	<0.3	NC	NC	NC

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours) at		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Goeree Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Hancox Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Heywood Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Jabiru Shoals	<0.3	<0.3	<0.3	NC	NC	NC
	Jones Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Karmt Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Lowry Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Mangola Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Marie Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Marsh Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Mermaid Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Moresby Shoals	<0.3	<0.3	<0.3	NC	NC	NC
	Moss Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Newby Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Parry Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Pee Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Penguin Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Penguin Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Shepparton Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Skottowe Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Taiyun Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Van Cloon Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Vee Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Victoria Shoal	<0.3	<0.3	<0.3	NC	NC	NC
	Vulcan Shoals	<0.3	<0.3	<0.3	NC	NC	NC
	Wells Shoal	<0.3	<0.3	<0.3	NC	NC	NC
Banks	Baldwin Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Bellona Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Branch Banks	<0.3	<0.3	<0.3	NC	NC	NC
	Favell Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Flat Top Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Foelsche Bank	<0.3	<0.3	<0.3	NC	NC	NC

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours) at		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Gale Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Goodrich Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Holothuria Banks	<0.3	<0.3	<0.3	NC	NC	NC
	Johnson Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Jones Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Margaret Harries Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Otway Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Parsons Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Sahul Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Sunrise Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Tait Bank	<0.3	<0.3	<0.3	NC	NC	NC
	Woodbine Bank	<0.3	<0.3	<0.3	NC	NC	NC
Marine Parks	Arafura AMP	<0.3	<0.3	<0.3	NC	NC	NC
	Arnhem AMP	<0.3	<0.3	<0.3	NC	NC	NC
	Ashmore Reef AMP	<0.3	<0.3	<0.3	NC	NC	NC
	Cartier Island AMP	<0.3	<0.3	<0.3	NC	NC	NC
	Charles Darwin NP	<0.3	<0.3	<0.3	NC	NC	NC
	Djukbinj NP	<0.3	<0.3	<0.3	NC	NC	NC
	Garig Gunak Barlu NP	<0.3	<0.3	<0.3	NC	NC	NC
	Kakadu NP	<0.3	<0.3	<0.3	NC	NC	NC
	Kimberley AMP	<0.3	<0.3	<0.3	NC	NC	NC
	North Lalang-garram MP & North Kimberley MP	<0.3	<0.3	<0.3	NC	NC	NC
	Mary River NP	<0.3	<0.3	<0.3	NC	NC	NC
	Oceanic Shoals AMP	<0.3	<0.3	<0.3	NC	NC	NC
	Prince Regent NP Coast	<0.3	<0.3	<0.3	NC	NC	NC
Key Ecological Features	Ancient Coastline at 125 m depth contour	<0.3	<0.3	<0.3	NC	NC	NC
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	<0.3	<0.3	<0.3	NC	NC	NC
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	<0.3	<0.3	<0.3	NC	NC	NC
	Carbonate bank & terrace system of Van Diemen Rise	<0.3	<0.3	<0.3	NC	NC	NC

RPS

	Receptor	Probability (%) of entrained hydrocarbon concentration contact at specific receptor depth			Minimum time to receptor waters (hours) at		
		≥10 ppb	≥100 ppb	≥500 ppb	≥10 ppb	≥100 ppb	≥500 ppb
	Carbonate bank and terrace system of Sahul Shelf	0.9	<0.3	<0.3	29	NC	NC
	Continental Slope Demersal Fish Communities	<0.3	<0.3	<0.3	NC	NC	NC
	Pinnacles of the Bonaparte Basin	<0.3	<0.3	<0.3	NC	NC	NC
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	<0.3	<0.3	<0.3	NC	NC	NC
	Shelf break and slope of the Arafura Shelf	<0.3	<0.3	<0.3	NC	NC	NC
Fisheries	Northern Prawn Fishery	<0.3	<0.3	<0.3	NC	NC	NC
Fisheries	North-West Slope Trawl Fishery	0.6	<0.3	<0.3	11	NC	NC
Fisheries	Southern Bluefin Tuna Fishery	5.4	1.8	1.2	1	1	1
Fisheries	Timor Reef Fishery (NT Managed)	<0.3	<0.3	<0.3	NC	NC	NC
Fisheries	Western Skipjack Fishery	5.4	1.8	1.2	1	1	1
Fisheries	Western Tuna and Billfish Fishery	5.4	1.8	1.2	1	1	1
Biologically Important Areas	Flatback Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC
Biologically Important Areas	Green Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC
Biologically Important Areas	Hawksbill Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC
Biologically Important Areas	Leatherback Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC
Biologically Important Areas	Loggerhead Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC
Biologically Important Areas	Olive Ridley Turtle BIA	<0.3	<0.3	<0.3	NC	NC	NC

NC: No contact to receptor predicted for specified threshold.

** Probabilities and maximum concentrations calculated at depth of submerged feature.*

RPS

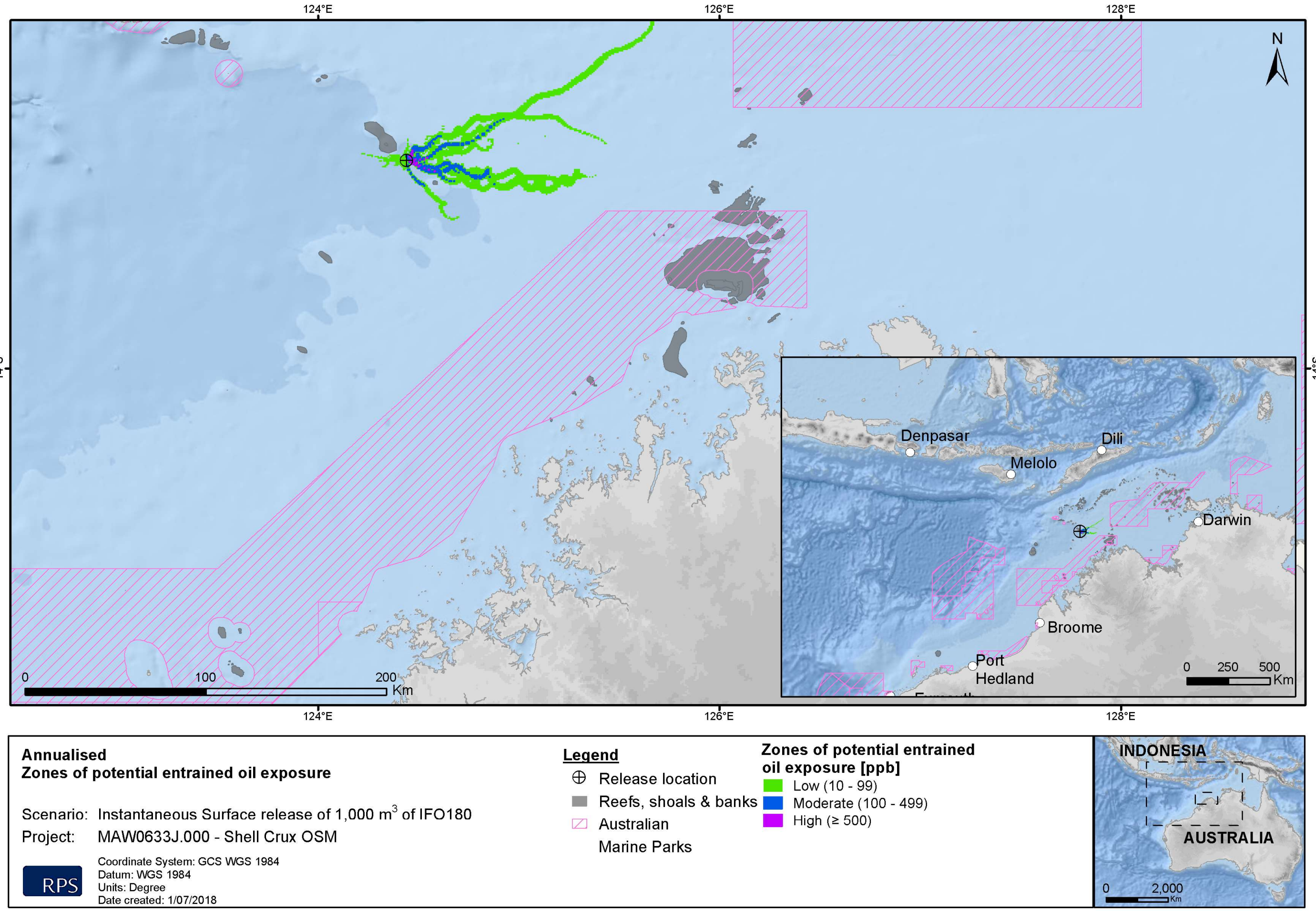


Figure 3.42 Subsurface Hydrocarbons | Entrained | Collision Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined entrained oil threshold concentrations resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

RPS

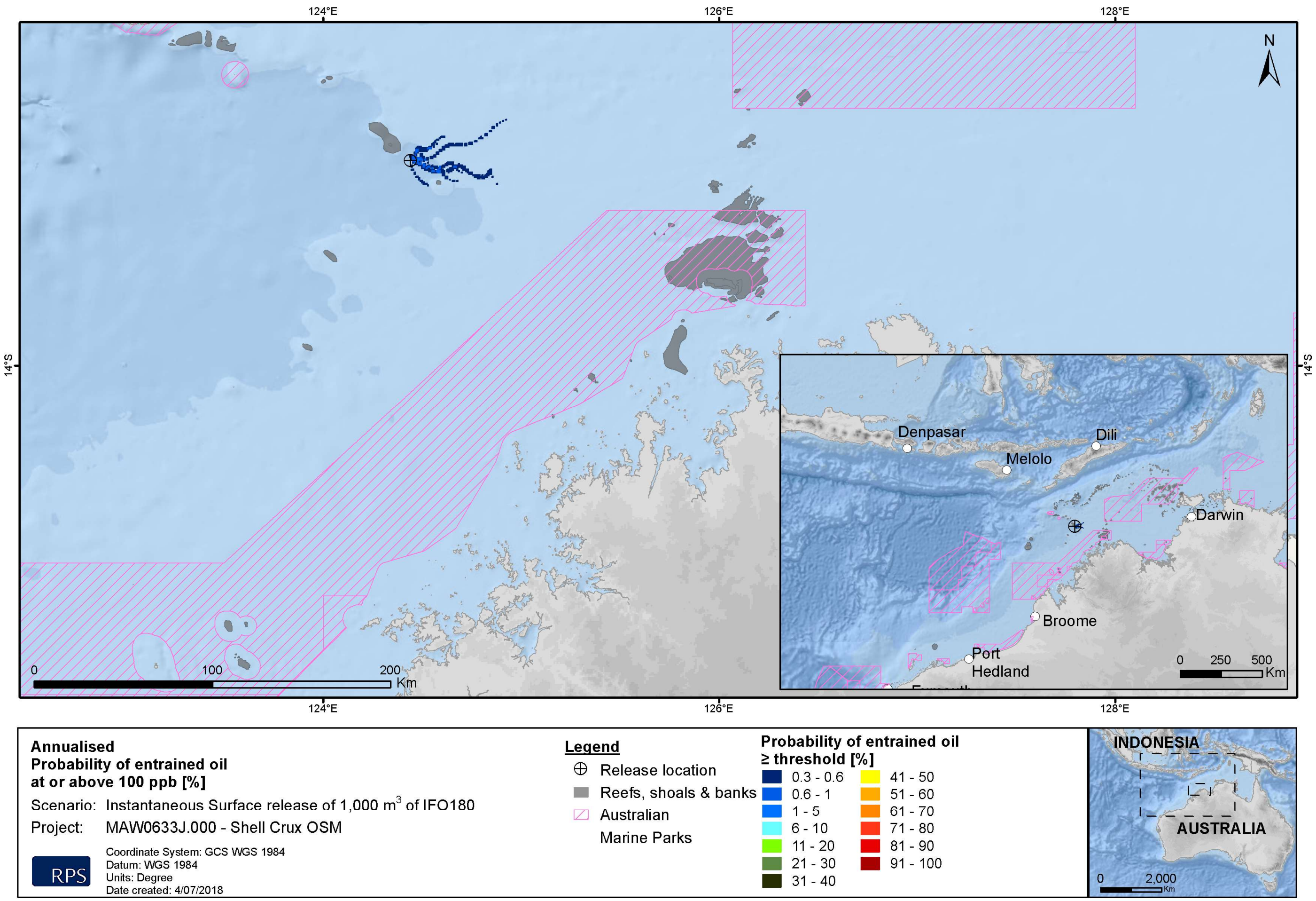


Figure 3.43 Subsurface Hydrocarbons | Entrained | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 100 ppb resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

RPS

3.5.4 Dissolved Aromatic Hydrocarbons

Table 3.19 Expected annualised dissolved aromatic hydrocarbon outcomes at sensitive receptors resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
Coastlines	Cobourg Peninsula	<0.3	<0.3	<0.3
	Darwin Coast	<0.3	<0.3	<0.3
	Indonesia	<0.3	<0.3	<0.3
	Joseph Bonaparte Gulf Northern Territory	<0.3	<0.3	<0.3
	Kakadu Coast	<0.3	<0.3	<0.3
	Kakadu National Park	<0.3	<0.3	<0.3
	Kimberley Coast	<0.3	<0.3	<0.3
	West Arnhem Land	<0.3	<0.3	<0.3
Islands	Admiralty Gulf Islands	<0.3	<0.3	<0.3
	Bathurst Island	<0.3	<0.3	<0.3
	Bigge Island	<0.3	<0.3	<0.3
	Bonaparte Archipelago	<0.3	<0.3	<0.3
	Browse Island	<0.3	<0.3	<0.3
	Cape Londonderry Islands	<0.3	<0.3	<0.3
	Cassini Island	<0.3	<0.3	<0.3
	Coronation Island Group	<0.3	<0.3	<0.3
	Croker Island	<0.3	<0.3	<0.3
	East Vernon Island	<0.3	<0.3	<0.3
	Eclipse Archipelago	<0.3	<0.3	<0.3
	Field Island	<0.3	<0.3	<0.3
	Greenhill Island	<0.3	<0.3	<0.3
	Jones Island	<0.3	<0.3	<0.3
	Lawson Island	<0.3	<0.3	<0.3
	Lesueur Island	<0.3	<0.3	<0.3
	Long Island Kimberley	<0.3	<0.3	<0.3
	McCluer Island	<0.3	<0.3	<0.3
	Melville Island	<0.3	<0.3	<0.3
	Mogogout Island	<0.3	<0.3	<0.3
	Montalivet Island	<0.3	<0.3	<0.3

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
	Morse Island	<0.3	<0.3	<0.3
	Napier Broome Bay Islands	<0.3	<0.3	<0.3
	New Year Island	<0.3	<0.3	<0.3
	North Goulburn Island	<0.3	<0.3	<0.3
	North West Vernon Island	<0.3	<0.3	<0.3
	Oxley Island	<0.3	<0.3	<0.3
	Peron Islands	<0.3	<0.3	<0.3
	Roche Islands and Reefs	<0.3	<0.3	<0.3
	South Goulburn Island	<0.3	<0.3	<0.3
	South West Vernon Island	<0.3	<0.3	<0.3
	Stewarts Islands	<0.3	<0.3	<0.3
	Troughton Island	<0.3	<0.3	<0.3
Reefs	Beatrice Reef	<0.3	<0.3	<0.3
	Christine Reef	<0.3	<0.3	<0.3
	Draytons Reef	<0.3	<0.3	<0.3
	East Holothuria Reef	<0.3	<0.3	<0.3
	Elphinstone Reef	<0.3	<0.3	<0.3
	Fish Reef	<0.3	<0.3	<0.3
	Harris Reef	<0.3	<0.3	<0.3
	Heritage Reef	<0.3	<0.3	<0.3
	Hibernia Reef	<0.3	<0.3	<0.3
	Hunt Patch	<0.3	<0.3	<0.3
	Ingram Reef	<0.3	<0.3	<0.3
	Jamieson Reef	<0.3	<0.3	<0.3
	Knight Reef	<0.3	<0.3	<0.3
	Long Reef	<0.3	<0.3	<0.3
	Lyne Reef	<0.3	<0.3	<0.3
	Middle Reef	<0.3	<0.3	<0.3
	Oliver Reef	<0.3	<0.3	<0.3
	Oliver Rock	<0.3	<0.3	<0.3
	Orontes Reef	<0.3	<0.3	<0.3
	Rothery Reef	<0.3	<0.3	<0.3

RPS

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
	Sandy Islet	<0.3	<0.3	<0.3
	Scott Reef North	<0.3	<0.3	<0.3
	Scott Reef South	<0.3	<0.3	<0.3
	Seringapatam Reef	<0.3	<0.3	<0.3
	Taylor Patches	<0.3	<0.3	<0.3
	The Boxers	<0.3	<0.3	<0.3
	The Boxers Area	<0.3	<0.3	<0.3
	Tregenna Reef	<0.3	<0.3	<0.3
	West Holothuria Reef	<0.3	<0.3	<0.3
Shoals	Abbott Shoal	<0.3	<0.3	<0.3
	Afghan Shoal	<0.3	<0.3	<0.3
	Ann Shoals	<0.3	<0.3	<0.3
	Barbara Shoal	<0.3	<0.3	<0.3
	Barracouta Shoals	<0.3	<0.3	<0.3
	Barton Shoal	<0.3	<0.3	<0.3
	Bassett-Smith Shoal	<0.3	<0.3	<0.3
	Beagle Shoals	<0.3	<0.3	<0.3
	Big Bank Shoals	<0.3	<0.3	<0.3
	Bill Shoal	<0.3	<0.3	<0.3
	Britomart Shoal	<0.3	<0.3	<0.3
	Calder Shoal	<0.3	<0.3	<0.3
	Cootamundra Shoal	<0.3	<0.3	<0.3
	Deep Shoal 1	<0.3	<0.3	<0.3
	Deep Shoal 2	<0.3	<0.3	<0.3
	Dillon Shoal	<0.3	<0.3	<0.3
	Echo Shoals	<0.3	<0.3	<0.3
	Echuca Shoal	<0.3	<0.3	<0.3
	Eugene McDermott Shoal	<0.3	<0.3	<0.3
	Fantome Shoal	<0.3	<0.3	<0.3
	Fitzpatrick Shoal	<0.3	<0.3	<0.3
	Giles Shoal	<0.3	<0.3	<0.3
	Goeree Shoal	<0.3	<0.3	<0.3

RPS

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth ≥6 ppb	≥50 ppb	≥400 ppb
	Hancox Shoal	<0.3	<0.3	<0.3
	Heywood Shoal	<0.3	<0.3	<0.3
	Jabiru Shoals	<0.3	<0.3	<0.3
	Jones Shoal	<0.3	<0.3	<0.3
	Karmt Shoal	<0.3	<0.3	<0.3
	Lowry Shoal	<0.3	<0.3	<0.3
	Mangola Shoal	<0.3	<0.3	<0.3
	Marie Shoal	<0.3	<0.3	<0.3
	Marsh Shoal	<0.3	<0.3	<0.3
	Mermaid Shoal	<0.3	<0.3	<0.3
	Moresby Shoals	<0.3	<0.3	<0.3
	Moss Shoal	<0.3	<0.3	<0.3
	Newby Shoal	<0.3	<0.3	<0.3
	Parry Shoal	<0.3	<0.3	<0.3
	Pee Shoal	<0.3	<0.3	<0.3
	Penguin Shoal	<0.3	<0.3	<0.3
	Penguin Shoal	<0.3	<0.3	<0.3
	Shepparton Shoal	<0.3	<0.3	<0.3
	Skottowe Shoal	<0.3	<0.3	<0.3
	Taiyun Shoal	<0.3	<0.3	<0.3
	Van Cloon Shoal	<0.3	<0.3	<0.3
	Vee Shoal	<0.3	<0.3	<0.3
	Victoria Shoal	<0.3	<0.3	<0.3
	Vulcan Shoals	<0.3	<0.3	<0.3
	Wells Shoal	<0.3	<0.3	<0.3
Banks	Baldwin Bank	<0.3	<0.3	<0.3
	Bellona Bank	<0.3	<0.3	<0.3
	Branch Banks	<0.3	<0.3	<0.3
	Favell Bank	<0.3	<0.3	<0.3
	Flat Top Bank	<0.3	<0.3	<0.3
	Foelsche Bank	<0.3	<0.3	<0.3
	Gale Bank	<0.3	<0.3	<0.3

RPS

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth		
		≥6 ppb	≥50 ppb	≥400 ppb
	Goodrich Bank	<0.3	<0.3	<0.3
	Holothuria Banks	<0.3	<0.3	<0.3
	Johnson Bank	<0.3	<0.3	<0.3
	Jones Bank	<0.3	<0.3	<0.3
	Margaret Harries Bank	<0.3	<0.3	<0.3
	Otway Bank	<0.3	<0.3	<0.3
	Parsons Bank	<0.3	<0.3	<0.3
	Sahul Bank	<0.3	<0.3	<0.3
	Sunrise Bank	<0.3	<0.3	<0.3
	Tait Bank	<0.3	<0.3	<0.3
	Woodbine Bank	<0.3	<0.3	<0.3
Marine Parks	Arafura AMP	<0.3	<0.3	<0.3
	Arnhem AMP	<0.3	<0.3	<0.3
	Ashmore Reef AMP	<0.3	<0.3	<0.3
	Cartier Island AMP	<0.3	<0.3	<0.3
	Charles Darwin NP	<0.3	<0.3	<0.3
	Djukbinj NP	<0.3	<0.3	<0.3
	Garig Gunak Barlu NP	<0.3	<0.3	<0.3
	Kakadu NP	<0.3	<0.3	<0.3
	Kimberley AMP	<0.3	<0.3	<0.3
	North Lalang-garram MP & North Kimberley MP	<0.3	<0.3	<0.3
	Mary River NP	<0.3	<0.3	<0.3
	Oceanic Shoals AMP	<0.3	<0.3	<0.3
	Prince Regent NP Coast	<0.3	<0.3	<0.3
Key Ecological Features	Ancient Coastline at 125 m depth contour	<0.3	<0.3	<0.3
	Ashmore Reef and Cartier Island and surrounding Commonwealth Waters	<0.3	<0.3	<0.3
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	<0.3	<0.3	<0.3
	Carbonate bank & terrace system of Van Diemen Rise	<0.3	<0.3	<0.3
	Carbonate bank and terrace system of Sahul Shelf	<0.3	<0.3	<0.3
	Continental Slope Demersal Fish Communities	<0.3	<0.3	<0.3

RPS

	Receptor	Probability (%) of dissolved aromatic concentration at specific receptor depth ≥6 ppb	≥50 ppb	≥400 ppb
	Pinnacles of the Bonaparte Basin	<0.3	<0.3	<0.3
	Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex	<0.3	<0.3	<0.3
	Shelf break and slope of the Arafura Shelf	<0.3	<0.3	<0.3
Fisheries	Northern Prawn Fishery	<0.3	<0.3	<0.3
	North-West Slope Trawl Fishery	<0.3	<0.3	<0.3
	Southern Bluefin Tuna Fishery	0.9	<0.3	<0.3
	Timor Reef Fishery (NT Managed)	<0.3	<0.3	<0.3
	Western Skipjack Fishery	0.9	<0.3	<0.3
	Western Tuna and Billfish Fishery	0.9	<0.3	<0.3
Biologically Important Areas	Flatback Turtle BIA	<0.3	<0.3	<0.3
	Green Turtle BIA	<0.3	<0.3	<0.3
	Hawksbill Turtle BIA	<0.3	<0.3	<0.3
	Leatherback Turtle BIA	<0.3	<0.3	<0.3
	Loggerhead Turtle BIA	<0.3	<0.3	<0.3
	Olive Ridley Turtle BIA	<0.3	<0.3	<0.3

NC: No contact to receptor predicted for specified threshold.

** Probabilities and maximum concentrations calculated at depth of submerged feature.*

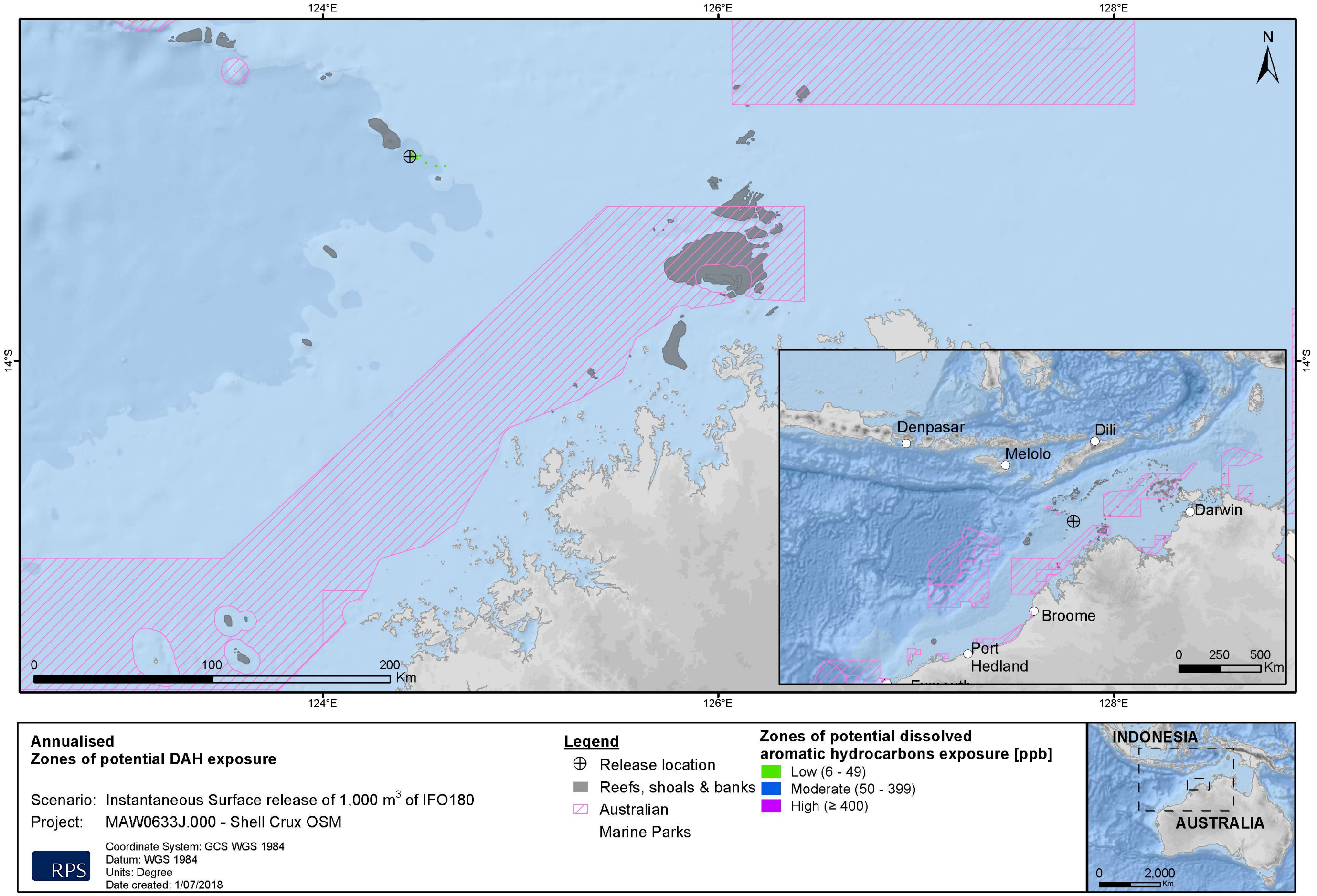


Figure 3.44 Subsurface Hydrocarbons | Dissolved | Collision Scenario | Stochastic Outcomes. Areal extent of potential exposure at defined dissolved aromatic hydrocarbon threshold concentrations resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

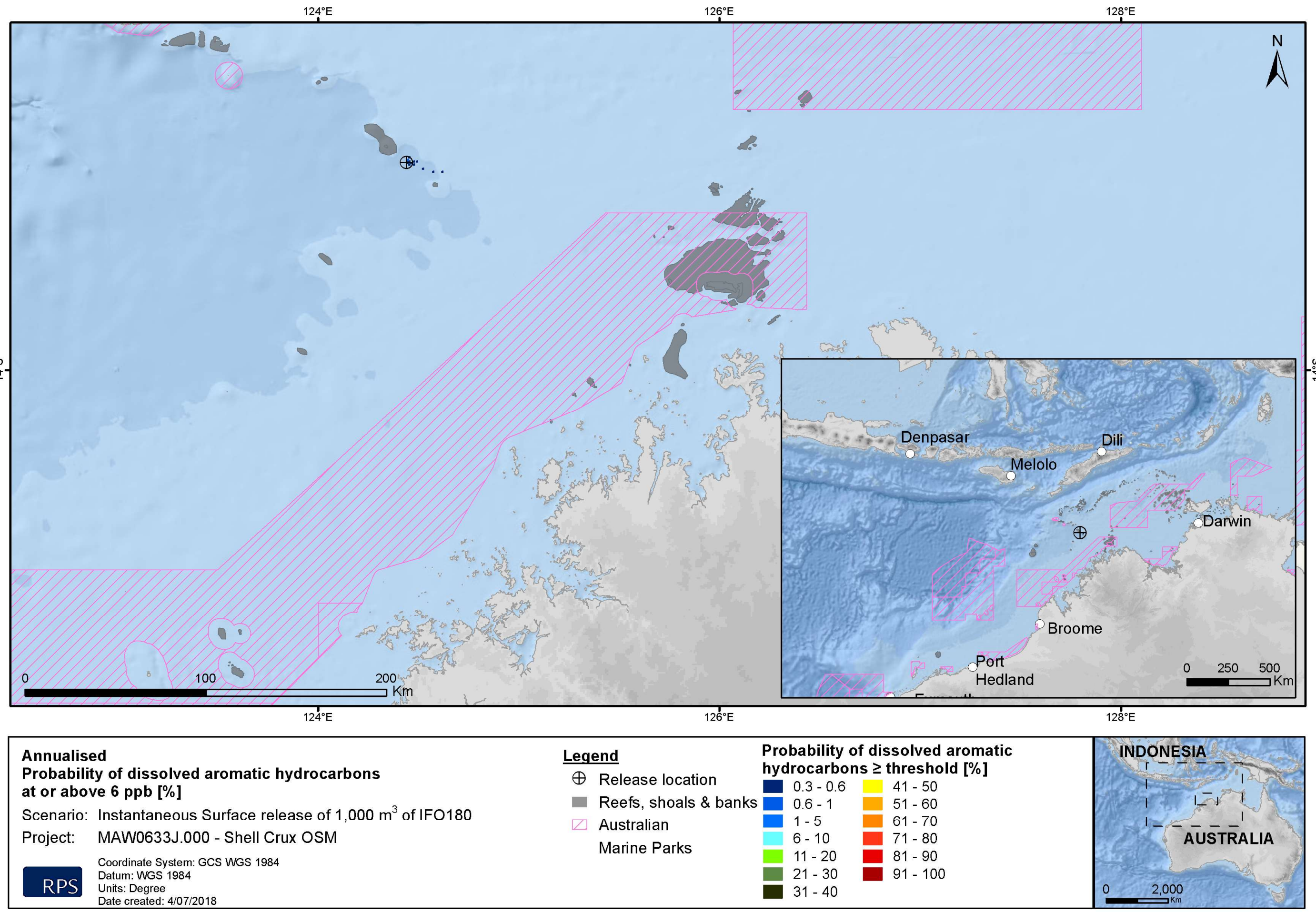


Figure 3.45 Subsurface Hydrocarbons | Dissolved | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 6 ppb resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

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Appendix A

Scenario 1 – Annualised Probability – Stochastic Modelling

Figures – Appendix A

RPS

Annualised Results

Floating and Shoreline Hydrocarbons

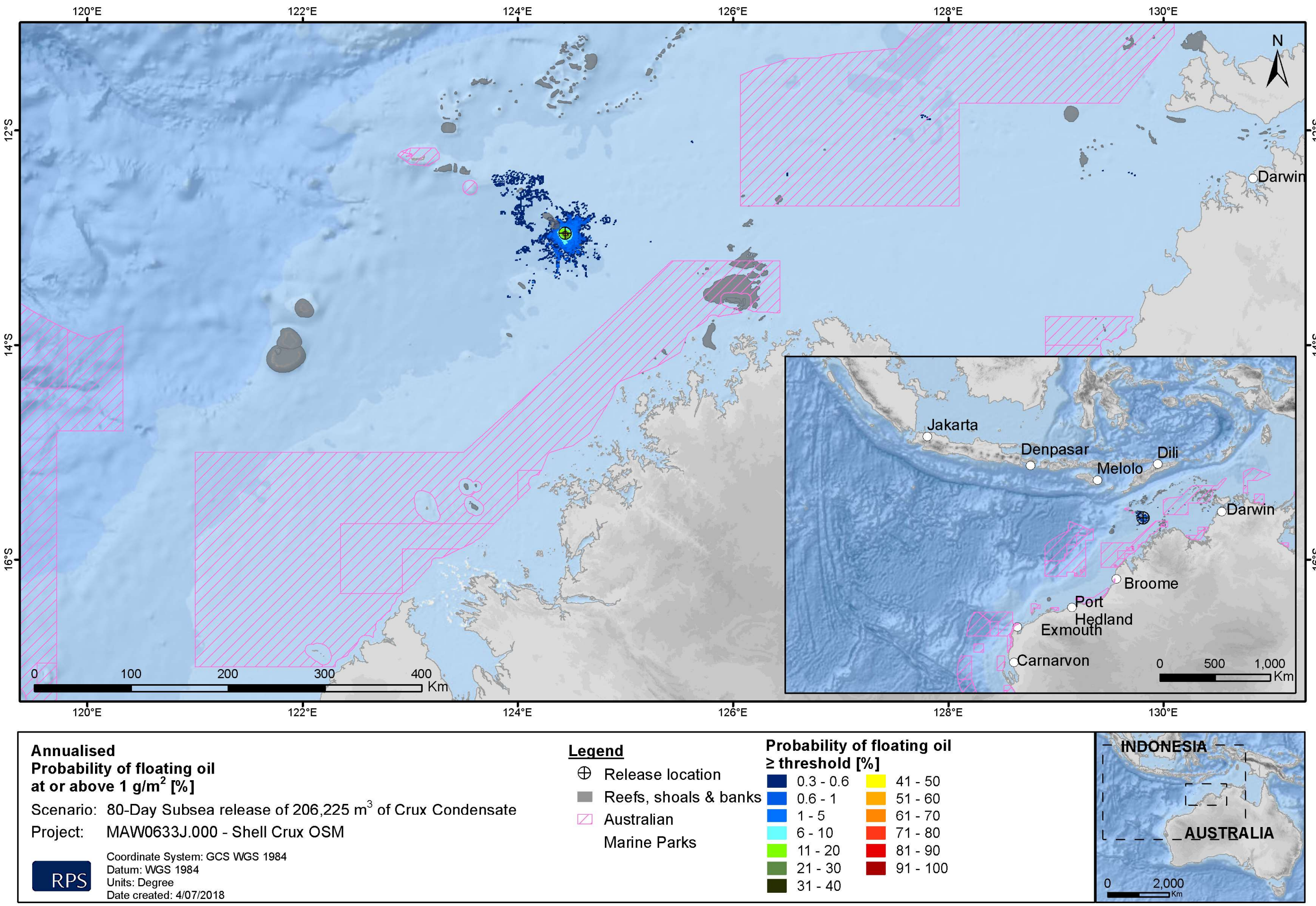


Figure A. 1 Surface Hydrocarbons | Blowout Scenario | Stochastic Outcomes. Predicted annualised probability of floating oil concentrations at or above 1 g/m^2 resulting from an 80-day subsurface release of Crux condensate at a development well.

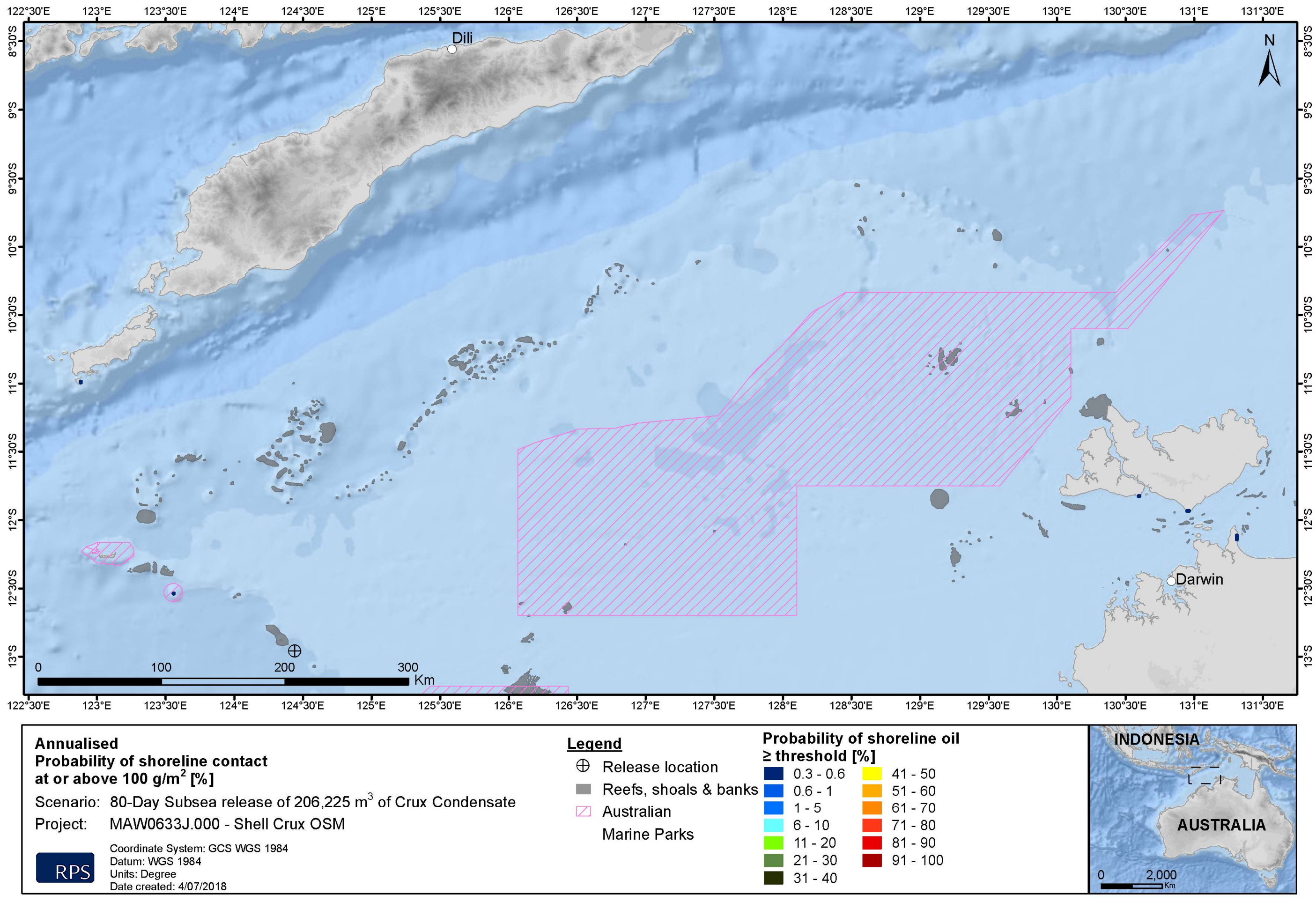


Figure A. 2 Shoreline Hydrocarbons | Blowout Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 100 g/m² resulting from an 80-day subsurface release of Crux condensate at a development well.

Entrained Hydrocarbons

RPS

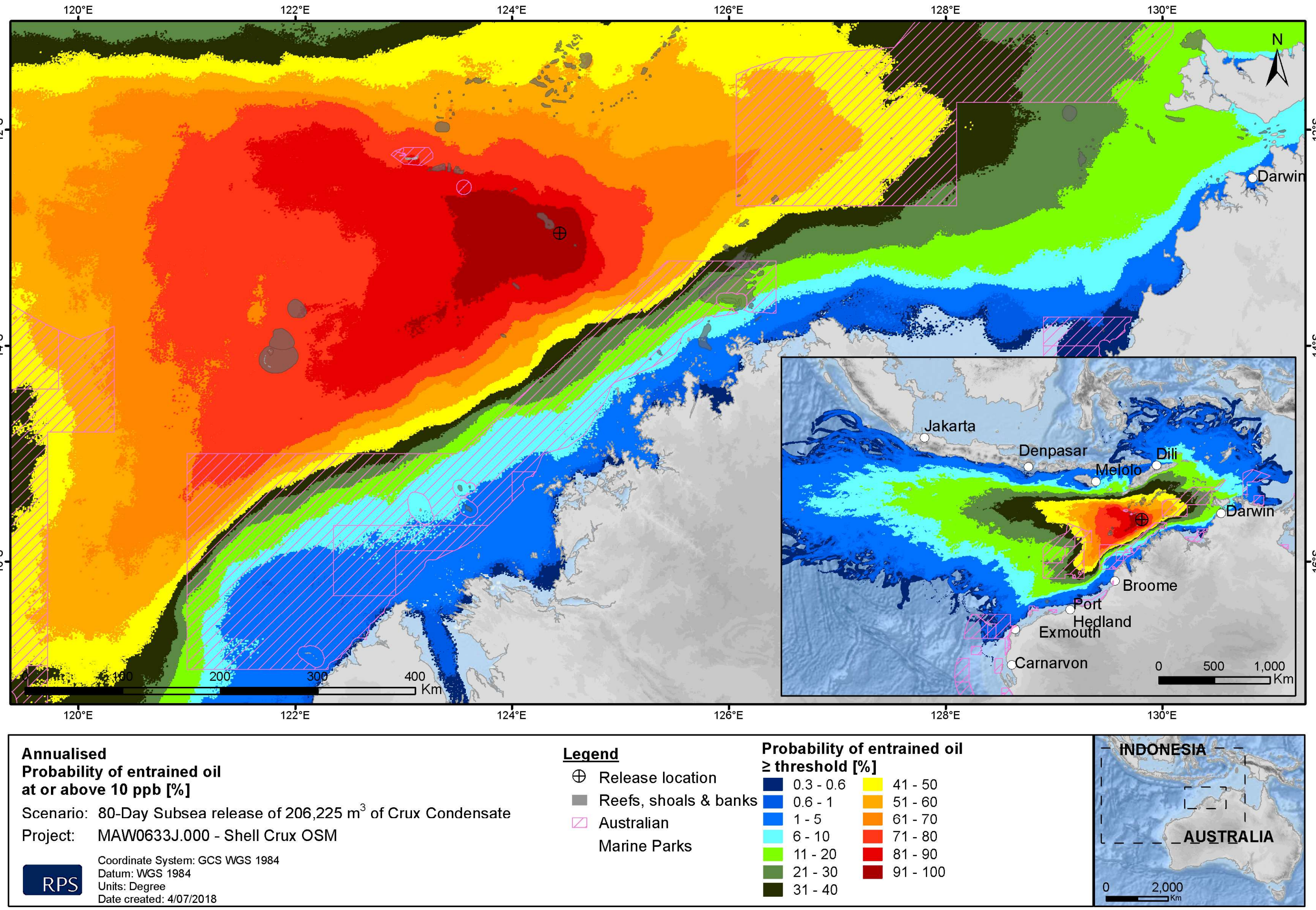


Figure A. 3 Subsurface Hydrocarbons | Entrained | Blowout Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 10 ppb resulting from an 80-day subsurface release of Crux condensate at a development well.

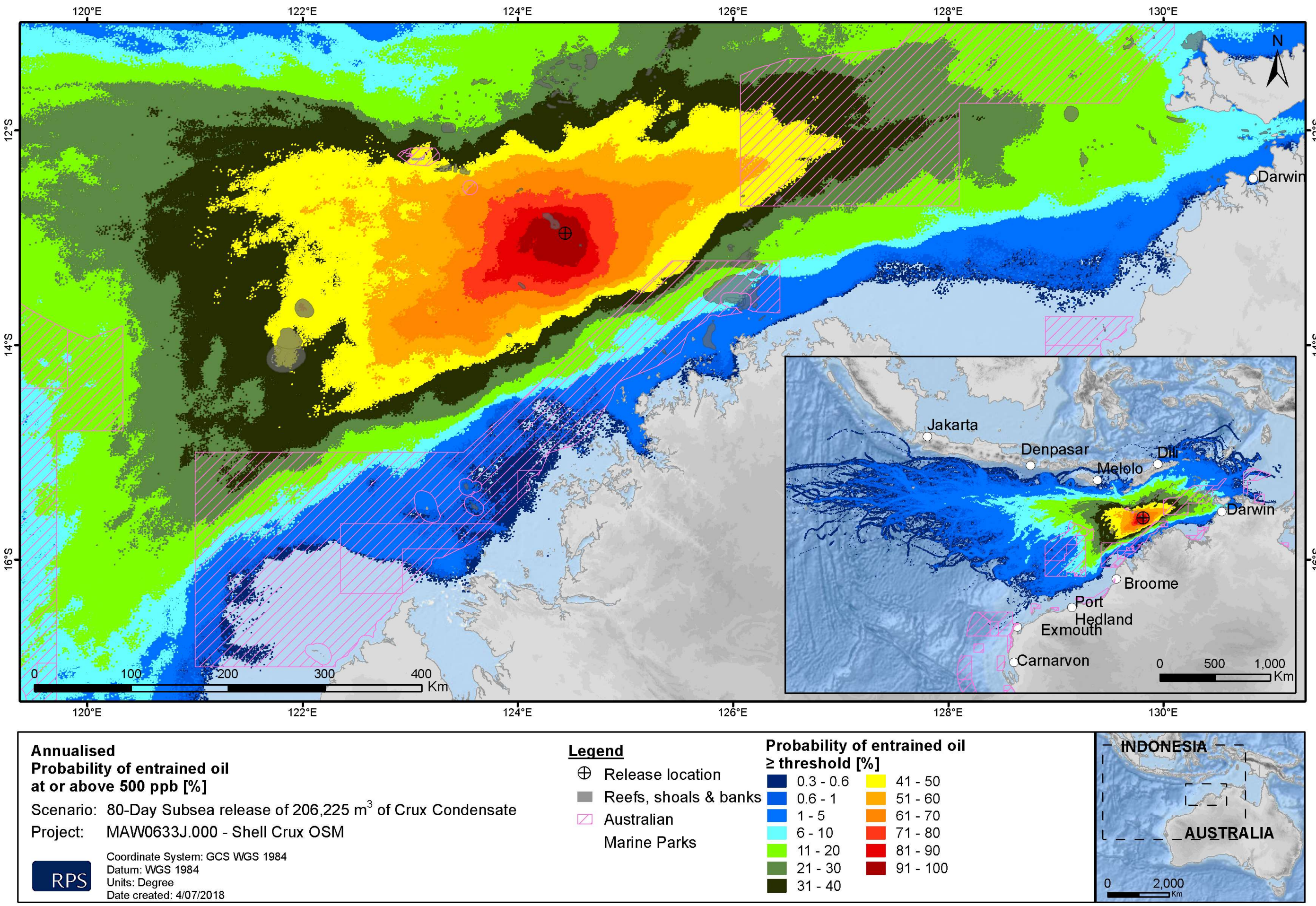


Figure A. 4 Subsurface Hydrocarbons | Entrained | Blowout Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 500 ppb resulting from an 80-day subsurface release of Crux condensate at a development well.

Appendix B
Scenario 2 – Annualised Probability – Stochastic Modelling

Figures – Appendix B

RPS

Annualised Results

Floating and Shoreline Hydrocarbons

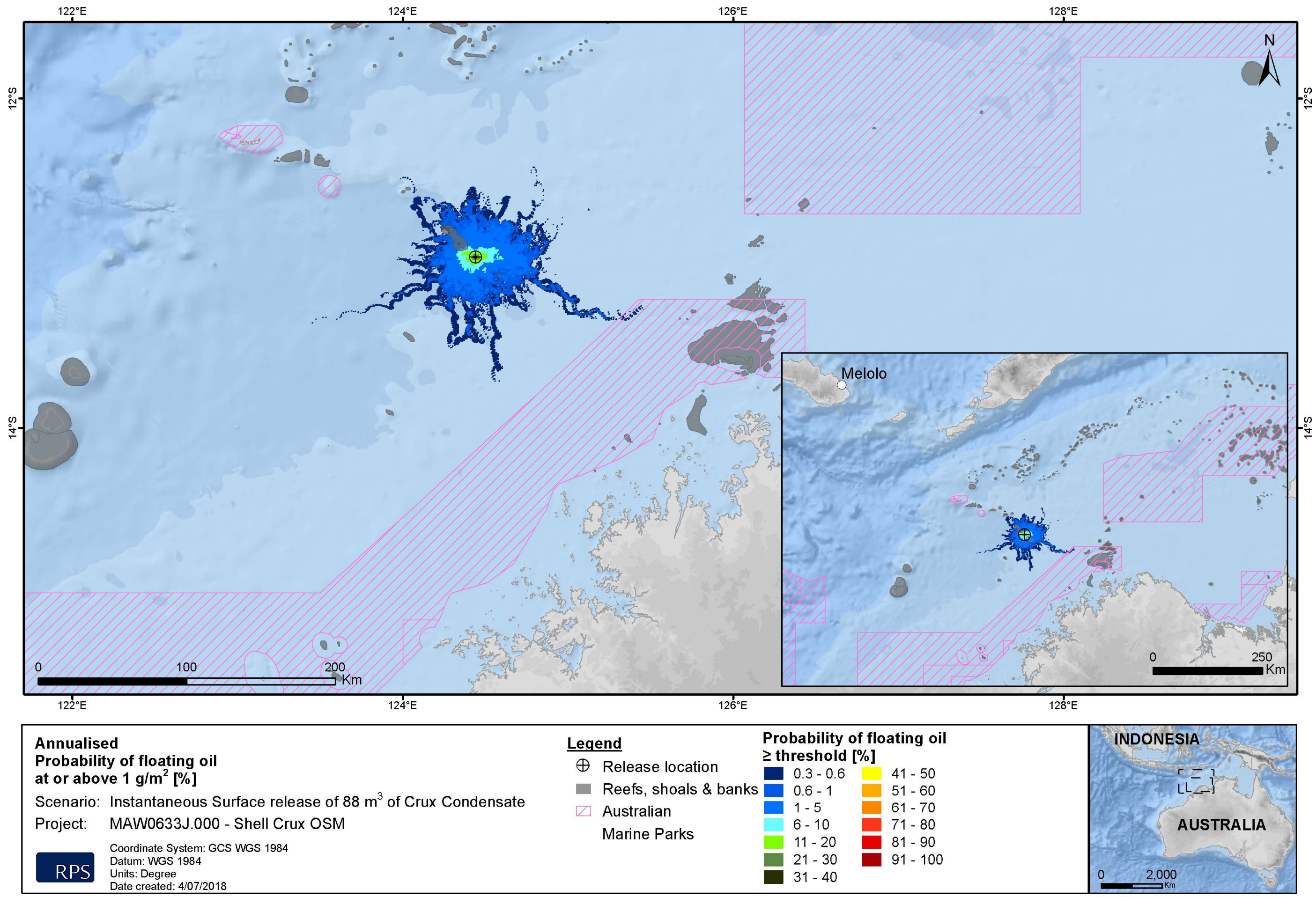
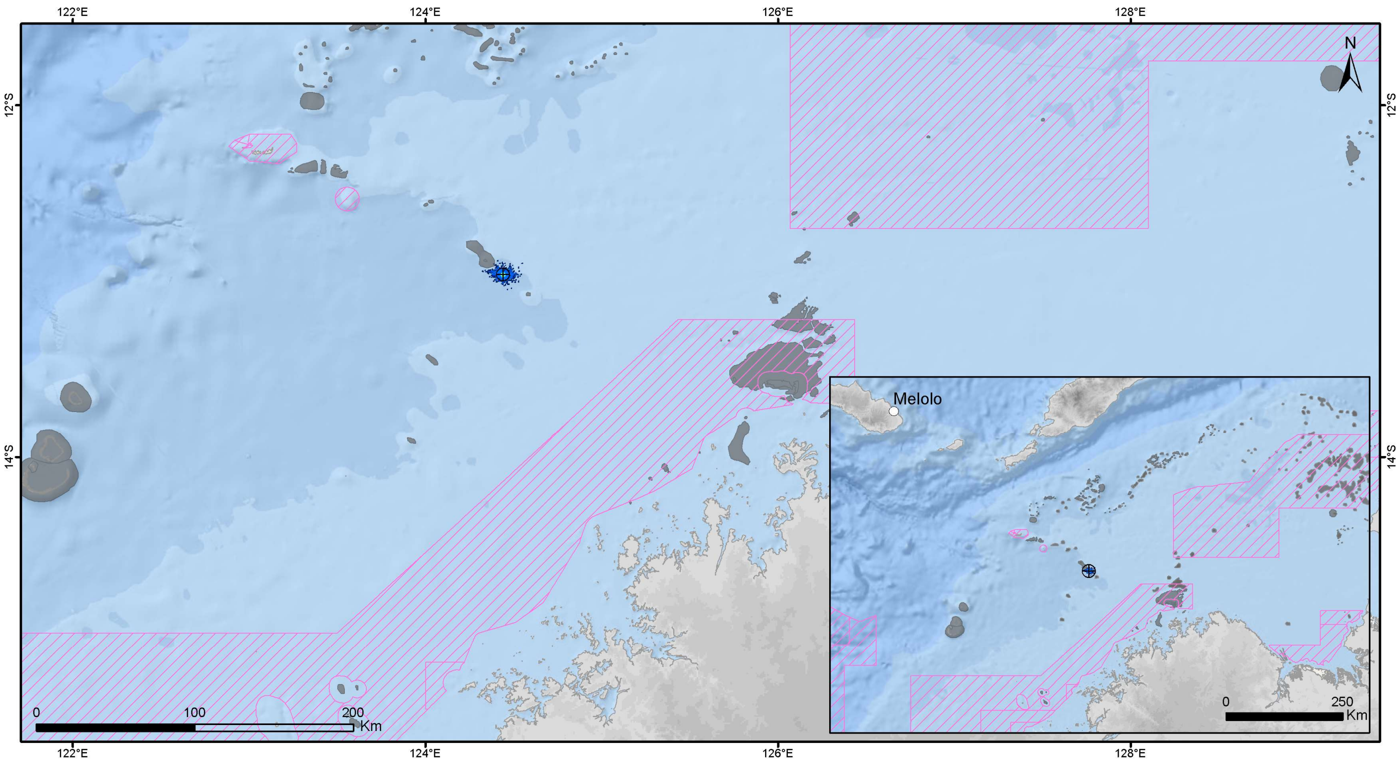


Figure B 1 Surface Hydrocarbons | Inventory Scenario | Stochastic Outcomes. Predicted annualised probability of floating oil concentrations at or above 1 g/m^2 resulting from an instantaneous surface release of Crux condensate at the Crux platform.



Annualised
Probability of floating oil
at or above 25 g/m² [%]

Scenario: Instantaneous Surface release of 88 m³ of Crux Condensate
Project: MAW0633J.000 - Shell Crux OSM

Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree
Date created: 4/07/2018

Legend
- Release location
- Reefs, shoals & banks
- Australian Marine Parks

Probability of floating oil ≥ threshold [%]

0.3 - 0.6; 0.6 - 1; 1 - 5; 6 - 10; 11 - 20; 21 - 30; 31 - 40; 41 - 50; 51 - 60; 61 - 70; 71 - 80; 81 - 90; 91 - 100

INDONESIA
AUSTRALIA
0 2,000 Km

Figure B 2 Surface Hydrocarbons | Inventory Scenario | Stochastic Outcomes. Predicted annualised probability of floating oil concentrations at or above 25 g/m² resulting from an instantaneous surface release of Crux condensate at the Crux platform.

RPS

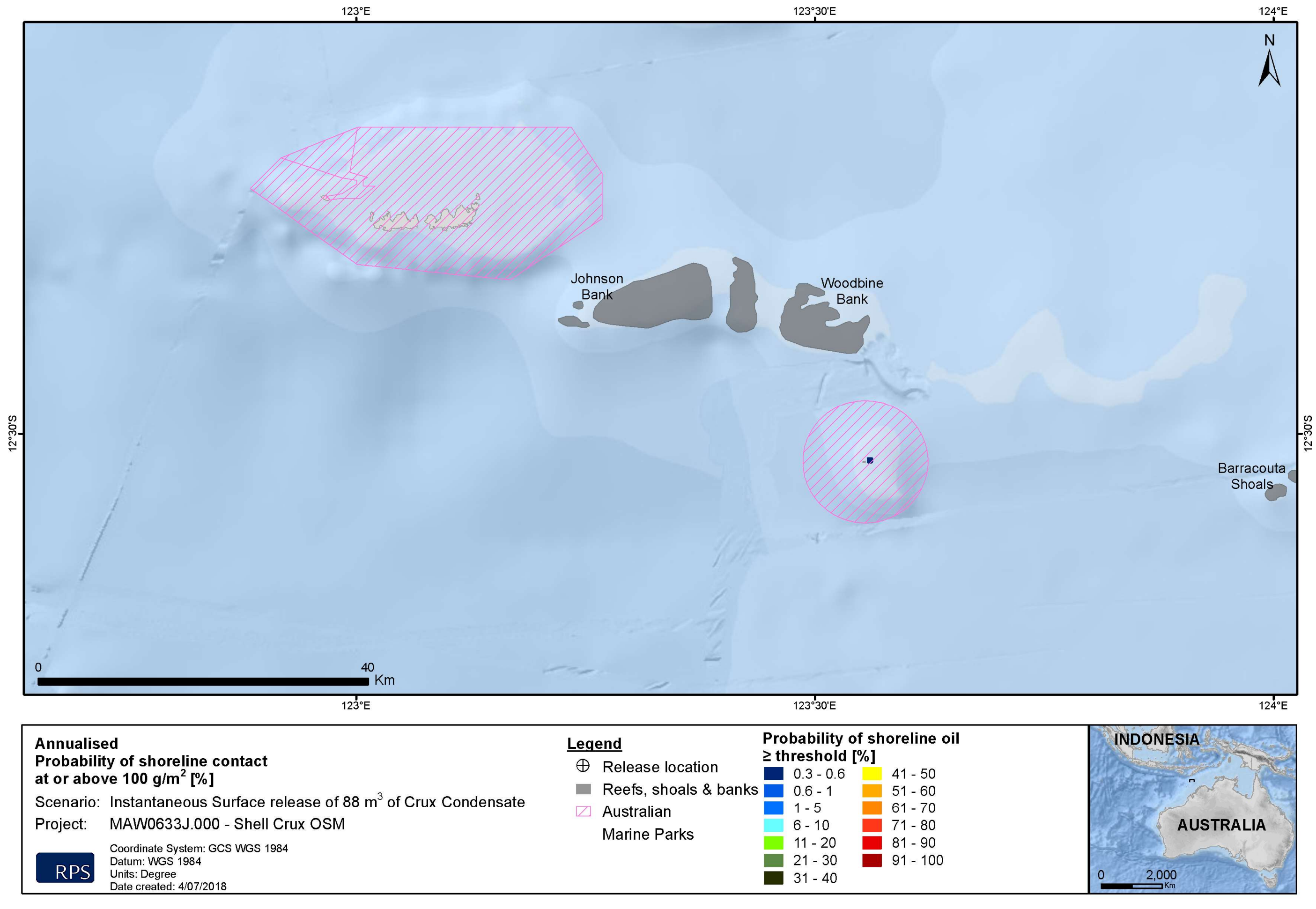


Figure B 3 Shoreline Hydrocarbons | Inventory Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of Crux condensate at the Crux platform.

Entrained Hydrocarbons

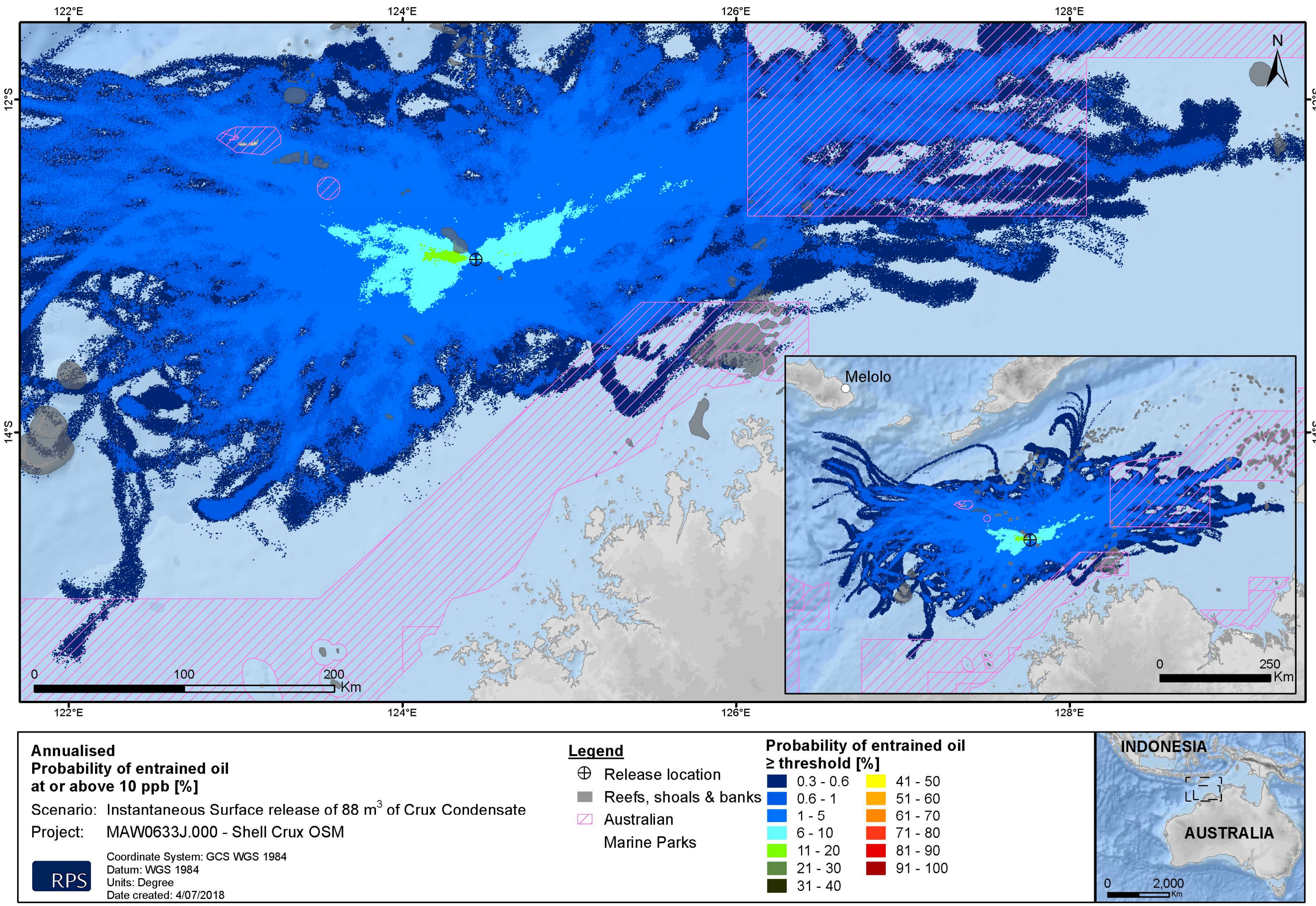


Figure B 4 Subsurface Hydrocarbons | Entrained | Inventory Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 10 ppb resulting from an instantaneous surface release of Crux condensate at the Crux platform.

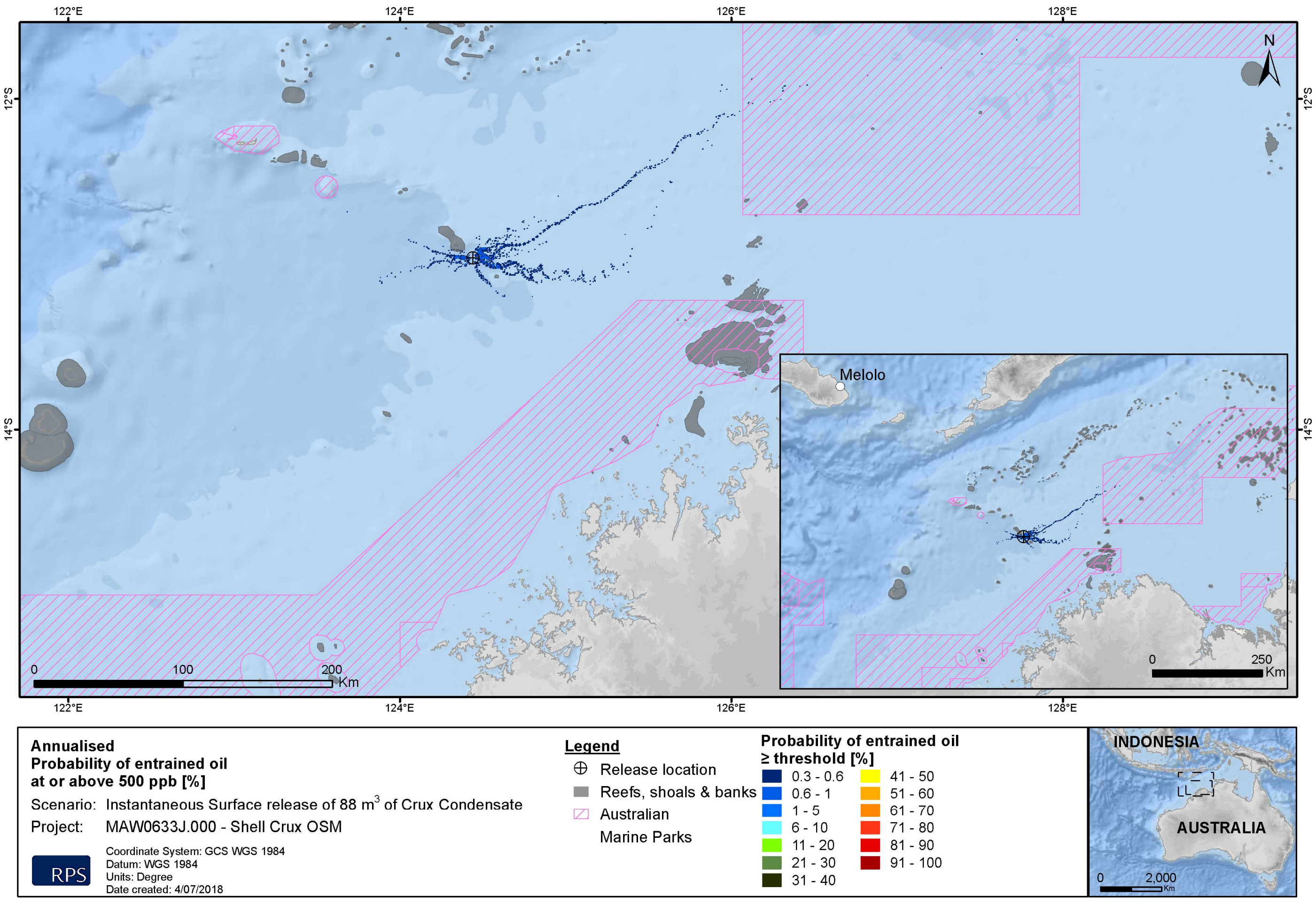


Figure B 5 Subsurface Hydrocarbons | Entrained | Inventory Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of Crux condensate at the Crux platform.

RPS

Appendix C
Scenario 3 – Annualised Probability – Stochastic Modelling

Figures – Appendix C

RPS

Annualised Results

Floating and Shoreline Hydrocarbons

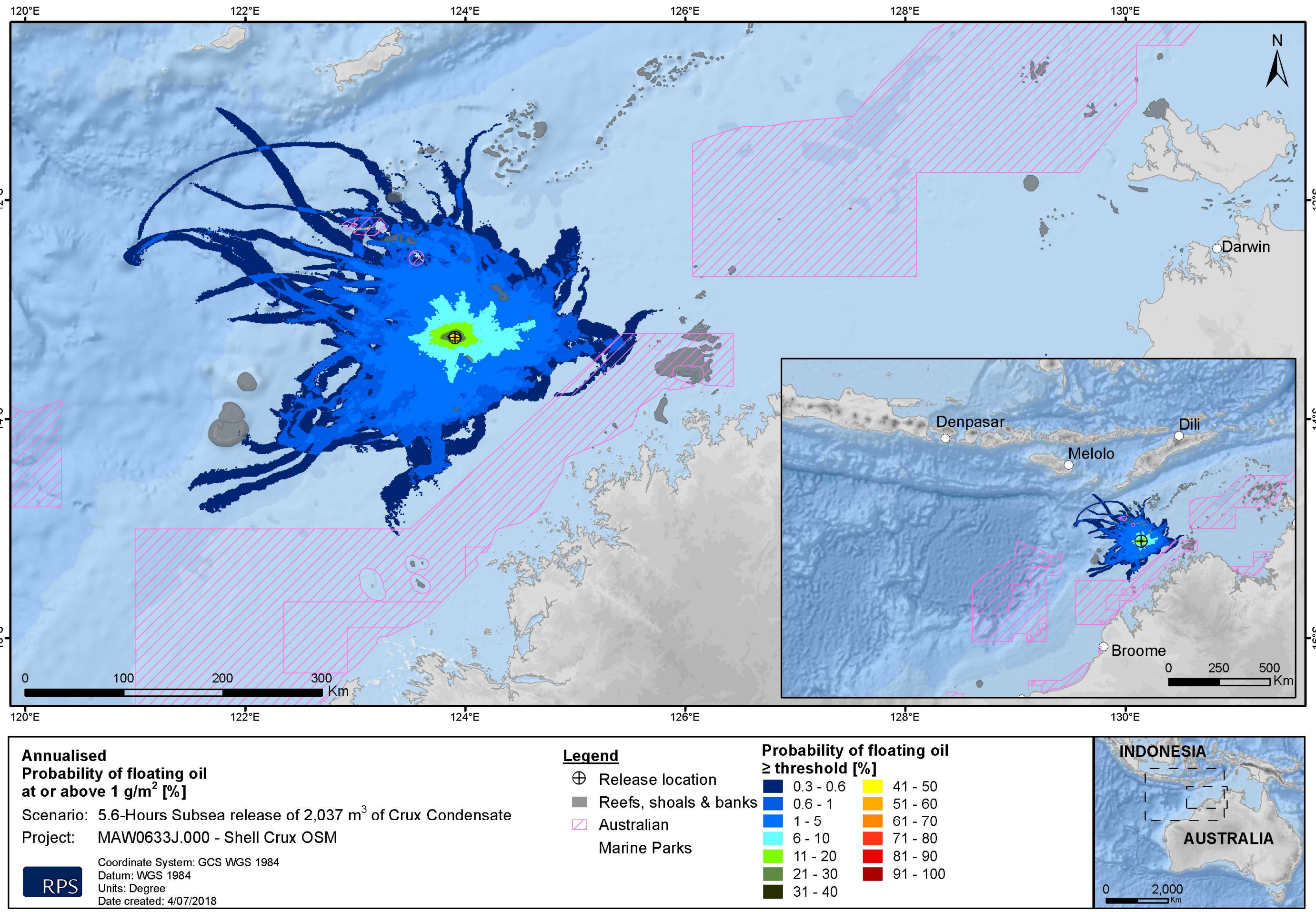


Figure C 1 Surface Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of floating oil concentrations at or above 1 g/m² resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

RPS

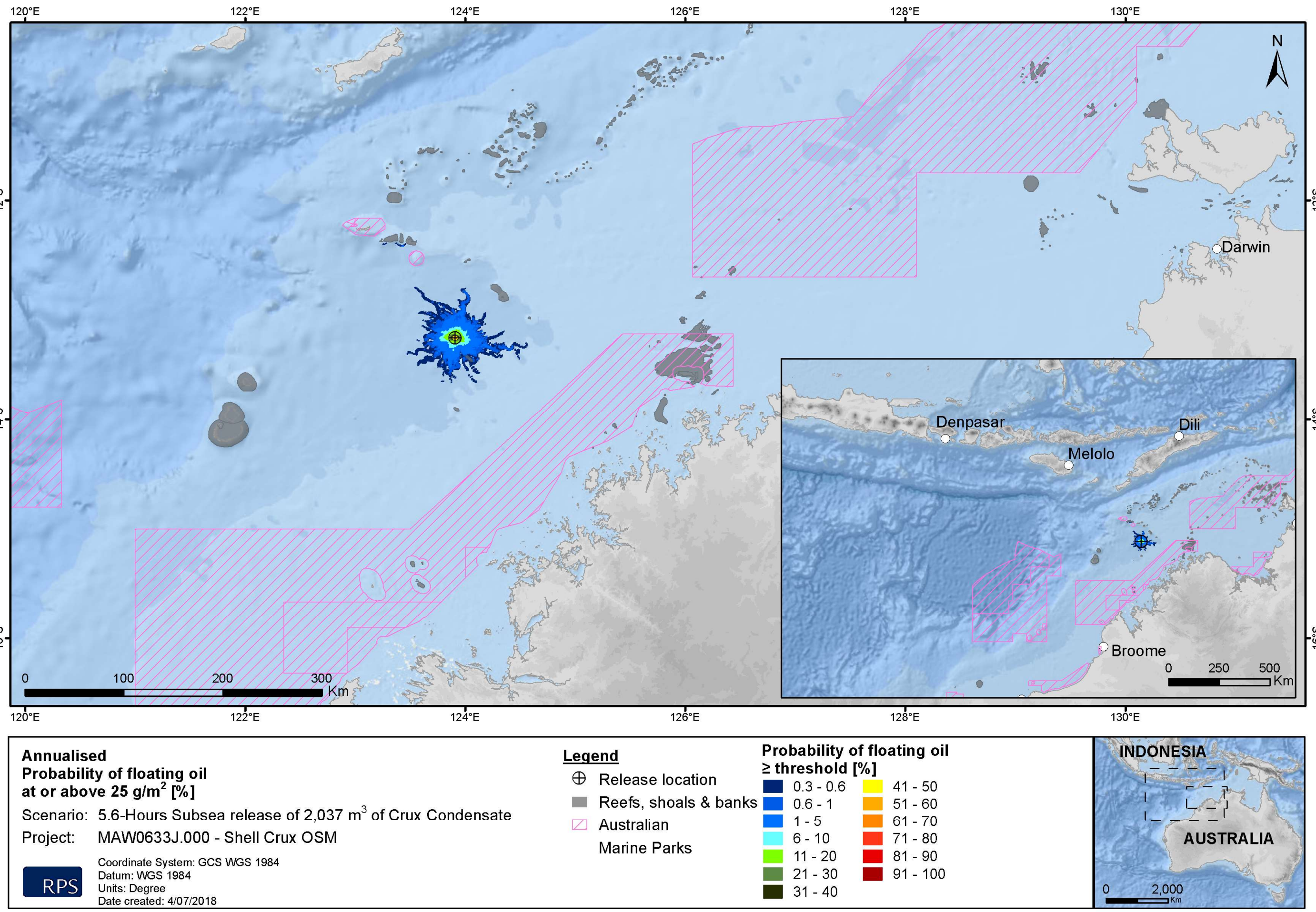


Figure C 2 Surface Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of floating oil concentrations at or above 25 g/m² resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

RPS

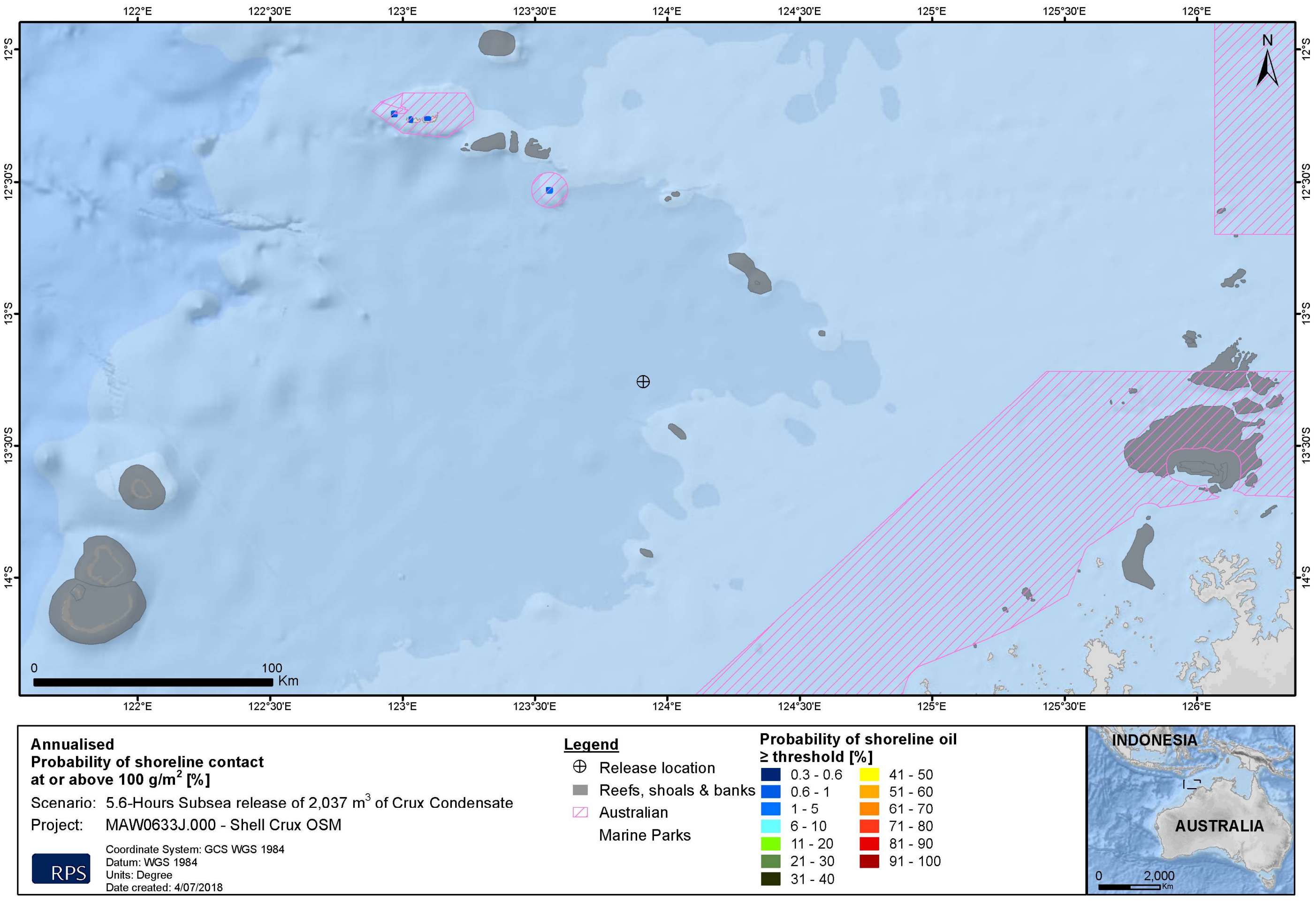


Figure C 3 Shoreline Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 100 g/m² resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

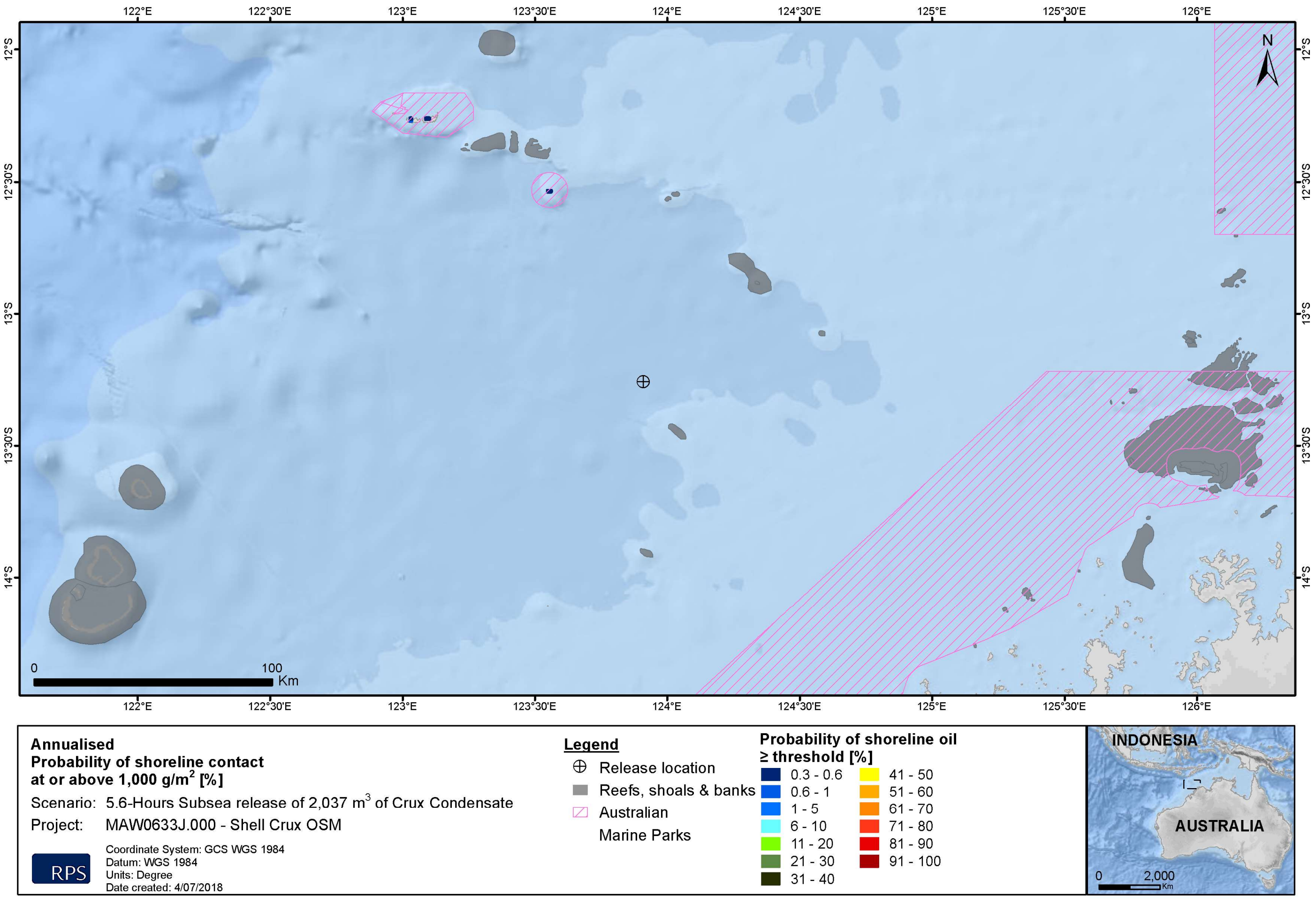


Figure C 4 Shoreline Hydrocarbons | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 1,000 g/m^2 resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

Entrained Hydrocarbons

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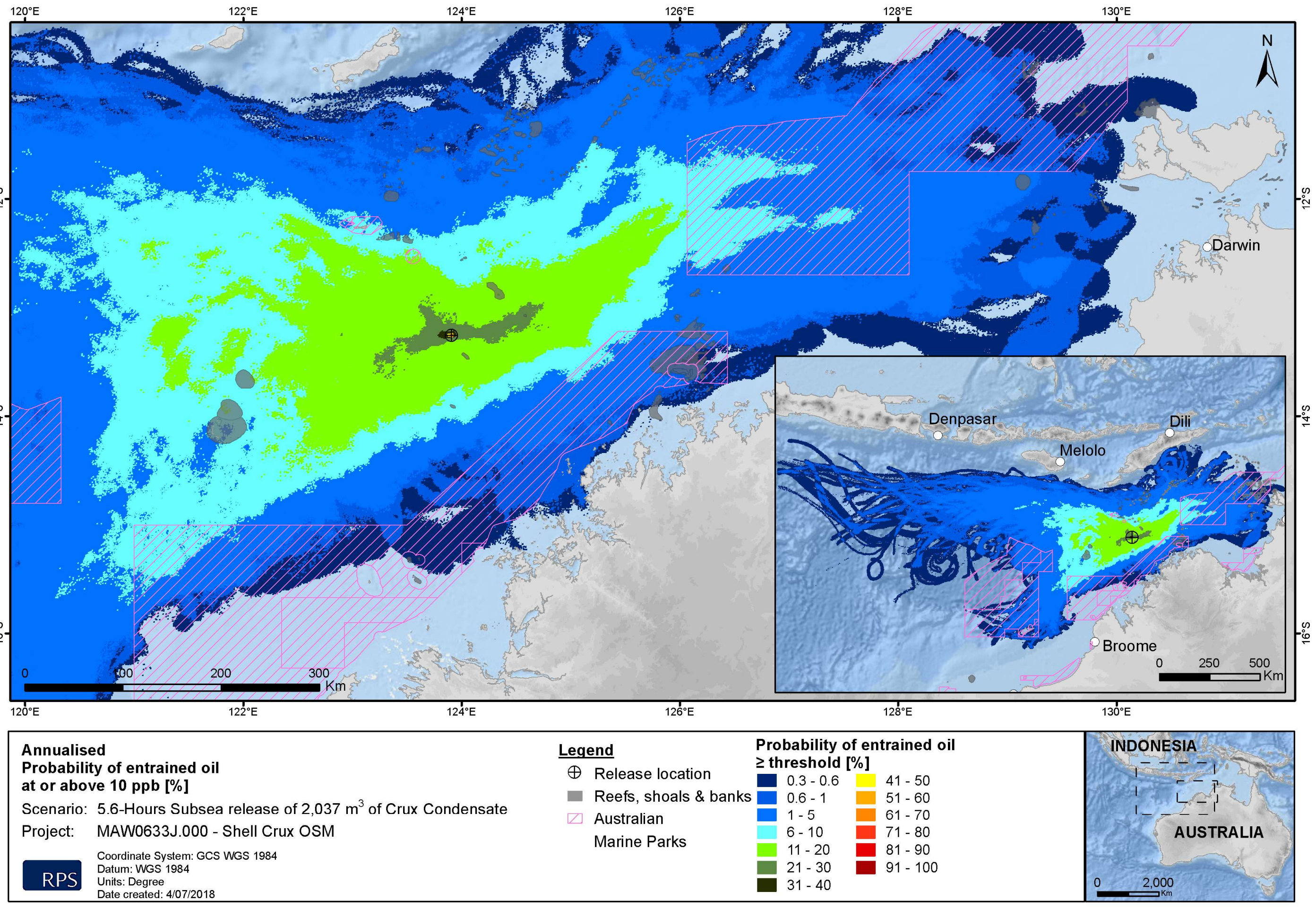

Figure C 5 Subsurface Hydrocarbons | Entrained | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 10 ppb resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

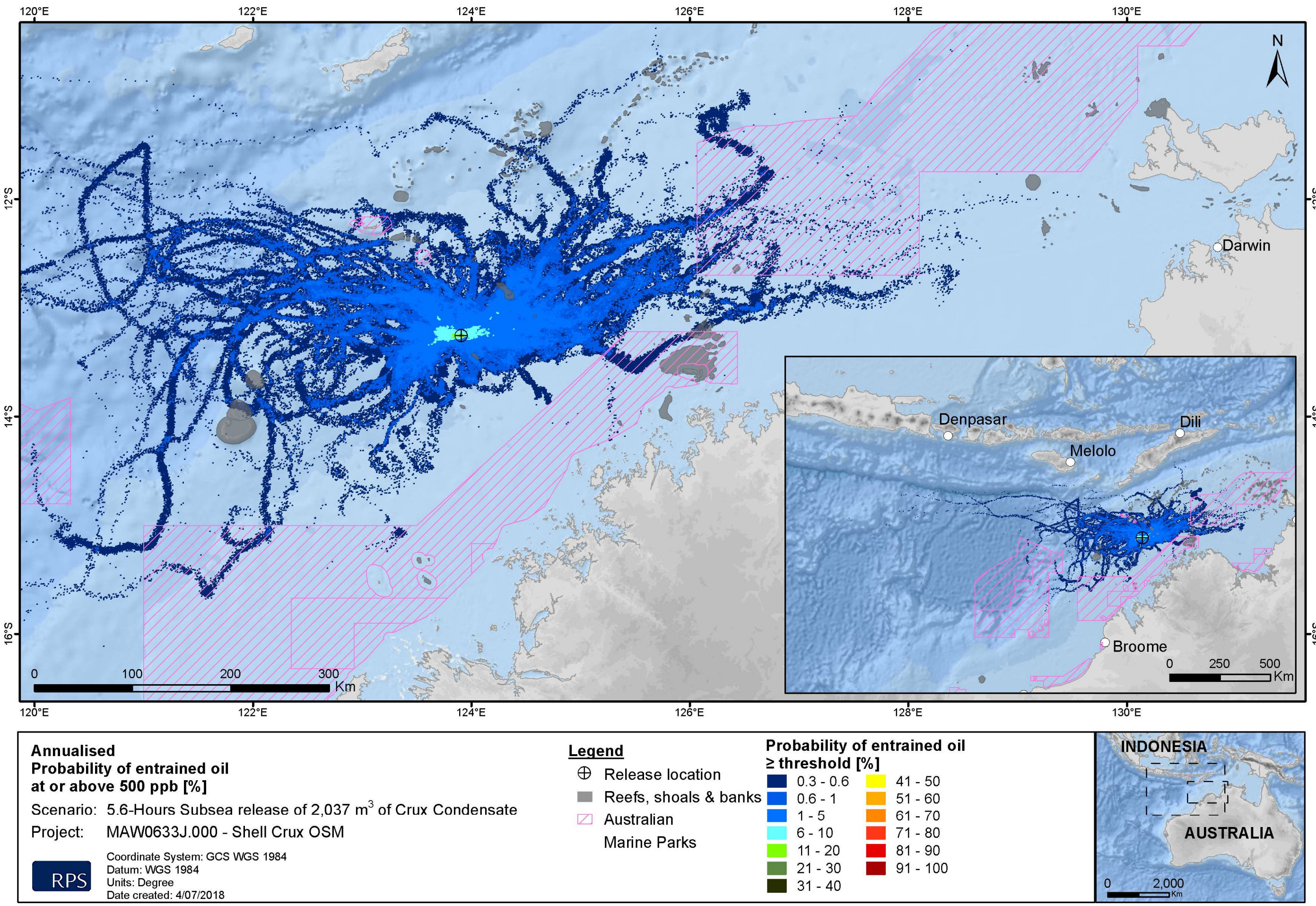

Figure C 6 Subsurface Hydrocarbons | Entrained | Pipeline Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 500 ppb resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline.

Appendix D
Scenario 4 – Annualised Probability – Stochastic Modelling

Figures – Appendix D

Annualised Results

Floating and Shoreline Hydrocarbons

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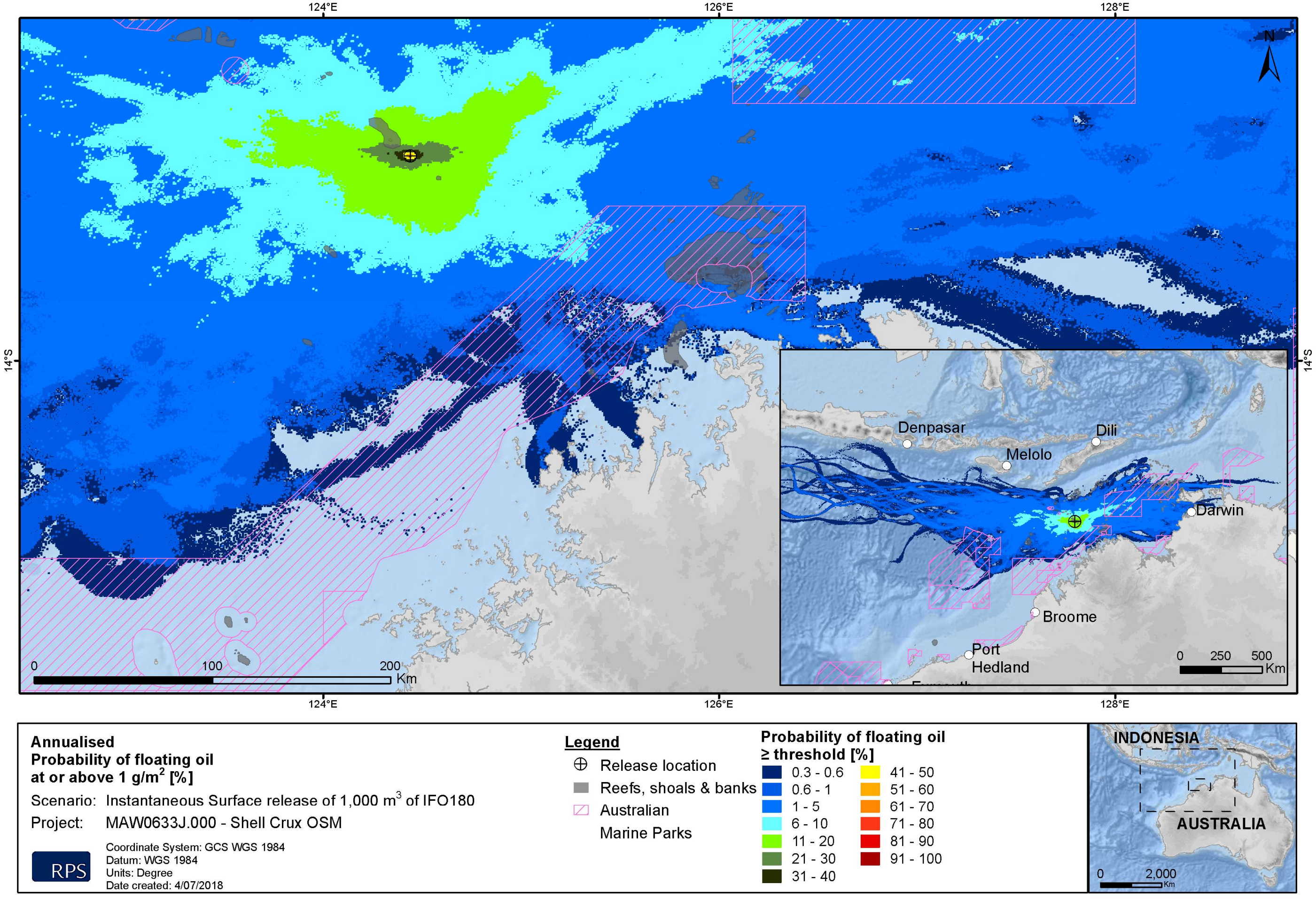

Figure D 1 Surface Hydrocarbons | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of floating oil concentrations at or above 1 g/m² resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

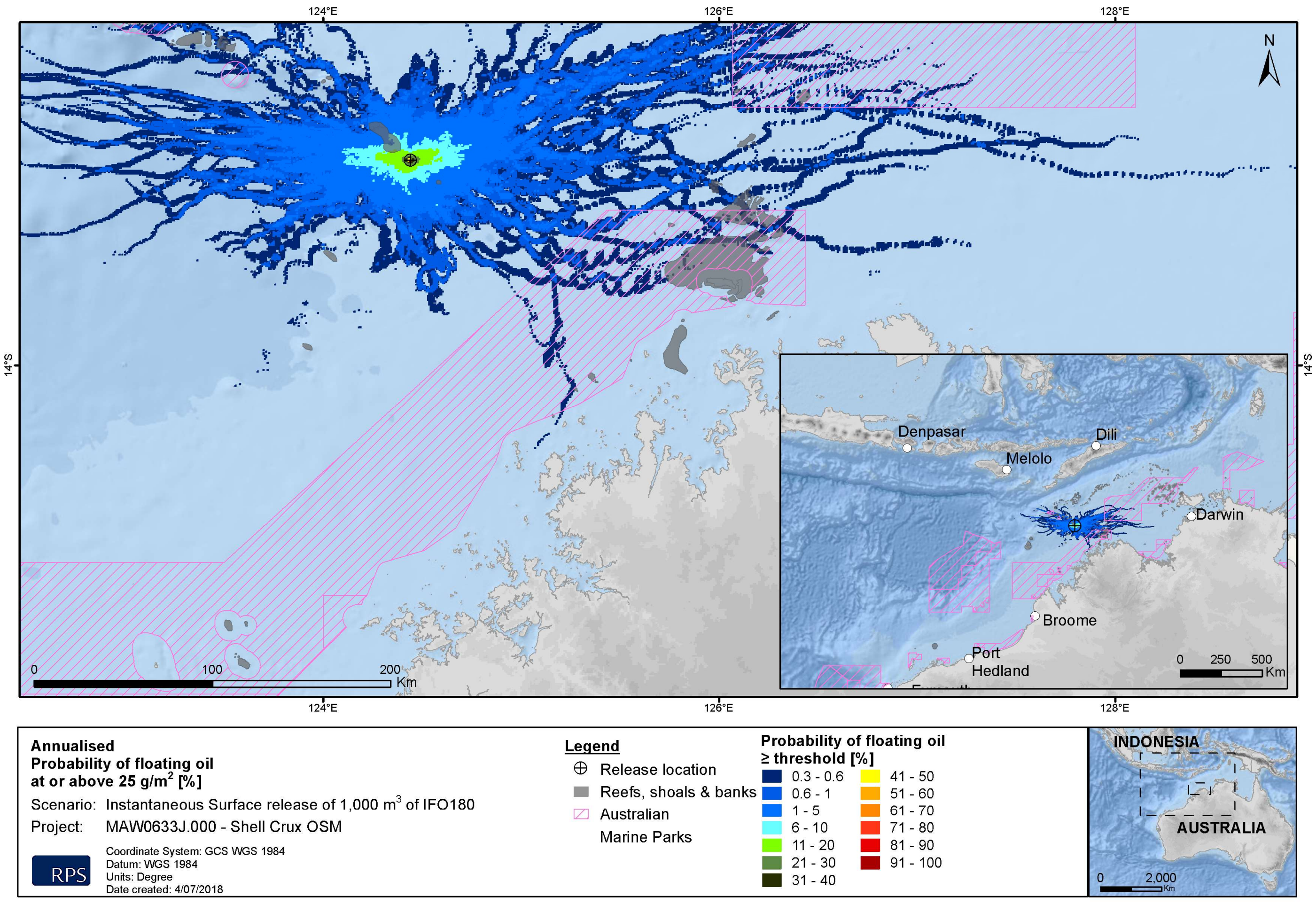

Figure D 2 Surface Hydrocarbons | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of floating oil concentrations at or above 25 g/m^2 resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

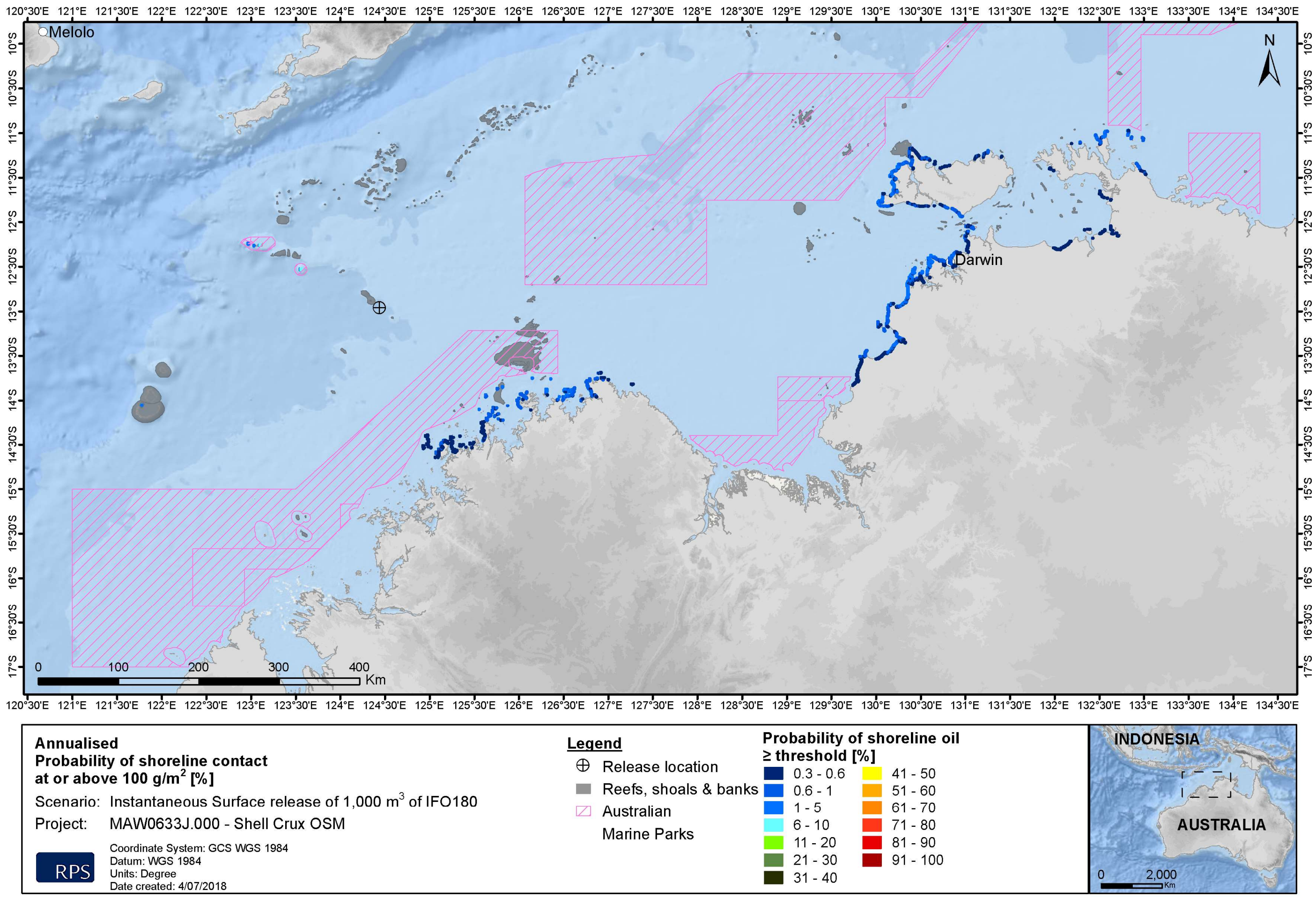

Figure D 3 Shoreline Hydrocarbons | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 100 g/m^2 resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

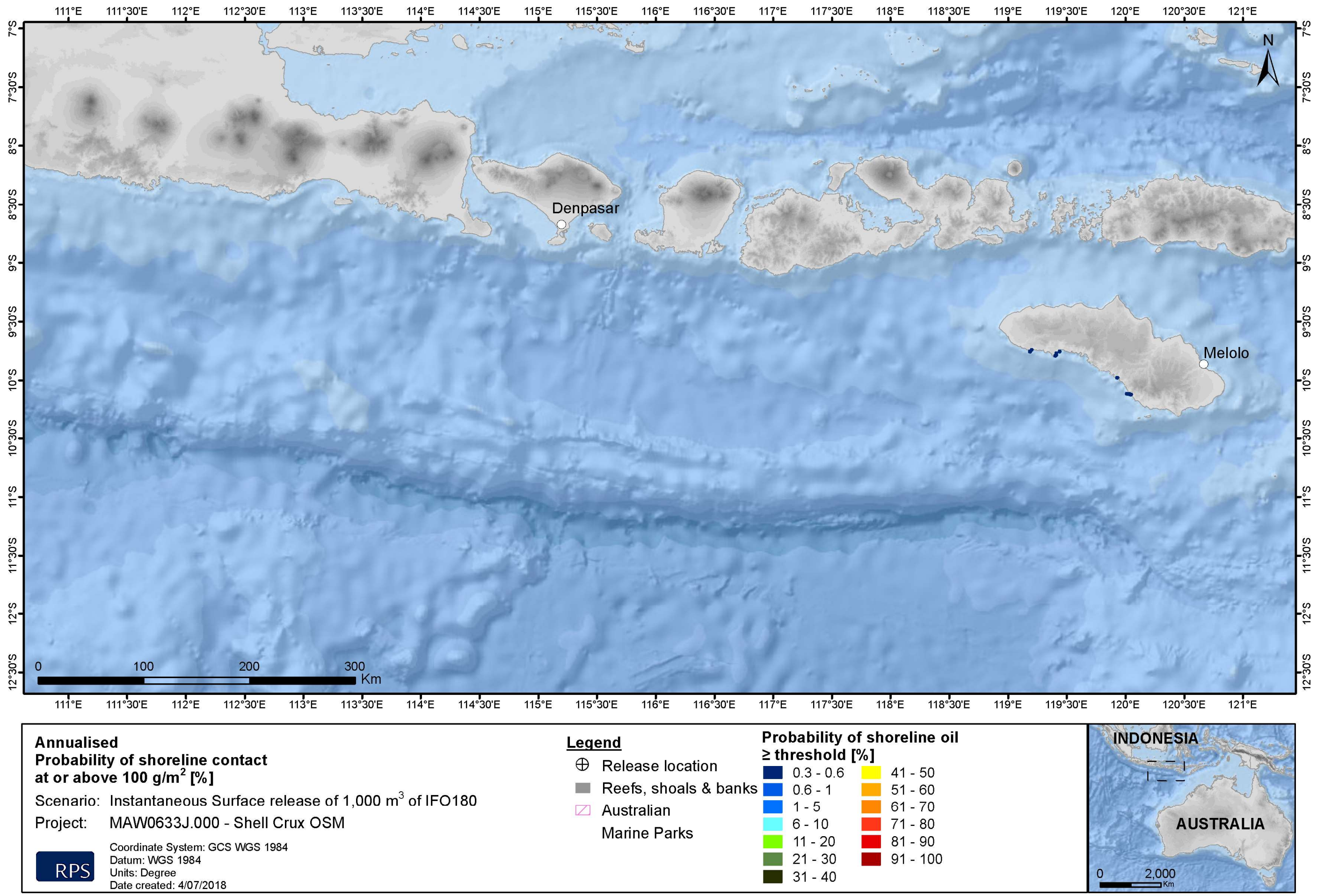

Figure D 4 Shoreline Hydrocarbons | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 100 g/m^2 resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

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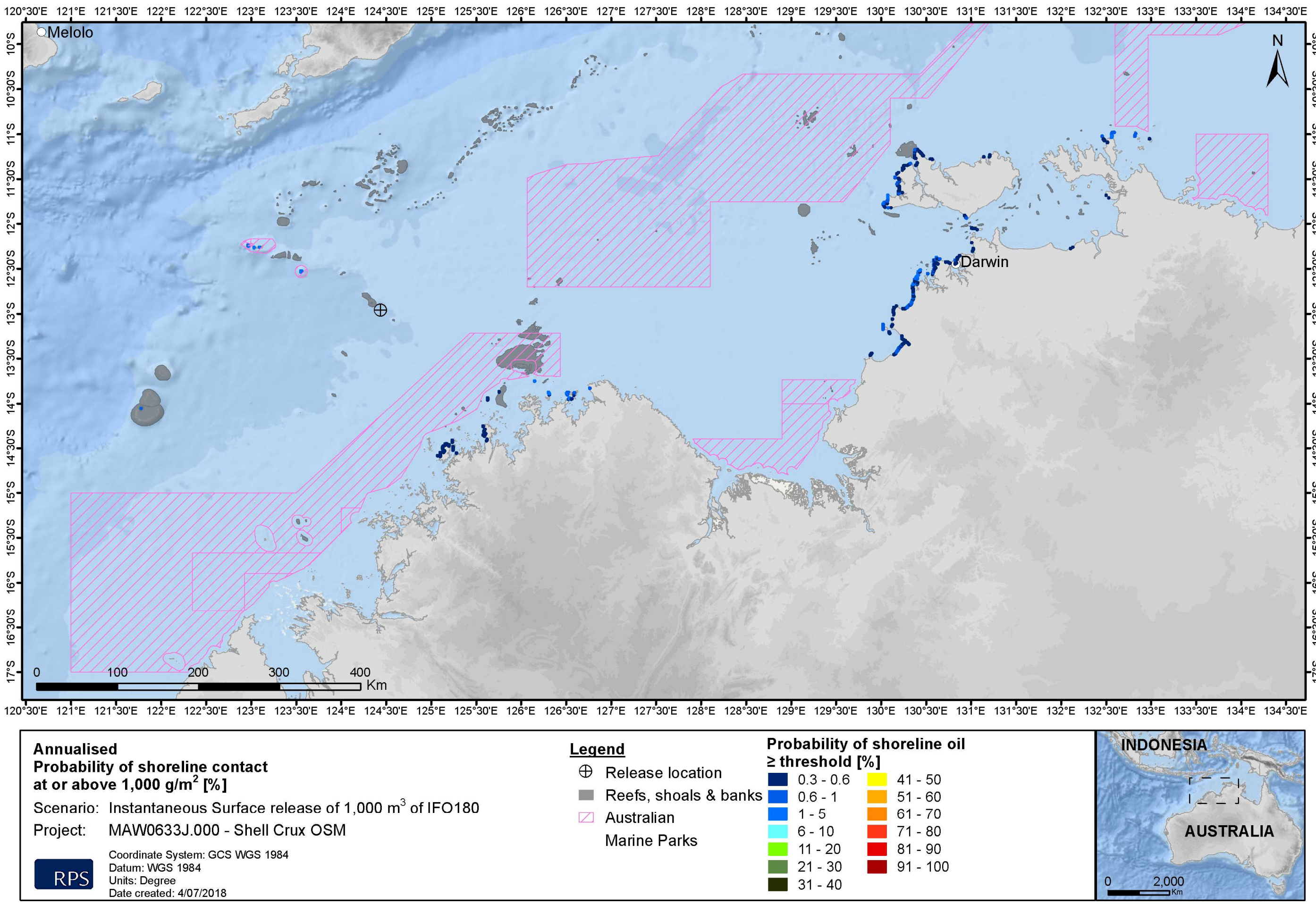

Figure D 5 Shoreline Hydrocarbons | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of shoreline oil concentrations at or above 1,000 g/m^2 resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

Entrained Hydrocarbons

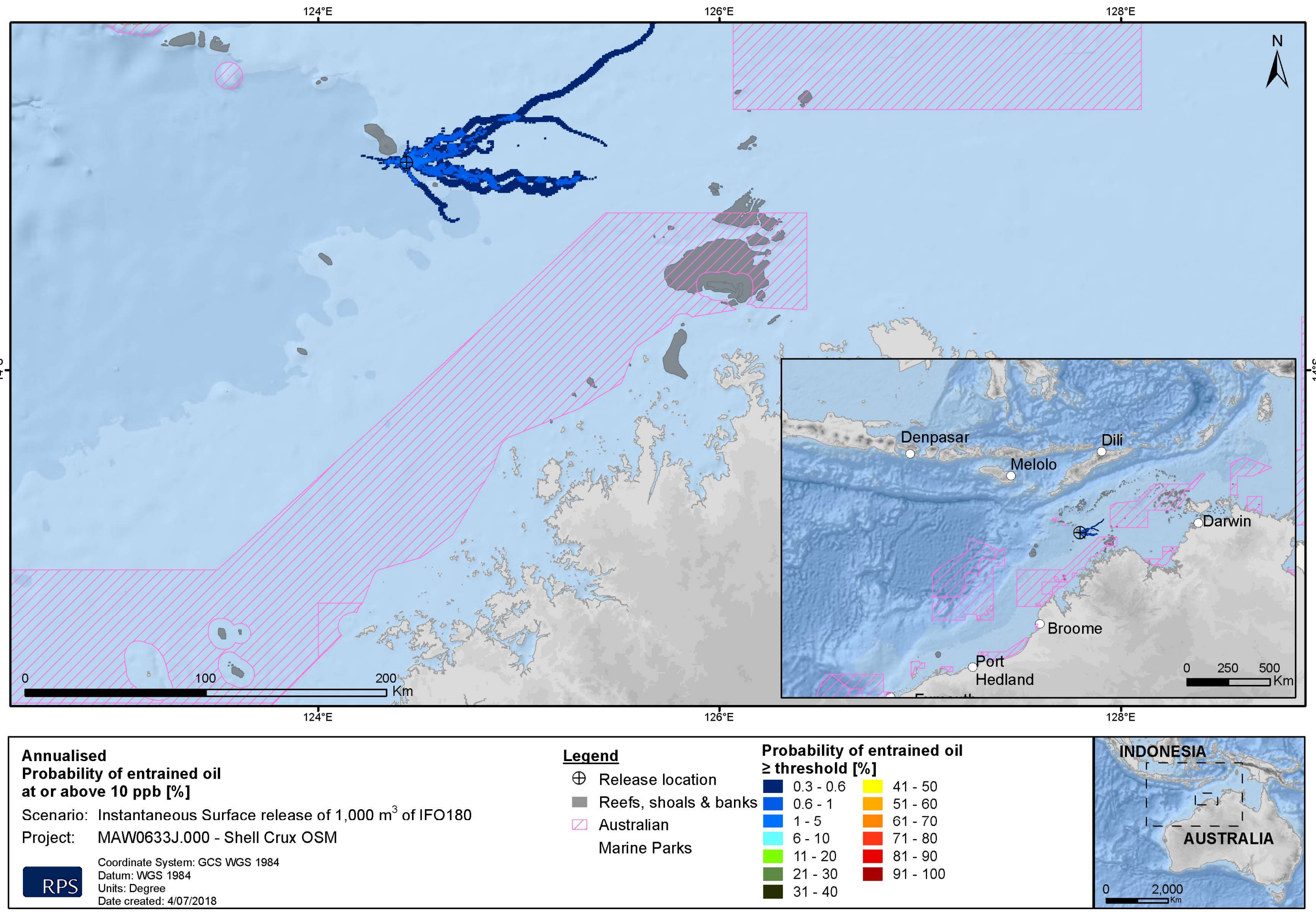

Figure D 6 Subsurface Hydrocarbons | Entrained | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 10 ppb resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

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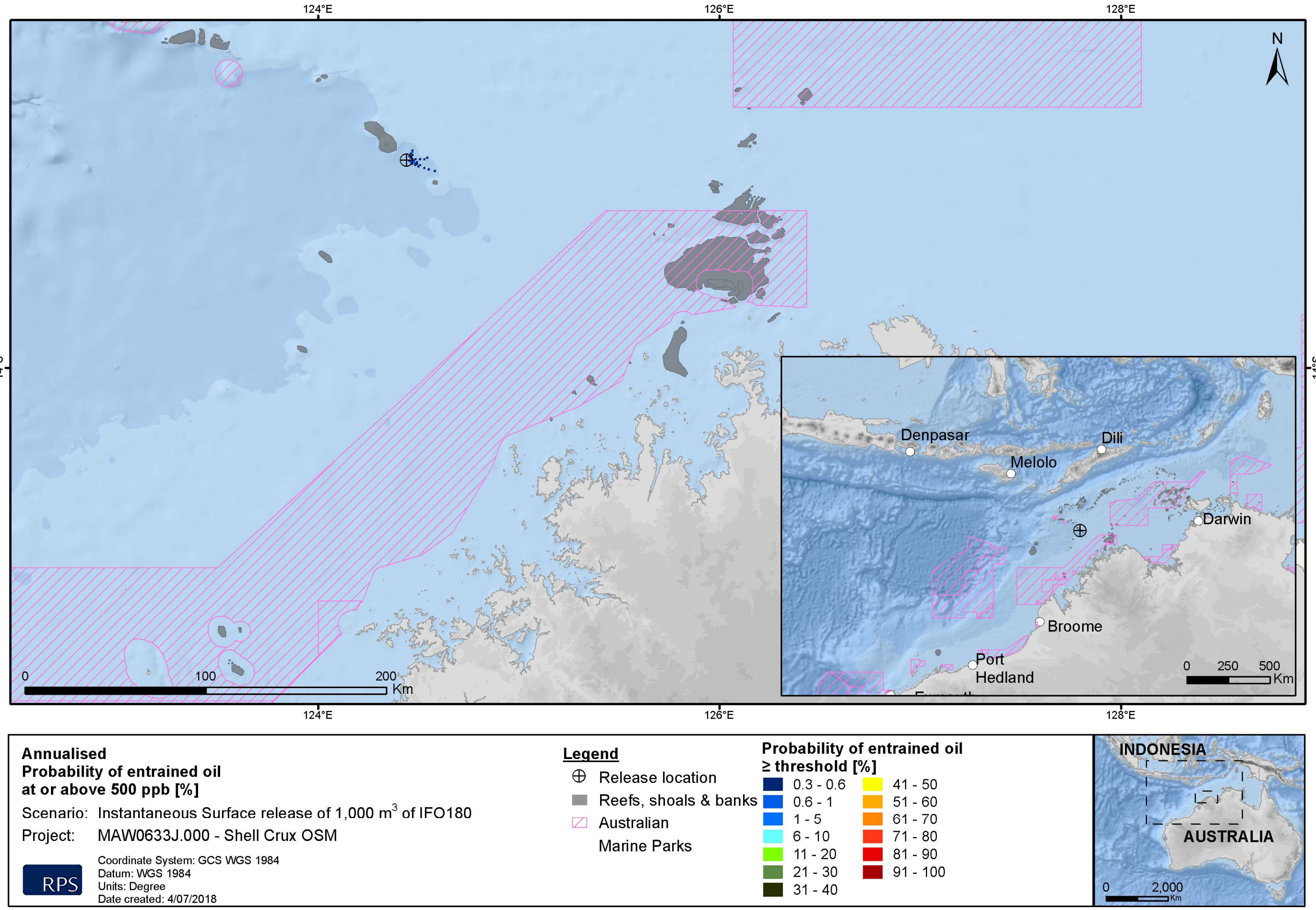


Figure D 7 Subsurface Hydrocarbons | Entrained | Collision Scenario | Stochastic Outcomes. Predicted annualised probability of entrained oil concentrations at or above 500 ppb resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline.

Appendix E
Deterministic Modelling

RPS

RPS

Scenario 1 – 80-Day Subsurface Blowout of Crux Condensate at a Development Well

Maximum Volume Ashore

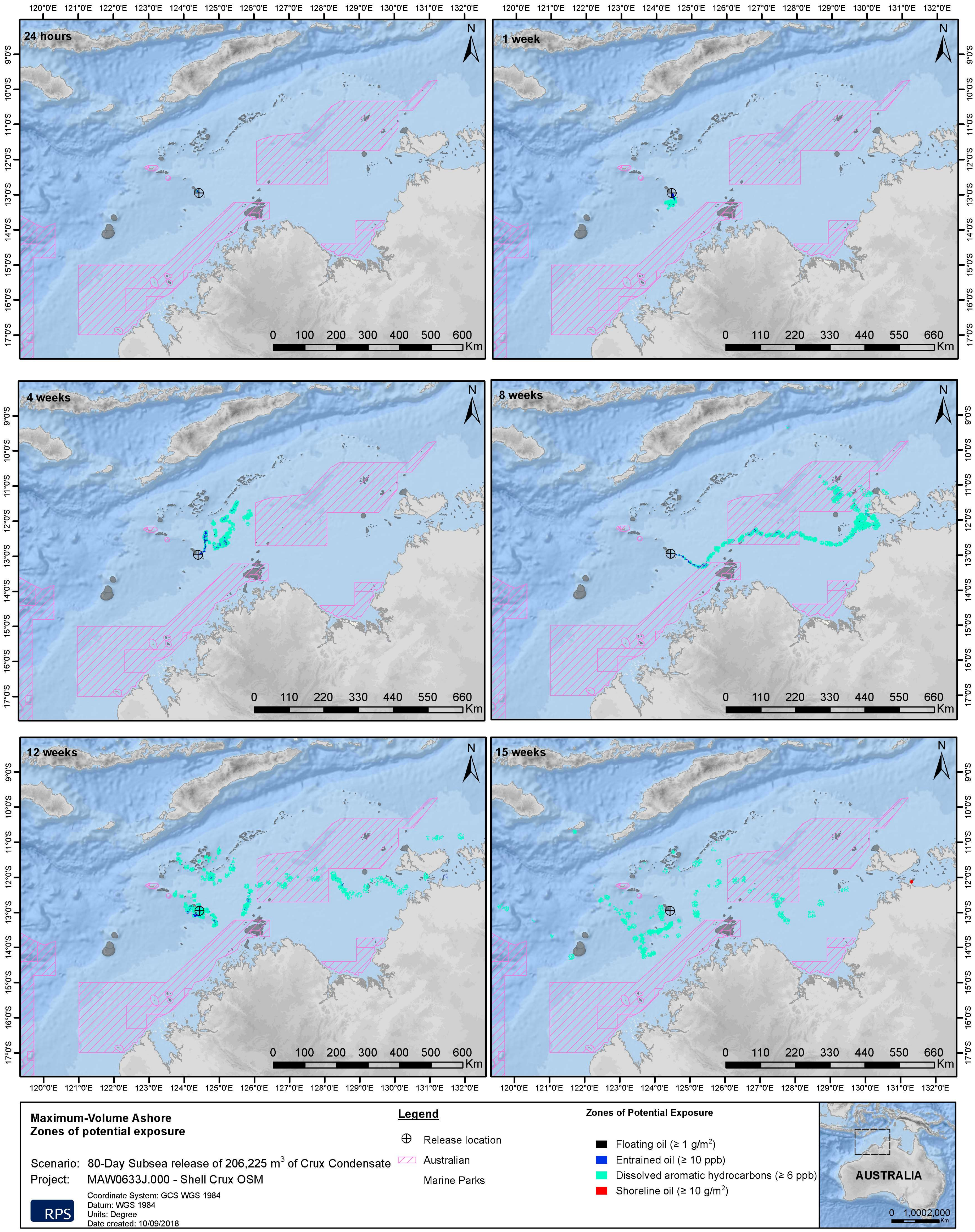


Figure E 1 Hydrocarbons | Blowout Scenario | Deterministic Outcomes. Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations resulting from an 80-day subsurface release of Crux condensate at a development well. Replicate simulation with maximum volume ashore.

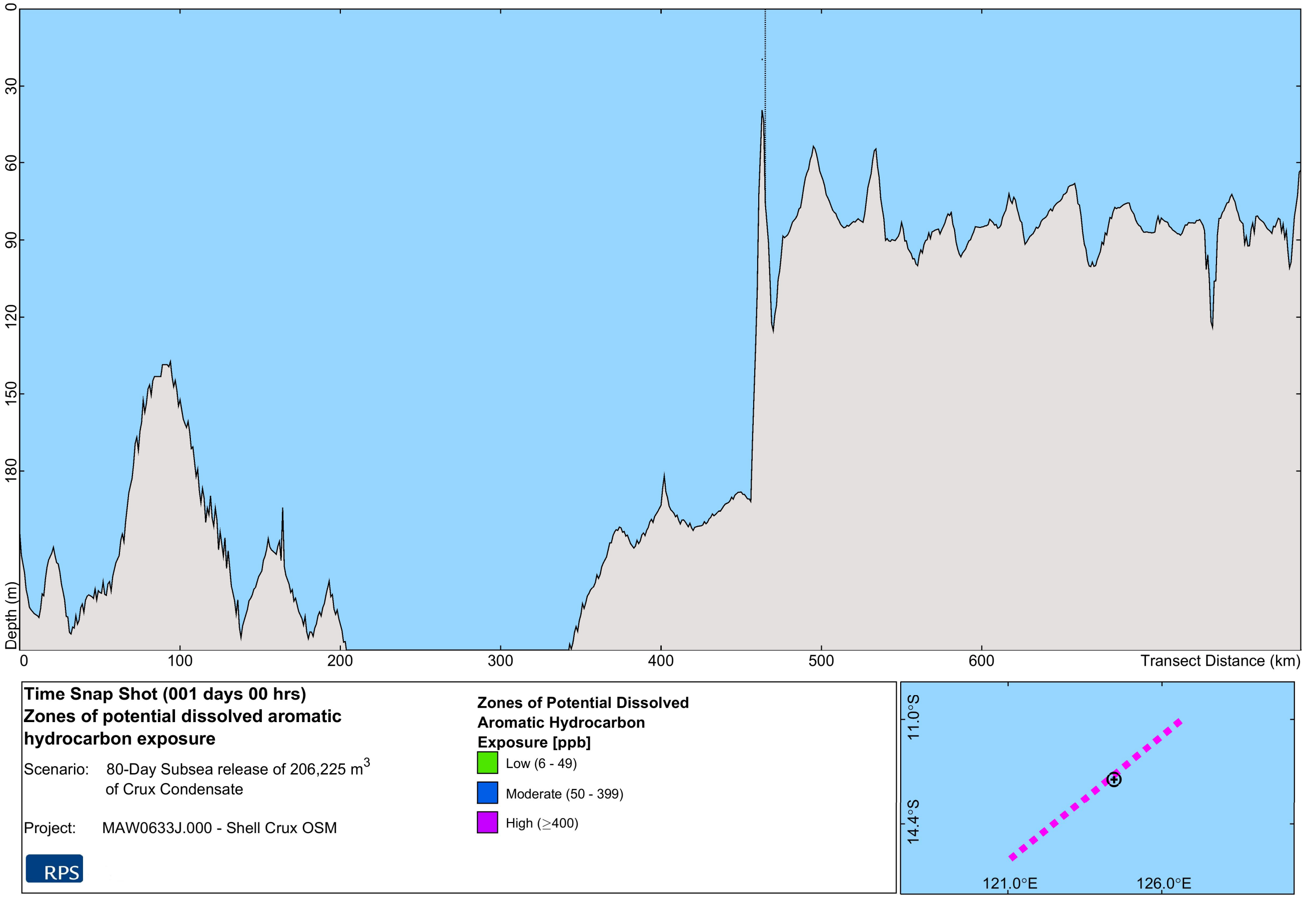


Figure E 2 Subsurface Hydrocarbons | Dissolved | Blowout Scenario | Deterministic Outcomes. Vertical distribution (after 24 hours) of potential exposure at defined dissolved aromatic hydrocarbon threshold concentrations resulting from an 80-day subsurface release of Crux condensate at a development well. Replicate simulation with maximum volume ashore.

RPS

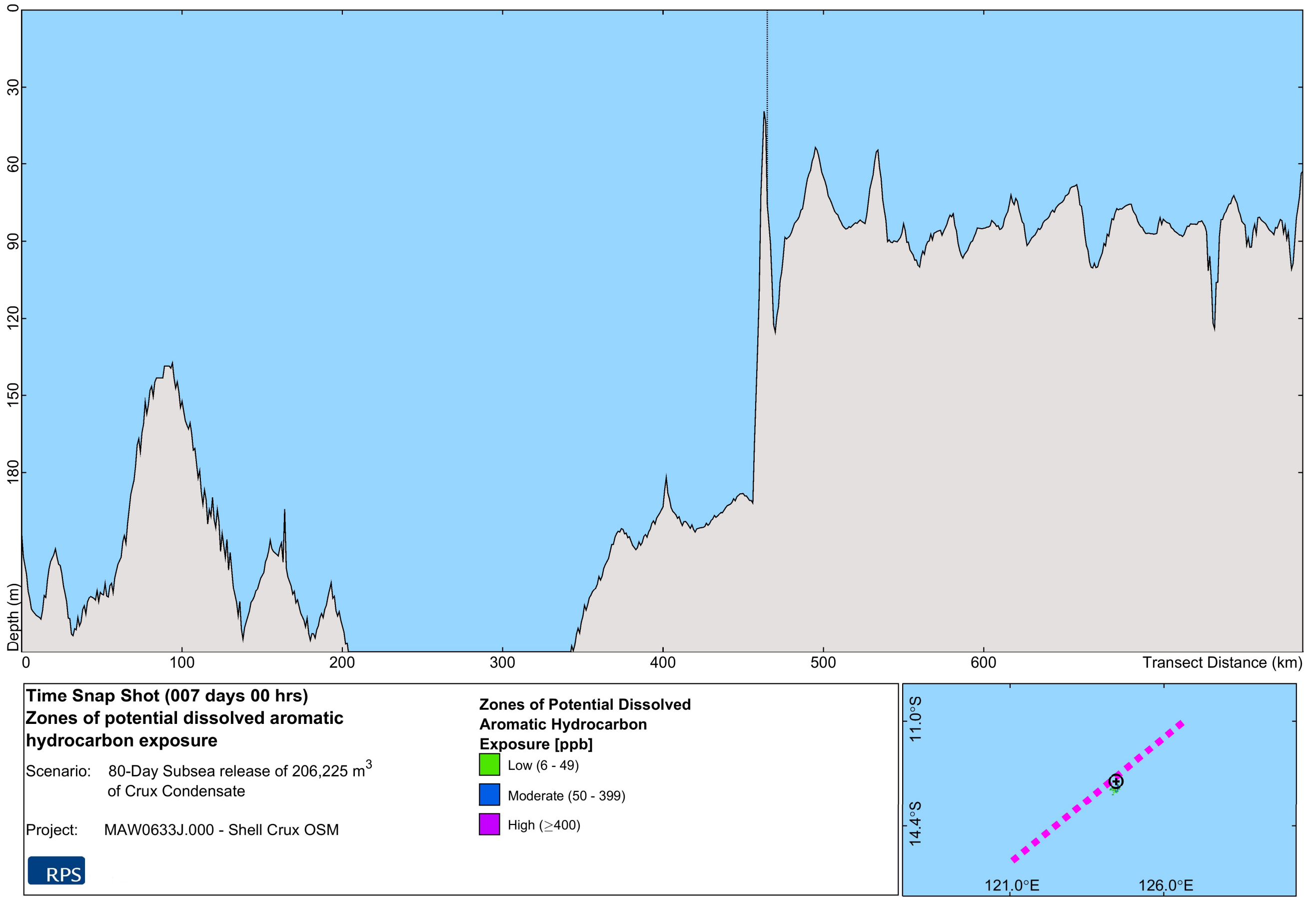


Figure E 3 Subsurface Hydrocarbons | Dissolved | Blowout Scenario | Deterministic Outcomes. Vertical distribution (after 1 week) of potential exposure at defined dissolved aromatic hydrocarbon threshold concentrations resulting from an 80-day subsurface release of Crux condensate at a development well. Replicate simulation with <u>maximum volume ashore</u>.

RPS

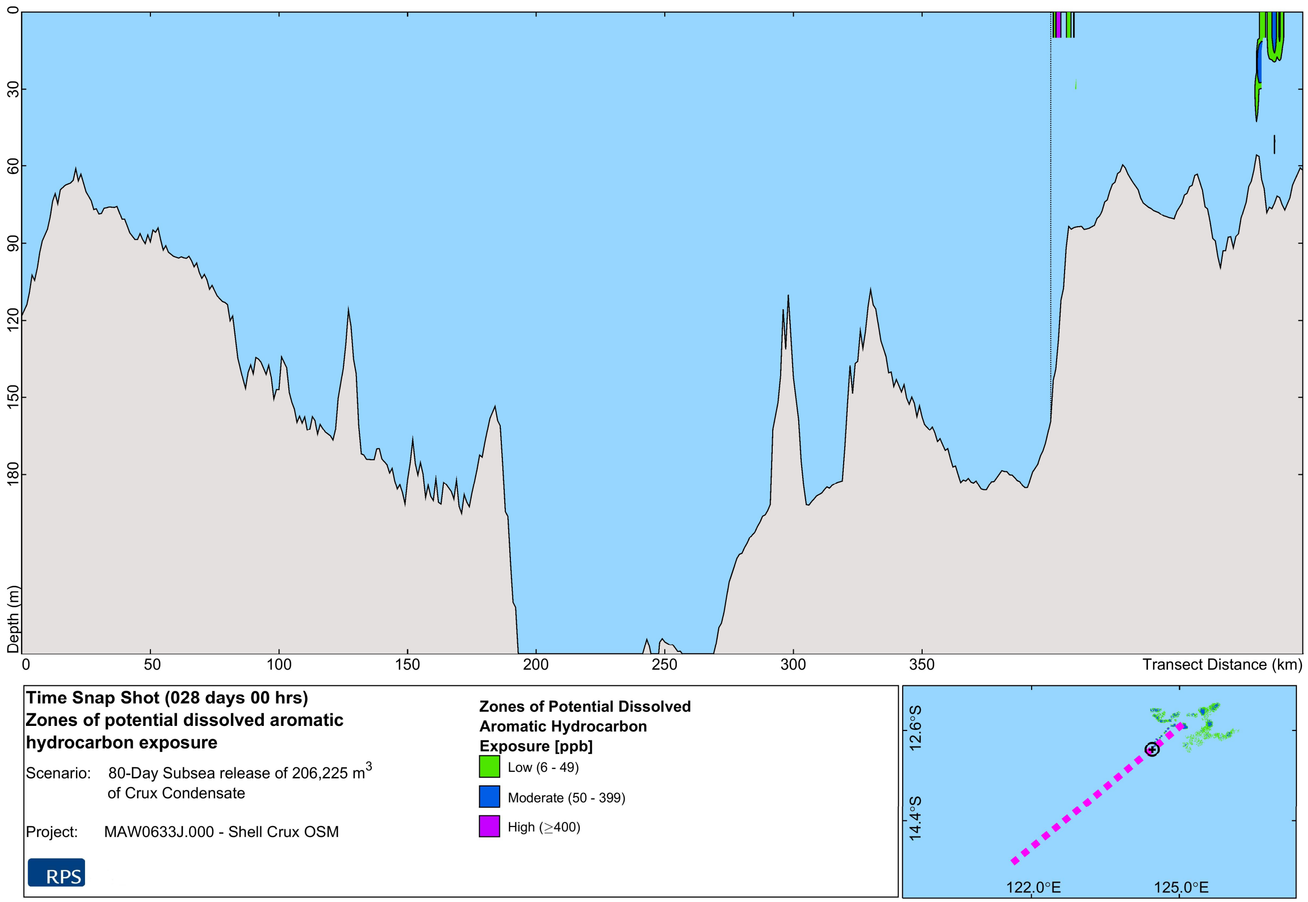


Figure E 4 Subsurface Hydrocarbons | Dissolved | Blowout Scenario | Deterministic Outcomes. Vertical distribution (after 4 weeks) of potential exposure at defined dissolved aromatic hydrocarbon threshold concentrations resulting from an 80-day subsurface release of Crux condensate at a development well. Replicate simulation with <u>maximum volume ashore</u>.

RPS

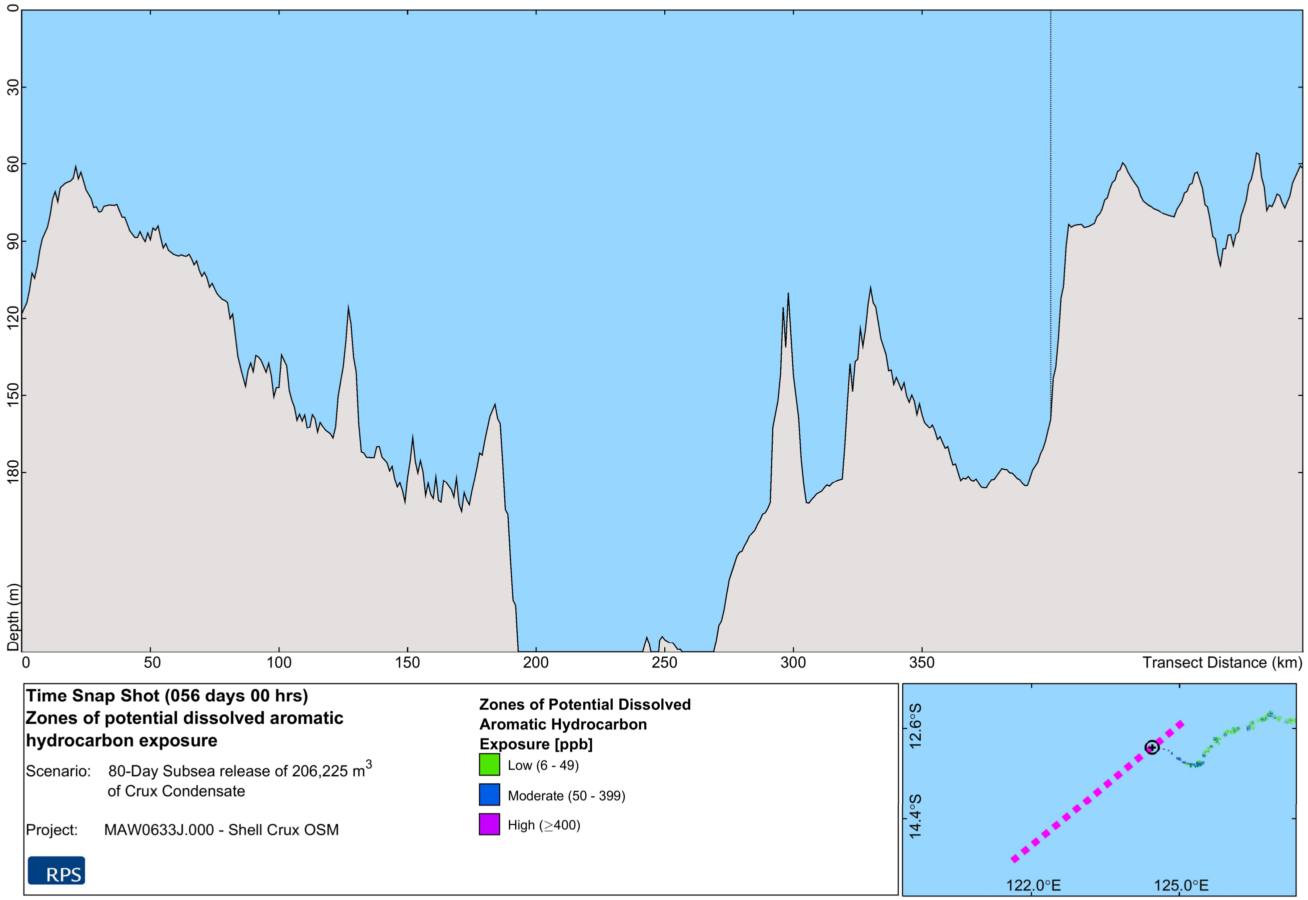


Figure E 5 Subsurface Hydrocarbons | Dissolved | Blowout Scenario | Deterministic Outcomes. Vertical distribution (after 8 weeks) of potential exposure at defined dissolved aromatic hydrocarbon threshold concentrations resulting from an 80-day subsurface release of Crux condensate at a development well. Replicate simulation with maximum volume ashore.

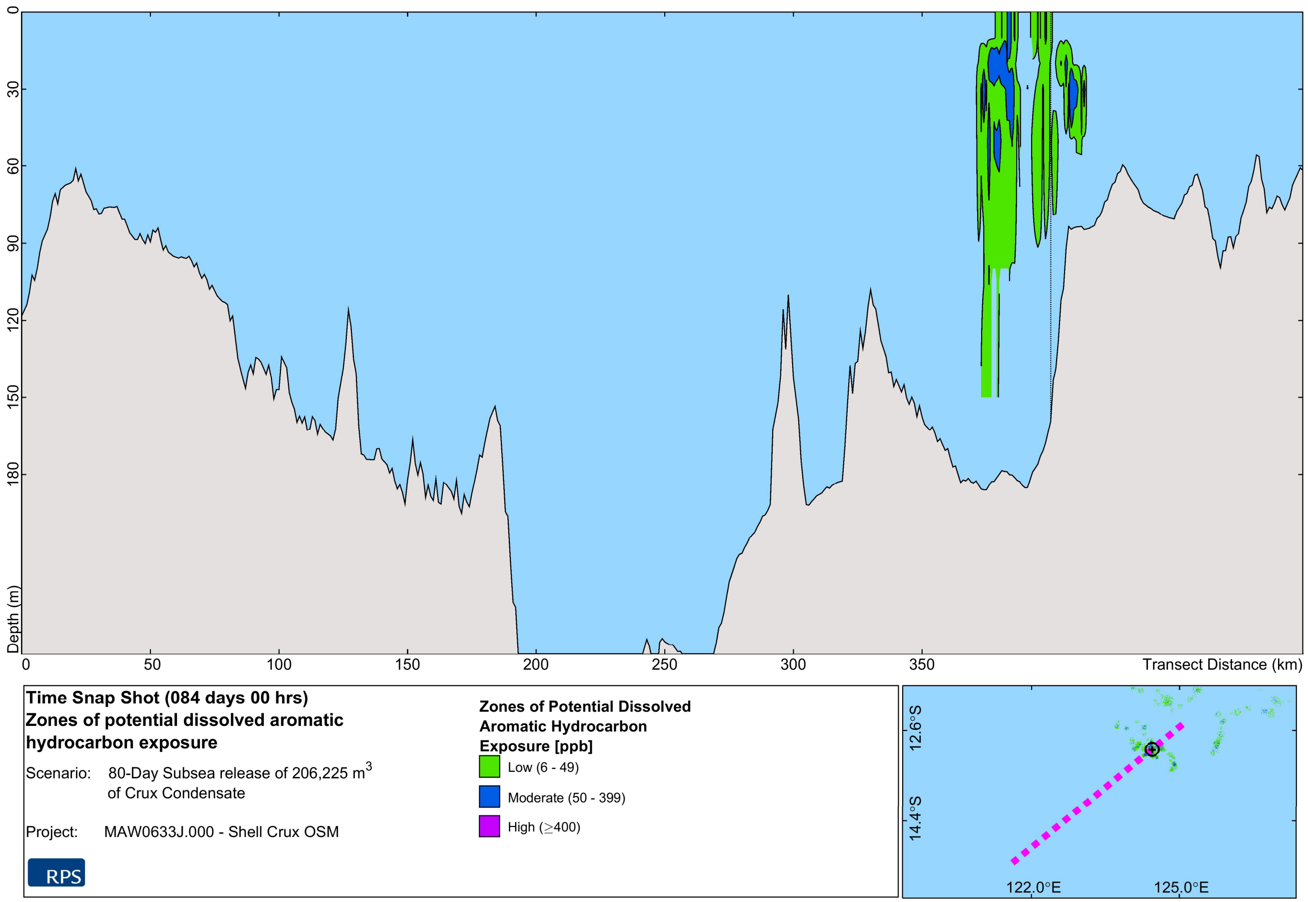
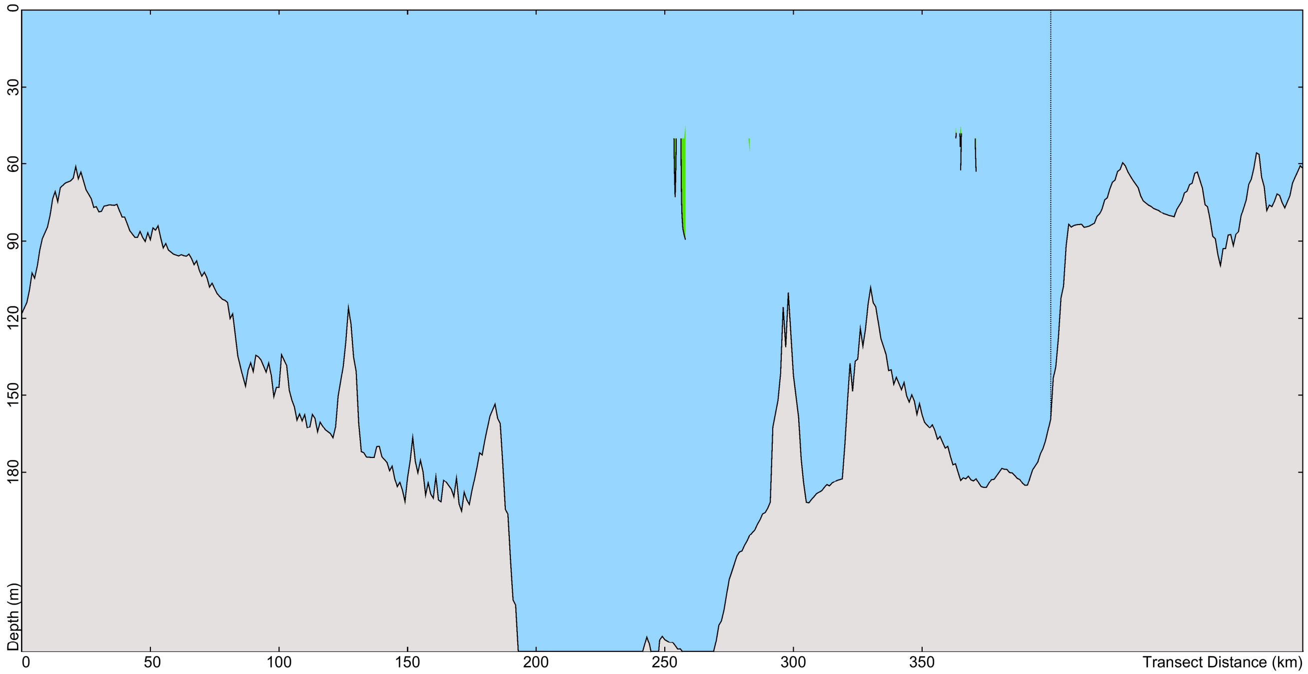


Figure E 6 Subsurface Hydrocarbons | Dissolved | Blowout Scenario | Deterministic Outcomes. Vertical distribution (after 12 weeks) of potential exposure at defined dissolved aromatic hydrocarbon threshold concentrations resulting from an 80-day subsurface release of Crux condensate at a development well. Replicate simulation with maximum volume ashore.



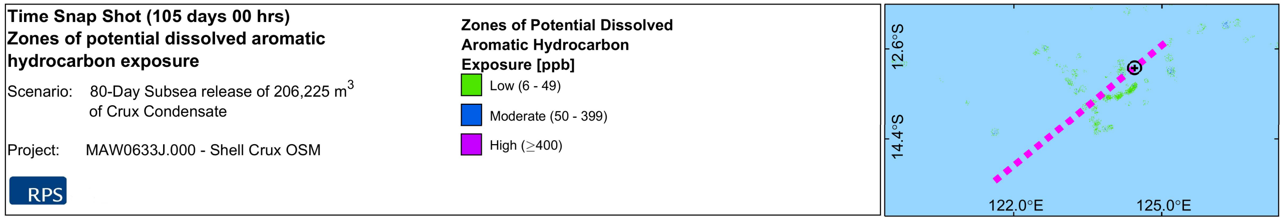


Figure E 7 Subsurface Hydrocarbons | Dissolved | Blowout Scenario | Deterministic Outcomes. Vertical distribution (after 15 weeks) of potential exposure at defined dissolved aromatic hydrocarbon threshold concentrations resulting from an 80-day subsurface release of Crux condensate at a development well. Replicate simulation with <u>maximum volume ashore</u>.

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Scenario 2 – Short-Term Surface Release of Crux Condensate at the Crux Platform

Maximum Volume Ashore

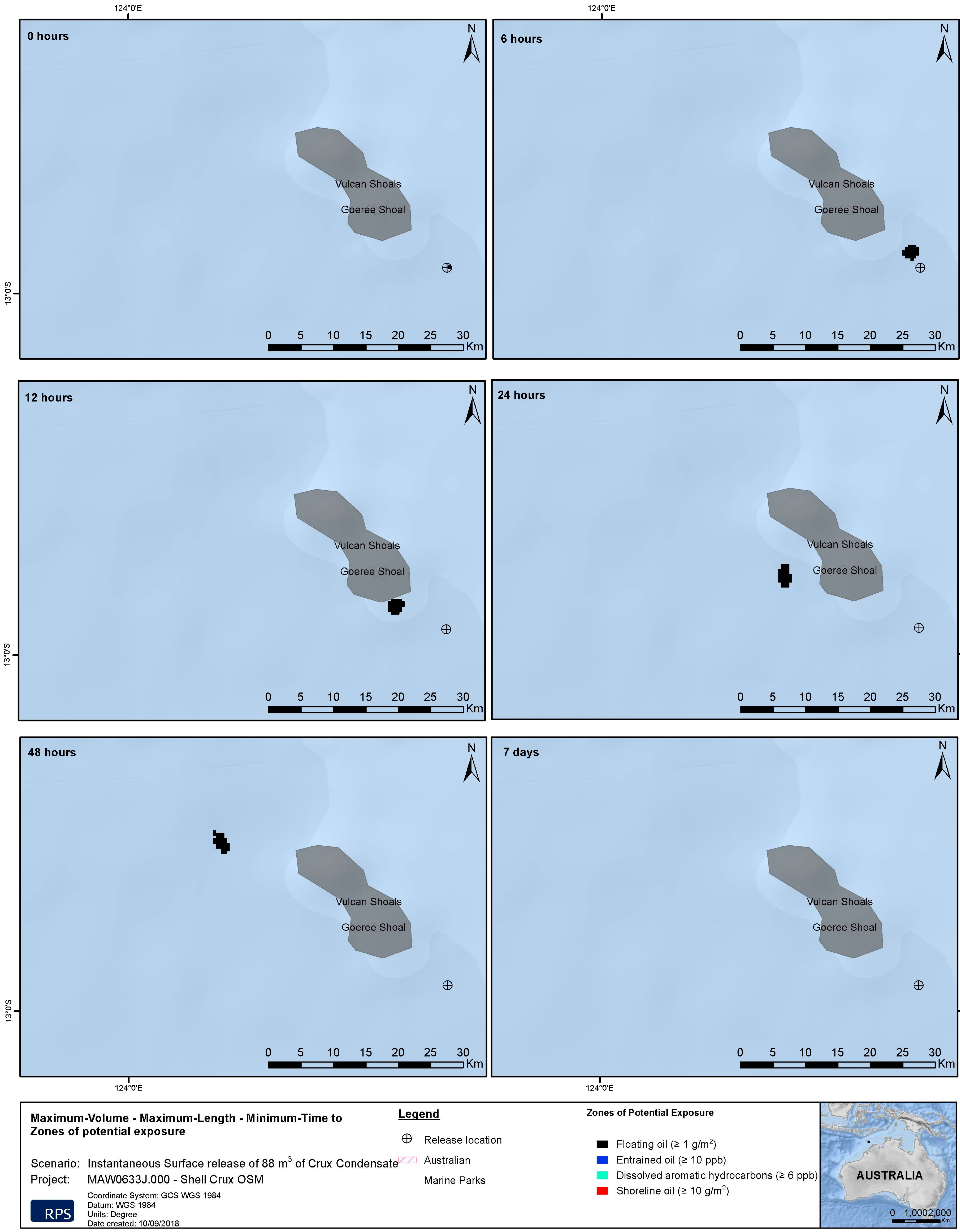

Figure E 8 Hydrocarbons | Inventory Scenario | Deterministic Outcomes. Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations resulting from an instantaneous surface release of Crux condensate at the Crux platform. Replicate simulation with maximum volume ashore.

RPS

Scenario 3 – Short-Term Subsurface Release of Crux Condensate from a Pipeline Rupture Near Heywood Shoal

Maximum Volume Ashore

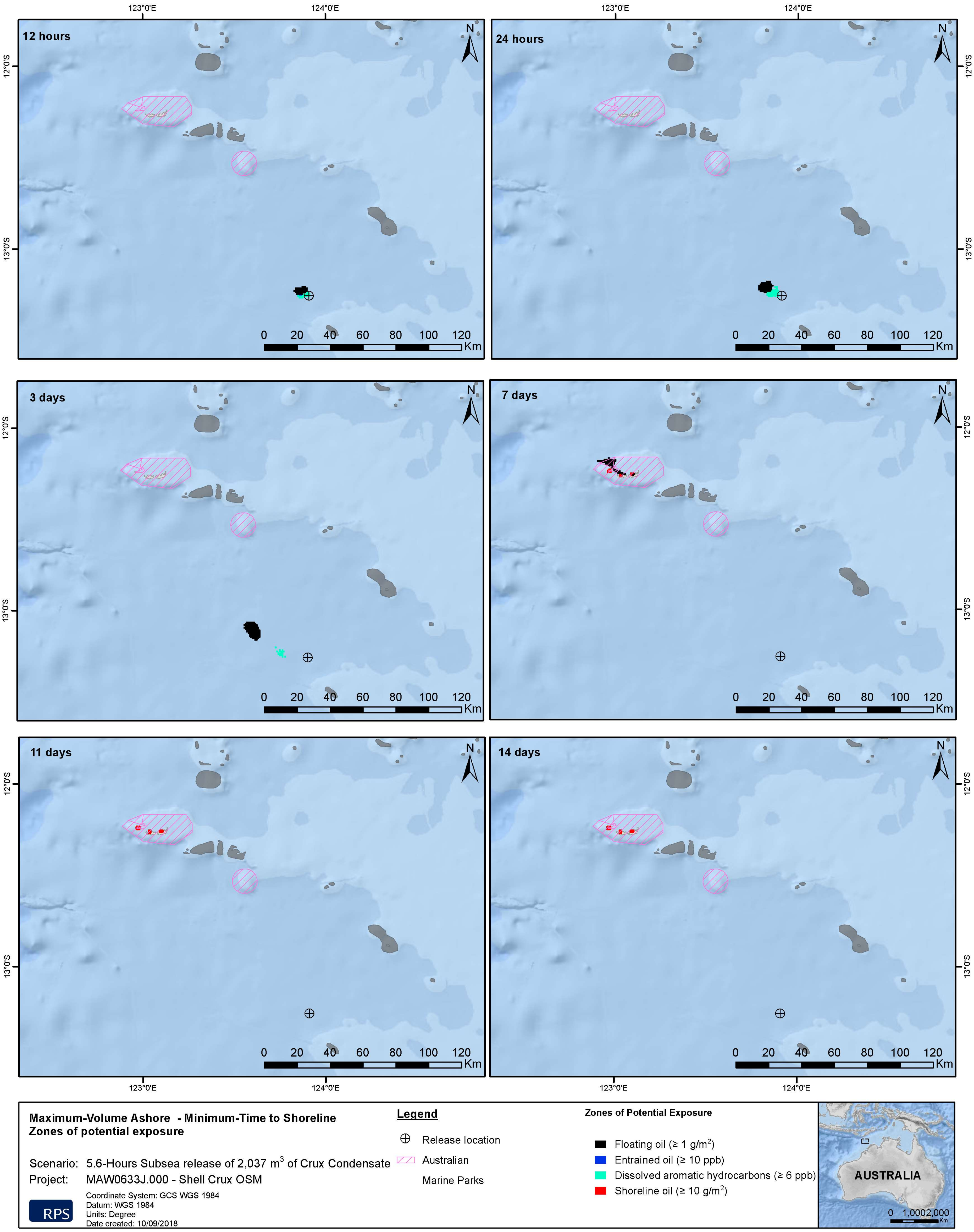

Figure E 9 Hydrocarbons | Pipeline Scenario | Deterministic Outcomes. Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline. Replicate simulation with maximum volume ashore.

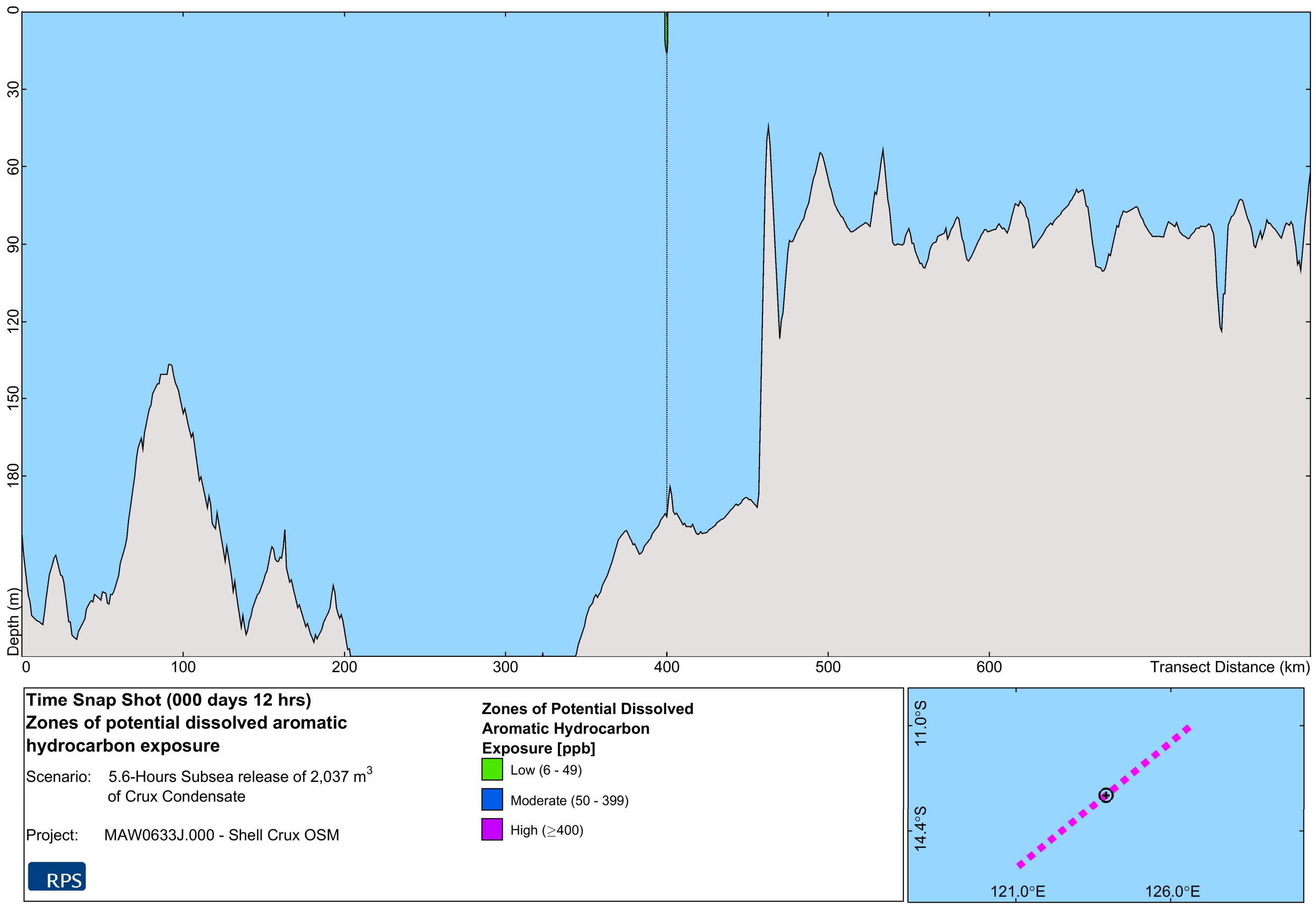

Figure E 10 Subsurface Hydrocarbons | Dissolved | Pipeline Scenario | Deterministic Outcomes. Vertical distribution (after 12 hours) of potential exposure at defined dissolved aromatic hydrocarbon threshold concentrations resulting from a 5.6-hour subsurface release of Crux condensate from the export pipeline. Replicate simulation with maximum volume ashore.

RPS

Scenario 4 – Short-Term Surface Release of IFO-180 from a Pipelay Vessel Collision at the Crux End of the Export Pipeline

Maximum Volume Ashore

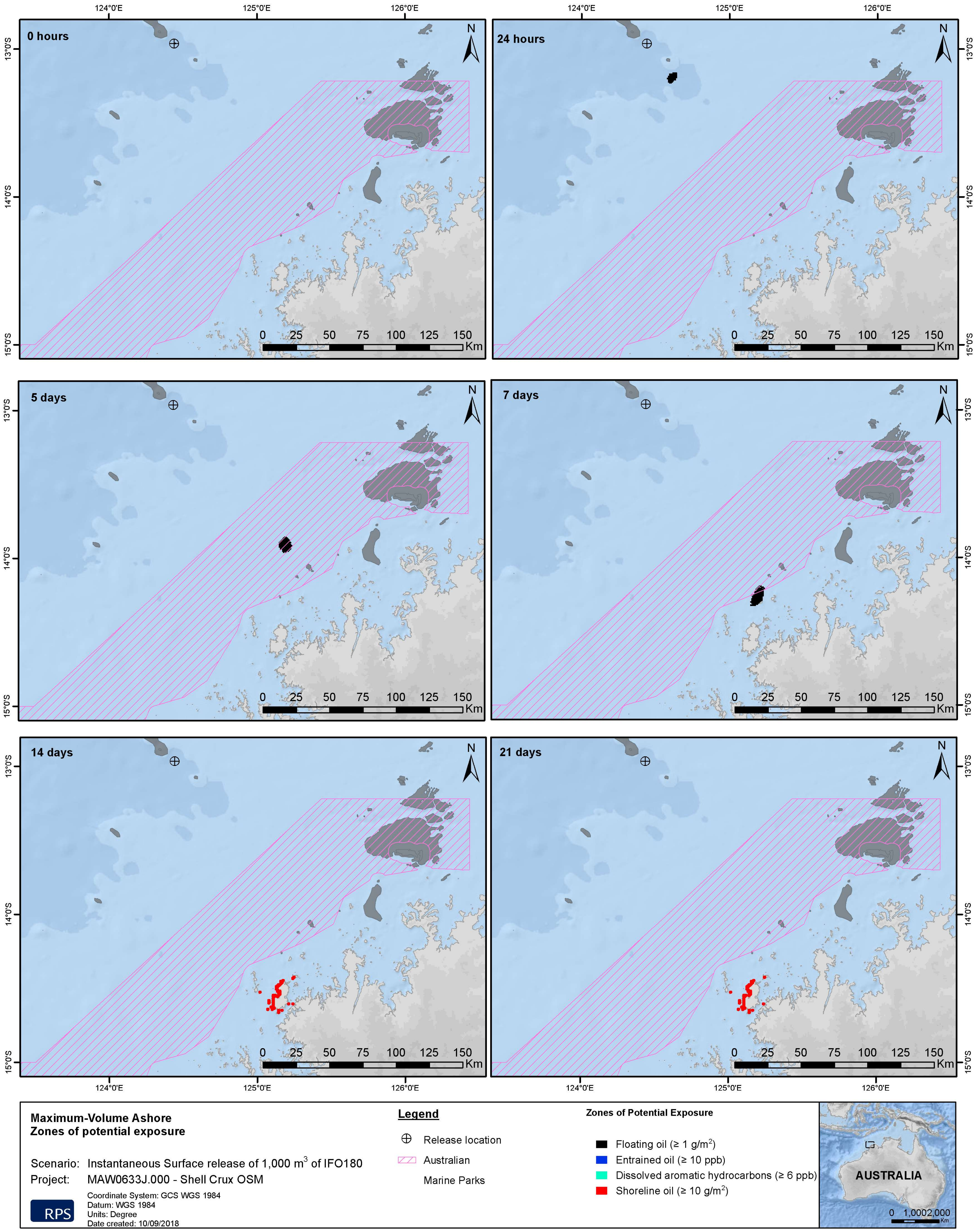

Figure E 11 Hydrocarbons | Collision Scenario | Deterministic Outcomes. Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations resulting from a 1-hour surface release of IFO-180 at the Crux end of the export pipeline. Replicate simulation with maximum volume ashore.

Appendix H: Light Modelling Study (Imbricata 2018)

imbricata
Environmental

Crux Project

Light Modelling Study

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Document Status

Report No	IM180001-1
Version	Rev B
Date	9 July 2018
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1.0 INTRODUCTION

Shell Australia Pty Ltd (Shell), in joint venture with SGH Energy and Osaka Gas, proposes to commercialise hydrocarbon resources from the Crux gas fields located in the northern Browse Basin, approximately 620 km north-north-east of Broome and 165 km north east of the Prelude FLNG facility (Figure 1). The offshore Crux Project will be tied back to the Prelude Floating LNG (FLNG) facility via an export pipeline. An initial five production wells are proposed to be drilled. The current concept for the Crux Project is a Not Normally Manned (NNM) platform containing minimal processing facilities, utility systems and accommodation. It will be operated remotely from the Prelude FLNG facility and only require periodic maintenance visits, significantly reducing light exposure to the surrounding marine environment. The notional drill rig will be located within the Crux development area, while the notional support vessel will be situated along the Crux export pipeline near the Crux development area (Figure 1).

CDM Smith, on behalf of Shell, contracted Imbricata Environmental (Imbricata) to undertake a light modelling study of the Crux Project including an NNM platform, drill rig and supply vessels to inform the preparation of an Offshore Project Proposal.

1.1 Purpose

The key purpose of the assessment was to characterise the sources of light emissions from the Crux Project and assess the predicted impact of light in the context of the nearest key habitats that support sensitive receptors.

1.2 Scope

Imbricata performed the following scope of work in undertaking this light modelling study:

- Provide context in relation to light theory (Section 2.1)
- Initial screening to identify potential sensitive receptors (Section 2.2)
- Define indicative lighting analogues and timing of the Crux Project light sources(e.g. Crux NNM platform (herein referred to as the Crux platform), drill rig and support vessel) to inform light modelling (Section 3.2)
- Undertake a Line of Sight (LOS) analysis to determine the extent of direct light from the Crux platform (including flaring), a drill rig and support vessel (Figure 1) (Section 4.1)
- Undertake light modelling to determine the extent and intensity of skyglow over the horizon from each light source (Section 4.2), and
- Identify the key habitats that the light will reach above ambient light conditions (i.e. moonless night with a clear sky) (Section 5).

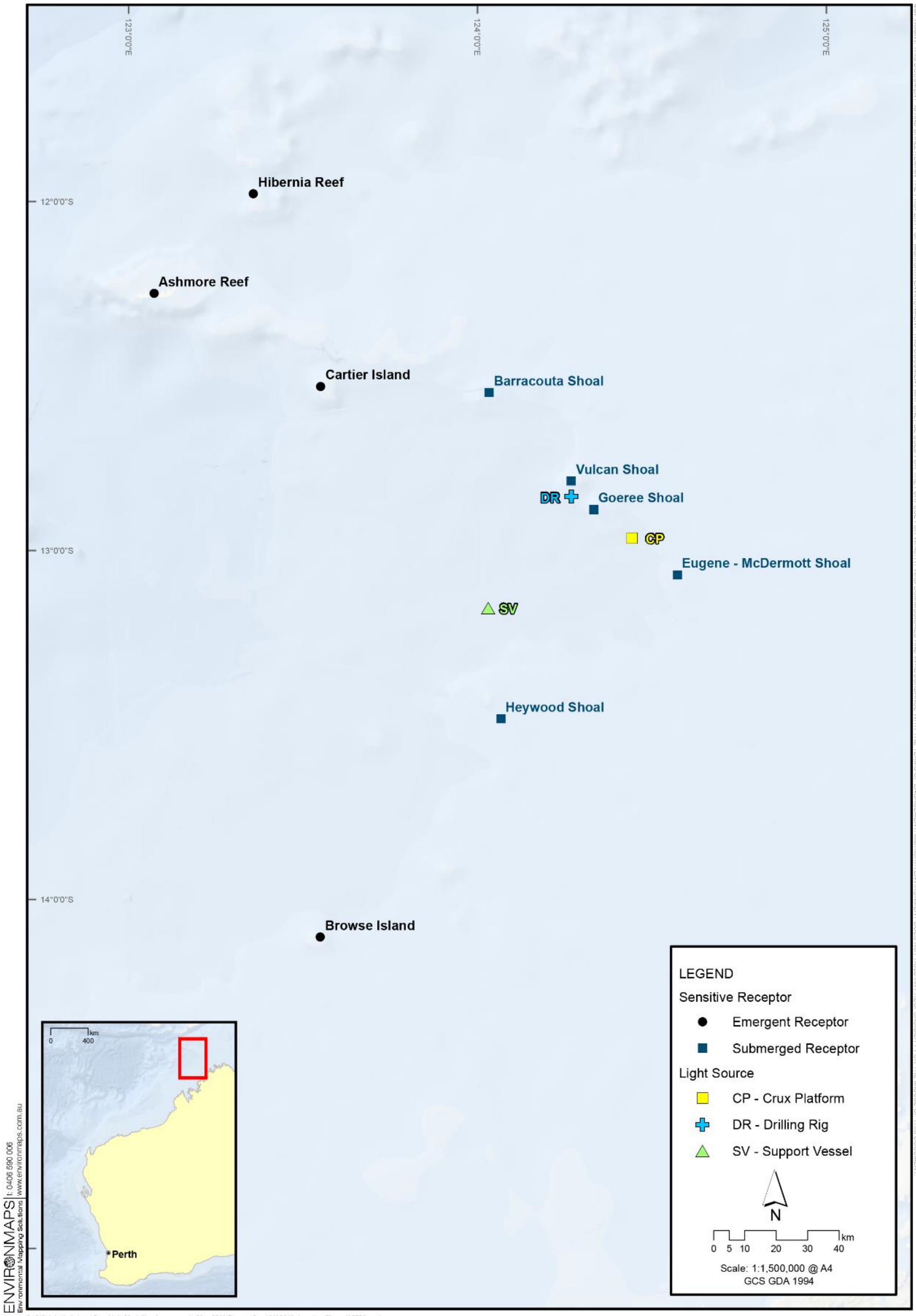

Figure 1 Location map of Crux Project with light sources and key receptors

2.0 BACKGROUND

2.1 Light Theory

2.1.1 Artificial Light Sources

Light propagating into the atmosphere directly from upward-directed, incompletely shielded sources, or after reflection from the ground, ocean or other surfaces, produce a diffuse glow that can be seen from large distances. Skyglow from artificial lights is most often noticed as a glowing dome of light over cities and towns.

Skyglow occurs when artificial light reflects off clouds and atmospheric particles such as dust and water vapour, causing a scattering effect. Sky glow is highly variable depending on localised weather conditions, quantity of dust and gas in the atmosphere, amount of light directed skyward, and the direction from which it is viewed. In cloudy weather conditions, more particles are present in the atmosphere to scatter the upward-bound light, so sky glow becomes a very visible effect of wasted light.

Air molecules are far smaller than the wavelength of light. They scatter light forwards and backwards equally, and scatter light sideways at half the forward intensity. They are very much more effective at scattering shorter (bluer) wavelengths. This is known as Rayleigh scattering (Strutt 1899), and is the reason why the sky appears blue. Aerosols are suspended water droplets and dust particles with sizes that are not always smaller than a wavelength of light. These scatter light sharply forwards, very little sideways, and only very slightly backwards, and are not affected by wavelength. This is known as Mie scattering (Cox 2002), and is why clouds appear white. Airborne particles, cloud density and height will all have an effect at which skyglow is perceived by an observer.

2.1.2 Skyglow and Distance

Sky glow brightness arising from artificial light sources decreases exponentially with distance from the light source, due to the geometric effects characterized by Rayleigh's inverse square law in combination with atmospheric absorption. Rayleigh's Law has been verified by observation to describe both the measurements of sky brightness at any given point or direction in the sky caused by a light source, as well as to integrated measures such as the brightness of the "light dome" over a city, or the integrated brightness of the entire night sky. At large distances (over about 50 km) the brightness of a light source falls more rapidly, largely due to extinction and geometric effects caused by the curvature of the Earth.

Different light sources produce differing amounts of visual sky glow. The dominant effect arises from the Purkinje shift, and not as commonly claimed from Rayleigh scattering of short wavelengths (Aubé et al. 2013; Luginbuhl et al. 2014). When observing the night sky, even from moderately light polluted areas, the eye becomes nearly or completely dark adapted or scotopic. The scotopic eye is much more sensitive to blue and green light, and much less sensitive to yellow and red light, than the photopic eye. Predominantly because of this effect, white light sources such as metal halide, fluorescent, or white LED can produce as much as three times the visual sky glow brightness of the most common high-pressure sodium lamp or a flame.

2.1.3 Influence of Clouds

The cloud-cover and cloud height influence the dispersal of skyglow by reflecting at the cloud-ceiling causing increased luminance at lower light intensities due to light scattering. Cloud cover refers to the fraction of the sky (oktas 1-8) obscured by clouds when observed from a particular location, with cloud coverage of oktas 8 being overcast.

Cloud height is defined by the height of the cloud-ceiling from the ground. Clouds that enhance skyglow are often lower clouds between 1 – 2 km Australian Height Datum (AHD) (e.g. nimbostratus and stratocumulus) and mid-level clouds up to 4 km (e.g. altocumulus), as artificial upward light intensity decreases with altitude. A recent study by (Jechow et al. 2017) tracked the reach of skyglow from an urban into a remote area on a clear and on a partly cloudy night. They showed that zenith luminance reached near-natural levels at 5 km distance from a town on the clear night, but similar levels were reached at 27 km on the partly cloudy night.

Clouds behave like random disperse media with enhanced multiple-scattering efficiency and reflect light according to the water content, especially as a function of the size, spatial density and asymmetry parameter of the water droplets (Kokhanovsky and Rozanov 2012). The clouds amplify the flux density of downwelling radiation through the diffuse reflection of up-light, in which the direct emissions and forward scatter dominate. The spectral and angular behaviour of upwardly propagated radiation differs from that scattered in a cloudless atmosphere. Therefore, no simple approach to calculating the amplification factor exists, and, rather than being a simple function of input parameters, the amplification factor will have a complex dependence on the optical properties of clouds, the position of an observer with respect to the position of the dominant light source, and its size and spectral properties. Due to this complexity, the amplitude of reflectance from the cloud-ceiling will not be considered in the analysis.

2.2 Key Habitats and Sensitive Receptors

The presence of artificial lighting associated with activities during all phases of the Crux Project has the potential to impact marine fauna and birds, particularly those that use visual cues for orientation, navigation, or other purposes. The distance of key habitats and associated sensitive receptors from the Crux Project light sources are presented in Table 1. Impacts from artificial lighting associated with the Crux Project may include the following:

- disorientation, attraction or repulsion
- disruption to natural behavioural patterns and cycles, and
- secondary impacts such as increased predation and reduced fitness.

Table 1 Key habitats and sensitive receptors within 165 km of the Crux Project. Sensitive receptors: MT=marine turtles; SB=seabirds; MSB=migratory shorebirds; FI=fish; ZP=zooplankton; CR=coral reef

Key habitats	Sensitive receptor	Approx. distance to the Crux platform (km)	Approx. distance to the notional drilling rig within the Crux development area (km)	Approx. distance to the notional support vessel situated along the Crux export pipeline (km)
Goeree Shoal (GS)	FI, ZP	13	8	46
Eugene McDermott Shoals (EMS)	FI, ZP	18	42	60
Vulcan Shoal (VS)	FI, ZP	22	4	49
Barracouta Shoals (BS)	FI, ZP	63	39	64
Heywood Shoal (HS)	FI, ZP	70	70	29
Cartier Island (CI)	MT, SB, MSB, CR	105	78	85
Ashmore Reef (AR)	MT, SB, MSB, CR	155	127	134
Browse Island (BI)	MT, SB, MSB, CR	158	160	117
Hibernia Reef (HR)	FI, CR	160	135	149

For the purpose of the assessment, indicative locations of a drilling rig and support vessel were identified to provide an informed, conservative assessment of light in relative proximity to nearest receptors. In reality, these sources are mobile and may occur within the Crux Project area.

2.2.1 Marine Turtles

Six species of marine turtle occur in Australian waters and have potential to pass through the project area, including green turtles (*Chelonia mydas*), flatback turtles (*Natator depressus*), hawksbill turtles (*Eretmochelys imbricata*), olive-ridley turtle (*Lepidochelys olivacea*), leatherback turtle (*Dermochelys coriacea*) and loggerhead turtles (*Caretta caretta*) (Commonwealth of Australia 2017). Green and hawksbill turtles are known to nest at Ashmore, Cartier and Browse Islands, while loggerhead turtles have been recorded at Ashmore Island, but infrequently (Commonwealth of Australia 2017). All marine turtle species are protected under the *Environment Protection and Biodiversity Conservation Act* (EPBC Act).

Light pollution on nesting beaches can alter critical nocturnal behaviours in adult and hatchling turtles. Research suggests that artificial lighting can disrupt or affect the choice of nesting location by female turtles, particularly light visible on the landward side of nesting beaches (Salmon et al. 1992) the onshore and offshore orientation turtle hatchlings (Salmon et al. 1992). These studies demonstrated that hatchlings crawl away from tall, dark horizons (sand dunes and vegetation) towards lower and lighter horizons (the sea and stars), and that artificial lighting can alter this response.

As hatchlings swim offshore from their natal beach, they become less influenced by light cue and rely predominantly by wave motion, currents and the earth's magnetic field (Lohmann and Lohmann 1992). Studies also suggest that light generated by flares may not affect hatchlings as much as other light sources. Witherington and Bjorndal (1991) examined the roles of light wavelength and intensity in the sea-finding mechanisms of loggerhead and green turtle hatchlings and found the most disruptive wavelengths to be in the range of 300 to 500 nanometres (nm) (blue – green wavelengths). Spectral analysis of flares at Thevenard Island (Pendoley 2000) suggests that flare light does not contain a high proportion of light wavelengths within this range.

2.2.2 Sea Snakes

Sea snakes are found in tropical waters in a diverse range of habitats (Heatwole and Cogger 1993). Sea snakes are abundant throughout the shallow seas and inshore waters of tropical Australia, and twenty species are reported to occur in the North-west Marine Region (Wilson and Swan 2003). They occur widely from coral reefs to turbid inshore waters and estuaries, but there are few species known from the region that inhabit deep-water, oceanic environments. Tagging experiments on Ashmore Reef have revealed that some species of sea snake remain resident in localised areas for some years (Guinea and Whiting 2005). All sea snakes are listed marine species under the EPBC Act.

There is no literature available on the effects of light on sea snakes. However, anecdotal evidence based on absence of sea snakes in waters surrounding offshore vessels suggest that sea snakes are not attracted to artificial light sources.

2.2.3 Seabirds

Studies conducted between 1992 and 2002 in the North Sea confirmed that artificial light was the reason that birds were attracted to and accumulated around lit offshore infrastructure (Marquenie et al. 2008) and that lights can attract birds from large catchment areas (Wiese et al. 2001). Birds may either be attracted by the light source itself or indirectly as structures in deep water environments tend to attract marine life at all trophic levels, creating food sources and shelter for seabirds (Surnam, 2002). The light from operating production facilities and flares may also provide further opportunities for seabirds to forage at night. Potential adverse impacts to seabirds attracted by artificial lighting are limited but includes collisions with infrastructure and flares and alteration of normal behaviours.

2.2.4 Migratory Shorebirds

There are recognised sites of importance for migratory shorebirds on the coast of northwest Western Australia (e.g. Roebuck Bay, 80 Mile Beach and the Lacepede Islands) and at Ashmore and Cartier Islands, which are 155 km and 105 km north-west of the Crux platform, respectively (Bamford et al. 2008) (Table 1). Migratory birds may pass in the vicinity of the Crux Project area 'en route' between these sites on mainland Australia and destinations on offshore islands or locations such as East Timor, Indonesia, Malaysia and Papua New Guinea (Commonwealth of Australia, 2002).

While little is known about how migratory shorebirds navigate, particularly over oceans and in the absence of terrestrial landmarks, many are thought to use the Earth's magnetic field, stars, the Sun and polarised light patterns to determine their migratory direction (Åkesson and Bäckman 1999). If migratory shorebirds are reliant on visual cues such as ambient light, moonlight and starlight to navigate, then artificial light could alter their natural migratory patterns, particularly over the ocean. Light from offshore platforms has been reported to attract migrating birds, particularly those that migrate during the night (Verheijen, 1985).

Studies have found that migratory shorebirds are particularly sensitive and attracted to the orange to red portion of the visible light spectrum (Van De Laar 2007). This equates to the wavelength range of roughly 590 – 750 nm within the electromagnetic spectrum. As most offshore infrastructure and vessels contain primarily white and orange (sodium vapour) coloured luminaries, a significant proportion of the total light emitted is within this range. Van De Laar (2007) reported that by replacing orange, red and white lights with primarily green and blue lights on an offshore platform, significantly reduced (up to ten times) the number of migratory shorebirds circling the platform. Whilst the literature suggests that migratory shorebirds are attracted to offshore light sources depending on their distance (< 5 km), there are no reports of migratory shorebirds landing on offshore platforms. It is likely that migratory shorebirds may be attracted to the light temporary during the night, but then continue their migration at daylight. The potential impacts on the migratory shorebirds population resulting from this temporary attraction to light sources is not well understood.

2.2.5 Cetaceans

There is no evidence to suggest that artificial light sources impact on the migratory, feeding or breeding behaviours of cetaceans. Cetaceans predominantly utilise acoustic senses to navigate their environment, rather than vision (Simmonds et al. 2004). However, anecdotal evidence from night observations on vessels suggest that dolphins prey on fish and other marine species that are attracted to artificial light sources. While this may present a minor change in behaviour of dolphins at a local scale, it is unlikely that the Crux Project will have a significant impact on cetacean species.

2.2.6 Zooplankton

The seas surrounding Australia contain a relatively low zooplankton biomass, particularly in the open ocean (Tranter 1962). Spatial and temporal patterns in the distribution and abundance of macrozooplankton on the North-west Shelf (which is representative of the Browse Basin area) are influenced by sporadic climatic and oceanographic events, with large inter-annual changes in assemblages (Wilson et al. 2003). Amphipods, euphausiids, copepods, mysids and cumaceans are among the most common components of the zooplankton in the region (Wilson et al. 2003).

Light has been reported as a fundamental factor controlling the daily vertical migration of zooplankton (Haney 1993). Light not only serves as the proximate cue triggering the ascent of zooplankton, but it also reduces the amplitude of migration if light levels are sufficiently high at night. Plankton migrate closer to the surface on dark nights than they do on clear, moonlit nights (Dietz 1962). Alterations of the ascent and descent cycles of marine plankton may indirectly affect the feeding of marine species. Some species of plankton have been reported foraging in darkness to avoid predation, only to be intensively predated when illuminated by a rising full moon (Gliwicz 1986).

2.2.7 Fish

Experiments using light traps have found that some fish species are attracted to light sources (Meekan et al. 2001), with traps drawing catches from up to 90 m (Milicich et al. 1992). The concentration of organisms attracted to light results in an increase in food source for predatory species and marine predators are known to aggregate at the edges of artificial light halos. A larval fish study around a platform in the Gulf of Mexico showed increased abundance of clupeids (herring and sardines) and engraulids (anchovies), which are both highly photopositive (Lindquist et al. 2005). Shaw et al. (2002), in a similar light trap study, noted that juvenile tunas (Scombridae) and jacks (Carangidae), which are highly predatory, may have been preying upon concentrations of zooplankton attracted to the light field of the platforms. This could potentially lead to increased predation rates compared to unlit areas.

2.2.8 Coral Reef

The Kimberley coast supports extensive reef systems, north of Cape Leveque. Coral reefs are also well developed around offshore islands including Ashmore, Cartier, Hibernia, Seringapatam and Scott Reefs, Browse Island and the Rowley Shoals. Coral distribution is likely driven by water depth and availability of hard substratum for anchorage.

The reef system at Cartier Island (105 km from the project area) represents the nearest major coral reef system in proximity to the Project area, with coral also observed to occur on the shoals and banks throughout the region.

3.0 METHODS

The light modelling assessment consisted of two methods for predicting the dispersal of light from a single light source, including:

- Line of sight (LOS) modelling - LOS modelling was undertaken to determine the extent of direct light to the horizon from the Crux Project light sources and identify which receptors fall within this area
- Light Intensity Modelling - Light intensity modelling was undertaken to calculate the intensity of luminance from the light sources to ambient light conditions.

It is important to note that, at the current stage of early engineering definition, the lighting design has not commenced and not likely to be definitively completed until significantly later in detailed design. Therefore, for this early stage assessment, the assumed inputs represent a current conservative project estimation of what could be reasonably expected in typical light scenarios from the Crux Project. Given the lighting philosophy has not been designed at the time of preparing this assessment, it may be subject to change / refinement over time.

3.1 Line of Sight Assessment

A LOS assessment was conducted to determine the visible extent of all of the direct light sources to the horizon. A total of nine points were chosen across the Crux Project to represent light source locations to be used in the assessment (Table 2). The points represent the key light sources that are likely to emit the greatest emissions from the highest points of the Crux Project (Figure 1).

The maximum height of the flares was calculated based on the estimated height of the flame plus the height of the flare stack. The flame height was estimated based on the rate of outputs and modelling undertaken for the Narrabri Gas Project (Imbricata 2018).

Lighting associated with deck locations on similar infrastructure typically consists of fluorescent 36 watt (W) fixtures, with HPS 500 W floodlights lights on the topside modules (Table 2). On the drill rig and support vessels, these lights will be used on a 24-hour basis in accordance with safety requirements during the operation. On the Crux platform, these lights will only be used during maintenance, which is expected to occur periodically only every 6-12 weeks throughout the year.

The frequency and timing of lights used was provided by Shell based on typical requirements for flaring during start-up, operations, maintenance and safety flaring events and during operations of the NNM Crux platform, drill rig and supply vessels (Table 2).

Imbricata used Viewshed in Global Map v15 (Blue Marble Geographics Hallowell, ME, USA.) to calculate the extent to which direct light reaches the distant horizon taking into account the curvature of the earth's surface. A Digital Evaluation Model was not required for this assessment given that there were no emergent features of high altitude within the study area.

3.2 Light Intensity Modelling

The extent of horizontal light intensity to ambient light conditions (i.e. moonless clear night, where exposure value (E_v) > 0.001 Lux) was modelled for three scenarios representing periodic flaring periods (start-up, safety flaring event and maintenance) and four scenarios representing continuous operations (pilot flaring, manned Crux platform, drill rig operations and supply vessel operations) (Table 3). A moonless clear night was considered the most frequent sky condition for the area and provides a conservative and realistic representation of ambient light conditions in the offshore northern Browse Basin.

The flaring analogues were extrapolated from in-situ luminance measurements taken from a light study for the Narrabri Gas Project (Imbricata 2018). The luminance from a single 4 m pilot flame was 5.7 Lux, while a 30 m flame during a safety flaring event was estimated to emit 1140 Lux from the same distance. The actual decay rates of light intensity validated the model outputs. These measurements were then used to estimate the maximum luminance of the proposed flaring scenarios at 100 m. These analogues were used to extrapolate the light intensity from the light sources until it reached ambient light conditions.

The operational lighting of the deck and topside modules of the Crux platform, drill rig and supply vessels were assumed to comprise different lighting outputs including florescent and HPS globes, which will emit light at lower wavelengths. Given that the specifications of these fixtures are currently unknown, Imbricata used the in-situ light measurements taken of the drill rig at the Torosa South-1 well (SKM and ERM 2008). The light intensity of the rig lighting was highest at 8.9 Lux, located 100 m from the rig and lowest at 0.03 Lux at the extremities of the survey grid approximately 1.4 km from the rig (SKM and ERM 2008). It was assumed that light emissions from the Torosa drill rig would be a realistic representation of the Crux platform, drill rig and supply vessels.

The dispersal of horizontal light emissions were estimated based on Rayleigh's inverse square law (intensity $\propto 1/r^2$), assuming consistent scattering at low altitude (Strutt 1899). The model outputs of the horizontal l propagation of light for each of the scenarios were presented in luminance/distance graphs and dispersal maps to show the exponential attenuation of light with distance. The intensity of light emitted from each scenario were divided into the following categories to compare against natural light conditions:

- >1 Lux (day light)
- 0.1 – 1 Lux (full moon to twilight)
- 0.01– 0.1 Lux (quarter moon to full moon), and
- 0.001 – 0.01 Lux (moonless clear night to quarter moon)

Table 2 Expected analogues and timing of light sources at the Crux Platform (CP), Drill Rig (DR) and Supply Vessel (SV).

Location of light source	Max. height above sea level (ASL) (m)	Type of light	Light shields/flame flow rate	Frequency	Max. time (hours)
Crux platform flaring					
CP flare – start-up	40	Flame	70 mmscf/d (+13m flame)	Start up	36
CP flare – operations (pilot)	90	Flame	3.5 mmscf/d (+ 5m flame)	Continuous	Continuous
CP flare - maintenance	91	Flame	4. 550 mmscf/d (+ 6m flame)	4 years	12
CP flare - safety event	115	Flame	550 mmscf/d (+ 30m flame)	1 year	0.4
Functional lighting					
CP deck (manned)	25	Fluorescent 36 W fixtures	Diffusing cover	Maintenance only	3 weeks
CP topside modules (manned)	75	HPS 500 W floodlights	Directional floodlights	Maintenance only	3 weeks
DR deck	25	Fluorescent 36 W fixtures	Diffusing cover	Continuous	Continuous
DR mast	75	HPS 500 W floodlights	Directional floodlights	Continuous	Continuous
SV stern	30	Fluorescent 36 W fixtures	Diffusing cover	Continuous	Continuous

Table 3 Lighting analogues and timing for light intensity modelling

Location of light source	Type of light	Modelling analogues (max. luminance at 100 m) (Lux)	Frequency	Max. time (hours)
Periodic flaring scenarios				
CP flare – start-up	13m flame	1.1	Start up only	36
CP flare - safety event	6m flame	103	approx. 4 years	12
CP flare - maintenance	30m flame	0.5	>1 year	0.4
Continuous operations				
CP flare – pilot (unmanned)	5m flame	0.5	Continuous	Continuous
CP deck & topside modules (manned)	Functional	8.9	Maintenance only	Continuous for ~3-week periods
DR deck & mast	Functional	8.9	Continuous	Continuous
SV stern	Functional	8.9	Continuous	Continuous

4.0 RESULTS

4.1 Line of Sight Assessment

The following section provides the results of the LOS assessment and are presented in Figure 2. The analysis shows that the theoretical limit of visibility from the Crux platform may extend up to 38.3 km during a safety flaring event, 34.1 km during maintenance, 33.7 km during operation and 22.6 km during start-up activities (Table 4). The direct light from all flaring scenarios has potential to be visible at Goeree Shoal, Eugene McDermott Shoals and Vulcan Shoal (Figure 2), however these represent submergent receptors with limited influence from atmospheric light.

Lights of the Crux platform and the drill rig and mast (assumed to be 25 m ASL) may be visible at distances of 30.9 km, encompassing Goeree Shoal, Eugene McDermott Shoals. The Crux platform and drill rig decks (assumed to be 25 m ASL) may be visible on the horizon at a distance of 17.9 km, which would be seen from Goeree Shoal. The lights of the supply vessel may be visible on the horizon at a distance of 19.6 km, which would not be visible from any of the key habitats (Table 4).

Table 4 Maximum distance that direct light will be visible at the horizon from each light source and key habitats within this distance

Location of light source	Max. height of light source ASL (m)	Direct LOS projection (km)	Key habitats reached *
CP flare - start-up	40	22.6	GS, EMS, VS
CP flare - operations (pilot)	90	33.9	GS, EMS, VS
CP flare - safety flaring event	115	38.3	GS, EMS, VS
CP flare - maintenance	91	34.1	GS, EMS, VS
CP deck (manned)	25	17.9	GS, EMS
CP topside modules (manned)	75	30.9	GS, VS
DR deck	25	17.9	GS, VS
DR mast	75	30.9	GS, VS
SV stern	30	19.6	none

* Note: Abbreviations of key habitats: Goeree Shoal (GS), Eugene McDermott Shoals (EMS) and Vulcan Shoal (VS).

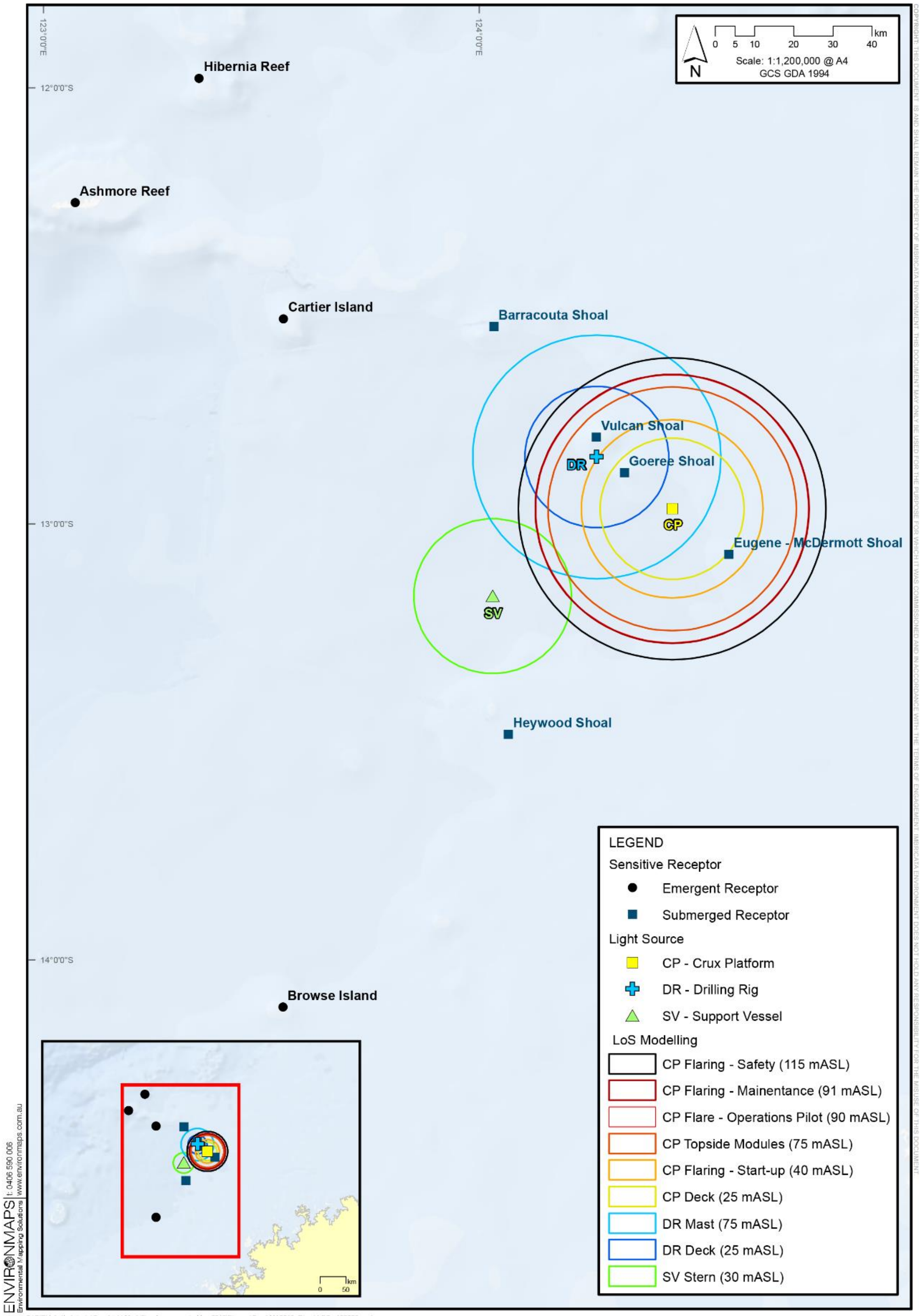

Figure 2 Theoretical limit of visibility from the Crux platform, drill rig and support vessel locations

4.2 **Light Intensity Modelling**

4.2.1.1 Periodic Flaring Scenarios

The following section provides the results of light intensity modelling outputs for the two flaring scenarios from the Crux platform: Safety flaring event (Figure 3), and start-up flaring (Figure 4). The extent of horizontal light propagation at ambient light conditions for each scenario are summarised in Table 5 and the spatial dispersal is presented in Figures 5 and 6. The modelling shows that the extent of horizontal light propagation at ambient conditions from a flaring event at the Crux platform was 32 km, which would reach Goeree Shoal (E_v= 0.0061 Lux), Eugene McDermott Shoals (E_v= 0.0031 Lux) and Vulcan Shoal (E_v= 0.0021 Lux) (Figure 5). The extent of horizontal light propagation at ambient conditions was significantly less for the start-up flaring scenario (3.2 km) and maintenance flaring (2.2 km) from the Crux platform (Table 5). Based on these estimates from these light sources, none of the sensitive receptors would be affected by light intensity greater than 0.001 Lux.

Table 5 Extent of horizontal and vertical light propagation at ambient light conditions (Luminance = 0.001 Lux) for various scenarios and key habitats within this range

Location of light source	Modelling analogues (max. luminance at 100 m) (Lux)	Horizontal light propagation (km)	Key habitats reached *
Periodic flaring scenarios			
CP flare - start up	1.1	3.2	none
CP flare - safety event	103	32	GS, EMS, VS
CP flare - maintenance	0.5	2.2	none
Continuous operations			
CP flare – pilot (unmanned)	0.5	2.2	none
CP deck & topside modules (manned)	8.9	9	none
DR deck & mast	8.9	9	GS, VS
SV stern	8.9	9	none

* Note: Abbreviations of key habitats: Goeree Shoal (GS), Eugene McDermott Shoals (EMS) and Vulcan Shoal (VS).

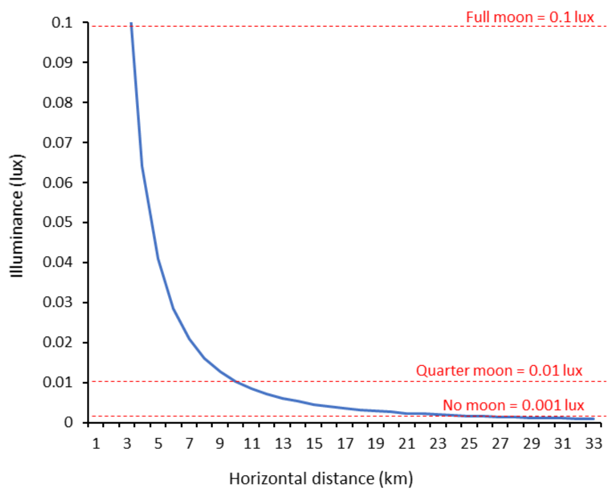

Figure 3 Modelling outputs for horizontal light propagation during a safety flaring event from the Crux platform

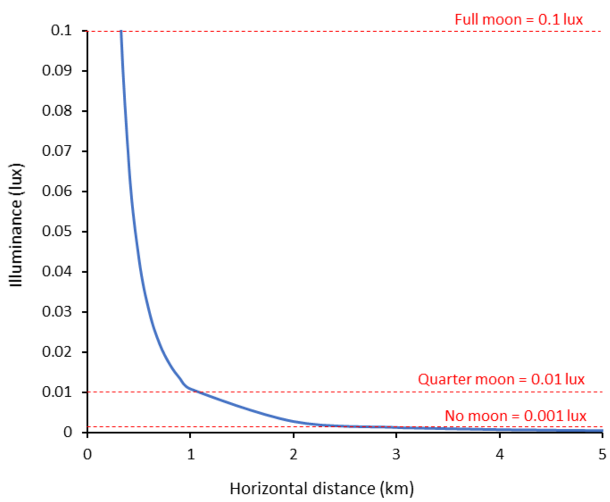

Figure 4 Modelling outputs for horizontal light propagation during a start-up flaring scenario from the Crux platform

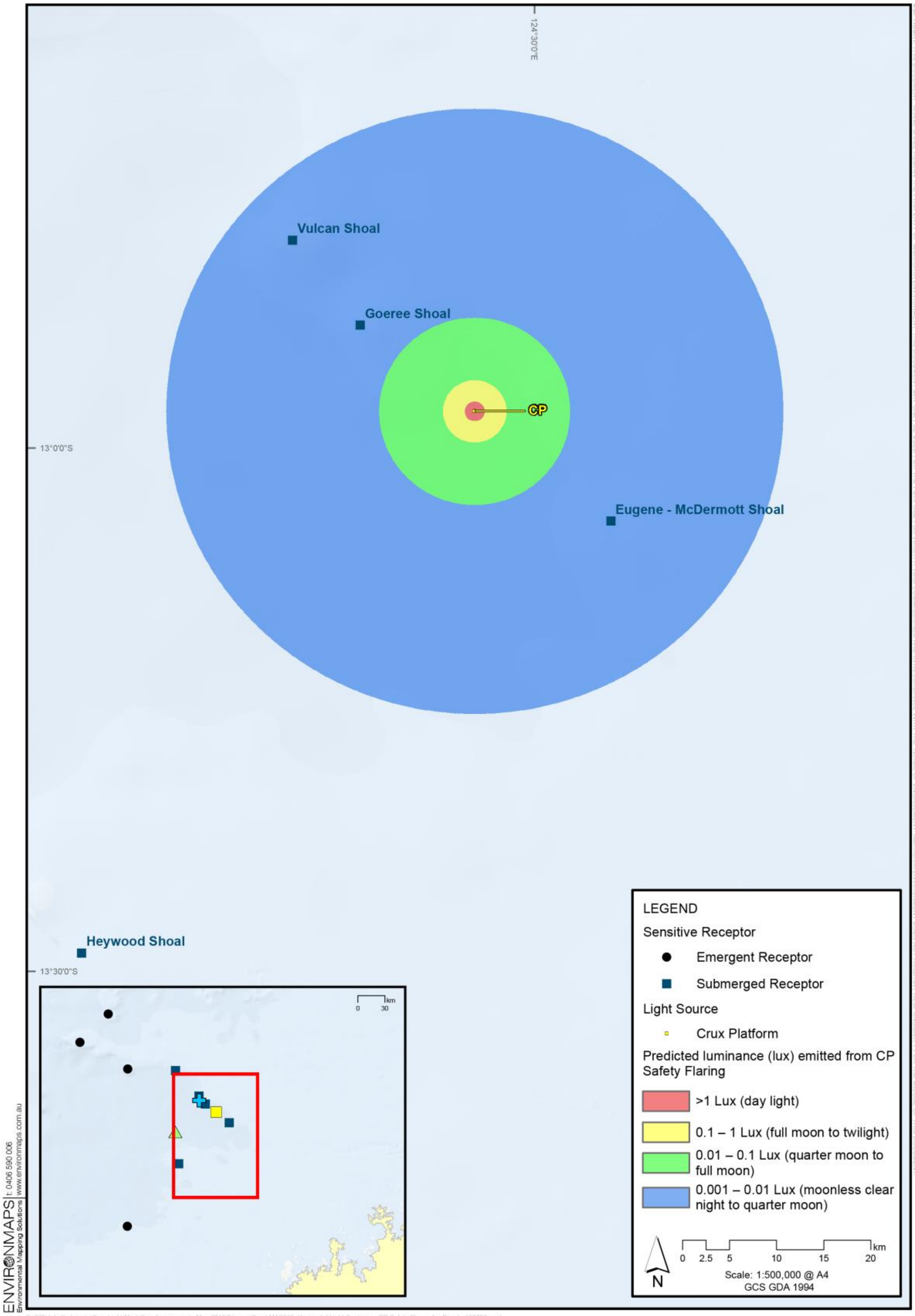

Figure 5 Horizontal light propagation during a safety flaring event from the Crux platform

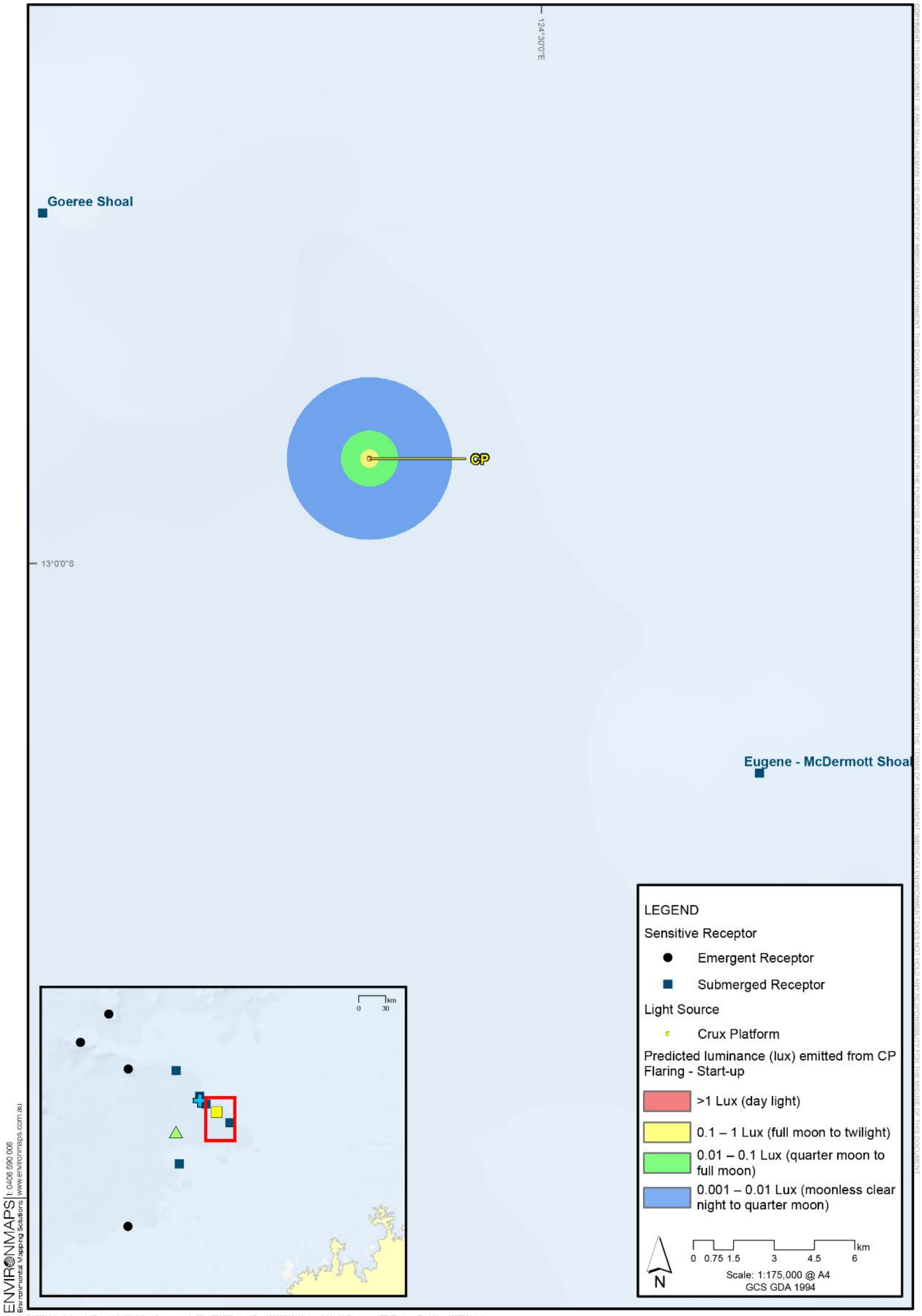

Figure 6 Horizontal light propagation during start-up flaring from the Crux platform.

4.2.1.2 Operations

The modelling outputs of the operations are shown in Figures 7 and 8. The spatial dispersal of light from the pilot flare (unmanned) is presented in Figure 9 and operations during maintenance at the Crux platform is presented in Figure 10. The modelling shows that the horizontal extent of continuous pilot flaring (assuming a period when the platform is unmanned, consistent with the NNM operational philosophy) is predicted to be 2.2 km. The functional lighting to ambient conditions is predicted to be 9 km from the Crux platform (when manned), drill rig and supply vessel (Table 5). Based on these calculations, the light from the drill rig may reach the nearest submergent receptors of Goeree Shoal (E_v= 0.0055 Lux) and Eugene McDermott Shoals (E_v= 0.0014 Lux), while the other light sources would not reach any of the key habitats at intensities greater than 0.001 Lux.

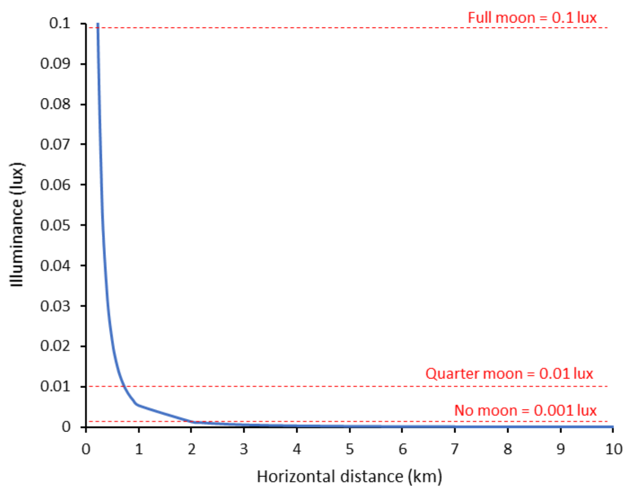

Figure 7 Modelling outputs for horizontal light propagation during pilot (unmanned) scenario from the Crux platform

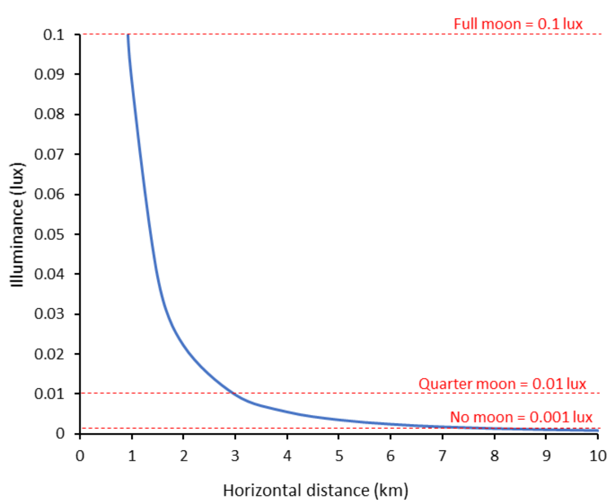

Figure 8 Modelling outputs for horizontal light projections from the Crux platform (manned), drill rig and supply vessel

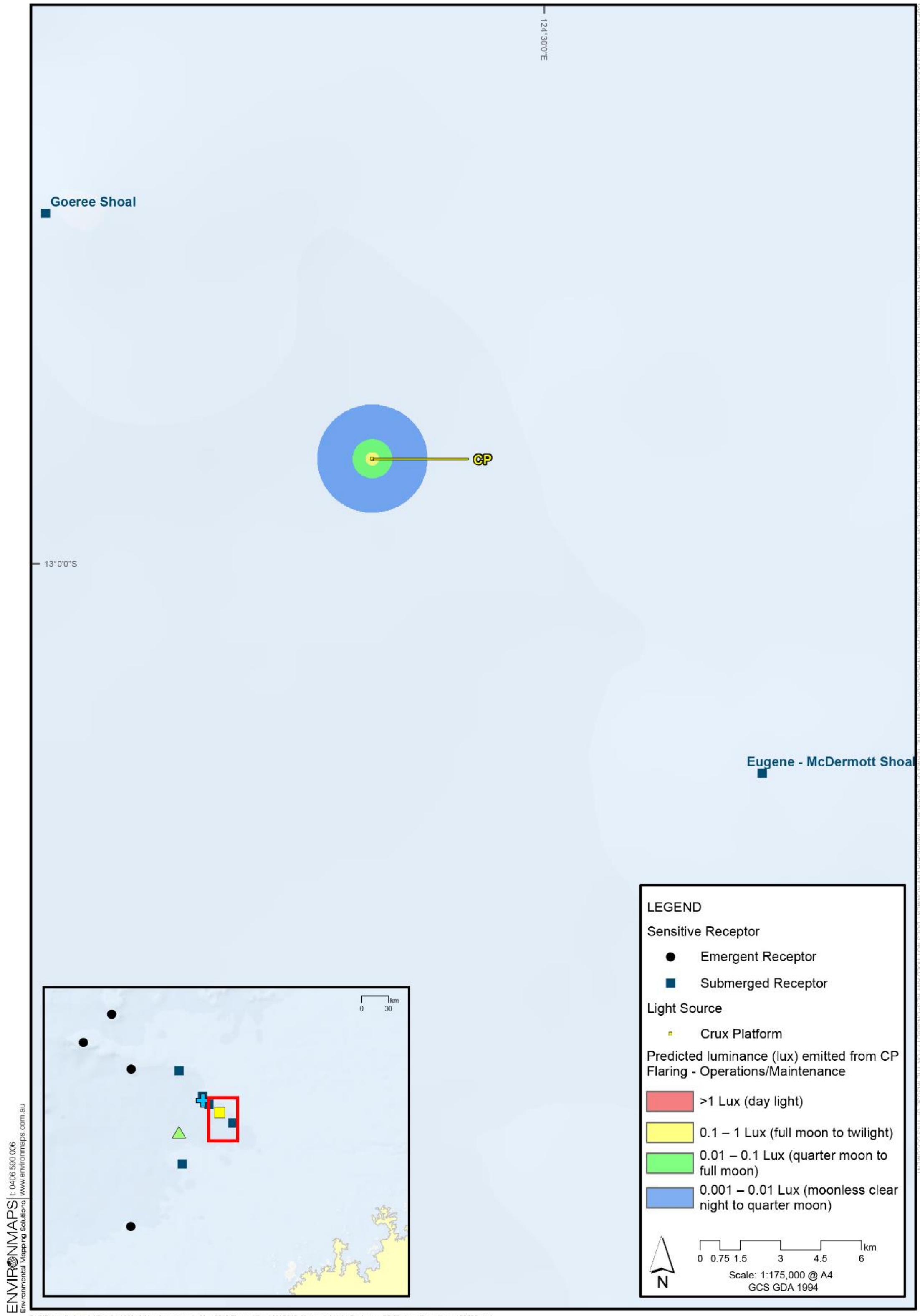

Figure 9 Horizontal light propagation during pilot flaring (unmanned) from the Crux platform

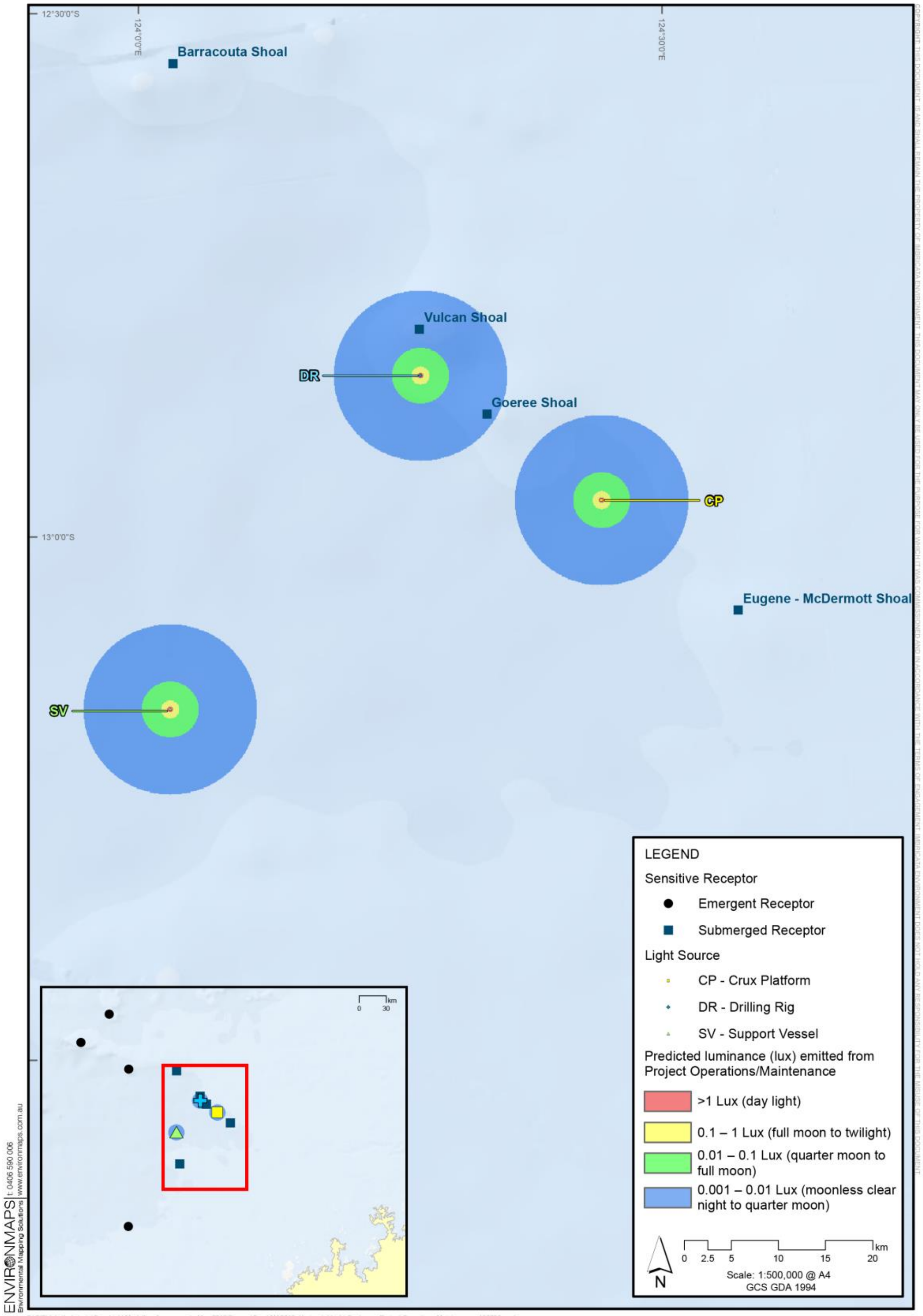

Figure 10 Horizontal light propagation during typical maintenance operations scenario including light from the Crux platform (manned), drill rig and supply vessel

5.0 DISCUSSION AND CONCLUSION

The outer area of influence from direct light is predicted to be approximately 38 km during a safety flaring event, which is expected to occur only under unanticipated rare operational conditions where the facility would need to flare to mitigate the potential for any over-pressuring of the topside infrastructure. However, the light intensity at this outer area was estimated to be less than ambient light conditions on a moonless clear night. Direct light spill from all flaring scenarios is predicted to extend over the shoals that occur in proximity to the Crux development area, including Goeree Shoal, Eugene McDermott Shoal and Vulcan Shoal. However, the light intensity is predicted to be at least an order of magnitude lower than the typical lux levels of a quarter moon on the horizon (E_v = 0.0061 Lux) at the nearest shoal.

The modelling outputs indicated that all light sources will be visible at Goeree Shoal, however only the safety flare and drill rig deck/mast will reach the shoal at intensities greater than ambient light conditions. All light sources from the Crux platform (including flaring and functional lighting) will be visible at Eugene McDermott Shoal, with no direct light visible from the drill rig or supply vessels. However, only the safety flaring will reach intensity greater than the ambient light conditions. From Vulcan Shoal, all light sources apart from the Crux platform deck and the supply vessels will be visible but only the safety flare and drill rig will reach the shoal at intensity greater than ambient light conditions.

Given the low levels of light reaching these habitats and that they are submergent features, the flaring and functional lighting scenarios would pose a low risk to sensitive receptors within the outer area of influence. The potential for increased predator activity is unlikely to result in a significant impact on the plankton population. Given the relatively small impact area surrounding the Crux Project in respect to zooplankton habitat, the potential effects are expected to be highly localised and unlikely to have a significant impact on zooplankton populations. Furthermore, the potential disturbance to fish surrounding the Crux Project is expected to be restricted to localised attraction, possibly extending up to 100 m from the light source. As such, any impacts to fish arising from light emissions are considered to be minor and localised to a small proportion of the population. The shoals surrounding the Crux Project area are not known to support large areas of coral communities, with the closest large reef system at Cartier Island (105 km from the project area). Therefore, it is unlikely that the project lighting will impede or disturb natural lighting cycles that may affect coral spawning.

Due to the high degree of variability in atmospheric conditions (e.g. cloud density, cover and ceiling height, aerosols and suspended participles), it is not feasible to accurately model the extent at which vertical skyglow will be visible at the key habitats. On a clear moonless night, the maximum vertical extent of skyglow may attenuate to 4 km above sea level (ASL) in the event of safety flaring (Imbricata 2018), which may be visible at a low angle (< 3^o) above the horizon. This skyglow will diminish exponentially over the horizon further away from the facilities and is unlikely to be visible from any emergent habitats identified within this study. Clouds can influence how skyglow is distributed at altitude by reflecting vertical light at the cloud-ceiling, which increases the perceived light across the sky at a specific observation point. The amount of light reflected off the cloud-ceiling will depend on the height, coverage and density of the clouds, and their proximity to the light source. While this factor will vary seasonally throughout the year, the worst-case scenario would be 100% cloud cover, with a cloud-ceiling height of 1 -– 4 km (e.g. altostratus, altocumulus). It is unclear the extent at which skyglow reflection on an overcast cloud-ceiling could potentially increase the outer area of attenuating light, but it would be limited to luminance less than ambient light at a low altitude angle over the horizon. Even during overcast nights, it is unlikely that the light reflected off the cloud-ceiling above the Crux Project area would reach any emergent habitat, which support nesting turtles, seabirds and migratory shorebirds, greater than ambient conditions.

Given that migratory shorebirds fly at an average altitude of 2 km (Richardson 1979), the Crux Project will be visible from a further distance than reported in this study. However, only a small number of individuals are expected to pass within the area of influence whilst in transit. Therefore, any behavioural disturbances such as disorientation, attraction and/or exhaustion are expected to affect a small proportion of the population, and not expected to result in any significant impacts on a regional or population level.

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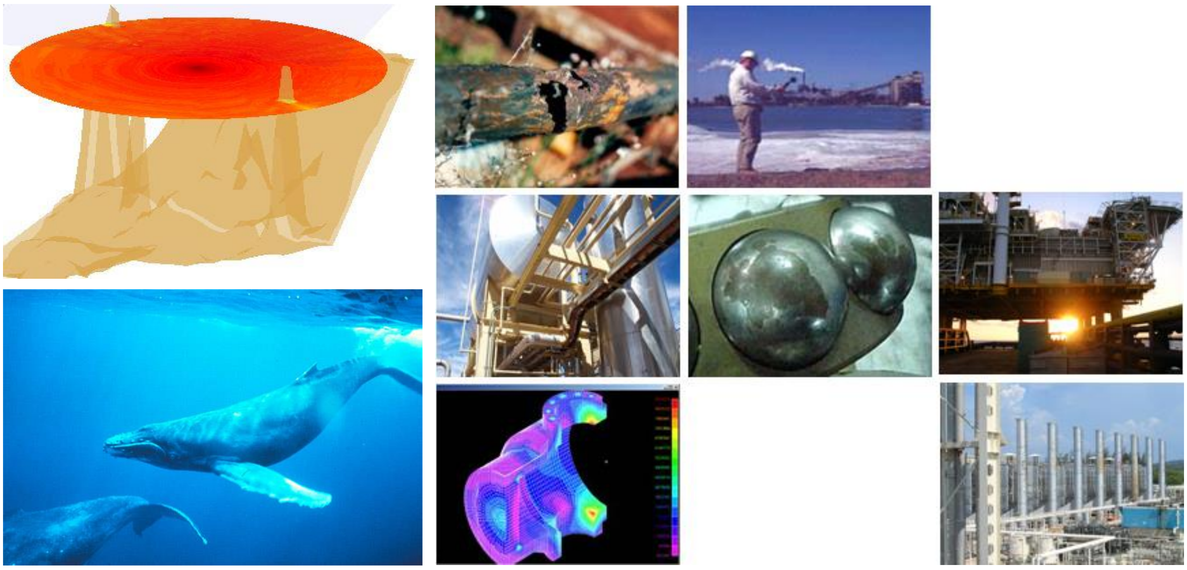
Appendix I: Underwater Noise Modelling Study (SVT 2018)

SVT ENGINEERING CONSULTANTS
A Wood Group Company

CRUX PROJECT- UNDERWATER NOISE ASSESSMENT



CDM SMITH

1402853-1-100-1402853-RevC-02 Jul 18

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SVT Job No: **1402853**

SVT Document No: **1402853-1-100-1402853-RevC-02 Jul 18**

Rev	Description	Prepared	Reviewed	Date
C	Issued for re-Review	Greg Stewart	Matthew Pettersson	02 Jul 18
B	Issued for Review	Ben Gicquel & Greg Stewart	Matthew Pettersson	03 May 18
C	Draft circulated for comments	Ben Gicquel	Greg Stewart	29 Mar 18

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EXECUTIVE SUMMARY

Shell Australia Pty Ltd (Shell) is progressing planning for the prospective development of the Crux development area, which is located approximately 160 km north-east of the Prelude field in the northern Browse Basin, offshore Western Australia, and is located in water depths of 110m to 170m.

The current development concept is for a not normally manned platform. The reference case is currently jacket platform with piled footings. This study assesses the underwater noise levels that are likely to occur due to activities within the Crux development area, and the impact on key values and sensitivities identified by comparison with established criteria. The noise is primarily due to:

- Pile Driving for installation of the platform jacket; and
- Drilling new wells, and working over existing wells, including the use of vertical seismic profiling (VSP) activities.

As part of the validation process, measured data from the Crux baseline geophysical, geotechnical and metocean studies have been used to inform the noise assessment, to provide bathymetry, seabed type, and parameters such as temperature vs depth, salinity vs depth.

Noise modelling was undertaken of a range of scenarios to provide an early assessment of noise from key sources including:

- Underwater noise generated by pile driving – 2 scenarios (main pile - small hammer; main pile - large hammer);
- Underwater noise generated by development drilling – including 2 scenarios to conservatively assess the potential for future drilling for future tiebacks in proximity to shoals (outside a defined exclusion zone) and a scenario for drilling at the Crux platform location;
- Underwater noise generated by downhole Vertical Seismic Profiling (VSP) activities at the Crux platform location; and
- A representative worst case operational noise scenario based on a Tender / Supply Boat operating with cavitating propellers in dynamic positioning (DP) mode.

The results are summarised in Table A-1 overleaf.

Table A - 1 Calculated Maximum Range for Effects during Pile Driving Activities

Marine Species		Impulsive Sources			Non-impulsive Sources		
	Permanent Injury or Fatality	Permanent Threshold Shift (PTS)	Temporary Threshold Shift (TTS)	Behavioural Disturbance	Permanent Threshold Shift (PTS)	Temporary Threshold Shift (TTS)	Behavioural Disturbance
Fish (No Swim Bladder)	Not Exceeded	Not Exceeded	13.3 km (2)	N/A	N/A	Not Exceeded	N/A
Fish (With Swim Bladder)	Not Exceeded	390 m (1)	13.3 km (2)	N/A	N/A	Not Exceeded	N/A
Sea Turtles	Not Exceeded	390 m (1)	N/A	Not Exceeded	N/A	N/A	N/A
Low-frequency Cetaceans	Not Relevant	17.3 km (1)	57.8 km (2)	2.7 km (3)	Not Exceeded	Not Exceeded	1.6 km (3)
Mid-frequency Cetaceans	Not Relevant	14.0 km (1)	56.9 km (2)	2.7 km (3)	Not Exceeded	Not Exceeded	Not Exceeded

(1) PTS from Accumulated Daily Exposure
(2) TTS from Accumulated Daily Exposure
(3) Sound Pressure Level (L_p)

The activities will have a localised and temporary impact on the marine fauna in the surrounding area, including fish (both with and without swim bladder), eggs and larvae, sea turtles and cetaceans. The modelling and analysis undertaken shows that underwater noise levels would:

- Fall below the relevant permanent injury and fatality criteria where applicable to the marine fauna type, and the relevant instantaneous permanent hearing damage criteria, at all locations;
- Fall below the relevant permanent hearing damage criteria based on daily exposures beyond ranges of 389 m for fish and sea-turtles, 14 km for Mid-Frequency Cetaceans and 17.3 km for Low-frequency cetaceans;
- Exceed the relevant temporary hearing threshold shift criteria (strike number and exposure time dependant) at ranges up to 13.3km for fish, to up to 57.8 km for cetaceans; and
- Fall below the relevant behavioural disturbance criteria for low-frequency cetaceans at ranges beyond 2.7 km.

The limiting (longest) ranges for the impact assessment are driven in by the daily exposure criteria (L_E). This metric reflects an accumulated dose for a 24h assessment based on the assumption that an animal is exposed to such noise levels at a fixed position. The corresponding radii are significantly larger than those for peak pressure criteria, and they represent an extremely unlikely worst case scenario. More realistically, marine mammals would not stay in the same location or at the same range for 24 hours. Therefore, a reported radius of L_E criteria does not mean that any animal travelling within this radius of the source will be injured, but rather that it there is potential for the onset of such injury if it remained in that range for 24 hours. Therefore, the cumulative 24-hour noise estimates are to be considered highly conservative and unlikely to represent the actual noise exposure by mobile transient marine fauna.

Underwater Noise Generated by Drilling

The impacts of underwater noise associated with drilling activities in the Crux development area are typical of the type of activity outlined. Minimal potential impacts are predicted.

- The modelling and analysis undertaken shows that underwater noise levels would fall below the relevant behavioural disturbance criteria for low-frequency cetaceans at ranges beyond 1.6 km; and
- Not exceed marine fauna criteria for fish, eggs and larvae, sea turtles, and mid-frequency cetaceans for any drilling scenario.

Underwater Noise Generated by Downhole VSP

No marine fauna criteria are exceeded at any location for any VSP scenario modelled. No potential impacts are predicted.

Operational Noise

The L_p criterion for behavioural disturbance to low-frequency cetaceans extends out to a range of 1.6 km (Tender on DP Scenario). No other potential impacts are predicted.

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Overview of the Crux Project

Shell Australia Pty Ltd (Shell) is progressing planning for the prospective development of the Crux development area, located approximately 160km north-east of the Prelude field in the northern Browse Basin, offshore the Kimberley coast, Western Australia (WA). The Crux Project will be located in Commonwealth marine waters in the northern Browse Basin, 160km offshore north-west Australia and 620km north-north-east of Broome. The field is located in water depths of 110m to 170m.

The current development concept is for an offshore (Not Normally Manned, NNM) platform, with a potential development area for future tie-backs defined within a 30km radius around the platform (Figure 1-1). The reference case is currently jacket platform likely with piled footings.

Shell are progressing an Offshore Project Proposal (OPP) for the Crux Project for submission to the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) in accordance with the Commonwealth Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS (E) Regulations), and have requested support in developing the OPP and associated specialist studies.

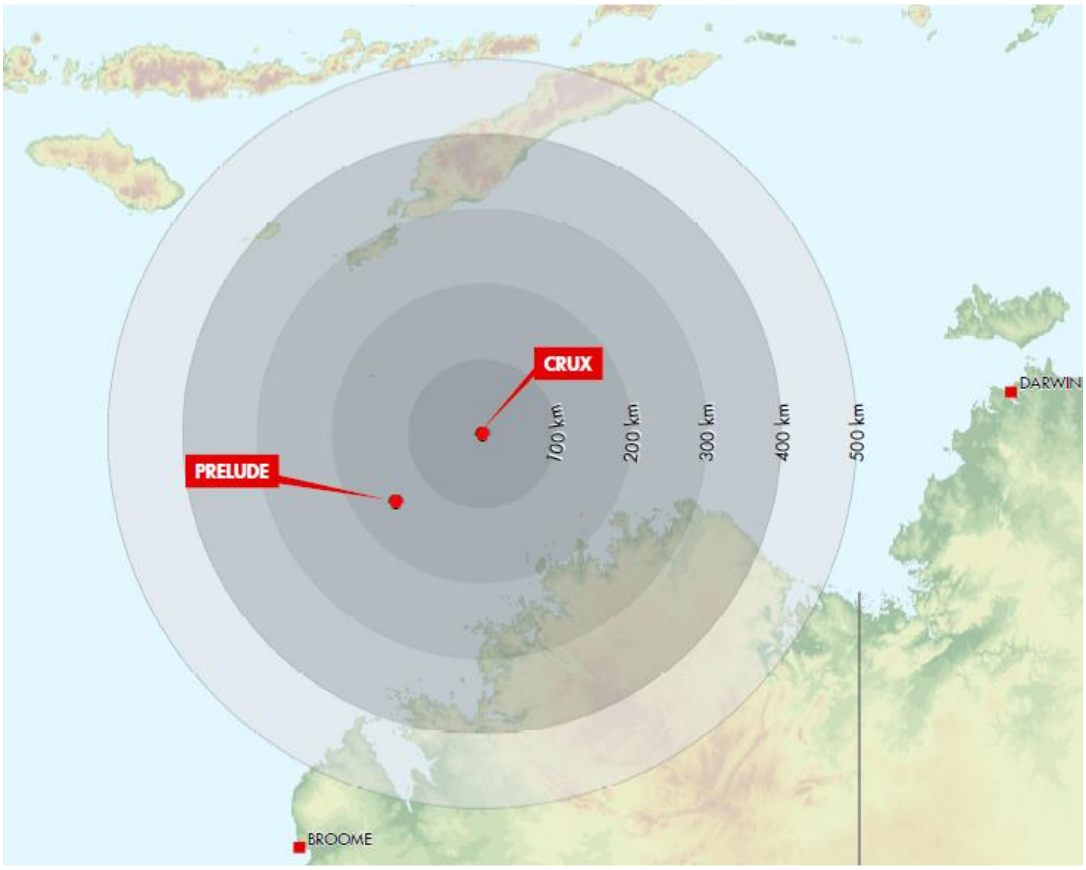

Figure 1-1 Overview of Proposed Crux Development Area

1.1.1 Noise Sources

The most significant sources of noise to be expected from the Crux Project are:

1. Pile driving during installation of the platform jacket; and
2. Development drilling - including drilling-related noise and the use of vertical seismic profiling (VSP), which involves a single noise source in the water column receiving transducers 'downhole'.

Given the nature of the development concept (NNM platform), there is little potential for significant underwater noise sources during the operational phase relative to the other project phases described above, and therefore is not a major focus of this study.

1.2 Scope

SVT was commissioned by CDM Smith, on behalf of Shell, to undertake an underwater noise impact assessment of the key noise-generating and operational activities associated with the Crux Project. This study assesses the underwater noise due to pile driving, drilling and downhole VSP activities that are likely to occur within the Crux development area, and the impact on key values and sensitivities identified by comparison with established criteria.

The scope of the study includes:

- A determination of the likely worst-case conditions for the generation of underwater noise from piling, drilling and VSP activities anticipated during the Crux Project;
- Calculation of the underwater noise levels (for 7 scenarios) from the activities expected to be conducted as part of the project, using a numerical model;
- Assessment of the modelled underwater noise levels against the marine fauna response criteria; and
- Provide a conclusion of the results and recommend underwater noise management strategies that may be considered as part of forward project planning.

1.3 Definitions, Acronyms

Table 1-1 provides a listing of acronyms used in this report. Technical terms are further defined in Appendix B.

Table 1-1 List of Acronyms

Acronym	Meaning
AHD	Australian Height Datum
BoM	Bureau of Meteorology
CF	Crest Factor – Refer Appendix B-3
DP	Dynamic Positioning
HAT	Highest Astronomical Tide

Acronym	Meaning
Mhf	High-Frequency Cetacean – A marine mammal grouping based on audiograms (sensitivity to noise). Refer also Appendix B-5
Mlf	Low-Frequency Cetacean– A marine mammal grouping based on audiograms (sensitivity to noise). Refer also Table 3-5 and Appendix B-5
Mmf	Mid-Frequency Cetacean– A marine mammal grouping based on audiograms (sensitivity to noise). Refer also Table 3-5 and Appendix B-5
MMO	Marine Mammal Observers
MMPE	Monterey Miami Parabolic Equation – Refer Appendix A-1
MPR	Modular Platform Rig
NOAA	National Oceanic and Atmospheric Administration
NNM	Not Normally Manned
PE	Parabolic Equation
PTS	Permanent Threshold Shift – Refer Appendix B-4
RMS, rms	Root Mean Squared – Refer Appendix B-3
$L_{E,p}$	Sound Exposure Level – Refer Appendix B-2
L_p	Sound Pressure Level – Refer Appendix B-1
L_{pk}	Peak Sound Pressure Levels – Refer Appendix B-3
SSP	Sound Speed Profile - – Refer Appendix B-3
TTS	Temporary Threshold Shift – Refer Appendix B-4
UTM	Universal Transverse Mercator
WA	Western Australia
WOA	World Ocean Atlas
VSP	Vertical Seismic Profiling

2. METHODOLOGY

2.1 Underwater Noise Modelling

SVT's underwater noise model (refer Appendix A for model description) predicts the transmission loss of underwater noise with changing ranges, depth, and bottom type. The model can predict transmission loss from multiple noise sources in both narrowband and broadband frequency ranges. The underlying calculation software kernel has been developed by the universities of Miami and Monterey[1] in the USA, while the front-end interface has been developed by SVT. The calculation kernel has been validated and is known as the Monterey Miami Parabolic Equation (MMPE) model.

SVT maintains a database of underwater noise sources based on field measurements and published data. This database allows SVT to directly enter the noise source frequency spectrum into the underwater noise model.

2.1.1 Data and Model Limitations

The following data and model limitations are noted:

1) **Rough Surface Scattering**. Acoustic wave scattering due to the roughness of the sea surface and seabed is not accounted for in the model, which makes the model more conservative.

2) **Vertical Launch Angles (±40°)**. The launch angle[2] of the model is limited to ±40°. The sound waves predicted at angles close to the noise source outside of this angle are evanescent waves, i.e. strongly decaying[3].

3) **Shear Speed**. As the model is based on a Parabolic Equation (PE), it does not accurately predict the effect of the high shear speed components of some bottom types, and therefore can make the model conservative in cases where the bottom type supports shear wave propagation of sound.

2.1.2 Model Validation

Underwater propagation models use bathymetric data, geo-acoustic[4] information and oceanographic parameters[5] as inputs to produce estimates of the acoustic field at any depth and distance from the source. The quality of the model's estimate is directly related to the quality of the environmental information used. For example, the geo-acoustic parameters of the seabed, such as compressional and shear sound speed, sound attenuation and sediment density, can affect acoustic propagation and can therefore affect the model predictions.

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[1] NPS (Naval Post Graduate School) Monterey California.

[2] MMPE implements the Pade equation approximation which gives small phase error angles in the main propagation direction.

[3] It must be noted that PE models are limited in vertical launch angles. For any angles outside of this limit, the model erroneously predicts evanescent waves.

[4] Geoacoustic parameters include material density, and compressional and shear speed.

[5] Oceanographic parameters include sound speed profiles of the water column and tidal heights. It is assumed that the sound speed velocity in the water column is the same for all ranges.

Measured data from the Crux baseline geophysical, geotechnical and metocean studies have been used to inform the noise assessment, to provide bathymetry, seabed type, and parameters such as temperature vs depth, salinity vs depth and highest astronomical tide.

Four general categories of acoustic propagation models are used in underwater acoustics: ray tracing; normal mode; parabolic equation (PE); and finite difference models. Of these model types, PE models are the most capable of making reliable predictions in range dependent shallow water[6] environments with changing bottom types, and with reasonable calculation solution times. The MMPE algorithm has been used as the basis of SVT's underwater noise model. This algorithm was selected because it has been rigorously tested and validated for shallow water environments at the Shallow Water Acoustic Modelling (SWAM 99) Workshop in Monterey California.

The temperature profile from baseline data collected within the Crux development area demonstrates that that there is no isothermal layer present – even though the depth may exceed 200m in some locations within the modelled domain. Additionally, the prediction range (> 25 km) is significantly larger than the depth. These observations validate the expectation of a "shallow water" environment and indicate that the selection of a parabolic equation for noise distribution modelling is appropriate for the Crux development area.

2.1.3 Noise Source Representation

In environmental acoustics, where the range to the assessment point (point of interest) is significantly greater than the dimensions of the source, noise sources are commonly modelled as idealised point sources. In determining noise emission source strength for underwater noise, the levels are commonly quoted as a level, in dB relative to the reference pressure (1uPa), and at a reference distance (1m) from the source location (e.g. 120 dB re 1uPa @ 1m). This level is typically calculated from measurements at far-field distances (i.e. a distance at which the source can be described as a point source). This does not mean that this quoted level is what would be measured at 1m, as the source has been idealised to encompass all of its energy into a sphere of radius 1m. Most sources are significantly larger than this dimension (in this case the wetted hull area of a semi-submersible drilling rig, or the surface area of a pile 160m to 185m long with a diameter of 2.44m to 2.94m), and in actuality the total sound energy will be distributed across the full actual surface area of the source. This then means that a mathematical noise model will predict noise levels in the near field (defined as a distance where the point source characterisation does not hold, generally less than 7 times the maximum source dimension) that are higher than they would be in reality.

2.2 Underwater Noise Generated by Pile Driving

In order to install the footings for the Crux NNM Platform, piles will be driven into the seabed by hydraulic impact piling. Impact piling operations involve the hammering of a pile into the seabed using (in this case) a hydraulically driven hammer located in the water. The hammering action results in radiation of noise from the pile into the surrounding water and seabed.

At each strike of the hammer, in addition to the whole displacement of the pile further into the seabed, the pile bends elastically and then returns to its original shape. This bending takes the form of flexural waves in the pile (see Figure 2-1), which propagate along the length of the pile and into

[6] Shallow water is defined to be depths < 200 m (see Richardson et al., 1995. Marine Mammals and Noise, Academic Press).

the seafloor[7]. The transverse component of the wave creates compression waves in the water which will propagate out from the pile as noise. The compressional component of the flexural wave will propagate into the seabed.

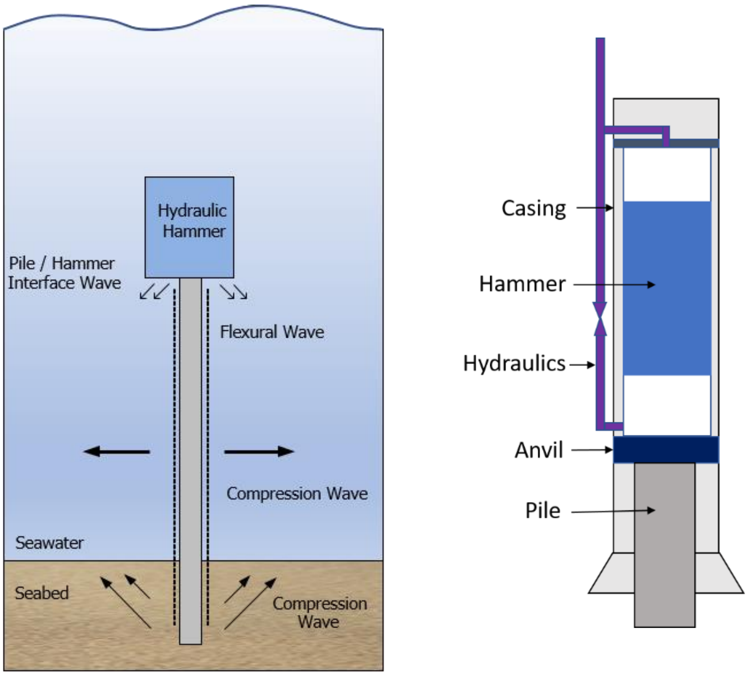


Figure 2-1 Underwater Noise Associated with Piling, and Schematic of underwater hydraulic hammer

The dominant underwater noise source from the piling activity is the compression wave generated from the surface of the pile in the water column. Studies have demonstrated that the magnitude of the noise emanating from a pile during piling is a function of the piling method (i.e. impact hammer or vibration), the pile material type (i.e. steel or concrete), the force applied to the pile (usually described by the hammer energy or hammer size), the pile size, and to lesser extent the characteristics of the substrate into which it is being driven. Selection of representative emission data for use in the model of the planned piling for the project is informed by these factors.

2.3 Pile Driving Assumptions

A piled foundation concept using main piles represents the current development concept for the Crux platform footings, in which four peripheral jacket legs will feature three rigid pile sleeves, through which a main pile is installed and secured to the sleeve. Hence, the estimated total number of piles is between 12 and 16.

2.3.1 Pile Diameter

The estimated primary pile length will be between 160m – 185m, with the insert pile being up to 260m in length. The current base case main pile configuration is 16 2.83m diameter main piles, driven to a penetration of 180m.

[7] Note: Depending on the resistivity of the soil, some of the energy will be reflected back up the length of the pile.

2.3.2 Hammer Energy

Two different hydraulic hammer types, have been modelled as separate scenarios:

- MHU-600 Hammer, 660kJ Energy, 95% efficiency; and
- MHU-2100 Hammer, 2,134kJ Energy, 95% efficiency.

2.3.3 Number of Strikes

Given the early stage of engineering definition at this OPP stage of assessment, the precise number of strikes is not feasibly known. As a conservative measure, in order to progress the assessment, estimates have been based on piling data from the Prelude FLNG project. The estimated number of strikes to full penetration that were used in the underwater noise study for the Prelude mooring piles were 6,530 for the main pile.

A detailed pile driveability analysis for Crux will not be carried out until FEED. Initial indication is that at least 100m of the total driven depth would require 'less' to 'significantly less' energy to progress than was the case for Prelude. The piles assumed in the Prelude study were significantly larger in diameter (5.5m), so assuming this number of strikes to full penetration for the Crux NNM Platform is a conservative measure.

The insert piles will be drilled and grouted.

The piles will be installed consecutively, such that only one pile will be installed per day. Therefore, the estimated maximum number of strikes per 24-hour period is 6,530 for the main pile.

2.3.4 Piling Location

The piling location used as the basis of the noise assessment is summarised in Table 2-1.

Table 2-1 Summary of Piling noise source location

Piling Location	Value
Crux Platform Location	656470 mE, 8566340 mN
Height Above Seabed	15m
Water Depth at source	168.5m

2.3.5 Estimation of Piling Source Noise Level and Spectrum

Case studies involving coastal piling or much larger offshore wind turbine piles are not considered representative of the proposed activities planned for the Crux Project.

It is theoretically reasonable that the source level for a particular hammer energy can be scaled using the relationship 10log(E2/E1). An examination of the body of published piling source values suggests that the relationship may not hold for long extrapolations, and engineering judgement suggests this scaling factor should only be applied for E2/E1 ratios that are near to 1.

MHU-2100 Hammer

CO.L.MAR [1] reported noise levels measured during the pile driving for the installation of a platform jacket in the Encana Buzzard field. The project used sub-surface piling, with 3,000 kJ hydraulic hammer with a maximum applied efficiency of 85%, in 139m of water. This compares favourably with the project conditions when compared to other potential data sources. The report provides measured peak pressure and spectrum for the piling measured at far field distances (815m), and also states the derived attenuation from source to received location based on the observed conditions. The report also states the measured RMS pressure, and pulse length. Using this information, and scaling with respect to hammer energy, SVT derived an $L_{E,p}$ for the project piling using the 2,027 kJ Hammer, based on maximum energy at refusal.

- 2,027 kJ Hammer: 220 dB re 1μPa2.s @ 1 m

MHU-600 Hammer

More data is available for hammers of this size and they can be used to drive relatively large piles in nearshore conditions. De Jong [2] provides a calculated source level for a 700kJ hammer pile driving activity, and this has been adopted as representative for the 660kJ hammer (with 95% efficiency) used in this project (scaling with respect to energy results in an insignificant adjustment).

- 632 kJ Hammer: 214 dB re 1μPa^2.s @ 1 m

The piling source spectrum was extracted from SVT's database of measured pile driving and scaled to match the overall expected source level. Figure 2-2 shows the piling pulse $L_{E,p}$ source spectra used in the underwater noise model.

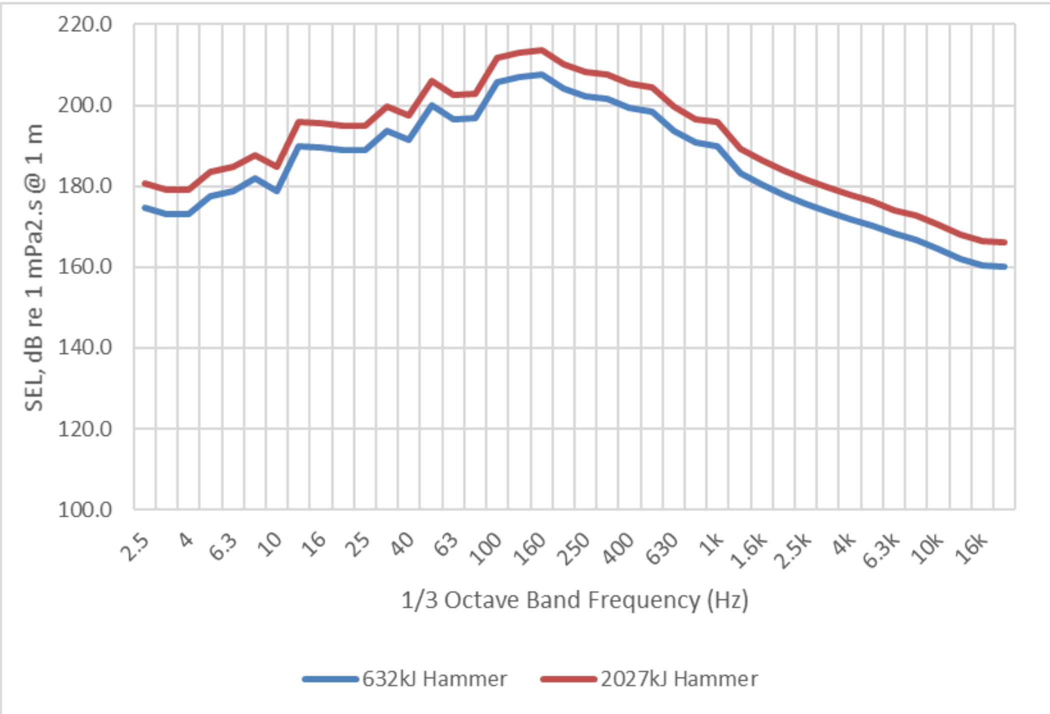


Figure 2-2 Hammer $L_{E,p}$ Source Level Spectra

2.3.6 Peak Pressure

SVT conducted an analysis of measured piling data collected during a the Ichthys project piling activities in Darwin Harbour, where both L_p and Peak noise levels were determined for each hammer strike. The data, which was collected at multiple distances and bearings from piling activity, demonstrated a crest factor (CF) of between 15 dB and 20 dB for piling sources. Based on this data, and as a conservative assessment measure, a CF of 20 dB has been applied for the model. This CF is consistent with the data reported by CO.L.MAR discussed above.

Predicted peak pressure noise levels were calculated from the calculated sound pressure level (L_p) with range using the CF. The relationship is:

$L_{pk} = L_p + CF.$

2.3.7 Summary of Piling Source Inputs and Assumptions

The following tables summarise the key information regarding the piling sources presented in the above sections.

Table 2-2 Hammer Specifications Used in the Underwater Noise Model

Hammer Specifications	
Hammer energy	632 kJ and 2,027 kJ
Modelled number of strikes	6,530
Estimated number of strikes per day	6,530

Table 2-3 Piling scenarios used in the Underwater Noise Model

Scenario		Hammer Energy (kJ)	Source Noise Level ($L_{E,p}$ dB re 1uPa^2.s at 1m) / strike	Number of Strikes (per 24 hours)	Source Level Offset (dB)
1	Main Pile, Small Hammer	632	214	6,530	$L_{E,p}$: 38.1 L_p: 4 L_{pk}: 20
2	Main Pile, Large Hammer	2,027	220	6,530	$L_{E,p}$: 38.1 L_p: 4 L_{pk}: 20

2.4 Underwater Noise Generated by Development Drilling

2.4.1 Drilling Activity Source Levels

Offshore drilling in waters of the project depth is typically conducted by semi-submersible drilling rigs, however other drilling platforms are available. The current project concept is for the initial Crux production wells proposed to be drilled with a semi-submersible drilling rig and later completed from the Crux platform using a temporary modular platform rig (MPR). Noise is emitted by the drill string and by the vessel hull.

McCauley [3] presented measured data for the semi-submersible drill rig Ocean General under changing operational scenarios. Extrapolation of the measured data suggests a source level for the drill rig (not drilling) of 160 dB re 1uPa at 1m. McCauley also observed a 4 dB increase in noise levels when drilling was underway. SVT has applied a 3dB safety factor (double the energy) to these levels to account for uncertainties potential differences between rigs, yielding a source level for a semi-submersible drill rig, during drilling activity, of 167 dB re 1uPa at 1m.

As drilling is a continual activity, and does not involve significant percussive elements, the peak pressure is not relevant to the assessment of noise impact. Additionally, there should be no difference between the average L_p and the $L_{E,p}$ over short periods. For drilling that occurs for 24 hours, the $L_{E,p}$ will exceed the L_p by 49.4 dB.

The drilling source levels and spectra is shown in Figure 2-3.

As part of an operational scenario, the DP of a supply boat/tender at the Crux Platform location has been modelled to conservatively represent operational noise from the facility. The drill rig has been modelled at the platform location and conservatively represents noise levels from the MPR.

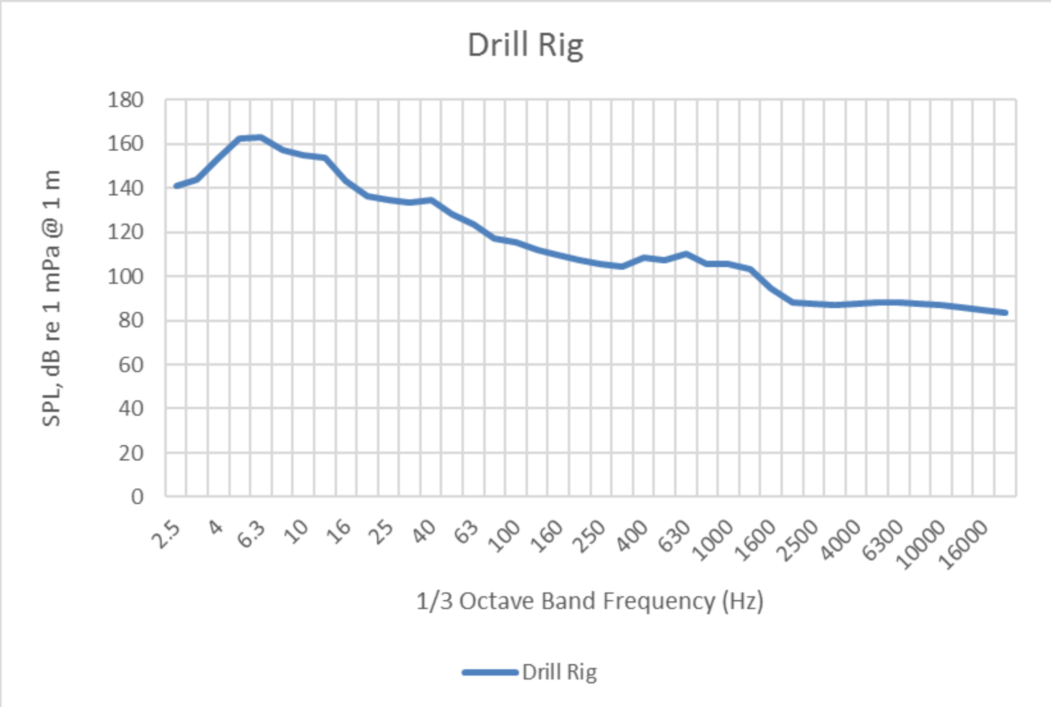


Figure 2-3 Drilling Source Spectra Used in the Underwater Noise Model

2.4.2 Summary of Drilling Source Inputs and Assumptions

Table 2-3 summarises the three drilling scenarios used in the model. This included a conservative assessment of potential drilling activity in proximity to two of the shoals that occur within the 30km radius that defines the Crux development area, outside the 1km buffer defined around these shoal features. While not part of the foundation development, the potential future tie-backs over the life of the Crux Project may define the need for future drilling activity in proximity to these shoals, and therefore have been conservatively incorporated as scenarios in this study to represent a credible worst-case location for the sound source to occur.

Table 2-4 Drilling Scenarios Used in the Underwater Noise Model

Scenario		Source location (UTM Zone 51)	Source Depth Below Surface (m)	Water Depth at Source (m)	Source Noise Level (L_p dB re 1uPa at 1m)
3	Drill Rig – in proximity to Eugene McDermott Shoal (outside 1km buffer)	674572 mE 8551496 mN	15	152	167
4	Drill Rig in proximity to Vulcan Shoal (outside 1km buffer)	635505 mE 8585910 mN	15	192	167
5	Drill Rig at Crux Platform Location	656470 mE 8566340 mN	15	168.5	167

Note: Noise emitted by temporary drilling equipment located on the Crux Platform is expected to be significantly less than that emitted by a semi-submersible rig. The use of the same source levels for this scenario also encompasses the possibility of float-over drilling rig equipment to be used.

2.4.3 Underwater Noise Generated by Vertical Seismic Profiling

VSP may be conducted during drilling activities. This involves the use of a hydrophone or geophone downhole, and the use of an airgun sound source in the water column. For downhole VSP, only one airgun is required, and therefore source levels are significantly lower than typically published for seismic survey campaigns that use arrays of airguns.

Source levels for airguns are dependent upon two critical factors: Charge pressure and charge volume, the source level being linearly proportional to charge pressure [5]. Taylor et al. [6] describe the VSP methodology used in the Offshore Drilling Program indicating an airgun volume of 300 in^3. Fewtrell et al. [7] used a single airgun with a volume of 330 in^3 and charge pressure of 1,500 psi, and stated that the source level was 192 dB re $1uPa^2s$. Typical charge pressures for airguns in the offshore industry are 2,000 psi. When scaled according to charge pressure, and rounded up to the nearest 0.5 dB the source strength for the VSP airgun is estimated at 193.5 dB re $1uPa^2s$.

Published spectra for airgun sources typically show several discrete frequencies where the source level is much lower than the adjacent frequencies – these frequencies are particular to the airgun, operating depth and observation angle, and is also influenced by the airgun array configuration. In conducting a noise prediction, based on unknown equipment, where the equipment operator has not provided specific information, a precautionary approach was taken. For this reason, a published spectrum [8] (for a single airgun) that shows a smoother frequency transition has been adopted as the source shape, and the spectrum has been shifted to match the overall source energy described above. The resulting spectrum is shown in Figure 2-4.

2.4.4 Summary of VSP Source Inputs and Assumptions

The single VSP source has been assumed to use up to 10 shots per event, with no more than one event in a day. The details of the downhole VSP source are provided in Table 2-5, and the modelled spectrum is provided in Figure 2-4.

Table 2-5 VSP Details used in the Underwater Noise Model

Item	Detail
Source Location (UTM Zone 51L)	656470 E, 8566340 N
Source Depth Below Surface (m)	15
Water Depth at Source (m)	168.5
Source Noise Level ($L_{E,p}$ dB re 1uPa^2.s at 1m)	193.5
Source Level Offset (dB)	L_{pk}: 20 L_p: 7 $L_{E,p}$: 10

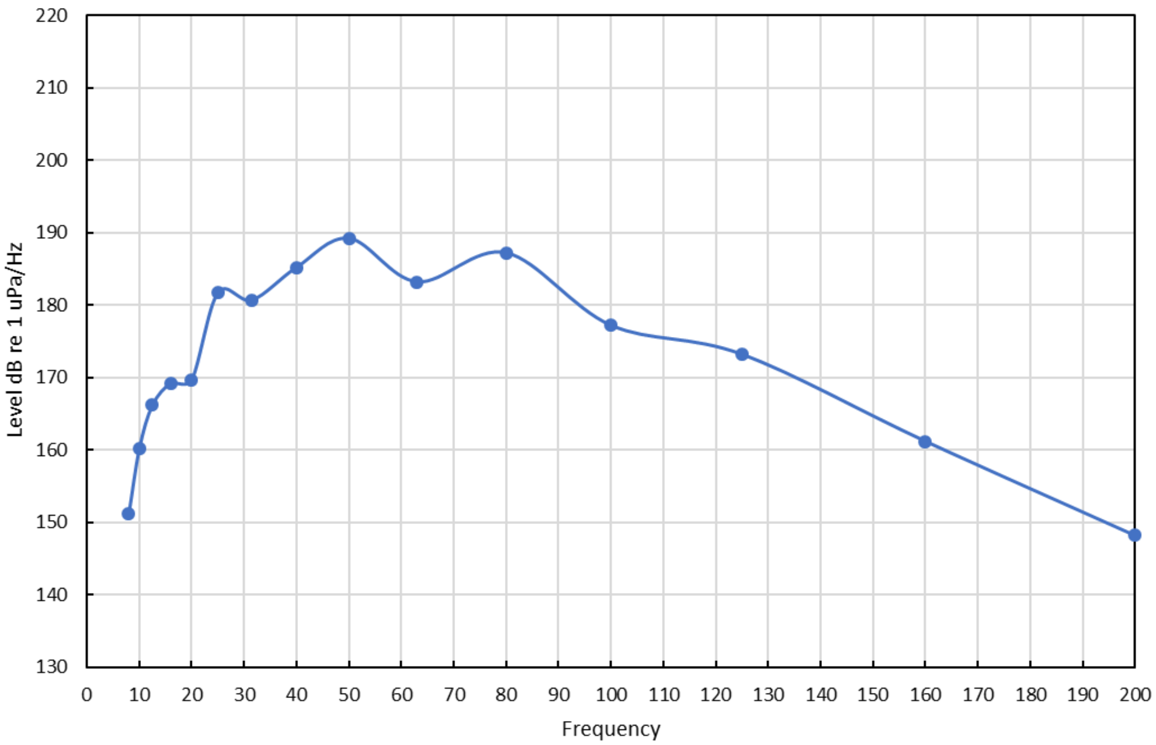


Figure 2-4 VSP Source Spectrum Used in the Underwater Noise Model

2.4.5 Other Noise Sources During Drilling

Other sources of noise are also present during pipelay and drilling activity – for example: underwater remote equipment uses sound for communication; sonar is used for depth finding; and, side-scan sonar is used for imaging equipment and the seafloor. This equipment operates at high frequencies (in the range 20 kHz to 90 kHz) and the attenuation rate will be significantly higher than the attenuation rate for the sources assessed. These sources are not expected to generate noise levels that will lead to an exceedance of the assessment criteria, and therefore do not feature as a key focus of this noise study.

2.5 Operational Noise

Noise emitted by the normal operation of the Platform is expected to be significantly less than from the drilling and construction activities. The coupling surface between the steel supports of the jacketed platform structure and the water is significantly less than that of the drill rig. As a NNM facility, normally operating mechanical equipment on the Crux platform is also expected to be minimal. The facility will occasionally require scheduled maintenance intervention, and during these times it is reasonable to expect the presence of a supply boat or tender. When operating close to facilities supply boats often maintain their position through dynamic positioning (DP), using bow and stern thrusters. Cavitation from the thruster propellers while in DP mode can be a significant source of underwater noise, the source will cycle on-off, and is not present for a majority of the time. McCauley [3] presented measured data for two tenders, which when extrapolated to 1m suggest source levels of 171 dB re1uPa at 1m and 183 dB re1uPa at 1m. The tender noise has been modelled at the higher of these two values. The octave band spectral contribution of the tender is as provided in Figure 2-5.

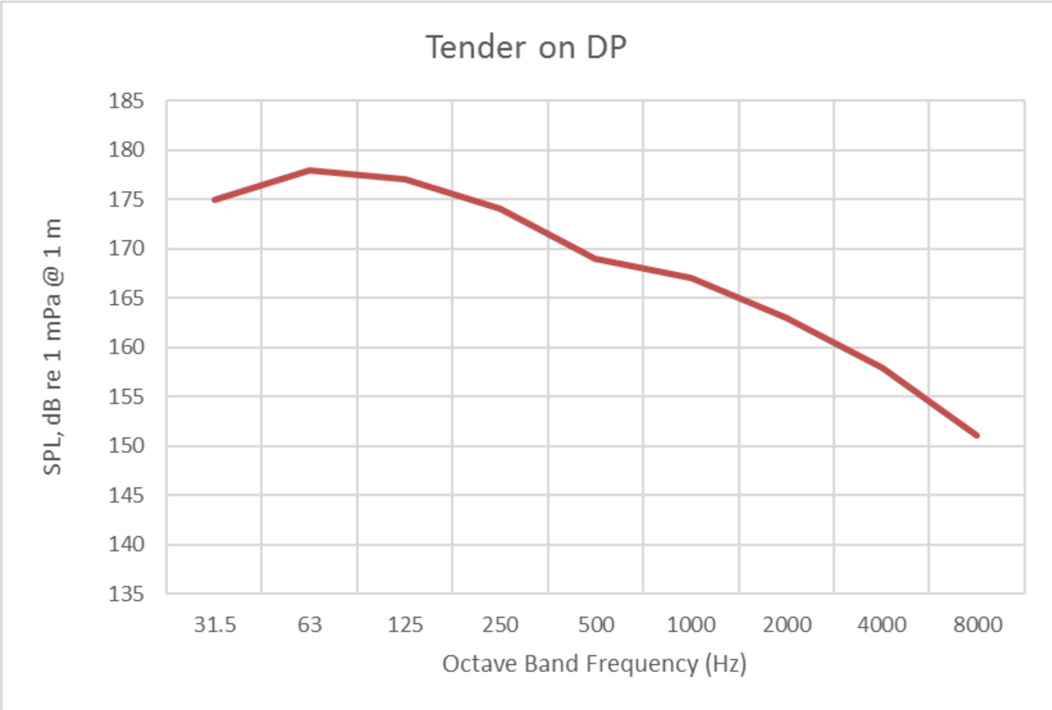


Figure 2-5 Modelled Spectrum of Supply boat / Tender on DP

2.6 Environmental Inputs

2.6.1 Important Environmental Factors

The propagation of noise through the water is dependent upon a number of environmental factors. The depth of the water limits the lowest frequency of noise that can propagate, the deeper the water the lower the cut-off frequency. Because of this, propagated noise levels may be higher in deeper water for the same source. This factor is important when conducting underwater noise assessments in shallow water, near shore, or, estuarine locations.

Temperature and salinity changes also affect the propagation of noise in water, causing refraction changes which may result in channelling of noise in the water column and also affect the reflection from the seabed. It is noted that due to the shallow depths, the Sound Speed Profile (SSP) behaves closely to pure isothermal conditions.

The type of seabed affects the fraction of noise that is reflected and transmitted at the water / sea bed boundary. This is dependent upon the impedance miss-match between the water and the seabed, and the acoustic impedance is primarily characterised by the speed of sound in the seabed. The ability of the sea bed to support compression and shear waves also influences the propagation of noise, and the transmission of noise from the sea bed into the water column.

This data, typically drawn from published research that lists sound speed and attenuation rates for various ground types, is input into the model as an attenuation rate for compression and shear wave types.

2.6.2 Model Environmental Data

The following environmental conditions were entered into the model:

Depth

The bathymetry of the project region and surrounds has been provided by Shell in the form of constant elevation lines, with depth increments of 10m. These depths ranged from 20m to 230m, with an average resolution (point to point distance) of 165m.

Tide Levels

Based on 12 months of concatenated tidal measurements recorded at the Crux location as part of the Crux baseline studies program, 18.6 years of tide heights are predicted. Analysis of these predictions indicates a Highest Astronomical Tide (HAT) of 2.81m. Therefore, a tide of 2.81m was modelled as representative of high tide conditions which are worst case for underwater noise propagation.

Seabed Types

The data from the baseline geotechnical survey undertaken as part of the Crux baseline studies program, was used to inform the derivation of seabed type, which influences the sound speed, density and attenuation rate for the seabed. The data [9] demonstrates that the seabed in the Crux development area is predominantly silt and fine sand. The geo-acoustic properties of the ground type used in the model are shown in Table 2-6[8], where sand was used to represent the ground type.

The reduced speed of sound for the bottom results in increased absorption of sound in the model, reducing the range at which adverse effects can be predicted.

[8] Note: the model uses the geo-acoustic properties to determine the attenuation and reflectivity of the waves as they travel through the seabed.

Table 2-6 Seabed Geo-Acoustic Properties

Seabed Type	Sound Speed	Density	Sound Attenuation
Sand [14]	1,650 m/s	1.9 g/cm^3	0.8 dB/m/kHz (Compressional) 2.5 dB/m/kHz (Shear)

Sound Speed Profile

The water depth in the modelling area is relatively shallow with no significant temperature gradients. Additionally, the salinity is expected to be relatively homogenous throughout the water column. The average monthly underwater sound speed profile (SSP) has been calculated based upon the monthly temperature and density data measured within the Crux development area, as presented in Figure 2-6.

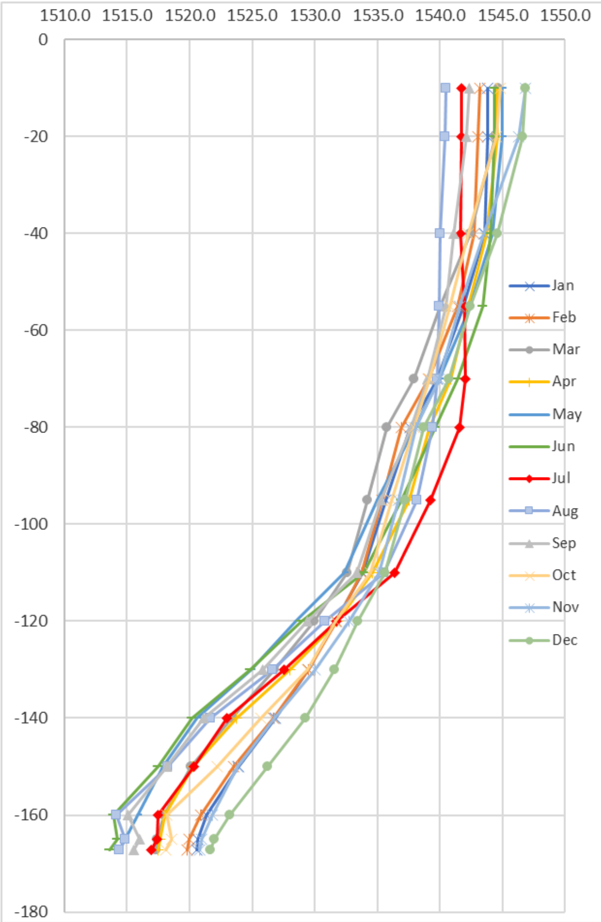


Figure 2-6 Monthly Average Sound Speed Profiles (July in Red)

Preliminary modelling was conducted to identify the conditions that could be considered representative worst-case. Analysis of modelled propagation loss for each monthly average SSP shows that at shallower water depths above 100m, the month of July can be considered the worst-case for sound propagation. The mean sound speed profile for the month of July has therefore been adopted in the model for all scenarios to provide for a conservative assessment.

Figure 2-7 shows a vertical transect of the sound propagation for the large (2,027 kJ) hammer, using the July mean SSP, with the source at the Crux NNM Platform and propagation due south (i.e. transect shown looking east). Based on this (and an examination of transects in other directions) an analysis depth of 50m has been chosen as representative of the worst-case.

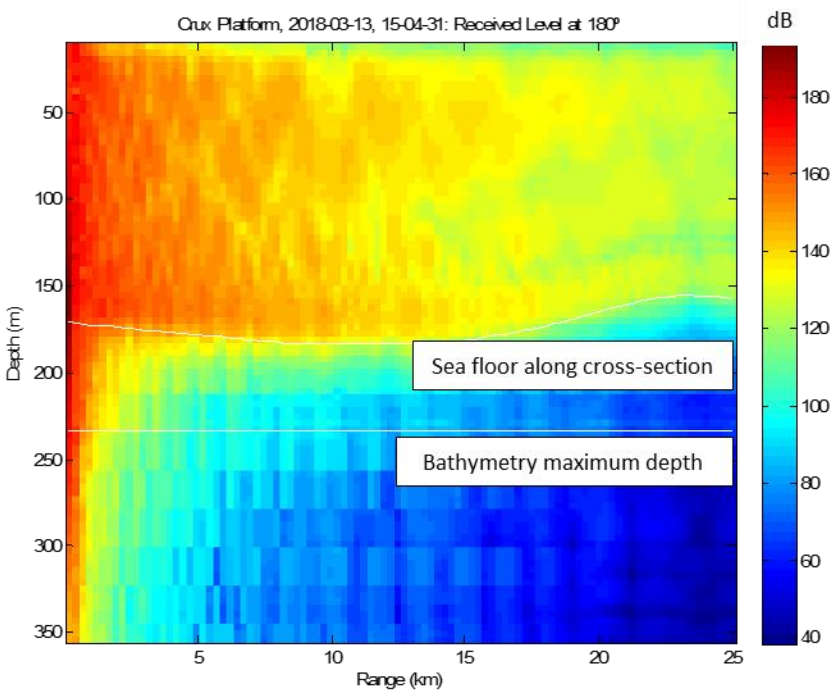


Figure 2-7 Vertical cross-section of Large Hammer Propagation, Travelling South

Model Resolution

For each noise source, additional parameters were used to generate the model results as summarised in Table 2-7.

Table 2-7 Model resolution

Noise Source	Maximum Range (km)	Angle Resolution (degrees)	Frequencies Modelled (Hz)
Piling	40	2	1/3 Octaves, 20 Hz to 4 kHz
Drilling	25	2	1/1 Octaves, 31.5 Hz to 4 kHz
VSP	25	2	1/1 Octaves, 31.5 Hz to 4 kHz

3. MARINE FAUNA ASSESSMENT CRITERIA

For the purpose of this noise assessment, the primary sensitive marine fauna that may occur, or have suitable habitat, in the Crux development area include:

- Marine Mammals;
- Marine Turtles;
- Sea Snakes;
- Fish;
- Elasmobranchs (sharks and rays); and
- Invertebrates.

The following sensitive marine fauna habitats are identified to occur in the vicinity of the Crux development area:

- Whale shark foraging area – a biologically important foraging area is recognised in open waters off the Northern WA coast, inclusive of the marine environment that overlaps the Crux development area. Due to their widespread distribution and highly migratory nature, whale sharks may occur in low numbers within the Crux development area;
- Marine turtle offshore biologically important foraging areas[9] - for flatback, green, loggerhead and olive ridley turtles (ranging from approximately 160km to 200km from the Crux NNM platform);
- Habitat critical to the survival of green turtles (nesting area) – Ashmore Reef (140km from the Crux NNM platform), Cartier Island (85km from the Crux NNM platform), and Browse Island (140km from the Crux NNM platform)[9];
- Pygmy blue whale migration corridor (approximately 121km from the Crux NNM platform at its nearest point);
- Humpback whale breeding and calving area (approximately 180km from the Crux NNM platform at its nearest point);
- Australian snubfin dolphin foraging and breeding areas (approximately 164km from the Crux NNM platform at its nearest point); and
- Indo-pacific humpback dolphin foraging areas (approximately 164km from the Crux NNM platform at its nearest point).

It should be noted that the list of relevant species has been informed by a search of the *Environment Protection and Biodiversity Conservation Act 1999* Protected Matters database and has been used as a guide only. This list is not considered exhaustive. Consideration has been given to the potential for high frequency cetacean species (pygmy sperm whale and dwarf sperm whale) to occur in the project area. A review of species distribution information was conducted and found that their distribution is

[9] Biologically important

typically in oceanic waters beyond the edge of the continental shelf. While they may occur in the broad marine environment, their occurrence in the project area in significant numbers is not expected.

Table 3-1 and Figure 3-1 summarises the significant geographical areas of interest in or near the Crux development area.

Table 3-1 Geographical Areas of Interest

Geographical Area	
Shoals	Vulcan Shoal Eugene McDermott Shoal Barracouta Shoal Heywood Shoal Echuca Shoal Goeree Shoal
Offshore reefs	Ashmore Reef Hibernia Reef
Islands	Cartier Island
Marine Parks	Kimberley Ashmore Reef Cartier Island

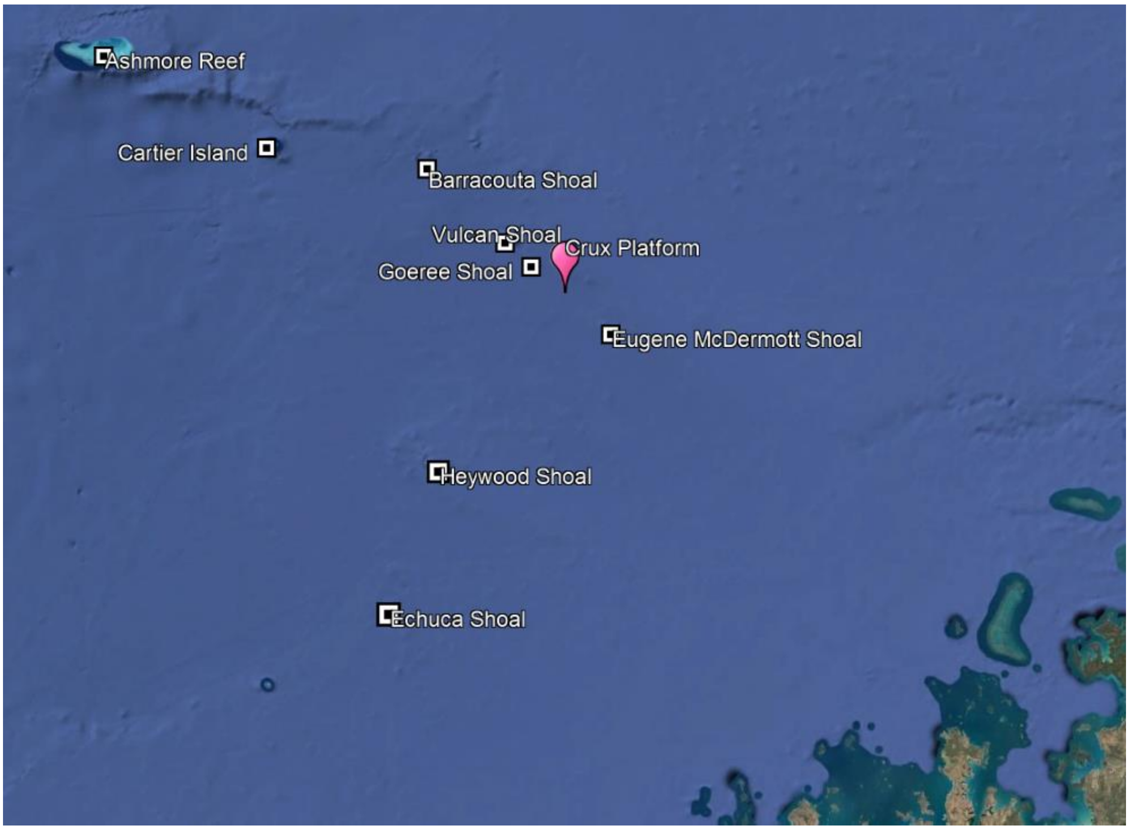


Figure 3-1 Geographical Areas of Interest Surrounding the Crux Development Area

3.1 Fish and Sea Turtles

Criteria for fish, larvae and sea turtles are defined in terms of L_p, $L_{E,p}$ and L_{pk} noise levels. The fish criteria are separated between fish with or without swim bladders, as the gas filled space increases the fish vulnerability to the changes in sound pressure. Fish eggs and larvae have been separated due to their vulnerability, reduced mobility and small size.

The physiology of turtle hatchling is different from fish. However, the air-filled cavities such as lungs of turtle hatchlings and swim bladders of fish have been found to be most susceptible to physical injury from impulsive waves such as a pile driving signal. Therefore, it is reasonable to correlate physical injury criteria for turtle hatchlings with that for fish. Due to the lack of scientific data availability, turtle hatchlings will be evaluated using both $L_{E,p}$ and L_{pk} for fish.

The criteria presented are in terms of sound pressure. Fish may also have a lateral line system which detect relative motion (displacement) between the body and the surrounding water. Popper et al*.* 2014 [10] states that "*relative motion only takes place very close to sound sources where there is a steep gradient of sound pressure and particle motion (Denton and Gray 1982, 1993; Kalmijn 1988). As a consequence, the operational range of the lateral line is usually restricted to no more than one or two body lengths away from the source." The guideline goes on to state "There have been no demonstrations to date of damage to lateral line systems as a result of exposure to intense man-made sounds or other signals (Hastings et al. 1996), although it is conceivable that damage may occur."* Hence as there is no evidence of impact at distance, and only very remote potential for such animals to be within a range where potential detection may occur (several body lengths), no criteria in terms of particle displacement have been presented.

3.1.1 Fish and Sea Turtles – Pile Driving Noise

Criteria for piling noise have been drawn from the Sound Exposure Guidelines for Fishes and Sea Turtles (Popper et al*.* 2014) [10]. The criteria are presented in Table 3-2 below.

Table 3-2 Fish, Larvae and Sea Turtle Noise Criteria for Pile Driving

Type of Animal	Mortality and Potential Mortal Injury	Impairment			Behaviour
		Recoverable Injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	> 219 dB $L_{E,p}$ or > 213 dB L_{pk}	> 216 dB $L_{E,p}$ or > 213 dB L_{pk}	> 186 dB $L_{E,p}$	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder is not involved in hearing (particle motion detection)	210 dB $L_{E,p}$ or > 207 dB L_{pk}	203 dB $L_{E,p}$ or > 207 dB L_{pk}	> 186 dB $L_{E,p}$	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB $L_{E,p}$ or > 207 dB L_{pk}	203 dB $L_{E,p}$ or > 207 dB L_{pk}	186 dB $L_{E,p}$	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate

Type of Animal	Mortality and Potential Mortal Injury	Impairment			Behaviour
		Recoverable Injury	TTS	Masking	
Eggs and larvae	210 dB $L_{E,p}$ or > 207 dB L_{pk}	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low
Sea turtles	>210 dB $L_{E,p}$ or >207 dB L_{pk}	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) High (I) Moderate (F) Low
Note: Where insufficient data existed to recommend objective guidelines, a subjective approach is adopted in which the relative risk (High, Moderate, Low) of an effect is placed in order of rank at three distances from the source – Near (N), Intermediate (I), and Far (F) (top to bottom within each cell of the table, respectively). "Near" might be considered to be in the tens of metres from the source, "intermediate" in the hundreds of metres, and "far" in the thousands of meters.					

Source: Popper et al. 2014 [10]

3.1.2 Fish, Larvae and Sea Turtles – VSP

The Sound Exposure Guidelines for Fishes and Sea Turtles [10] also provide criteria for exposure to seismic airguns. The criteria are presented in Table 3-3 below, and conservatively assumed to be applied for this assessment, although noting that downhole VSP generates a significantly smaller noise profile than wide array seismic activities.

Two trials [11] conducted on the response of a green and loggerhead turtle to impulsive signals (air-gun) showed that at L_p of 175 dB re 1 µPa the turtle behaviour became more erratic, which was presumed to be an avoidance response. A L_p of 175 dB re 1 µPa is equivalent to a $L_{E,p}$ of 164 dB re 1µPa^2.s, where it is assumed that a pulse length of 90ms was used during the experiment.

Table 3-3 Fish, Larvae and Sea Turtle Noise Criteria for VSP

Type of Animal	Mortality and Potential Mortal Injury	Impairment			Behaviour
		Recoverable Injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	> 219 dB $L_{E,p}$ or > 213 dB L_{pk}	> 216 dB $L_{E,p}$ or > 213 dB L_{pk}	> 186 dB $L_{E,p}$	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder is not involved in hearing (particle motion detection)	210 dB $L_{E,p}$ or > 207 dB L_{pk}	203 dB $L_{E,p}$ or > 207 dB L_{pk}	> 186 dB $L_{E,p}$	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB $L_{E,p}$ or > 207 dB L_{pk}	203 dB $L_{E,p}$ or > 207 dB L_{pk}	186 dB $L_{E,p}$	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate
Eggs and larvae	210 dB $L_{E,p}$ or > 207 dB L_{pk}	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low

Type of Animal	Mortality and Potential Mortal Injury	Impairment			Behaviour
		Recoverable Injury	TTS	Masking	
Sea turtles	>210 dB $L_{E,p}$ or >207 dB L_{pk}	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Low (I) Low (F) Low	175 dB L_p 164 dB $L_{E,p}$ [11]
Note: Where insufficient data existed to recommend objective guidelines, a subjective approach is adopted in which the relative risk (High, Moderate, Low) of an effect is placed in order of rank at three distances from the source – Near (N), Intermediate (I), and Far (F) (top to bottom within each cell of the table, respectively). "Near" might be considered to be in the tens of metres from the source, "intermediate" in the hundreds of metres, and "far" in the thousands of metres.					

Source: Popper et al. 2014 [10]

3.1.3 Fish, Larvae and Sea Turtles – Continuous Noise Sources

The Sound Exposure Guidelines for Fishes and Sea Turtles [10] also provide criteria for exposure to shipping and other continuous sources (e.g. drilling). The criteria are presented in Table 3-4 below.

Table 3-4 Fish, Larvae and Sea Turtle Noise Criteria for Shipping and Continuous Sounds

Type of Animal	Mortality and Potential Mortal Injury	Impairment			Behaviour
		Recoverable Injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder is not involved in hearing (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	(N) Low (I) Low (F) Low	170 dB L_p for 48 h	158 dB L_p for 12 h	(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) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low
Sea turtles	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low
Note: Where insufficient data existed to recommend objective guidelines, a subjective approach is adopted in which the relative risk (High, Moderate, Low) of an effect is placed in order of rank at three distances from the source – Near (N), Intermediate (I), and Far (F) (top to bottom within each cell of the table, respectively). "Near" might be considered to be in the tens of metres from the source, "intermediate" in the hundreds of metres, and "far" in the thousands of metres.					

Source: Popper et al. 2014 [10]

The criteria for turtles, fish eggs and larvae, and the values in the table were derived from studies on fish.

3.2 Mammals

3.2.1 Criteria for Marine Mammals

Recent publications cited by NOPSEMA [12] have been considered in selection of marine mammal noise assessment criteria. Finneran [13] suggests that temporary and permanent threshold shifts for marine mammals should include independent criteria for both $L_{E,p}$ and L_{pk} levels. When considering behavioural disturbance thresholds for marine mammals, literature [14] generally specifies criteria in the form of $L_{E,p}$ and/or L_p. Technical guidance [15] highlights that the sensitivity of hearing differs between cetacean species, which should be considered when determining assessment criteria.

Assessment criteria for marine mammals has been drawn from the National Oceanic and Atmospheric Administration (NOAA), Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing [17]. The criteria are presented for impulsive sources (e.g. pile driving) and non-impulsive sources (e.g. drilling and vessel noise). Cumulative energy exposure criteria include the use of a weighting function, to account for the different hearing frequency ranges for marine mammals.

In the NOAA guidelines [17], cetaceans (mammals) are divided into three groups based on their hearing dominant auditory function – Low-frequency weighted cetacean (Mlf); Mid-frequency weighted cetacean (Mmf) and High-frequency weighted cetacean (Mhf). For this study Mlf and Mmf criteria and weightings are of particular relevance, based on the key marine mammal species known to occur in the marine environment in the vicinity of the Crux development area. The relevant species and respective hearing group are summarised in Table 3-5 below.

Table 3-5 Cetacean Frequency Weightings

Mammal Hearing Group	Relevant Species
Low-frequency weighted cetacean (Mlf)	Pygmy Blue Whale Humpback Whale
Mid-frequency weighted cetacean (Mmf)	Australian Snubfin Dolphin Indo-Pacific Humpback Dolphin

A chart of the frequency weightings is shown in Appendix B-5.

NOAA, in their Interim Sound Threshold Guidance for Marine Mammals [18], presented proposed behavioural response criteria for marine mammals, which were subsequently omitted in response to comments from peer reviewers from the final document when published in 2016. However, in the intervening period these suggested limits were re-published in the South Australian Underwater Piling Noise Guidelines [19]. The values can also still be found on NOAA's website.

The criteria adopted for Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) of hearing sensitivity in the South Australian Guidelines are less conservative than that of the NOAA Guidance, therefore they have not been considered in this study.

The NOAA guidelines provide $L_{E,p}$ and L_{pk} noise levels at which TTS and PTS may occur (at a more conservative level than South Australian guidelines) for low, mid and high frequency cetaceans. These are summarised in Table 3-6.

Table 3-6 Mammal Sound Exposure Criteria

Type of Animal	PTS - Permanent Injury [17]		TTS - Impairment [17]		Behaviour [18],[19]	
	Impulsive	Non-Impulsive	Impulsive	Non-Impulsive	Impulsive	Non-Impulsive
Low-frequency cetaceans	219 dB L_{pk} 183 dB $L_{E,p}$	199 dB $L_{E,p}$	213 dB L_{pk} 168 dB $L_{E,p}$	179 dB $L_{E,p}$	160 dB L_p	120 dB L_p
Mid-frequency cetaceans	230 dB L_{pk} 185 dB $L_{E,p}$	198 dB $L_{E,p}$	224 dB L_{pk} 170 dB $L_{E,p}$	178 dB $L_{E,p}$	160 dB L_p	120 dB L_p
High-frequency cetaceans	202 dB L_{pk} 155 dB $L_{E,p}$	173 dB $L_{E,p}$	196 dB L_{pk} 140 dB $L_{E,p}$	153 dB $L_{E,p}$	160 dB L_p	120 dB L_p

The South Australian guideline for underwater piling recommends management measures with defined observation and shutdown zones, based on the predicted $L_{E,p}$ (1 strike) at distances of either 100m or 300m. The basis for the distances is the estimation that a received single strike $L_{E,p}$ of 150 dB re 1 µPa^2.s will cumulate to the TTS limit of 183 dB (Mmf) re 1 µPa^2.s over a period of 30 minutes. The guideline is summarised in Table 3-7 for cetaceans. The modelling for this project (as shall be demonstrated later) demonstrates a L_p (which is similar to single strike $L_{E,p}$) greater than 150 dB at 300m and, therefore, the criteria in the third line of the table (shown in bold) is applicable.

Table 3-7 Summary of Safety Zones for Impact Piling

Species	Noise Exposure Threshold SEL in dB(M) re 1 µ Pa2.s	Observation Zone	Shut Down Zone	Zone of Behavioural Response
Low/Mid/High-frequency cetaceans	≤150 dB (M_{mf} / Ml_f/ Mh_f) at 100m	1 km	100 m	≤ 150 m
	≤150 dB (M_{mf} / Ml_f/ Mh_f) at 300m	1.5 km	300 m	≤ 500 m
	>150 dB (M_{mf} / Ml_f/ Mh_f) **at 300m**	**2 km**	**1 km**	**≤ 3 km**

3.3 Other Marine Fauna

3.3.1 Elasmobranchs (Sharks and Rays)

Fish species that lack a gas filled cavity, including elasmobranchs, are less vulnerable to changes in sound pressure. Therefore, whale sharks that reside (and other shark/ray species that may occur) in the surrounding area can be considered as fish without a swim bladder and can be assessed as per the criteria outlined earlier in Section 3.1.

3.3.2 Sea Snakes

SVT is not aware of any published studies or guidelines on the potential for anthropogenic noise to cause injury or disturbance to sea snakes. General information on snakes suggests that their hearing is poor and that therefore the sense of vibration the skull and associated inner ear is the more significant vector. Therefore, use of the criteria presented for fish (with no swim bladder) as per Section 3.1 is expected to be a conservative approach.

3.3.3 Invertebrates

Chan et al. [23] has shown that exposure to increased anthropogenic noise can mask the approach of predators, making invertebrate fauna such as crabs more vulnerable to predation. Wale et al. [24] showed that signs of increased oxygen consumption in crabs with exposure to anthropogenic noise indicating increased metabolic rate, and postulated that if greater energy expenditure is not matched by an increased uptake of food, decreased growth and survival may result. The same study, however, suggests the potential for habituation to the noise. In each study the noise source used was representative of general shipping, and not impulsive noise such as that generated by pile driving or seismic surveys. Several studies [25] suggest that crabs and other crustacea may use underwater sound to orient to the shore where they can settle. Stanley et al. [26] found that ambient underwater sound is likely to be an important settlement cue for the megalopae of many crab species. This may suggest that levels of continuous anthropogenic noise of sufficient magnitude to mask the 'natural' background underwater sound may result in reduction of adult crustacea recruitment into fisheries.

Day et al. [27] studied the effect of seismic noise on scallops and lobsters, finding that lobsters and scallops showed no mortality from exposure. In lobsters a reflexive response was shown and the ability to right was shown to be compromised, which was statistically correlated with damage to the statocyst sensory hairs. Additionally, the study noted that lobsters sourced from a site subject to high levels of anthropogenic aquatic noise showed substantial damage to the statocyst prior to the experiment. For scallops the study showed physiological effects described as substantial disruptions in the biochemistry of the haemolymph, and behavioural changes such as a reduction of classic behaviours and a novel velar flinch during exposure. The study used an airgun source with cumulative $L_{E,p}$'s between 190 and 200 dB re 1 μPa2·s.

Richardson et al. [29], in response to McCauley et al. [30] found substantial impacts of seismic activity on zooplankton populations within the Northwest Shelf Bioregion, with a decline in population reaching up to 22%, limited to the area of the seismic activity and within 15km; these impacts were barely discernible within 150 km of the survey area, were not discernible at the largest scale of the Northwest Shelf Bioregion. Zooplankton populations recovered quickly after seismic exposure due to their fast growth rates and the dispersal and mixing of zooplankton from both inside and outside of the area. It is noted that this is in the context of wide array seismic survey activity, which is a significantly different context to the localised downhole VSP activities which are the subject of this assessment.

No studies however have progressed to providing suggested quantitative noise exposure limitations for invertebrates. There is currently insufficient basis for the setting of interim quantitative impact assessment criteria, however qualitative criteria based on relative risk, such as those adopted by Popper et al. may be appropriate, as summarised in Table 3-8.

SVT is not aware of any published studies or guidelines on the potential invertebrate response to non-impulsive/continuous noise sources (e.g. drilling).

Table 3-8 Suggested Invertebrate Sound Exposure Assessment Criteria for Impulsive Sources

Type of Animal	Mortality and Potential Mortal Injury	Impairment	Behaviour
		Recoverable Injury	
Invertebrates	(N) Moderate (I) Low (F) Low	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low

4. NOISE PROPAGATION PLOTS

The following pages provide noise contour (isopleth) maps generated for each assessed scenario and each assessed noise index. These include:

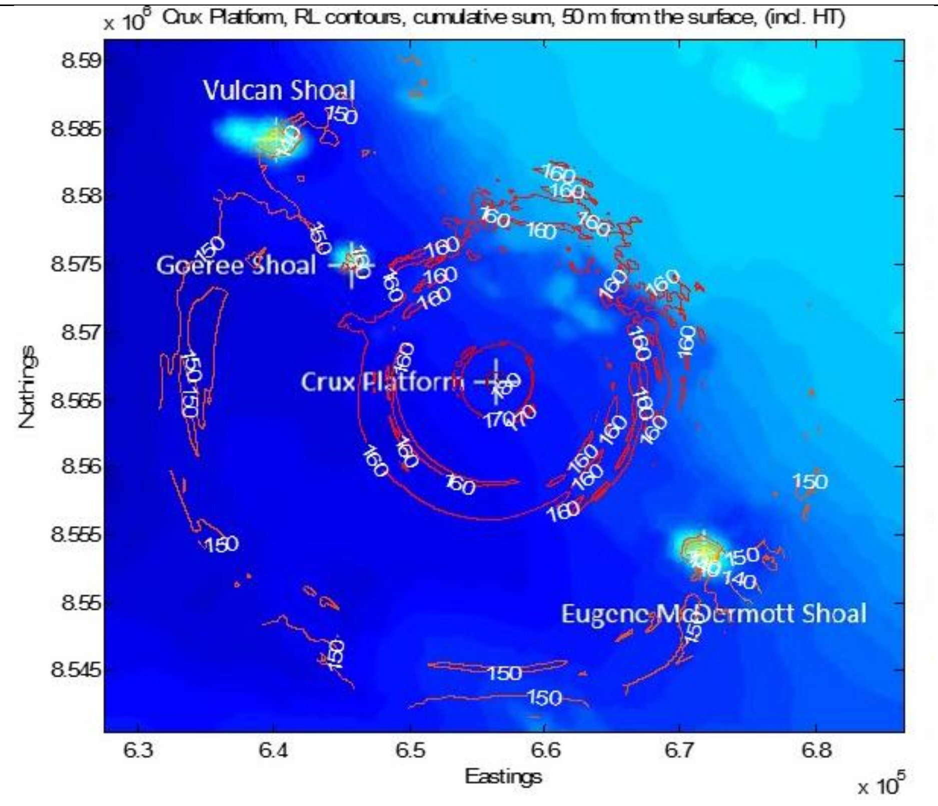
- L_{pk},
- Unweighted L_p;
- Marine Mammal weighted L_p;
- Unweighted $L_{E,p}$;
- Marine Mammal weighted $L_{E,p}$;

Adjacent to each contour plot is a plot of level with range is provided for a representative worst-case direction. On these Level-Range plots, the criteria relevant to the that particular noise index are also plotted for ease of reference.

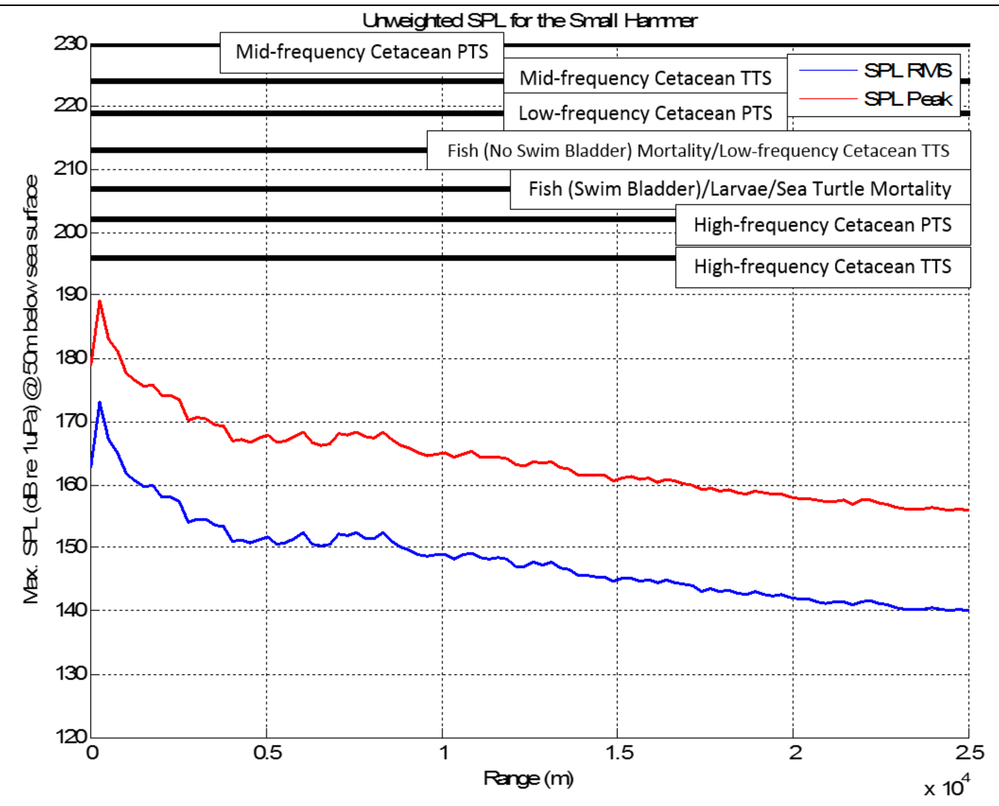
4.1 Pile Driving

4.1.1 Noise Propagation Plots for Small Hammer Pile Driving

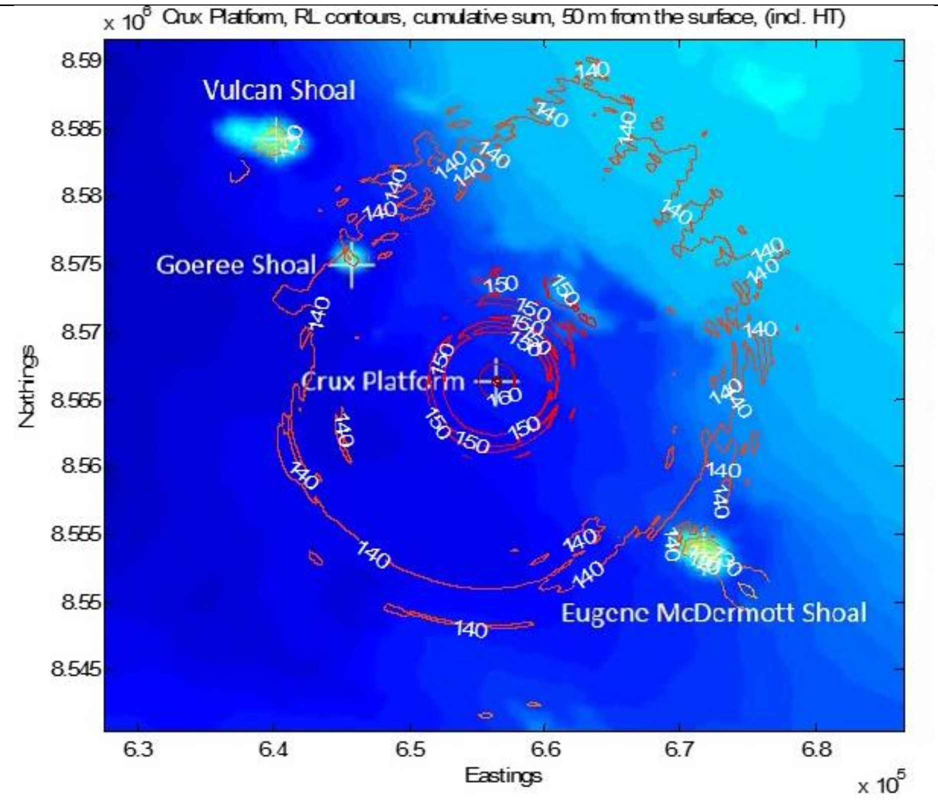
The following pages provide the noise results charts for the small hammer pile driving scenarios.



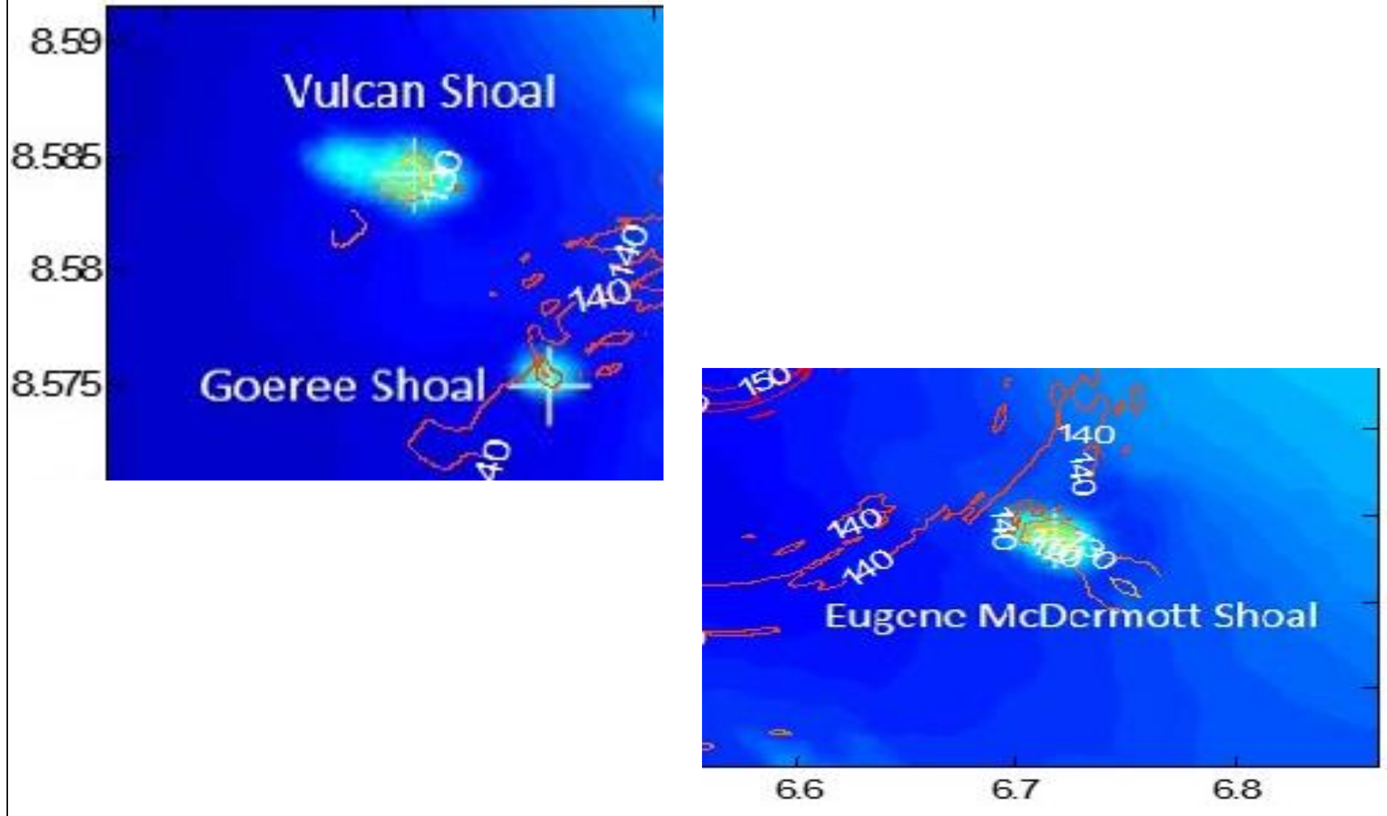
A: Contour Showing L_{pk} for Small Hammer Piling



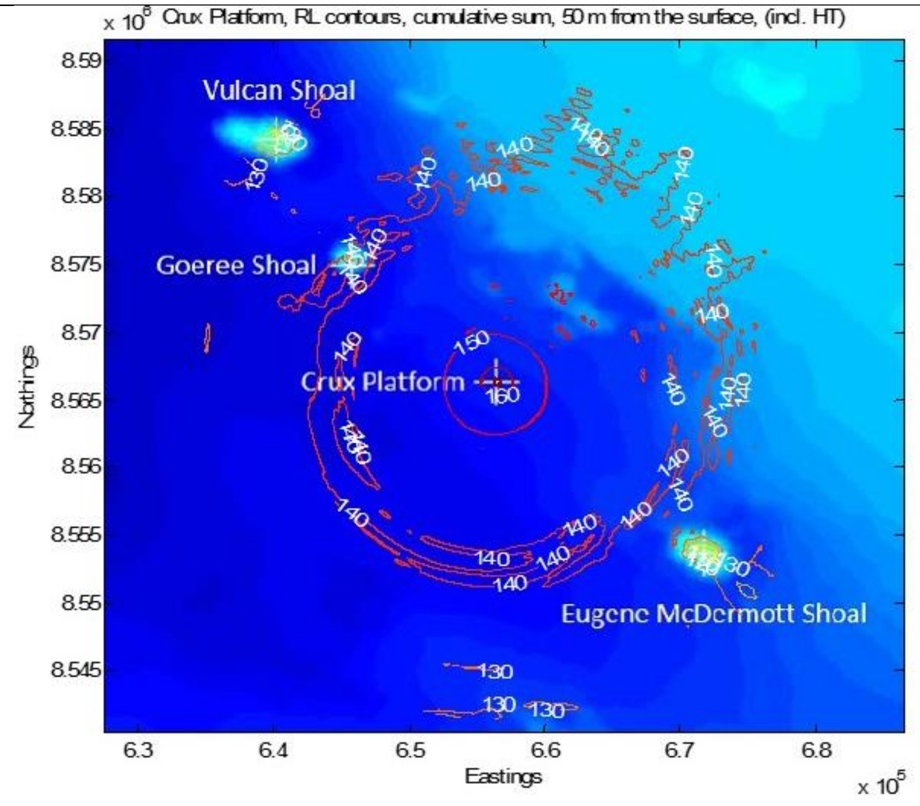
B: Maximum L_p dB and L_{pk} dB Range for Small Hammer Piling



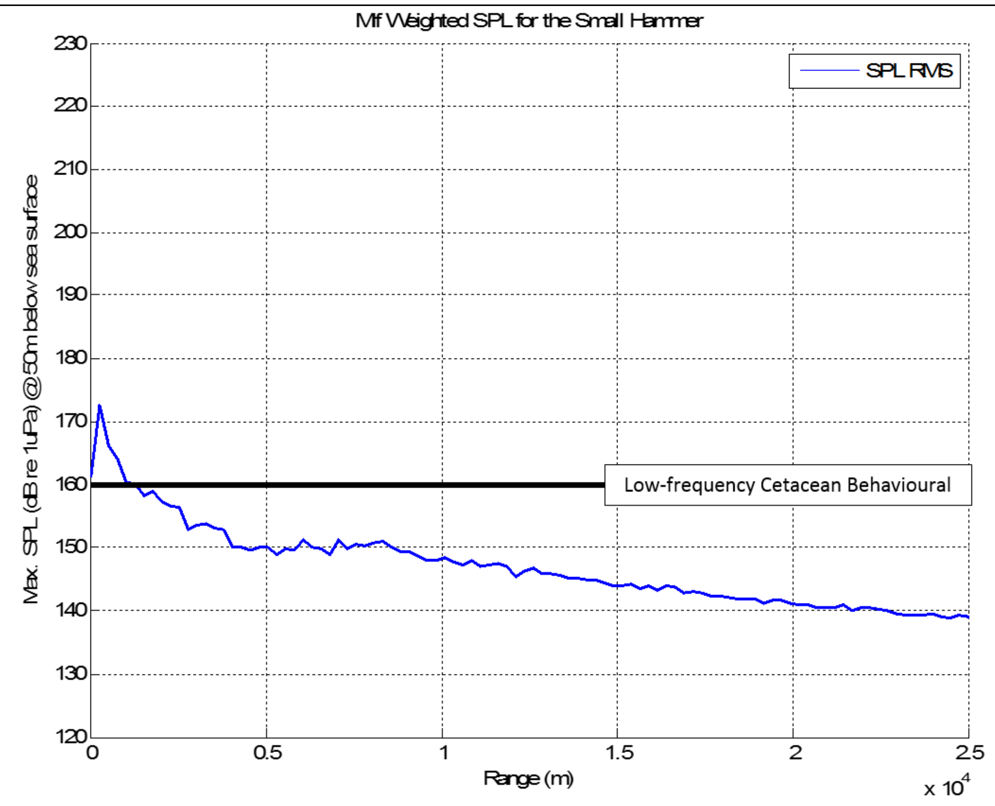
C: Noise Contour Showing Unweighted L_p for Small Hammer Piling



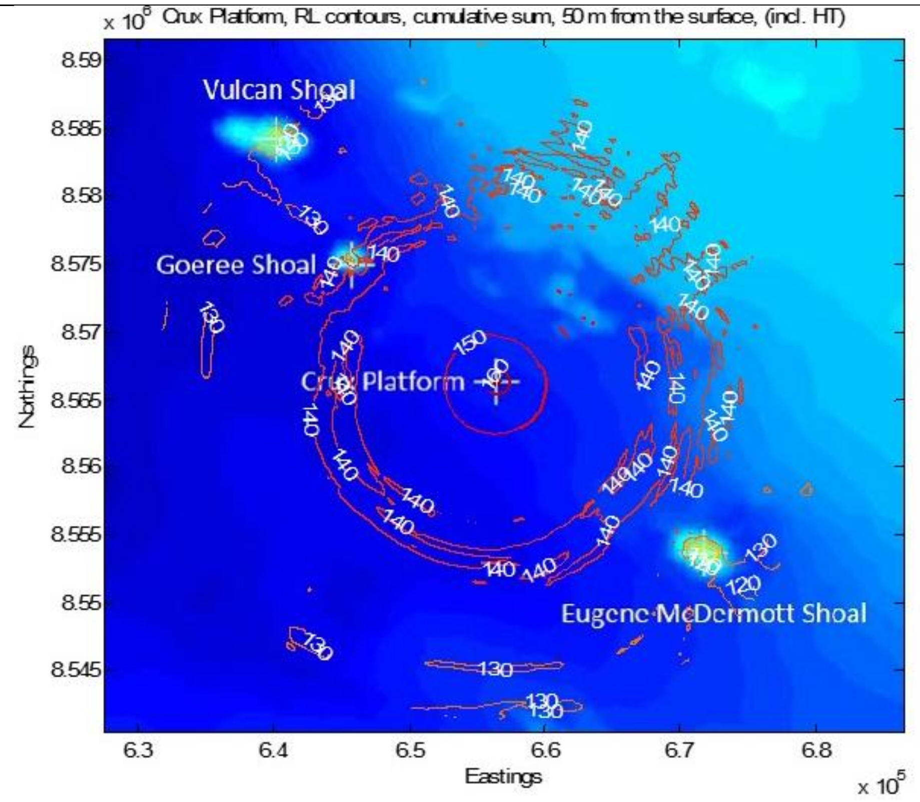
D: Zoomed Noise Contours of L_{pk} for Small Hammer Piling



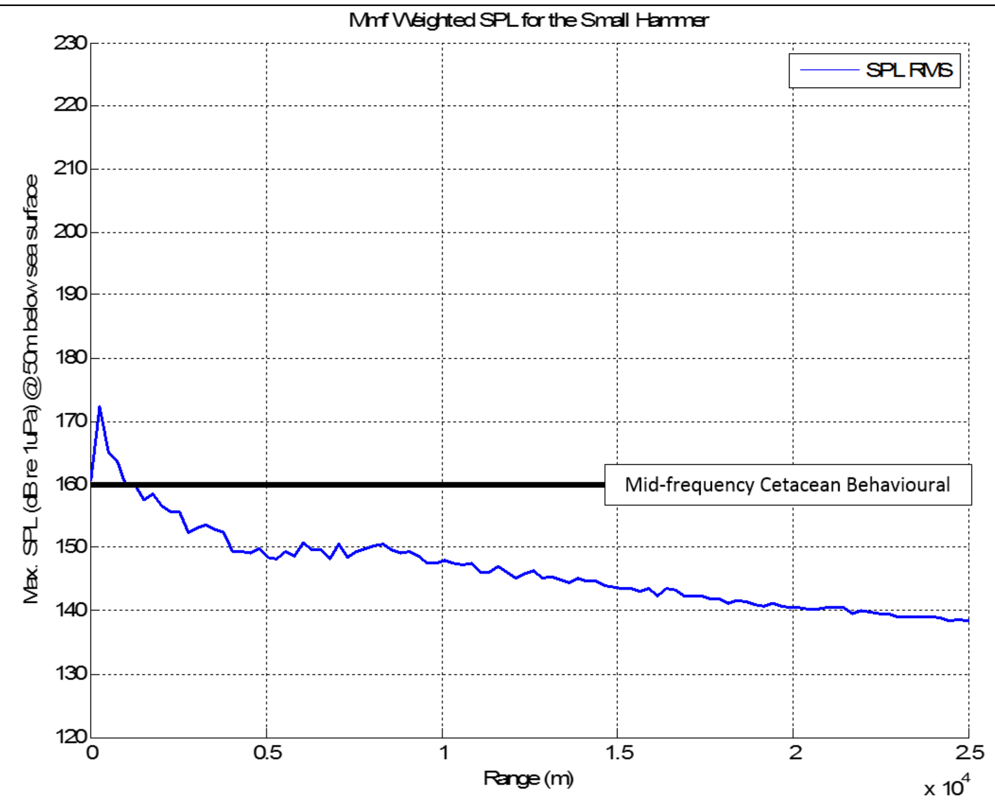
E: Noise Contour showing Mlf Weighted L_p for Small Hammer Piling



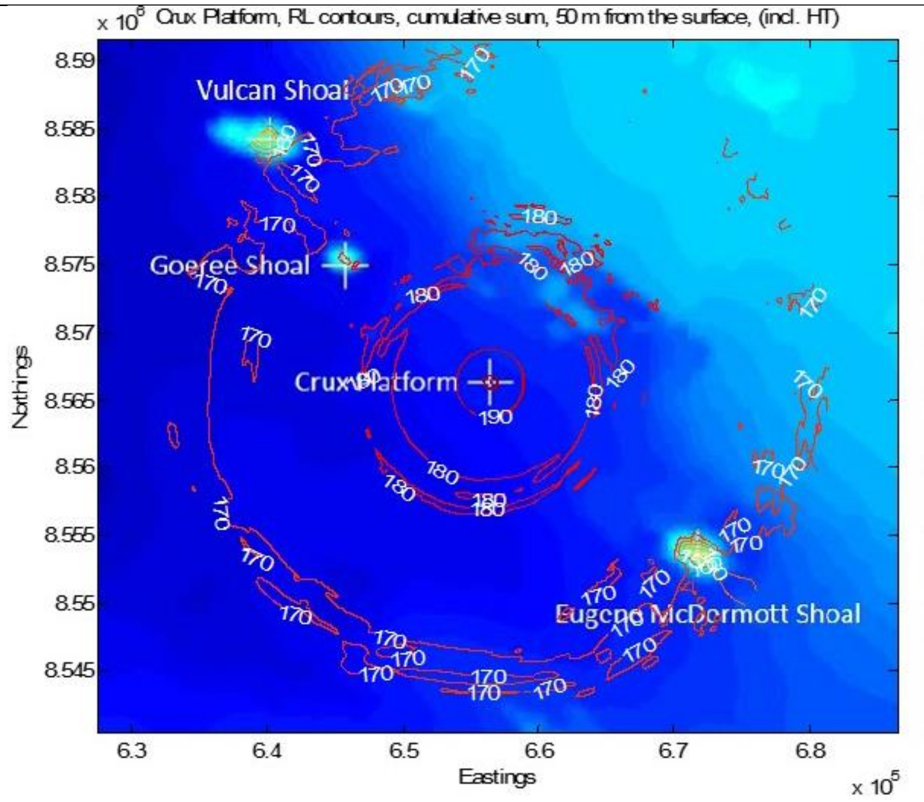
F: Maximum Mlf Weighted L_p versus Range for Small Hammer Piling



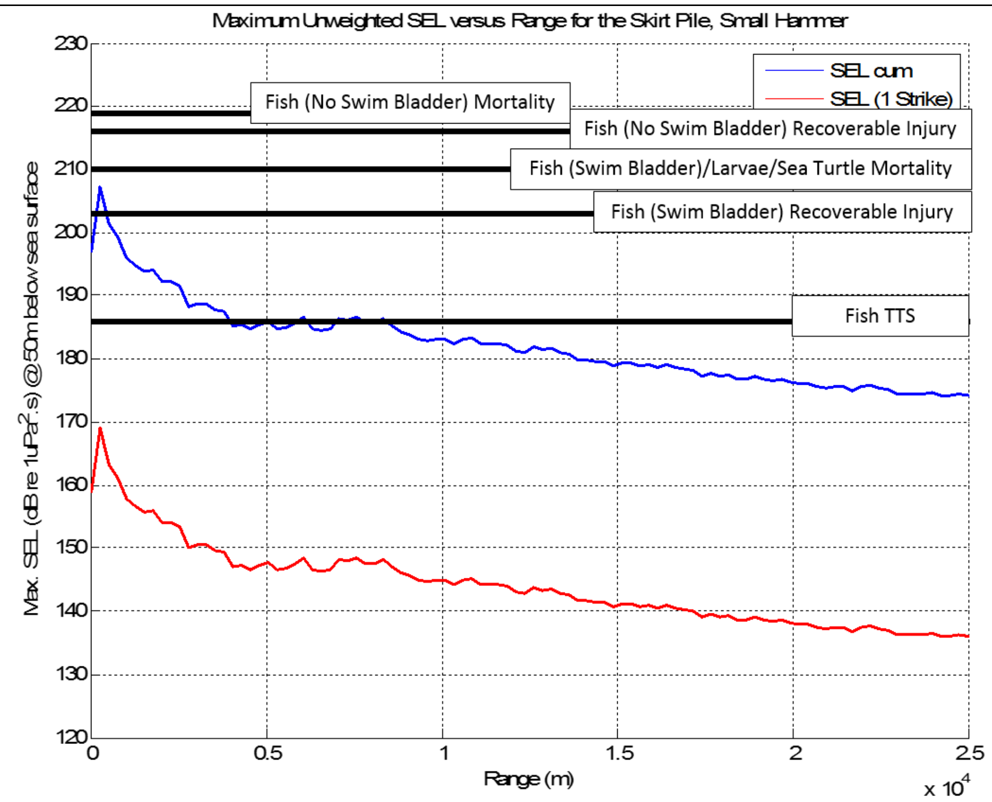
G: Noise Contour Showing Mmf Weighted L_p for Small Hammer Piling



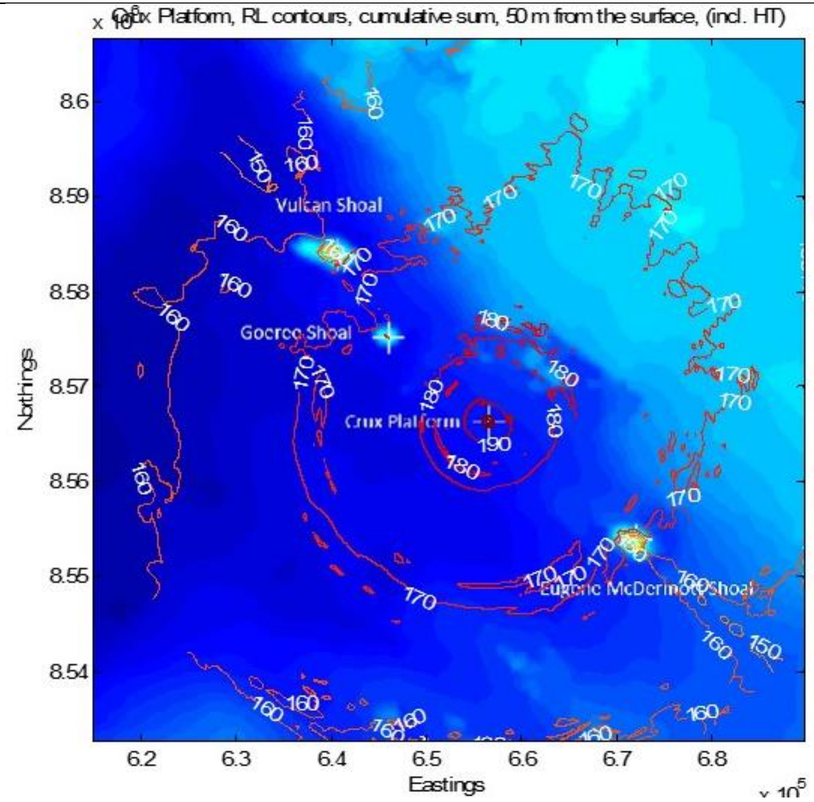
H: Maximum Mmf Weighted L_p versus Range for Small Hammer Piling



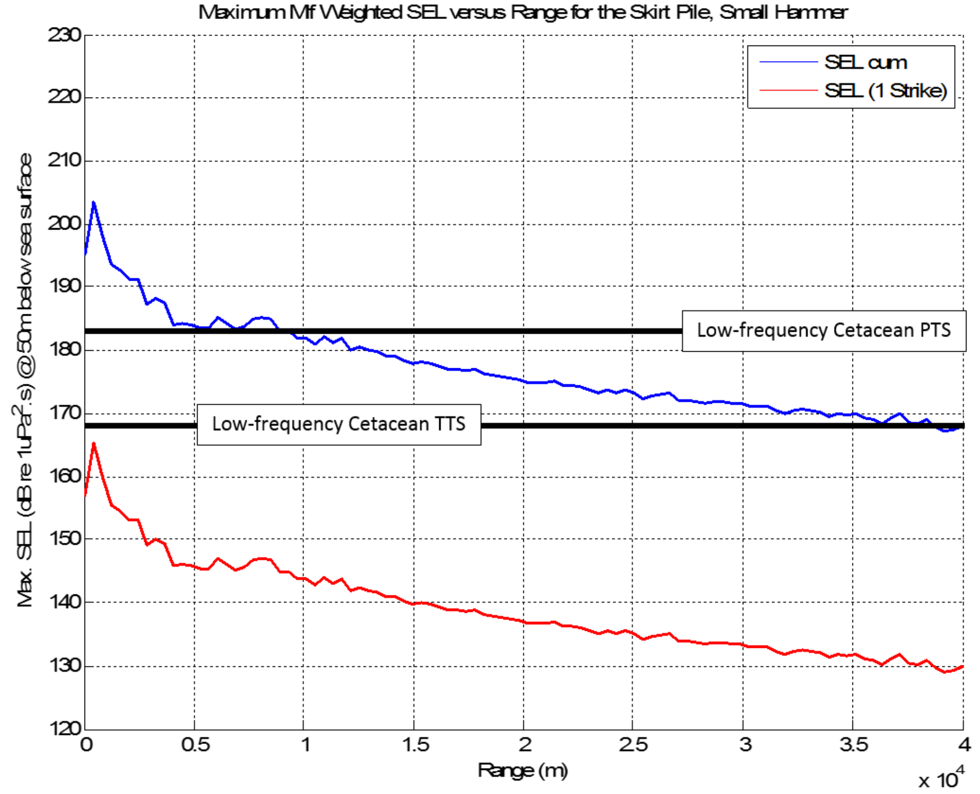
I: Noise Contour Showing Unweighted $L_{E,p}$ for Piling, Small Hammer



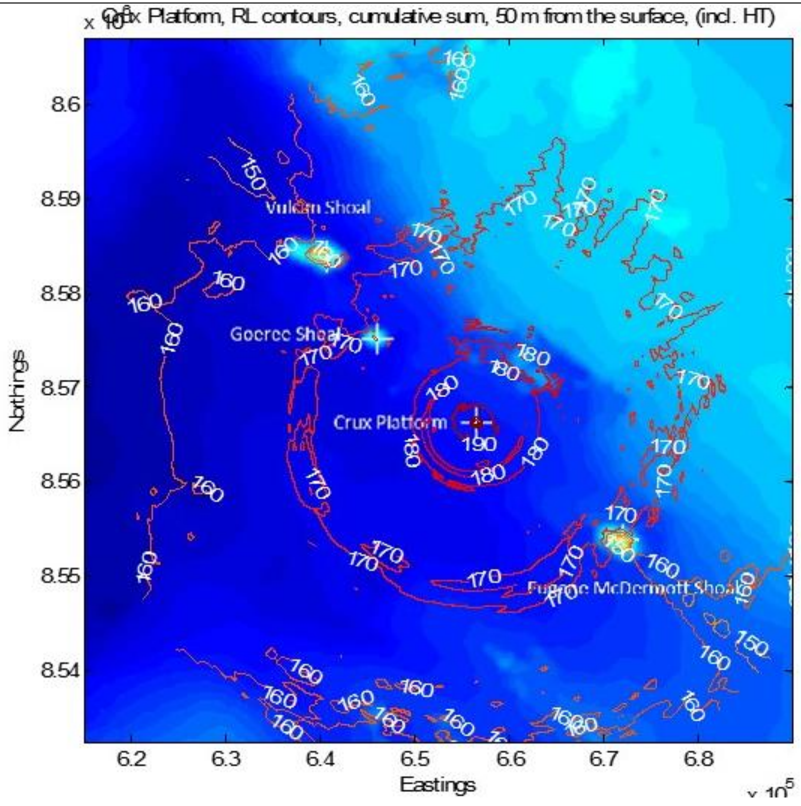
J: Maximum Unweighted $L_{E,p}$ versus Range for Piling, Small Hammer



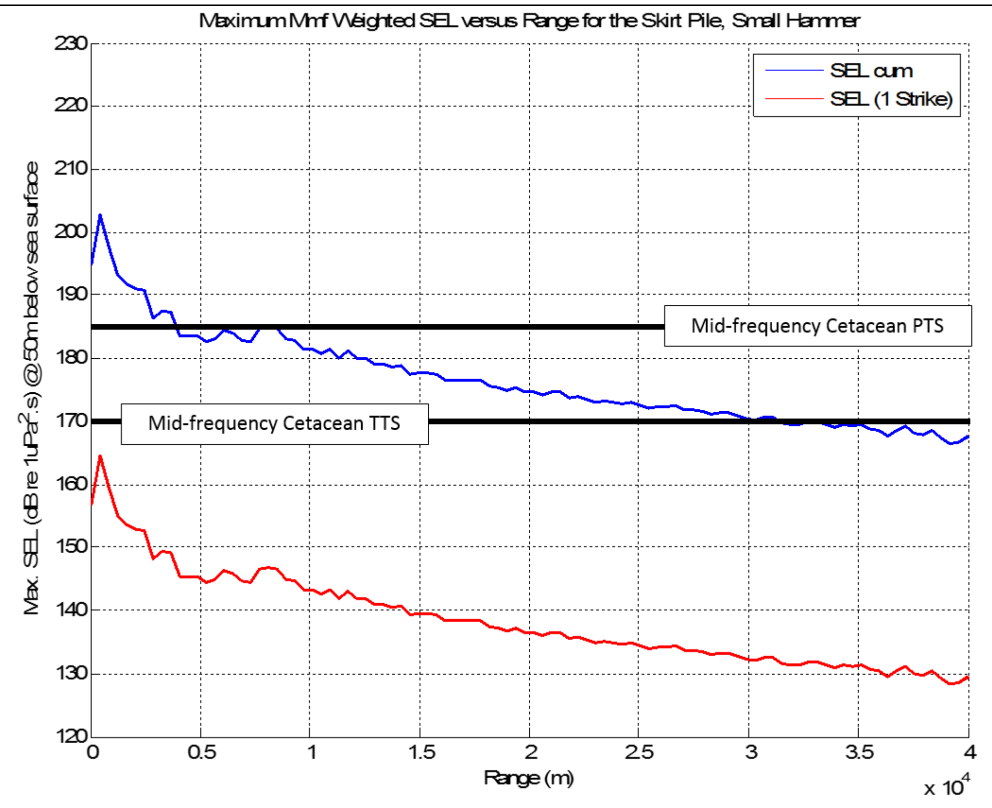
K: Noise Contour Showing Mlf Weighted $L_{E,p}$ for Piling, Small Hammer



L: Maximum Mlf Weighted $L_{E,p}$ versus Range for Piling, Small Hammer

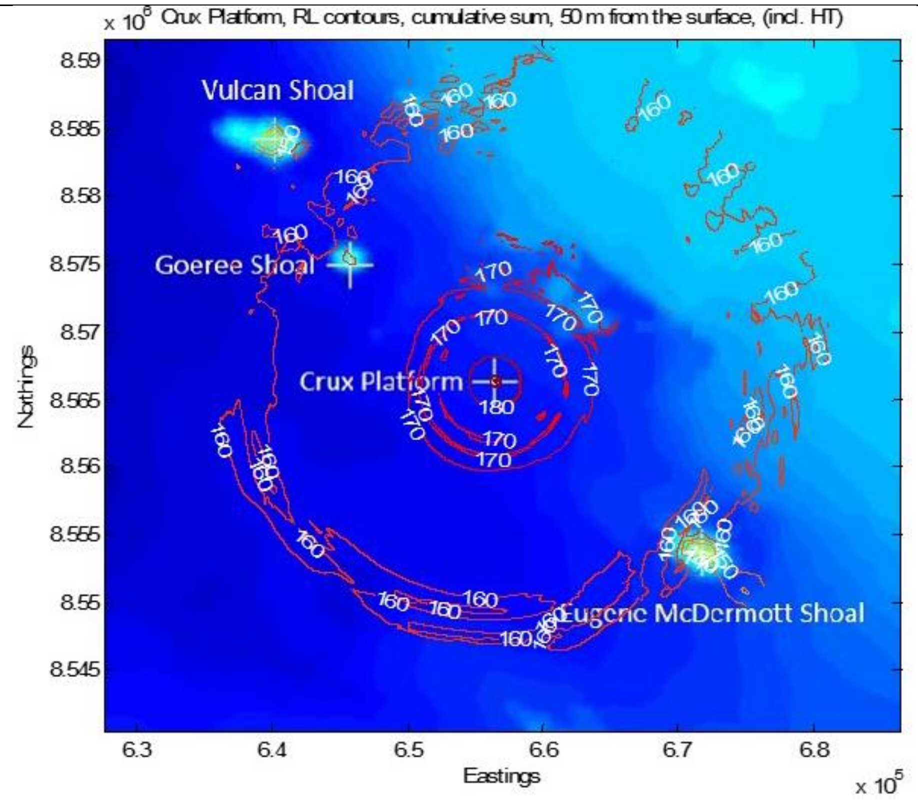


M: Noise Contour Showing Mmf Weighted $L_{E,p}$ for Piling, Small Hammer

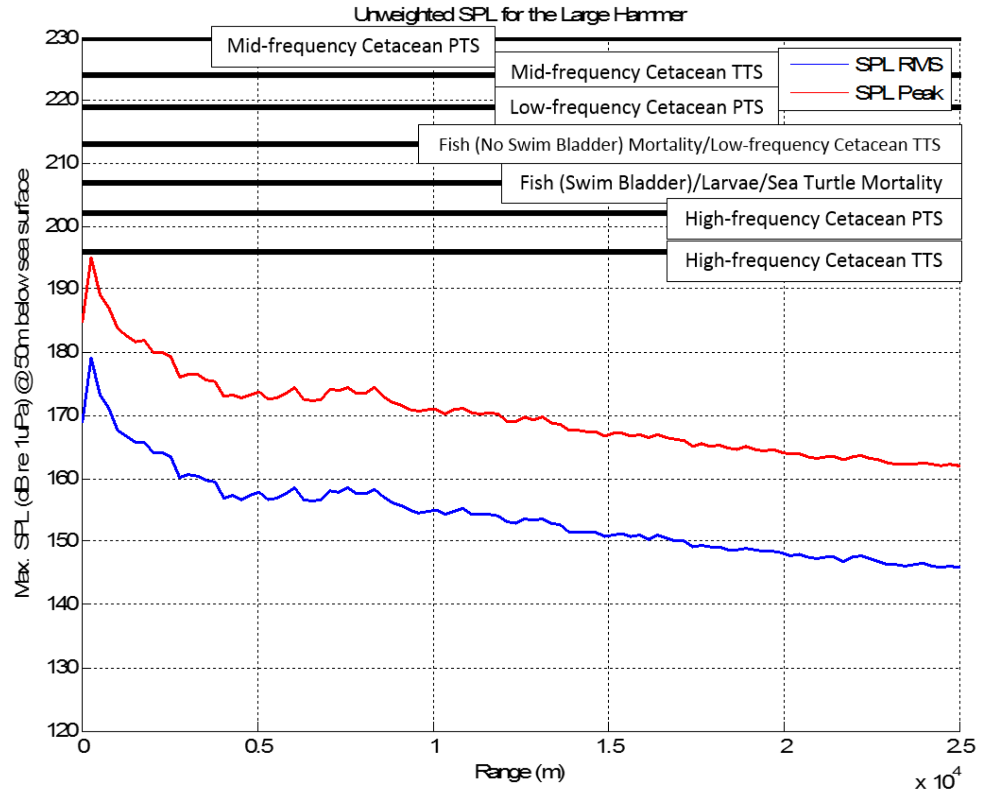


N: Maximum Mmf Weighted $L_{E,p}$ versus Range for Piling, Small Hammer

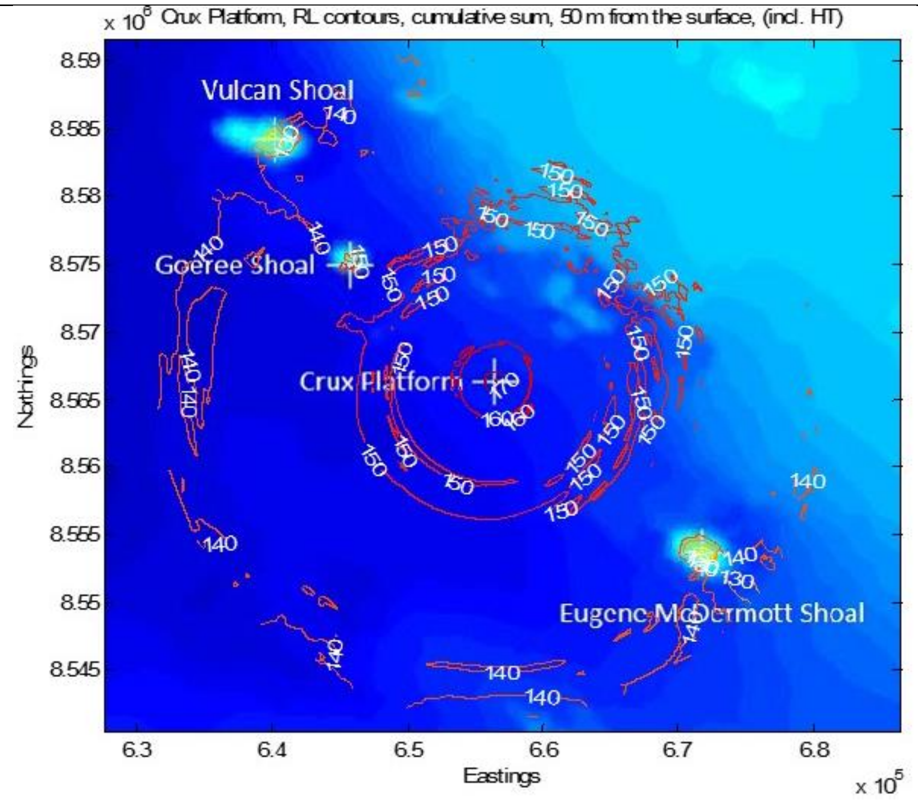
4.1.2 Noise Propagation Plots for Large Hammer Piling



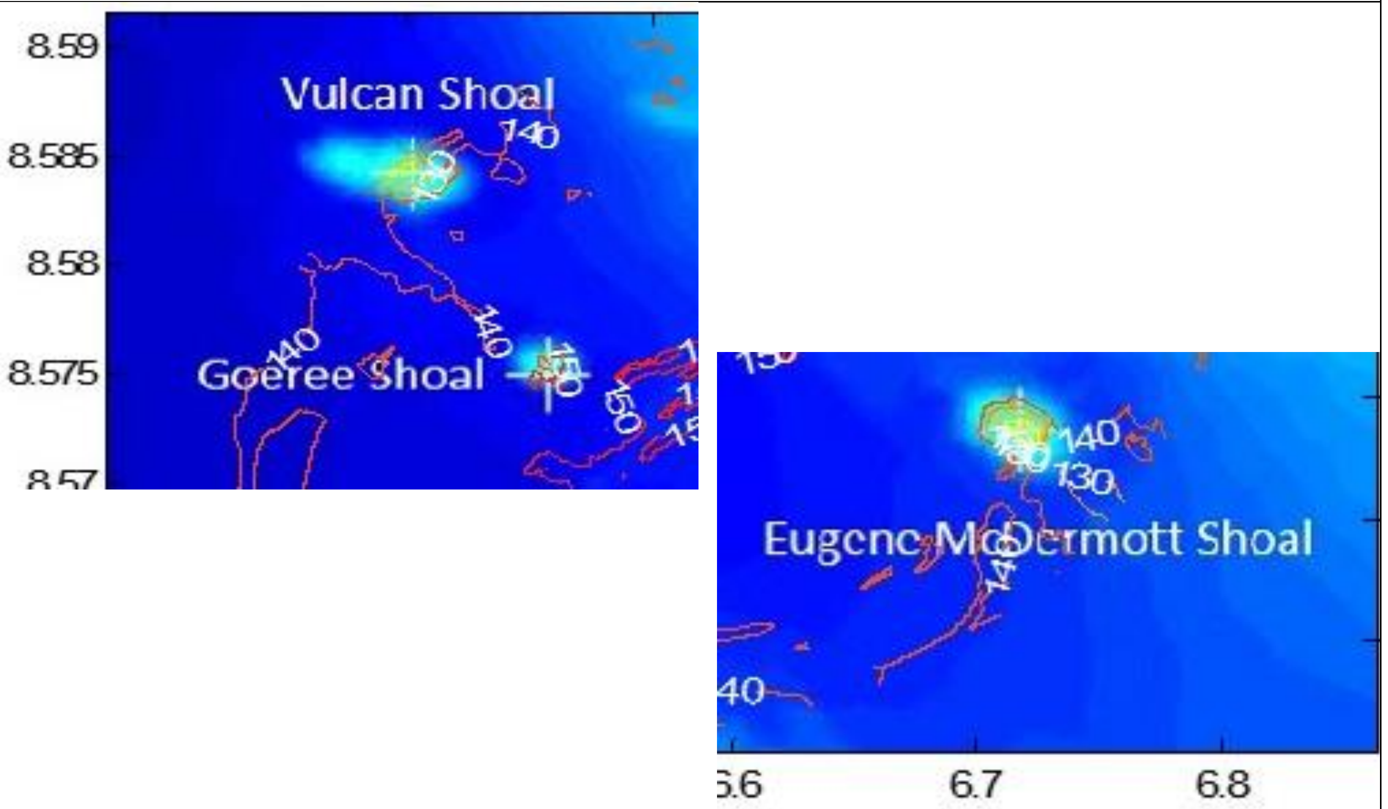
A: Noise Contour Showing L_{pk} for Large Hammer Piling



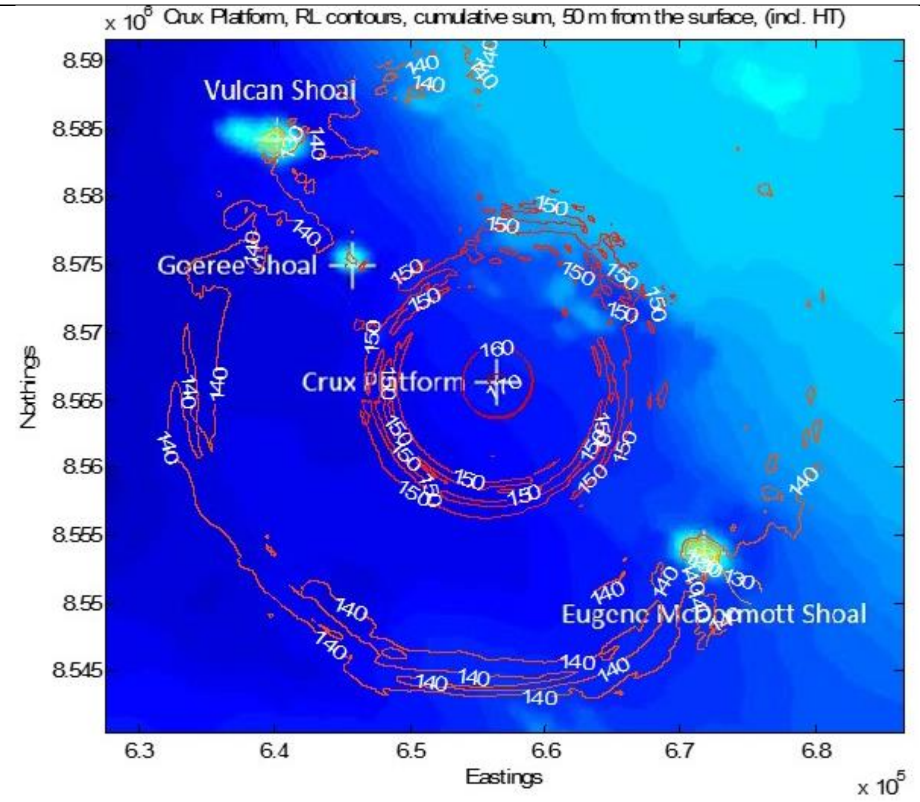
B: Maximum Unweighted L_p versus Range for Large Hammer Piling



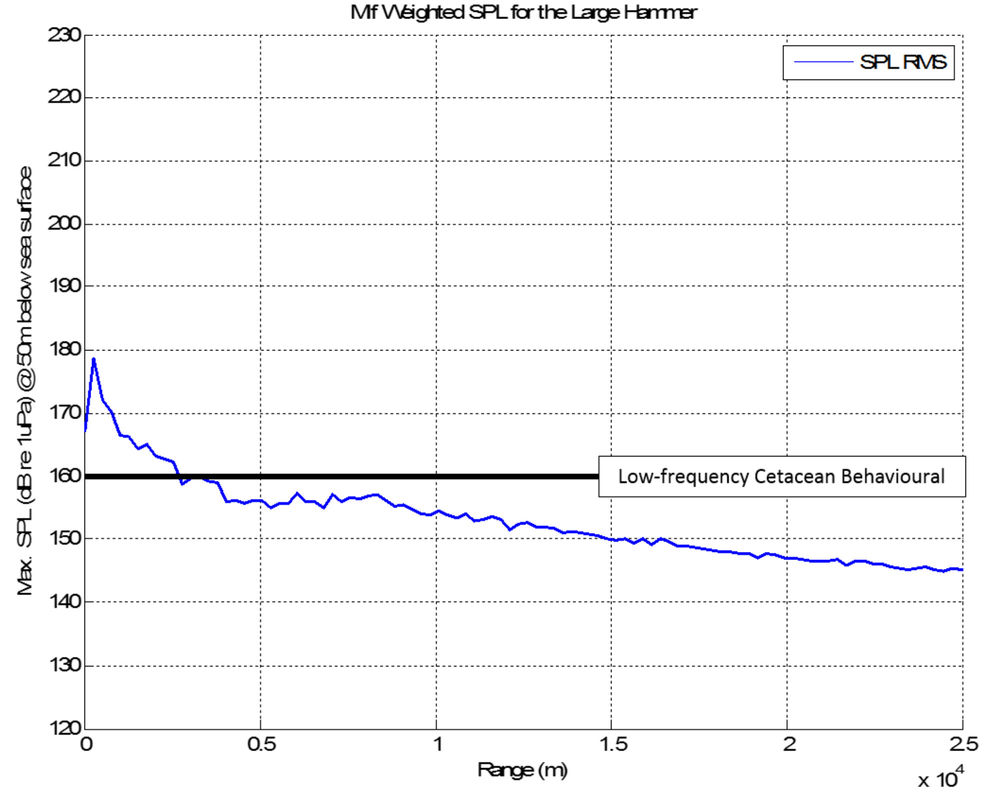
C: Noise Contour Showing Unweighted L_p for Large Hammer Piling



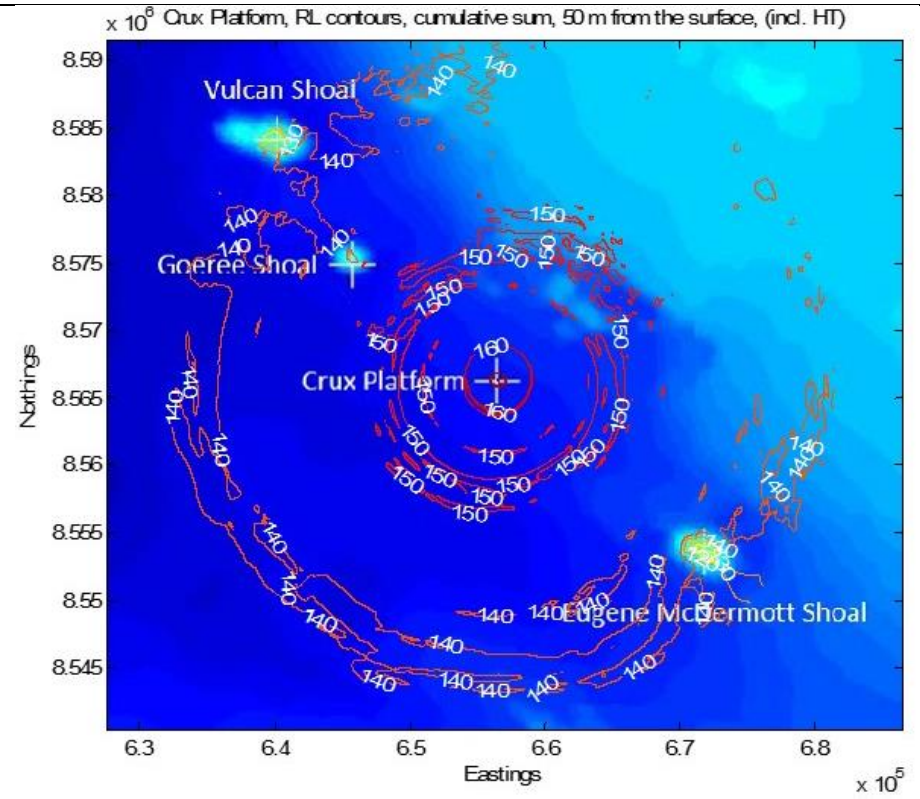
D: Zoomed Noise Contours of L_{pk} for Large Hammer Piling



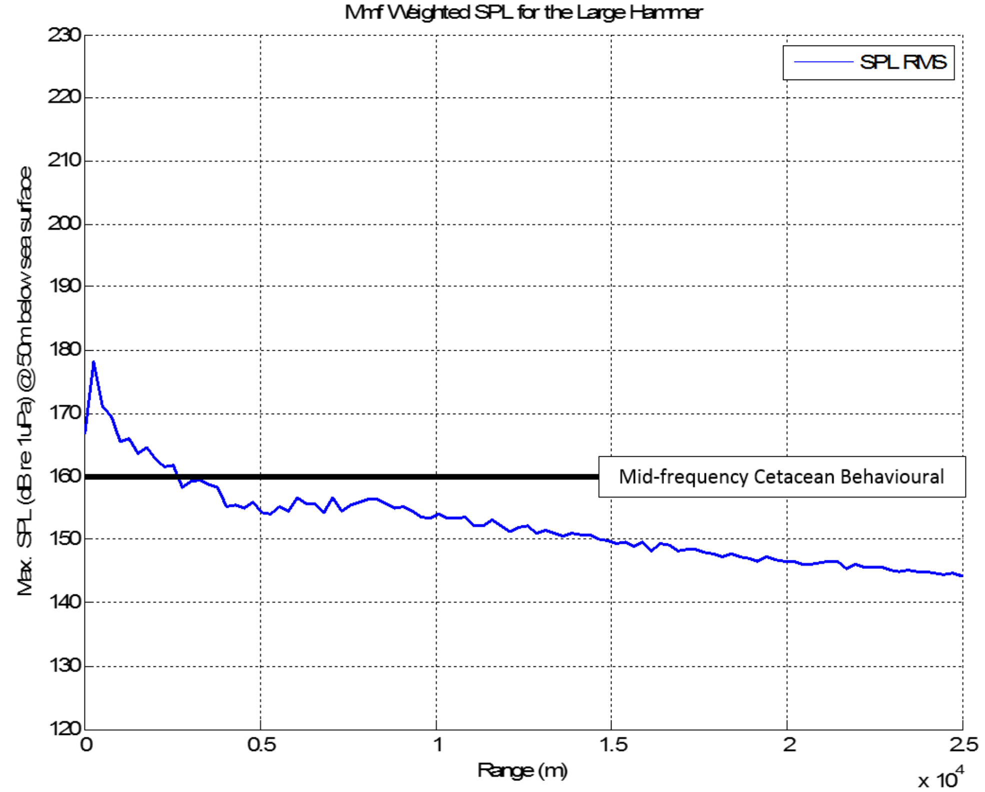
E: Noise Contour Showing Mlf Weighted L_p for Large Hammer Pilling



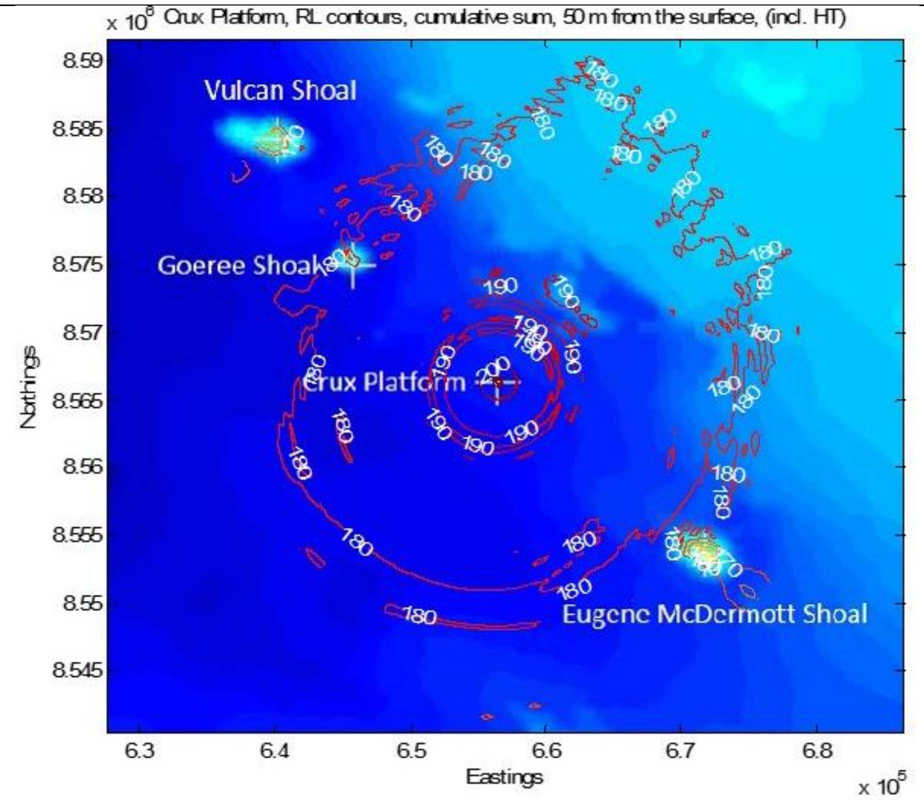
F: Maximum Mlf Weighted L_p versus Range for Large Hammer Piling



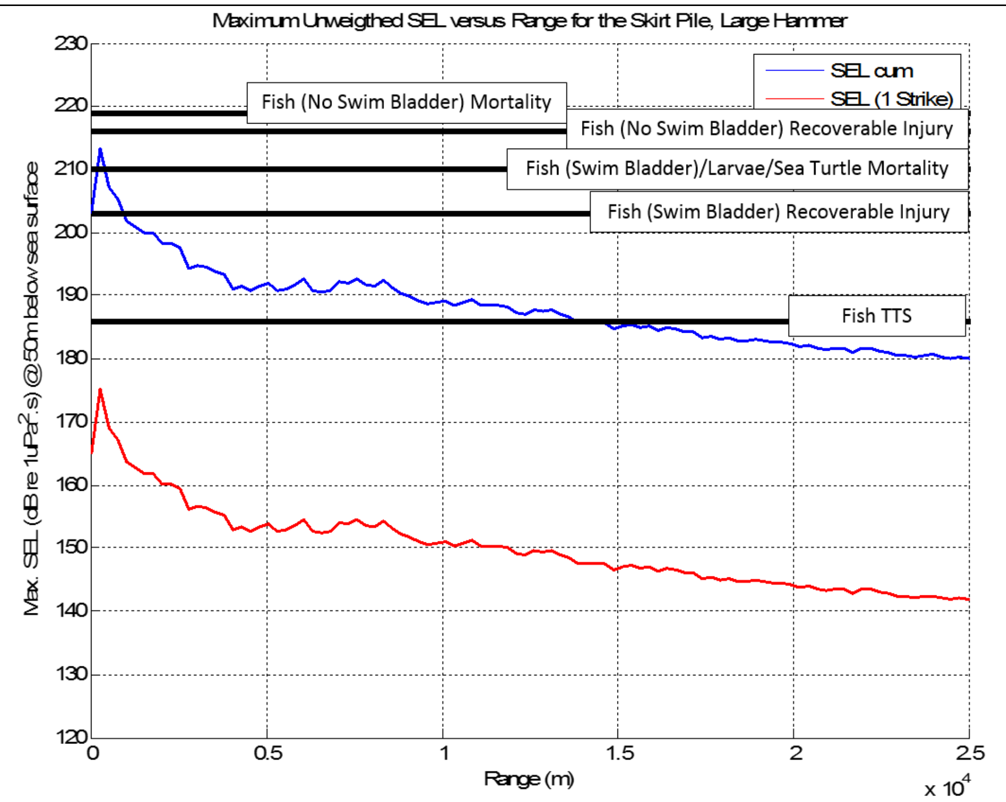
G: Noise Contour Showing Mmf Weighted L_p for Large Hammer Pilling



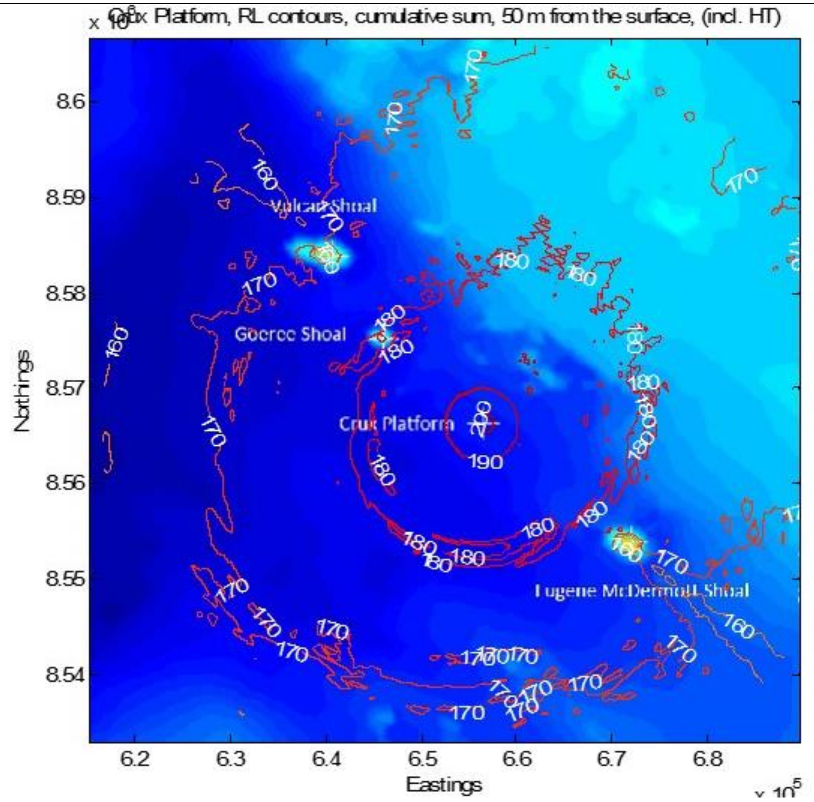
H: Maximum Mmf Weighted L_p versus Range for Large Hammer Piling



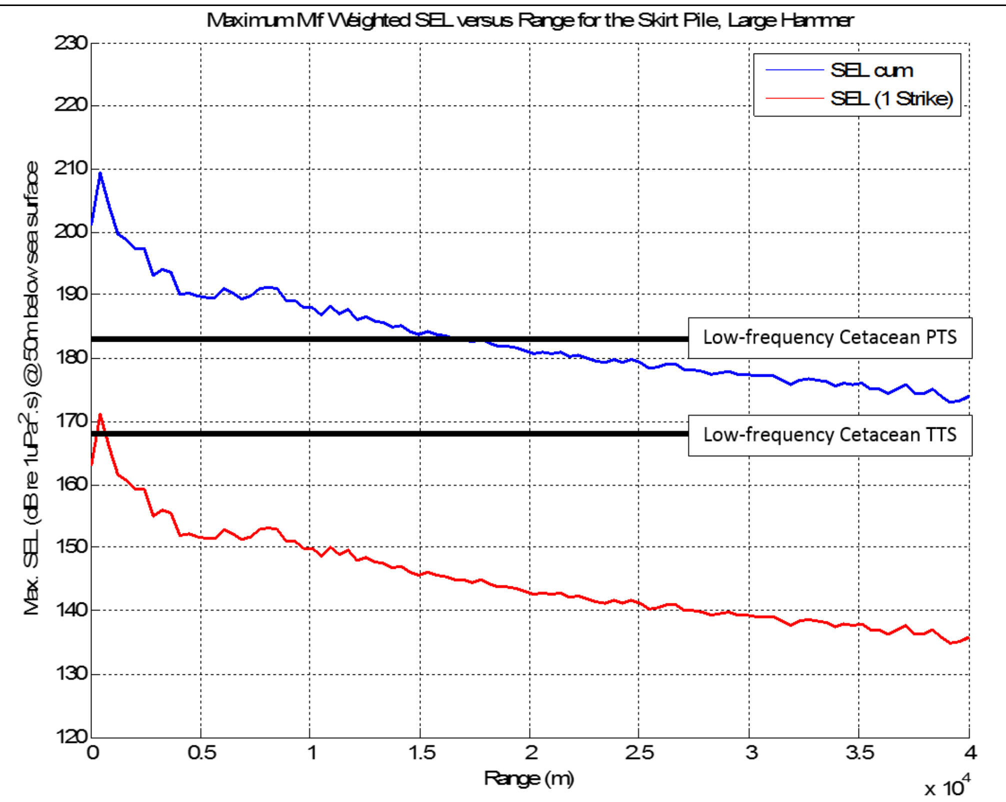
I: Noise Contour Showing Unweighted $L_{E,p}$ for Large Hammer Piling



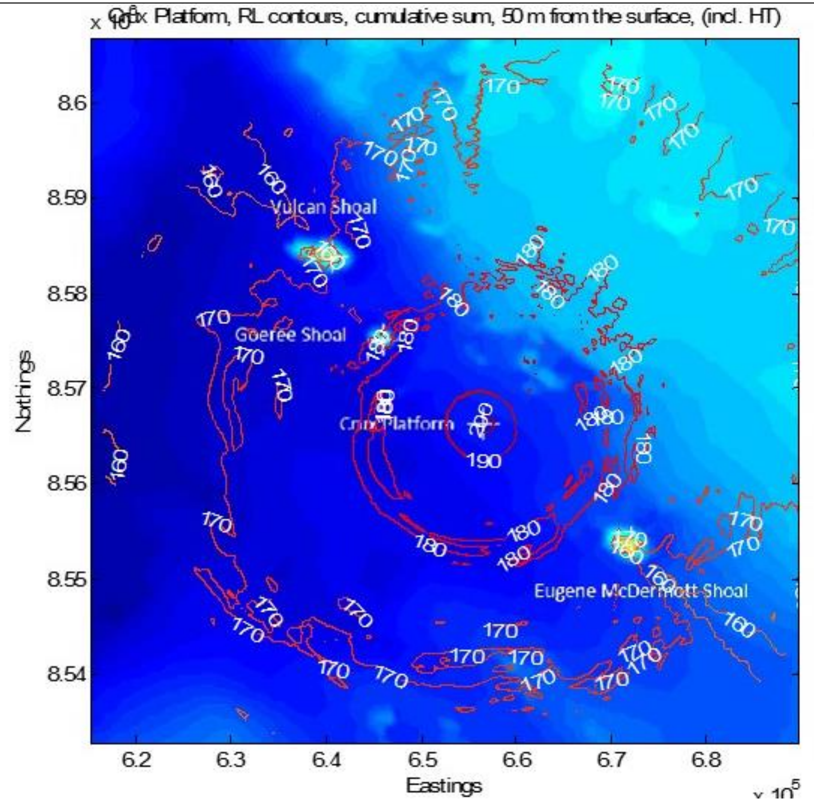
J: Maximum Unweighted $L_{E,p}$ versus Range for Large Hammer Piling



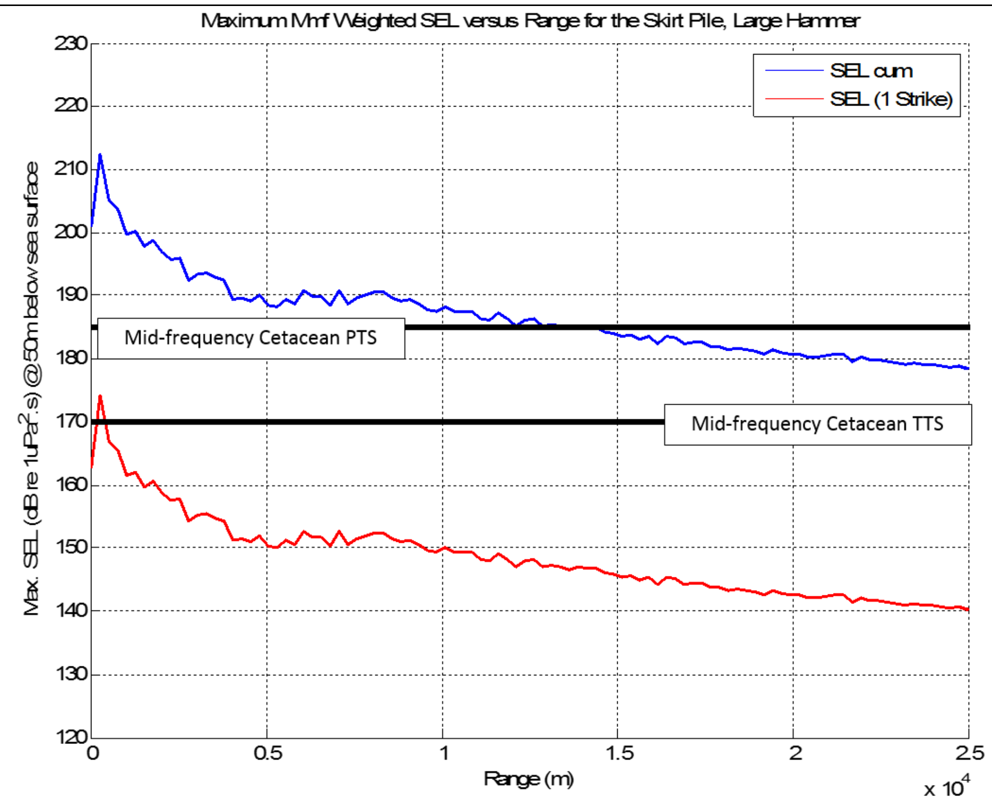
K: Noise Contour Showing Mlf Weighted $L_{E,p}$ for Large Hammer Piling



L: Maximum Mlf Weighted $L_{E,p}$ versus Range for Large Hammer Piling



M: Noise Contour Showing Mmf Weighted $L_{E,p}$ for Large Hammer Piling



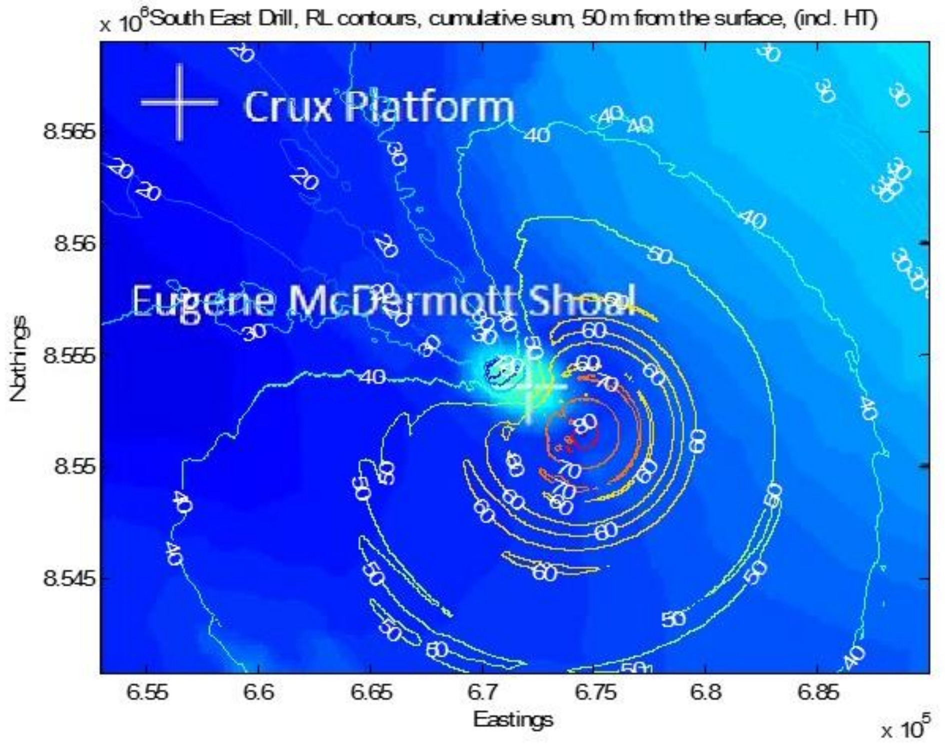
N: Maximum Mmf Weighted $L_{E,p}$ versus Range for Large Hammer Piling

4.2 Development and Operational Drilling

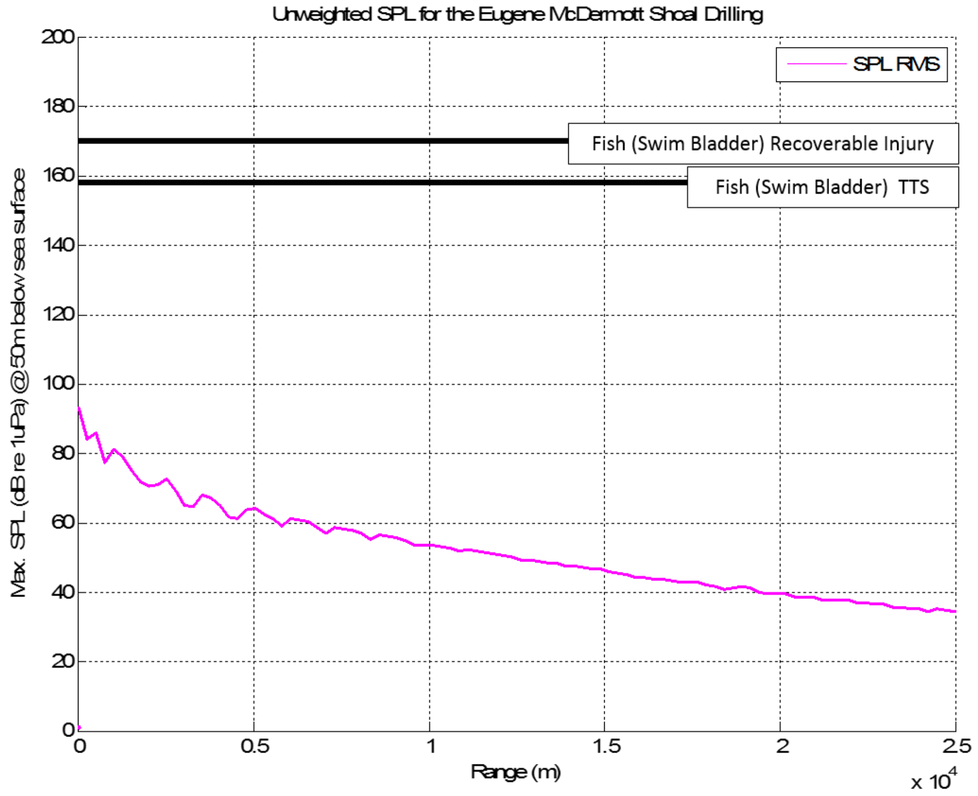
The following pages provide the noise results charts for three drilling scenarios:

1. Drill rig in proximity to Eugene McDermott Shoal
2. Drill rig in proximity to Vulcan Shoal
3. MPR on the Crux Platform

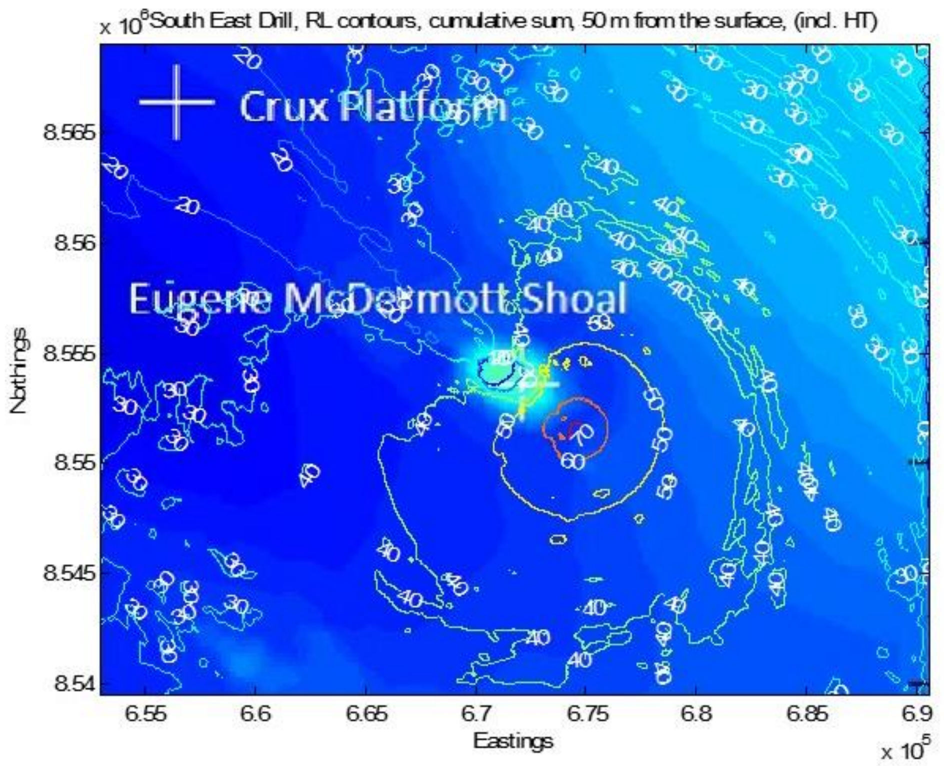
4.2.1 Drill Rig in Proximity to Eugene McDermott Shoal (Outside 1 km buffer)



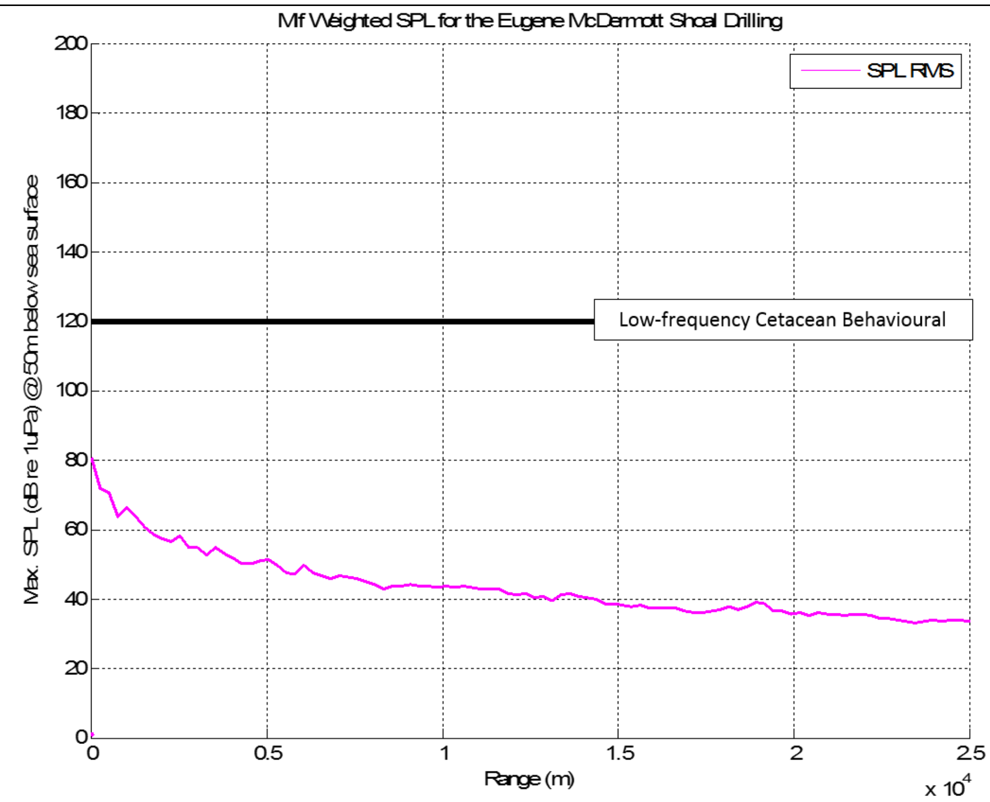
A: Noise Contour Showing Unweighted L_p for Eugene McDermott Shoal Drill Rig



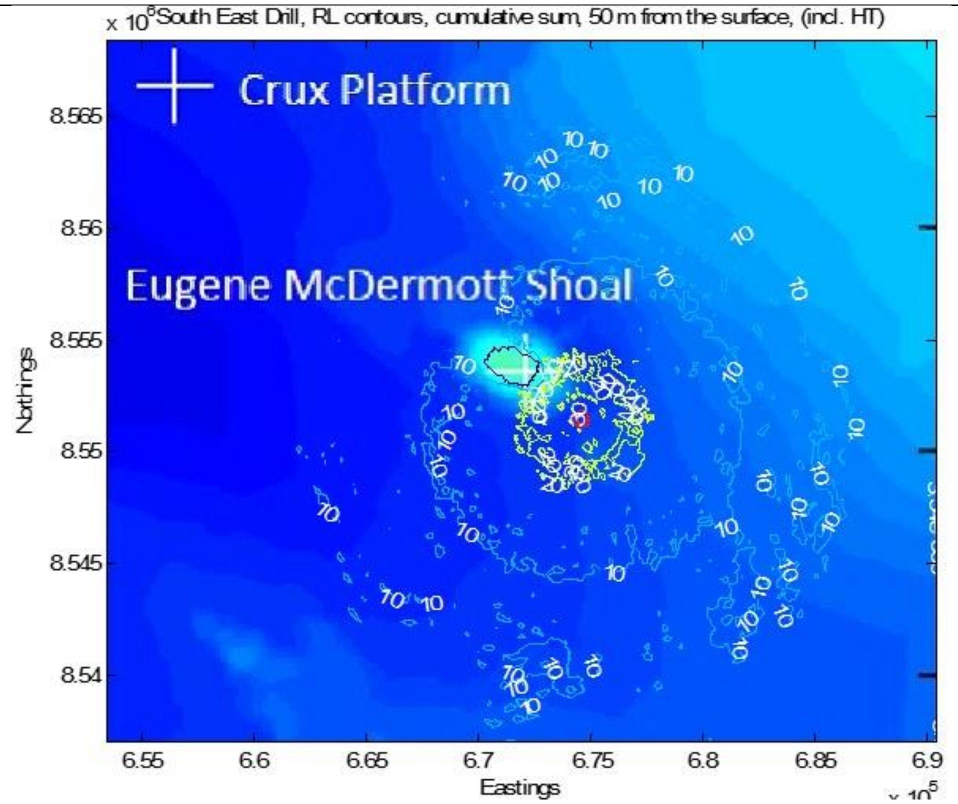
B: Maximum Unweighted L_p versus Range for Eugene McDermott Shoal Drill Rig



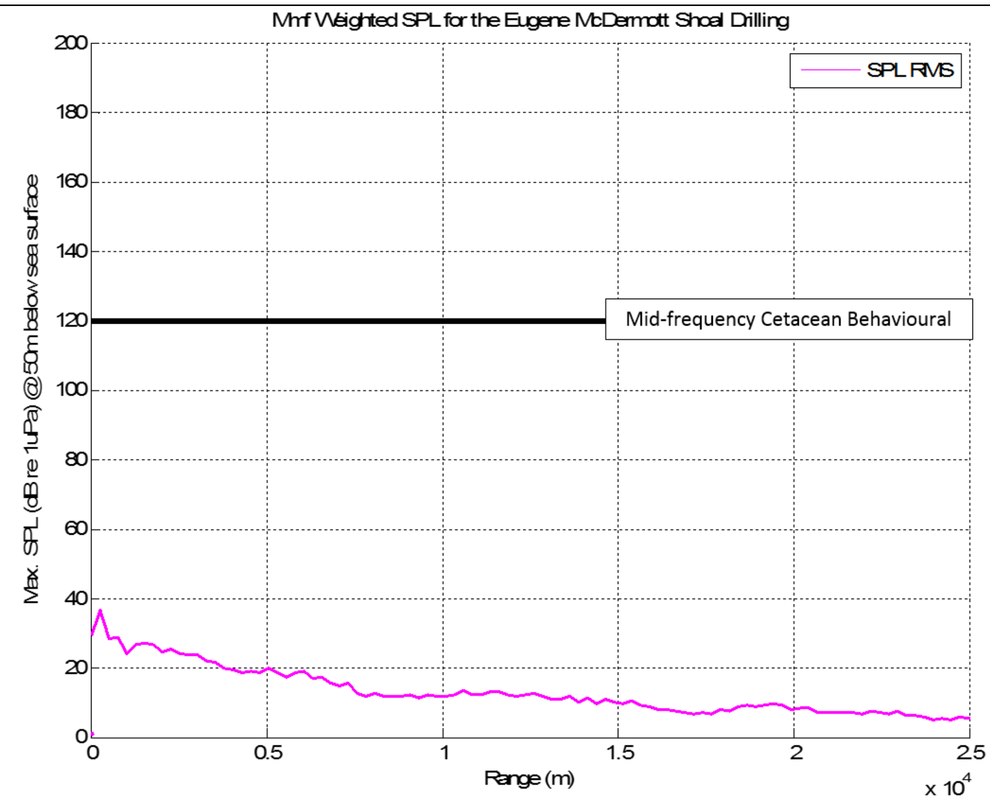
C: Noise Contour Showing Mlf-Weighted L_p for Eugene McDermott Shoal Drill Rig



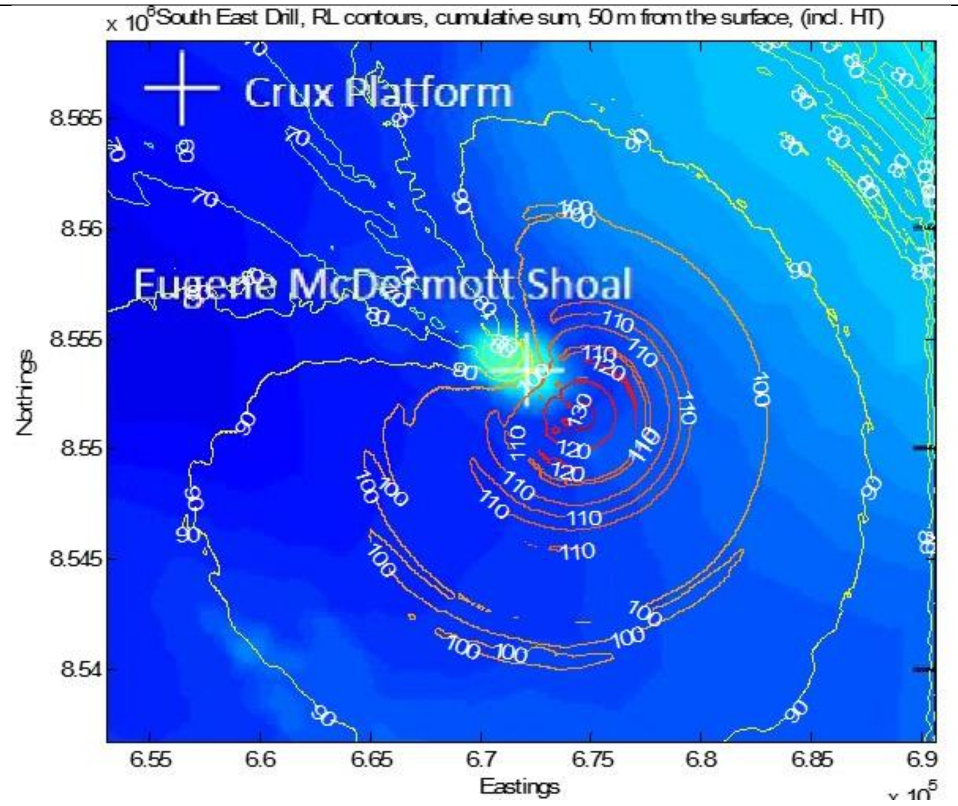
D: Maximum Mlf-Weighted L_p versus Range for Eugene McDermott Shoal Drill Rig



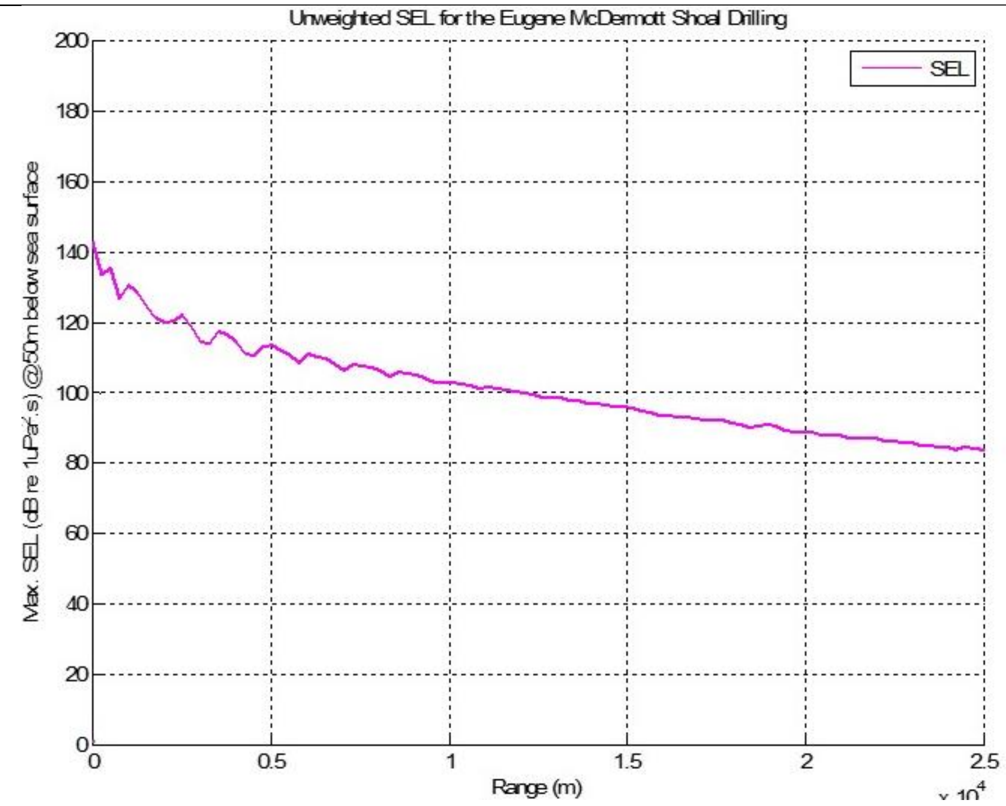
E: Noise Contour Showing Mmf-Weighted L_p for Eugene McDermott Shoal Drill Rig



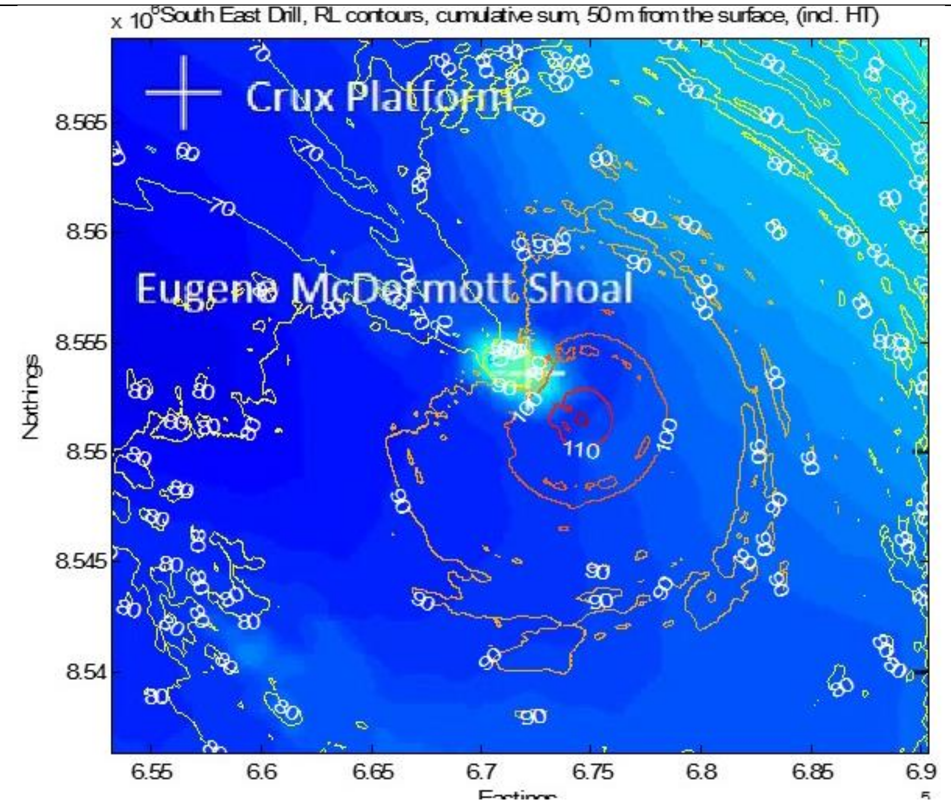
F: Maximum Mmf-Weighted L_p versus Range for Eugene McDermott Shoal Drill Rig



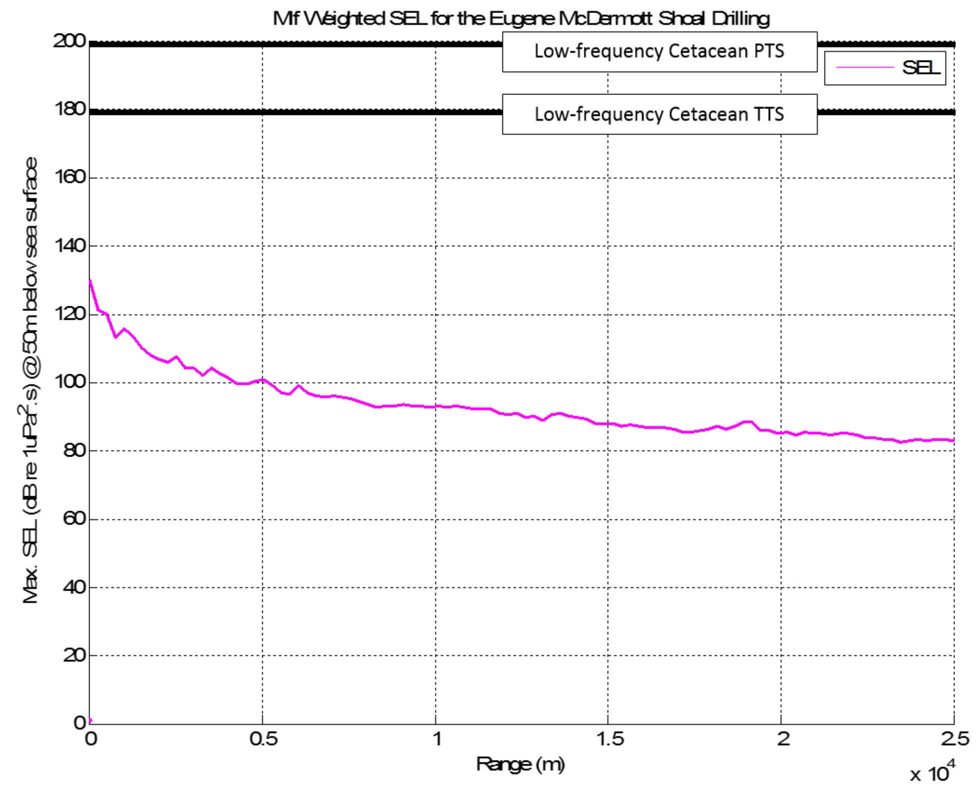
G: Noise Contour Showing Unweighted $L_{E,p}$ for Eugene McDermott Shoal Drill Rig



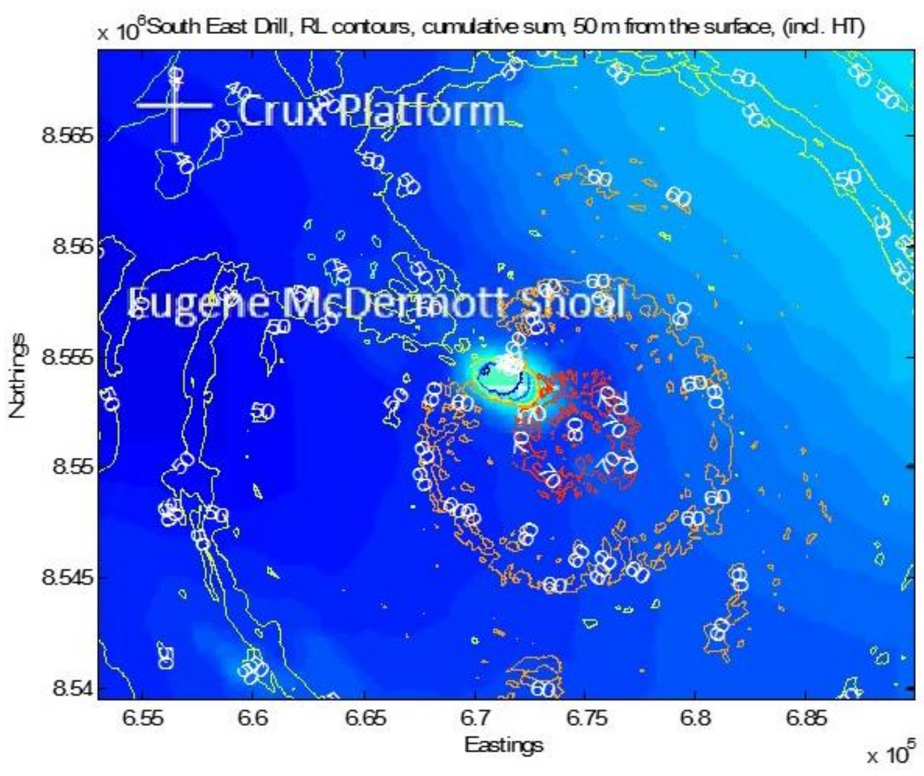
H: Maximum Unweighted $L_{E,p}$ versus Range for Eugene McDermott Shoal Drill Rig



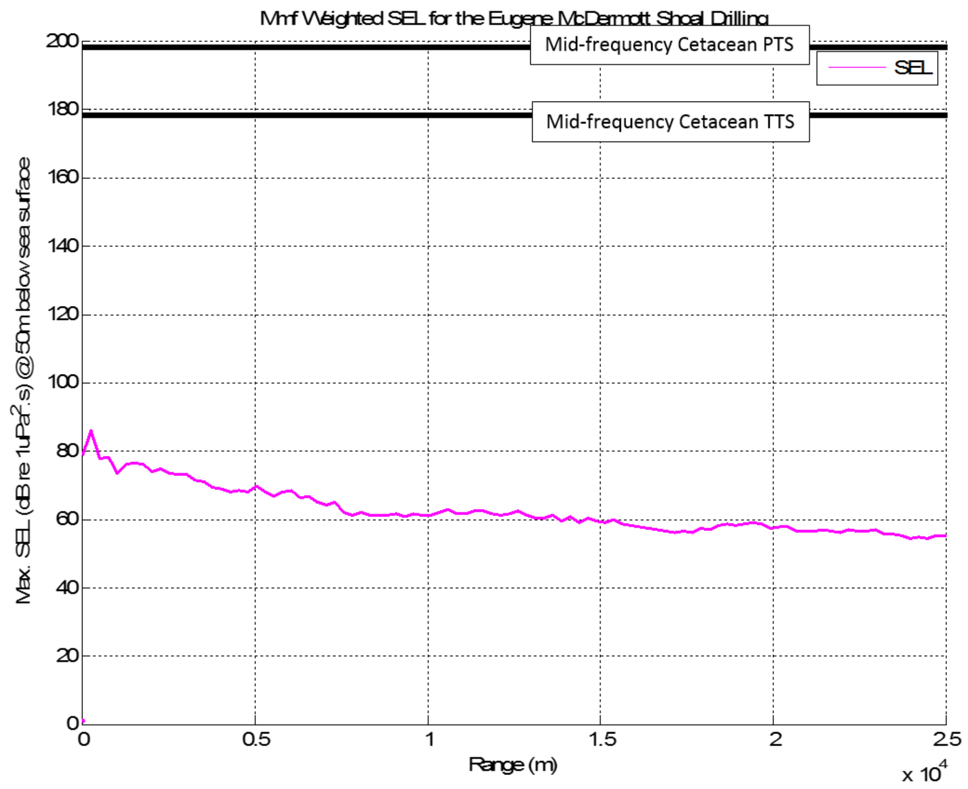
I: Noise Contour Showing Mlf-Weighted $L_{E,p}$ for Eugene McDermott Shoal Drill Rig



J: Maximum Mlf-weighted $L_{E,p}$ versus Range for Eugene McDermott Shoal Drill Rig

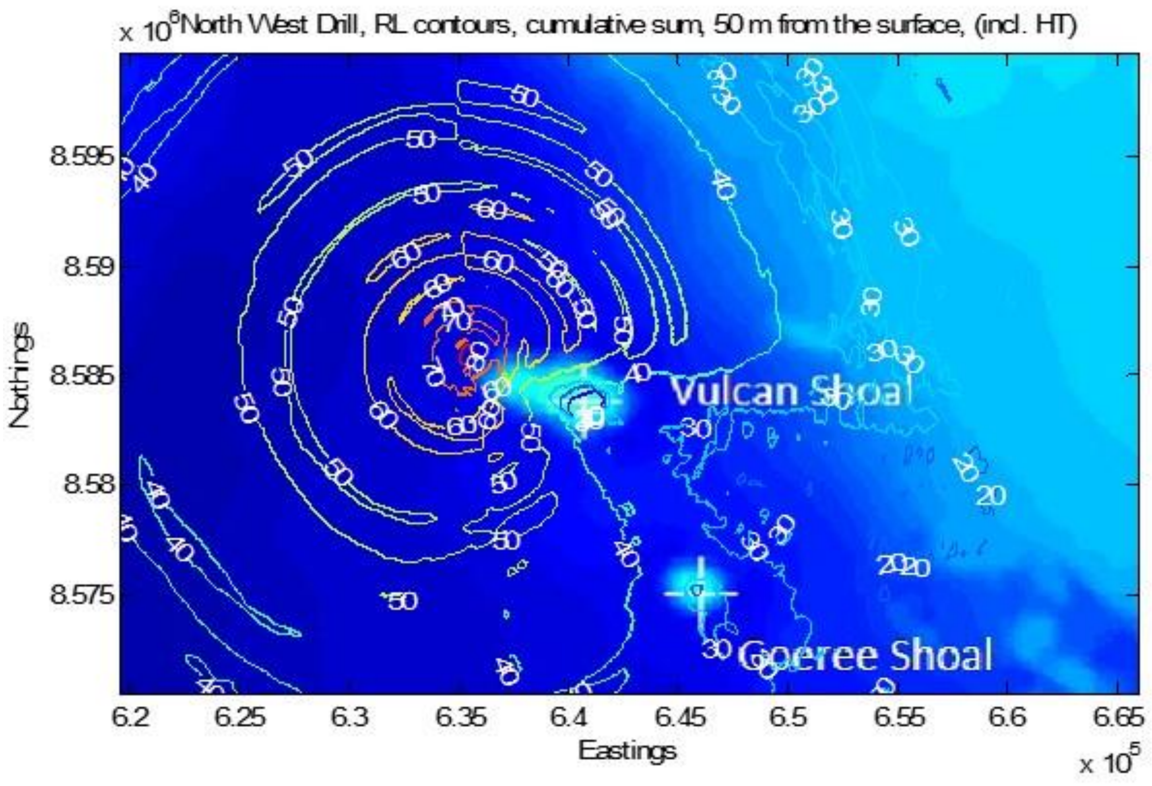


K: Noise Contour Showing Mmf-Weighted $L_{E,p}$ for Eugene McDermott Shoal Drill Rig

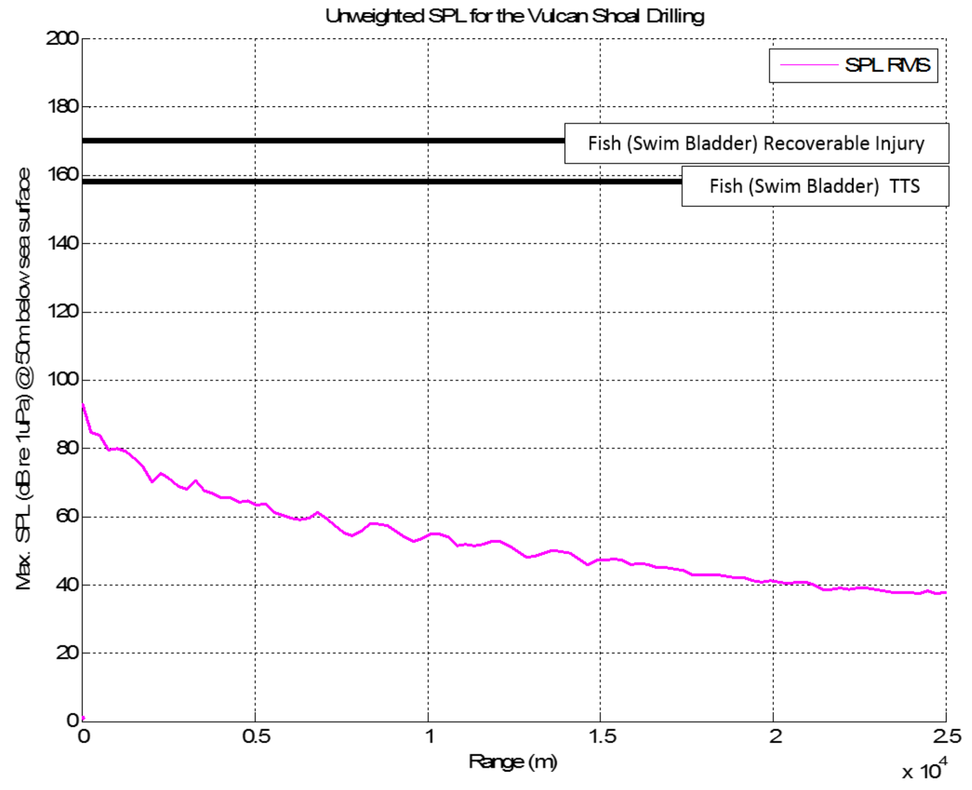


L: Maximum Mmf-Weighted $L_{E,p}$ versus Range for Eugene McDermott Shoal Drill Rig

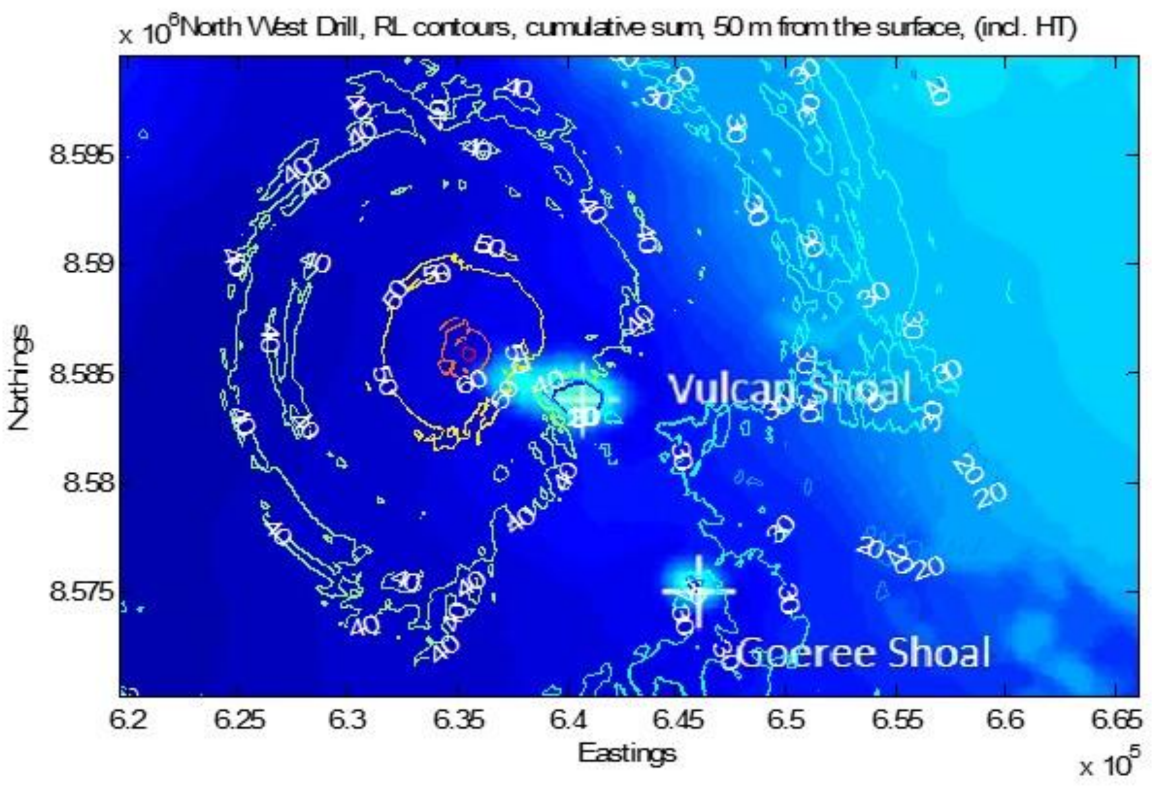
4.2.2 Drill Rig in Proximity to Vulcan Shoal (outside 1 km buffer)



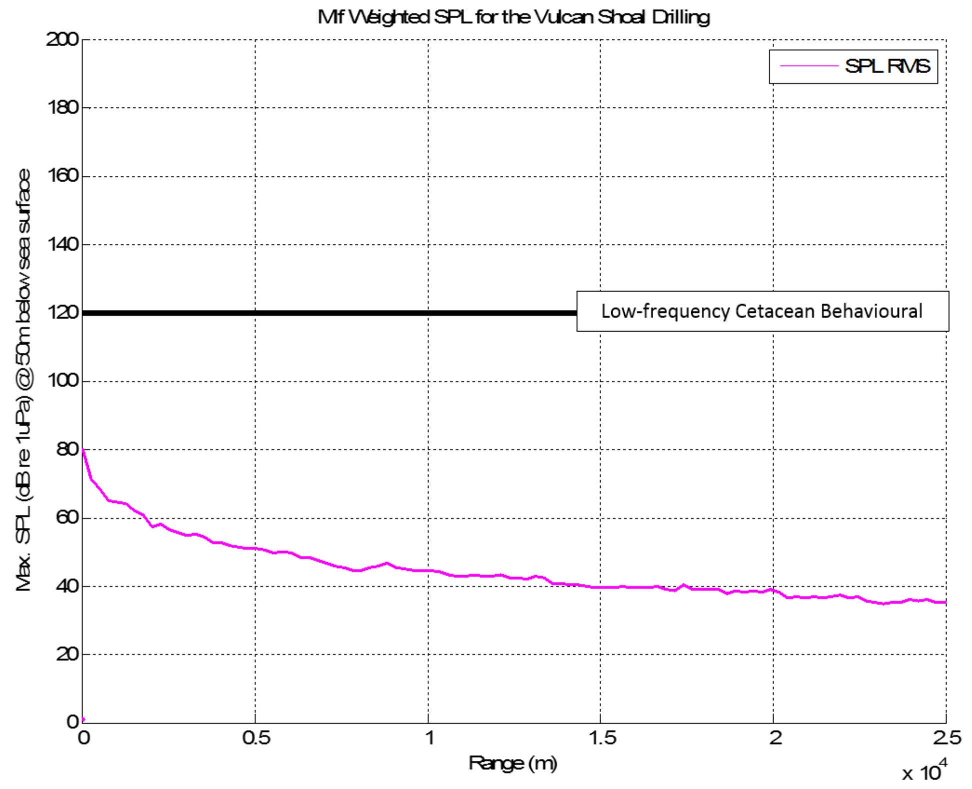
A: Noise Contour Showing Unweighted L_p for Vulcan Shoal Drill Rig



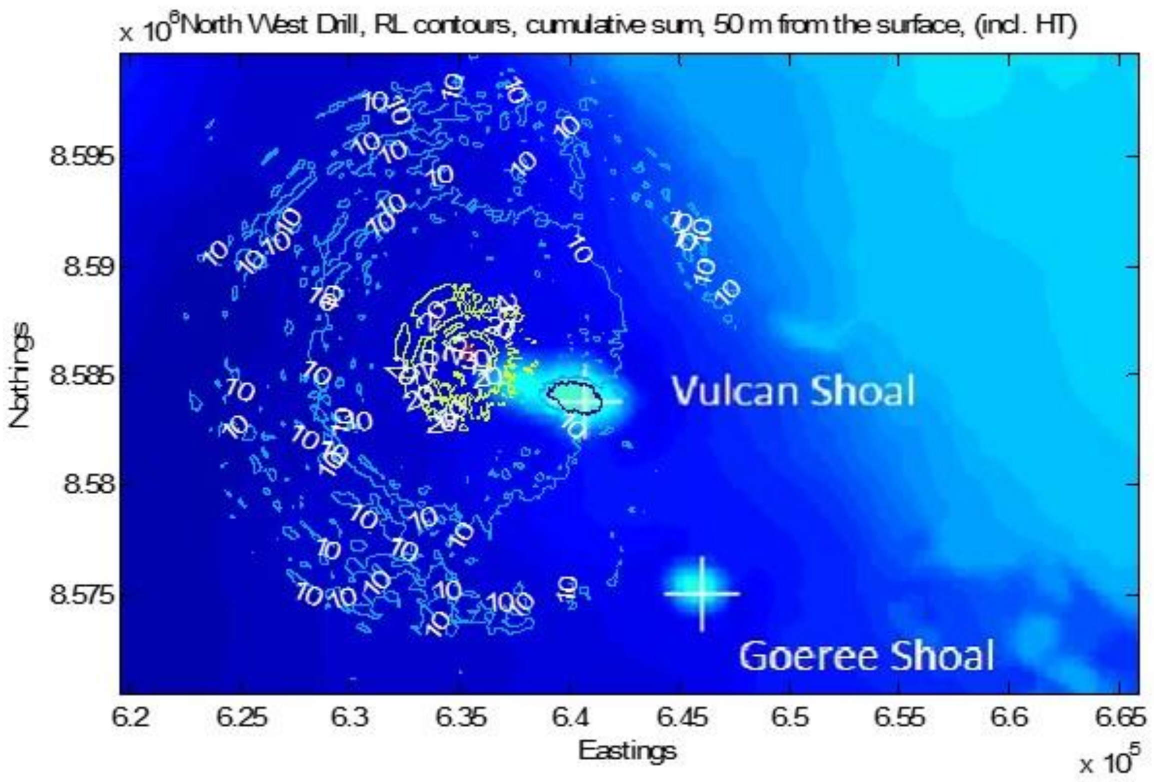
B: Maximum Unweighted L_p versus Range for Vulcan Shoal Drill Rig



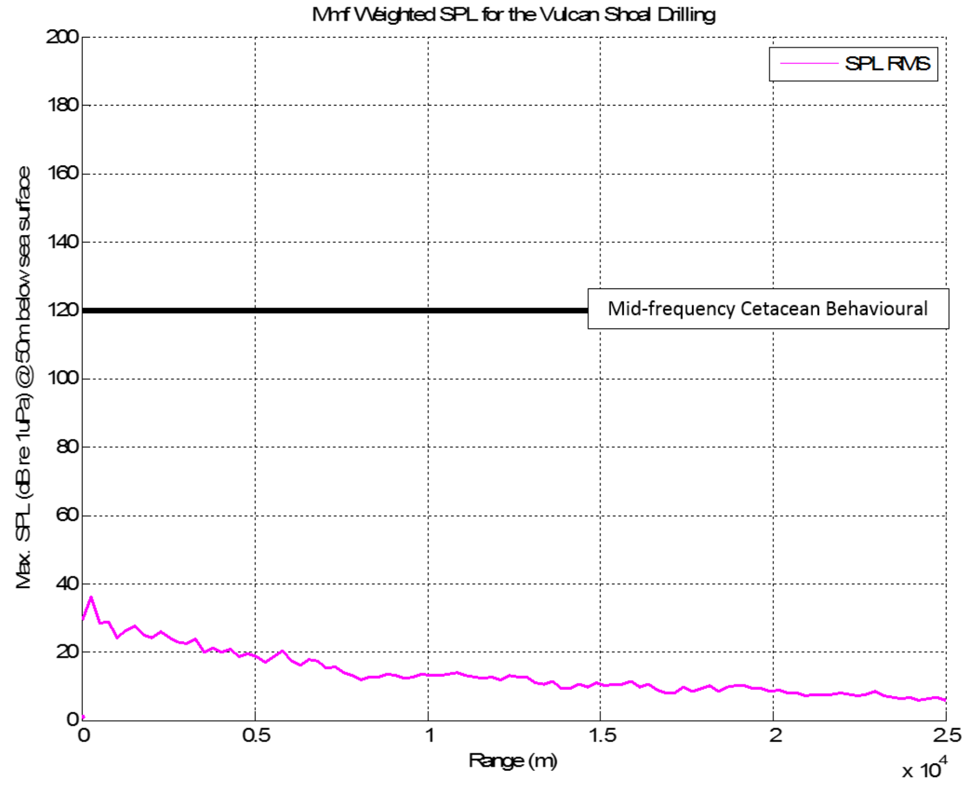
C: Noise Contour Showing Mlf-Weighted L_p for Vulcan Shoal Drill Rig



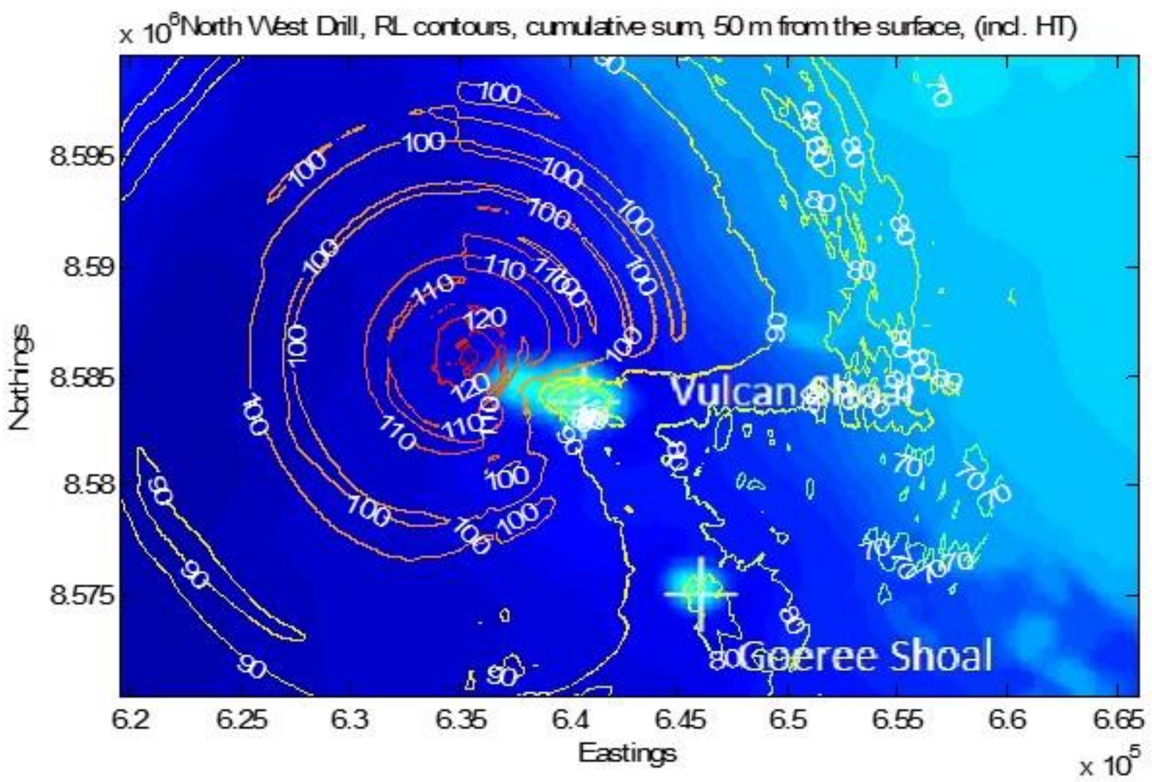
D: Maximum Mlf-Weighted L_p versus Range for Vulcan Shoal Drill Rig



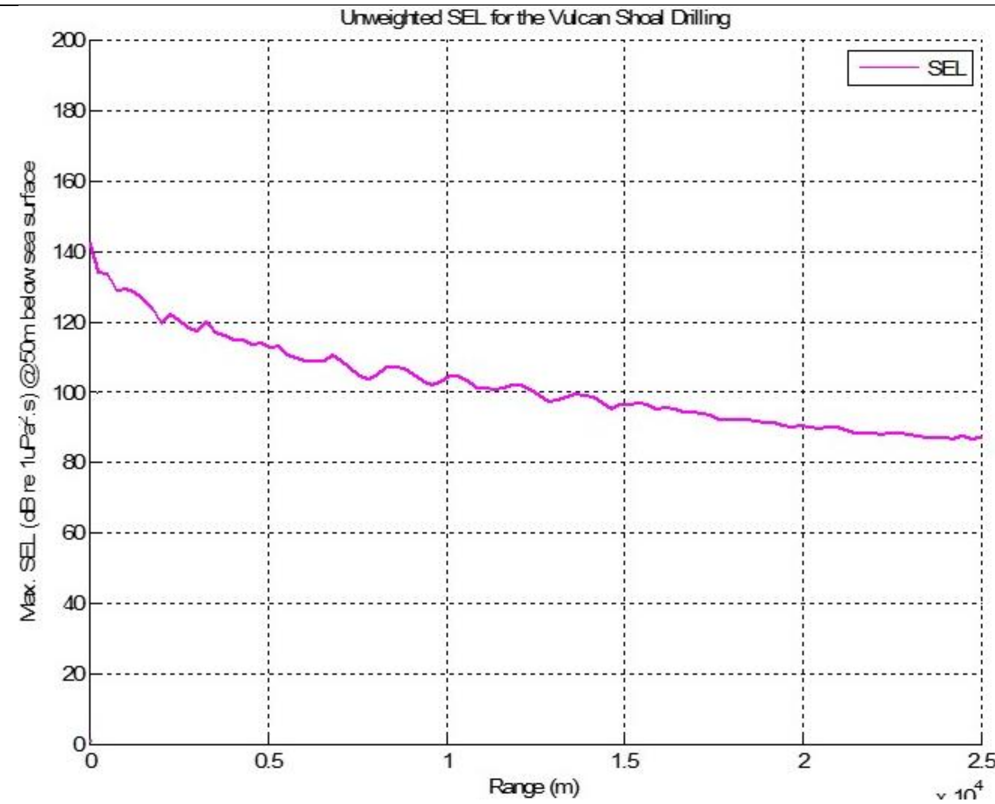
E: Noise Contour Showing Mmf-Weighted L_p for Vulcan Shoal Drill Rig



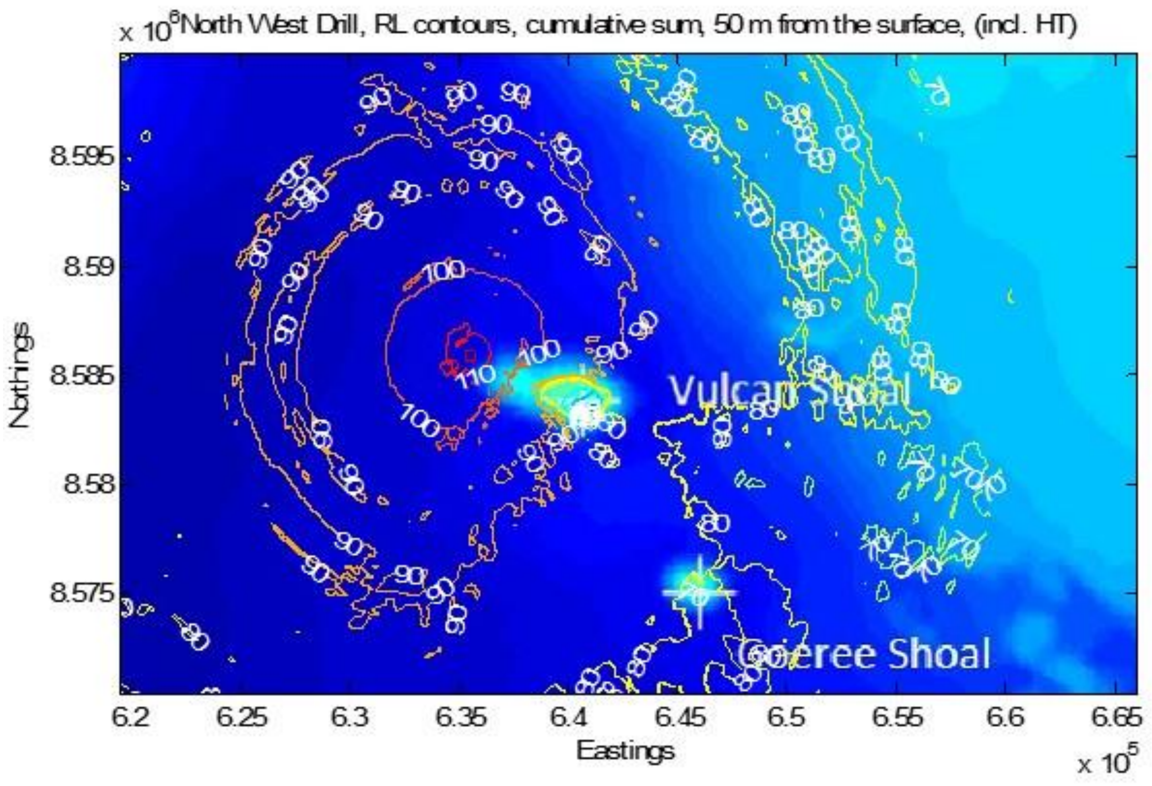
F: Maximum Mmf-Weighted L_p versus Range for Vulcan Shoal Drill Rig



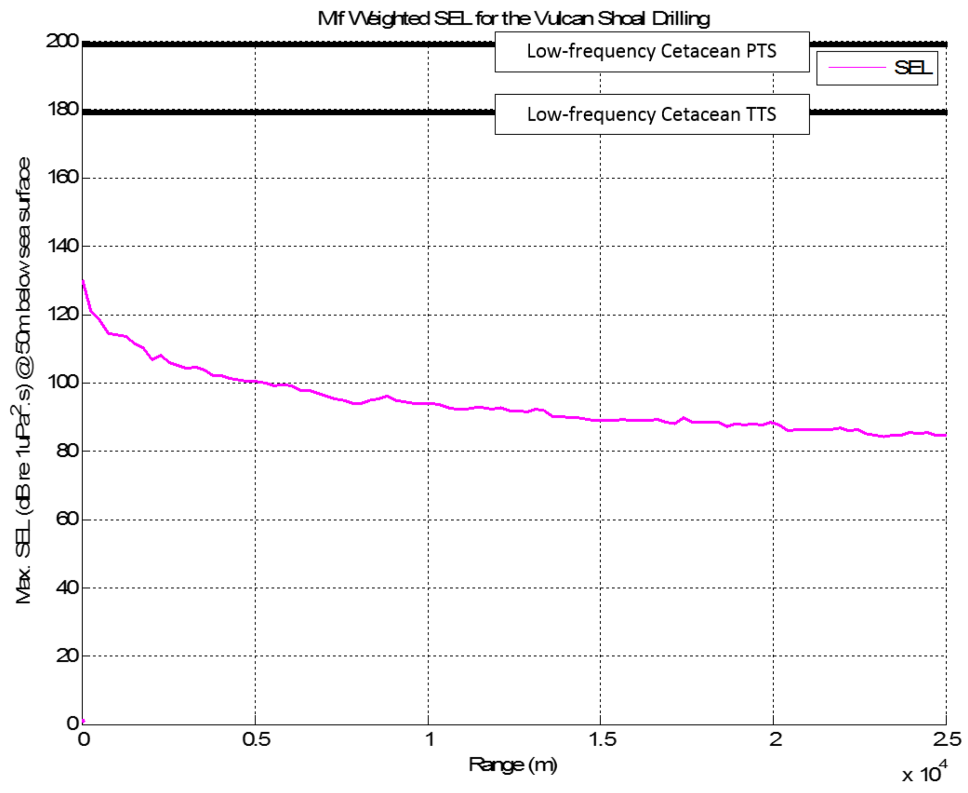
G: Noise Contour Showing Unweighted $L_{E,p}$ for Vulcan Shoal Drill Rig



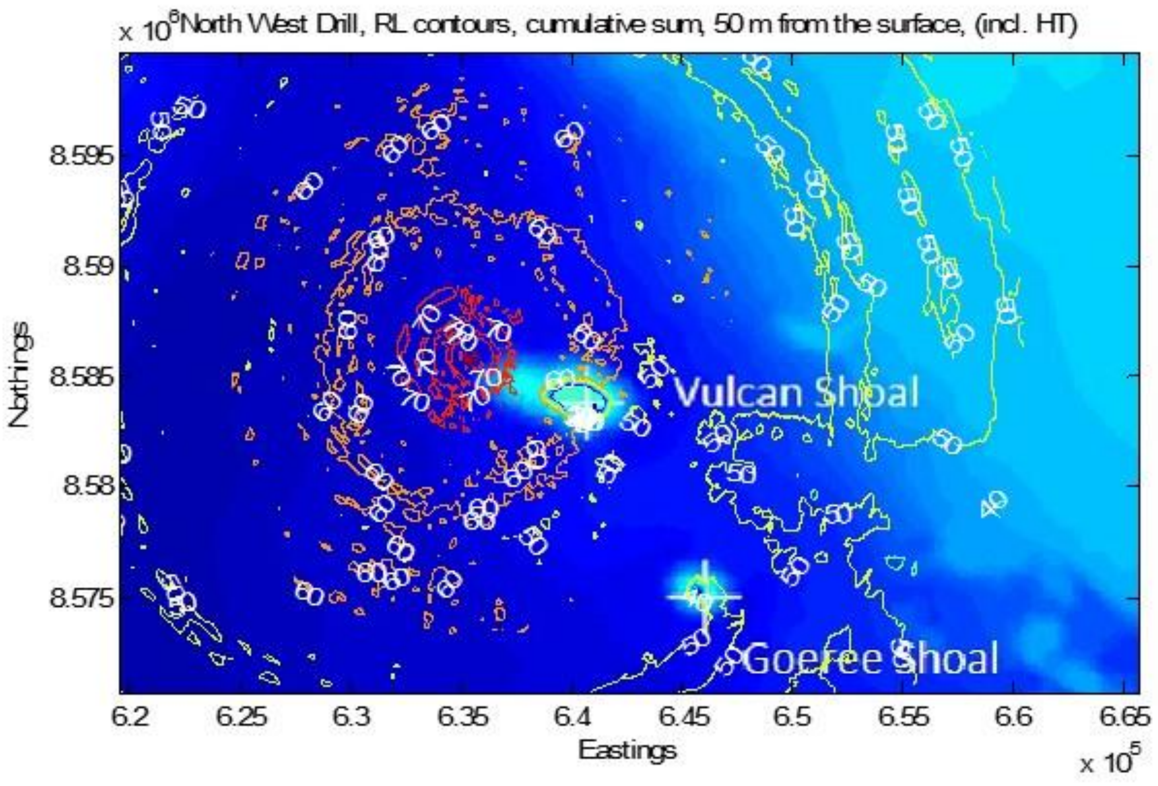
H: Maximum Unweighted $L_{E,p}$ versus Range for Vulcan Shoal Drill Rig



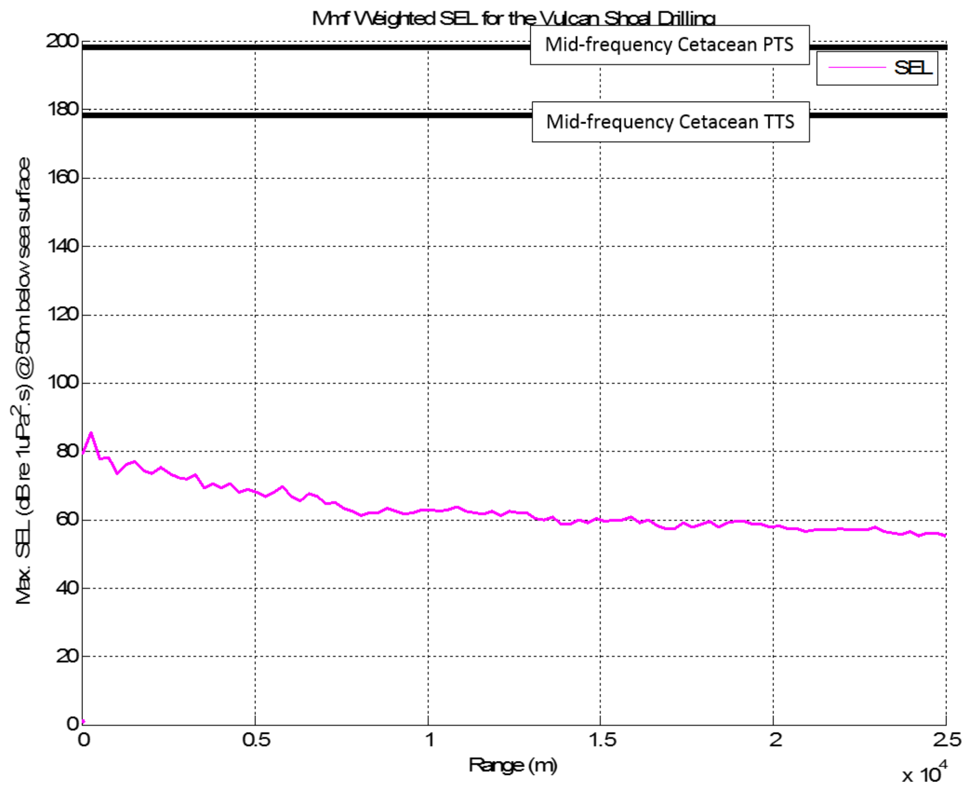
I: Noise Contour Showing Mlf-Weighted $L_{E,p}$ for Vulcan Shoal Drill Rig



J: Maximum Mlf-Weighted $L_{E,p}$ versus Range for Vulcan Shoal Drill Rig

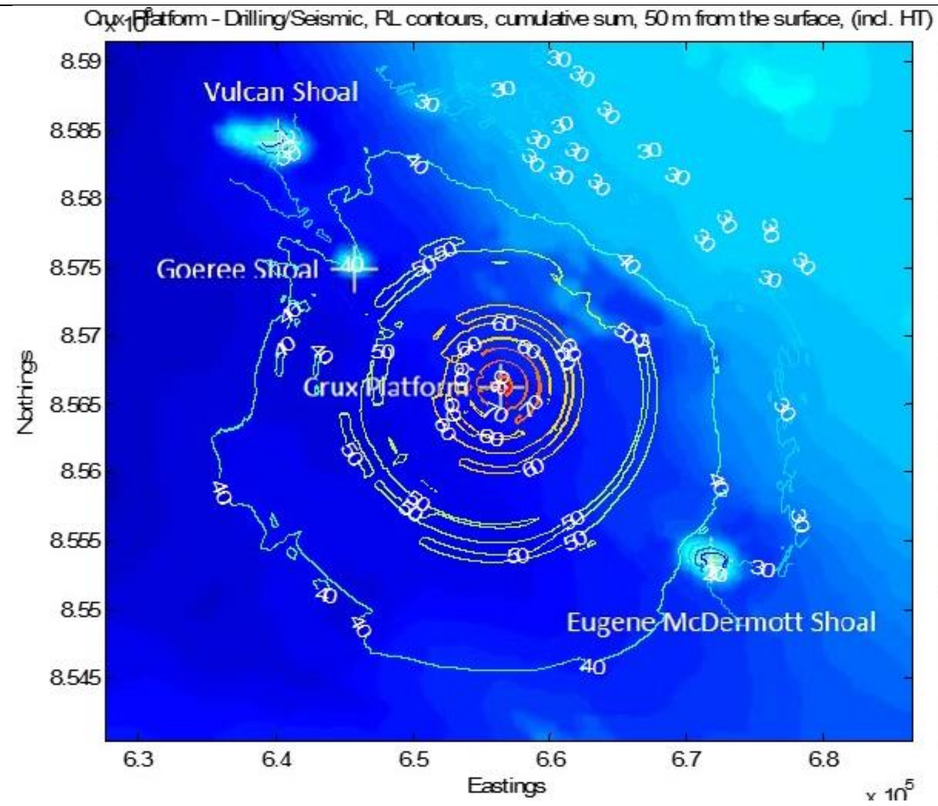


K: Noise Contour Showing Mmf-Weighted $L_{E,p}$ for Vulcan Shoal Drill Rig

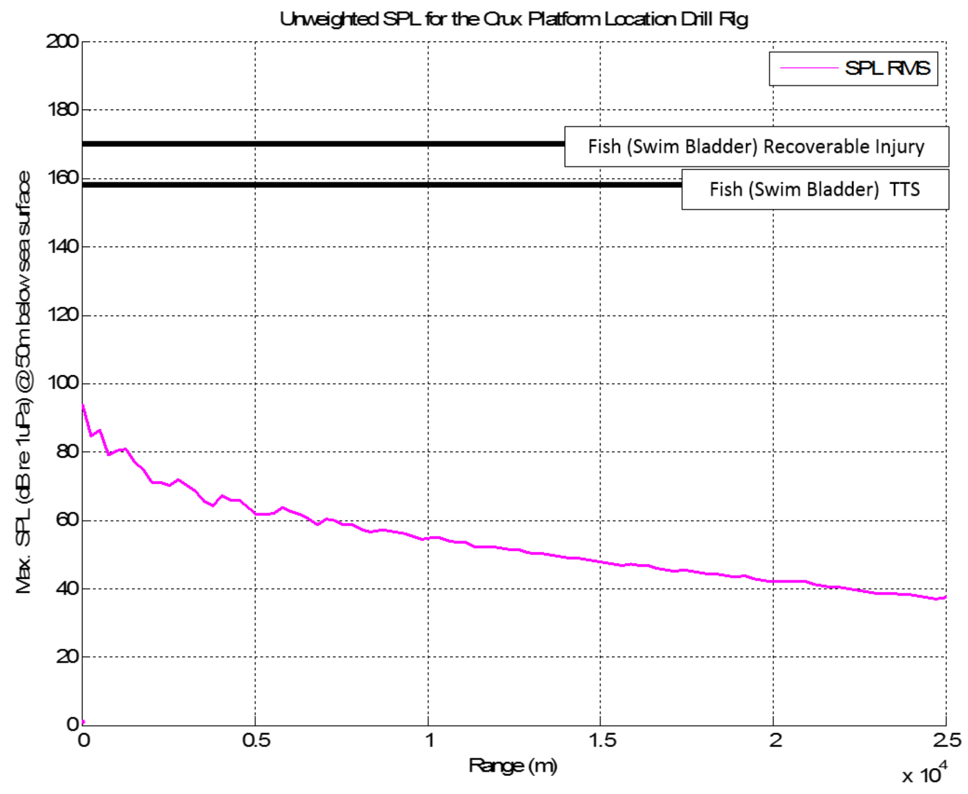


L: Maximum Mmf-Weighted $L_{E,p}$ versus Range for Vulcan Shoal Drill Rig

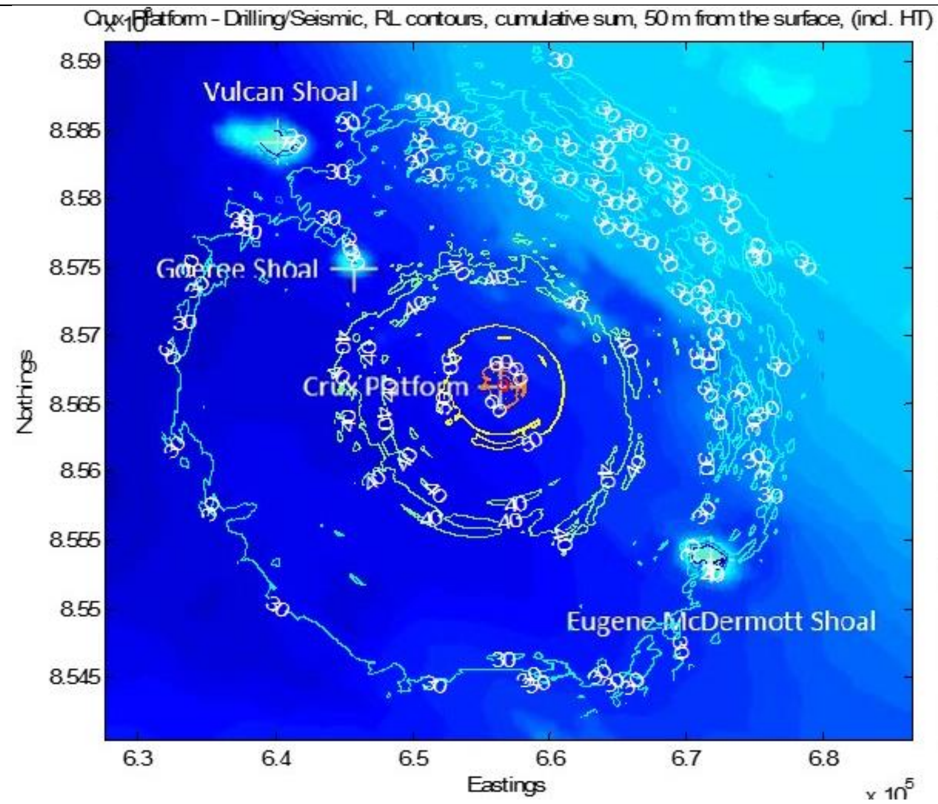
4.2.3 Drilling from Crux Platform Location



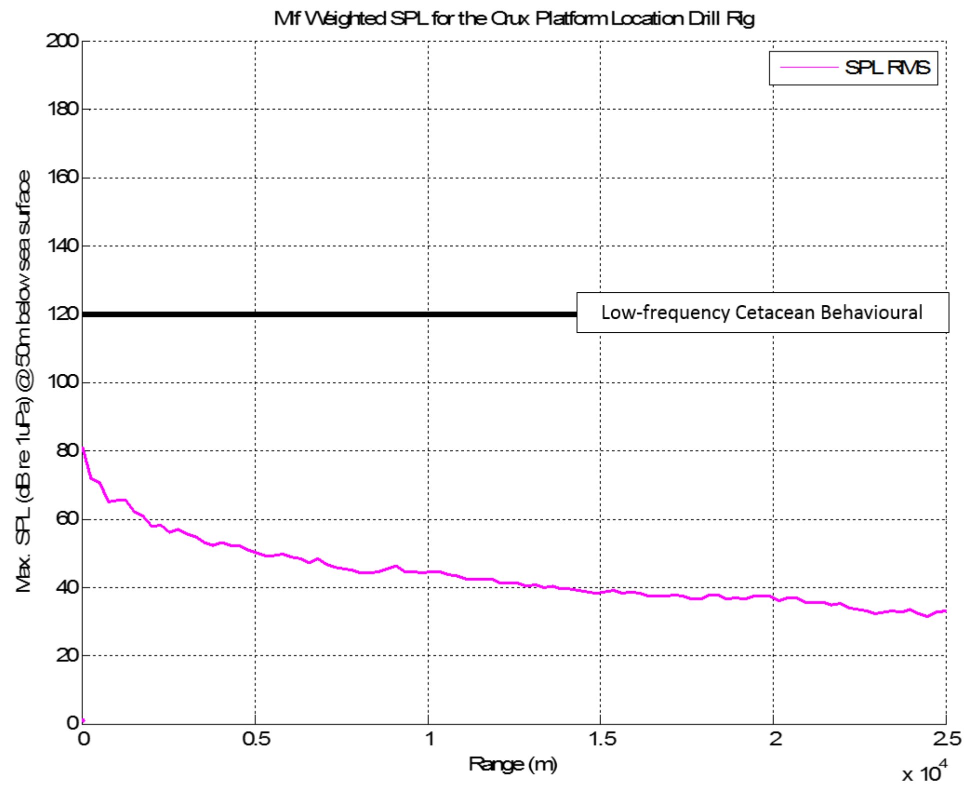
A: Noise Contour Showing Unweighted L_p for Drilling at Crux Platform



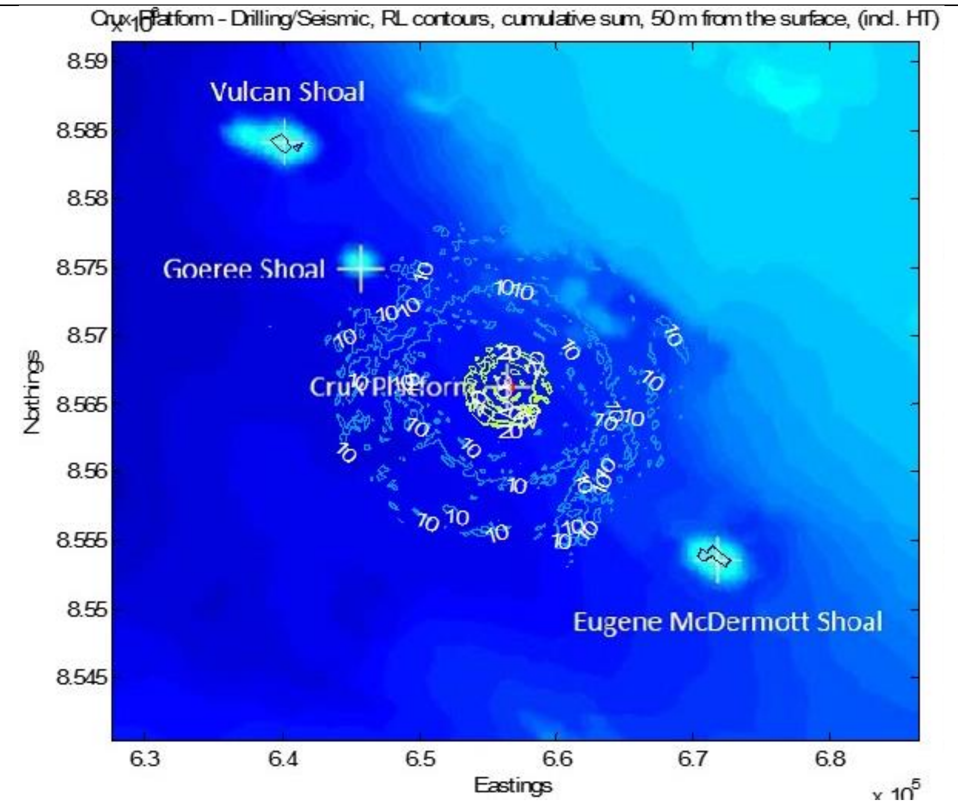
B: Maximum Unweighted L_p versus Range for Drilling at Crux Platform



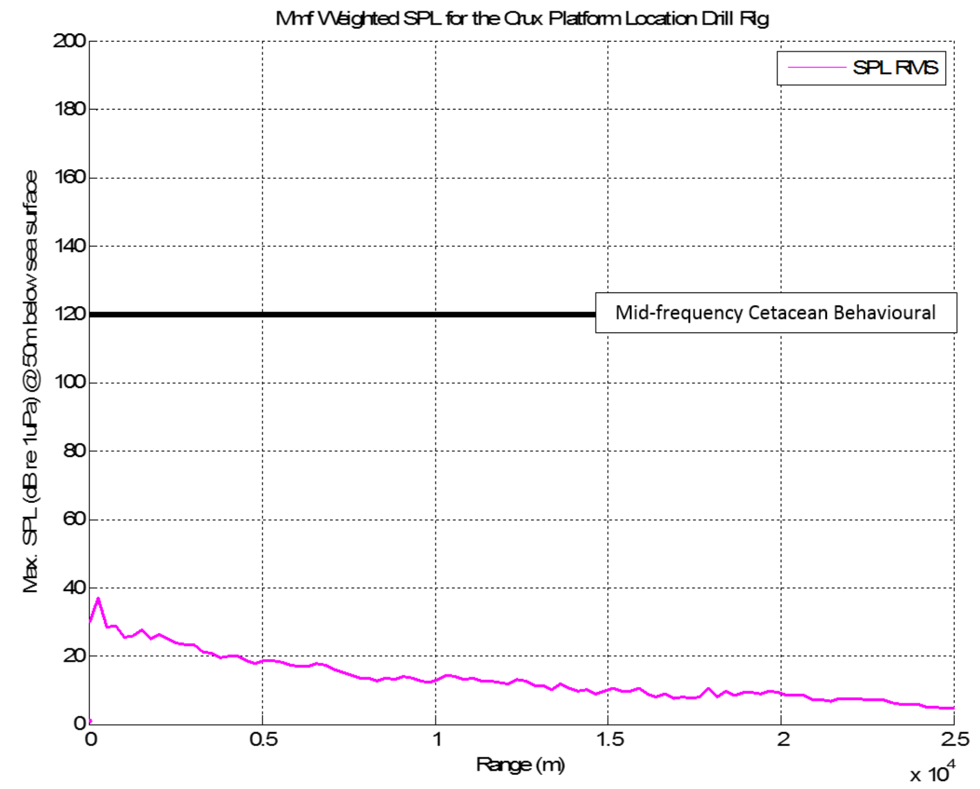
C: Noise Contour Showing Mlf-Weighted L_p for Drilling at Crux Platform



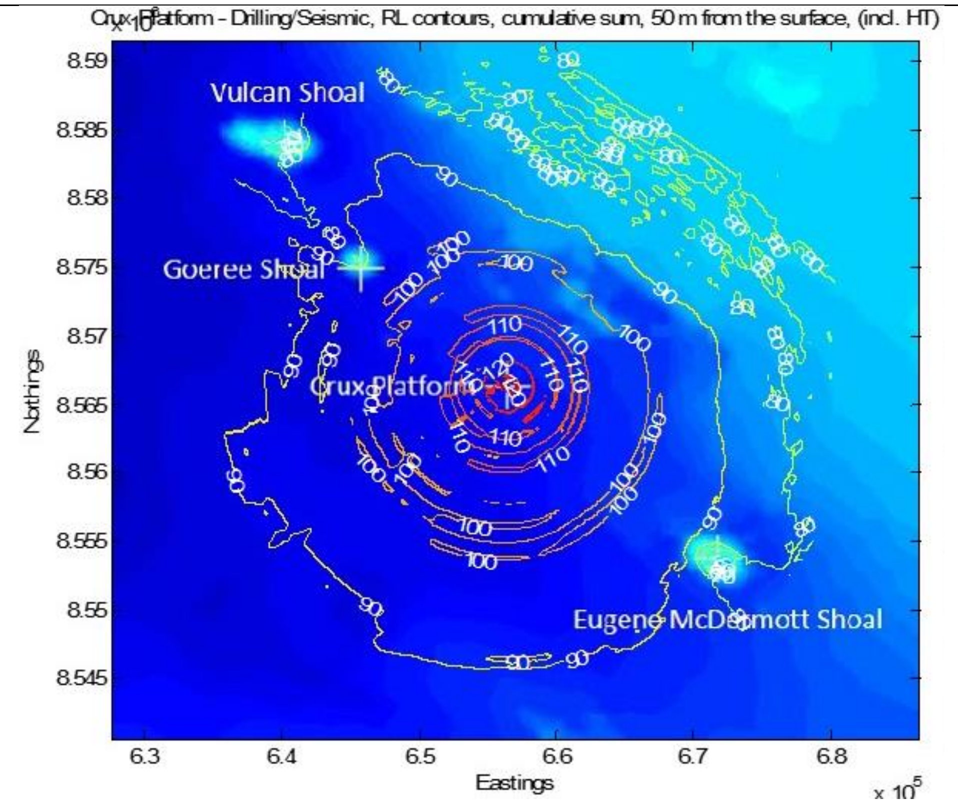
D: Maximum Mlf-Weighted L_p versus Range for Drilling at Crux Platform



E: Noise Contour Showing Mmf-Weighted L_p for Drilling at Crux Platform

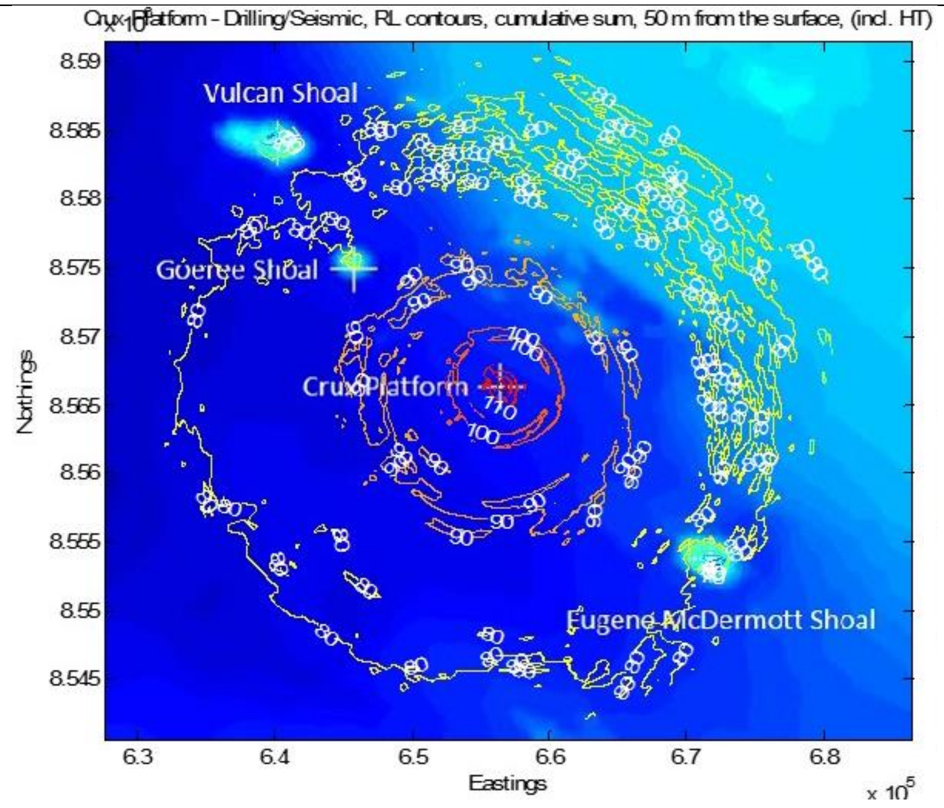


F: Maximum Mmf-Weighted L_p versus Range for Drilling at Crux Platform

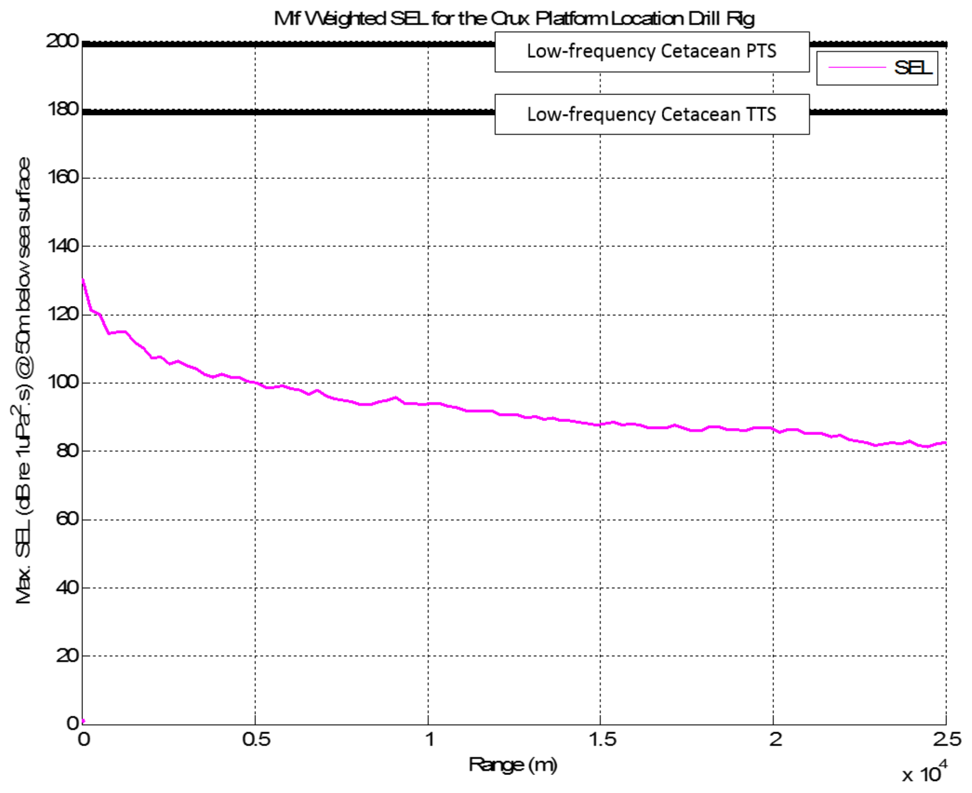


G: Noise Contour Showing Unweighted $L_{E,p}$ for Drilling at Crux Platform

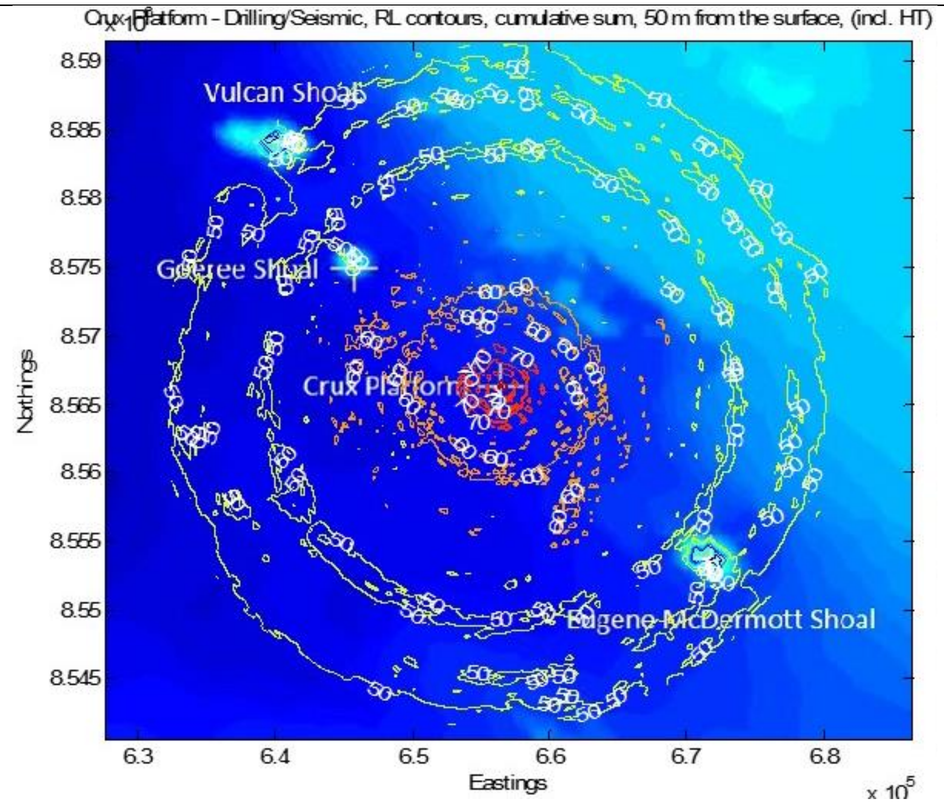
H: Maximum Unweighted $L_{E,p}$ versus Range for Drilling at Crux Platform



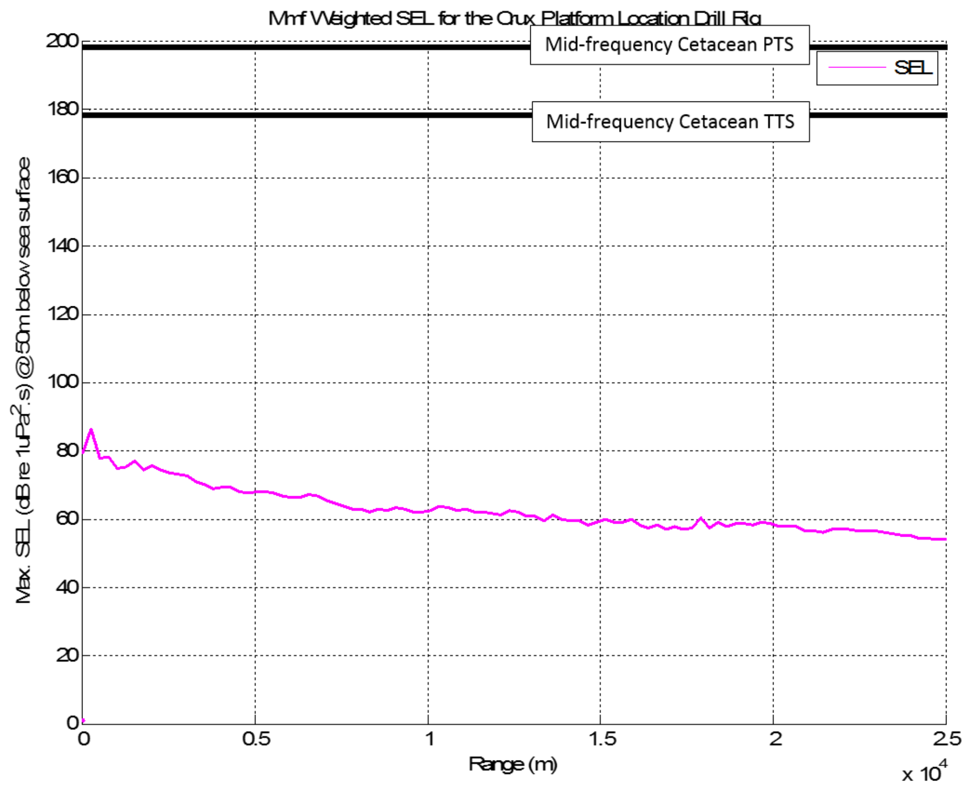
I: Noise Contour Showing Mlf-Weighted $L_{E,p}$ for Drilling at Crux Platform



J: Maximum Mlf-Weighted $L_{E,p}$ versus Range for Drilling at Crux Platform



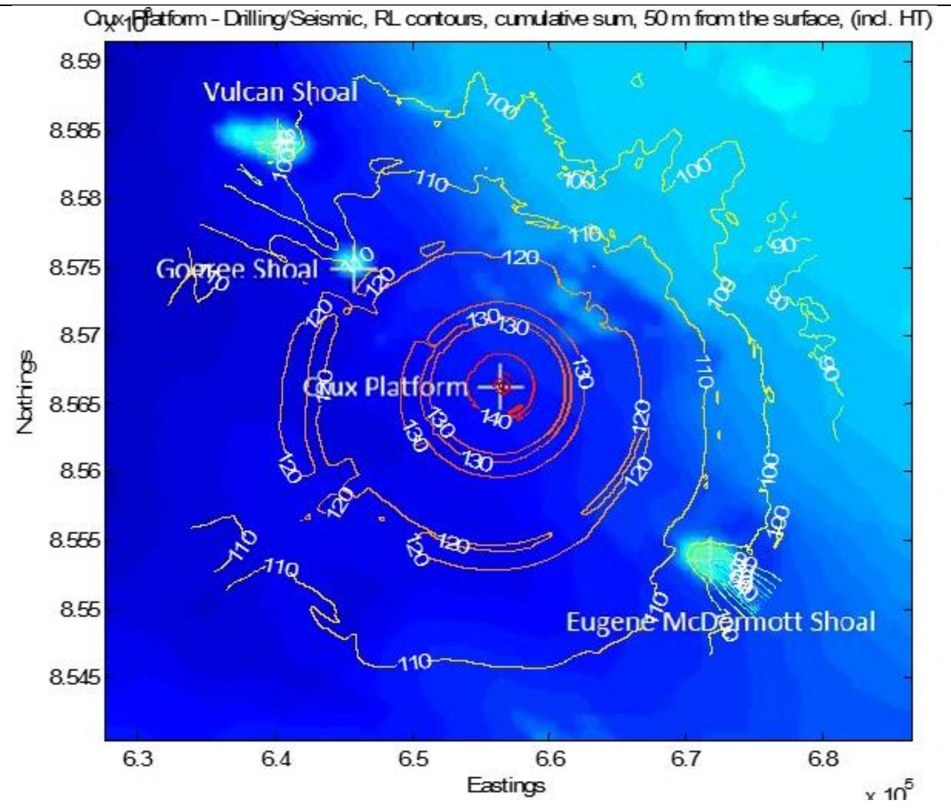
K: Noise Contour Showing Mmf-Weighted $L_{E,p}$ for Drilling at Crux Platform



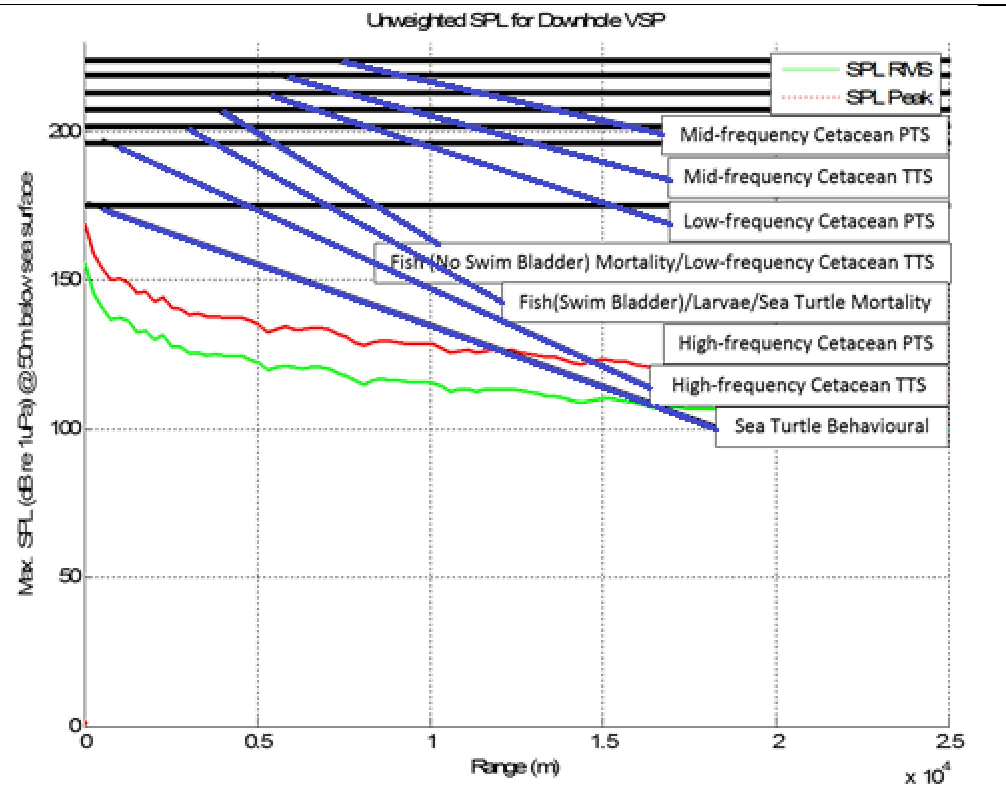
L: Maximum Mmf-Weighted $L_{E,p}$ versus Range for Drilling at Crux Platform

4.3 Downhole VSP

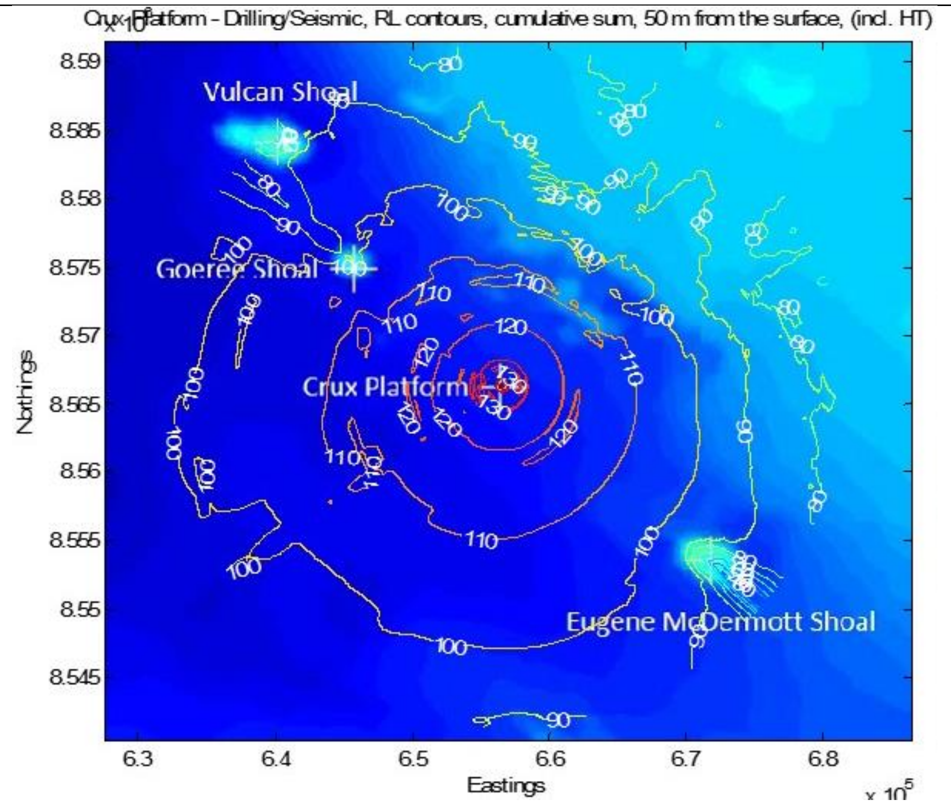
4.3.1 Sound Pressure Level for VSP activities (airgun)



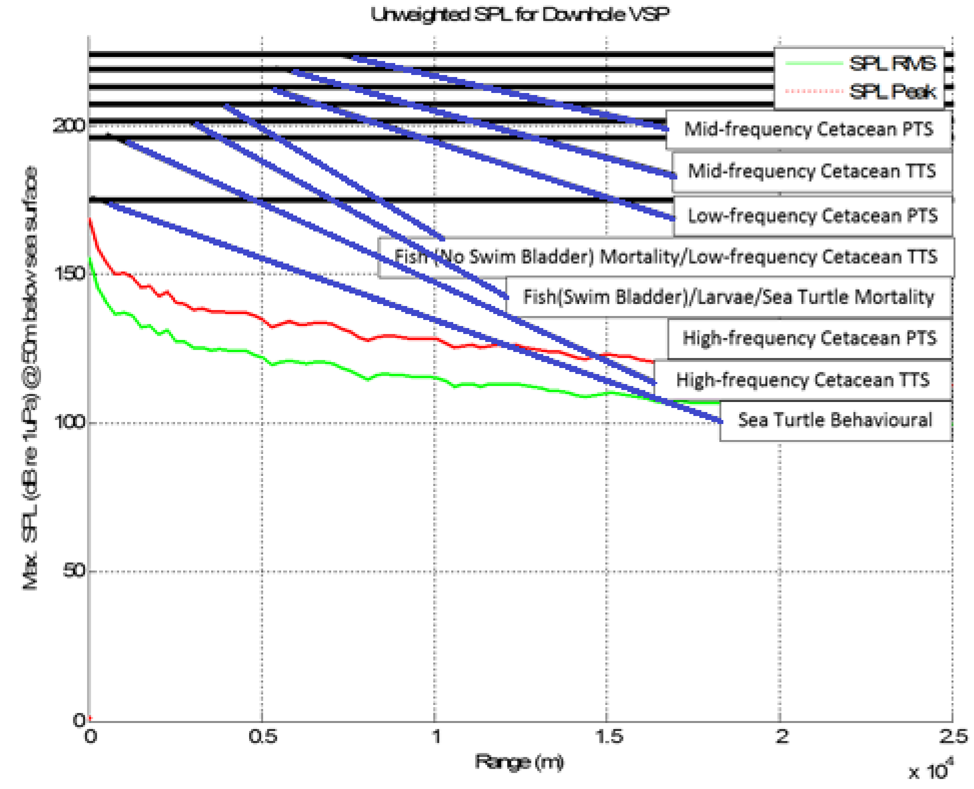
A: Noise Contour Showing L_{pk} for VSP



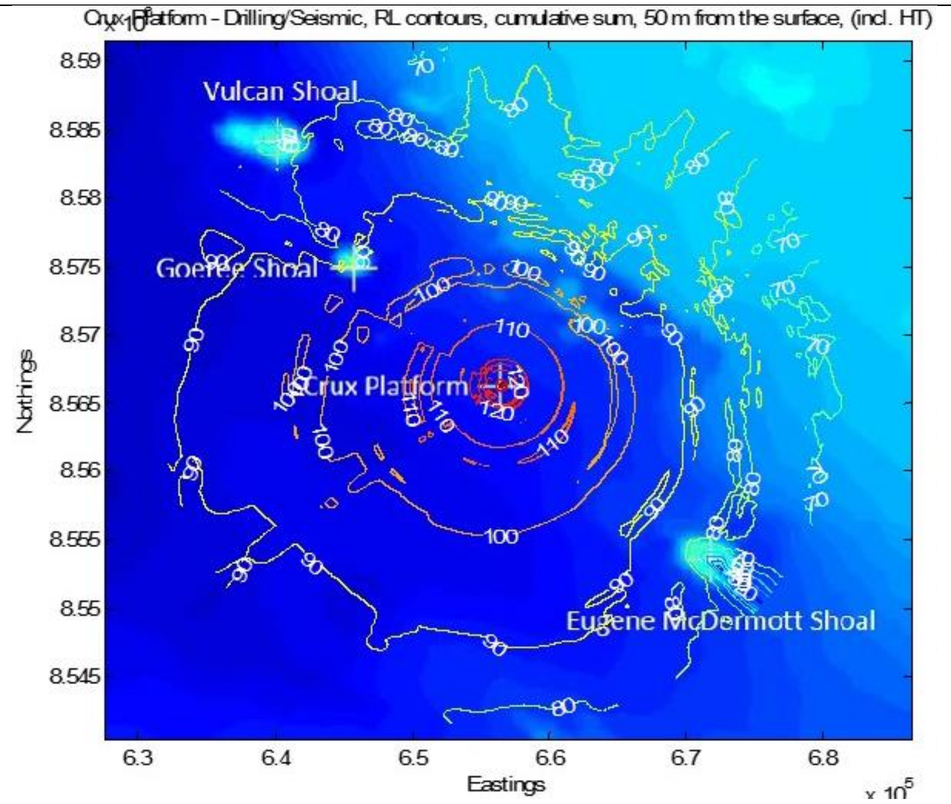
B: Maximum Unweighted L_p versus Range for VSP



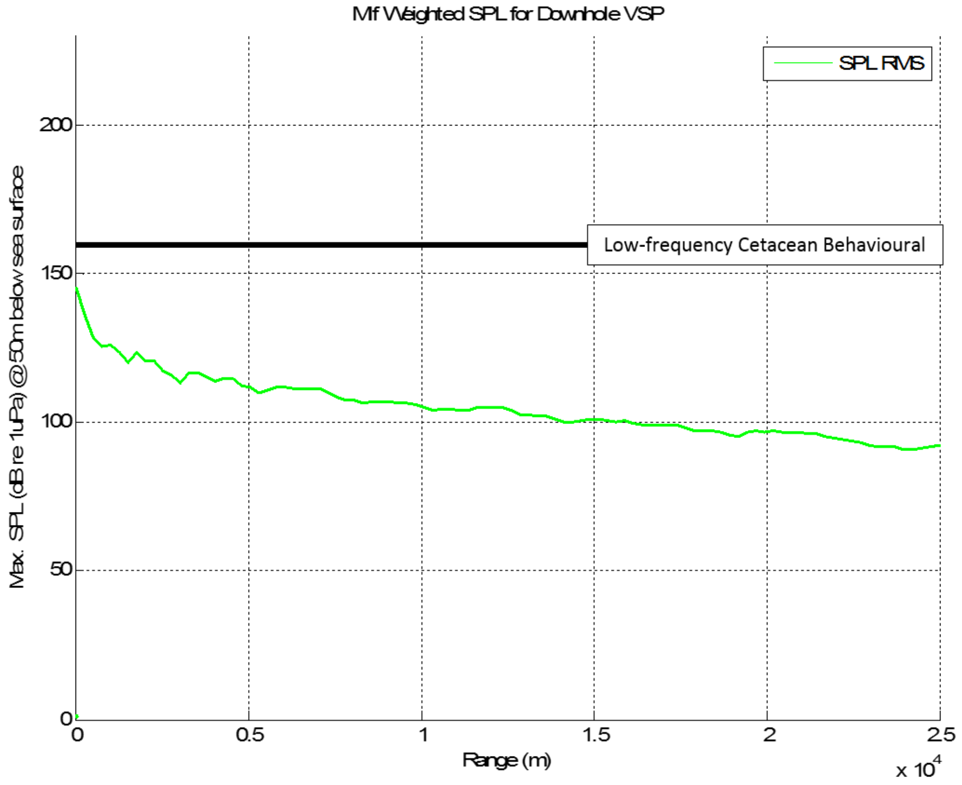
C: Noise Contour Showing Unweighted L_p for VSP



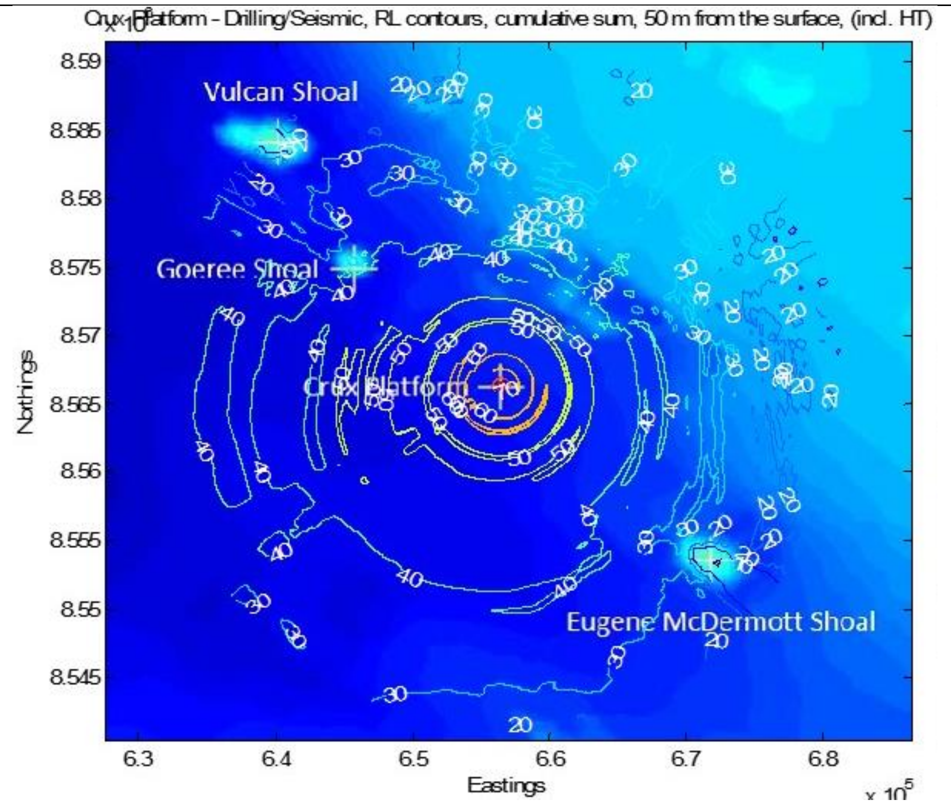
D: Maximum Unweighted L_p versus Range for VSP



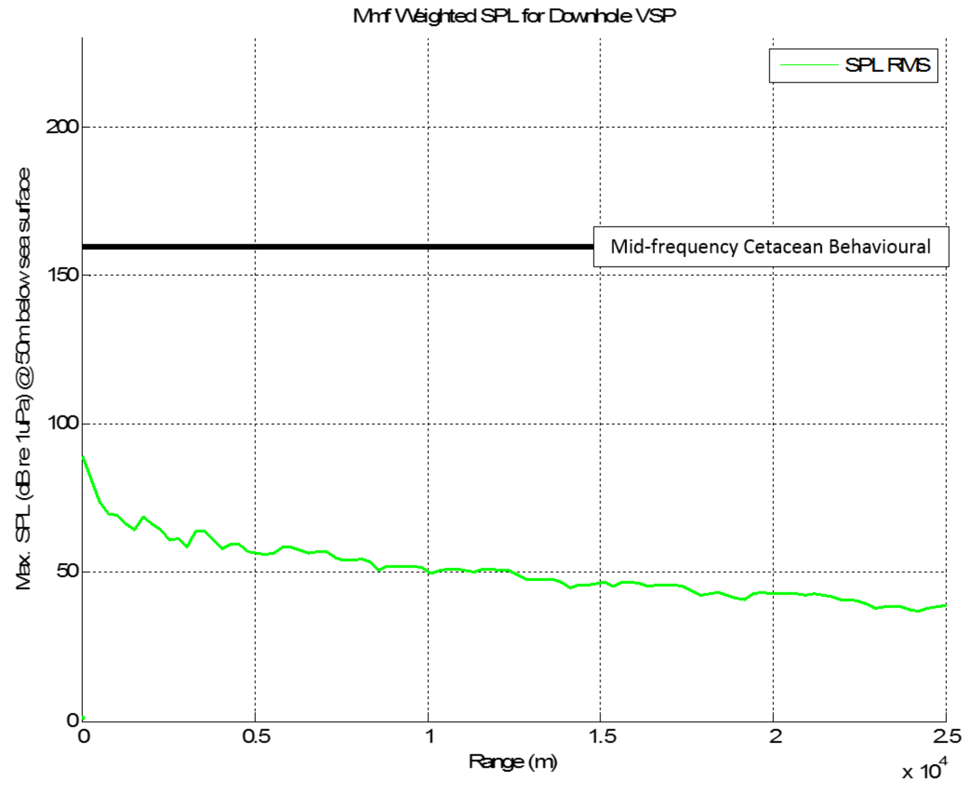
E: Noise Contour Showing Mlf-Weighted L_p for VSP



F: Maximum Mlf-Weighted L_p versus Range for VSP

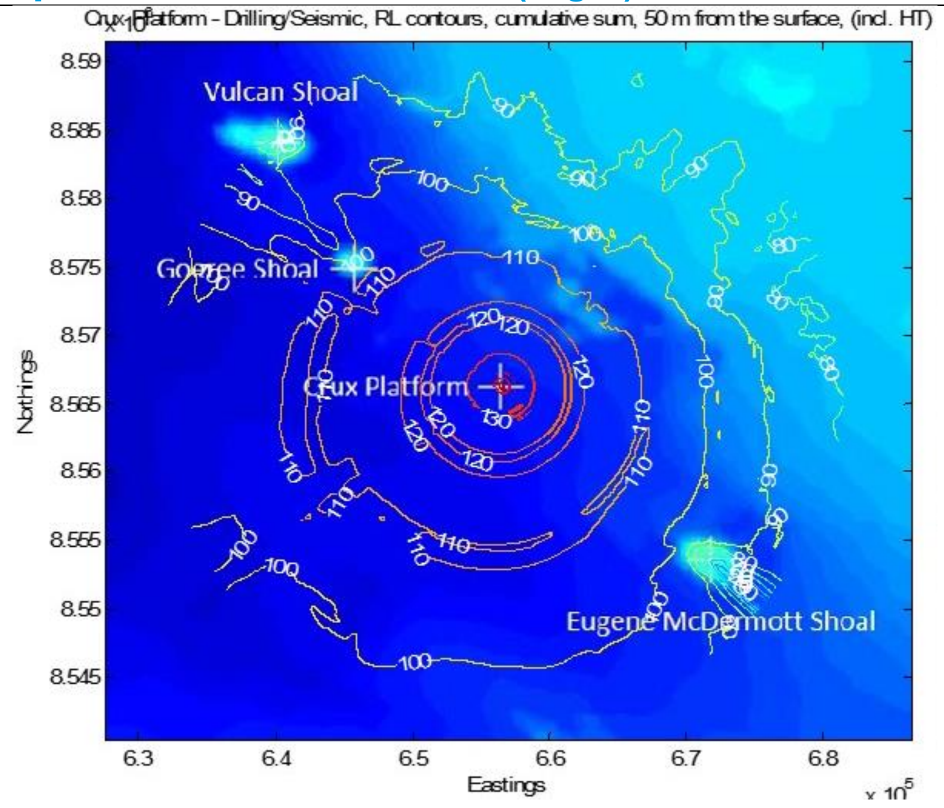


G: Noise Contour Showing Mmf-Weighted L_p for VSP

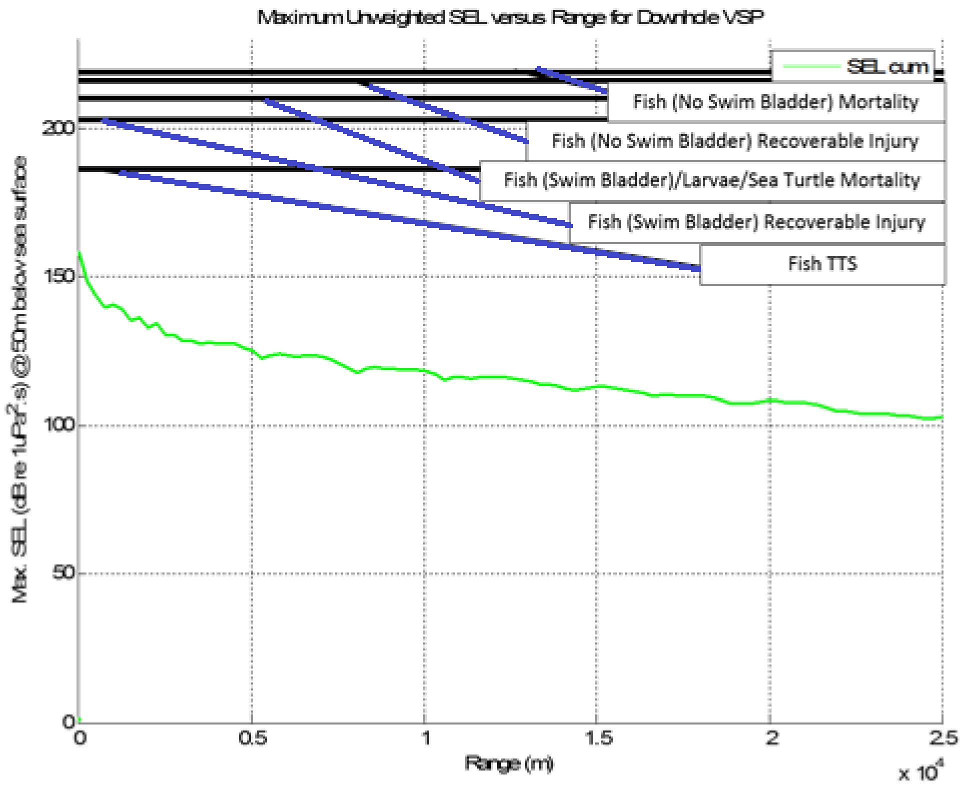


H: Maximum Mmf-Weighted L_p versus Range for VSP

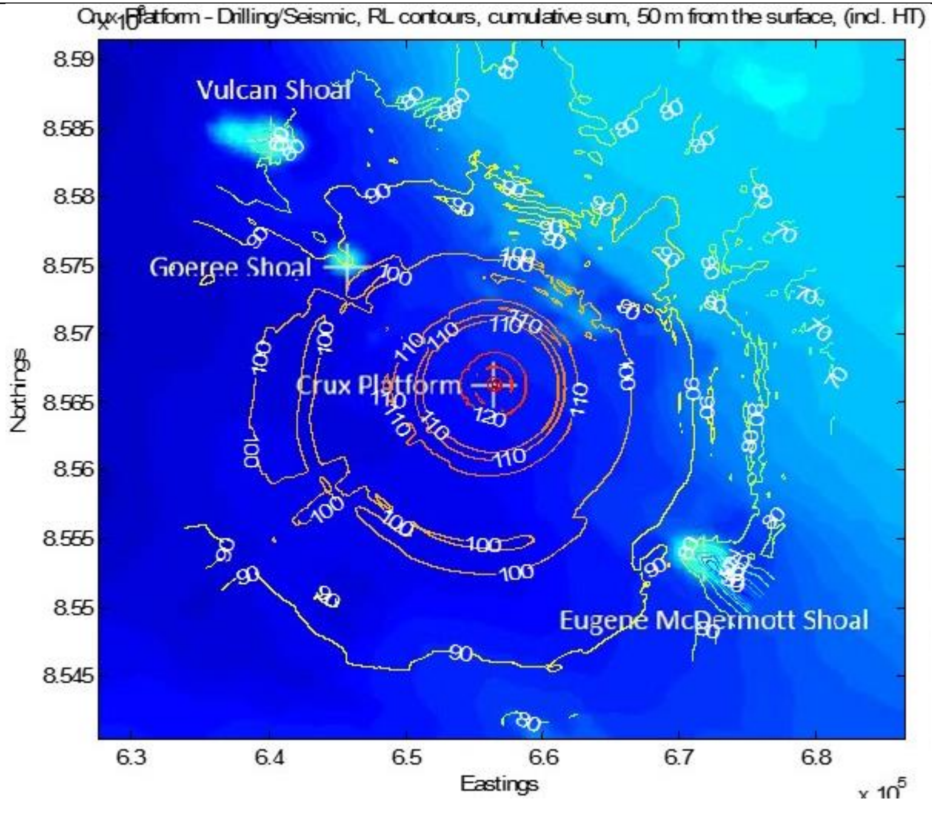
4.3.2 Sound Exposure Level for VSP activities (airgun)



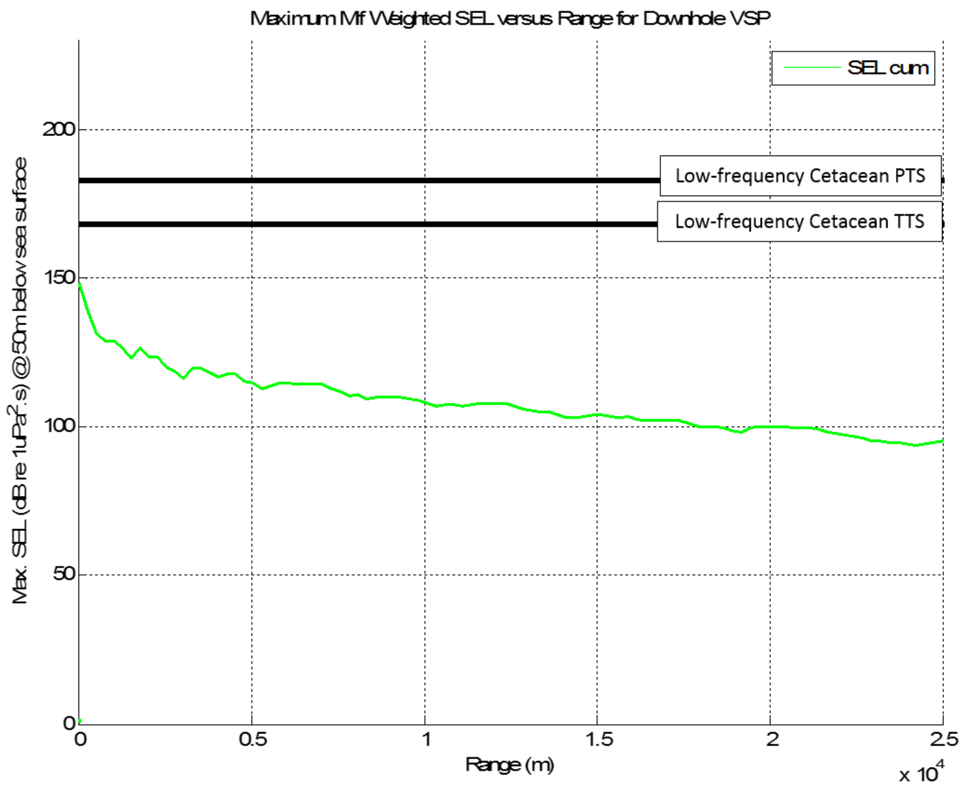
A: Noise Contour Showing Unweighted $L_{E,p}$ for VSP



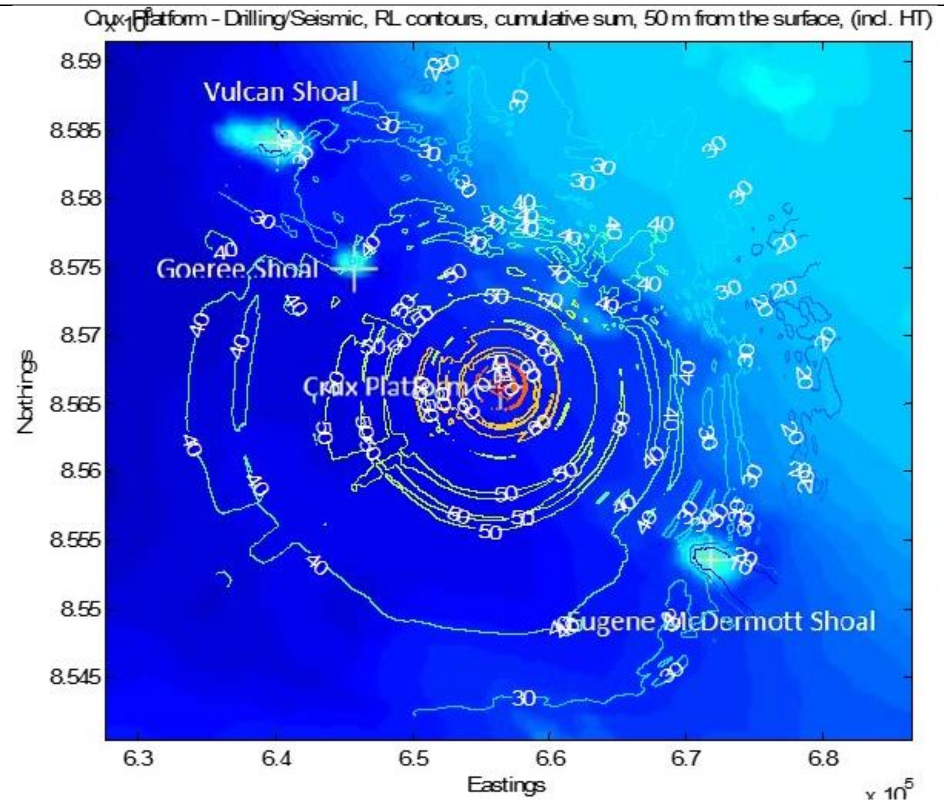
B: Maximum Unweighted $L_{E,p}$ versus Range for VSP



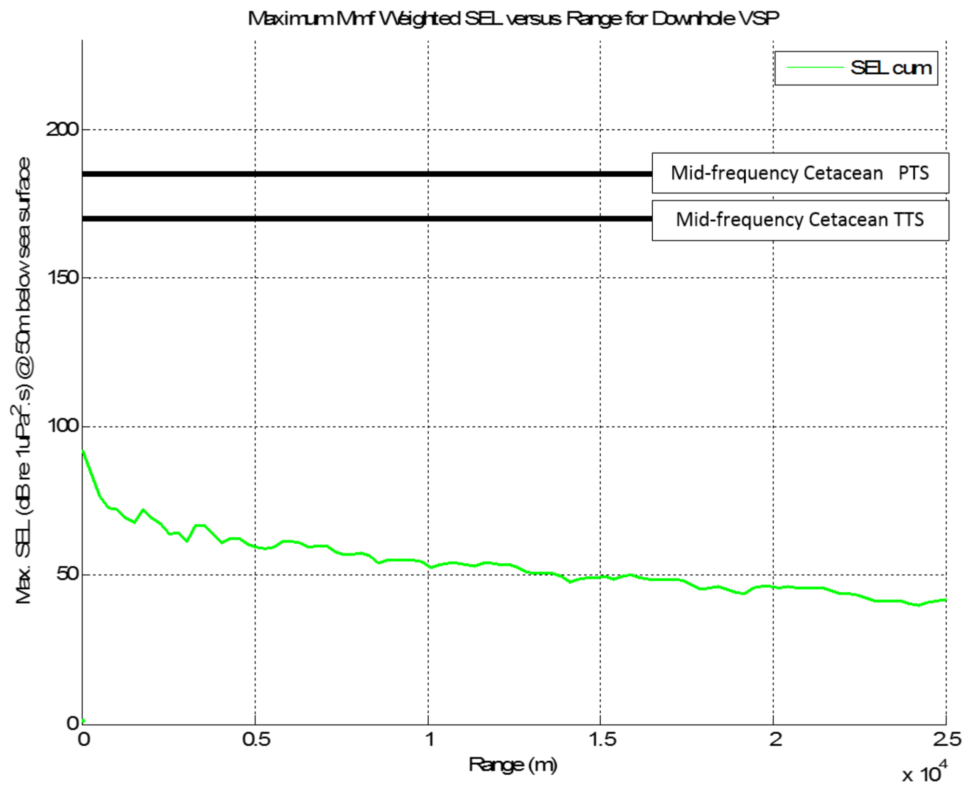
C: Noise Contour Showing Mlf-Weighted $L_{E,p}$ for VSP



D: Maximum Mlf-Weighted $L_{E,p}$ versus Range for VSP



E: Noise Contour Showing Mmf-Weighted $L_{E,p}$ for VSP



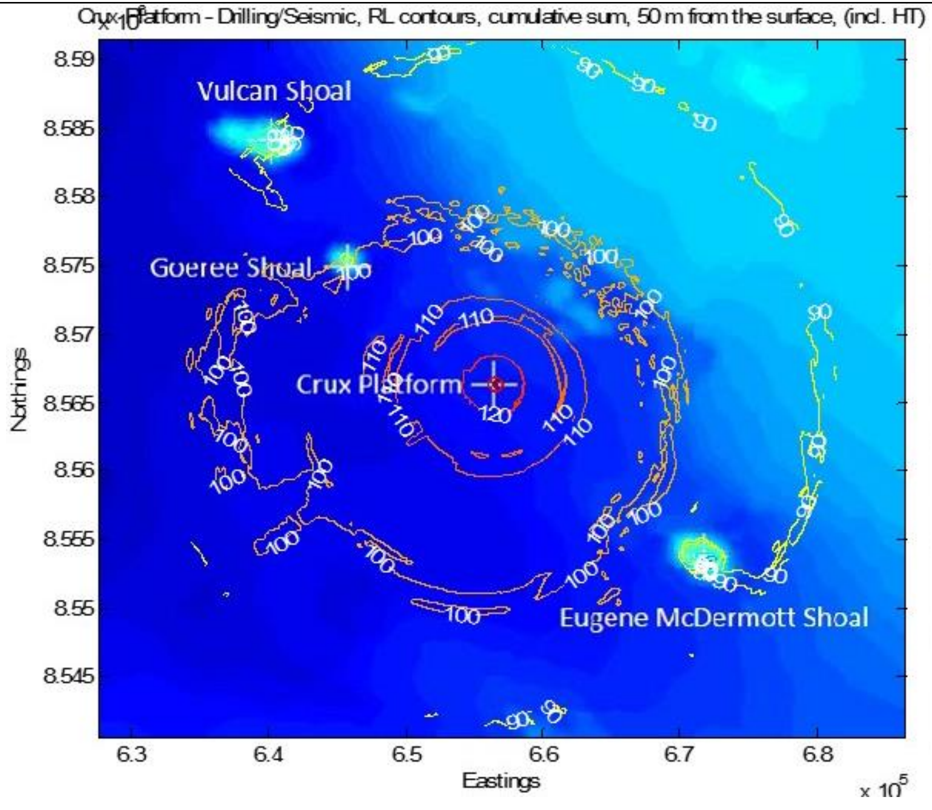
F: Maximum Mmf-Weighted $L_{E,p}$ versus Range for VSP

4.4 Operational Noise Levels

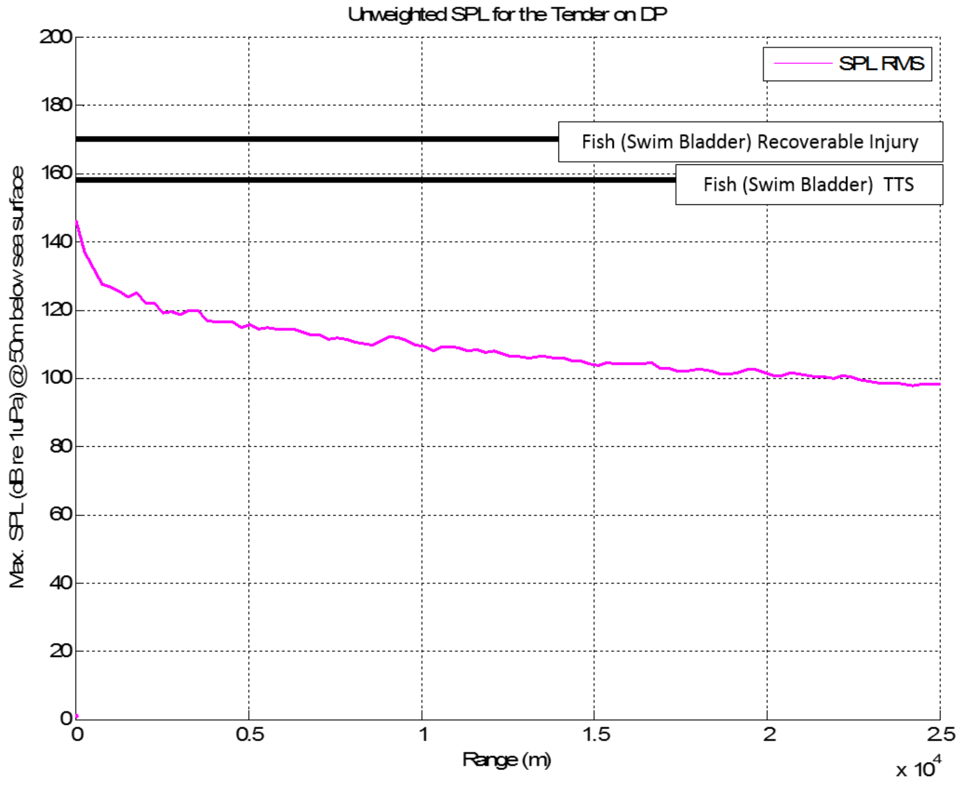
The following charts provide the noise contour (isopleth) maps for worst case operational noise levels, based on a supply boat / tender at the Crux Platform location. Adjacent to each contour plot is a plot of level with range is provided for a representative worst-case direction. On these Level-Range plots, the criteria relevant to the that particular noise index are also plotted for ease of reference.

- Unweighted L_p;
- Marine Mammal weighted L_p;
- Unweighted $L_{E,p}$ (based on 1 hr on DP); and
- Marine Mammal weighted $L_{E,p}$ (based on 1 hr on DP).

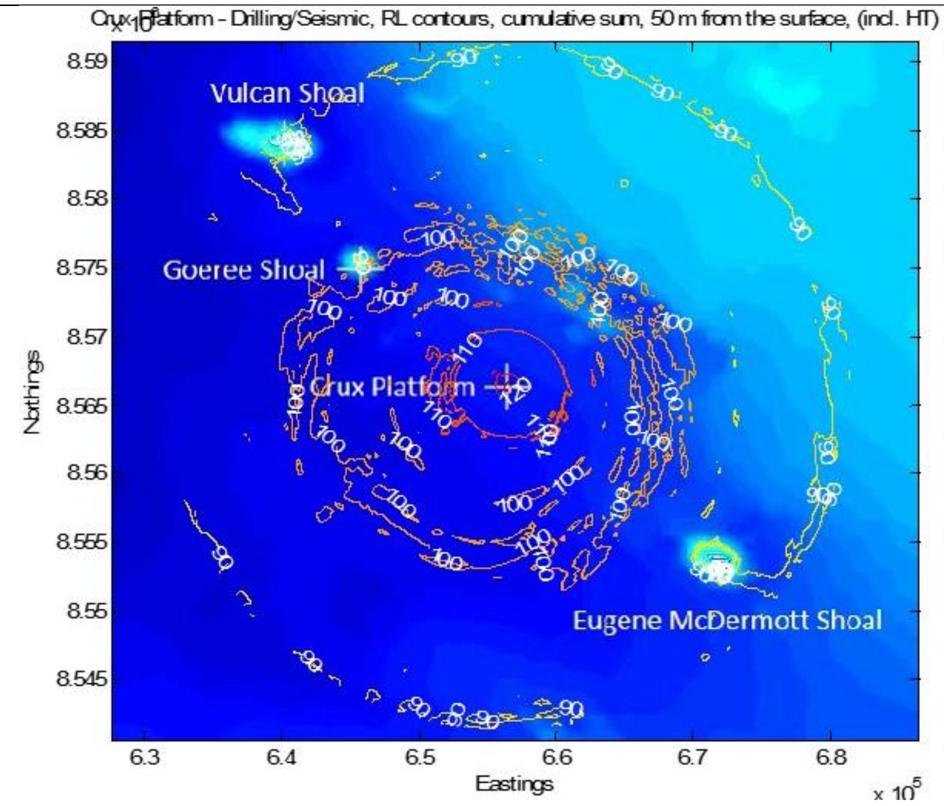
4.4.1 Scenario 8: Crux Platform Location (Tender on DP)



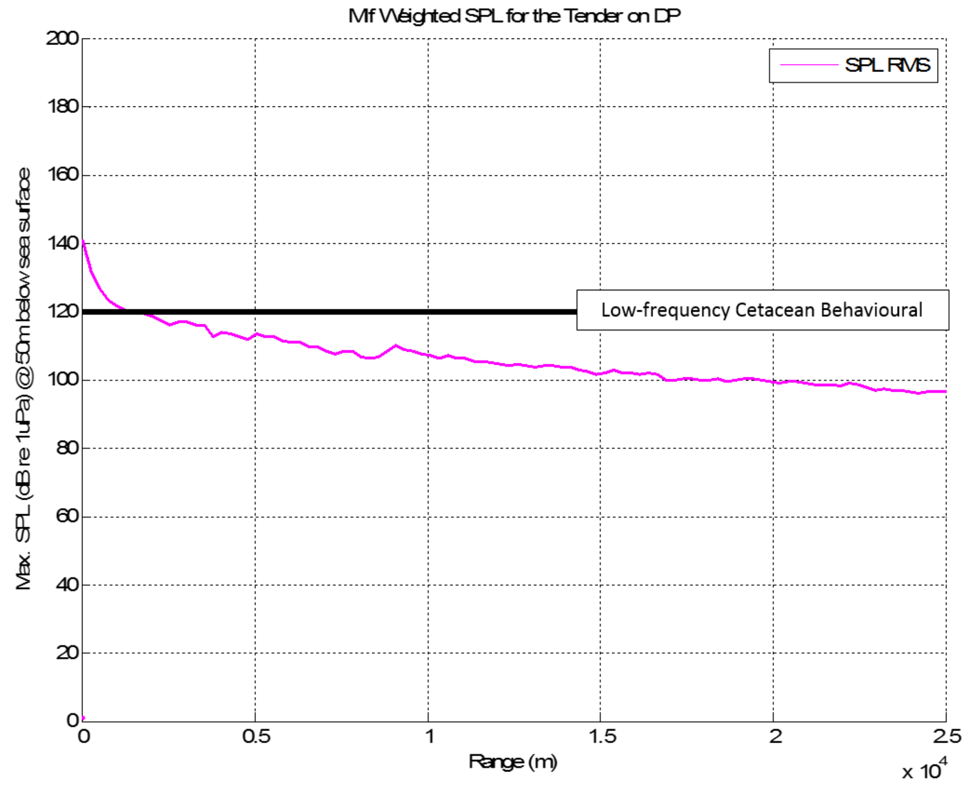
A: Noise Contour Showing Unweighted L_p for Tender on DP



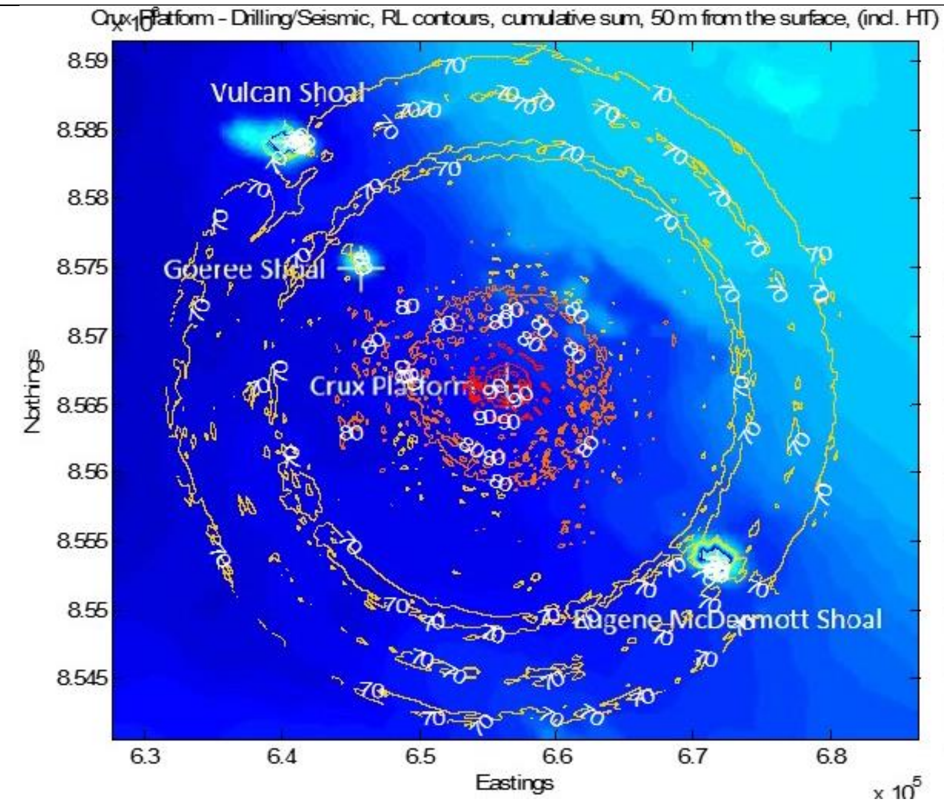
B: Maximum Unweighted L_p versus Range for Tender on DP



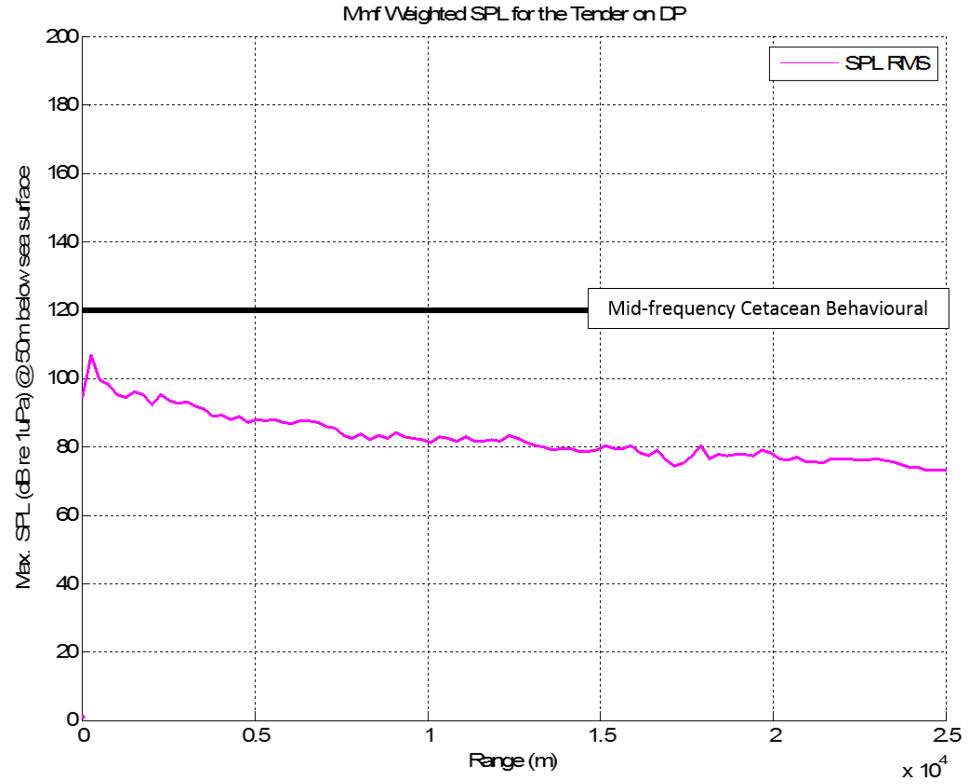
C: Noise Contour Showing Mlf-Weighted L_p for Tender on DP



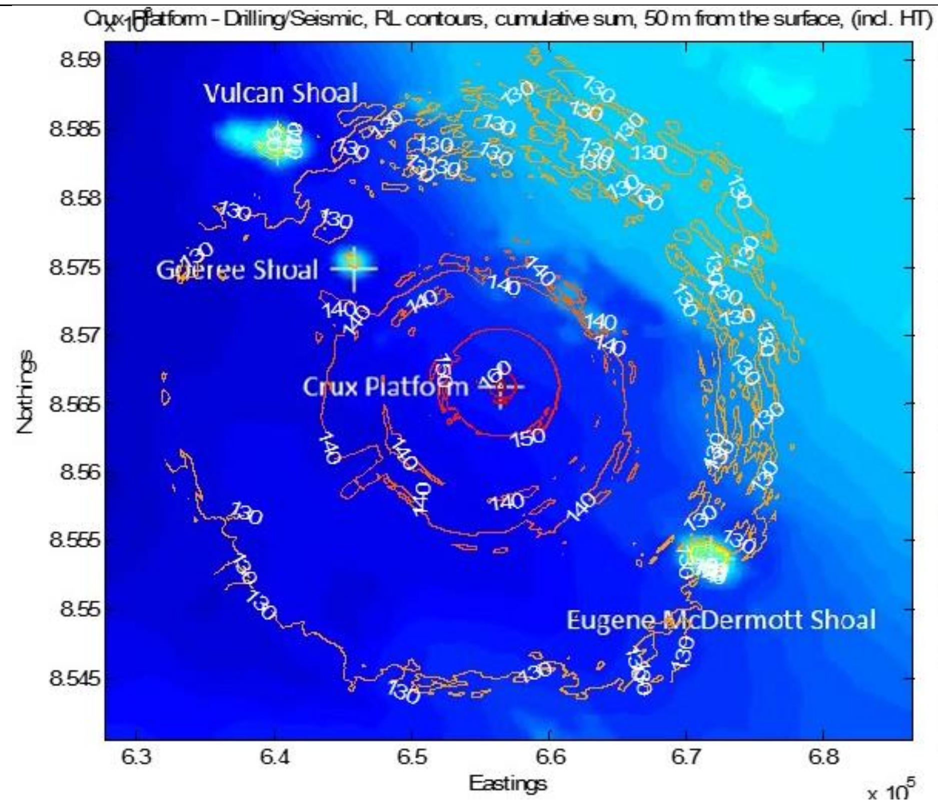
D: Maximum Mlf-Weighted L_p versus Range for Tender on DP



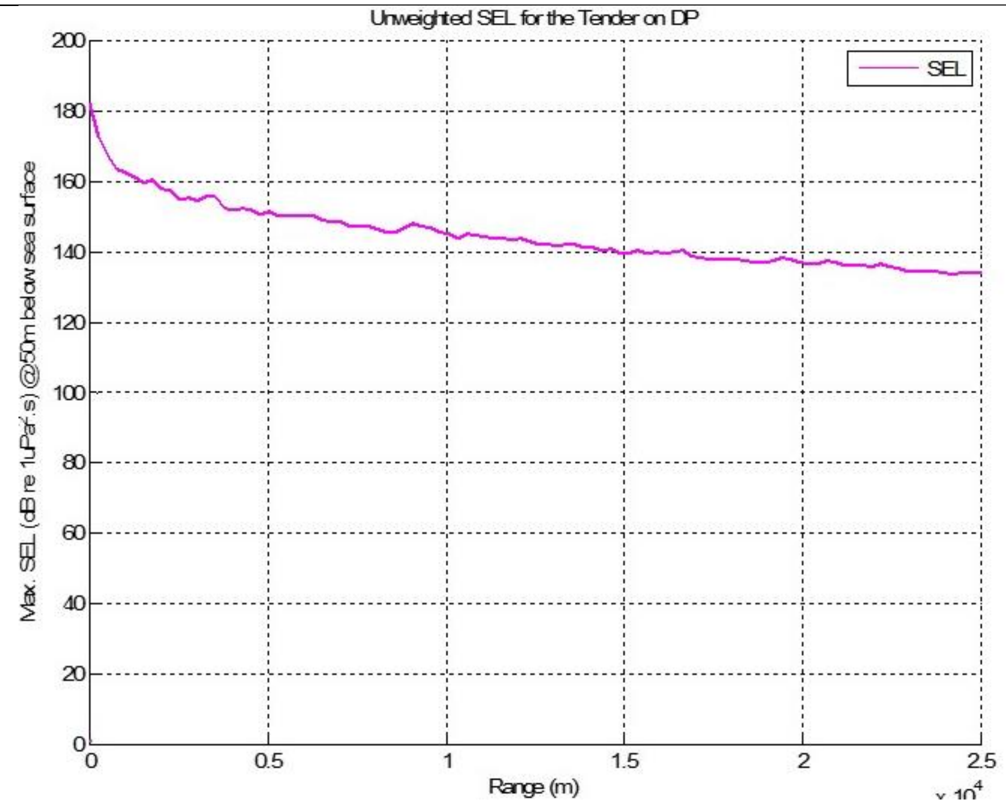
E: Noise Contour Showing Mmf-Weighted L_p for Tender on DP



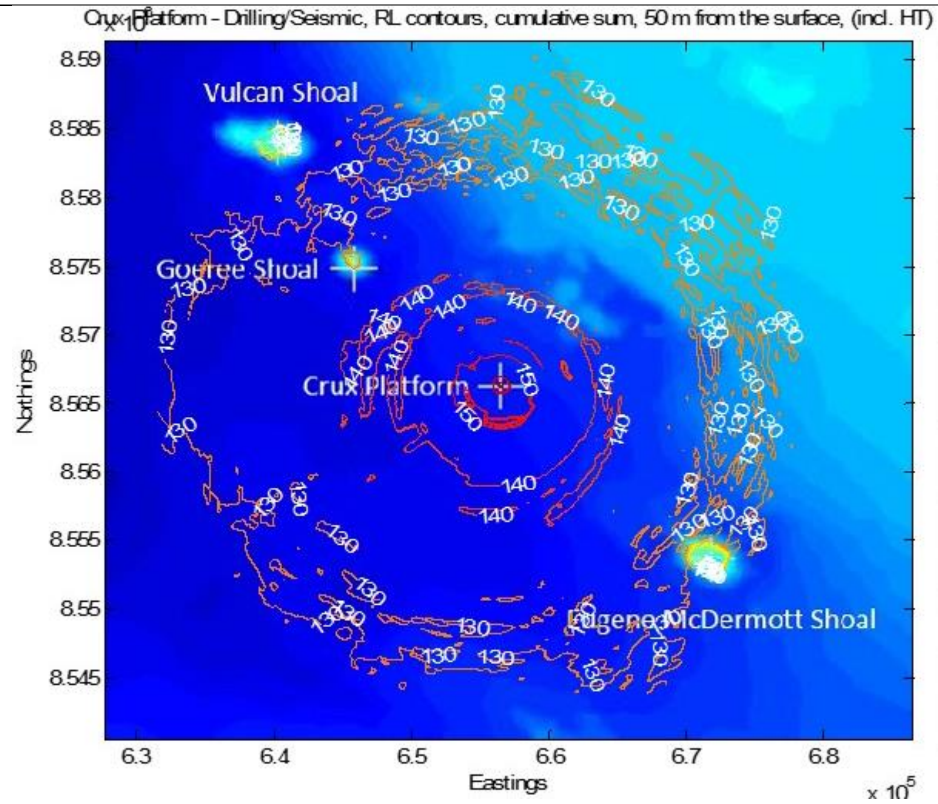
F: Maximum Mmf-Weighted L_p versus Range for Tender on DP



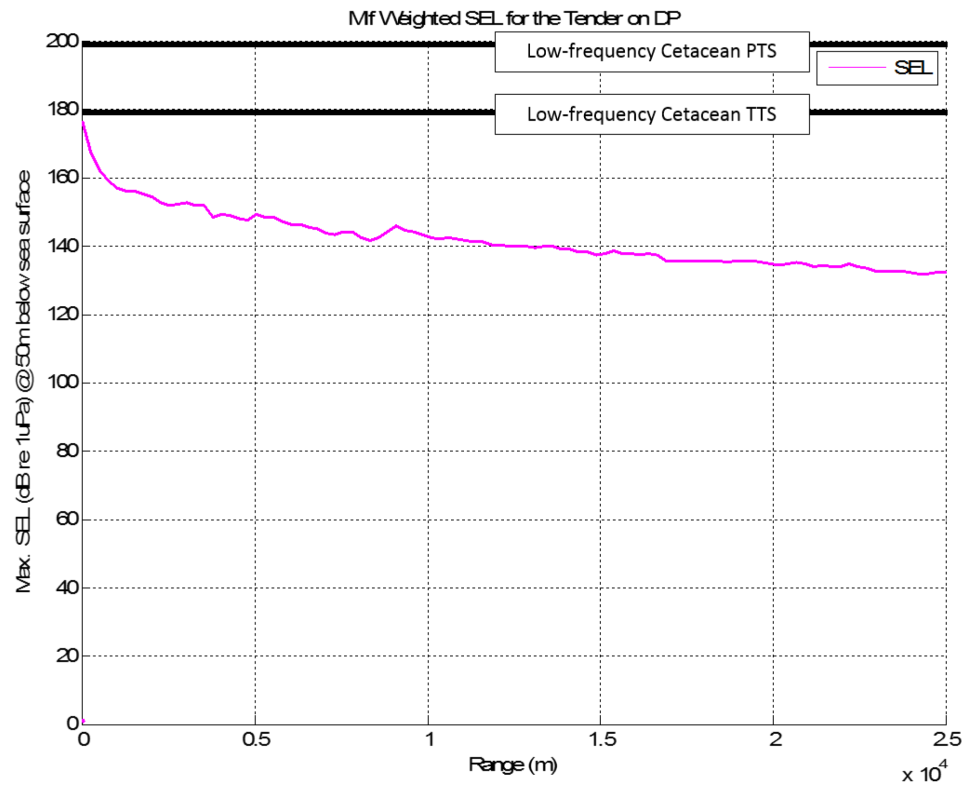
G: Noise Contour Showing Unweighted $L_{E,p}$ for Tender on DP



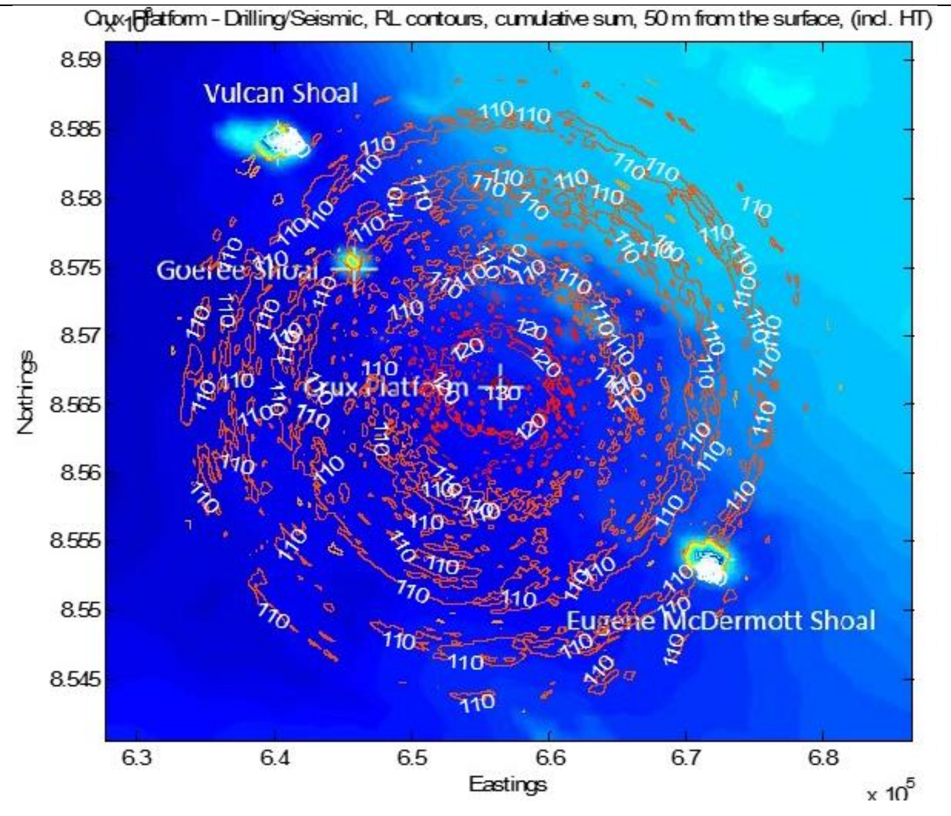
H: Maximum Unweighted $L_{E,p}$ versus Range for Tender on DP



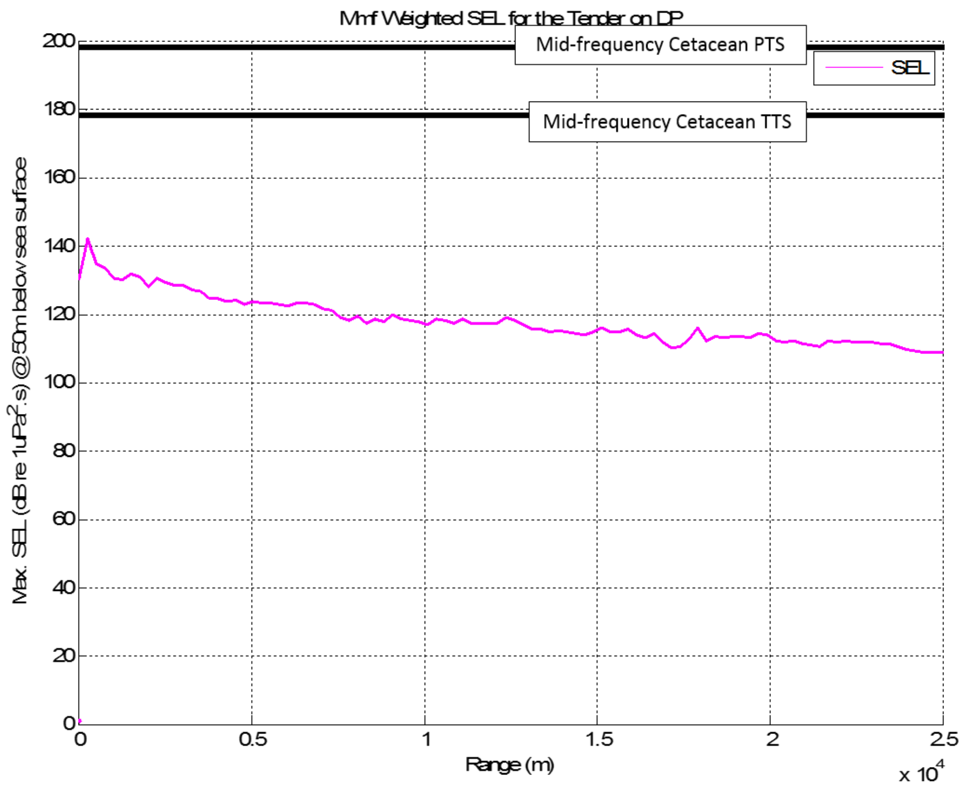
I: Noise Contour Showing Mlf-Weighted $L_{E,p}$ for Tender on DP



J: Maximum Mlf-Weighted $L_{E,p}$ versus Range for Tender on DP



K: Noise Contour Showing Mmf-Weighted $L_{E,p}$ for Tender on DP



L: Maximum Mmf-Weighted $L_{E,p}$ versus Range for Tender on DP

5. MODEL RESULTS

5.1 Overall Model Outputs

The modelled underwater noise levels have been plotted as contours for each respective piling, drilling and VSP scenarios and are presented in Section 4. Graphs of the noise levels with range (L_p, $L_{E,p}$, L_{pk}) along the worst-case bearing are also presented in Section 4.

The following tables show a summary of the range to criteria divided into three broad categories of marine fauna impacts:

- Injury or Permanent Impact;
- Temporary or Recoverable Impact; and
- Behavioural Impacts.

The range of the model predictions, extends across the supplied bathymetry, to 25 km. It should be noted that the source position for the piling has been modelled as 15m above the seabed (i.e. at a depth of 153.5m). The output data are generated for a depth of 50m as this depth correlates to the worst-case sound propagation (see Section 2.6.2). This means that the output plane does not intersect with the source location, and the nearest distance to the source represented in the results is 103.5m. Additionally, as discussed in Section 2.1.1, the model algorithm limits launching angles for sound propagation to ±40°, the effect of this at very close range can be seen in the charts.

Similarly, the sources associated with drilling have been modelled at a depth of 15m, and outputs generated for receptor depth of 50m, meaning the closest the prediction plane approached to the source position is 35m.

As discussed in Section 2.1.3 the nearfield prediction from the model will be significantly higher than the actual measured levels at close range because of the point source representation in the model. The prediction plane in each case approaches the source location to within one (1) dimension of each source, and therefore, while not as high as the model would produce if the prediction plane intersected the source point, the predictions are still expected to be higher than would be measured at these close ranges in practice.

The following conservatism in the modelling needs to be taken into account when interpreting the results:

- The prediction plane has been selected as the worst case;
- The level with range is for the worst case; and
- The point source assumption leads to high nearfield predictions.

Regarding the Sound Exposure criteria ($L_{E,p}$) the ranges assume that the assessed fauna will be stationary and present in the area for the 24 hours. In this process, NOAA acknowledges that this could lead to unrealistically large isopleths, which is a gross worst case assumption. It is possible to calculate an SEL for a moving receiver, however such a calculation requires an assumption of the receivers' path, depth(s), and speed(s) of advance. These assumptions introduce significant compounding uncertainty, especially when undertaken for open waters such as exist around this project, such that the result offers little value.

For piling, the results also assume that the pile is driven at maximum energy for the maximum number of strikes.

5.2 Pile Driving

The ranges presented in Table 5-1 to meet the $L_{E,p}$ criteria are for 6,530 strikes (1 pile) per day for the main piles. . The table shows that whales (low-frequency cetaceans) and dolphins (mid-frequency cetaceans) are the most sensitive fauna (i.e. the longest range to the criteria).

An examination of the figures in chapter 4 indicated that:

- If the number of strikes were halved, the predicted potential impact ranges for the $L_{E,p}$ criteria could reduce by 7 to 10 km; and
- If the number of strikes were reduced by a factor of 10 the predicted potential impact ranges for the $L_{E,p}$ criteria could reduce by 17 to 25 km.

Table 5-1 Ranges at which the Marine Fauna Criteria are met for Pile Driving

Marine Fauna Criteria	Main Pile, Small Hammer	Main Pile, Large Hammer
Injury or Permanent Injury Impact		
Fish (No Swim Bladder) Injury (213 dB L_{pk})	Not Reached (< 100m)	Not Reached (< 100m)
Fish (No Swim Bladder) Injury (219 dB $L_{E,p}$)	Not Reached (< 100m)	Not Reached (< 100m)
Fish, Larvae and Sea Turtle Injury (207 dB L_{pk})	Not Reached (< 100m)	Not Reached (< 100m)
Fish, Larvae and Sea Turtle Injury (210 dB $L_{E,p}$)	Not Reached (< 100m)	390 m
Low-frequency Cetacean PTS (219 dB $L_{pk)}$ dB	Not Reached (< 100m)	Not Reached (< 100m)
Low-frequency Cetacean PTS (183 $L_{E,p}$) dB(Mlf)	9.3 km	17.3 km
Mid-frequency Cetacean PTS (230 dB $L_{pk)}$ dB	Not Reached (< 100m)	Not Reached (< 100m)
Mid-frequency Cetacean PTS (185 $L_{E,p}$) dB(Mmf)	3.9 km	14 km
Invertebrates	Low Risk	Low Risk
Temporary or Recoverable Injury Impacts		
Fish TTS (186 dB $L_{E,p}$)	8.5 km	13.4 km
Fish (No Swim Bladder) Recoverable Injury[1] (216 $L_{E,p}$)	Not Reached (< 100m)	Not Reached (< 100m)
Fish (Swim Bladder) Recoverable Injury[1] (203 $L_{E,p}$)	450 m	1 km
Low-frequency Cetacean TTS (213 dB L_{pk})	Not Reached (< 100m)	Not Reached (< 100m)
Low-frequency Cetacean TTS (168 $L_{E,p}$) dB (Mlf)	38.8 km	~58 km
Mid-frequency Cetacean TTS (224 dB L_{pk})	Not Reached (< 100m)	Not Reached (< 100m)
Mid-frequency Cetacean TTS (170 $L_{E,p}$) dB (Mmf)	32.8 km	~57 km
Invertebrates	Low Risk	Low Risk
Behavioural Impacts		
Low-frequency Cetacean Behavioural (160 L_p) dB(Mlf)	1.3 km	2.7 km
Mid-frequency Cetacean Behavioural (160 L_p) dB(Mmf)	1 km	2.7 km
Invertebrates	Low Risk	Low Risk
Note 1. Recoverable injury thresholds for fish and turtles for L_{pk} are the same as those for permanent injury, and the results have therefore not been repeated in the table. Ranges that extend beyond 40 km are based on model generated results for directions where bathymetry was available at these ranges.		

5.3 Drilling Activities

5.3.1 Drilling Noise

The following table shows that all marine fauna criteria for continuous noise sources are not exceeded under any modelled drilling scenario.

Table 5-2 Ranges at Which the Marine Fauna Criteria are met during Development Drilling

Marine Fauna Criteria	Drill Rig in proximity to Eugene McDermott Shoal (1km buffer)	Drill Rig in proximity to Vulcan Shoal (1 km buffer)	Crux Platform Drilling
Injury or Permanent Injury Impact			
Low-frequency Cetacean PTS (199 $L_{E,p}$) dB(Mlf)	Not Reached (< 35m)	Not Reached (< 35m)	Not Reached (< 35m)
Mid-frequency Cetacean PTS (198 $L_{E,p}$) dB(Mmf)	Not Reached (< 35m)	Not Reached (< 35m)	Not Reached (< 35m)
Invertebrates	Low Risk	Low Risk	Low Risk
Temporary or Recoverable Injury Impacts			
Fish Recoverable Injury (170 L_p)	Not Reached (< 35m)	Not Reached (< 35m)	Not Reached (< 35m)
Fish TTS (158 L_p)	Not Reached (< 35m)	Not Reached (< 35m)	Not Reached (< 35m)
Low-frequency Cetacean TTS (179 $L_{E,p}$) dB (Mlf)	Not Reached (< 35m)	Not Reached (< 35m)	Not Reached (< 35m)
Mid-frequency Cetacean TTS (178 $L_{E,p}$) dB (Mmf)	Not Reached (< 35m)	Not Reached (< 35m)	Not Reached (< 35m)
Invertebrates	Low Risk	Low Risk	Low Risk
Behavioural Impacts			
Low-frequency Cetacean Behavioural (120 L_p) dB(Mlf)	Not Reached (< 35m)	Not Reached (< 35m)	Not Reached (< 35m)
Mid-frequency Cetacean Behavioural (120 L_p) dB(Mmf)	Not Reached (< 35m)	Not Reached (< 35m)	Not Reached (< 35m)
Invertebrates	Low Risk	Low Risk	Low Risk

5.3.2 VSP

The ranges presented in Table 5-3 to meet the $L_{E,p}$ criteria are for 10 pulses of the VSP airgun source. Ranges presented to meet L_p criteria are assuming a 0.2s signal pulse length. The following table shows that no marine fauna criteria for downhole VSP are exceeded under any modelled VSP scenario.

Table 5-3 Ranges at Which the Marine Fauna Criteria are Met during Downhole VSP

Marine Fauna Criteria	Maximum Range
Injury or Permanent Injury Impact	
Fish (No Swim Bladder) Injury (213 dB L_{pk})	Not Reached (< 35m)
Fish (No Swim Bladder) Injury (219 dB $L_{E,p}$)	Not Reached (< 35m)
Fish, Larvae and Sea Turtle Injury (207 dB L_{pk})	Not Reached (< 35m)
Fish, Larvae and Sea Turtle Injury (210 dB $L_{E,p}$)	Not Reached (< 35m)
Low-Frequency Cetacean PTS (219 dB L_{pk}) dB	Not Reached (< 35m)
Low-frequency Cetacean PTS (183 $L_{E,p}$) dB(Mlf)	Not Reached (< 35m)
Mid-frequency Cetacean PTS (230 dB L_{pk}) dB	Not Reached (< 35m)
Mid-frequency Cetacean PTS (185 $L_{E,p}$) dB(Mmf)	Not Reached (< 35m)
Invertebrates	Low Risk
Temporary or Recoverable Injury Impacts	
Fish TTS (186 dB $L_{E,p}$)	Not Reached (< 35m)
Fish (No Swim Bladder) Recoverable Injury (216 $L_{E,p}$)	Not Reached (< 35m)
Fish (Swim Bladder) Recoverable Injury (203 $L_{E,p}$)	Not Reached (< 35m)
Low-frequency Cetacean TTS (213 dB L_{pk})	Not Reached(< 35m)
Low-frequency Cetacean TTS (168 $L_{E,p}$) dB (Mlf)	Not Reached (< 35m)
Mid-frequency Cetacean TTS (224 dB L_{pk})	Not Reached (< 35m)
Mid-frequency Cetacean TTS (170 $L_{E,p}$) dB (Mmf)	Not Reached (< 35m)
Invertebrates	Low risk
Behavioural Impacts	
Low-frequency Cetacean Behavioural (160 L_p) dB(Mlf)	Not Reached (< 35m)
Mid-frequency Cetacean Behavioural (160 L_p) dB(Mmf)	Not Reached (< 35m)
Sea Turtle Behavioural (175 L_p) dB	Not Reached (< 35m)
Invertebrates	Moderate to low risk

5.3.3 Operational Noise

The ranges presented in Table 5-3 to meet the $L_{E,p}$ criteria are for the tender operating on DP, (at high propeller rates inducing significant cavitation), for a total of 1 hour. The following table shows that no marine fauna injury criteria for are exceeded under any modelled operational scenario. However, the low-frequency cetacean behavioural criterion may be exceeded by a tender on DP, provided that the animal remains within this range for the entire event.

Table 5-4 Ranges at Which the Marine Fauna Criteria are Met During Facility Operations

Marine Fauna Criteria	Tender on DP
Low-frequency Cetacean PTS (199 $L_{E,p}$) dB(Mlf)	Not Reached (< 35m)
Mid-frequency Cetacean PTS (198 $L_{E,p}$) dB(Mmf)	Not Reached (< 35m)
Invertebrates	Low Risk
Fish Recoverable Injury (170 L_p)	Not Reached (< 35m)
Fish TTS (158 L_p)	Not Reached (< 35m)
Low-frequency Cetacean TTS (179 $L_{E,p}$) dB (Mlf)	Not Reached (< 35m)
Mid-frequency Cetacean TTS (178 $L_{E,p}$) dB (Mmf)	Not Reached (< 35m)
Invertebrates	Low Risk
Low-frequency Cetacean Behavioural (120 L_p) dB(Mlf)	1.6 km
Mid-frequency Cetacean Behavioural (120 L_p) dB(Mmf)	Not Reached (< 35m)
Invertebrates	Low Risk

6. CONCLUSION

An assessment of the underwater noise generated by the piling, and drilling operations planned in the Crux development area has been undertaken. The results are summarised below.

The limiting (longest) ranges for the impact assessment are drawn in each case from the daily exposure criteria. The criteria sum the overall sound energy (from the source) received by the animal for a 24-hour period, and in this case, are calculated for 6,530 pile driving strikes. The calculation does not take account of the potential for the animal to flee outside of the affected area during the course of the activity, or the change in range inherent in the activities of a mobile receiver. Nor does the calculation take account of the possibility for the activity to be completed in a lesser number of strikes. Furthermore, the modelled sound energy per strike is based on the maximum energy expected at refusal. Therefore, the results are considered to be conservative worst-case.

6.1 Pile Driving

Permanent Injury or fatality, or Permanent Threshold Shift

Using the instantaneous assessment criteria (L_{pk} and L_p) the following results are obtained:

- The limit for onset of potential Permanent Threshold Shift for low-frequency cetaceans of 219 dB L_{pk} is not reached at any location;
- The limit for onset of potential Permanent Threshold Shift criterion for mid-frequency cetaceans of 230 dB L_{pk} is not reached at any location;
- The instantaneous permanent injury criterion for both fish (with swim bladder), larvae and sea turtles of 207 dB L_{pk} is not reached at any location; and
- The instantaneous permanent injury criterion for fish (no swim bladder) of 213 dB L_{pk} is not reached at any location.

Using the daily exposure criteria ($L_{E,p}$), which are dependent upon the number of pile driving strikes in a day and upon the presence of the receiving animal remaining in the area for the 24-hour period assessed, the following results are identified:

- The criterial for permanent injury to fish (no swim bladder) for a likely daily exposure is not reached at any location;
- There is potential for onset of permanent threshold shift in low-frequency cetaceans within a range of up to 17.3 km based on the daily exposure criterion;
- There is potential for onset of permanent threshold shift in mid-frequency cetaceans within a range of up to 14 km based on the daily exposure criterion; and
- There is potential for permanent injury to fish (with swim bladder), larvae and sea turtles within a range of up to 390 m, based on the daily exposure criterion.

The $L_{E,p}$ is a 24-hour cumulative metric that reflects the accumulated 'dose' impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The corresponding radii are significantly larger than those for peak pressure criteria, or behavioural disturbance, but they represent an extremely unlikely worst-case scenario. More realistically, marine mammals would not stay in the same location or at the same range for 24 hours. Therefore, a reported radius of $L_{E,p}$ criteria does not mean that any animal travelling within this radius of the source will be injured, but rather that it could be injured if it remained in that range for 24 hours. Therefore the cumulative 24-hour noise estimates are to be considered highly conservative and unlikely to represent the actual noise exposure by mobile transient marine fauna.

An examination of the noise model results indicates that:

- If the number of strikes were halved, the predicted potential impact ranges for the $L_{E,p}$ criteria could reduce by 7 to 10 km; and
- If the number of strikes were reduced by a factor of 10 the predicted potential impact ranges for the $L_{E,p}$ criteria could reduce by 17 to 25 km.

Recoverable Injury and TTS

Using the instantaneous assessment criteria (L_{pk} and L_p) the following results are obtained:

- The instantaneous recoverable injury and TTS criterion for low-frequency cetaceans of 213 dB L_{pk} is not reached at any location; and
- instantaneous recoverable injury and TTS criterion for mid-frequency cetaceans of 224 dB L_{pk} is not reached at any location.

Using the daily exposure criteria, which are dependent upon the number of pile driving strikes in a day and upon the presence of the receiving animal for the 24-hour period assessed (and taking note of the discussion above regarding the application of this criteria), the following results are identified:

- The potential for onset of TTS in low-frequency cetaceans using the daily exposure criterion extends out to a range of 57.8 km;
- The potential for onset of TTS in mid-frequency cetaceans using the daily exposure criterion extends out to a range of 56.9 km;
- The range for onset of recoverable injury for fish (with swim bladder) is met at 1 km using the daily exposure criterion;
- The range for recoverable injury for fish (no swim bladder) using the daily exposure criterion is not reached at any location; and
- There is potential for onset of TTS in fish within a range of 13.4 km using the daily exposure criterion.

Behavioural Disturbance

- The single strike (L_p) criterion for onset of behavioural disturbance to low-frequency cetaceans extends out to a range of 2.7 km; and
- The single strike (L_p) criterion for onset of mid-frequency cetacean behavioural disturbance also extends out to 2.7 km.

6.2 Drilling

6.2.1 Drilling Noise

Permanent Injury or fatality

No marine fauna PTS or permanent injury criteria are exceeded at any location for any drilling scenario modelled.

Recoverable Injury and TTS

No marine fauna Recoverable injury or TTS criteria are exceeded at any location for any drilling scenario modelled.

Behavioural Disturbance

No marine fauna behavioural disturbance criteria are exceeded at any location for any drilling scenario modelled.

6.2.2 VSP

No marine fauna criteria are exceeded at any location for any VSP scenario modelled.

6.3 Operational Noise

Permanent Injury or fatality

No marine fauna criteria PTS or permanent injury are exceeded at any location for any drilling scenario modelled.

Recoverable Injury and TTS

- There is potential for permanent injury to low-frequency cetaceans within a range of up to 350 m based on the daily exposure criterion (Tender on DP scenario), if the animal remains with this range for the duration of the event.

Marine fauna criteria for fish, larvae, sea turtles and mid-frequency cetaceans are not exceeded at any location for any operational scenario modelled.

Behavioural Disturbance

- The L_p criterion for behavioural disturbance to low-frequency cetaceans extends out to a range of 1.6 km (Tender on DP Scenario).

Marine fauna criteria for fish, larvae, sea turtles and mid-frequency cetaceans are not exceeded at any location for any operational scenario modelled.

7. REFERENCES

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APPENDIX A UNDERWATER NOISE MODEL

Appendix A-1 Underwater Noise Model Selection

Various numerical techniques are used to develop underwater acoustic propagation models, including wavenumber integration, ray theory, normal modes, parabolic equation (PE) and finite differences/finite elements. When determining which model is to be used for the modelling prediction, it is necessary to define the application for which it is to be used and the type of underwater environment it is going to simulate. For the model applied in this assessment, the underwater environment has the following characteristics:

- Strong range dependence
- A deep and shallow water ocean environment
- Differing bottom types

Parabolic Equation (PE) models are capable of making predictions in various conditions: shallow water, areas that have changing bottom types and under environmental conditions that are range dependent. A PE model called the Monterey Miami Parabolic Equation (MMPE) model was selected because it has been benchmark-tested for shallow water environments. The PE model is a well-recognized algorithm for transmission loss prediction and is widely used in the field of underwater acoustics. SVT have validated the model in multiple instances, for example: seismic survey modelling in Bassett Field (SVT for Total, 'Underwater Noise Modelling Validation and Results for 3D Seismic Survey in Bassett Field', 2010, Job Ref: 1052786-3-200).

The MMPE is a broadband model, and makes use of transmission loss calculations at multiple frequencies. With higher frequency comes greater computational overhead, and therefore to speed up the modelling process an upper-bound on frequency must be chosen. SVT chose to model frequencies from 20 Hz to 4 kHz, which is considered as being reasonable since most of the pile energy is in the first 4 kHz. This is a standard approach that has been followed by others such as, for example, the Centre for Marine Science and Technology (CMST) at Curtin University.

Furthermore, the absorption of sound in sea water increases significantly with high frequencies. Jensen et al. [14] provide the well-recognised expression for the frequency dependence of attenuation (see equation A.1), where α is the attenuation in dB/km and f is the frequency of the sound in kHz.

$$\alpha = (3.3)(10^{-3}) + \frac{0.11f^2}{1+f^2} + \frac{44f^2}{4100+f^2} + (3.0)(10^{-4}) \qquad \text{(A.1)}$$

Using this equation will result in 4.1 dB/km attenuation for a sound wave at 20 kHz, compared to 0.8 dB/km at 8 kHz and 0.1 dB/km at 2 kHz.

Appendix A-2 Seabed Sound Propagation Effects

Sound propagates both through the water and through the sea bed due to efficient transmission due to their similar acoustic impedances. This is not the case with the air-water boundary at the sea surface. Therefore the effect of airborne propagation can be assumed insignificant, and more importantly the surface will act as a near perfect reflector of underwater sound. Bottom loss must also be considered and is a function of the bottom type and the grazing angle. The limiting frequency f_0 below which no propagation is possible within the sediment is given by equation B.6:

$$f_0 = \frac{c_{water}}{4h}\sqrt{\frac{1}{1-(c_{water}/\,c_{sediment})^2}} \tag{B.6}$$

APPENDIX B PRINCIPLES OF UNDERWATER NOISE

Appendix B-1 Sound Pressure Level

Sound Pressure Level – The RMS level of sound at the instant (or in practice within one second) of the noise occurring. Since sound travels as a pressure wave, with high and low pressure amplitudes, the sound pressure level is always varying in time. Sound pressure level is expressed in dB, with relation to a reference sound pressure p_{ref}. The mathematical definition of sound pressure level (L_p) is:

$$L_P = 10 \log_{10}\left(\frac{\overline{p^2}}{p_{ref}^2}\right) \tag{B.1}$$

(SPL is the commonly used descriptor for sound pressure level in a number of historical published documents, however the official standard descriptor is L_p. For clarity and consistency with ISO 18405:2007 SVT uses L_p in this report.)

Because sound pressure is a continuously varying value, it is useful to average the sound pressure over a certain time period, to provide a reliable and meaningful comparison of the amplitude of sound. This averaging is conducted on an energy basis, and because sound pressure is varying about a zero mean pressure, the root mean square (rms) is used. In airborne acoustics, this averaging yields a value commonly referred to as the *Equivalent Level*, or L_{eq}. While L_{eq} is the commonly accepted and used notation, the official standard term and notation for this value is *Time Averaged Level*, L_T.

In a number of publications regarding the impact of underwater noise, "SPL" has been used as the descriptor for continuous received noise upon which the proposed assessment criteria are based. In these documents the term sound pressure level has been defined as an ***averaged*** sound pressure. This definition, mathematically, is the same as that for the Time Averaged Level, discussed above.

Additional opportunity for confusion has arisen in the field since the NOAA guidelines (2016) [17] have reverted to the original definition of "SPL".

Since SVT is referring in this document to criteria that use the "SPL descriptor", and this descriptor was intended to mean an averaged level by the author of the publication, SVT will use L_p in this document to mean a time averaged level of rms sound pressure. Therefore, for this document, the following definition of Sound Pressure Level is adopted:

Sound Pressure Level (L_p) is defined as the sound pressure, relative to some reference pressure, averaged over the time period T. For underwater acoustics, the reference pressure is generally taken to be p_{ref} = 1 µPa. Mathematically this is expressed as:

$$L_p = 10 \log_{10}\left(\frac{1}{T}\int_0^T \frac{p(t)^2}{p_{ref}^2}\,dt\right) \tag{B.2}$$

Appendix B-2 Sound Exposure Level

The Sound Exposure Level ($L_{E,p}$), also known as the energy flux density, the constant sound pressure level that if maintained for one second, would deliver the same total sound energy as the original source. It is usually used to describe discrete noise events. SEL is the commonly used (ANSI defined) descriptor for sound exposure level such as it is used in the NOAA guidelines [17], however the official standard descriptor is $L_{E,p}$,. For conformity to ISO 18405:2007 SVT has used the $L_{E,p}$ notation in this study.

The Sound Exposure Level is especially useful as it can be used in an accumulative context by summing all energy over an extended time period T, or over N discrete events, to find the total received sound energy level. The disturbance and injury criteria for marine life is commonly given in $L_{E,p}$ for impulsive noise sources such as pile-driving, and $L_{E,p}$ (i.e. SEL) is also used by NOAA [17] for newer criteria even for non-impulsive sources.

$$L_{E,p} = 10\ \log_{10}\left(\int_{0}^{T} \frac{p(t)^2}{p_{ref}^2} dt\right) \tag{B.3}$$

In deriving the $L_{E,p}$ for a continuous source, the time T should be taken as 1 second.

The Cumulative $L_{E,p}$ (denoted SEL_{cum} in ANSI standards and ANSI compliant publications such as the NOAA guidelines) is the total sound energy for a set number of discrete events, or in the instance of a continuous source, for the total period under consideration.

For *n* pulses, the cumulative $L_{E,p}$ can be derived from the single pulse $L_{E,p}$ by equation B.4:

$$L_{E,p} = L_{E,p\ (single\ event)} + 10\log(n) \tag{B.4}$$

For *a continuous source*, the cumulative $L_{E,p}$ for a defined exposure time T can be can be derived from the $L_{E,p}$ by equation B.5:

$$L_{E,p} = L_{E,p} + 10\log(T) \tag{B.5}$$

Appendix B-3 Other Descriptors of Sound

Hz	Hertz, the SI unit of frequency, meaning cycles per second.
Impulsive	Sound sources that produce sounds that are typically transient, brief (less than 1 second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay (ANSI 1986; NIOSH 1998; ANSI 2005). They can occur in repetition or as a single event. Examples of impulsive sound sources include: explosives, seismic airguns, and impact pile drivers [17].
L_{pk}	The absolute maximum peak pressure level (not RMS or mean level) reached at any time within the measurement period. L_{pk} gives a true representation of the actual maximum physical pressure of an acoustic wave.
Crest Factor	The peak amplitude of the waveform divided by the RMS value of the waveform. The Crest Factor describes the how the peak of a wave form relates the average (rms) level. The Crest Factor is also sometimes called the Peak to Average Ratio (PAR) when expressed in engineering units (i.e. for sound when expressed as

pressure (Pa). Because sound is typically expressed in dB, (a logarithmic unit) and log(ab) = Log(a) + Log(b), when the crest factor is expressed in dB it is the difference between the peak value and the mean value, i.e. CF = L_{pk} - L_p

Octave Band — A 'constant percentage bandwidth' where each successive band centre frequency is double the previous one. International standards define nominal centre frequencies of 16 Hz, 31.5Hz, 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz, and 16kHz. Each octave band has a bandwidth which is proportional to the frequency so that there are no gaps or overlaps between bands. A separate noise level can be measured for each band, allowing definition of the frequency content of the noise.

Non-Impulsive — Sound sources that produce sounds that can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent) and typically do not have a high peak sound pressure with rapid rise time that impulsive sounds do. Examples of non-impulsive sound sources include: marine vessels, machinery operations/construction (e.g., drilling), and vibratory pile drivers [17].

Pa — Pascal, the SI unit for pressure.

RMS — Root Mean Square – the mathematical means by which a regularly oscillating signal is 'averaged' such that the result is not zero.

SSP — Sound Speed Profile – A table or graph showing how the speed of sound varies in a fluid (usually a body of water). The speed of sound in water is dependent upon temperature, pressure, and salinity. Differing speeds of sound through the water column causes refraction and in some cases reflection of the sound waves, and is therefore an important consideration in underwater noise propagation modelling.

Tonality — A qualitative term used to identify when a noticeable tone or series of tones are detectable. In environmental noise this can be used to can be used describe noise that may be more annoying (due to its frequency content), than other noise of a similar overall level – when it is so used, the appropriate authority will usually define a quantitative means for determining when a noise demonstrates 'tonality'.

Appendix B-4 Effects of Noise

PTS — Permanent Threshold Shift - A permanent, irreversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range above a previously established reference level [17]. Noise-induced PTS represents tissue injury [16].

TTS — A temporary, reversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range above a previously established reference level [17]. Although TTS involves reduced hearing sensitivity following exposure, it results primarily from the fatigue (as opposed to loss) of cochlear hair cells and supporting structures and is, by definition, reversible. Since TTS represents a temporary change in sensitivity without permanent damage to sensory cells or support structures, it is not considered to represent tissue injury [16].

Behavioural Disturbance — Encompasses a broad range of potential responses to noise, including but not limited to: orienting to hear it; investigating it; changes or interruptions to normal behaviour (feeding, breeding, communicating etc), and panic or fleeing.

Appendix B-5 M Weighting

To account for the different hearing frequency ranges for marine mammals, particularly when criteria are set for cumulative energy exposure (such as L_p or $L_{E,p}$) and for disturbance criteria, weightings have been developed for each species group. The weightings provided by NOAA as applied in this report are presented below.

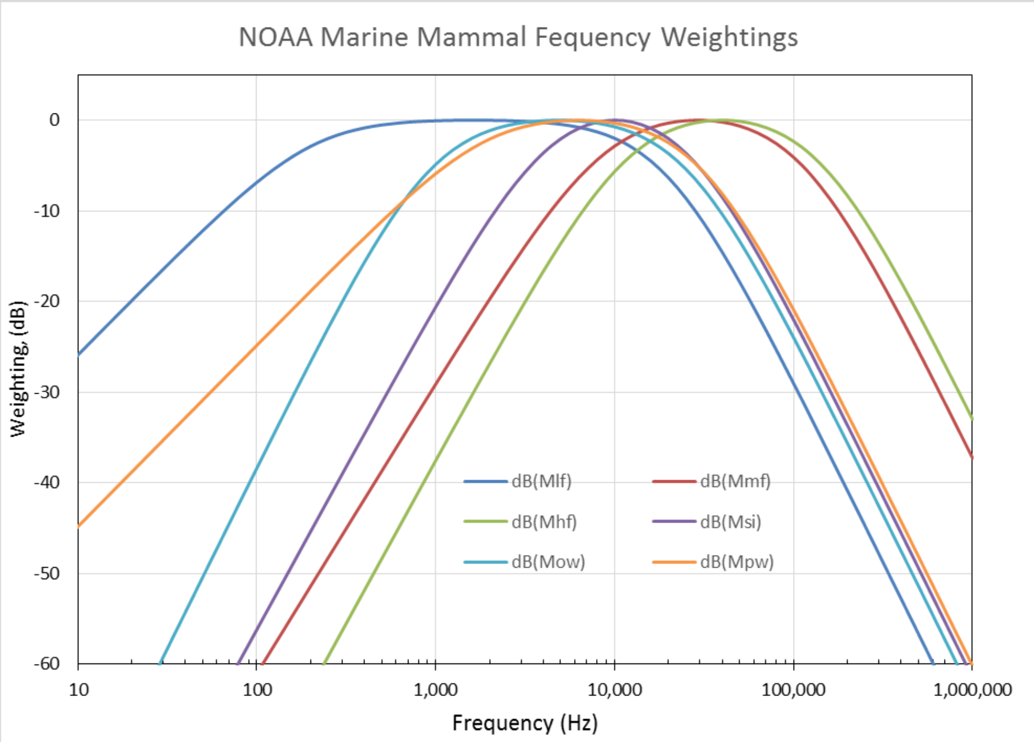

Figure B - 1 NOAA Marine Mammal Frequency Weightings

Appendix J: EPBC Protected Matter Search Results

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.

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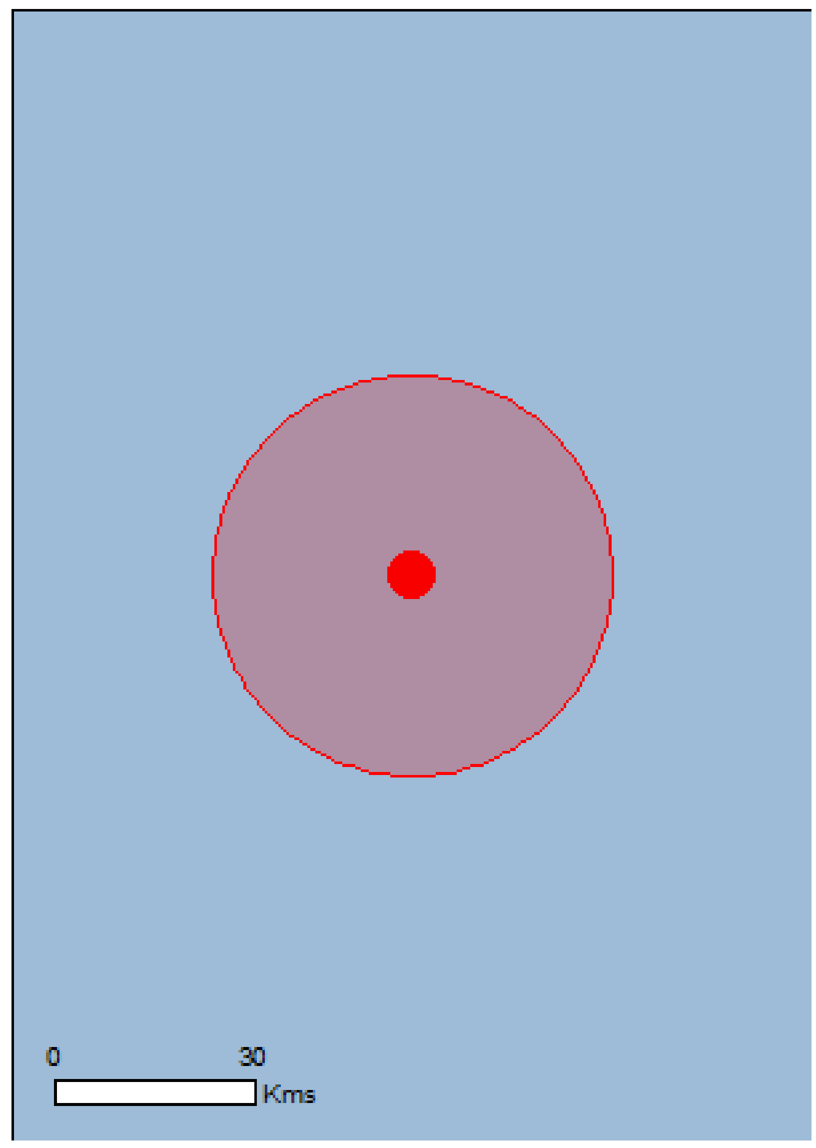

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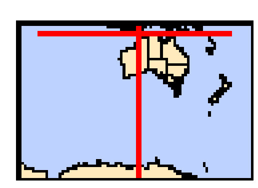

Summary

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:	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:	20
Listed Migratory Species:	33

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:	61
Whales and Other Cetaceans:	25
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	1

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
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 may occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically 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
Papasula abbotti		
Abbott's Booby [59297]	Endangered	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	Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Reptiles		
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Species or species habitat known to occur within area
Sharks		
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki		
Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may 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 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

Name	Threatened	Type of Presence
		habitat may occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour 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
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat likely 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 likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	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
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

Name	Threatened	Type of Presence
		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
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 ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* 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
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	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

Name	Threatened	Type of Presence
		area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur 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
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		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 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

Name	Threatened	Type of Presence
		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 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 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 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
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

Name	Threatened	Type of Presence
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely 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
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area

Name	Threatened	Type of Presence
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 likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat likely to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		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

Name	Status	Type of Presence
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

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

-12.96444 124.4425

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.

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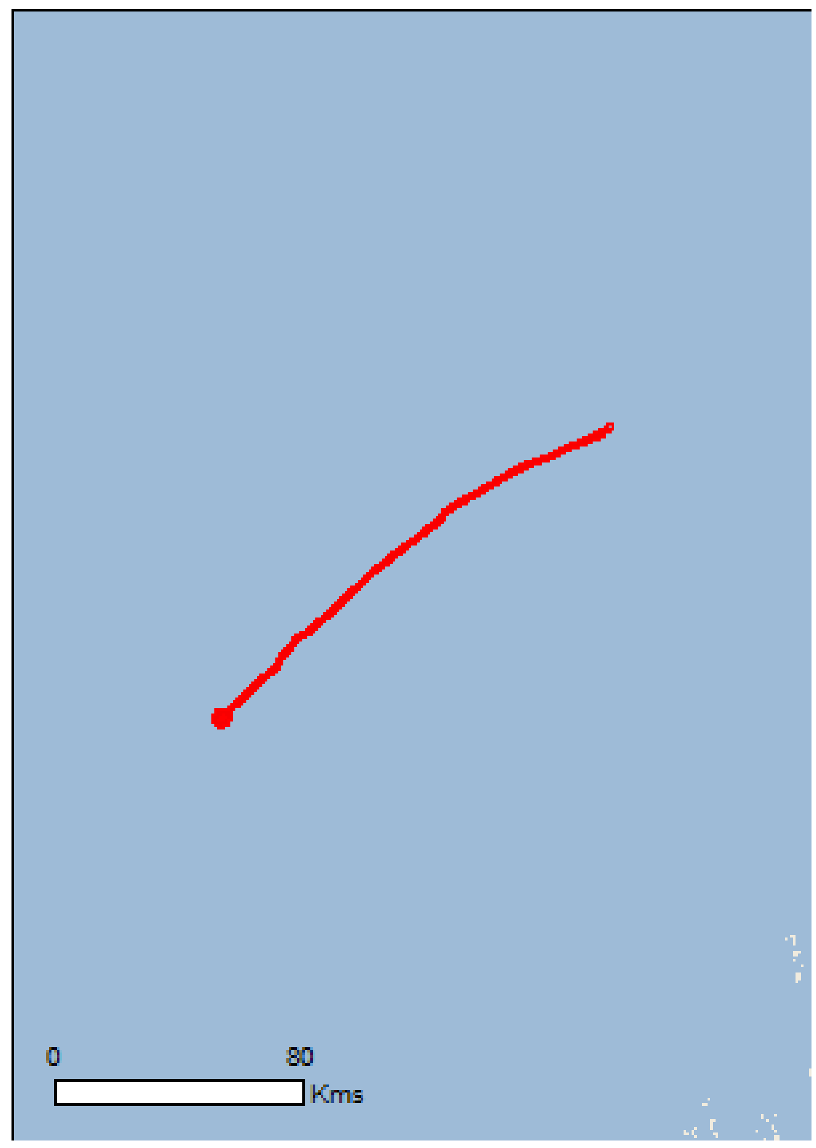

Coordinates
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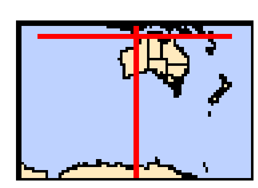

Summary

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:	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:	20
Listed Migratory Species:	33

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:	61
Whales and Other Cetaceans:	22
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	1

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
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 may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically 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
Papasula abbotti Abbott's Booby [59297]	Endangered	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	Species or species

Name	Status	Type of Presence
		habitat likely 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 habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to 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	Species or species habitat known to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may 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 may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known 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]		Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species

Name	Threatened	Type of Presence
		habitat may occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat 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 known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat 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
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 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	Species or species habitat likely 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

Name	Threatened	Type of Presence
		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
[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 ferruginea] Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
[Calidris melanotos] Pectoral Sandpiper [858]		Species or species habitat may occur within area
[Numenius madagascariensis] Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* 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
[Anous tenuirostris melanops] Australian Lesser Noddy [26000]	Vulnerable	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

Name	Threatened	Type of Presence
		area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known 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]		Foraging, feeding or related behaviour likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		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 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

Name	Threatened	Type of Presence
		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 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 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 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
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

Name	Threatened	Type of Presence
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
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
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
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

Name	Threatened	Type of Presence
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 likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat 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
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus (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
Continental Slope Demersal Fish Communities	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

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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
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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.

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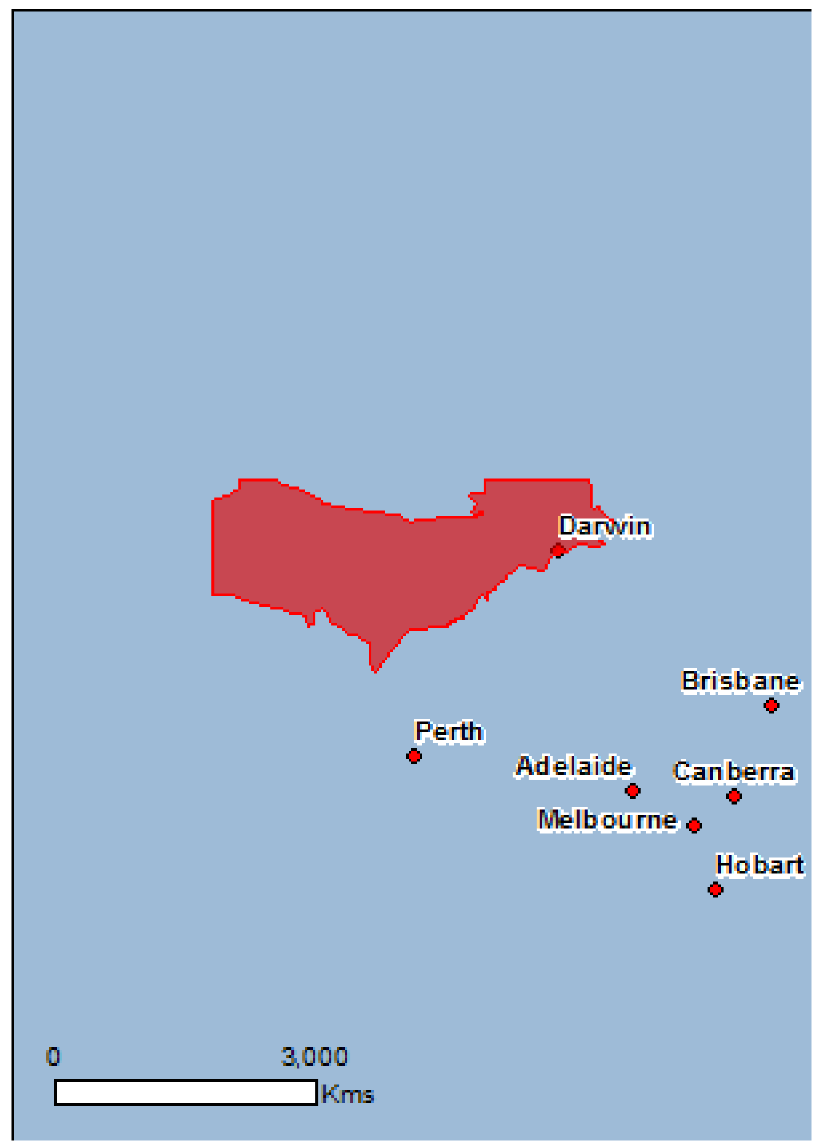

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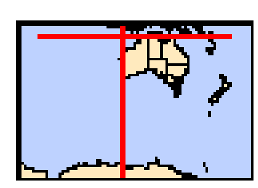

Summary

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:	None
National Heritage Places:	1
Wetlands of International Importance:	5
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	96
Listed Migratory Species:	95

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:	6
Commonwealth Heritage Places:	35
Listed Marine Species:	169
Whales and Other Cetaceans:	32
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	25

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	30
Regional Forest Agreements:	None
Invasive Species:	37
Nationally Important Wetlands:	9
Key Ecological Features (Marine)	15

Details

Matters of National Environmental Significance

National Heritage Properties

[Resource Information]

Name	State	Status
Natural		
The West Kimberley	WA	Listed place

Wetlands of International Importance (Ramsar)

[Resource Information]

Name	Proximity
Ashmore reef national nature reserve	Within Ramsar site
Cobourg peninsula	Within Ramsar site
Hosnies spring	Within Ramsar site
Pulu keeling national park	Within Ramsar site
The dales	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
North-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
Monsoon vine thickets on the coastal sand dunes of Dampier Peninsula	Endangered	Community likely to occur within area

Listed Threatened Species

[Resource Information]

Name	Status	Type of Presence
Birds		
Accipiter hiogaster natalis Christmas Island Goshawk [82408]	Endangered	Species or species habitat known to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding 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

Name	Status	Type of Presence
Calidris tenuirostris Great Knot [862]	Critically Endangered	Foraging, feeding or related behaviour known to occur within area
Chalcophaps indica natalis Christmas Island Emerald Dove, Emerald Dove (Christmas Island) [67030]	Endangered	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Foraging, feeding or related behaviour known to occur within area
Epthianura crocea tunneyi Alligator Rivers Yellow Chat, Yellow Chat (Alligator Rivers) [67089]	Endangered	Species or species habitat may occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat known to occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat known to occur within area
Falcunculus frontatus whitei Crested Shrike-tit (northern), Northern Shrike-tit [26013]	Vulnerable	Species or species habitat likely to occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Breeding known to occur within area
Geophaps smithii blaauwi Partridge Pigeon (western) [66501]	Vulnerable	Species or species habitat likely to occur within area
Geophaps smithii smithii Partridge Pigeon (eastern) [64441]	Vulnerable	Species or species habitat known to occur within area
Hypotaenidia philippensis andrewsi Buff-banded Rail (Cocos (Keeling) Islands), Ayam Hutan [88994]	Endangered	Translocated population known to occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Melanodryas cucullata melvillensis Tiwi Islands Hooded Robin, Hooded Robin (Tiwi Islands) [67092]	Critically Endangered	Species or species habitat known to occur within area
Mirafra javanica melvillensis Horsfield's Bushlark (Tiwi Islands) [81011]	Vulnerable	Species or species habitat known to occur within area
Ninox natalis Christmas Island Hawk-Owl, Christmas Boobook [66671]	Vulnerable	Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species

Name	Status	Type of Presence
		habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat known to occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Breeding likely to occur within area
Polytelis alexandrae Princess Parrot, Alexandra's Parrot [758]	Vulnerable	Species or species habitat known to occur within area
Pterodroma arminjoniana Round Island Petrel, Trinidade Petrel [89284]	Critically Endangered	Breeding likely 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, Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche cauta cauta Shy Albatross, Tasmanian Shy Albatross [82345]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta steadi White-capped Albatross [82344]	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
Turdus poliocephalus erythropleurus Christmas Island Thrush [67122]	Endangered	Species or species habitat likely to occur within area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat known to occur within area
Tyto novaehollandiae melvillensis Tiwi Masked Owl, Tiwi Islands Masked Owl [26049]	Endangered	Species or species habitat known to occur within area
Mammals		
Antechinus bellus Fawn Antechinus [344]	Vulnerable	Species or species habitat known to occur within area
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

Name	Status	Type of Presence
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Conilurus penicillatus Brush-tailed Rabbit-rat, Brush-tailed Tree-rat, Pakooma [132]	Vulnerable	Species or species habitat known to occur within area
Crocidura trichura Christmas Island Shrew [86568]	Critically Endangered	Species or species habitat likely to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area
Isoodon auratus auratus Golden Bandicoot (mainland) [66665]	Vulnerable	Species or species habitat likely to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat known to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Mesembriomys gouldii gouldii Black-footed Tree-rat (Kimberley and mainland Northern Territory), Djintamoonga, Manbul [87618]	Endangered	Species or species habitat known to occur within area
Mesembriomys gouldii melvillensis Black-footed Tree-rat (Melville Island) [87619]	Vulnerable	Species or species habitat known to occur within area
Mesembriomys macrurus Golden-backed Tree-rat, Koorrawal [119]	Vulnerable	Species or species habitat known to occur within area
Notomys aquilo Northern Hopping-mouse, Woorrentinta [123]	Vulnerable	Species or species habitat may occur within area
Petrogale concinna canescens Nabarlek (Top End) [87606]	Endangered	Species or species habitat may occur within area
Petrogale concinna monastria Nabarlek (Kimberley) [87607]	Endangered	Species or species habitat known to occur within area
Phascogale pirata Northern Brush-tailed Phascogale [82954]	Vulnerable	Species or species habitat known to occur within area
Phascogale tapoatafa kimberleyensis Kimberley brush-tailed phascogale, Brush-tailed Phascogale (Kimberley) [88453]	Vulnerable	Species or species habitat known to occur within area
Pipistrellus murrayi Christmas Island Pipistrelle [64383]	Critically Endangered	Species or species habitat known to occur within area
Pteropus natalis Christmas Island Flying-fox, Christmas Island	Critically Endangered	Roosting known to occur

Name	Status	Type of Presence
Fruit-bat [87611]		within area
Saccolaimus saccolaimus nudicluniatus		
Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat known to occur within area
Sminthopsis butleri		
Butler's Dunnart [302]	Vulnerable	Species or species habitat known to occur within area
Xeromys myoides		
Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat known to occur within area
Plants		
Asplenium listeri		
Christmas Island Spleenwort [65865]	Critically Endangered	Species or species habitat known to occur within area
Burmannia sp. Bathurst Island (R.Fensham 1021)		
[82017]	Endangered	Species or species habitat likely to occur within area
Hoya australis subsp. oramicola		
a vine [55436]	Vulnerable	Species or species habitat known to occur within area
Mitrella tiwiensis		
a vine [82029]	Vulnerable	Species or species habitat likely to occur within area
Pneumatopteris truncata		
fern [68812]	Critically Endangered	Species or species habitat known to occur within area
Stylidium ensatum		
a triggerplant [86366]	Endangered	Species or species habitat likely to occur within area
Tectaria devexa		
[14767]	Endangered	Species or species habitat likely to occur within area
Typhonium jonesii		
a herb [62412]	Endangered	Species or species habitat known to occur within area
Typhonium mirabile		
a herb [79227]	Endangered	Species or species habitat known to occur within area
Xylopia monosperma		
a shrub [82030]	Endangered	Species or species habitat known to occur within area
Reptiles		
Acanthophis hawkei		
Plains Death Adder [83821]	Vulnerable	Species or species habitat known to occur within area
Aipysurus apraefrontalis		
Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama		
Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur

Name	Status	Type of Presence
		within area
Cryptoblepharus egeriae Christmas Island Blue-tailed Skink, Blue-tailed Snake-eyed Skink [1526]	Critically Endangered	Species or species habitat likely to occur within area
Cryptoblepharus gurrmul Arafura Snake-eyed Skink [83106]	Endangered	Species or species habitat known to occur within area
Cyrtodactylus sadleiri Christmas Island Giant Gecko [86865]	Endangered	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
Emoia nativitatis Christmas Island Forest Skink, Christmas Island Whiptail-skink [1400]	Critically 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	Breeding known to occur within area
Lepidodactylus listeri Christmas Island Gecko, Lister's Gecko [1711]	Critically Endangered	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Ramphotyphlops exocoeti Christmas Island Blind Snake, Christmas Island Pink Blind Snake [1262]	Vulnerable	Species or species habitat likely to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Glyphis garricki Northern River Shark, New Guinea River Shark [82454]	Endangered	Breeding known to occur within area
Glyphis glyphis Speartooth Shark [82453]	Critically Endangered	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

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Breeding known 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 may 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
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Breeding known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to 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
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known 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 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
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Thalassarche cauta Tasmanian 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

Name	Threatened	Type of Presence
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	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
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	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	Breeding known to occur within area

Name	Threatened	Type of Presence
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 brevirostris Irrawaddy Dolphin [45]		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 clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Breeding known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat known to occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to 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 known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Migratory Wetlands Species		

Name	Threatened	Type of Presence
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Foraging, feeding or related behaviour known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Foraging, feeding or related behaviour known to occur within area
Calidris alba Sanderling [875]		Foraging, feeding or related behaviour 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]		Foraging, feeding or related behaviour known to occur within area
Calidris subminuta Long-toed Stint [861]		Foraging, feeding or related behaviour known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Foraging, feeding or related behaviour known to occur within area
Charadrius dubius Little Ringed Plover [896]		Foraging, feeding or related behaviour known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Foraging, feeding or related behaviour known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Foraging, feeding or related behaviour known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Foraging, feeding or related behaviour known to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Foraging, feeding or related behaviour likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Foraging, feeding or related behaviour known to occur within area

Name	Threatened	Type of Presence
Limicola falcinellus Broad-billed Sandpiper [842]		Foraging, feeding or related behaviour known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Foraging, feeding or related behaviour 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]		Foraging, feeding or related behaviour 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]		Foraging, feeding or related behaviour known to occur within area
Numenius phaeopus Whimbrel [849]		Foraging, feeding or related behaviour known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Foraging, feeding or related behaviour known to occur within area
Pluvialis squatarola Grey Plover [865]		Foraging, feeding or related behaviour known to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Foraging, feeding or related behaviour known to occur within area
Tringa glareola Wood Sandpiper [829]		Foraging, feeding or related behaviour known to occur within area
Tringa incana Wandering Tattler [831]		Foraging, feeding or related behaviour 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]		Foraging, feeding or related behaviour known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Species or species habitat known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Foraging, feeding or related behaviour 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 -
Commonwealth Land - Australian Government Solicitor
Commonwealth Land - Christmas Island National Park
Commonwealth Land - Pulu Keeling National Park
Defence - QUAIL ISLAND BOMBING RANGE
Defence - YAMPI SOUND TRAINING AREA

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Ashmore Reef National Nature Reserve	EXT	Listed place
Christmas Island Natural Areas	EXT	Listed place
Mermaid Reef - Rowley Shoals	WA	Listed place
North Keeling Island	EXT	Listed place
Scott Reef and Surrounds - Commonwealth Area	EXT	Listed place
Yampi Defence Area	WA	Listed place
Historic		
Administration Building Forecourt	EXT	Listed place
Administrators House Precinct	EXT	Listed place
Bungalow 702	EXT	Listed place
Captain Ballards Grave	EXT	Listed place
Direction Island (DI) Houses	EXT	Listed place
Drumsite Industrial Area	EXT	Listed place
Early Settlers Graves	EXT	Listed place
Government House	EXT	Listed place
Home Island Cemetery	EXT	Listed place
Home Island Foreshore	EXT	Listed place
Home Island Industrial Precinct	EXT	Listed place
Industrial and Administrative Group	EXT	Listed place
Malay Kampong Group	EXT	Listed place
Malay Kampong Precinct	EXT	Listed place
Oceania House and Surrounds	EXT	Listed place
Old Co-op Shop (Canteen)	EXT	Listed place
Phosphate Hill Historic Area	EXT	Listed place
Poon Saan Group	EXT	Listed place
Qantas Huts (former)	EXT	Listed place
RAAF Memorial	EXT	Listed place
Settlement Christmas Island	EXT	Listed place
Six Inch Guns	EXT	Listed place
Slipway and Tank	EXT	Listed place
South Point Settlement Remains	EXT	Listed place
Type 2 Residences	EXT	Listed place
Type T Houses Precinct	EXT	Listed place
West Island Elevated Houses	EXT	Listed place
West Island Housing Precinct	EXT	Listed place
West Island Mosque	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		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Anous minutus Black Noddy [824]		Breeding known to occur within area
Anous stolidus Common Noddy [825]		Breeding known to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Anseranas semipalmata Magpie Goose [978]		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
Arenaria interpres Ruddy Turnstone [872]		Foraging, feeding or related behaviour known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Foraging, feeding or related behaviour known to occur within area
Calidris alba Sanderling [875]		Foraging, feeding or related behaviour 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]		Foraging, feeding or related behaviour known to occur within area
Calidris subminuta Long-toed Stint [861]		Foraging, feeding or related behaviour known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Foraging, feeding or related behaviour known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Charadrius dubius Little Ringed Plover [896]		Foraging, feeding or related behaviour known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Name	Threatened	Type of Presence
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Foraging, feeding or related behaviour known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Foraging, feeding or related behaviour known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Foraging, feeding or related behaviour known to occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat known to occur within area
Fregata andrewsi Christmas Island Frigatebird, Andrew's Frigatebird [1011]	Endangered	Breeding known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Foraging, feeding or related behaviour known to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Foraging, feeding or related behaviour likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Foraging, feeding or related behaviour known to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Heteroscelus brevipes Grey-tailed Tattler [59311]		Foraging, feeding or related behaviour known to occur within area
Heteroscelus incanus Wandering Tattler [59547]		Foraging, feeding or related behaviour known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Foraging, feeding or related behaviour known to occur within area
Hirundo daurica Red-rumped Swallow [59480]		Species or species habitat 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
Limicola falcinellus Broad-billed Sandpiper [842]		Foraging, feeding or related behaviour known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Foraging, feeding or related behaviour known to occur within area

Name	Threatened	Type of Presence
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Foraging, feeding or related behaviour known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	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 known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Foraging, feeding or related behaviour known to occur within area
Numenius phaeopus Whimbrel [849]		Foraging, feeding or related behaviour 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 known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon lepturus fulvus Christmas Island White-tailed Tropicbird, Golden Bosunbird [26021]	Endangered	Breeding likely to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Foraging, feeding or related behaviour known to occur within area
Pluvialis squatarola Grey Plover [865]		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 carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Species or species habitat may occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species

Name	Threatened	Type of Presence
		habitat known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat may occur within area
Sterna albifrons Little Tern [813]		Breeding known to occur within area
Sterna anaethetus Bridled Tern [814]		Breeding known to occur within area
Sterna bengalensis Lesser Crested Tern [815]		Breeding known to occur within area
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]		Foraging, feeding or related behaviour 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
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Thalassarche cauta Tasmanian 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 may occur within area
Tringa glareola Wood Sandpiper [829]		Foraging, feeding or related behaviour 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]		Foraging, feeding or related behaviour known to occur within area

Name	Threatened	Type of Presence
Tringa totanus Common Redshank, Redshank [835]		Species or species habitat known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Foraging, feeding or related behaviour known 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 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 sculptus Sculptured Pipefish [66197]		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 haematopterus Reef-top Pipefish [66201]		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
Cosmocampus maxweberi Maxweber's Pipefish [66209]		Species or species habitat may occur within area
Doryrhamphus baldwini Redstripe Pipefish [66718]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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 cinctus Girdled Pipefish [66214]		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 macrorhynchus Whiskered Pipefish, Ornate Pipefish [66222]		Species or species habitat may occur within area
Halicampus mataafae Samoan Pipefish [66223]		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 cyanospilos Blue-speckled Pipefish, Blue-spotted Pipefish [66228]		Species or species habitat may occur within area
Hippichthys heptagonus Madura Pipefish, Reticulated Freshwater Pipefish [66229]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hippichthys parvicarinatus Short-keel Pipefish, Short-keeled Pipefish [66230]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippichthys spicifer Belly-barred Pipefish, Banded Freshwater Pipefish [66232]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus brevirostris thorntail Pipefish, Thorn-tailed Pipefish [66254]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		

Name	Threatened	Type of Presence
Dugong dugon Dugong [28]		Breeding known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus fuscus Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus 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	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnston's River Crocodile [1773]		Species or species habitat may 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
Enhydrina schistosa Beaked Seasnake [1126]		Species or species

Name	Threatened	Type of Presence
		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 atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis inornatus Plain Seasnake [1107]		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
Hydrophis pacificus Large-headed Seasnake, Pacific Seasnake [1112]		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	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Parahydrophis mertoni Northern Mangrove Seasnake [1090]		Species or species habitat may 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		Species or species

Name	Status	Type of Presence
Whale [67812]		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 may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
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
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
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area

Name	Status	Type of Presence
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]		Breeding 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
Arafura	Multiple Use Zone (IUCN VI)
Arafura	Special Purpose Zone (IUCN VI)
Arafura	Special Purpose Zone (Trawl) (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)
Arnhem	Special Purpose Zone (IUCN VI)
Ashmore Reef	Recreational Use Zone (IUCN IV)
Ashmore Reef	Sanctuary Zone (IUCN Ia)
Cartier Island	Sanctuary Zone (IUCN Ia)
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)
Joseph Bonaparte Gulf	Multiple Use Zone (IUCN VI)
Joseph Bonaparte Gulf	Special Purpose Zone (IUCN VI)
Kimberley	Habitat Protection Zone (IUCN IV)

Name	Label
Kimberley	Multiple Use Zone (IUCN VI)
Kimberley	National Park Zone (IUCN II)
Mermaid Reef	National Park Zone (IUCN II)
Montebello	Multiple Use Zone (IUCN VI)
Oceanic Shoals	Habitat Protection Zone (IUCN IV)
Oceanic Shoals	Multiple Use Zone (IUCN VI)
Oceanic Shoals	National Park Zone (IUCN II)
Oceanic Shoals	Special Purpose Zone (Trawl) (IUCN VI)

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Adele Island	WA
Balanggarra	WA
Bardi Jawi	WA
Bedout Island	WA
Browse Island	WA
Casuarina	NT
Christmas Island	EXT
Coulomb Point	WA
Dambimangari	WA
Djukbinj	NT
Garig Gunak Barlu	NT
Indian Island	NT
Lacepede Islands	WA
Lawley River	WA
Lesueur Island	WA
Low Rocks	WA
Prince Regent	WA
Pulu Keeling	EXT
Swan Island	WA
Tanner Island	WA
Unnamed WA28968	WA
Unnamed WA37168	WA
Unnamed WA41775	WA
Unnamed WA44669	WA
Unnamed WA44672	WA
Unnamed WA44673	WA
Unnamed WA44674	WA
Unnamed WA44677	WA
Uunguu	WA
Vernon Islands	NT

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		
Anas platyrhynchos Mallard [974]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Gallus gallus Red Junglefowl, Domestic Fowl [917]		Species or species habitat likely to occur within area
Gallus varius Green Junglefowl [81207]		Species or species habitat likely to occur within area
Lonchura oryzivora Java Sparrow [59586]		Species or species habitat likely to occur within area
Meleagris gallopavo Wild Turkey [64380]		Species or species habitat likely to occur within area
Passer montanus Eurasian Tree Sparrow [406]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat known to occur within area
Mammals		
Bos javanicus Banteng, Bali Cattle [15]		Species or species habitat likely to occur within area
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Bubalus bubalis Water Buffalo, Swamp Buffalo [1]		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
Rattus exulans Pacific Rat, Polynesian Rat [79]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Plants		
Andropogon gayanus Gamba Grass [66895]		Species or species habitat likely to occur within area
Brachiaria mutica Para Grass [5879]		Species or species habitat likely to occur within area
Cabomba caroliniana Cabomba, Fanwort, Carolina Watershield, Fish Grass, Washington Grass, Watershield, Carolina Fanwort, Common Cabomba [5171]		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
Hymenachne amplexicaulis Hymenachne, Olive Hymenachne, Water Stargrass, West Indian Grass, West Indian Marsh Grass [31754]		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
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Mimosa pigra Mimosa, Giant Mimosa, Giant Sensitive Plant, ThornySensitive Plant, Black Mimosa, Catclaw Mimosa, Bashful Plant [11223]		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
Pennisetum polystachyon Mission Grass, Perennial Mission Grass, Missiongrass, Feathery Pennisetum, Feather Pennisetum, Thin Napier Grass, West Indian Pennisetum, Blue Buffel Grass [21194]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species habitat likely to occur within area
Lepidodactylus lugubris Mourning Gecko [1712]		Species or species habitat likely to occur within area
Lycodon aulicus Wolf Snake, Common Wolf Snake, Asian Wolf Snake [83178]		Species or species habitat likely to occur within area
Lygosoma bowringii Christmas Island Grass-skink [1312]		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

Name	Status	Type of Presence
		within area

Nationally Important Wetlands

[Resource Information]

Name	State
"The Dales", Christmas Island	EXT
Adelaide River Floodplain System	NT
Ashmore Reef	EXT
Cobourg Peninsula System	NT
Finniss Floodplain and Fog Bay Systems	NT
Hosine's Spring, Christmas Island	EXT
Mermaid Reef	EXT
Pulu Keeling National Park	EXT
Yampi Sound Training Area	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
Carbonate bank and terrace system of the Van	North
Pinnacles of the Bonaparte Basin	North
Shelf break and slope of the Arafura Shelf	North
Tributary Canyons of the Arafura Depression	North
Ancient coastline at 125 m depth contour	North-west
Ashmore Reef and Cartier Island and surrounding	North-west
Canyons linking the Argo Abyssal Plain with the	North-west
Canyons linking the Cuvier Abyssal Plain and the	North-west
Carbonate bank and terrace system of the Sahul	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west
Glomar Shoals	North-west
Mermaid Reef and Commonwealth waters	North-west
Pinnacles of the Bonaparte Basin	North-west
Seringapatam Reef and Commonwealth waters in	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

-7.825 95.017,-7.258 95.057,-6.889 95.237,-6.546 96.79,-5.888 97.702,-5.082 97.709,-5.082 101.768,-5.414 102.196,-5.93 103.76,-7.147 106.451,-7.373 106.405,-7.371 106.464,-7.442 106.953,-7.744 107.995,-7.905 109.722,-8.356 111.662,-8.658 114.361,-9.316 115.483,-9.106 116.195,-9.15 116.927,-8.821 119.311,-8.755 122.28,-8.452 122.881,-8.181 122.864,-8.618 122.351,-8.542 122.084,-8.149 121.927,-7.45 122.23,-6.573 121.494,-6.268 121.687,-6.441 122.623,-6.416 123.13,-5.113 123.133,-5.113 133.938,-5.756 134.147,-7.713 134.118,-7.969 134.501,-7.815 135.134,-8.241 135.302,-8.909 135.884,-9.195 136.427,-9.473 136.375,-9.844 136.011,-9.831 135.131,-10.246 134.206,-10.601 134.135,-10.823 135.421,-10.709 134.224,-11.029 134.456,-11.348 135.339,-11.563 135.522,-11.768 134.789,-11.405 132.823,-12.258 131.691,-12.208 131.004,-12.913 130.189,-14.271 129.243,-13.816 126.757,-13.977 126.369,-14.59 125.843,-14.391 125.612,-14.655 125.271,-14.96 125.273,-15.436 124.511,-16.112 124.318,-16.25 123.58,-17.181 123.449,-16.508 122.977,-17.191 122.224,-17.832 121.993,-18.363 121.112,-18.861 120.844,-19.26 119.724,-19.711 119.219,-20.146 115.456,-22.107 113.387,-23.866 112.25,-24.037 111.896,-23.478 111.438,-22.327 111.418,-21.302 111.244,-21.164 110.494,-20.578 110.015,-20.556 109.025,-19.69 108.376,-19.261 107.083,-18.477 106.843,-17.955 106.373,-18.429 105.463,-19.468 105.407,-19.652 105.038,-18.834 104.781,-18.465 104.174,-18.39 103.302,-17.903 102.18,-18.024 101.627,-17.698 100.31,-17.302 99.413,-17.054 98.178,-16.713 97.326,-16.574 96.068,-16.593 95.119,-7.825 95.017

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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Appendix K: Response to Public Comments

Individual/ Organisation	Key Theme	Summary of the Items Raised	Shell Assessment of Merit and Response	Amendments to the OPP
Anonymous	GHG emissions	• Carbon capture should be implemented for the GHG emissions vented and produced at the Prelude FLNG facility and Crux platform to offset the emissions of these facilities to similar levels of projects that do not contain such significant amounts of carbon dioxide.	The option of introducing carbon capture on the Crux platform has been assessed and is not considered viable on technical, economic and safety grounds. Shell Australia as operator, in joint venture with SGH Energy and Osaka Gas, is working to optimise the Crux platform design to minimise GHG emissions. Options that have been evaluated are summarised in the OPP (Section 5.8.3). These options need to balance the emissions reduction upside with technical and economic viability. CCS was considered during Prelude's design phase however it was ruled out on technical, economic and safety grounds.	On review of the merit of this submission, Shell considers the items raised to be adequately addressed and no amendments are required.
		• The volume of carbon dioxide vented and produced at both the Prelude FLNG facility and Crux platform should be more clearly presented and comparisons made to the equivalent carbon dioxide emitted by cars or other activities.	The OPP relates to the Crux platform only and emissions associated with compression and flaring from this development are clearly set out in Section 5.7.5. It is anticipated this this will be approximately [175,100 tonnes CO_2 equivalent emissions for projected normal operations], extending out to [457,000 tonnes CO_2 equivalent emissions] if potential future compression is required. Crux gas will be processed at the separate Prelude FLNG Facility, and the projected emissions profile for that facility over its lifetime, including the Crux backfill gas, was set out in the Prelude EIS: https://www.shell.com.au/promos/sustainability/prelude-eis/jcr_content.stream/1475632907147/15a771833defe107c1336c8a4854a95607408b1d/prelude-eis.pdf.	
		• The approach and terminology present the information in a manner to confuse members of the public, for example referring to "acid gas" rather than nearly pure carbon dioxide.	A gas that can form acidic solutions when mixed with water is called 'acid gas'. The most common acid gases are hydrogen sulfide (H_2S) and CO_2 gases. Both gases cause corrosion, and therefore it is critical to have these removed prior to processing. Therefore, it is not correct to correlate 'acid gas' with pure carbon dioxide. Furthermore, the terms "acid gas" and "acid gas removal unit" (the infrastructure utilised to remove these gases in the liquefaction process) are widely used throughout the oil and gas industry. We will update our glossary of terms on the Crux project website (https://www.shell.com.au/about-us/projects-and-locations/the-crux-project.html) to include a reference to acid gas specifically.	
		• The government should more aggressively work to reduce impacts on climate change by the venting of nearly pure carbon dioxide into the atmosphere.	Shell has set clear public targets on net carbon footprint – By 2050, our ambition is to align Shell's Net Carbon Footprint with the footprint of the energy mix in the global energy system. We aim to reduce the Net Carbon Footprint of the energy products we sell – expressed in grams of CO_2 equivalent per megajoule consumed – by around 50% by 2050. As an interim step, by 2035, and predicated on societal progress, we aim for a reduction of around 20% compared with our 2016 level. Shell is a willing and able player in the energy transition. We see opportunity in participating in the global drive to provide more and cleaner energy solutions. The greatest contribution Shell can make is to continue to grow the role of natural gas – which emits around half the CO_2 and less than one-tenth of the air pollutants (including nitrogen oxide and sulphur oxide) that coal does when burnt to produce electricity – to fuel transport, heat and light homes, and power industries. For more information visit https://www.shell.com/sustainability-report2018.html *References:* Australian Government. 2018. Quarterly Update of Australia's National Greenhouse Gas Inventory: June 2018. Available from: http://www.environment.gov.au/system/files/resources/e2b0a880-74b9-436b-9ddd-941a74d81fad/files/nggi-quarterly-update-june-2018.pdf (accessed: 5/04/2019).	

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			Shell. 2019. Shell Energy Transition Report. Available from: https://www.shell.com/energy-and-innovation/the-energy-future/shell-energy-transition-report.html (accessed: 5/04/2019).	
Michael Robinson	Unplanned spills GHG emissions	• The proposed Crux Well is located adjacent to a plethora of key Ecological features, Marine Parks and important fishing areas, which is completely unacceptable, there are huge risks with any possible leakages, spillages or disasters that may affect the platform in that location. Based on the prevailing currents, travelling West to East in that location, the rest of the marine park due East of the proposed location will be exposed immediately to the contamination. • Furthermore, 165 km of pipelines, which are well-renowned for their unreliability are planned for this development, which will traverse through more of the environment. I do not think that the area will benefit from further Oil Drilling at a time when we should be reducing our Carbon Footprint and Green House Gas emissions.	Shell Australia as operator, in joint venture with SGH Energy and Osaka Gas, is committed to ensuring there are no hydrocarbon releases during the Crux project. We will apply our considerable experience and knowledge in the offshore petroleum industry to minimise the risk of a release during the Crux project. Shell will implement a suite of industry standard controls to manage the risk of unplanned hydrocarbon spills. Furthermore, the activity-specific Environment Plans are required to have an Oil Pollution Emergency Plan commensurate to the nature and scale of the hydrocarbon pollution risks for the activity. These will be submitted to the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) for acceptance before the activity commences. A detailed evaluation of the potential risks and impacts associated with unplanned spills during the life of the project, including a potential loss of well control or loss of containment from the gas export pipeline, is provided in Section 8.4.8 of the OPP. A conservative approach to the identification and modelling of the credible worst-case hydrocarbon spills has been applied to inform the evaluation of the environmental impacts and risks. In the highly unlikely event of a major unplanned release, it is acknowledged that some environmental values and sensitivities will be exposed to hydrocarbons above adverse impact thresholds. While a hydrocarbon release is unacceptable to Shell, based on the outcomes of the evaluation of impacts and risks, Shell considers that the residual environmental risks of the unplanned spill aspect of the Crux project are acceptable (refer to Table 8-40 in the OPP). For further explanation of deterministic and stochastic modelling, please refer to Section 8.4.7.2 of the OPP or the NOPSEMA website for the following materials: • Factsheet – Oil spill modelling at a glance – available at: https://www.nopsema.gov.au/assets/Publications/A626200.pdf • Oil spill modelling animation – available at: https://www.nopsema.gov.au/resources/animation-2/ (or https://vimeo.com/user97479557).	On review of the merit of this submission, Shell considers the items raised to be adequately addressed and no amendments are required.
		• Additionally, with the majority of the Drilling Platforms to be largely unmanned rigs, this will not bring increased employment opportunities into the region.	Crux has been identified as the primary source of backfill gas supply to the Prelude FLNG facility. Keeping the Prelude FLNG facility supplied with gas will ensure continued provision of skilled and stable employment for Australians for at least 25 years. Two hundred and forty people work on Prelude offshore and on rotation and are supported by 200 staff in Shell House, Perth. Shell Australia as operator, in joint venture with SGH Energy and Osaka Gas, will prepare an Australian Industry Participation (AIP) Plan under the *Australian Jobs Act 2013* for approval by the Department of Industry, Innovation and Science. The overarching aim of the Plan is to ensure investment and project delivery is contained within Australia; and that offshore spend is limited as much as possible. Please refer to Section 2.5 of the OPP for further detail on the AIP Plan and its objectives. Shell is expecting the AIP Plan to be approved in 2019.	
		• Also the safety record of Shell Australia and its parent company, Royal Dutch Shell is far from exemplary.	We work to deliver energy responsibly and safely. We aim to do no harm to people and to have no leaks across our operations. We refer to this as our Goal Zero ambition.	

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			The decision to proceed with a not normally manned (NNM) platform is partly based on significantly reducing safety exposure when compared with a manned platform.	
		• Furthermore citing a recent case in the Land and Environment Court, Gloucester Resources Limited v Minister for Planning [2019] NSWLEC, it has been noted that Mining Companies do not account in their sustainability studies, the impacts of the materials that are extracted from the ground in their environmental impact studies. • There is no carbon offset plan for the extracted fuels, once they are sold off. Only harm minimalisation plans for the proposed mining, which is not even 1/10th of the actual risk to the planet and environment. This plan is too narrow minded and is only focused on the 'micro-detail', not 'macro-detail'. • I would strongly urge that no further drilling is commenced until Australia has an environmental and sustainability plan in place and there is a plan to offset the carbon and emissions from the Crude Oil that will be extracted, rather than just a plan on how to manage the environment specifically around the location of the proposed Oil well. • Citing texts from many sources and the international community as well as local research it was noted that the fossil fuels should be left in the ground where they belong, not extracted and burnt. Supporting texts referenced below: • Bell-James, J and Ryan, S, "Climate change litigation in Queensland: A case study in incrementalism" (2016) 33 EPLJ 515: 53 • Bennett, K, "Australian climate change litigation: Assessing the impact of carbon emissions" (2016) 33 EPLJ 53: 546-548 • Bonyhady, T, "A Useable Past: The Public Trust in Australia" (1995) 12 EPLJ 329 • Figueres C et al (2017), "Three years to safeguard our climate", Nature 546: 593-595 • Global warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate	Shell Australia as operator, in joint venture with SGH Energy and Osaka Gas, have an obligation to undertake exploration and develop any commercially viable hydrocarbon reserves to meet the offshore permit retention lease requirements. Therefore, the development of the Crux project cannot be put on hold until the Australian Government formalises a strategy to the management of GHG emissions. Section 8.4.4 of the OPP provides a detailed evaluation of the potential risks/impacts associated with the Crux project atmospheric emissions and provides key management controls to manage these emissions. As the project progresses into the Final Investment Decision stage, Shell will be reviewing and updating the Crux Greenhouse Gas and Energy Management Plan to incorporate the Crux project updates which have occurred during FEED.	

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		poverty [V. Masson-Delmotte, et al (eds.)]. World Meteorological Organization, Geneva, Switzerland • Guidelines for the Economic Assessment of Mining and Coal Seam Gas Proposals (December 2015) • McGlade C and Ekins P (2015), "The Geographical Distribution of Fossil Fuels unused when limiting Global Warming to 2ºC", Nature 517: 187-190 • Trenberth, K E, "Climate change caused by human activities is happening and it already has major consequences" (2018) 36 Journal of Energy and Natural Resources Law 463-481		
Ian Stephenson	Concept premise - Not Normally Manned (NNM) platform	• Shell have determined that a Not Normally Manned Fixed Platform solution offers the most beneficial means of Project Execution. The conclusions seem reasonable and logical. However, the lack of detailed evaluation of a future potential change to a fully manned and human occupied facility should be addressed more fully.	Shell Australia as operator, in joint venture with SGH Energy and Osaka Gas, re-confirms the proposal as presented in the OPP – that the development concept for Crux is a NNM fixed platform. This is a fundamental decision point for the foundation (or initial) Crux project. While the intent of the text relating to the NNM platform concept remains correct, as cited in the respondent’s letter, further engineering definition has become available since the release of the Crux OPP for public comment. As such, Section 5.5.1.2 of the OPP (within the ‘Operations and Accommodation’ sub-heading) has been updated as follows to reflect this: *As a NNM platform, the intent is that the Crux platform will be operated remotely from the Prelude FLNG facility.* *Upon achieving steady state operations, the workforce for campaign and turnaround maintenance will be accommodated on a ‘Walk to Work Vessel’ and access to the Crux platform via a gangway.* *The Crux platform design will be such that a future accommodation module can be installed without the need to extend the current platform deck footprint (by installing it above the temporary refuge location).* The refinements made to reflect this additional engineering information do not change the project activity and do not affect the evaluation of potential environmental impacts and risks presented in Section 8.4 of the OPP.	Section 5.5.1.2 of the OPP (‘Operations and Accommodation’) has been revised to incorporate additional engineering definition regarding the Crux NNM platform accommodation during operations. The revisions do not significantly change the project activity, nor do they affect the evaluation of environmental impacts and risks.

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	Potential future change to manned philosophy	• The document uses a Table style format {referring to Table 5-2 in the OPP} to highlight Key Project Stages and development Activities including, key activities associated with and in consideration of future development within the Operations and Maintenance Stage. There is no obvious consideration of the reconfiguration potential to realise the option to install a 50-person accommodation facility. Because this is a major change, presumably Shell would be obliged to implement a full Management of Change process at the time and in addition, Shell would likely be required by legislation to resubmit the facility Safety Case to the Regulator. This omission, of what is a major change, conflicts with the overarching statement that the OPP as presented represents a 'whole of project assessment'.	The foundation (or initial) Crux project is premised on a NNM platform philosophy. As noted, if circumstances arise which identify the need to re-visit this over the life of the project, there are clear mechanisms in place to ensure that the risks and impacts, across health, safety and environment (HSE), technical, commercial and socio-economic factors, are duly evaluated in collaboration with stakeholders. As correctly highlighted in the submission, a management of change process would be followed to guide this decision-making.	
		• Table 5.7, Qualitative Comparison of Feasible Host Types for the Crux Project, does not include any evaluation of a fully 50 person occupied fixed platform facility. It is of concern that matters such as IRPA and PLL within the human factor's consideration have been so significantly highlighted as a benefit at the expense of a fully occupied facility. From this comparison and presumably justification 'driver', should Shell determine to exercise the option to move to a fully occupied facility then risk to persons occupying the facility would increase by 50% and Shell therefore perceive this as acceptable. Without seeing the QRA evaluation data I do hesitate – but instinctively, I believe this perceived gain at the expense of a fully manned facility is exaggerated and open to challenge. The same positive verses negative style 'justification' or 'rationale'; permeates throughout this table in Vessel Movements, Light Emissions etc. This table presents a fundamental conflict and should be reworked to include a proper evaluation of risk potential for both a Manned Facility and a Not Normally Manned Facility with clear reference to not only Qualitative Assessment but Quantitative Assessment with verifiable and auditable data as it pertains to the Crux fixed platform facility as currently envisaged.	The decision for a NNM platform is premised in a reduction in safety exposure risk to personnel. Shell appreciates that a key principle of safety is to eliminate the hazard/risk in the first place, and not putting people in harms' way is the most inherently safe approach. The qualitative comparison of feasible host types was intended as stated – to provide a qualitative assessment of the relative merit of the key options that were evaluated. It was not intended as a quantitative assessment of personnel risks, that would otherwise be quantified in a quantitative risk assessment (QRA). Further QRA and Safety Case documentation will be developed as the Crux project progresses and the Crux Safety Case is subject to assessment and acceptance by NOPSEMA.	
Prof. John Chandler	Principles of Ecologically Sustainable Development (ESD)	• The principles of ecologically sustainable development (ESD) require decision making processes to effectively integrate "both long term and short term economic, environmental, social and equitable considerations". The proposal is deficient because it does not provide: 1. a framework for the evaluation of economic, social and equitable considerations, and	The environmental receptors that were identified as being credibly impacted by, or at risk of impacts from aspects of the Crux project, have all been assessed to be "acceptable". As noted within the comment, the principles of ESD were one of the factors considered by Shell in establishing the acceptable levels of impacts and risks. Subsequently, an evaluation of the project risks/impacts for each key project aspect (i.e. physical presence, vessel movements, light emissions, underwater noise, atmospheric emissions, invasive marine species, liquid discharges, waste	On review of the merit of this submission, Shell considers the items raised to be adequately addressed

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		2. sufficient information about those matters to allow a comparison of relevant matters or a judgement by NOPSEMA about them. • Although the proposal mentions the principles of ESD (for example at Section 7.1.1) its main focus is on paragraph (d) and it does not deal sufficiently with the other paragraphs • The principles of ESD in Australia were developed in the early 1990s. As one report of the time puts it: 'The intergenerational issue of how a society decides what resources / assets should be passed on to future generations involves valuing future costs and benefits and the key question as to whether and to what extent it is appropriate to substitute human made capital for natural capital.' This necessarily involves a comparison of costs and benefits. If the costs exceed the benefits, then how is it possible to say that the development is sustainable or maintains the environment (which for this purpose can include petroleum) for the benefit of future generations? If significant costs or repayments to Shell arise at the end of the project, whether in terms of the cost of decommissioning or tax refunds, how can the development be said to meet the principle of inter-generational equity? • Offshore project proposals are dealt with in part 1 A of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009. Adopted as part of its red tape reduction programme policy by the Coalition Government that took office in September 2013, streamlining had two main elements. The first took the form of a revision of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 in 2014, requiring NOPSEMA's approval for "offshore projects", defined as activities for the recovery of petroleum, other than on an appraisal basis, according to criteria and procedures defined in the Regulations, which have been amended in a number of respects to reflect the concerns of the EPBC. Second, by virtue of a decision of the Minister for Environment under the EPBC Act, NOPSEMA environmental approval of most petroleum activities in Commonwealth waters, whether within or outside the framework of an "offshore project", is taken to satisfy EPBC Act requirements as to approval of actions subject to control under the Act. The effect of the changes made in 2014 is to require an evaluation of costs and benefits as required by the principles of ESD.	management and emergency events) and their consistency with ESD is provided within the sub-sections of Section 8.4.	and no amendments are required.

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		• Regulation 3(a) supports the view of ESD suggested in this comment. It is also supported in relation to environmental outcomes by Regulation 5 D (6)(d). The point of Regulation 5D (6)(d) is that the environmental performance outcomes need to be consistent with the principles of ESD, but also that the impacts and risks will be managed to an acceptable level. It is suggested that measurable levels of performance include matters which go to whether the proponent will be able to manage relevant risks. An example is in relation to decommissioning. If the overall cash flows from the development and the decommissioning cost are not estimated at this stage how can the regulator make a judgement, which it is suggested it should, that the development will be sufficiently profitable to discharge decommissioning responsibilities. Also what is acceptable should take into account inter-generational issues.		
	Socio-economic environment, balance of impacts and benefits	• The socio-economic and cultural environment specified in Section 6.6 is too narrow in that its focus is 'existing marine users and interests relevant to the offshore context of the NMM platform in Commonwealth marine waters, reflecting the scope of the OPP'. For any major project, particularly one with a 20 year design life (see Table 5.1) the principle of intergenerational equity ('that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations') requires the interests of Australians in general to be considered.	All components of the principles of ESD, as defined in Section 3A of the EPBC Act, and socio-economic/cultural environment were given consideration as appropriate to the scope of an OPP, as required by Regulation 4 and 5A of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS (E) Regulations) and outlined in the NOPSEMA 2018 'Guidance Note: Offshore Project Proposal content requirements'. Shell is confident that the scope of Section 6 is adequate as it describes all physical, biological, socio-economic and cultural characteristics of the existing environment that may be affected by the project (planned activities and emergency events). The area that may be affected is discussed in Section 6.1. As outlined in Section 1.1, the Crux project is the primary source of backfill gas supply to the Prelude FLNG facility, which was previously approved under the EPBC Act, through decision EPBC 2008/4146. With this being the development concept, it is premised that the Crux project will generally seek to utilise existing support facilities and services used for the Prelude FLNG facility. The Crux project is not expected to significantly increase the demand on these facilities/services.	
		• Matters that need to be dealt with in the OPP include the value of the resource provided to Shell by its licence (that is the amount of petroleum which is anticipated will be produced), the value of change to the environment as a result of the development (one measure would be the anticipated cost of rehabilitation of the sea bed and surrounding environment if the development proceeds and produces as planned), an assessment of the risk of the development not proceeding as planned because of say a spill of petroleum into the sea, the economic benefits provided by the development and the social benefits provided by the development.	The information and level of detail provided in the Crux OPP is consistent with other recent NOPSEMA approvals and precedents and aligns with the requirements of the OPGGS (E) Regulations. Detailed cost/benefit analyses or quantification of revenue are not key components of an OPP approval.	

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		• In further support of this, it should be noted that the definition of 'environment' in regulation 4 of the Regulations includes 'natural and physical resources' and 'the social, economic and cultural features' of those resources. Petroleum is a natural resource for these purposes and so the proposal must deal with the effect of the development on the petroleum subject to Shell's licence and the social and economic features of it. • The objects of the development in section 1.2 do not contain any mention of the provision of socio-economic benefits. • The OPP provides insufficient material on the economic and social benefits to be derived from the development. At the very least these should include estimates of the contribution to the gross domestic product and gross national product of Australia and relevant state and territory areas, state and federal taxes and employment. This necessarily involves disclosure of projections of revenue from the development and the assumptions on which they are based.		
	Atmospheric or other emissions	• The OPP does not set out any strategy or targets for reducing atmospheric and other emissions or improving energy efficiency (Section 5.7.5).	Section 8.4.4 of the OPP provides a detailed evaluation of the potential risks/impacts associated with project atmospheric emissions and provides key management controls to manage these emissions. As the project progresses into the Final Investment Decision stage, Shell will be reviewing and updating the Crux Greenhouse Gas and Energy Management Plan to incorporate the Crux project updates which have occurred during FEED.	
	Decommissioning cost projections	• In relation to decommissioning a draft proposal is required to include the information set out in Regulation 5 A which include: '(v) a description of the actions proposed to be taken, following completion of the project, in relation to those facilities;'. The OPP's treatment of decommissioning should elaborate what would be required if the default decommissioning requirement set out in Section 5.6.6 has to be complied with and provide estimates of the anticipated cost, how Shell and its joint venture partners will provide for it and the impact on government revenue of decommissioning costs which can be set against tax or give rise to a tax refund.	The detailed evaluation of risk/impacts presented in Section 8.4 takes into consideration the condition of the existing environment when assessing potential risks/impacts over the life of the project. The OPP quantifies the nature and scale of all potential environmental impacts (i.e. disturbances, changes), such as the direct disturbance to the seabed, and outlines a forward approach for decommissioning the project. In recognition that it is premature to define a detailed decommissioning strategy, the key decommissioning risks have been broadly addressed in Section 8 of the OPP. Further detailed information will be provided in the activity-specific Decommissioning Environment Plan, which will be submitted to NOPSEMA for assessment. This is an explicit commitment in the Crux OPP. Shell has and will continue to consider decommissioning strategies in the design of the facility.	
[redacted]	Reservoir gas / condensate extraction and recycling	• The planned extraction via the NNM platform will leave condensate in situ. Pressure of this retrograde gas-condensate reservoir is just above the dew point, and extraction of any gas will cause condensate to liquefy in the reservoir, losing a valuable asset (and the resulting tax!) and also blocking the pores of the reservoir, hindering gas removal. Surely a gas recycle	There are three elements that detract from implementing a liquids-stripping project in Crux. Firstly, the seismic data shows the reservoir to be heavily faulted, resulting in compartmentalisation in many areas and hydraulic enhancement in some other parts. The compartmentalised blocks would require a producer-injector pair in each major fault block to maintain pressure above the dew-point, while the hydraulically enhanced faults would lead to areas of rapid lean-gas breakthrough. Secondly, the stratigraphy at Crux has resulted in two or three sandstone units within each fault block that differ in their level of permeability. To achieve uniform sweep and pressure conformance between the layers	On review of the merit of this submission, Shell considers the items raised to be adequately addressed and no amendments are required.

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		phase should be used first, to remove as much condensate as possible (as used on Bayu Undan) before gas extraction – this is in line with Nexus' original plans for this field. The Arun condensate field in Indonesia displayed a 50% reduction in gas productivity with only about 1.1% of condensate dropout in the wellbore regions (Afidick et al., 1994). And the worst example at Cal Canal field in California showed that condensation even completely killed the gas well. (SPE-146786).	would require a comprehensive completion design in both the injectors and producers, with no guarantee that such measures would achieve their conformance objectives. Thirdly, the condensate-gas-ratio in Crux is 30% of that occurring in both the Bayu-Undan and the Arun fields, and is half the level typically required for a commercially viable liquids-stripping project. Each factor by itself is a major hurdle, but unfortunately for Crux multiple factors combine to make gas recycling a high risk proposition both technically and commercially. Regarding the potential risk of near-wellbore liquid dropout leading to impaired inflow, this has been recognised but is not expected to be significant. This is due to the combination of high permeability and mostly uniform depressurisation that accompanies production into a gradually increasing backfill ullage profile.	
	Subsea well isolation philosophy	• Having five production wells with subsea wellhead system tied back through rigid concentric tubulars to the NNM platform and completed with dry trees leaves the equipment prone to damage by cyclones. Damage to the platform and the surface wells could leave the reservoirs only isolated by one barrier, the downhole safety valve. Wouldn't all-subsea wells (with xmas trees on each wellhead) provide better isolation?	The probability of a cyclone causing catastrophic damage to the surface tree is extremely unlikely. The platform is designed for a 1 in a 1000 year cyclone and the tieback riser system is intended to be designed to withstand the same 1000-year cyclone survival conditions. In the extremely unlikely event that the surface tree is damaged however, the downhole safety valve is designed to safely contain the well until such a time that the surface equipment can be reinstated, or a BOP is installed on the well to intervene. Subsea wells are designed with the same philosophy with the downhole safety valve being the failsafe barrier in the event that the subsea tree is damaged.	
	GHG emissions	• This is another Shell project releasing greenhouse gases, like Prelude. Can't the carbon dioxide be sequestered like Chevron are doing on Gorgon? It is known that gas sequestration in the Browse Basin is possible. https://d28rz98at9flks.cloudfront.net/76510/Rec2014_011.pdf • The Crux gas is 8% CO_2, so if five production wells are envisaged, only one CO_2 disposal well should be needed. This should not be too onerous for this project.	Crux gas will be processed at the separate Prelude FLNG Facility, and the projected emissions profile for that facility over its lifetime, including reservoir emissions from other reservoirs to support the operation of the Prelude FLNG facility, was set out in the Prelude EIS: https://www.shell.com.au/promos/sustainability/prelude-eis/_jcr_content.stream/1475632907147/15a771833defe107c1336c8a4854a95607408b1d/prelude-eis.pdf. Shell invests in CCS projects, which use a combination of technologies to capture and store CO_2 deep underground. We also work with partners to find new ways of using CO_2 once it has been captured. We believe CCS must play a significant role in the global climate response. CCS projects are happening around the world and the technology is proven but more projects need to be built. For more information visit https://www.shell.com/sustainability-report2018.html The option of introducing carbon capture on the Crux platform has been assessed and is not considered viable on technical, economic and safety grounds. The Project Team is working to optimise the Crux platform design to minimise GHG emissions. Options that have been evaluated are summarised in the OPP (Section 5.8.3). These options need to balance the emissions reduction upside with technical and economic viability.	
	LNG export and domestic gas supply	• Again, Australian gas is being shipped overseas with no consideration for the domestic market. Why can't this project deliver gas to the mainland for use in WA? A small pipeline could easily deliver 15% of the gas to the mainland.	The Crux project is being progressed in order to secure future sources of backfill gas to supply the continued operation of the Prelude FLNG facility. Therefore, the export of LNG, as is the case for the operational Prelude FLNG facility, remains the route for the viable delivery of gas to international users, and this was previously addressed in Prelude FLNG approvals. Shell Australia is meeting its domestic gas obligations as part of our state agreements on LNG production from NWS and Gorgon in Western Australia. Also, Shell Australia, through QGC, has actively supplied gas to the domestic market in Eastern Australia and has a Heads of Agreement with the Australian Government to assure domestic gas supply in 2019 and 2020.	

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Jenni Mclain	General objection Pollution	• In-principle objection to offshore oil and gas development in Australian waters. • Pollution of the environment.	Shell notes the objections provided. As outlined in Section 5.8.4 of the OPP, the project aligns with the Australian Government's broad mandate to develop offshore oil and gas resources. Shell and its Joint Venture partners also have an obligation to undertake exploration and develop any commercially viable hydrocarbon reserves to satisfy offshore permit retention lease requirements. In this context, the 'no development' alternative is not consistent with the legal obligations and commercial objectives of Shell. Section 8 of the OPP presents a detailed evaluation all of the potential environmental impacts and risks associated with the Crux project (including waste management, planned liquid discharges and unplanned spills) to environmental values and sensitivities that may be affected by both planned and unplanned events, including the physical environment (e.g. water quality and sediment quality), marine fauna (turtles), benthic communities and shorelines (e.g. beaches). Section 8 identifies a suite of key management controls that will be implemented to manage these potential impacts/risks. The section also provides a statement of acceptability against project-specific acceptable levels (as summarised in Table 7-3 of the OPP) and environmental performance outcomes that Shell will be held to achieving by NOPSEMA as part of compliance reporting for the project. The environmental performance objectives provided in the Crux OPP provide specific, measurable levels of environmental performance that are consistent with the principles of ESD, and demonstrate that the environmental impacts and risks of the Crux project are of an acceptable level. *Oil Spills* With regards to large-scale releases of hydrocarbons during the Crux project, Shell believes these to be unacceptable and acknowledge that such spills have potential to result in significant environmental impacts. Consequently, Shell will apply its considerable experience and knowledge in the offshore petroleum industry to ensure such a release during the Crux project never occurs. Shell has applied a conservative approach to the identification and modelling of the credible worst-case hydrocarbon spills. This information was used to inform the evaluation of the environmental impacts and risks, and is consistent with the precautionary principle. Shell will implement industry standard controls to manage the risk of unplanned hydrocarbon spills. Furthermore, the activity-specific Environment Plans are required to have an Oil Pollution Emergency Plan commensurate to the nature and scale of the hydrocarbon pollution risks for the activity. These will be submitted to the NOPSEMA for acceptance before the activity commences. *Renewable Energy* As outlined in the response to the Anonymous comment relating to GHG emissions, Shell has set clear public targets on net carbon footprint – By 2050, our ambition is to align Shell's Net Carbon Footprint with the footprint of the energy mix in the global energy system. We aim to reduce the Net Carbon Footprint of the energy products we sell – expressed in grams of CO_2 equivalent per megajoule consumed – by around 50% by 2050. As an interim step, by 2035, and predicated on societal progress, we aim for a reduction of around 20% compared with our 2016 level. Shell is committed to supporting the energy transition in a responsible and sustainable manner. It is recognised that achieving net-zero emissions essentially involves re-wiring of the whole global economy, while at the same time meeting greater energy demand due to population growth, development, new energy services, and the extended use of existing services. There is yet no clear development pathway for an emerging economy that does not include traditional energy sources and the drive towards net-emissions is challenging due to the current lack of low-carbon substitutes for many emission intensive industries. Gas is recognised as an important fuel in the energy transition,	On review of the merit of this submission, Shell considers the items raised to be adequately addressed and no amendments are required.
Gerad Adams	General objection Pollution	• In-principle objection to offshore oil and gas development in Australian waters. • Environmental pollution of Australia's pristine waters.		
Carter Nicklin	General objection	• In-principle objection to offshore oil and gas development in Australian waters. • Environmental risk is too high and consequence too large.		
Thomas Langley	General objection	• In-principle objection to offshore oil and gas development in Australian waters.		
Ryan Price	General objection	• In-principle objection to offshore oil and gas development in Australian waters.		
Name not supplied	General objection	• In-principle objection to offshore oil and gas development in Australian waters.		
Meg Rasheed	General objection	• In-principle objection to offshore oil and gas development in Australian waters. • Ruining of the environment.		
Casey Schaefer	General objection	• In-principle objection to offshore oil and gas development in Australian waters. • Destruction of the environment.		
Anonymous	General objection	• In-principle objection to offshore oil and gas development in Australian waters. • Environmental risks (general). • Potential environmental damage in Australian waters.		
Juliette Sherrard	General objection	• In-principle objection to offshore oil and gas development in Australian waters. • Environmental damage.		
Will Dow	General objection	• In-principle objection to offshore oil and gas development in Australian waters. • Environmental damage.		
Chloe Furnari	General objection	• In-principle objection to offshore oil and gas development in Australian waters. • Environmental damage to the ocean.		
Emma Kent	General objection	• In-principle objection to offshore oil and gas development in Australian waters. • Destruction of the environment.		
Anja Green	General objection Unplanned spills	• In-principle objection to offshore oil and gas development in Australian waters. • Oil spills.		
Kane Bourke	Unplanned spills	• Consequences associated with potential oil spill.		

Individual/ Organisation	Key Theme	Summary of the Items Raised	Shell Assessment of Merit and Response	Amendments to the OPP
		• Focus on renewable energy.	especially for economies which are currently powered by coal and is key to reducing GHG intensity of the energy supply chain. The Crux project, therefore, contributes to this transition.	
Sassy Bloch	General objection	• In-principle objection to offshore oil and gas development in Australian waters. • Detrimental environmental impacts (general). • Use of renewable energy sources.		
[redacted]	General objection Unplanned spills	• Potential impacts to beaches.		
Nathan Ceddia	General objection Unplanned spills	• In-principle objection to offshore oil and gas development in Australian waters. • Detrimental environmental impacts (natural disaster from oil spill).		
Neil Waldron	Unplanned spills	• The potential worse-case scenario for this development in a pristine ocean environment outweighs any potential benefits.		
Madeleine Atkins	Unplanned spills	• Impacts to beaches and wildlife from an oil spill		
Harry Retief	General objection Marine turtles	• In-principle objection to offshore oil and gas development in Australian waters. • Impacts to marine turtles.		
Tot Jok	-	• None – no text was provided in the comment submitted.	Shell are unable to provide a response as no comment has been provided.	No amendments required.
Libby Ross				
Olivia Evans				
Brooke Pithie				
Sam Larritt				
Uma Manasseh				
Edward Royle				
Jack Mullen				
Eddie McDonald				
Annabel Kirby				
Amanda Muschamp				
William Bowden				
Teegan Donaghey				